

**APPENDIX D: HUMAN HEALTH
AND WORKER SAFETY**

D.1 INTRODUCTION

This appendix to the Y-12 Site-Wide Environmental Impact Statement (SWEIS) provides supplemental information pertaining to potential human health impacts associated with radiation exposures, chemical exposures, and worker safety issues due to No Action - Status Quo Alternative operations and those proposed under the No Action - Planning Basis Operations Alternative, the Highly Enriched Uranium (HEU) Storage Mission, and the Special Materials Mission Alternatives analyzed in the Y-12 SWEIS. Human health risks from radiological and chemical exposures are presented in Sections D.2 and D.3, respectively. In these sections, a comprehensive evaluation of the potential risks associated with human exposure to environmental media (air, surface water, soils, sediment, and groundwater) was conducted using either data from 1998 or the most recent data available to establish the No Action - Status Quo Alternative baseline.

Impacts to worker safety are evaluated in Section D.4. The summaries presented in Section D.5 provide public health profiles pertaining to cancer incidence rates and mortalities for the United States, Tennessee, Anderson County, and Roane County. Section D.6 presents a description of relevant epidemiologic studies. Section D.7 presents technical analysis of potential impacts to workers and the public due to accidents.

D.2 RADIOLOGICAL IMPACTS ON HUMAN HEALTH

D.2.1 Radiation and Radioactivity

Radiation is everywhere. Although most radiation occurs naturally, a small percentage is manmade. Humans are constantly exposed to naturally occurring radiation through sources such as the solar system and the earth's rocks and soils. This type of radiation is referred to as *background radiation*, and it always surrounds us. Background radiation remains relatively constant over time and is present in the environment today just as it was hundreds of years ago. Manmade sources of radiation include medical and dental x-rays, radio and television transmissions, household smoke detectors, and materials released from nuclear and coal-fired powerplants. The following sections describe some important principles concerning the nature, types, sources, and effects of radiation and radioactivity.

D.2.1.1 What Is Radiation?

All matter in the universe is composed of tiny particles called atoms, and it is the activity of these particles that produces radiation. While the atom is infinitesimally small, it is composed of even smaller particles, called electrons, protons, and neutrons. *Electrons* are negatively charged particles that are principally responsible for chemical reactivity. *Protons* are positively charged particles, and *neutrons* are neutral. Protons and neutrons are located in the center of the atom, called the nucleus. Electrons reside in a designated space around the *nucleus*. The total number of protons in an atom is called its *atomic number*.

Atoms of different types are known as elements. There are over 100 natural and manmade elements. Atoms of the same element always contain the same number of protons and electrons, but may differ by their number of constituent neutrons. Atoms of an element having a different number of neutrons are called the *isotopes* of the element. The total number of protons and neutrons in the nucleus of an atom is called its *mass number*, which is used to name the isotope. For example, the element uranium has 92 protons. Therefore, all isotopes of uranium have 92 protons. Each isotope of uranium is designated by its unique mass number: ^{238}U , the principal naturally occurring isotope of uranium, has 92 protons and 146 neutrons; ^{234}U has 92 protons and 142 neutrons; and ^{235}U has 92 protons and 143 neutrons. Atoms can lose or gain electrons in a process known as *ionization*.

Ionizing radiation has enough energy to free electrons from atoms, creating ions that could cause biological damage. Although it is potentially harmful to human health, ionizing radiation is used in a variety of ways,

many of which are familiar to us in our everyday lives. An x-ray machine is one form of ionizing radiation. Likewise, most home smoke detectors use a small source of ionizing radiation to detect smoke particles in the room's air. The two most common mechanisms in which ionizing radiation is generated are the electrical acceleration of atomic particles such as electrons (as in x-ray machines) and the emission of energy from nuclear reactions in atoms. Examples of ionizing radiation include alpha, beta, and gamma radiation.

Alpha radiation occurs when a particle consisting of two protons and two neutrons is emitted from the nucleus. Alpha particles, because of their relatively large size, do not travel very far and do not penetrate materials well. Alpha particles lose their energy almost as soon as they collide with anything, and therefore a sheet of notebook paper or the skin's surface can be used to block the penetration of most alpha particles. Alpha particles only become a source of radiation dose after they are inhaled, ingested, or otherwise taken into the body.

Beta radiation occurs when an electron or positron is emitted from an atom. Beta particles are much lighter than alpha particles and therefore can travel faster and farther. Greater precautions must be taken to stop beta radiation. Beta particles can pass through a sheet of paper but can be stopped by a thin sheet of aluminum foil or glass. Most of the radiation dose from beta particles occurs in the first tissue they penetrate, such as the skin, or dose may occur as the result of internal deposition of beta emitters.

Gamma and x-ray radiation are known as electromagnetic radiation and are emitted as energy packets called *photons*, similar to light and radio waves, but from a different energy region of the electromagnetic spectrum. Gamma rays are emitted from the nucleus as waves of pure energy, whereas x-rays originate from the electron field surrounding the nucleus. Gamma rays travel at the speed of light, and because they are so penetrating, concrete, lead, or steel is required to shield them. For example, to absorb 95 percent of the gamma energy from a ^{60}Co source, 6 cm of lead, 10 cm of iron, or 33 cm of concrete would be needed.

The neutron is another particle that contributes to radiation exposure, both directly and indirectly. Indirect exposure is associated with the gamma rays and alpha particles that are emitted following neutron capture in matter. A neutron has about one quarter of the weight of an alpha particle and can travel 2.5 times faster than an alpha particle. Neutrons are more penetrating than beta particles, but less penetrating than gamma rays. They can be shielded effectively by water, graphite, paraffin, or concrete.

Some elements such as uranium, radium, plutonium, and thorium, share a common characteristic—they are unstable or radioactive. These radioactive isotopes are called *radionuclides* or *radioisotopes*. As these elements attempt to change into more stable forms, they emit invisible rays of energy or particles at rates which decrease with time. This emission is known as radioactive decay. The time it takes a material to lose half of its original radioactivity is referred to as its half-life. Each radioactive isotope has a characteristic half-life. The half-life may vary from a millionth of a second to millions of years, depending upon the radionuclide. Eventually, the radioactivity will essentially disappear.

As a radioactive element emits radioactivity, it often changes into an entirely different element that may or may not be radioactive. Eventually, however, a stable element is formed. This transformation may require several steps, known as a decay chain. Radium, for example, is a naturally occurring radioactive element with a half-life of 1,622 years. It emits an alpha particle and becomes radon, a radioactive gas with a half-life of only 3.8 days. Radon decays to polonium and, through a series of steps, to bismuth, and ultimately to lead.

Nonionizing radiation bounces off or passes through matter without displacing electrons. Examples include visible light and radio waves. At this time, scientists are unclear as to the effects of nonionizing radiation on human health. In this Y-12 SWEIS, the term radiation is used to describe ionizing radiation.

D.2.1.2 How is Radiation Measured?

Scientists and engineers use a variety of units to measure radiation. These different units can be used to determine the amount, and intensity of radiation. Radiation can be measured in *curies*, *rads*, or *rems*. The *curie* describes the activity of radioactive material. The rate of decay of 1 gram of radium is the basis of this unit of measure. It is equal to 3.7×10^{10} disintegrations (decays) per second.

The *rad* is used to measure the absorbed dose of radiation. One rad is equal to the amount of radiation that leads to the deposition of 0.01 joule of energy per kilogram (kg) of absorbing material.

A *rem* is a measurement of the dose from radiation based on its biological effects. The rem is used to measure the effects of radiation on the body. As such, 1 rem of one type of radiation is presumed to have the same biological effects as 1 rem of any other type of radiation. This standard allows comparison of the biological effects of different types of radiation. Note that the term millirem (mrem) is also often used. A millirem is one one-thousandth (0.001) of a rem.

D.2.1.3 How Does Radiation Affect the Human Body?

Ionizing radiation affects the body through two basic mechanisms. The ionization of atoms can generate chemical changes in body fluids and cellular material. Also, in some cases the amount of energy transferred can be sufficient to actually knock an atom out of its chemical bonds, again resulting in chemical changes. These chemical changes can lead to alteration or disruption of the normal function of the affected area. At low levels of exposure, such as the levels experienced in an occupational or environmental setting, these chemical changes are very small and ineffective. The body has a wide variety of mechanisms that repair the damage induced. However, occasionally, these changes can cause irreparable damage that could ultimately lead to initiation of a cancer, or change to genetic material that could be passed to the next generation. The probability for the occurrence of health effects of this nature depends upon the type and amount of radiation received, and the sensitivity of the part of the body receiving the dose.

At much higher levels of acute exposure, at least 10 to 20 times higher than the legal limits for occupational exposures (the limit for annual occupational exposures is 5 rem), damage is much more immediate, direct, and observable. Health effects range from reversible changes in the blood to vomiting, loss of hair, temporary or permanent sterility, and other changes leading ultimately to death at acute exposures (above about 100 times the regulatory limits). In these cases, the severity of the health effect is dependent upon the amount and type of radiation received. Exposures to radiation at these levels are quite rare, and, outside of intentional medical procedures for cancer therapy, are almost always due to accidental circumstances.

For low levels of radiation exposure, the probabilities for induction of various cancers or genetic effects have been extensively studied by both national and international expert groups. The problem is that the potential for health effects at low levels is extremely difficult to determine without extremely large, well-characterized populations. For example, to get a statistically valid estimate of the number of cancers caused by an external dose equivalent of 1 rem, 10 million people would be required for the test group, with another 10 million for the control group (BEIR 1990). The risk factors for radiation-induced cancer at low levels of exposure are very small, and it is extremely important to account for the many nonradiation-related mechanisms for cancer induction, such as smoking, diet, lifestyle, chemical exposure, and genetic predisposition. These multiple factors also make it difficult to establish cause-and-effect relationships that could attribute high or low cancer rates to specific initiators.

The most significant ill-health effects that result from environmental and occupational radiation exposure are cancer fatalities. These ill-health effects are referred to as “latent” cancer fatalities (LCFs) because the

cancer may take many years to develop and for death to occur. Furthermore, when death does occur, these ill-health effects may not actually have been the cause of death.

Health impacts from radiation exposure, whether from sources external or internal to the body, generally are identified as somatic (affecting the individual exposed) or genetic (affecting descendants of the exposed individual). Radiation is more likely to produce somatic effects rather than genetic effects. The somatic risks of most importance are the induction of cancers.

For a uniform irradiation of the body, the incidence of cancer varies among organs and tissues. The thyroid and skin demonstrate a greater sensitivity than other organs; however, such cancers also produce relatively low mortality rates because they are relatively amenable to medical treatment.

D.2.1.4 *What are Some Types of Radiation Dose Measurements?*

The amount of ionizing radiation that the individual receives during the exposure is referred to as *dose*. An external dose is delivered only during the actual time of exposure to the external radiation source. An internal dose, however, continues to be delivered as long as the radioactive source is in the body, although both radioactive decay and elimination of the radionuclide by ordinary metabolic processes decrease the dose rate with the passage of time. The measurement of radiation dose is called *radiation dosimetry* and is completed by a variety of methods depending upon the characteristics of the incident radiation.

External radiation is measured as a value called deep dose equivalent. Internal radiation is measured in terms of the committed effective dose equivalent (CEDE). The sum of the two contributions (deep dose equivalent and CEDE) provides the total dose to the individual, called the total effective dose equivalent (TEDE). Often the radiation dose to a selected group or population is of interest and is referred to as the collective dose equivalent, with the measurement units of *person-rem*.

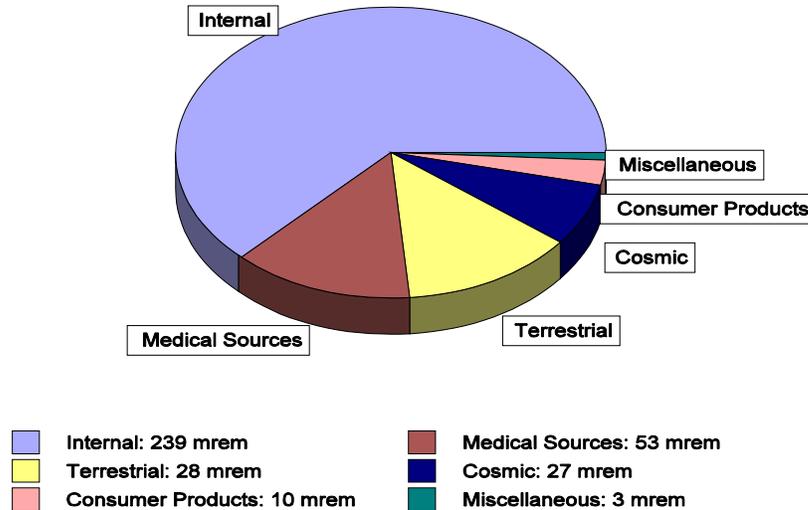
D.2.1.5 *What are Some Sources of Radiation?*

Several different sources of radiation have been identified. The majority of them are naturally occurring or background sources, which can be categorized as cosmic, terrestrial, or internal radiation sources. Manmade radiation sources include consumer products, medical sources, and other miscellaneous sources. The average American receives a total of about 360 mrem per year from all sources of radiation, both natural and manmade (Figure D.2.1-1).

Cosmic radiation is ionizing radiation resulting from energetically charged particles from space that continuously hit the earth's atmosphere. These particles and the secondary particles and photons they create are referred to as cosmic radiation. Because the atmosphere provides some shielding against cosmic radiation, the intensity of this radiation increases with altitude above sea level. For example, a person in Denver, CO, is exposed to more cosmic radiation than a person in New Orleans, LA. The average annual dose to persons in the United States is about 27 mrem. The average cosmogenic dose contribution (mostly due to carbon-14) adds another 1 mrem. The average dose equivalent in Tennessee is about 45 mrem per year. When shielding and the time spent indoors are considered, the dose for the surrounding population is reduced to about 36 mrem per year.

Terrestrial radiation is radiation emitted from the radioactive materials in the earth's rocks, soils, and minerals. Radon, radon progeny, potassium, isotopes of thorium, and isotopes of uranium are the elements responsible for most terrestrial radiation. The average annual dose from terrestrial radiation is about 28 mrem, but the dose varies geographically across the country. Typically reported values are about 16 mrem on the Atlantic and Gulf coastal plains and about 63 mrem on the eastern slopes of the Rocky Mountains.

The average external gamma exposure rate in the vicinity of the Oak Ridge Reservation (ORR) is about 51 mrem per year.



Source: DOE 1999c.

FIGURE D.2.1–1.—Average U.S. Annual Doses from Common Radiation Sources.

Internal radiation arises from the human body metabolizing natural radioactive material that has entered the body by inhalation ingestion, or through an open wound. Natural radionuclides in the body include isotopes of uranium, thorium, radium, radon, bismuth, polonium, potassium, rubidium, and carbon. The major contributors to the annual dose equivalent for internal radioactivity are the short-lived decay products of radon which contribute about 200 mrem per year. The average dose from other internal radionuclides is about 39 mrem per year, most of which results from potassium-40 and polonium-210.

Consumer products also contain sources of ionizing radiation. In some products, like smoke detectors and airport x-ray machines, the radiation source is essential to the operation of the product. In other products, such as televisions and tobacco products, the radiation occurs incidentally to the product function. The average annual dose from consumer products is about 10 mrem.

Medical source radiation is an important diagnostic tool and is the main source of exposure to the public from manmade radiation. Exposure is deliberate and directly beneficial to the patient exposed. In general, medical exposures from diagnostic or therapeutic x rays result from beams directed to specific areas of the body. Thus, all body organs generally are not irradiated uniformly. Nuclear medicine examinations and treatments involve the internal administration of radioactive compounds or radiopharmaceuticals by injection, inhalation, consumption, or insertion. Even then, radionuclides are not distributed uniformly throughout the body. Radiation and radioactive materials also are used in the preparation of medical instruments, including the sterilization of heat-sensitive products such as plastic heart valves. Diagnostic x rays result in an average annual exposure of 39 mrem. Nuclear medical procedures result in an average annual exposure of 14 mrem. It is recognized that the averaging of medical doses over the entire population does not account for the potentially significant variations in annual dose among individuals, where greater doses are received by older or less healthy members of the population.

A few additional sources of radiation contribute minor doses to individuals in the United States. The doses from nuclear fuel cycle facilities, such as uranium mines, mills, and fuel processing plants, nuclear power plants, and transportation routes have been established to be less than 1 mrem per year. Radioactive fallout from atmospheric atomic bomb tests, emissions of radioactive material from DOE facilities, emissions from certain mineral extraction facilities, and transportation of radioactive materials contributes less than 1 mrem per year to the average individual dose. Air travel contributes approximately 1 mrem per year to the average dose.

D.2.2 Radioactive Materials at Y-12

The release of radiological contaminants into the environment at Y-12 occurs almost exclusively as a result of plant production, maintenance, and waste management activities. This section describes the primary radioactive sources at Y-12, how DOE regulates radiation and radioactive materials, and the data sources and methodologies used to evaluate the potential health effects of radiation exposure to the worker and public.

D.2.2.1 What Are Some Y-12 Sources That May Lead to Radiation Exposure?

Historically, Y-12 has conducted many operations that involve the use of enriched, natural, and depleted uranium. These have included recovery and recycle operations; purification processes; and metal forming, machining, and material handling operations. The releases from these operations consisted primarily of uranium particulates, fumes, and vapors. Under the current Y-12 mission to dismantle weapons components, store nuclear material, and pursue new technologies, uranium remains the primary radionuclide. In addition to the Y-12 operations, the Oak Ridge National Laboratory (ORNL) also operates research facilities located at Y-12. The ORNL facilities emit a variety of radionuclides from small-scale research projects conducted by the Life Sciences Division and Chemical Technology Division laboratories.

Potential radiation exposures at Y-12 could result primarily from process materials, industrial radiation generation equipment, and criticality or nuclear accidents. The most common process materials are enriched uranium and depleted uranium. Both materials are primarily alpha emitters. However, ^{235}U does emit low-level gamma radiation. In addition, protactinium, neptunium, and thorium have been detected as secondary radionuclides. Most of the external dose from depleted uranium results from the ^{234}Th and ^{234}Pa daughter products, with ^{234}Pa being the stronger contributor, due to its emission of a strong beta particle as well as several gamma and X rays.

Airborne emissions contribute the most significant potential for radiation dose at Y-12. National Emission Standards for Hazardous Air Pollutants (NESHAP) regulations specify that any source that potentially can contribute >0.1 mrem/year TEDE to an off site individual is to be considered a “major source” and emissions from that source must be continuously sampled. As such, there are a number of process exhaust stacks at Y-12 that are considered major sources. At the end of 1998, Y-12 had 51 active stacks that were being monitored.

In addition to major sources, there are a number of minor sources that have the potential to emit radionuclides to the atmosphere. Minor sources are composed of any ventilation systems or components such as vents, laboratory hoods, room exhausts, and stacks that do not meet the criteria for a major source but are located in or vent from a radiological control area. Emissions from Y-12 room ventilation systems are estimated from radiation control data collected on airborne radioactivity concentrations in the work areas. Other emissions from unmonitored processes and laboratory exhausts are categorized as minor emission sources. There were 54 unmonitored areas of uranium emissions from room ventilation systems or process stacks, and 28 minor emission points were identified from ORNL activities at facilities within the boundary of Y-12. Seven minor emission points were identified at the Analytical Chemistry Organization (ACO) Union Valley Laboratory.

In addition, there are also five areas of potential fugitive and diffuse sources at Y-12, consisting of a contaminated metal salvage yard, three storage areas, and a tooling lay-down area. Diffuse and fugitive sources include any source that is spatially distributed, diffuse in nature, or not emitted with forced air from a stack, vent, or other confined conduit. They include emissions from sources where forced air is not used to transport the radionuclides to the atmosphere. In this case, radionuclides are transported entirely by diffusion or thermally driven air currents. Typical examples include emissions from building breathing; resuspension of contaminated soils, debris, or other materials; unventilated tanks; ponds, lakes, and streams; wastewater treatment systems; outdoor storage and processing areas; and leaks in piping, valves, or other process equipment.

Liquid discharges are another source of radiation release and exposure. Three types of liquid discharge sources at Y-12 include treatment facilities, other point- and area-source discharges, and in-stream locations. In addition, the sanitary sewer is monitored since Y-12 is permitted to discharge domestic wastewater to the city of Oak Ridge publicly owned treatment works (POTW).

Soils and sediment also provide a potential for radiation exposure. The generation of fugitive dust from potentially contaminated surface soils is captured by both the perimeter air monitoring stations and onsite uranium particulate monitoring. Sediment exposed on creek banks and flood plains or transported to the off-site environment serves as an additional source of radiation exposure.

Groundwater transport of radionuclides to potential off-site receptors also provides the potential for radiation exposure. A comprehensive groundwater monitoring program is in place at the Y-12 Plant to track contaminant transport and to ensure the public safety.

D.2.2.2 *How Does DOE Regulate Radiation Exposure?*

The release of radioactive materials and the potential level of radiation doses to workers and the public are regulated by the U.S. Department of Energy (DOE) for its contractor facilities. Under conditions of the *Atomic Energy Act* (as amended by the *Price-Anderson Amendments Act of 1988*), DOE is authorized to establish Federal rules controlling radiological activities at the DOE sites. The act also authorizes DOE to impose civil and criminal penalties for violations of these requirements. Some Y-12 activities are also regulated through a DOE Directives System that is contractually enforced.

Occupational radiation protection is regulated by the Occupational Radiation Protection Rule, 10 CFR 835. DOE has set occupational dose limits for an individual worker at 5,000 mrem per year. Accordingly, Y-12 has set administrative exposure guidelines at a fraction of this exposure limit to help enforce the goal to manage and control worker exposure to radiation and radioactive material as low as reasonably achievable (ALARA). The Y-12 ALARA administrative control level for the whole body is 1,500 mrem per year for enriched uranium operation workers and 1,000 mrem per year for other Y-12 workers.

Environmental radiation protection is currently regulated contractually with DOE Order 5400.5. This Order sets annual dose standards to members of the public, as a consequence of routine DOE operations, of 100 mrem through all exposure pathways. The Order requires that no member of the public receive an annual dose greater than 10 mrem from the airborne pathway and 4 mrem from ingestion of drinking water. In addition, the dose requirements in the Radionuclide National Emission Standards for Hazardous Air Pollutants (Rad-NESHAP) limit exposure of an individual member of the public to airborne releases of radionuclides to a maximum of 10 mrem/year.

D.2.2.3 *Data Sources Used to Evaluate Public Health Consequences from Routine Operations*

Because Y-12 operations have the potential to release measurable quantities of radionuclides to the environment that result in exposure to the worker and the public, Y-12 conducts environmental surveillance

and monitoring activities. These activities provide data that are used to evaluate radiation exposures that contribute to dose to the public. Each year, environmental data from the ORR and each of the facilities, including Y-12, are collected and analyzed in accordance with the guidelines specified in DOE Order 5400.1 *General Environmental Protection Program*. The results of these environmental monitoring activities are summarized in the Oak Ridge Reservation's *Annual Site Environmental Report* (ASER) (DOE 1999c). The environmental monitoring conducted at Y-12 consists of two major activities: effluent monitoring and environmental surveillance.

Effluent monitoring involves the collection and analysis of samples or measurements of liquid (waterborne) and gaseous (airborne) effluents prior to release into the environment. These analytical data provide the basis for the evaluation and official reporting of contaminants, assessment of radiation and chemical exposures to the public, and demonstration of compliance with applicable standards and permit requirements.

Environmental surveillance data provide a direct measurement of contaminants in air, water, groundwater, soil, food, biota, and other media subsequent to effluent release into the environment. These data verify Y-12's compliance status and, combined with data from effluent monitoring, allow the determination of chemical and radiation dose and exposure assessment of Y-12 Plant operations and effects, if any, on the local environment. The effluent and environmental surveillance data presented in the ASER were used as the primary source of data for the analysis of radiation exposure to the public for the No Action Alternative.

Ongoing remedial investigation data for soils, surface water, and groundwater collected from areas of concern at Y-12 served as an additional source of environmental data to evaluate the potential health effects of radiation and chemical exposure presented in the SWEIS. The remedial investigation data were collected to support a determination of the need for remedial action, if any, to protect human health and the environment at locations where radiological and/or chemical contaminants were known to have been treated, stored, disposed of, or released to the environment. The Remedial Investigation for the Upper East Fork Poplar Creek (UEFPC) characterization area encompasses the developed Y-12 industrial areas and includes waste management areas as well as dispersed areas of contamination from operations not related to the management of wastes. The remedial investigation documents the nature and extent of contamination, environmental conditions, results of fate and transport modeling, and the estimated risks to human health and the environment. Because the UEFPC characterization area is within the bounds and covers the majority of the area evaluated in the SWEIS, the data presented therein will be used to supplement the information contained in the ASER.

D.2.2.4 Methodology for Estimating Radiological Impacts

Airborne Radionuclides. The public health consequences of radionuclides released to the atmosphere from operations at Y-12 were characterized and calculated in the ASER. TEDEs were derived for a maximally exposed offsite individual and to the entire population residing within 80 km (50 mi) of the center of the ORR (See Appendix E.4). The dose calculations were modeled using *The Clean Air Act Assessment Package of 1988* (CAP-88) package of computer codes (Beres 1990). CAP-88 was developed to demonstrate compliance with the Rad-NESHAP, 40 CFR 61, Subpart H, which governs the emissions of radionuclides other than radon from DOE facilities. Six emission points were modeled for Y-12. Table D.2.2-1 lists the emission point parameter values and receptor locations used in the dose calculations. Meteorological data used in the calculations were in the form of joint frequency distributions of wind direction, wind speed class, and atmospheric stability category derived from data collected at the 60-m height on Tower MT6 for all sources at Y-12.

The exposure assumptions for the dose calculations were that each person remained at home (actually, outside of the house), unprotected, during the entire year and obtained food according to the rural pattern defined in the NESHAP background documents (DOE 1999k). This pattern specifies that 70 percent of the vegetables and produce, 44.2 percent of the meat, and 39.9 percent of the milk consumed by each person are

produced in the local area (e.g., a home garden). The remaining portions of each food group are assumed to be produced within 80 km (50 mi) of the ORR. For collective TEDE estimates, production of beef, milk, and crops within 80 km (50 mi) of the ORR was calculated using the state-specific production rates provided with CAP-88.

**TABLE D.2.2-1.—Emission Point Parameters and Receptor Locations
Used in the Dose Calculations**

Source Name	Type	Release Height (m)	Diameter (m)	Gas Exit Velocity (m/s)	Gas Exit Temperature (°C)	Distance (m) and Direction to Maximally Exposed Individual			
						Y-12		ORR	
Y-Monitored Stacks	Point	20	NA	NA	Ambient	1,080	NNE	12,200	SSW
Y-Minor Processes	Point	20	NA	NA	Ambient	1,080	NNE	12,200	SSW
Y-Lab Hoods	Point	20	NA	NA	Ambient	1,080	NNE	12,200	SSW
Y-ASO Union Valley	Point	9.75	0.8	10	Ambient	2,410	WSW	15,000	SW
Y-9207	Point	20	NA	NA	Ambient	700	NW	13,100	S
Y-9204-3	Point	20	NA	NA	Ambient	1,100	N	12,100	SSW

Source: Adapted from DOE 1999c.

Surface Water. The health consequences of radionuclides contained in surface water were characterized and evaluated from surveillance and monitoring data in the ASER. Water samples were collected and analyzed to determine the concentration of selected radiological parameters. The resultant concentrations of radionuclides in surface water were compared to established risk-based concentration values to identify contaminants of concern.

Sediment and Soil. Sediment data were collected and presented in the ASER. Due to the limited number of samples and analytes, no risk evaluation was performed for these data. The soil/sediment data collected as part of the remedial investigation of the UEFPC were used to evaluate potential exposure to the public. In the risk assessment for the UEFPC characterization area, data were segregated into exposure units, representative concentrations were derived, and risks/hazards were calculated for several exposure pathways. The pathway considered most appropriate for use in this Y-12 SWEIS was the open-recreational land use scenario. Risks/hazards were calculated for this scenario using standard U.S. Environmental Protection Agency (EPA) risk methodology and default exposure parameters.

Groundwater. Data from the Y-12 groundwater monitoring program were compiled and evaluated as part of the remedial investigation for the UEFPC characterization area. Excess lifetime cancer risks and hazard quotients (HQs) were calculated for groundwater contaminants under two exposure scenarios: drinking water ingestion for a non-protected Y-12 Plant worker and ingestion, inhalation, and dermal contact for an off-site resident. For purposes of this SWEIS, the industrial drinking water ingestion scenario is considered to be of use in evaluating potential exposure under normal operating conditions. The industrial drinking water ingestion scenario assumes that a Plant worker ingests 1 L/day of groundwater for 250 days/year for 25 years. The residential scenario is a hypothetical future exposure scenario that is currently known to be an incomplete exposure pathway where no current receptors exist and therefore is not considered to be representative of current conditions.

D.2.2.5 Risk Characterization and Interpretation of Radiological Data

The risk estimators for determining the health consequences of radiation exposure are 500 excess fatal cancers per million person-rem for the general public and 400 excess fatal cancers per million person-rem for workers (BEIR 1990). The higher risk estimator for the general public reflects the inclusion of sensitive population groups, such as children. Based on recommendations of the International Commission on Radiological Protection (ICRP 1991), the health risk estimators for nonfatal cancer and genetic disorders among the general public are 20 percent (100 per million person-rem) and 26 percent (130 per million person-rem), respectively, of the fatal cancer risk estimator of 400 Latent Cancer Fatalities (LCFs) per million person-rem. In this SWEIS, only fatal cancers are presented.

The number of LCFs in the general population or in the workforce is determined by multiplying 500 LCFs per million person-rem with the calculated collective population dose (person-rem), or 400 LCFs per million person-rem with the calculated collective workforce dose (person-rem), respectively.

For example, in a population of 100,000 people exposed only to natural background radiation of 0.3 rem per year, 15 cancer fatalities per year would be inferred to be caused by the radiation ($100,000 \text{ persons} \times 0.3 \text{ rem per year} \times 0.0005 \text{ cancer fatalities per person-rem} = 15 \text{ cancer fatalities per year}$).

Sometimes, calculations of the number of excess cancer fatalities associated with radiation exposure do not yield whole numbers and, especially in environmental applications, may yield numbers less than 1.0. For example, if a population of 100,000 were exposed as above, but to a total dose of only 0.001 rem, the collective dose would be 100 person-rem, and the corresponding estimated number of cancer fatalities would be 0.05 ($100,000 \text{ persons} \times 0.001 \text{ rem} \times 0.0005 \text{ cancer fatalities/person-rem} = 0.05 \text{ fatal cancers}$).

A nonintegral number of cancer fatalities such as 0.05 should be interpreted as a statistical estimate. That is, 0.05 is interpreted as the average number of deaths that would result if the same exposure situation were applied to many different groups of 100,000 people. In most groups, no person (0 people) would incur a cancer fatality from the 0.001 rem dose each member would have received. In a small fraction of the groups, one fatal cancer would result; in exceptionally few groups, two or more fatal cancers would occur. The average number of deaths over all the groups would be 0.05 fatal cancers (just as the average of 0, 0, 0, and 1 is 1/4, or 0.25). The most likely outcome is 0 cancer fatalities.

These same concepts apply to estimating the effects of radiation exposure on a single individual. Consider the effects, for example, of exposure to background radiation over a lifetime. The “number of cancer fatalities” corresponding to a single individual’s exposure over a (presumed) 72-year lifetime to 0.3 rem per year is the following:

$$1 \text{ person} \times 0.3 \text{ rem/year} \times 72 \text{ years} \times 0.0005 \text{ cancer fatalities/person-rem} = 0.011 \text{ cancer fatalities}$$

<p>Total number of fatal cancers in general population from annual exposure =</p> $\left(\frac{500}{10^6 \text{ person-rem}} \right) \times \left(\text{annual collective dose (person-rem)} \right)$ <p>or</p> <p>Total number of fatal cancers in worker population from annual exposure =</p> $\left(\frac{400}{10^6 \text{ person-rem}} \right) \times \left(\text{annual worker population collective dose (person-rem)} \right)$
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This could be interpreted that the estimated effect of background radiation exposure on the exposed individual would produce a 1.1 percent chance that the individual might incur a fatal cancer caused by the exposure.

Health effects resulting from exposure to both airborne and waterborne radionuclides may also be evaluated by comparing estimated concentrations to established radionuclide-specific, risk-based concentration values. For example, DOE Order 5400.5 establishes Derived Concentration Guidelines (DCGs) for the inhalation of air and the ingestion of water. The DCG is the concentration of a given radionuclide for one exposure pathway (e.g., ingestion of water) that would result in a TEDE of 100 mrem per year to a reference man, as defined by the International ICRP Publication 23 (ICRP 1975).

To ensure that exposure via the drinking water pathway is limited to the established 4 mrem/year, 4 percent of the DCG values are used as comparison values. Members of the public are assumed to ingest 730 L/year (2 L/day) of water or to inhale 8,400 m³/yr (23 m³/day) of air at the DCG level. The exposure is assumed to occur 24 hours per day for 365 days per year. The DCG values are used as reference concentrations for conducting environmental protection programs at DOE sites, as screening values for considering best available technology for treatment of liquid effluents, and for making dose comparisons. Using radiological data, percentages of the DCG for a given isotope are calculated.

D.2.3 Risk Estimates and Health Effects for Potential Radiation Exposures to Workers

For the purpose of evaluating radiation exposure, Y-12 workers may be designated as radiation workers, nonradiation workers, or visitors based upon the potential level of exposure they are expected to encounter in performing their work assignments.

Radiation workers are either Lockheed Martin Energy Systems, Inc. (LMES) employees, or subcontractors whose job assignments place them in proximity to radiation-producing equipment and/or radioactive materials. These workers are trained for unescorted access to radiological areas, and may also be trained radiation workers from another DOE site. These workers are assigned to areas that could potentially contribute to an annual TEDE of more than 100 mrem per year. All trained radiation workers wear dosimeters.

Nonradiation workers may be either LMES employees or subcontractors who are not currently trained as radiation workers but whose job assignment may require their occasional presence within a radiologically controlled area with an escort. They may be exposed to transient radiation fields as they pass by or through a particular area, but their job assignments are such that annual dose equivalents in excess of 100 mrem are unlikely. Based upon the locations where such personnel work on a daily basis, they may be issued a Personal Nuclear Accident Dosimeter.

Visitors are individuals who do not perform routine work at Y-12. They are not trained radiation workers and are not expected to receive 100 mrem in a year. Their presence in radiological areas is limited, in terms of time and access. These individuals generally enter specified radiological areas on a limited basis for walk-through or tours with a trained escort. As appropriate, visitors participate in dosimetry monitoring when requested by the hosting division.

D.2.3.1 *Radiological Health Effects for Workers Under Alternative 1A (No Action - Status Quo Alternative)*

A primary goal of the Y-12 Radiation Protection Program is to keep worker exposures to radiation and radioactive material ALARA. Such a program must evaluate both external and internal exposures with the goal to minimize worker radiation dose. The worker radiation dose presented in this SWEIS is the total TEDE incurred by workers as a result of normal operations. This dose is the sum of the external whole body dose, including dose from both photons and neutrons, and internal dose, as required by 10 CFR 835. The internal dose is the 50-year CEDE. These values are determined through the Y-12 Plant External and Internal Dosimetry Programs.

The External Dosimetry Program at Y-12 provides personnel monitoring information necessary to determine the dose equivalent received following external exposure of a person to ionizing radiation. The program is based on the concepts of effective dose equivalent, as described in publications of the ICRP and the International Commission on Radiation Quantities and Units.

Internal dose monitoring programs are conducted at Y-12 to estimate the quantity and distribution of radionuclides to which a worker may have been exposed. The internal dose monitoring program consists of urinalysis, fecal analysis, lung counting, continuous air monitoring, and retrospective air sampling. Dose assessments are generally based on bioassay data. Bioassay monitoring methods and participation frequencies are required to be established for individuals who are likely to receive intakes that could result in a CEDE that is greater than 100 mrem.

Table D.2.3-1 lists the individual and collective doses for all radiation workers from 1990 to 1998, as presented in the Y-12 Dosimetry Record System (DRS) database. Table D.2.3-2 lists the individual collective doses for all monitored workers, from 1990 to 1998. Monitored workers include radiation workers, nonradiation workers, and visitors. The doses projected for the No Action - Status Quo Alternative are based on 1998 data.

Note that the 1998 data reflect higher dose values as a result of the use of a more conservative risk model in 1998 than that used in previous years and the resumption of some operations. This model contains parameters based upon conservative assumptions pertaining to the solubility of materials in the body. This resulted in higher internal dose contributions; however, DOE has recently approved the use of a new dosimetry model using more accurate dose assumptions that could potentially lower doses by as much as 20 percent. Implementation of the new model will affect dose calculations for the period beginning January 1, 2000. The radiation doses and projected health impacts to workers for No Action - Status Quo Alternative are summarized in Table D.2.3-3.

TABLE D.2.3-1.—Y-12 Annual Individual and Collective Radiation Doses for all Rad Workers from 1990 - 1998

Year	Number of Rad Workers	Average Individual Worker Dose (mrem)	Rad Worker Collective Dose (person-rem)
1990	2,907	14.8	43.16
1991	3,050	7.3	22.27
1992	2,787	13.1	36.46
1993	2,701	6.8	18.48
1994	2,533	5.4	13.58
1995	2,924	3.1	9.10
1996	3,140	3.1	9.73
1997	3,552	2.96	10.51
1998 ^a	3,563	11.4	40.61

^a 1998 data reflect higher doses due to the use of a more conservative risk model in 1998 than that used in previous years and the resumption of some operations.

Source: Adapted from Y-12 1999.

TABLE D.2.3-2.—Annual Individual and Collective Radiation Doses for All Monitored Y-12 Workers (Rad and Non-Rad) from 1990 - 1998

Year	Number of Monitored Workers	Average Individual Worker Dose (mrem)	Site Worker Collective Dose (person-rem)
1990	9,799	5.0	48.95
1991	10,824	2.7	29.60
1992	10,273	3.7	37.91
1993	9,995	2.1	20.52
1994	9,748	1.6	15.31
1995	9,327	1.1	10.27
1996	9,159	1.2	10.90
1997	4,758	2.2	10.69
1998 ^a	5,128	8.0	41.24

^a 1998 data reflect higher doses due to the use of a more conservative risk model in 1998 than that used in previous years.

Source: Adapted from Y-12 1999.

TABLE D.2.3-3.—Radiation Doses and Estimated Health Impacts to Workers from Y-12 No Action - Status Quo Alternative Normal Operations

	Worker Dose	Radiation Dose	No. of LCFs
Baseline			
Annual Average Individual Worker Dose (mrem/yr)		8.0	3.2×10^{-6a}
Annual Workforce Collective Dose (person-rem/yr)		41.02	1.64×10^{-2}

^a This represents the risk of latent cancer fatality for an individual worker.

The radiological doses for rad and non-rad workers within the major production operations for No Action - Status Quo Alternative are presented in Appendix E (Table E.4.2-3). Dose values from this table were used to estimate the number of projected LCFs and are presented in Table D.2.3-4.

D.2.3.2 Radiological Health Effects for Workers Under Alternative 1B (No Action - Planning Basis Operations Alternative)

For No Action - Planning Basis Operations Alternative, it was determined that annual enriched uranium emissions and other effluents for the 2001-2010 time period can be assumed to be 65 percent of the 1987 levels (LMES 2000a). However, internal dose reporting requirements were not in effect until 1989. Prior to that time, only external (deep) dose was reported. The average deep dose for all monitored Y-12 employees was 16 mrem in 1987, 12 mrem in 1989, and less than 5 mrem for subsequent years. Consequently, 1989 radiation doses provide the best available data for estimating radiation impacts to the worker for No Action - Planning Basis Operations Alternative. The full value of the 1989 dose, rather than 65 percent, was used to provide a conservative estimate of the average worker dose. The radiation doses and projected health impacts to workers for No Action - Planning Basis Operations Alternative are presented in Tables D.2.3-5 and D.2.3-6. The projected health impacts to workers for major production operations are presented in Table D.2.3-7.

D.2.3.3 Radiological Health Effects Under the Highly Enriched Uranium Storage Mission Alternative

The process operations projected for the HEU Materials Facility include loading, unloading, and storage of canned materials and general fissile containers; nondestructive evaluation activities; sampling, canning, and recontainerization of special nuclear materials; and materials inventory and tracking. Because these activities closely mirror current operations at the 9720-5 facility, radiation doses from 9720-5 warehouse operations were used to estimate the projected health impacts to HEU workers. Table D.2.3-8 presents the radiation dose and projected health impact to workers for the No Action - Planning Basis Operations Alternative and for two operating scenarios (new facility and upgrade to Bldg. 9215) under the HEU Storage Mission Alternative. Under the No Action - Planning Basis Operations Alternative, normal operations at the 9720-5 warehouse would be expected to continue at the levels conducted in 1998.

It is expected that 90 to 95 percent of the designated on-site materials will be relocated to the HEU Materials Facility during the first year of operation. Operations during the initial relocation would more closely resemble 1999 activities. During 1999, much of the HEU inventory was retrieved from storage, weighed, tagged, and returned to storage as part of a criticality safety validation process. The doses incurred by workers through the increased handling of materials during this process provide a reasonable estimate of the dose that would likely be received during the initial phase of facility operation. The average deep dose for 1999 was increased by a factor of 3 to account for the relative increase in the number of hours projected for workers during the relocation phase.

After the relocation phase, normal HEU Materials Facility operations should result in annual worker doses at or below the 1998 levels (15 - 21 mrem) due to:

- The use of gloveboxes, inert atmosphere, negative air pressure, and other engineered controls
- Automated inventory and tracking system should result in significant reduction in dose from 1998 levels
- Management of facility operations to minimize and eliminate, where possible, the use and creation of radiologically contaminated areas
- Decreased number of workers

TABLE D.2.3-4.—Estimated Radiological Health Effect for Workers for Major Production Operations (No Action - Status Quo Alternative)

Operation	Radiological Workers				All Workers (Radiological and Non-Radiological)			
	Number of Workers	Individual Worker Doses (mrem)	Collective Dose (person-rem)	LCFs	Number of Workers	Average Individual Worker Dose (mrem)	Collective Dose (person-rem)	LCFs
Enriched Uranium	192	85.83	16.48	6.59×10^{-3}	393	8.0	3.14	1.26×10^{-3}
Depleted Uranium	220	10.92	2.40	9.6×10^{-4}	223	8.0	1.78	7.12×10^{-4}
Assembly/Disassembly/ Quality Evaluation	150	10.63	1.59	6.36×10^{-4}	160	8.0	1.28	5.12×10^{-4}
Product Certification	125	3.2	0.4	1.6×10^{-4}	150	N/A	1.20	4.80×10^{-4}
Analytical Chemistry Organization	126	0.95	0.12	4.8×10^{-5}	163	N/A	1.30	5.20×10^{-4}
Y-12 Plant	3563	11.4	40.61	1.62×10^{-2}	5128	8.0	41.24	1.64×10^{-2}

Source: Based on Appendix E, Table E.4.2.-3.

The Special Materials Mission Alternatives would have no impact on the No Action - Planning Basis Operations Alternative levels because there were no radiological operations associated with this mission.

TABLE D.2.3-5.—Y-12 Worker Individual and Collective Radiation Doses for Alternative 1B No Action - Planning Basis Operations Alternative

All Workers (Rad and Non-Rad)	
No. of workers	5,128
Average worker dose (mrem)	11.6
Collective dose (person-rem)	59.48

Source: Y-12 1999.

TABLE D.2.3-6.—Radiation Doses and Health Impacts to Workers Under the No Action - Planning Basis Operations Alternative

Worker Dose	Radiation Dose	No. of LCFs
Annual Average Individual Worker Dose (mrem/yr)	11.6	4.64×10^{-6a}
Annual Workforce Collective Dose (person-rem/yr)	59.48	2.38×10^{-2}

^a This represents the risk of latent cancer fatality for an individual worker.

Source: Y-12 1999.

TABLE D.2.3-7.—Radiological Health Effects for Workers for Major Production Operations Under the No Action - Planning Basis Operations Alternative

All Workers (Rad and Non-Rad)				
Operation	No. of Workers	Average Individual Worker Dose (mrem)	Collective Dose (person-rem)	Latent Fatal Cancers
Enriched Uranium	492	11.6	5.71	2.28×10^{-3}
Depleted Uranium	223	11.6	2.59	1.04×10^{-3}
Assembly/Disassembly/ Quality Evaluation	160	11.6	1.86	7.44×10^{-4}
Product Certifications	158	11.6	1.83	7.32×10^{-4}
Analytical Services	180	11.6	2.09	8.36×10^{-4}
Y-12 Plant	5128	11.6	59.48	2.38×10^{-2}

Source: Based on LMES 2000a.

TABLE D.2.3–8.—Radiation Doses and Health Impacts to Workers Under the Highly Enriched Uranium Storage Mission Alternative

No Action - Planning Basis Operations Alternative	
Dose (mrem)	21
No. of involved workers	35
Collective dose (person-rem)	0.74
No. of fatal cancers	3×10^{-4}
HEU Storage Mission Alternatives	
<i>Initial Relocation Operations</i>	
Dose (mrem)	150
No. of involved workers	35
Collective dose (person-rem)	5.25
No. of fatal cancers	2.1×10^{-3}
<i>Normal Operations</i>	
Dose (mrem)	21
No. of involved workers	14
Collective dose (person-rem)	0.29
No. of fatal cancers	1.16×10^{-4}

Source: Based on LMES 2000a; LMES 2000b.

D.2.4 Risk Estimates and Health Effects for Potential Radiation Exposures to the Public for Alternative 1A (No Action - Status Quo Alternative)

Dose estimates for exposure to releases of radiological contaminants from Y-12 were compiled from the ASER for 1997 and 1998 and the remedial investigation for UEFPC to establish the No Action - Status Quo Alternative for contaminant environmental concentrations and the subsequent potential exposure results. Dose estimates for the determined alternatives were calculated using standard environmental transport codes and exposure assumptions. In both cases, the dose estimates were then compared to relevant regulatory criteria and are presented below.

D.2.4.1 Health Effects of Airborne Radionuclides

Effluent Monitoring. Releases of radiological contaminants, primarily uranium, into the atmosphere at Y-12 are continuously monitored in accordance with NESHAP regulations. NESHAP regulations specify that any source that potentially can contribute >0.1 mrem/year TEDE to an offsite individual is to be considered a “major source” and emissions from that source must be continuously sampled. Uranium stack losses were measured continuously on 51 of 57 (six were temporarily shut down) process exhaust stacks (major sources) in 1998. Particulate matter (including uranium) was filtered from the stack sample; filters at each location were changed routinely, from one to three times per week, and analyzed for total uranium. In addition, the sampling probes and tubing were removed quarterly and washed with nitric acid; the washing

was analyzed for total uranium. At the end of the year, the probe-wash data were included in the final calculations in determining total emissions from each stack.

In addition to the active stacks at Y-12, “minor sources” of radionuclide release are included in the estimate of emissions. Minor sources at the Y-12 Plant are described below:

- **Laboratory exhaust:** Uranium and other radionuclides are handled in millicurie quantities at facilities within the boundary of Y-12 as part of ORNL and Y-12 ACO laboratory activities. In addition, emissions from the ACO laboratory located 1/3 mile east of the Plant on Union Valley Road are included in Y-12 source term. The releases from the ACO are minimal and have negligible effects on the total Y-12 dose.
- **Room Exhaust:** Radionuclide releases from process room ventilation systems are estimated from radiation control data collected on airborne radioactivity concentrations in the work areas. Areas where the monthly average concentrations exceeded 10 percent of the DOE derived air concentration worker protection guidelines are included in the annual emissions estimate.

Emissions from unmonitored process and laboratory exhausts, categorized as minor emission sources, are estimated according to EPA-approved calculation methods. In 1998, 50 minor emission points were identified from unmonitored radiological processes and laboratories. Twenty-eight minor emission points were identified from ORNL activities at facilities within the boundary of Y-12. Seven minor emission points were identified at the ACO Union Valley laboratory. No areas were identified where room ventilation emissions exceeded 10 percent of the derived air concentration worker protection guidelines. Table D.2.4-1 lists the quantities of enriched and depleted uranium estimated to have been released into the atmosphere as a result of Y-12 Plant activities during 1998.

TABLE D.2.4-1.—Y-12 Plant Airborne Uranium Emission Estimates, 1998

Source of Emissions	Quantity Emitted	
	Ci	kg
<i>Enriched Uranium</i>		
Process exhaust (monitored)	0.012	0.184
Process and laboratory exhaust (unmonitored)	0.00009	0.0014
Room exhaust (from health physics data)	0.00	0.00
<i>Depleted Uranium</i>		
Process exhaust (monitored)	0.0021	3.93
Process and laboratory exhaust (unmonitored)	0.0031	5.85
Room exhaust (from health physics data)	0.00	0.00
Total	0.017	9.97

Source: DOE 1999c.

Environmental Surveillance. Ambient air monitoring is performed to measure radiological parameters directly in the ambient air adjacent to the facility. Ambient air monitoring provides direct measurement of airborne concentrations of radionuclides and other hazardous pollutants in the environment, allows facility personnel to determine the relative level of contaminants at the monitoring locations during an emergency, verifies that the contributions of fugitive and diffuse sources are insignificant, and serves as a check on dose-modeling calculations. In 1998, three low-volume uranium particulate monitoring stations were operated by Y-12 within the Plant boundaries. For 1998, the average 7-day concentration of uranium at the three monitored locations ranged from a low of 0.00001 $\mu\text{g}/\text{m}^3$ to a high of 0.00044 $\mu\text{g}/\text{m}^3$ (DOE 1999c).

Additionally, air monitoring was conducted on the ORR to perform surveillance of airborne radionuclides at the reservation perimeter and to collect reference data from a remote location not affected by activities on the ORR. The closest perimeter monitoring station, Station 40, monitors the east end of the Y-12. Station 46 measures off-site impacts of the Y-12 operations in the Scarboro Community and is located near the theoretical area of maximum public pollutant concentrations as calculated by air quality modeling. A comparison of data collected from the monitoring locations indicates that there is no appreciable difference between the concentrations of radionuclides detected at the monitoring locations, Stations 40 and 46, and the reference station, Station 52 (Table D.2.4-2).

TABLE D.2.4-2.—Environmental Surveillance Perimeter Air Monitoring Results

Monitoring Location	⁷ Be	⁶⁰ Co	¹³⁷ Cs	⁴⁰ K	³ H	²³⁴ U	²³⁵ U	²³⁸ U	Gross alpha	Gross beta
Station 40	2.6 x 10 ⁻¹⁴	<i>b</i>	2.3 x 10 ⁻¹⁷	<i>b</i>	3.5 x 10 ⁻¹²	1.8 x 10 ⁻¹⁷	1.0 x 10 ⁻¹⁸	1.3 x 10 ⁻¹⁷	1.9 x 10 ⁻¹⁵	4.7 x 10 ⁻¹⁵
Station 46	3.7 x 10 ⁻¹⁴	<i>b</i>	<i>b</i>	<i>b</i>	<i>b</i>	1.5 x 10 ⁻¹⁷	<i>b</i>	1.5 x 10 ⁻¹⁷	<i>b</i>	<i>b</i>
Station 52 (reference)	3.1 x 10 ⁻¹⁴	<i>b</i>	3.6 x 10 ⁻¹⁷	4.7 x 10 ⁻¹⁶	3.3 x 10 ⁻¹²	5.0 x 10 ⁻¹⁸	7.5 x 10 ⁻¹⁹	4.6 x 10 ⁻¹⁸	2.4 x 10 ⁻¹⁵	<i>b</i>
Inhaled Air DCG	4.0 x 10 ⁻⁸	8 x 10 ⁻¹¹	4 x 10 ⁻¹⁰	9 x 10 ⁻¹⁰	2 x 10 ⁻¹	9.0 x 10 ⁻¹⁴	1.0 x 10 ⁻¹³	1.0 x 10 ⁻¹³	<i>c</i>	<i>c</i>

^a All values are mean concentrations in $\mu\text{Ci/mL}$.

^b Not detected at 95 percent confidence level.

^c No DCGs are available for gross alpha and beta.

Source: Adapted from DOE 1999c.

Summary of Health Effects from Airborne Radionuclides. The TEDE received by the hypothetical maximally exposed individual (MEI) for Y-12 was calculated to be 0.53 mrem (0.0053 mSv) based on both monitored and estimated effluent data (see Appendix E). This individual is located about 1,080 m (0.7 mi) north-northeast of the Y-12 release point. The major radionuclide emissions from Y-12 are nuclides ²³⁴U, ²³⁵U, ²³⁶U, and ²³⁸U. The contribution of Y-12 emissions to the 50-year committed collective TEDE to the population residing within 80 km (50 mi) of the ORR was calculated to be about 4.3 person-rem (0.043 person-Sv) which is approximately 35 percent of the collective TEDE (12 person-rem) for the ORR. Both the individual and collective TEDE are well below all applicable DOE and NESHAP criteria.

D.2.4.2 Health Effects of Waterborne Radionuclides

Effluent Monitoring. Radiological monitoring is conducted in accordance with the guidelines specified in the *Radiological Monitoring Plan for the Oak Ridge Y-12 Plant: Surface Water*, (LMES 1995a). The results of this monitoring are submitted quarterly as an addendum to the *National Pollutant Discharge Elimination System [NPDES] Discharge Monitoring Report*. Under the monitoring program, effluent monitoring is continued at three types of locations: treatment facilities, other point and area source discharges, and in-stream locations. Table D.2.4-3 lists the radiological parameters monitored at Y-12 in 1998. These parameters were selected based on operational history and the results of past monitoring activities. Table D.2.4-4 provides a summary of the locations sampled along with the sum of DCG percentages for each location.

The Radiological Monitoring Plan also addresses monitoring of the sanitary sewer. Y-12 is permitted to discharge domestic wastewater to the city of Oak Ridge POTW. Radiological monitoring of this discharge is also conducted and is reported to the city of Oak Ridge. The following parameters are monitored routinely: alpha, beta, and gamma activity, plutonium, and uranium.

Radiological monitoring of storm water is required by the NPDES permit, and a comprehensive monitoring plan has been designed to fully characterize pollutants in stormwater runoff. The most recent version of the plan was issued in December of 1998, *Storm Water Pollution Prevention Plan for the Oak Ridge Y-12 Plant*, which incorporates the radiological monitoring requirements (LMES 1996).

TABLE D.2.4-3.—Surface Water Radiological Parameters Monitored at the Y-12 Plant in 1998

Parameters	Specific Isotopes	Ingested Water DCG (pCi/L) ^a	Rationale for Monitoring
Uranium isotopes	²³⁴ U	20	These parameters reflect the major activity, uranium processing, throughout the history of Y-12 and are the dominant detectable radiological parameters in surface water.
	²³⁵ U	24	
	²³⁸ U	24	
	total U	20	
	weight percent ²³⁵ U	NA	
Fission and activation products	³ H	80,000	These parameters reflect a minor activity at Y-12, processing recycled uranium from reactor fuel elements, from the early 1960s to the late 1980s and will continue to be monitored as tracers for beta and gamma radionuclides, although their concentrations in surface water are low.
	⁹⁰ Sr	40	
	⁹⁹ Tc	4,000	
	¹³⁷ Cs	120	
Transuranium isotopes	²⁴¹ Am	1.2	These parameters are related to recycle uranium processing. Monitoring continued because of their half-lives and presence in groundwater.
	²³⁷ Np	1.2	
	²³⁸ Pu	1.6	
	^{239/240} Pu	1.2	
Other isotopes of interest	²²⁶ Ra	4 ^b	These parameters reflect historical thorium processing and natural radionuclides necessary to characterize background radioisotopes.
	²²⁸ Ra	4 ^b	
	²²⁸ Th	16	
	²³⁰ Th	12	
	²³² Th	2	

^aIngested water DCGs are 4 percent of the water DCGs recommended in DOE Order 5400.5 Chapter III Derived Concentration Guides for Air and Water and represent the DOE criterion of 4 mrem EDE from ingestion of drinking water.

^bCombined radium-226 and radium-228 shall not exceed 5×10^{-9} $\mu\text{Ci/mL}$ per DOE Order 5400.5.

Source:DOE 1999c.

Environmental Surveillance. Surface water environmental surveillance monitoring is conducted on the ORR to assess the impact of past and current DOE operations on the quality of local surface water. Sampling locations are downstream of ORR waste sources, at reference points on streams and reservoirs upstream of waste sources, and at public water intakes. Discharges from Y-12 enter the Clinch River via Bear Creek and the East Fork Poplar Creek (EFPC), both of which enter Poplar Creek before it enters the Clinch River, and by discharges from Rogers Quarry into McCoy Branch and then into Melton Hill Lake. Sampling locations pertinent to the evaluation of Y-12's impact on surface water quality and the parameters analyzed are listed in Table D.2.4-5 along with the results and the appropriate DCG.

TABLE D.2.4-4.—Summary of Y-12 Plant Radiological Monitoring Plan Sampling Locations and Results for 1998

Outfall No.	Location	Sum of DCG percentage
<i>Y-12 Plant wastewater treatment facilities</i>		
501	Central Pollution Control Facility	1.6
502	West End Treatment Facility	8.6
503	Steam Plant Wastewater Treatment Facility	No flow
512	Groundwater Treatment Facility	6.1
520	Steam Condensate	No flow
551	Central Mercury Treatment Facility	4.6
<i>Other Y-12 Plant point and area source discharges</i>		
S17	Kerr Hollow Quarry	2.8
S19	Rogers Quarry	3.6
<i>Y-12 Plant instream locations</i>		
BCK 4.55	Bear Creek, plant exit (west)	5.0
Station 17	East Fork Poplar Creek, plant exit (east)	3.9
200	North/south pipes	6.5

Source: DOE 1999c.

Sampling and analysis of surface water at the easternmost monitoring station (Station 17 on UEFPC) and at the westernmost monitoring station (BCK 4.55/NPDES Outfall 304) provide information regarding the concentrations of radionuclides from Y-12 operations that contribute to increased risk to the public. Table D.2.4-6 lists the monitoring results for these two locations along with the associated DCG. In comparing the 4 percent DCG with the average values of the detected radionuclides, none were found to exceed the DCG. However, a comparison of the maximum detected value with the DCG would identify radium (^{228}Ra) as the only radionuclide to exceed the DCG as was reported in the 1998 ASER.

Summary of Health Effects from Waterborne Radionuclides. Radiological data for all effluent monitoring locations were well below the allowable DCGs. The highest summed percentage of DCGs was from the West End Treatment Facility (WETF). Radium (^{228}Ra) was the major contributor of radioactivity there, contributing 7.6 percent to the total 8.6 percent of the sum of the percentages of the DCGs. In 1998, the total mass of uranium and associated curies released from the Y-12 Plant at the eastern-most monitoring station (Station 17 on UEFPC) and the western-most monitoring station (BCK 4.55) was 375 kg or 0.167 Ci. No single radionuclide in the Y-12 contribution to the sanitary sewer exceeded 1 percent of the DCG. Radiological monitoring of storm water is consistent with past years. Uranium is the dominant constituent and increases during storm flow either due to surface sources or increased groundwater flow. Radionuclide concentrations in surface water do not, therefore, pose an adverse health impact to the public.

TABLE D.2.4-5.—Oak Ridge Reservation Surface Water Surveillance Sampling Pertinent to Y-12

Location	Parameters	Maximum Results (pCi/L) ^a	4% Ingested Water DCG (pCi/L)	Results/DCG (percent)
Bear Creek downstream from the Y-12 Plant inputs (Bear Creek km 0.6)	⁶⁰ Co	3.1	200	0.02
	Gross alpha	6.1	15 ^{b,c}	<i>c</i>
	Gross beta	5.7	<i>c</i>	<i>c</i>
	Total U	5.2	20	0.26
	²³⁴ U	2.0	20	0.10
	²³⁵ U	0.080	24	0.003
	²³⁸ U	4.2	20	0.21
East Fork Poplar Creek (EFPC) prior to entering Poplar Creek (EFPC km 0.1)	Gross alpha	3.0	15 ^{b,c}	<i>c</i>
	Gross beta	5.4	<i>c</i>	<i>c</i>
	Total U	2.5	20	0.13
	²³⁴ U	1.0	20	0.05
	²³⁸ U	1.4	20	0.07
EFPC downstream from floodplain (EFPC km 5.4)	⁶⁰ Co	3.0	200	0.02
	Gross alpha	2.5	15 ^{b,c}	<i>c</i>
	Gross beta	4.5	<i>c</i>	<i>c</i>
	Total U	3.0	20	0.15
	²³⁴ U	1.5	20	0.08
	²³⁸ U	1.4	20	0.07
McCoy Branch prior to entering the Clinch River (McCoy Branch km 1.8)	⁶⁰ Co	2.7	200	0.01

^a All radionuclide concentrations were determined to be significantly greater than zero.

^b A National Primary Drinking Water Standard of 15 pCi/L is available for gross alpha.

^c No DCG is available for gross alpha or beta. The allowable drinking water dose to the public established in DOE Order 5400.5 is 4 mrem/year.

Source: Adapted from DOE 1999c.

D.2.4.3 Health Effects from Sediment Radionuclides

No sediment samples were collected at either in-stream locations or at outfalls during calendar year 1998. As such, the most recent sediment data available, 1997, are presented herein. In addition, sediment data collected as part of the remedial investigation of the UEFPC characterization area are presented to supplement the available historical data.

Environmental Surveillance. In 1997, the Environmental Monitoring Plan for the ORR was modified and sediment sampling at Y-12 in EFPC and Bear Creek was discontinued. However, as a best management practice, Y-12 collected one sample from EFPC and one from Bear Creek. The samples were analyzed for mercury, PCBs, and isotopes of uranium since historical data indicated these are contaminants of concern that are present at detectable levels in the sediment. The purpose of the annual sampling is to determine if these contaminants are accumulating in the sediment. The results for the radionuclides measured are presented in Table D.2.4-7.

TABLE D.2.4–6.—Environmental Surveillance Surface Water Monitoring Results (pCi/L) Collected to Determine Release of Radionuclides to the Off-site Environment.^a

Radionuclide	Concentration at Station 17	Concentration at Station BCK 4.55	4 percent Drinking Water DCG
²⁴¹ Am	0.76	<i>b</i>	1.2
⁶⁰ Co	1.1	<i>b</i>	200
²³⁷ Np	0.058	<i>b</i>	1.2
²³⁸ Pu	0.078	<i>b</i>	1.6
^{239/24} Pu	0.0067	<i>b</i>	1.2
²²⁸ Ra	2.1	<i>b</i>	4
⁹⁹ Tc	7.6	14	4,000
²²⁸ Th	0.093	0.061	16
²³⁰ Th	0.35	0.5	12
²³² Th	0.018	<i>b</i>	2
²³⁴ Th	4	7.8	400
³ H	262	<i>b</i>	80,000
²³⁴ U	1.8	4	20
²³⁵ U	0.095	0.23	24
²³⁸ U	4	7.8	20

^a Yearly average values reported.

^b Not detected above minimum analytical detection value.

Source: Adapted from DOE 1999c.

Sediment data collected at mainstream locations indicate that gross alpha, gross beta, ²⁴¹Am, total radium, ²²⁸Ra, and ²³⁰Th were detected. Isotopes with background levels that were detected above their associated background concentration are ²³⁷Np, ⁹⁹Tc, ^{233/234}U, ²³⁵U, and ²³⁸U. Isotopic activities for total radioactive strontium, ¹³⁷Cs, ²²⁸Th, and ²³²Th were not above their respective background values.

Sediment data collected within pipes and catch basins corresponding to particular outfalls or location indicate that uranium isotopes are ubiquitous and were detected at all but one sampled location. The most prevalent isotope was ²³⁸U (DOE 1998c).

Remedial Investigation. Sediment data collected in support of the remedial investigation for the UEFPC characterization area were aggregated into two categories: samples collected *inside* the Y-12 Plant boundary and those collected *outside* the Y-12 Plant boundary. Estimates of exposure for the open recreational land use were calculated for each aggregate. All data collected were compared to radionuclide-specific risk-based concentration values. The result of this comparison is a list of radionuclides detected in sediment that were evaluated quantitatively in the risk assessment and includes ²³⁷Np, ²²⁸Ra, total radium-alpha activity, ^{233/234}U, ²³⁵U, and ²³⁸U. The risk assessment for the UEFPC characterization area concludes that exposure to sediment via the open recreational exposure scenario for radionuclides would not result in risks within the EPA range of concern (10⁻⁴–10⁻⁶) for either the inside or outside Y-12 Plant boundary aggregates. Thus, limited exposure to radionuclides in sediment does not pose a significant health threat.

TABLE D.2.4-7.—1997 Results of Y-12 Plant Sediment Monitoring

Analyte (pCi/g)	Station 17 (EFPC)	Station 9.4 (Bear Creek)
²²⁶ Ra	2.8	2.4
²²⁸ Th	0.97	0.70
²³⁰ Th	1.2	0.41
²³² Th	0.73	0.68
²³⁴ U	2.6	3.6
²³⁵ U	0.13	0.20
²³⁸ U	2.9	6.3

Source: DOE 1998b.

D.2.4.4 Health Effects from Radionuclides in Soils

Soil samples are not collected as part of the environmental monitoring activities at the ORR. Therefore, the remedial investigation data for the UEFPC characterization area will be used as the sole source of soil data (DOE 1998c). The investigation of UEFPC characterization area evaluated both exposure to surface and subsurface soils. Evaluation of the open recreational land use scenario indicated that the primary contributor to radiological risks for the adult receptor was ¹³⁷Cs. Excess cancer risks (ECRs) were calculated according to the methods outlined in Section D.3.1.3 for the ingestion, inhalation, and external exposure pathway and are 1.8×10^{-6} , 6.3×10^{-12} , and 1.1×10^{-4} , respectively. The risk from external exposure was the primary contributor to unacceptable risk. This external exposure was mitigated by a removal action that occurred subsequent to the sampling and analysis and is therefore no longer a public health concern. Radionuclides detected in subsurface soils were not determined to pose a potential threat of adverse health effects. Excess cancer risks were well below the EPA range of concern.

D.2.4.5 Health Effects from Radionuclides in Groundwater

Radionuclides detected in groundwater monitoring data that exceeded risk-based radionuclide-specific screening levels were evaluated quantitatively in the risk assessment for the UEFPC Characterization Area and include ²⁴¹Am, ¹³⁷Cs, ²³⁸Pu, ²²⁶Ra, ²²⁸Ra, ²²⁸Th, Tritium, ²³⁴U, ²³⁵U, ²³⁶U, and ²³⁸U (DOE 1998c). An evaluation of the risks resulting from exposure to radionuclides in groundwater was conducted for an industrial and residential scenario only. Data were compiled and sorted into four aggregates: an exit pathway aggregate, a shallow clastics aggregate, an intermediate clastics aggregate, and Union Valley and arboretum wells aggregate. An ECR was calculated for each aggregate for each receptor. No unacceptable ECRs were calculated for the industrial scenario for any aggregate. Evaluation of the residential ingestion of groundwater indicated that exposure to concentrations of radionuclides in the exit pathway aggregate and the shallow clastics aggregate would result in ECRs within the EPA range of concern. The total pathway risk for the residential exit pathway aggregate was 1.1×10^{-4} and for the shallow clastics aggregate was 1.6×10^{-4} . The radionuclides contributing to these pathway risks are listed in Table D.2.4-8.

TABLE D.2.4-8.—Radionuclides of Concern for Residential Groundwater Scenario

Aggregate	Radionuclide of Concern	Excess Cancer Risk
Pathway Residential Exit	¹³⁷ Cs	2.5 x 10 ⁻⁶
	²²⁶ Ra	1.2 x 10 ⁻⁵
	²²⁸ Ra	7.5 x 10 ⁻⁶
	²²⁸ Th	1.1 x 10 ⁻⁶
	²³⁴ U	4.4 x 10 ⁻⁵
	²³⁵ U	1.8 x 10 ⁻⁶
	²³⁸ U	3.9 x 10 ⁻⁵
Shallow Clastics	¹³⁷ Cs	2.3 x 10 ⁻⁶
	²²⁶ Ra	5.5 x 10 ⁻⁵
	²²⁸ Ra	4.6 x 10 ⁻⁶
	⁹⁹ Tc	6.2 x 10 ⁻⁵
	²²⁸ Th	7.0 x 10 ⁻⁶
	²³⁴ U	8.3 x 10 ⁻⁶
	²³⁸ U	1.7 x 10 ⁻⁵

Source: Adapted from LMES 2000a (Remedial Investigation/ East Fork Poplar Creek).

D.2.5 Risk Estimates for Potential Radiation Exposures to the Public for the Alternatives

The additional proposed actions under consideration in this Y-12 SWEIS include HEU Storage Mission Alternatives, and the Special Materials Mission Alternative. Each of these actions will be discussed in the following subsections relative to their respective impact on the risk estimates for potential radiation exposure to the public.

D.2.5.1 Alternative 1B (No Action - Planning Basis Operations Alternative)

No Action - Planning Basis Operations Alternative does not include the construction or significant upgrade/expansion of any new or existing DP facilities. The Y-12 Plant would continue to use the existing storage facilities and the existing special materials operation facilities to perform the HEU Storage Mission and the Special Materials Mission, respectively. Under this alternative, the major production activities during the 2001-2010 time period will involve weapons production, weapons dismantlement, quality evaluation, special production, and enriched uranium recovery.

Production operations and enriched uranium recovery operations were significantly decreased during the 1990's because of major upgrades and the 1994 stand-down of the Y-12 Plant. As such, a review was conducted to determine what historical data were available that would most accurately represent the operations and emissions for the projected workload in the 2001-2010 time period (LMES 2000a). The 1987 Y-12 Plant emissions data were determined to be the most appropriate for use in this assessment.

During 1987, 50 percent of the environmental emissions were attributed to production operations and the remaining 50 percent were from enriched uranium recovery operations. The projected work load for 2001-2010 assumes that weapons production, quality evaluation, and special production will be approximately 30 percent of the 1987 level experienced for production operations, and that the enriched uranium recovery operations will be 100 percent of the 1987 level experienced for recovery operations. Thus, the radiological

airborne emissions data were collected for 1987, the results were multiplied by 65 percent, and the modified values served as the basis for the modeling conducted to estimate airborne emissions for the 2001-2010 workload under No Action - Planning Basis Operations Alternative (Appendix E).

Airborne Emissions. A total of 0.14 Ci of uranium was released from the Y-12 Plant during 1987 (Rogers 1988). Sixty-five percent of this amount, 0.0908 Ci, is assumed to be released per year from the Y-12 Plant under No Action - Planning Basis Operations Alternative. Given these assumptions, the modeling results indicate that the TEDE to the hypothetical maximally exposed individual was 4.5 mrem/year. Although this dose is higher than the 1998 baseline dose of 0.53 mrem/year, it is still well below the NESHAP standard of 10 mrem/year. The 50-year collective TEDE resulting from CAP88 modelling for No Action - Planning Basis Operations Alternative to the population residing within 80 km (50 mi) of the Y-12 Plant was 33.7 person-rem. That is approximately 0.01 percent of the dose the same population would receive from natural sources of radiation. Thus, no adverse health impacts to the public would result from increased operations under No Action - Planning Basis Operations Alternative.

In 1987, 12 perimeter ambient air monitors were operated at the Y-12 Plant. Uranium, fluoride, SO₂, and total suspended particulates data were collected. The results of this monitoring are presented and summarized in the report *Environmental Surveillance of the U.S. Department of Energy Oak Ridge Reservation and Surrounding Environs During 1987* (MMES 1988). Ambient uranium isotope concentrations measured were within the guidelines established in DOE Order 5480.1. Table D.2.5-1 lists the range of concentrations for each isotope.

TABLE D.2.5-1.—Ranges of Uranium Isotopic Concentrations at Perimeter Air Monitoring Stations During 1987

Isotope	Minimum (μg/m ³)	Maximum (μg/m ³)
²³⁴ U	0.13	24
²³⁵ U	0.013	0.72
²³⁸ U	0.0098	0.39

Source: LMES 1995a.

Waterborne Emissions. The existing *Radiological Monitoring Plan* was not in place and effective until 1995 (LMES 1995a). As such, radiological data for liquid discharges in 1987 was limited to two sampling locations. The first location, Bear Creek kilometer 12.4 (near the former S-3 ponds area), was sampled weekly in response to a 1983 complaint and order from the Tennessee Department of Health and Environment (TDHE). The second location, influent to New Hope Pond, was sampled in order to determine the effectiveness of Y-12 Source area controls and to determine the appropriate closure recommendations for the pond.

The results of the sampling for each of these locations is summarized in Table D.2.5-2. Only the radionuclides that were detected are included along with their associated ingested water DCG.

As is evidenced in Table D.2.5-2, the maximum detected values for ²⁴¹Am, ²³⁷Np, and ²²⁶Ra exceed the associated ingested water DCG. All other radionuclides were below their associated DCG.

These data are not directly comparable to 1998 data due to a difference in sampling location, sample collection methods, and subsequent *Resource Conservation and Recovery Act* (RCRA) closure activities. As such, the surface water data as presented in the baseline is also considered as representative of the No Action - Status Quo Alternative (see Section D.2.4.2).

TABLE D.2.5-2.—Results of 1987 Radiological Surface Water Sampling

Radionuclide	Maximum (pCi/L)	Minimum (pCi/L)	Average (pCi/L)	4 percent Ingested Water DCG
<i>Upper Bear Creek, kilometer 12.4</i>				
Gross alpha	1,000	6.7	496.5	NA
Gross beta	2,000	9.3	776.1	NA
²³⁷ Np	18	0.23	<2.43	1.2
²³⁵ U	40	<0.58	<11.17	24
U total (mg/L)	1.69	0.019	0.969	20
<i>New Hope Pond Influent</i>				
²⁴¹ Am	4.3	<0.27	<1.01	1.2
²²⁶ Ra	6.1	<0.4	<1.6	4
²²⁸ Th	4.1	0.15	0.97	16
²³⁴ U	19	<0.85	<10	20
²³⁵ U	19	<0.34	<2.3	24
²³⁸ U	10	0.3	<5.5	24
U total (mg/L)	0.029	0.007	0.017	20

Source: Adapted from DOE 1999c.

Sediment and Soil data. Soils and sediment data were not collected from locations representative of Y-12 effluents in 1987. Soil samples were collected as part of the ORR environmental surveillance activities to provide a measure of the quantity of radioactivity or other pollutants that were deposited from the atmosphere. No discussion or differentiation was made regarding the relative contribution of the various facilities to the measured concentrations. As such, the baseline sediment and soil data presented in Sections D.2.4.3 and D.2.4.4 are considered to be representative of No Action - Planning Basis Operations Alternative.

Groundwater Data. Groundwater data were collected and analyzed in 1987 for a limited suite of contaminants in accordance the existing RCRA permitting requirements. The focus was not on determining off-site transport of contaminants to potential receptors, but rather on monitoring of permitted facilities. Currently, a comprehensive groundwater monitoring program is conducted for Y-12 that includes monitoring to comply with the requirements of RCRA postclosure regulations, to support *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) remedial investigation/feasibility study efforts and records of decision, to comply with Tennessee Department of Environment and Conservation (TDEC) solid waste management regulations, and to support DOE Order 5400.1 requirements. As such, the data collected under this comprehensive program is considered appropriate for use in determining the potential impacts to the public for both No Action - Status Quo Alternative and No Action - Planning Basis Operations Alternative (see Section D.3.5).

In summary, airborne emissions of radiological contaminants would increase over current No Action - Status Quo Alternative emissions by a factor of 5.3 based on the projected activities to be undertaken in the No Action - Planning Basis Operations Alternative (Table D.2.5.1-2). However, the resulting impact to the public would remain well below all applicable exposure criteria. Surface water, soil/sediment, and groundwater concentrations are not expected to vary significantly from the No Action - Status Quo Alternative due to the increase in effectiveness and efficiency of current pollution control measures.

D.2.5.2 *Highly Enriched Uranium Storage Mission Alternatives*

There are three proposed alternatives for the HEU Storage Mission at Y-12: No Action - Planning Basis Operations Alternative, Alternative 2A (Construction and Operation of a New HEU Materials Facility), and Alternative 2B Upgrade Expansion to existing Building 9215 (see Section 3.2.2). The emission data for No Action - Planning Basis Operations Alternative is assumed to include all the emissions from the storage of HEU in existing facilities. The emissions for the HEU storage mission action alternatives are expected to be at or below the current levels due to administrative and engineering controls such as multiple levels of high-efficiency particulate filters at the new facilities. Risks to the public from environmental emissions would remain the same as were presented in Section D.2.5.1 for Alternative 1B (No Action - Planning Basis Operations Alternative).

D.2.5.3 *Special Materials Mission Alternatives*

There are two proposed alternatives for the Special Materials Mission at Y-12: No Action - Planning Basis Operations Alternative and Alternative 3A (Construction and Operation of a new Special Materials Complex) (see Section 3.2.3). The Special Materials Complex does not have radiological material. Under the No Action - Planning Basis Operations Alternative the new Special Materials Complex would not be constructed. The Y-12 Plant would continue to use the existing special materials operations facilities and the radiological impacts to the public would remain the same as under Alternative 1B (No Action - Planning Basis Operations Alternative) discussed in Section D.2.5.1.

The purpose of and the materials produced under the Special Materials Mission would not result in any increase in airborne radiological emissions. Surface water, soil/sediment, and groundwater concentrations of radionuclides would also not be affected.

D.3 HAZARDOUS CHEMICAL IMPACTS TO HUMAN HEALTH

D.3.1 Chemicals and Human Health

Chemicals are ever present in our environment. We use chemicals in our everyday tasks—as pesticides in our gardens, cleaning products in our homes, insulating materials in buildings, and as ingredients in medications. Potentially hazardous chemicals can be found in all of these products, but usually the quantities are not large enough to cause adverse health effects.

In contrast to home use, chemicals used in industrial settings are often found in concentrations that may affect the health of individuals in the workplace and in the surrounding community. The following sections describe both the carcinogenic and noncarcinogenic effects of chemicals on the body and how these effects are assessed.

D.3.1.1 *How Do Chemicals Affect the Body?*

Industrial pollutants may be released either intentionally or accidentally to the environment in quantities that could result in health effects to those who come in contact with them. Chemicals that are airborne, or

released from stacks and vents, can migrate in the prevailing wind direction for many miles. The public may then be exposed by inhaling chemical vapors or particles of dust contaminated by the pollutants. Additionally, the pollutants may be deposited on the surface soil and biota (plants and animals) and subsequent human exposure could occur. Chemicals may also be released from industries as liquid or solid waste (effluent) and can migrate or be transported from the point of release to a location where exposure could occur.

Exposure is defined as the contact of a person with a chemical or physical agent. For exposure to occur, a chemical source or contaminated media such as soil, water, or air must exist. This source may serve as a point of exposure, or contaminants may be transported away from the source to a point where exposure could occur. In addition, an individual (receptor) must come into either direct or indirect contact with the contaminant. Contact with a chemical can occur through ingestion, inhalation, dermal contact, or external exposure. The exposure may occur over a short (acute or subchronic) or long (chronic) period of time. These methods of contact are typically referred to as exposure routes. The process of assessing all of the methods by which an individual might be exposed to a chemical is referred to as an exposure assessment.

An exposure assessment is the determination or estimation (qualitative or quantitative) of the magnitude, frequency, duration, route of exposure, and receptor population for each pathway evaluated. During the exposure assessment process, the assessor:

- Characterizes the exposure setting in an effort to identify the potentially exposed populations (receptors), their activity patterns, and any other characteristics that might increase or decrease their likelihood of exposure
- Determines exposure pathways based on the characterization of the exposure setting, identifying the unique mechanisms by which a population may be exposed to the contaminants
- Quantifies the exposure to a contaminant by estimating concentrations using environmental data to which a receptor may be exposed
- Calculates a chemical-specific intake (referred to as the chronic daily intake) and/or a radionuclide-specific dose for each exposure pathway

The result of an exposure assessment is a list of pathways by which a chemical may migrate or be transported to a receptor who can then be exposed. Exposure to a chemical is quantified as a rate of intake and is measured in quantity per body weight per time. Intake rates are typically expressed as mg/kg-day for chemicals and are calculated using the following general equation:

$$\text{CDI} = \text{C} \times \text{IR} \times \text{EF} \times \text{ED} / \text{BW} \times \text{AT}$$

where, CDI = Chronic Daily Intake
C = Media-specific Concentration (e.g., mg/L, mg/m³, mg/kg)
IR = Intake Rate (e.g., mg/day, m³/day)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT = Averaging Time (period over which exposure is averaged - days)

Once an individual is exposed to a hazardous chemical, the body's metabolic processes typically alter the chemical structure of the compound in its efforts to expel the chemical from the system. For example, when compounds are inhaled into the lungs they may be absorbed depending on their size (for particulates) or solubility (for gases and vapors) through the lining of the lungs directly into the blood stream. After absorption, chemicals are distributed in the body and may be metabolized, usually by the liver, into metabolites that may be more toxic than the parent compound. The compound may reach its target tissue,

organ, or portion of the body where it will exert an effect, before it is excreted via the kidneys, liver, or lungs. The relative toxicity of a compound is affected by the physical and chemical characteristics of the contaminant, the physical and chemical processes ongoing in the human body and the overall health of an individual. For example, infants, the elderly, and pregnant women are considered more susceptible to certain chemicals.

Chemicals have various types of effects on the body. Generally, when considering human health, chemicals are divided into two broad categories: chemicals that cause health effects but do not cause cancer (noncarcinogens) and chemicals that cause cancer (carcinogens). Note that exposure to some chemicals can result in the manifestation of both noncarcinogenic health effects and an increased risk of cancer.

D.3.1.2 Chemical Noncarcinogens

Chemical noncarcinogens are chemicals or compounds that when introduced to the human body via ingestion, inhalation, or dermal absorption may result in a systemic effect if the intake exceeds a level that can be effectively eliminated. For example, a noncarcinogenic chemical or compound may affect the central nervous system, renal (kidney) function, or other systems that have an effect on the body's metabolic processes. They may also cause milder effects such as irritation to the eyes or skin, or asthmatic attacks. The level of the effects are directly related both to the chemical and the level of exposure.

For many noncarcinogenic effects, the body is equipped with protective mechanisms that must be overcome before an adverse effect is manifested from a chronic chemical exposure. For example, where a large number of cells perform the same or similar function, the cell population may have to be significantly depleted before an effect is seen. The body can tolerate a range of exposure where there is essentially no change in expression of adverse effects. This is known as the "threshold" or "nonstochastic" concept and has been observed in multiple animal studies. The results of these animal studies are a set of guidelines that serve as the basis for the development of noncarcinogenic toxicity values. The No Observed Adverse Effect Level (NOAEL) is an estimate of the threshold dose and the Lowest Observed Adverse Effect Level (LOAEL) is the lowest dose where an adverse effect was seen.

The EPA applies uncertainty factors to the NOAEL or LOAEL to obtain the Reference Dose (RfD) for both subchronic and chronic exposures to noncarcinogenic chemicals. These uncertainty factors usually include a factor of 10 for extrapolating effects from animals to humans, 10 for including the most sensitive humans, and another 10 for incomplete data. Chronic RfDs are developed for protection from long-term exposure to a chemical (7 years to a lifetime); subchronic RfDs are used to evaluate short-term exposure (2 weeks to 7 years). In this assessment, only long-term, chronic exposures to contaminants are evaluated. RfDs used in this document were obtained from the EPA's *Integrated Risk Information System* (IRIS) (EPA 1999).

Noncarcinogenic effects are expressed as a comparison of a daily exposure level (chronic daily intake [CDI]) averaged over a specified period of time with an RfD. The ratio of the average daily exposure level of a single toxicant to the RfD for that toxicant is defined as an HQ.

$$\text{HQ} = \text{CDI} / \text{RfD} \text{ or } \text{HQ} = \text{Air concentration}/\text{RfC}$$

where, HQ = Hazard Quotient
CDI = Chronic Daily Intake
RfD = Noncarcinogenic reference dose
RfC = Noncarcinogenic reference concentration

The sum of more than one HQ for multiple toxicants and/or multiple exposure pathways is called a hazard index (HI). An HQ or an HI ≥ 1 is considered unacceptable. Note that because the HI is not a percentage or probability, the level of concern does not necessarily increase linearly as the HI approaches or exceeds unity.

In addition to the RfD, the EPA has calculated a Reference Concentration (RfC) for many chemicals. The RfC is an estimate of a continuous (24 hours per day, 365 days per year for 70 years) inhalation exposure to the human population without appreciable risk of deleterious noncancer effects during a lifetime. The RfC is to be used only under these exposure conditions and is not applicable to varying exposure parameters unless the appropriate corrections are made. The RfC is a chemical-specific concentration expressed in $\mu\text{g}/\text{m}^3$ that can be directly compared to a measured air concentration without necessitating the calculation of a CDI. Provided the ratio (HQ) of the measured concentration to the RfC is less than or equal to 1.0, no unacceptable adverse health effects are expected.

D.3.1.3 Chemical Carcinogens

Over the past century, many chemicals have been identified that cause cancer in humans. Examples of these carcinogens include asbestos in insulation, vinyl chloride in the rubber industry, and benzene in solvents. Cancers caused by industrial chemicals can occur in any organ in the body, including the respiratory tract, bladder, bone marrow, gastrointestinal tract, or liver. Unlike noncancer effects, cancer-causing agents are assumed to have no safe intake or dose levels.

Currently, chemicals are categorized as either confirmed human carcinogens, suspected human carcinogens, or confirmed animal carcinogens. For cancer agents (including all radionuclides), EPA provides toxicity information that can be used to determine the probability that cancer may occur. The toxicity factors used to assess exposures to carcinogens are referred to as cancer slope factors (CSFs). The CSFs represent the slope of the dose-response curve from various toxicity studies. Most of the CSFs for nonradionuclides were developed based on the data from chemical-specific 2-year animal studies.

The CSFs for chemicals are the upper-bound estimate of the probability of a response per unit intake of a chemical over a lifetime. This slope factor is expressed in units of $\text{mg}/\text{kg}\text{-day}$. Because the slope factors are the 95th percentile upper confidence limit on the probability of a carcinogenic response, the carcinogenic risk estimate represents an upper confidence bound estimate. Therefore, a 5 percent probability exists that the actual risk will be higher than the estimate presented, and the actual risk may well be less than the estimate. Radionuclide CSFs are central tendency estimates based primarily on measured human data.

Cancer risk from exposure to a chemical or multiple chemicals (including radionuclides) is expressed as an ECR or, stated differently, cancer incurred in addition to normally expected rates of cancer development. The excess cancer risk for carcinogens is calculated by multiplying the calculated intake/dose for each contaminant by the appropriate slope factors.

$$\text{ECR} = \text{CDI} \times \text{CSF} \text{ or } \text{ECR} = \text{CDI} \times \text{UR}$$

where, ECR = Excess Cancer Risk
 CDI = Chronic Daily Intake
 CSF = Cancer Slope Factor
 UR = Inhalation Unit Risk

This estimate of ECR represents the potential of an individual developing excess cancer over a lifetime, above and beyond the normal, unavoidable incidence of cancer. For example, an excess cancer risk of 1.0×10^{-6} indicates one person in one million is predicted to incur cancer from exposure to this contamination level over a 70-year lifetime.

Consideration is given to exposure to multiple chemicals as well as multiple exposure pathways when calculating the risk of an individual developing cancer. This is accomplished via summing excess cancer risks for each chemical both within a given pathway and across pathways within an exposure scenario. Although chemical concentrations that represent an upper-bound excess lifetime cancer risk to an individual of between 10^{-4} and 10^{-6} are under some circumstances considered acceptable (55 FR 46), risks above 10^{-6} are undesirable. The risk to an individual should not exceed 10^{-4} .

The EPA has derived unit risk factors to evaluate human exposure to chemicals via inhalation. The unit risk is the upper-bound (1.0×10^{-6}) excess lifetime cancer risk estimated to result from a continuous (24 hours per day, 365 days per year, for 70 years) exposure to a cancer-causing chemical at a concentration of $1 \mu\text{g}/\text{m}^3$. The unit risk factor is to be used only under these exposure conditions and is not applicable to varying exposure parameters unless the appropriate corrections are made.

D.3.2 What are Some Y-12 Sources that May Lead to Chemical Exposure?

Airborne emissions of chemicals used at Y-12 occur as a result of plant production, maintenance, and waste management operations and steam generation. Most process operations are served by ventilation systems that remove air contaminants from the workplace. In 1997, a major effort was expended to prepare Y-12's first major source operating permit application for these sources under Title V of the *Clean Air Act*. Nonradionuclide emissions at Y-12 include chemical processing aids (hydrochloric, sulfuric, and nitric acids), cleaning and cooling aids (methanol), refrigerants (Freon 11, 12, 22, 13, and 502), and emissions from the steam plant (particulates, SO_2 , carbon monoxide, volatile organic compounds [VOCs], and NO_2). More than 90 percent of the pollutants emitted from Y-12 are the result of steam plant operations. The level of pollutant emissions from Y-12 is expected to decline in the future because of the changing mission and downsizing of production areas.

Additionally, past operational or accidental releases of contaminants into the surrounding environment serve as on-going sources of potential chemical emissions. In particular, mercury used in the former lithium separation process was released to the storm sewer system and ultimately UEFPC during the period of 1950 to 1982. Although mercury is not presently used in any experimental or manufacturing processes at the Y-12 Plant, small amounts of mercury continue to escape the Y-12 Plant. Outdoor airborne mercury vapor at the Y-12 Plant is primarily the result of vaporization from mercury-contaminated soils and drains, fugitive emissions from former mercury-use area buildings, and releases from coal burning at the Y-12 Steam Plant. Current operational activities at the Y-12 Plant include a Special Materials Mission of which beryllium production operations are a key component. The existing special materials operations facilities are housed in buildings that are from 27 to 50 years old and must rely heavily on administrative controls and personal protective equipment to provide for the protection of workers, the public, and the environment from the hazards associated with beryllium and other special materials. In 1997, compliance tests were conducted to determine the rate of emissions of beryllium from those facilities housing beryllium operations. The results of these tests indicate that no measurable amount of beryllium is released to the atmosphere via the exhaust stacks.

Liquid discharges to surface water are sources for potential transport and migration of chemicals from Y-12. These discharges include process effluents and storm water as permitted under the existing Y-12 NPDES permit, and sanitary wastewater discharged to the City of Oak Ridge POTW under the Industrial and Commercial Users Wastewater Permit Number 1-91. Discharges to surface water allowed under the NPDES permit include storm drainage, cooling water, cooling tower blowdown, and treated process wastewaters, including effluents from wastewater treatment facilities. Sumps that collect groundwater inflow in building basements are also permitted for discharge to the creeks. Both sources are monitored to ensure compliance with existing permitting requirements. NPDES samples are collected and may be analyzed for pH, residual chlorine, oil and grease, ammonia, mercury, total toxic organics, inorganics, and PCBs depending on the

outfall permitting requirements. Sanitary wastewater is sampled and analyzed for a variety of inorganic constituents, oil and grease, specified organics (benzene, methylene chloride, toluene, and trichloroethene) and other physical and chemical parameters.

Again, although mercury is not presently used in experimental or manufacturing processes at the Y-12 Plant, small amounts of mercury continue to escape the Y-12 Plant. The foundations of former separation plants and equipment drains and sumps still contain some residual mercury. Rain water and storm drainage have also washed mercury into pipings and building foundations at other locations around Y-12. Trapped in porous spaces along foundations and storm sewer outfalls, mercury continues to dissolve slowly into the water that flows through these conduits. This water flow eventually leads to outfalls and the UEPFC.

Soils and sediments provide another potential source of nonradiological contaminants. Operational and historical information as well as environmental sampling have confirmed the presence of chemical contaminants in both surface and subsurface soils at particular locations within the Y-12 area. In addition, sediment samples collected at in-stream locations and from floodplain areas indicate the presence of mercury and PCBs.

Groundwater is another potential pathway for exposure to hazardous chemicals and provides a means of contaminant transport and migration. A comprehensive groundwater monitoring program is in-place at Y-12 to address all DOE, state, and Federal regulatory requirements relative to groundwater surveillance and monitoring. The primary groundwater contaminants at Y-12 are nitrate, VOCs, trace metals, and radionuclides.

D.3.3 How Does DOE Regulate Chemical Exposures?

D.3.3.1 Environmental Protection Standards

DOE Order 5400.1 establishes environmental protection program requirements, authorities, and responsibilities for DOE operations to ensure compliance with applicable Federal, state, and local environmental protection laws and regulations, executive orders, and internal DOE policies. The Order specifically defines the mandatory environmental protection standards (including those imposed by Federal and state statutes), establishes reporting of environmental occurrences and periodic routine significant environmental protection information, and provides requirements and guidance for environmental monitoring programs. Applicable Federal and state environmental acts/agreements include:

- RCRA
- CERCLA as amended by the *Superfund Amendments and Reauthorization Act (SARA)*
- *Federal Facility Compliance Agreement*
- *Endangered Species Act*
- *Safe Drinking Water Act*
- *Clean Water Act* (which resulted in the establishment of the NPDES and pretreatment regulations for POTW)
- *Clean Air Act* (Title III, Hazardous Air pollutants Rad-NESHAP, Asbestos NESHAP)
- *Toxic Substances Control Act (TSCA)*
- *Federal Insecticide, Fungicide, and Rodenticide Act*

Many of these acts/agreements include environmental standards that must be met to ensure the protection of the public and the environment. Most of the acts/agreements require completed permit applications in order to treat, store, dispose of, or release contaminants to the environment. The applicable environmental standards and reporting requirements are set forth in the issued permits and must be met to ensure compliance.

The *Emergency Planning and Community Right-To-Know Act*, also referred to as SARA Title III, requires reporting of emergency planning information, hazardous chemical inventories, and environmental releases to federal, state, and local authorities. The annual Toxic Release Inventory Report addresses releases of toxic chemicals into the environment, waste management activities, and pollution prevention activities associated with those chemicals.

D.3.3.2 Regulated Occupational Exposure Limits

Occupational limits for hazardous chemicals are regulated by the Occupational Safety and Health Administration (OSHA). The permissible exposure limits (PELs) represent the legal concentration levels set by OSHA that are safe for 8-hour exposures without causing noncancer health effects. Other agencies, including the National Institute for Occupational Safety and Health (NIOSH) and the American Conference of Governmental Industrial Hygienists (ACGIH) provide guidelines. The NIOSH guidelines are Recommended Exposure Limits and the ACGIH guides are Threshold Limit Values (TLVs). Occupational limits are further defined as time-weighted averages (TWAs), or concentrations for a conventional 8-hour workday and a 40-hour workweek, to which it is believed nearly all workers may be exposed, day after day, without adverse effects. Often ceiling limits, or airborne concentrations that should not be exceeded during any part of the workday, are also specified. In addition to the TWA and ceiling limit, short-term exposure limits may be set. Short-term exposure limits are 15-minute TWA exposures that should not be exceeded at any time during a workday, even if the 8-hour TWA is within limits. OSHA also uses action levels to trigger certain provisions of a standard, for instance appropriate workplace precautions, training, and medical surveillance, for workers whose exposures could approach the PEL.

D.3.4 Data Sources Used to Evaluate Public Health and Worker Consequences from Routine Operations

Airborne emissions, with the exception of mercury, are represented by modeled concentrations based on the purchases recorded and maintained in the Y-12 Hazardous Materials Inventory System (HMIS) (LMES 1998) and engineering calculations for emissions from the Y-12 Steam Plant. Modeled concentrations of noncarcinogenic and carcinogenic materials both on-site and at the plant boundary were calculated for an MEI and an 8-hour worker exposure. On-site emissions concentrations are not available for the Y-12 Steam Plant because the stack height used in the modeling effort negates the possibility for the modeled plume to disperse prior to the facility boundary. With the exception of mercury, these data are considered representative of emissions of nonradionuclides under current operations at Y-12. Mercury is the only nonradionuclide for which actual air measurements were available.

Outdoor airborne mercury vapor at Y-12 is primarily the result of vaporization from mercury-contaminated soils, fugitive emissions from former mercury-use area buildings, and releases from coal burning at the Y-12 Steam Plant. Four outdoor ambient mercury monitoring stations (boundary stations) are operated at Y-12. A monitoring station is located on the east and west ends of the plant and two stations are located near Building 9201-4, a former lithium isotope separation facility contaminated with mercury. The yearly average concentrations of mercury vapor will be used in lieu of modeled data for this contaminant.

Liquid discharges are represented by both the results of the effluent monitoring conducted to meet the requirements of the NPDES permit and routine surface water surveillance monitoring. The current Y-12 Plant NPDES permit, issued on April 28, 1995, requires sampling, analysis, and reporting at various effluent locations. Currently, the Y-12 Plant has outfalls and monitoring points in the following water drainage areas: EFPC, Bear Creek, and several unnamed tributaries on the south side of Chestnut Ridge that eventually drain to the Clinch River. The environmental surveillance monitoring is conducted as a best management practice and is above and beyond that required by the NPDES permit (DOE 1999c). Environmental surveillance monitoring was conducted in:

- EFPC near the junction of Scarboro and Bear Creek roads. The samples are analyzed for mercury, ammonia-N, inductively coupled plasma metals, and total suspended solids.
- Bear Creek at the western boundary of the Y-12 area of responsibility. Samples are analyzed for mercury, anions (sulfate, chloride, nitrate, nitrite), inductively coupled plasma metals, total phenols, and total suspended solids.
- NPDES location S19 at Rogers Quarry, the exit pathway for Chestnut Ridge regime. This location is an instream location of McCoy Branch and is sampled for inductively coupled plasma metals.

Additionally, a network of real-time monitors is located at in-stream locations along UEFPC and at key points on the storm drain system that flows to the creek. Samples are analyzed for inorganics.

Sediment data were not collected during 1998. As such, the most recent data (DOE 1998c) are presented below in Table D.3.4-1. These data were collected to determine whether mercury and PCBs are accumulating in sediments in EFPC and Bear Creek. Due to the limited number of samples collected (one in each location) and the limited set of analytes, these data are not considered to be representative of the sediment contaminant concentrations for these streams and floodplain areas. No comparison or risk calculations were performed for these sample data. As such, the results of the remedial investigation for the UEFPC Characterization Area (DOE 1998c) are presented as representative of hazards and risks associated with exposure to sediment contaminant concentrations.

TABLE D.3.4-1.—1998 Results of Y-12 Sediment Monitoring

Parameter	Station 17	Bear Creek Kilometer 9.4
Mercury ($\mu\text{g/g}$)	9.5	0.3
Total PCBs ($\mu\text{g/kg}$)	370 J ^a	350 J

^a The J flag of the PCB data indicates an estimated value below the analytical method reporting limit.

Source: DOE 1998c.

Soil data are not collected as part of the annual surveillance activities at Y-12. Therefore, data collected and presented in the *Remedial Investigation Report for the Upper East Fork Poplar Creek Characterization Area* (DOE 1998b) are used to summarize the contaminants of concern in both surface and subsurface soils.

A comprehensive groundwater monitoring program is conducted for Y-12 that includes monitoring to comply with requirements of RCRA postclosure regulations, to support CERCLA remedial investigation/feasibility study efforts and records of decision, to comply with TDEC solid waste management regulations, and to support DOE Order 5400.1 requirements. The data from the Y-12 comprehensive groundwater monitoring program was compiled and evaluated in the risk assessment presented in the remedial investigation for the Characterization Area, (DOE 1998d) which was used to evaluate the potential for adverse health effects resulting from worker and public exposure to hazardous chemicals detected in groundwater.

D.3.5 Methodology for Estimating Hazardous Chemical Impacts

Concentrations of airborne hazardous chemicals were modeled for an MEI located at the Y-12 boundary and for a maximally exposed onsite worker. Exposure point concentrations were derived based on purchase data and are considered to be conservative estimates of actual emissions. Exposure assumptions for both the maximally exposed individual and the onsite worker are listed in Table D.3.5-1. Toxicity information (i.e.,

inhalation reference concentrations and unit risks) for the contaminants of concern as identified in the Air Quality Analysis (see Appendix E) was obtained from IRIS (EPA 1999). This toxicity information was used to calculate HQs and excess lifetime cancer risks for all contaminants of concern.

TABLE D.3.5–1.—Exposure Assumptions for Evaluation of Risk/Hazard to Workers and the Public

Parameter	Worker	MEI
Inhalation rate (IR)	20 m ³ /day	20 m ³ /day
Exposure time (ET)	8 hours/24 hours	24 hours/24 hours
Exposure frequency (EF)	250 days/year	365 days/year
Exposure duration (ED)	40 years	70 years
Body weight (BW)	70 kg	70 kg
Averaging time (AT)-noncarcinogens	ED x 365 days/year	ED x 365 days/year
Averaging time (AT)-carcinogens	70 years x 365 days/year	70 years x 365 days/year

Note: AT - averaging time; BW - body weight; ED - exposure duration; EF - exposure frequency; ET - exposure time; IR -inhalation rate.

D.3.6 Risk Estimates and Health for Potential Chemical Exposures for the No Action - Status Quo Alternative

Airborne Emissions. The results of the air modeling of purchase data and engineering calculations for the Y-12 Steam Plant are presented in Tables D.3.6-1 through D.3.6-5. The contaminants and associated concentrations to which an onsite worker and an MEI located at the plant boundary might be exposed, based on the modeled purchase data, are listed in Tables D.3.6-1 through D.3.6-4. Modeled concentrations of Y-12 Steam Plant emissions data are listed in Table D.3.6-5 for the maximally exposed individual at the plant boundary. On-site emissions concentrations are not available for the Y-12 Steam Plant because the stack height used in the modeling effort negates the possibility for the modeled plume to disperse prior to the facility boundary. Toxicity values for both noncarcinogenic and carcinogenic exposures were obtained and HQs and excess cancer risks were calculated for the maximally exposed individual of the public and for a maximally exposed onsite worker. The results of these assessments are also presented in Tables D.3.6-1 through D.3.6-5.

TABLE D.3.6–1. —Y-12 Facility Operations Maximum Boundary Hazardous Air Pollutants Noncarcinogenic Chemical Hazard Quotients

Chemical	Maximum Boundary Concentration ($\mu\text{g}/\text{m}^3$)	Inhalation RfC - Chronic (mg/m^3) ^a	Hazard Quotient
Cobalt & Compounds	3.31×10^{-2}	<i>b</i>	<i>c</i>
Lead Compounds	3.43×10^{-2}	<i>b</i>	<i>c</i>
Methylene Bisphenyl Isocyanate	9.82×10^{-2}	6.00×10^{-4}	1.64×10^{-1}

^aToxicity values were obtained from the EPA's IRIS (EPA 1999).

^bToxicity values are not currently available.

^cNot calculated due to lack of toxicity values.

TABLE D.3.6-2.—Y-12 Facility Operations Maximum Boundary Hazardous Air Pollutants Carcinogenic Chemical Excess Cancer Risk

Chemical	Maximum Boundary Concentration ($\mu\text{g}/\text{m}^3$)	Inhalation Unit Risk (mg/m^3) ^{-1a}	Excess Cancer Risk
Cadmium & Compounds	1.42×10^{-5}	1.8×10^0	2.56×10^{-8}

^aToxicity values were obtained from the EPA's IRIS (EPA 1999).

The HQs and excess cancer risks for the chemicals and compounds that were determined to be of concern as a result of the air quality screening of purchase data (see Section 5.7.1) are listed in Tables D.3.6-1 through D.3.6-4. Two exposure scenarios were evaluated: maximally exposed individual (residential), and on-site worker (industrial). The hazard quotients and excess cancer risks for contaminant concentrations modeled to the maximally exposed individual of the public were all below levels of concern. Thus, no adverse health impacts to the public are anticipated from exposure to airborne nonradiological contaminants emitted from Y-12 Plant normal operations. The hazard quotient for the on-site worker exposed to the maximum on-site concentration of methylene biphenyl isocyanate was determined to be greater than 1.0. Therefore, methylene biphenyl isocyanate is considered to be a baseline contaminant of concern for on-site workers.

TABLE D.3.6-3.—Y-12 Facility Operations Maximum On-Site Hazardous Air Pollutants Noncarcinogenic Chemical Hazard Quotients

Chemical	Maximum On-site Concentration ($\mu\text{g}/\text{m}^3$)	Inhalation RfD - Chronic (mg/m^3) ^a	Hazard Quotient
Cobalt & Compounds	5.88×10^1	<i>b</i>	<i>c</i>
Lead Compounds	6.10×10^1	<i>b</i>	<i>c</i>
Methylene Bisphenyl Isocyanate	1.75×10^2	1.71×10^{-4}	6.68×10^1

^aToxicity values were obtained from the EPA's IRIS (EPA 1999).

^bToxicity values are not currently available.

^cNot calculated due to lack of toxicity values.

TABLE D.3.6-4.—Y-12 Facility Operations Maximum On-Site Hazardous Air Pollutants Carcinogenic Chemical Excess Cancer Risks

Chemical	Maximum On-site Concentration ($\mu\text{g}/\text{m}^3$)	Inhalation Slope Factor ($\text{mg}/\text{kg}\cdot\text{day}$) ^{-1a}	Excess Cancer Risk
Cadmium & Compounds	2.52×10^{-2}	6.30×10^0	5.92×10^{-6}

^aToxicity values were obtained from the EPA's IRIS (EPA 1999).

TABLE D.3.6-5.—Y-12 Steam Plant Maximum Boundary Hazardous Air Pollutant Carcinogenic Chemical Concentrations

Chemical	Maximum Boundary Concentration ($\mu\text{g}/\text{m}^3$)	Inhalation Unit Risk (mg/m^3) ⁻¹	Excess Cancer Risk
Arsenic	7.71×10^{-5}	4.3×10^0	3.32×10^{-7}
Beryllium	1.16×10^{-5}	2.4×10^0	2.78×10^{-8}
Cadmium	1.00×10^{-5}	1.8×10^0	1.8×10^{-8}
Nickel	1.85×10^{-4}	<i>b</i>	<i>c</i>

^aToxicity values were obtained from the EPA's IRIS (EPA 1999).

^bToxicity values are not currently available.

^cNot calculated due to lack of toxicity values.

Cadmium and compounds under the on-site exposure scenario were also determined to pose an excess cancer risk within the EPA's range of concern and are also considered a baseline contaminant of concern for the on-site worker.

No noncarcinogenic contaminants exceeded the preliminary air quality screening of Y-12 Steam Plant emissions data (Volume I, Chapter 5, Section 5.7). As such, no noncarcinogenic chemicals were included in the evaluation of public exposures. The carcinogenic contaminants and their associated excess cancer risks resulting from Y-12 Steam Plant emissions are presented in Table D.3.6-5. No excess cancer risks were determined to fall within the EPA's range of concern. Thus, no noncarcinogenic or carcinogenic contaminants of concern were determined to be associated with Y-12 Steam Plant emissions.

Average mercury vapor concentrations in 1998 for the four sites currently monitored are comparable to those reported for the last 2 years and are presented in Table D.3.6-6. In 1998, although ambient mercury concentrations at the two monitoring sites near Building 9201-4 were still elevated above natural background, results indicate that concentrations of mercury vapor are well below the ACGIH threshold limit value of $50 \mu\text{g}/\text{m}^3$ and the EPA reference concentration of $0.3 \mu\text{g}/\text{m}^3$ for chronic inhalation exposure. Average concentrations at the two boundary monitoring sites located at the east and west ends of Y-12 are comparable to levels measured at the reference site on Chestnut Ridge. The measured mercury vapor concentrations for 1998 are presented in Table D.3.6-6 along with the associated RfC and RfD. HQs were calculated for each location in an effort to demonstrate that the measured concentrations are below (i.e., $\text{HQ} < 1.0$) both the threshold for continuous public and occupational exposure. The results indicate that mercury is not a concern for either the public or on-site workers.

Surface Water. More than 500 surface water surveillance samples were collected in 1998. The monitoring locations include:

- Station 17 in EFPC near the junction of Scarboro and Bear Creek Roads
- BCK 4.55 in Bear Creek which is the western boundary of the Y-12 Plant area of responsibility
- NPDES location S19 at Rogers Quarry which is the exit pathway from the Chestnut Ridge hydrologic regime
- Instream locations along the UEPFC and at key points on the storm drain system

TABLE D.3.6-6.—Mercury Ambient Air Concentrations and Evaluation

Ambient Mercury Monitoring Stations	1998 Average (mg/m ³)	Regulated Exposure Limits/Risk Factors		Hazard Quotients	
		RfC (mg/m ³)	RfD (mg/kg-d)	Maximally Exposed Individual	Worker 8 hours
Station 2 (east end)	4.8x10 ⁻⁶	3.00x10 ⁻⁴	8.57x10 ⁻⁵	1.60x10 ⁻²	3.65x10 ⁻³
Station 8 (west end)	7.4x10 ⁻⁶	3.00x10 ⁻⁴	8.57x10 ⁻⁵	2.5x10 ⁻²	5.63x10 ⁻³
Building 9422-13 (SW of Building 9201-4)	4.4x10 ⁻⁵	3.00x10 ⁻⁴	8.57x10 ⁻⁵	1.47x10 ⁻¹	3.35x10 ⁻²
Building 9805-1 (SE of Building 9201-4)	5.7x10 ⁻⁵	3.00x10 ⁻⁴	8.57x10 ⁻⁵	1.9x10 ⁻¹	4.34x10 ⁻²
Reference Site, 1988	6.0x10 ⁻⁶	3.00x10 ⁻⁴	8.57x10 ⁻⁵	2.00x10 ⁻²	4.57x10 ⁻³
Reference Site, 1989	5.0x10 ⁻⁶	3.00x10 ⁻⁴	8.57x10 ⁻⁵	1.67x10 ⁻²	3.81x10 ⁻³

Source: DOE 1998a

Comparisons with Tennessee water quality criteria indicate that only silver, mercury, zinc, and copper from samples, collected at Station 17 were detected at values exceeding a criteria maximum. Results are shown in Table D.3.6-7. Of all the parameters measured in the surface water as a best management practice, mercury is the only demonstrated contaminant of concern.

Table D.3.6-7.—Surface Water Surveillance Measurements Exceeding Tennessee Water Quality Criteria at the Y-12 Plant, 1998

Parameter Detected	Number of Samples	Concentration (mg/L)			Water Quality Criteria (mg/L) ^a	Number of Measurements Exceeding Criteria
		Detection Limit	Max	Aver		
Mercury	413	0.0002	0.0191	<0.001	0.00015	408
Silver	148	0.02	<0.02	<0.008	0.0041	1
Copper	148	0.02	0.0388	<0.01	0.0177	13
Zinc	148	0.05	0.15	<0.04	0.117	21

^a The most restrictive of either the freshwater fish and aquatic life "criterion maximum concentration" or the "Recreation concentration for organisms only" is reported. The comparison is made for information purposes only. Source: Adapted from DOE 1999c.

Sediment. The UEFPC risk assessment evaluated sediment samples collected both within and outside of the plant boundary. The risk assessment evaluated exposure via three scenarios: industrial, open recreational, and residential. The results for the industrial and open recreational scenario are considered applicable for the purpose of evaluating worker and public exposure in the SWEIS and are presented below.

- No contaminants of concern were identified for sediments within the plant boundary for the industrial receptor. Excess cancer risks in the range of 10⁻⁵ from PCBs and polycyclic aromatic hydrocarbon (PAHs) were the primary contributors to total risk outside the plant boundary. Cadmium (HI = 0.059) and mercury (HI = 0.043) were the primary contributors to unacceptable hazards for the industrial receptor outside the plant boundary.

- Cadmium (HI = 0.016), mercury (HI = 0.019), and PCB-1254 (HI = 0.075) resulted in unacceptable hazards to the adult under the open recreational land use both inside and outside the plant boundary. No carcinogenic contaminants of concern were identified within the plant boundary. Elevated ECRs outside the plant boundary were primarily from benzo[a]pyrene (ECR = 1.4×10^{-4}), several other PAHs with ECRs in the 10^{-5} range, and PCBs (ECR = 2.4×10^{-5}). Risks and hazards to a child receptor were the same as those for the adult.

Soils. The investigation of the UEFPC Characterization Area evaluated both exposure to surface and subsurface soils. Soil samples were aggregated for the eastern plant area, western plant area, central plant area, and outside the plant area. The scenarios evaluated for the three plant areas include an industrial and residential exposure. Residential and open recreational land use scenarios were evaluated for the outside the plant area aggregate. The results for the industrial and open recreational scenario are considered applicable for the purpose of evaluating worker and public exposure in the SWEIS and are presented below.

- *Eastern Plant Aggregate.* Dibenzo[a,h]anthracene (ECR = 1.5×10^{-4}), which is a PAH that was the primary contributor to surface soil risk for an industrial receptor.
- *Western Plant Aggregate.* Beryllium (ECR = 1.2×10^{-5}) and PCB-1260 (ECR = 1.3×10^{-5}) were the primary contributors to the industrial risks.
- *Central Plant Area Aggregate.* Dibenzo[a,h]anthracene (ECR = 3.1×10^{-5}) and PCB-1254 (ECR = 3.0×10^{-5}) were the primary contributors to industrial risks. PCB-1254 (HQ = 2.1) was the primary contributor to industrial hazards.
- *Outside the Plant Area Aggregate.* PCB-1242 (ECR = 1.2×10^{-4}) was the primary contributor to the open recreational land use surface soil risks while PCB-1254 (HI = 2.9) was the primary contributor to hazards.

The risk assessment for the UEFPC Characterization Area also evaluated exposure to subsurface soil (soil at a depth greater than 5 ft). The results indicate that no contaminants of concern were identified for the eastern or central plant area for the industrial receptor. For the western plant area, no noncarcinogenic contaminants of concern were identified. However, beryllium was determined to contribute significantly to the risks in the western plant area subsurface soil.

Groundwater. Exposure point concentrations for groundwater were developed for four exposure unit aggregates based on the geological formations and sampling locations. The aggregates are shallow clastics, intermediate clastics, Maynardville and Copper Ridge exit pathways wells, and offsite wells. Exposure scenarios included incidental ingestion by a worker and residential exposure via ingestion, inhalation, and dermal absorption.

Exposure point concentrations for groundwater were developed in the remedial investigation for UEFPC for four exposure unit aggregates based on the geological formations and sampling locations. Table D.3.6-8 lists the groundwater contaminants for each aggregate that either exceeded an HQ of 1.0 or had an excess cancer risk greater than 10^{-5} . Note that groundwater is not used at Y-12 as a potable water supply. Potential contact with contaminants in groundwater is limited to those individuals who routinely collect groundwater samples for various compliance, surveillance, and remedial investigation activities. These samplers are trained in the appropriate Environmental Safety and Health Procedures, are routinely audited for compliance with health and safety protocols, and are protected under occupational safety and health standards.

TABLE D.3.6–8.—Groundwater Contaminants of Concern by Aggregate and Scenario

Aggregate	Industrial Contaminants	
	HQ>1.0	Risk>10 ⁻⁵
Shallow Clastics	Arsenic	Arsenic
	Nitrate (as N)	1,1-DCE
Intermediate Clastics	1,2-DCE	1,1-DCE
	Cadmium	Beryllium
	Manganese	Carbon tetrachloride
	Nitrate (as N)	Vinyl choride
Exit Pathways		Benzene
		Beryllium
	Cadmium	Carbon tetrachloride
	Carbon tetrachloride	Tetrachloroethene Vinyl choride

Source: DOE 1998c.

D.3.7 Summary: Contaminants of Concern for No Action - Status Quo Alternative Operations

Table D.3.7-1 summarizes the potential contaminants of concern for each of the media addressed in the preceding sections. The most prevalent contaminants of concern are mercury, beryllium, PAHs, and PCBs. Mercury is of concern for surface water and sediment. PAHs and PCBs, both of which are relatively insoluble in water, tend to precipitate or adhere to particulates, and are persistent in the environment, are also contaminants of concern for both sediment and soil. Several inorganic constituents (arsenic, beryllium, and manganese) are identified as contaminants of concern for groundwater. The presence of elevated concentrations of these inorganic constituents is attributable to both historical operations at Y-12 and emissions from the Y-12 Steam Plant. VOCs are present primarily as contaminants in groundwater.

Some of the chemicals used at Y-12 are of particular concern due to their extensive use in plant operations, the nature and extent of contamination from past operations, or the potential adverse health effects from exposure to these chemicals. These include mercury, beryllium, PCBs, PAHs and VOCs. Additional information regarding the historical use and current controls to mitigate exposure to these contaminants is discussed in the following text.

D.3.7.1 Mercury

Y-12 historically used mercury in the greatest quantity for lithium separation operations in the 1950s and 1960s. Over 20 million pounds of mercury were required for the three lithium production facilities. Releases of mercury occurred over the same time period into the EFPC and into air. The waterborne releases were largely the result of a process where mercury was washed with nitric acid. Most airborne mercury releases were the result of ventilation from the lithium process buildings designed to protect worker health. The Oak Ridge Health Studies mercury project team estimated that more than 280,000 lb of mercury were released into EFPC and over 74,000 lb were released to the air from 1950 to 1993 as a result of the lithium separation work (ChemRisk 1997a).

TABLE D.3.7-1.—Contaminants of Concern Matrix

Chemical	Air	Surface Water	Sediment	Soil	Groundwater
Arsenic					X
Benzene					X
Beryllium				X	X
Cadmium	X		X		X
Carbon					X
1,1-					X
1,2-					X
Lead	X				
Manganese					X
Methylene	X				
Mercury		X	X		
Nitrate (as N)					X
PAHs			X	X	
PCBs			X	X	
Tetrachloroethene					X
Vinyl chloride					X

Corrective actions conducted since 1985 by DOE have greatly reduced releases of mercury from former mercury-use facilities. These corrective actions include:

- Storm sewer cleaning and relining
- Storm sewer replacement
- Piping reroutes
- Mercury source removals
- Treatment of mercury-contaminated sump water

In keeping with DOE's priority to protect the public and the environment from dangers related to mercury and other hazardous substances from its sites, the identification and elimination of known mercury sources is an ongoing concern. Efforts continue to further understand the nature of the mercury released to UEFFPC. Sources of mercury from surface runoff, erosion of the creek bank and sediments, and from the plant itself are under continual investigation. Experimental approaches and new investigations are currently in progress to assess the feasibility of other corrective actions.

D.3.7.2 Beryllium

Since the 1950s, the processing of beryllium metals and alloys has been an important part of the Y-12 mission. Beryllium-containing compounds have been used for research and development, testing, and manufacturing operations at multiple locations throughout the Y-12 Plant. Included in the beryllium operations have been melting and molding, grinding, and machine tooling of parts. Worker exposures have been through inhalation of beryllium dust or particles.

Y-12 implemented a Chronic Beryllium Disease Prevention Program in response to DOE requirements in DOE Order 440.1A, *Worker Protection Management for DOE Federal and Contractor Employees*. Chronic beryllium disease is a disease of the lungs caused by the body's reaction to inhaled beryllium dust or fumes. The Y-12 prevention program was designed to reduce the number of workers exposed to beryllium, minimize

the levels of exposure, and establish medical surveillance procedures to identify workers with early stages of chronic beryllium disease. The Department of Energy published a final rule to establish the Chronic Beryllium Disease Prevention Program in the *Federal Register* on Wednesday, December 8, 1999. This new rule became effective on January 7, 2000. The new rule has incorporated a revised action level of $0.2 \mu\text{g}/\text{m}^3$ that corresponds to the new TWA proposed by the ACGIH.

To evaluate the beryllium-contaminated areas and to protect worker health, the Y-12 Industrial Hygiene Department has developed a sampling and analysis plan to identify the areas within the plant where beryllium was once used. Approximately 300 legacy areas were identified in 39 buildings. These beryllium legacy areas were defined to protect the workers at risk, including beryllium-sensitized individuals, to provide data for modernization projects and to reduce the number of beryllium-contaminated areas.

Ongoing activities at Y-12, in addition to the identification of beryllium legacy areas, include

- Initial and periodic exposure monitoring (currently includes monitoring of all beryllium workers)
- Hazard assessment
- Posting of beryllium work areas
- Medical Surveillance, Respiratory Protection
- Training
- Counseling for the sensitized workers
- Warning signs
- Waste disposal

D.3.7.3 Polychlorinated Biphenyls

The largest use of PCBs at Y-12 has been in the electrical systems (including transformers and capacitors), as PCB-containing cutting oils for the machining of enriched uranium, and in the electromagnetic separation process cooling system (Z-oil system). In addition, PCBs were used in the hydraulic systems throughout the plant (Chem Risk 1997b). Y-12 manages PCBs in accordance with state and federal regulations, LMES policies and procedures, and Y-12 Site Standards. These regulations include the strict control of the use, storage, disposal, decontamination, transport and spill clean-up of PCB-containing materials.

D.3.7.4 Polycyclic Aromatic Hydrocarbons

Polycyclic Aromatic Hydrocarbons (PAHs) are a group of chemicals that are formed during the incomplete combustion of wood and fuel, including coal, oil, gas, and other organic substances. Exposure to PAHs may occur via inhalation, ingestion, and dermal contact. In any medium, PAHs most often exist as complex mixtures of compounds, and these compounds have been divided into carcinogenic and noncarcinogenic PAHs.

Carcinogenic PAHs

benzo[a]pyrene
benzo[a]anthracene
benzo[b]fluoranthene
benzo[k]fluoranthene
chrysene
dibenzo[a,h]anthracene
indeno[1,2,3-cd]pyrene

Noncarcinogenic PAHs

acenaphthene
acenaphthylene
anthracene
benzo[g,h,i]perylene
fluoranthene
fluorene
methylnaphthalene
naphthalene
phenanthrene
pyrene

PAHs detected in environmental media at Y-12 are believed to be associated mainly with the burning of coal at the Y-12 Steam Plant. Other potential Y-12 sources include accidental releases of various organic substances and/or gas and oil.

D.3.7.5 Volatile Organic Compounds

Volatile Organic Compounds (VOCs) detected at Y-12 that are of concern to human health are benzene, carbon tetrachloride, 1,1-dichloroethene, 1,2-dichloroethene, tetrachloroethene, and vinyl chloride. The majority of these compounds were historically used as solvents or degreasers at Y-12. Several are components of compounds used in the paint shops. Note that most of these compounds are no longer used at the facility and have been replaced by safer products. In addition, all chemicals purchased for use at the facility are now inventoried and their use is closely supervised under existing Industrial Hygiene and Environmental Safety and Health protocols.

D.3.8 Risk Estimates for Potential Chemical Exposures for HEU Storage Mission and Special Materials Mission Alternatives

The additional proposed actions under consideration in this SWEIS include: HEU Storage Mission Alternatives, and the Special Materials Mission Alternative. Each of these actions will be discussed in the following subsections relative to their respective impact on the risk estimates for potential radiation exposure to the public.

D.3.8.1 Alternative 1B (No Action - Planning Basis Operations Alternative)

No Action - Planning Basis Operations Alternative does not include the construction or significant upgrade/expansion of any new or existing DP facilities. The Y-12 Plant would continue to use the existing storage facilities and the existing special materials operation facilities to perform the HEU Storage Mission and the Special Materials Mission, respectively. Under the No Action - Planning Basis Operations Alternative, the major production activities during the 2001-2010 time period will involve weapons production, weapons dismantlement, quality evaluation, special production, and enriched uranium recovery.

Nonradiological airborne discharges from Y-12 mission facilities under No Action - Planning Basis Operations Alternative consist of those criteria and chemical pollutant emissions from the Y-12 Steam Plant and chemical emissions from Y-12 operations. No adverse direct or indirect air quality inputs are expected from normal operations associated with the continuation of Y-12 missions under No Action - Planning Basis Operations Alternative (see Section 5.7).

In 1987, 12 perimeter ambient air monitors were operated at the Y-12 Plant. Uranium, fluoride, SO₂, and total suspended particulates data were collected. The results of this monitoring are presented and summarized in the report *Environmental Surveillance of the U.S. Department of Energy Oak Ridge Reservation and Surrounding Environs During 1987* (MMES 1988). Fluoride and SO₂ concentrations were below all applicable state standards. Total suspended particulates did exceed state standards four times during 1987, but this was attributed to road dust in the area of the station before its relocation. Mercury was not monitored at these ambient air stations in 1987.

Available surface water historical data for the release of chemical contaminants as a result of process operations are limited to the reported NPDES monitoring data in the above mentioned report. In general, the data are reported as either less than or greater than the detection/reporting limits and actual measurements are not readily available. In addition, the sampling locations were monitored for primarily inorganic constituents and physical characteristics (i.e., temperature, turbidity, pH, etc.). The other compounding factors in using the historical data are that waste process treatment facilities have been upgraded and

improved during the subsequent years and administrative and engineering controls have improved. Lastly, increased production and recovery operations during the 2001-2010 time period are not expected to result in any increased release of chemical contaminants to the environment compared to current operations. Therefore, the data for the 1998 baseline is considered representative for No Action - Status Quo Alternative.

D.3.8.2 *Highly Enriched Uranium Storage Mission Alternatives*

There are three proposed alternatives for the HEU Storage Mission at Y-12: No Action - Planning Basis Operations Alternative, Alternative 2A (Construction and Operation of a New HEU Materials Facility), and Alternative 2B (Upgrade Expansion to existing Building 9215) (see Volume I, Chapter 3). The emission data for No Action - Planning Basis Operations Alternative is assumed to include all the emissions from the storage of HEU in existing facilities. The impacts associated with the criteria and toxic pollutants presented would be the same as described for Alternative 2B (No Action - Status Quo Alternative) environmental consequences. Similarly, chemical emissions are considered to be the same as those for No Action - Status Quo Alternative (1998 baseline). Contributions from the current HEU Storage Mission facilities are reflected in the emissions from the Y-12 Steam Plant which supplies steam to the facilities (see Section 5.7). In addition, the environmental emissions for the HEU Storage Mission Alternatives are expected to be at or below the current levels due to administrative and engineered controls. Risks to the public from environmental emissions would remain the same or below those presented in Section D.2.5.1 for Alternative 1B (No Action - Planning Basis Operations Alternative).

D.3.8.3 *Special Materials Mission Alternatives*

There are two proposed alternatives for the Special Materials Mission at Y-12: No Action - Planning Basis Operations Alternative, Alternative 3A (Construction and Operation of a new Special Materials Complex) (see Chapter 3). Under No Action - Planning Basis Operations Alternative the Special Materials Complex would not be constructed. The Y-12 Plant would continue to use the existing special materials operations facilities and the chemical impacts to the public would remain the same as under Alternative 1B (No Action - Planning Basis Operations Alternative) discussed in Section D.2.5.1.

No criteria pollutant emissions would be generated from the new Special Materials Complex facilities. Chemical emissions with the exception of beryllium are considered to be the same as those in the 1998 baseline as the activities to be undertaken will not change only the location at which these activities are completed will change. Additional steam generation for heating requirements at the new complex would be off-set by a reduction in heating requirements of the old facilities.

The construction of the New Special Materials Complex includes a new Beryllium Facility. The transfer of beryllium operations to the new facility would result in a positive impact by reducing emissions at the Y-12 Plant. The new Beryllium Facility would be equipped with a 99.5 percent pre-filtration system through which process exhausts would be filtered prior to passing through a high-efficiency particulate air (HEPA) filtration system and subsequent exhausting through the building stacks. The new filtration system is estimated to reduce current baseline emissions of beryllium by 90 percent (LMES 2000c).

D.4 IMPACTS TO WORKER SAFETY

Y-12 worker risks from radiation and chemical hazards are closely controlled by health and safety requirements. In addition to these risks, workers at Y-12 have the potential for industrial accidents, injuries, and illnesses due to everyday operations. Due to these potential impacts, injury and illness rates are included in this SWEIS.

The Safety Program at Y-12 encompasses the DOE Orders described below and implements the Integrated Safety Management System as the facility safety structure. The objective of the Integrated Safety Management System is to provide a safe workplace to perform work safely while protecting the worker, the public, and the environment. Integrated Safety Management System principles include the line management responsibility for safety, clear lines of authority for ensuring safety, input and support from all workers, and the effective hazard controls to ensure the safety of work.

D.4.1 Department of Energy Regulation of Worker Safety

DOE Order 440.1A, *Worker Protection Management for DOE Federal and Contractor Employees*, regulates the health and safety of workers at all DOE sites. This comprehensive standard directs the contractor facilities to establish the framework for an effective worker protection program that will reduce or prevent injuries, illnesses, and accidental losses by providing DOE Federal and contractor workers with a safe and healthful workplace. Baseline exposure assessments are outlined in this requirement, along with day-by-day health and safety responsibilities.

Industrial hygiene limits for occupational chemical exposures at federal sites are regulated by 29 CFR 1910 and 29 CFR 1926, *Occupational Safety and Health Standards*, including the PELs set by OSHA. DOE requires that all sites comply with the PELs unless a lower limit (more protective) exists in the ACGIH TLVs.

The Y-12 Safety Program conducts investigations of plant accidents according to DOE Order 225.1A, *Accident Investigations*, and reports work-related fatalities, injuries, and illnesses according to DOE Order 231.1, *Environment, Safety and Health Reporting*.

D.4.2 Y-12 Injury/Illness Rates

The Y-12 worker nonfatal injury/illness rates presented in Table D.4.2-1 were used to calculate the 4-year average (1995-1998) injury/illness rate for 100 workers (or 200,000 hours). The average 4-year injury/illness rate and the 4-year average Y-12 worker population size were then used to calculate the total number of Y-12 worker nonfatal injury/illness per year for the entire Y-12 workforce under the No Action - Planning Basis Operations Alternative. It was assumed that the 4-year average rate would remain constant.

TABLE D.4.2-1.—Y-12 Four-Year Average (1995-1998) Illness/Injury Rate per 100 Workers

Data Items	1995	1996	1997	1998	4-Year Average
Annual Y-12 Worker Population	5,777	5,034	5,034	5,105	5,238
Annual Y-12 Nonfatal Occupational Injury/Illness Rate	8.03	9.14	9.53	7.68	8.58

Source: LMES 1999.

The estimated Y-12 worker population under each alternative was multiplied by the 4-year averaged nonfatal injury/illness rate (per 100 workers) to obtain the total number of nonfatal injuries/illnesses per year for the entire Y-12 workforce for each alternative (Table D.4.2-2).

TABLE D.4.2–2.—Calculated Nonfatal Injuries/Illnesses per Year for Y-12 Workforce by Alternative

Data Items	4-Year Average	No Action - Status Quo Alternative	No Action - Planning Basis Operations Alternative
Y-12 Worker Population	5,238	5,105	5,128 ^a
Y-12 Nonfatal Occupational Injury/Illness (per 100 workers) 4-year average (1995-98)	8.58	8.58	8.58
Total Number of Nonfatal Occupational Injuries/Illnesses for the Y-12 Workforce	449	438	440

^aWorker population is assumed to remain the same as the current level of 5,128.

D.5 PUBLIC HEALTH DATA PROFILES

The supplemental information in this section provides the context for the human health analysis and epidemiologic studies presented in this SWEIS. The following sections provide public health profiles pertaining to cancer incidence rates and mortalities for the United States, Tennessee, Anderson County, and Roane County, along with definitions necessary for the interpretation of results.

D.5.1 Definition of Terms used in Health and Epidemiologic Studies

Standardization: A statistical method to remove the effects of differences in age, gender, or other characteristics when comparing two or more population groups.

Standardized Mortality Ratio (SMR): The ratio of the number of deaths observed in a study population to the number that would be expected. Usually, the expected number of deaths is based on the U. S. or State of Tennessee (reference) population for these studies. The risk of death in the study group is the same as the risk in the reference group if the SMR is 1. The study population is at greater risk of death than the reference group if the SMR is greater than 1, and at less risk if the SMR is less than one.

Confidence Interval: A range around a variable, (e.g., rate) constructed so that this range has a specified probability of including the true value of the variable.

D.5.2 Public Health in the United States

According to the Centers for Disease Control (CDC 1999) the age-adjusted death rate (these rates are age-adjusted to eliminate the distorting effects of the aging population) for the United States in 1997 was the lowest on record, 479.1 deaths per 100,000 U.S. population. While death rates have been declining for the past 20 years, the leading causes of death in the U.S. have remained fairly consistent. Heart disease remains the number one cause of death, followed by cancer and strokes.

Life expectancy at birth for 1997 reached a record high of 76.5 years, an increase of 0.4 year compared with life expectancy in 1996. This is attributed to a decline in deaths from AIDS, heart disease, cancer, stroke, and homicide.

Table D.5.2-1 shows the leading causes of death and the age-adjusted death rates per 100,000 U.S. population for the year 1997 along with the percent change since 1979.

TABLE D.5.2-1.—Age-Adjusted Mortality Rates

Cause of Death	Age-adjusted Death Rate of 1997	Percent of Total Deaths (1997)	Percent Change Since 1979
Heart disease	130.5	31.4	-34.6
Cancer	125.6	23.3	-4.0
Stroke	25.9	6.9	-37.7
Chronic obstructive pulmonary disease	21.1	4.7	44.5
Accidents	30.1	4.1	-29.8
Pneumonia and influenza	12.9	3.7	15.2
Diabetes mellitus	13.5	2.7	37.8
Suicide	10.6	1.3	-9.4
Nephritis	4.4	1.1	2.3
Chronic liver disease and cirrhosis	7.4	1.1	-38.3

Source: CDC 1999.

For the first time in many years, the incidence and death rates for cancer in the United States have declined. A collaborative report from the American Cancer Society, National Cancer Institute, and CDC (CDC 1998) announced the downshift. The report used cancer incidence data from the CDC's Surveillance, Epidemiology and End Results program and mortality data from the CDC's National Center for Health Statistics.

Before the release of the new data, cancer incidence and death rates had shown a steady increase for 20 years. Incidence rates, or rates of new cancers, increased 1.2 percent per year from 1973 to 1990 and then started a downward trend, averaging a decline of 0.7 percent per year from 1990 to 1995.

The four leading cancers reported during 1990-1995 were lung, prostate, breast, and colon, accounting for over half of the newly diagnosed cancers. These four sites were also the top causes of cancer death. Lung cancer incidence and deaths are continuing to rise for women, largely attributed to the increase in smoking among women. This is in contrast to the lung cancer rates in men, which rose sharply from 1940 to 1990, but have been declining over the past 10 years with the decline in cigarette smoking.

D.5.3 Comparison of U. S. and Tennessee Cancer Rates

Tennessee has a higher mortality rate for lung cancer and prostate cancer than the United States as a whole (Table D.5.3-1). Tennessee ranks 12th highest overall in cancer mortality rates among the 50 states and

Washington, D.C. (CDC 1998). Age-adjusted cancer death rates have declined in Tennessee over the past 5 years, following the pattern for the United States as a whole.

TABLE D.5.3-1.—Average Annual Age-adjusted Mortality Rates for Cancer-related Deaths per 100,000 Persons, 1991-1995

Type of cancer	Tennessee	National
Lung	59.4	49.8
Breast	25.7	26.0
Colorectal	17.6	17.8
Prostate	26.9	26.1

Source: CDC 1998.

D.5.4 Anderson and Roane County Cancer Rates

The following cancer incidence and mortality data are included to augment the epidemiologic studies and reflect the cancers of concern in the reported studies. The data presented in Tables D.5.4-1 through D.5.4-6 are compiled by the Tennessee Cancer Registry, Tennessee Department of Health. The Tennessee population data is provided from the U.S. Bureau Census. Four year age-adjusted rates were used to compare Anderson and Roane Counties to the Tennessee rates. The U.S. rates are not compared in this data profile since national population data differs from that compiled by the State of Tennessee.

According to the CDC, the prostate-specific antigen test for prostate cancer was introduced in the late 1980s and early 1990s and caused an increase in the diagnoses of previously undetected prostate cancers. The CDC projects that since these prevalent cancers have been detected, the rate may be dropping to an equilibrium that more represents the actual incidence.

TABLE D.5.4-1.—1989-1992 Age-adjusted^a Cancer Mortality Rates with 95 Percent Confidence Interval (CI) and Number of Cases^b

Site		Anderson Co.	Roane Co.	Tennessee
Female Breast	Rate	16.7	14.3	24.5
	No. Cases	40	19	3,169
	95 percent CI	11.4-22.1	7.8-20.9	23.7-25.4
Leukemias	Rate	6.7	5.0	6.0
	No. Cases	26	12	1,443
	95 percent CI	4.0-9.3	2.1-7.8	5.7-6.3
Lung	Rate	52.6	64.2	56.5
	No. Cases	196	169	12,813
	95 percent CI	45.1-60.1	54.4-73.9	55.5-57.5
Nervous System	Rate	4.7	6.1	5.0
	No. Cases	15	15	1,096
	95 percent CI	2.2-7.1	3.0-9.3	4.7-5.3
Non-Hodgkins Lymphomas	Rate	6.3	8.4	5.9
	No. Cases	24	24	1,417
	95 percent CI	3.8-8.9	5.0-11.8	5.6-6.2
Myelomas	Rate	3.0	2.9	3.4
	No. Cases	12	8	812
	95 percent CI	1.3-4.7	0.9-5.0	3.1-3.6
Prostate	Rate	24.6	19.0	26.1
	No. Cases	37	19	2,507
	95 percent CI	16.5-32.6	10.3-27.7	25.1-27.2
Thyroid	Rate	0.6	-	0.3
	No. Cases	2	-	77
	95 percent CI	-0.2-1.4	-	0.2-0.4
Total Cancer Mortality	Rate	160.8	166.1	172.2
	No. Cases	620	440	40,493
	95 percent CI	147.9-173.7	150.4-181.8	170.5-173.9

^aAge-adjustment methodology adjusts to the 1970 U.S. standard population.

^bData are as reported to the Tennessee Department of Health, Health Statistics and Research, Nashville, TN.
Source: CDC 1998.

TABLE D.5.4-2.—1993-1996 Age-adjusted^a Cancer Mortality Rates with 95 Percent Confidence Interval (CI) and Number of Cases^b

Site		Anderson Co.	Roane Co.	Tennessee
Female Breast	Rate	19.3	22.3	25.0
	No. Cases	46	34	3,576
	95 percent CI	13.4-25.1	14.6-29.9	24.1-25.8
Leukemias	Rate	6.3	8.0	6.3
	No. Cases	28	24	1,655
	95 percent CI	3.9-8.7	4.7-11.2	6.0-6.6
Lung	Rate	62.7	67.6	58.9
	No. Cases	258	195	14,601
	95 percent CI	54.9-70.5	58.0-77.2	57.9-59.8
Nervous System	Rate	7.8	3.2	5.0
	No. Cases	27	8	1,188
	95 percent CI	4.7-10.9	0.9-5.6	4.7-5.3
Non-Hodgkins Lymphomas	Rate	4.7	6.1	6.7
	No. Cases	23	17	1,759
	95 percent CI	2.8-6.7	3.2-9.1	6.4-7.0
Myelomas	Rate	4.4	2.7	3.4
	No. Cases	18	8	902
	95 percent CI	2.3-6.5	0.8-4.5	3.2-3.6
Prostate	Rate	24.5	21.1	26.3
	No. Cases	41	26	2,748
	95 percent CI	16.9-32.0	12.9-29.2	25.3-27.3
Thyroid	Rate	1.1	-	0.3
	No. Cases	5	-	86
	95 percent CI	0.1-2.2	-	0.2-0.4
Total Cancer Mortality	Rate	175.5	171.7	177.7
	No. Cases	738	503	45,723
	95 percent CI	162.6-188.5	156.4-186.9	176.1-179.4

^aAge-adjustment methodology adjusts to the 1970 U.S. standard population.

^bData are as reported to the Tennessee Department of Health, Health Statistics and Research, Nashville, TN.

Source: CDC 1998.

TABLE D.5.4-3.—1989-1992 Age-adjusted^a Cancer Incidence Rates 95 Percent Confidence Interval (CI) and Number of Cases^b

Site		Anderson Co.	Roane Co.	Tennessee
Female Breast	Rate	110.1	74.0	85.4
	No. Cases	216	104	10,636
	95 percent CI	94.9-125.2	59.4-88.6	83.7-87.1
Leukemias	Rate	6.9	8.5	6.2
	No. Cases	25	18	1,366
	95 percent CI	4.0-9.7	4.4-12.6	5.9-6.6
Lung	Rate	68.9	74.7	58.5
	No. Cases	258	195	13,104
	95 percent CI	60.3-77.4	64.1-85.3	57.5-59.5
Nervous System	Rate	8.0	5.5	5.9
	No. Cases	25	12	1,232
	95 percent CI	4.7-11.2	2.3-8.7	5.6-6.3
Non-Hodgkins Lymphomas	Rate	11.5	11.0	10.9
	No. Cases	43	28	2,482
	95 percent CI	8.0-15.0	6.9-15.2	10.4-11.3
Myelomas	Rate	3.8	4.3	3.2
	No. Cases	15	11	742
	95 percent CI	1.9-5.8	1.7-6.8	2.9-3.4
Prostate	Rate	153.5	104.7	95.8
	No. Cases	248	119	9,314
	95 percent CI	134.2-172.9	85.7-123.6	93.9-97.8
Thyroid	Rate	1.1	0.4	1.7
	No. Cases	3	1	392
	95 percent CI	-0.2-2.5	-0.4-1.2	1.6-1.9
Total Incidence	Rate	394.3	349.3	317.3
	No. Cases	1,474	904	72,839
	95 percent CI	373.7-414.8	326.2-372.3	315.0-319.7

^aAge-adjustment methodology adjusts to the 1970 U.S. standard population.

^bData are as reported to the Tennessee Department of Health Cancer Registry, Nashville, TN.

Source: CDC 1998.

TABLE D.5.4-4.—1993-1996 Age-adjusted^a Cancer Incidence Rates with 95 Percent Confidence Interval (CI) and Number of Cases^b

Site		Anderson Co.	Roane Co.	Tennessee
Female Breast	Rate	96.8	81.0	93.3
	No. Cases	204	124	12,659
	95 percent CI	83.1-110.6	66.4-95.7	91.6-94.9
Leukemias	Rate	5.4	6.2	7.1
	No. Cases	20	15	1,674
	95 percent CI	2.9-7.9	2.9-9.6	6.7-7.4
Lung	Rate	72.1	70.9	64.4
	No. Cases	288	204	15,681
	95 percent CI	63.7-80.6	61.1-80.7	63.4-65.4
Nervous System	Rate	6.7	4.2	6.2
	No. Cases	22	10	1,394
	95 percent CI	3.7-9.6	1.4-6.9	5.8-6.5
Non-Hodgkins Lymphomas	Rate	9.5	9.6	11.6
	No. Cases	39	23	2,885
	95 percent CI	6.4-12.6	5.5-13.7	11.2-12.1
Myelomas	Rate	4.3	3.3	3.6
	No. Cases	17	10	916
	95 percent CI	2.2-6.4	1.2-5.4	3.4-3.9
Prostate	Rate	100.6	86.1	93.2
	No. Cases	170	110	9,674
	95 percent CI	85.4-115.7	70.0-102.3	91.3-95.1
Thyroid	Rate	5.8	5.1	3.6
	No. Cases	21	13	868
	95 percent CI	3.3-8.3	2.3-7.8	3.4-3.9
Total Incidence	Rate	345.1	328.6	335.2
	No. Cases	1,367	921	82,730
	95 percent CI	326.4-363.8	306.9-350.3	332.9-337.5

^aAge-adjustment methodology adjusts to the 1970 U.S. standard population.

^bData are as reported to the Tennessee Department of Health Cancer Registry, Nashville, TN.
Source: CDC 1998.

TABLE D.5.4-5.—Four-Year Average Age-specific Childhood Cancer Mortality for Tennessee Residents

County		Age Group (1989 - 1992)				Total
		00-04	05-09	10-14	15-19	
Anderson	Cases	2	3	0	2	7
	Population	17,072	18,717	18,970	18,740	73,499
	Age-Specific Rate	11.72	16.03	0.00	10.67	9.52
Roane	Cases	0	1	0	1	2
	Population	10,744	12,085	13,410	14,012	50,251
	Age-Specific Rate	0.00	8.27	0.00	7.14	3.98
Total	Cases	52	70	68	79	269
	Population	1,349,134	1,367,900	1,372,540	1,474,378	5,563,952
	Age-Specific Rate	3.85	5.12	4.95	5.36	4.83

Four-Year Average Age-specific Childhood Cancer Mortality for Tennessee Residents

County		Age Group (1993 - 1996)				Total
		00-04	05-09	10-14	15-19	
Anderson	Cases	0	1	2	2	5
	Population	17,829	19,578	19,406	18,758	75,571
	Age-Specific Rate	0.00	5.11	10.31	10.66	6.62
Roane	Cases	0	0	0	0	0
	Population	10,829	12,090	13,194	13,411	49,524
	Age-Specific Rate	0.00	0.00	0.00	0.00	0.00
Total	Cases	60	62	52	86	260
	Population	1,441,383	1,469,146	1,448,870	1,497,132	5,856,531
	Age-Specific Rate	4.16	4.22	3.59	5.74	4.44

Note: As reported to the Tennessee Department of Health Cancer Registry, Nashville, TN.
Source: CDC 1998

TABLE D.5.4-6.—Four-Year Average Age-specific Childhood Cancer Incidence for Tennessee Residents

County		Age Group (1989 - 1992)				Total
		00-04	05-09	10-14	15-19	
Anderson	Cases	4	1	2	1	8
	Population	17,072	18,717	18,970	18,740	73,499
	Age-Specific Rate	23.43	5.34	10.54	5.34	10.88
Roane	Cases	1	1	1	1	4
	Population	10,744	12,085	13,410	14,012	50,251
	Age-Specific Rate	9.31	8.27	7.46	7.14	7.96
Total	Cases	273	168	128	239	808
	Population	1,349,134	1,367,900	1,372,540	1,474,378	5,563,952
	Age-Specific Rate	20.24	12.28	9.33	16.21	14.52

Four-Year Average Age-specific Childhood Cancer Incidence for Tennessee Residents

County		Age Group (1993 - 1996)				Total
		00-04	05-09	10-14	15-19	
Anderson	Cases	0	4	2	3	9
	Population	17,829	19,578	19,406	18,758	75,571
	Age-Specific Rate	0.00	20.43	10.31	15.99	11.91
Roane	Cases	2	3	0	4	9
	Population	10,829	12,090	13,194	13,411	49,524
	Age-Specific Rate	18.47	24.81	0.00	29.83	18.17
Total	Cases	275	165	149	253	842
	Population	1,441,383	1,469,146	1,448,870	1,497,132	5,856,531
	Age-Specific Rate	19.08	11.23	10.28	16.90	14.38

Note: As reported to the Tennessee Cancer Reporting System.
Source: CDC 1998