APPENDIX D: HUMAN HEALTH AND ACCIDENTS

APPENDIX D: HUMAN HEALTH AND ACCIDENTS

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, accidents, and worker safety issues due to operations under Alternative 1 (No Action Alternative) and those proposed under Alternative 2 (New Uranium Processing Facility Alternative) Alternative 3, (Upgrade in-Place Alternative), Alternative 4 (Capability-Based Alternatives), and Alternative 5 (No Net Production/Capability-sized UPF Alternative) analyzed in this Y-12 SWEIS. Located at the end of this appendix is a separate reference section.

D.1 RADIOLOGICAL IMPACTS ON HUMAN HEALTH

D.1.1 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 power plants. The following sections describe some important principles concerning the nature, types, sources, and effects of radiation and radioactivity.

D.1.1.1 *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 centimeters of lead, 10 centimeters of iron, or 33 centimeters 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.1.1.2 *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 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 mrem is one one-thousandth (0.001) of a roentgen equivalent man (rem).

D.1.1.3 *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. 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. Refer to the glossary for the definition of risk. 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. Because fatal cancer is the most serious effect of environmental and occupational radiation exposures, this SWEIS presents estimates of LCFs rather than cancer incidence. The numbers of LCFs can be used to compare the risks among the various alternatives. Nonfatal cancers can be estimated by comparing them with the LCF estimates (see Table D.1.1.3-1).

Table D.1.1.3-1. Nominal Health Risk Estimators Associated With Exposure to 1 Rem of Ionizing Radiation.

Exposed Individual	Fatal Cancer	Nonfatal Cancer
Worker	0.0006	0.0008
Public	0.0006	0.0008

Source: DOE 2002d.

D.1.1.4 *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.1.1.5 *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.

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.

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 U.S. Department of Energy (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. Due to radioactive material found in coal, coal-fired power plants are also a source of radiation, but contribute less than 1 mrem per year to the average individual dose.

D.1.2 Radioactive Materials at Y-12

The release of radiological contaminants into the environment at Y-12 occurs almost exclusively as a result of Y-12 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.1.2.1 *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 greater than 0.1 mrem per 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 1999, 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 11 unmonitored areas of uranium emissions from process stacks, and 32 minor emission points were identified from ORNL activities at facilities within the boundary of Y-12. Eight 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).

D.1.2.2 *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 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 *Code of Federal Regulations* (CFR) Part 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 *National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities* (40 CFR Part 61, Subpart H) limit exposure to the maximally exposed individual (MEI) of the public from all air emissions to 10 mrem per year.

Limits of exposure to members of the public and radiation workers are derived from International Commission on Radiological Protection (ICRP) recommendations. The U.S. Environmental Protection Agency (EPA) uses the National Council on Radiation Protection and Measurements and the ICRP recommendations and sets specific annual exposure limits (usually less than those specified by the ICRP) in *Radiation Protection Guidance to Federal Agencies* documents. Each regulatory organization then establishes its own set of radiation standards. The various exposure limits set by DOE and the EPA for radiation workers and members of the public are given in Table D.1.2.2-1.

Table D.1.2.2-1. Exposure Limits for Members of the Public and Radiation Workers.

Guidance Criteria (organization)	Public Exposure Limit at the Site Boundary	Worker Exposure Limit
10 CFR Part 835 (DOE)	--	5,000 millirem per year [a]
10 CFR 835.1002 (DOE)	--	1,000 millirem per year [b]
DOE Order 5400.5 (DOE) [c]	10 millirem per year (all air pathways) 4 millirem per year (drinking water pathways) 100 millirem per year (all pathways)	--
40 CFR Part 61 (EPA)	10 millirem per year (all air pathways)	--
40 CFR Part 141 (EPA)	4 millirem per year (drinking water pathways)	--

[a] Although this is a limit (or level) that is enforced by DOE, worker doses must be managed in accordance with as low as is reasonably achievable principles. Refer to footnote b.

[b] This is a control level. It was established by DOE to assist in achieving its goal to maintain radiological doses as low as is reasonably achievable. 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

[c] Derived from 40 CFR Part 61, 40 CFR Part 141, and 10 CFR Part 20.

D.1.3 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 doses to the public. Each year, environmental data from ORR and each of the facilities, including Y-12, are collected and analyzed. The results of these environmental monitoring activities are summarized in the ORR's *Annual Site Environmental Report* (ASER). 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 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.

D.2 METHODOLOGY FOR ESTIMATING RADIOLOGICAL IMPACTS

D.2.1 Airborne Radionuclides

The public health consequences of radionuclides released to the atmosphere from operations at Y-12 were characterized and calculated in the ASER. Radiation dose to the maximally exposed offsite individuals, to onsite members of the public where no physical access controls are managed by DOE, and to the entire population residing within 50 miles of the center of ORR. The dose calculations were made using the CAP-88 package (version 3) of computer codes (EPA 2008), which was developed under EPA sponsorship to demonstrate compliance with 40 CFR Part 61, Subpart H, which governs the emissions of radionuclides other than radon from DOE facilities. This package implements a steady-state Gaussian plume atmospheric dispersion model to calculate concentrations of radionuclides in the air and on the ground and uses Regulatory Guide 1.109 (NRC 1977) food-chain models to calculate radionuclide concentrations in foodstuffs (vegetables, meat, and milk) and subsequent intakes by humans.

A total of 8 emission points at the Y-12 complex, each of which includes one or more individual sources, was modeled during 2004. Table D.2.1-1 is a list of the emission point parameter values and receptor locations used in the dose calculations.

Meteorological data used in the calculations for 2007 were in the form of joint frequency distributions of wind direction, wind speed class, and atmospheric stability category. During 2007, rainfall, as averaged over the four rain gauges located on ORR, was 91.1 centimeters. The average air temperature was 70 degrees Fahrenheit (°F), and the average mixing-layer height was 1,936 feet. The mixing height is the depth of the atmosphere adjacent to the surface within which air is mixed (DOE 2008).

For occupants of residences, the dose calculations assume that the occupant remained at home (actually, unprotected outside the house) during the entire year and obtained food according to the rural pattern defined in the NESHAP background documents (EPA 1989). 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 are produced in the local area (e.g., a home garden). The remaining portion of each food is assumed to be produced within 50 miles of ORR. The same assumptions are used for occupants of businesses, but the resulting doses are divided by 2 to compensate for the fact that businesses are occupied for less than one-half a year and that less than one-half of a worker's food intake occurs at work. For collective effective dose equivalent (EDE) estimates, production of beef, milk, and crops within 50 miles of ORR was calculated using production rates provided with CAP-88 (DOE 2008).

Table D.2.1-1. Emission Point Parameters and Receptor Locations Used in the Dose Calculations.

Source ID	Stack height (m)	Stack diameter (m)	Effective exit gas velocity (m/s)	Exit gas temperature (°C)	Distance (m) and Direction to the Maximally Exposed Individual			
					Y-12 maximum		ORR maximum	
Y-9422-22 Air Stripper	3.96	0.153	0	Ambient	614	NNW	614	NNW
Y-9616-7 Degas	12.20	0.2	4.36	Ambient	4184	NE	4184	NE
Y-9616-7 Lab Hood	12.20	0.25	0.69	Ambient	4184	NE	4184	NE
Y-9623 Lab Hood	8.50	0.25	0.64	Ambient	2496	NE	2496	NE
Y-Monitored	20.00	0	0	Ambient	2306	ENE	2306	ENE
Y-Union Valley Lab	4.27	0.762	13.08	Ambient	751	WSW	751	WSW
Y-Unmonitored Processes	20.00	0	0	Ambient	2306	ENE	2306	ENE
Y-Unmonitored Lab Hoods	20.00	0	0	Ambient	2306	ENE	2306	ENE

Source: DOE 2005a.

D.2.2 Surface Water

Radionuclides discharged to surface waters from the Y-12 Complex enter the Clinch River via Bear Creek and 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. This section discusses the potential radiological impacts of these discharges to persons who drink water; eat fish; and swim, boat, and use the shoreline at various locations along the Clinch and Tennessee rivers.

For assessment purposes, surface waters potentially affected by ORR are divided into seven segments: (1) Melton Hill Lake above all possible ORR inputs, (2) Melton Hill Lake, (3) Upper Clinch River (from Melton Hill Dam to confluence with Poplar Creek), (4) Lower Clinch River (from confluence with Poplar Creek to confluence with the Tennessee River), (5) Upper Watts Bar Lake (from near confluence of the Clinch and Tennessee Rivers to below Kingston), (6) Lower System (the remainder of Watts Bar Lake and Chicamauga Lake to Chattanooga), and (7) Poplar Creek (including the confluence of EFPC).

Two methods are used to estimate potential radiation doses to the public. The first method uses radionuclide concentrations in the medium of interest (i.e., in water and fish) determined by laboratory analyses of water and fish samples. The second method calculates possible radionuclide concentrations in water and fish from measured radionuclide discharges and known or estimated stream flows. The advantage of the first method is the use of radionuclide concentrations measured in water and fish; disadvantages are the inclusion of naturally occurring radionuclides (i.e., K-40 and natural uranium, thorium, and their progeny), the possible inclusion of radionuclides discharged from sources not part of ORR, the possibility that some radionuclides of ORR origin might be present in quantities too low to be measured, and the possibility that the presence of some radionuclides might be misstated (e.g., present in a quantity below the detection limit). Estimated doses from measured radionuclide concentrations are presented without and with contributions of naturally occurring radionuclides. The advantages of the second method are that most radionuclides discharged from ORR will be quantified and that naturally occurring radionuclides will not be considered or will be accounted for separately; the disadvantage is the use of models to estimate the concentrations of the radionuclides in water and fish. Both methods use the same models (DOE 2008) to estimate radionuclide concentrations in media and at locations other than those that are sampled (e.g., downstream). However, combining the two methods should allow the potential radiation doses to be bounded.

In the following drinking water and fish subsections, the estimated maximum dose is based on either the first method, which uses radionuclide concentrations measured in the medium of interest (i.e., in water and fish), or by the second method, which calculates possible radionuclide concentrations in water and fish from measured radionuclide discharges and known or estimated stream flows.

Drinking Water. Several water treatment plants that draw water from the Clinch and Tennessee River systems could be affected by discharges from ORR. No in-plant radionuclide concentration data are available for any of these plants; all of the dose estimates given below are likely high because they are based on water concentrations before it enters the processing plants. For purposes of assessment, it was assumed that the drinking water consumption rate for the maximally exposed individual is 730 liters per year and the drinking water consumption rate for the average person is 370 liters per year. The average drinking water consumption rate is used to estimate the collective dose. At all locations in 2007, the estimated maximum doses to a person drinking water were calculated using measured radionuclide concentrations in off-site surface water and exclude naturally occurring radionuclides (DOE 2008).

Fish. Fishing is quite common on the Clinch and Tennessee River systems. For purposes of assessment, it was assumed that avid fish consumers would have eaten 21 kilograms of fish during 2007 and that the average person, who is used for collective dose calculations, would have consumed 6.9 kilograms of fish. As mentioned above, the estimated maximum effective dose will be based on either the first method, measured radionuclide concentrations in fish, or by the second method, which calculates possible radionuclide concentrations in fish from measured radionuclide discharges and known or estimated stream flows and excludes naturally occurring radionuclides (DOE 2008).

Other Uses. Other uses of ORR area waterways include swimming or wading, boating, and use of the shoreline. A highly exposed other user was assumed to swim or wade for 30 hours per year, boat for 63 hours per year, and use the shoreline for 60 hours per year. The average individual, who is used for collective dose estimates was assumed to swim or wade for 10 hours per year, boat 21 hours per year, and use the shoreline for 20 hours per year. Measured and calculated concentrations of radionuclides in water and the LADTAP XL code (DOE 2008) were used to estimate potential effective doses from these activities. At all locations in 2004, the estimated highly exposed individual effective doses were based on measured offsite surface water radionuclide concentrations and exclude naturally occurring radionuclides. When compared with doses from eating fish from the same waters, the doses from these other uses are relatively insignificant (DOE 2008).

D.2.3 Other Environmental Media

The CAP-88 computer codes are used to calculate radiation doses from ingestion of meat, milk, and vegetables that contain radionuclides released to the atmosphere. These doses are included in the dose calculations for airborne radionuclides. However, some environmental media, including the three mentioned, are sampled as part of the surveillance program. The following dose estimates are based on environmental sampling results and may include contributions from radionuclides occurring in the natural environment, released from ORR, or both (DOE 2008).

Milk. Milk collected at two locations at a distance from ORR contained detected strontium-90 concentrations (DOE 2008). At all three locations, tritium was detected in the samples. The sample data were used to calculate potential doses to hypothetical persons who drank 310 liters (NRC 1977) of sampled milk during the year. These hypothetical persons could have received a dose of about 0.07 mrem from drinking milk from the near locations and about 0.007 mrem from the remote location, excluding the contribution from naturally occurring radionuclides (DOE 2008).

Food Crops. The food-crop sampling program is described in the 2007 ASER (DOE 2008). Samples of tomatoes, lettuce, and turnips were obtained from six local gardens. These vegetable represent fruit-bearing, leafy, and root vegetables. All radionuclides found in the food crops are found in the natural environment and in commercial fertilizers, and all but two radionuclides also are emitted from ORR. Dose estimates are based on hypothetical consumption rates of vegetables that contain statistically significant amounts of detected radionuclides that could have come from ORR. Based on a nationwide food consumption survey (EPA 1997), a hypothetical home gardener was assumed to have eaten 32 kilograms of homegrown tomatoes, 10 kilograms of homegrown lettuce, and 37 kilograms of homegrown turnips. The hypothetical gardener could have received a 50-year committed effective dose of between 0.007 and 0.1 mrem, depending on garden location. Of this total, between 0 and 0.05 mrem could have come from eating tomatoes, between 0.007 and 0.04 mrem from eating lettuce, and between 0.02 and 0.09 mrem from eating turnips. The highest dose to a gardener could have been about 0.1 mrem from consuming all three types of homegrown vegetables (DOE 2008).

White-Tailed Deer. The Tennessee Wildlife Resources Agency (TWRA) conducted three 2-day deer hunts during 2007 on the Oak Ridge Wildlife Management Area, which is part of ORR (see Sect. 6.7). During the hunts, 361 deer were harvested and were brought to the TWRA checking station. At the station, a bone sample and a tissue sample were taken from each deer and were field-counted for radioactivity to ensure that the deer met wildlife release criteria (less than 20 picocuries (pCi) per gram of beta-particle activity in bone or 5 pCi per gram of cesium-137 in edible tissue). Three deer exceeded the limit for beta-particle activity in bone and were confiscated. The remaining 358 deer were released to the hunters.

Tissue samples collected in 2007 from 12 deer (9 released and 3 retained) were subjected to laboratory analysis. Comparison of the field to analytical cesium-137 concentrations results found that the field concentrations were greater than the analytical results with the exception of one retained deer. All were less than the administrative limit of 5 pCi per gram. The strontium-90 concentrations analyzed in these tissue samples were all less than the minimum detectable levels. Using analytical tissue data and actual deer weights, the estimated doses for these 12 deer ranged between 0.4 to 1 mrem (DOE 2008).

Canada Geese. During the 2007 goose roundup, 202 geese were weighed and subjected to whole-body gamma scans. The geese were field-counted for radioactivity to ensure that they met wildlife release criteria (less than 5 pCi per gram of cesium-137 in tissue). The average cesium-137 concentration was 0.19 pCi per gram, with maximum cesium-137 concentration in the released geese of 0.4 pCi per gram. Most of the cesium-137 concentrations were less than minimum detectable activity levels. If a person consumed a released goose with an average weight of 8.2 pounds and an average cesium-137 concentration of 0.19 pCi per gram, the estimated dose would be about 0.02 mrem. It is assumed that approximately half the weight of a Canada goose is edible. The maximum estimated dose to an individual who consumed a hypothetical released goose with the maximum cesium-137 concentration of 0.4 pCi per gram and the maximum weight of 11 pounds was about 0.05 mrem (DOE 2008).

It is possible that one person could eat more than one goose that spent time on ORR. Most hunters harvest on average one to two geese per hunting season. If one person consumed two geese of maximum weight with the highest measured concentration of cesium-137, that person could have received a dose of about 0.1 mrem (DOE 2008).

Eastern Wild Turkey. Two wild turkey hunts were held on the reservation in 2007, one on March 31–April 1 and the other on April 14–15. Thirty-one birds were harvested, and none were retained. The average cesium-137 concentration measured in the released turkeys was 0.1 pCi per gram, and the maximum cesium-137 concentration was 0.21 pCi per gram. The average weight of the turkeys released was about 18.9 pounds. The maximum turkey weight was about 23.2 pounds.

If a person consumed a wild turkey with an average weight of 18.9 pounds and an average cesium-137 concentration of 0.1 pCi per gram, the estimated dose would be about 0.02 mrem. The maximum estimated dose to an individual who consumed a hypothetical released turkey with the maximum cesium-137 concentration of 0.21 pCi per gram and the maximum weight of 23.2 pounds was about 0.06 mrem. It is assumed that approximately half the weight of a wild turkey is edible. The dose from one person consuming two average weight turkeys with average cesium-137 concentrations was estimated to be about 0.04 mrem. No tissue samples were analyzed in 2007 (DOE 2008).

The collective dose from consuming all the harvested wild turkey meat (31 birds) with an average field-derived cesium-137 concentration of 0.1 pCi per gram and average weight of 18.9 pounds is estimated to be about 0.0007 person-rem (DOE 2008).

D.3 RISK CHARACTERIZATION AND INTERPRETATION OF RADIOLOGICAL DATA

DOE recommends a risk estimator of 6 × 10^{-4} excess (above those naturally occurring) fatal cancers per person-rem of dose in order to assess health effects to the public and to workers (DOE 2002d). The probability of an individual worker or member of the public contracting a fatal cancer is 6 × 10^{-7} per millirem. Radiation exposure can also cause nonfatal cancers and genetic disorders. Because fatal cancer is the most serious effect of environmental and occupational radiation exposures, this SWEIS presents estimates of LCFs rather than cancer incidence. Nonfatal cancers can be estimated by comparing them with the LCF estimates (see Table D.1.1.3-1).

The radiation exposure risk estimators are denoted as excess because they result in fatal cancers above the naturally occurring annual rate, which is 171.4 per 100,000 population nationally (Ries et al. 2002). Thus, approximately 1,782 fatal cancer deaths per year would be expected to naturally occur in the approximately 1,040,041 people surrounding Y-12. The doses to which they are applied is the effective dose equivalent, which weights the impacts on particular organs so that the dose from radionuclides that affect different organs can be compared on a similar (effect on whole body) risk basis. All doses in this document are effective dose equivalent unless otherwise noted.

The number of LCFs in the general population or in the workforce is determined by multiplying 600 LCFs per million person-rem with the calculated collective population dose (person-rem), or calculated collective workforce dose (person-rem). For example, in a population of 100,000 people exposed only to natural background radiation of 0.3 rem per year, 18 cancer fatalities per year would be inferred to be caused by the radiation (100,000 persons x 0.3 rem per year × 0.0006 cancer fatalities per person-rem = 18 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 0.06 (100,000 persons × 0.001 rem × 0.0006 cancer fatalities/person-rem = 0.06 fatal cancers).

A nonintegral number of cancer fatalities such as 0.06 should be interpreted as a statistical estimate. That is, 0.06 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 0.06 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 person × 0.3 rem/year × 72 years × 0.0006 cancer fatalities/person-rem =
0.013 cancer fatalities

This could be interpreted that the estimated effect of background radiation exposure on the exposed individual would produce a 1.3 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 per year, 4 percent of the DCG values are used as comparison values. Members of the public are assumed to ingest 730 liters per year (2 liters per day) of water or to inhale 8,400 cubic meters per year (23 cubic meters per 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.4 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 B&W Y-12 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 B&W Y-12 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.4.1 Radiological Health Effects for Workers

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 Part 835. The internal dose is the 50-year CEDE. These values are determined through the Y-12 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.

The implementation of the New Uranium Processing Facility (UPF) Alternative would result in a net decrease in the number of radiation workers at Y-12 and their radiation dose. For the Upgrade in-Place Alternative there would be no change in the number of radiation workers at Y-12 and their radiation dose from the No Action Alternative. Under the Capability-Based Alternatives, the number of radiation workers at Y-12 and their radiation dose would decrease from the No Action Alternative. The radiation doses and projected health effects for each of the alternatives are presented in Table D.4.1-1.

Table D.4.1-1. Annual Radiation Doses and Health Impact to the Total Monitored Workers at Y-12 for the Alternatives.

	No Action Alternative	UPF Alternative	Upgrade in-Place Alternative	Capability-sized UPF Alternative	No Net Production/ Capability-sized UPF Alternative
Y-12 Monitored Workers	2,400	2,050 [a]	2,400	1,825[c]	1,600[d]
Average Individual Worker Dose (mrem)	20.6	10.3 [b]	20.6	10.3	10.3
Collective Worker Dose (person-rem)	49.4	21.1 [e]	49.4	18.8 [e]	16.5 [e]
Latent Cancer Fatalities	0.03	0.013	0.03	0.01	0.009

a - The total number of monitored workers at Y-12 for the UPF Alternative was derived by reducing the No Action Alternative workforce by 635 to reflect the reductions associated with more efficient operations in the UPF (less 235 workers) and other reductions (400 workers), including the consolidation of the Protected Area from 150 acres to 15 acres. Of these 635 fewer workers, 350 are "radiation workers".

b - Average dose for UPF assumes the internal dose is reduced by 50 percent.

c – Capability-sized UPF Alternative assumes an approximately 25 percent reduction in UPF personnel, which would reduce the total Y-12 monitored workers to 1,825 (see Section 3.2.4).

d – No Net Production/Capability-sized UPF Alternative assumes an approximately 33 percent reduction in UPF personnel, which would reduce the total Y-12 monitored workers to 1,600 (see Section 3.2.5).

e – After UPF becomes operational, NNSA has estimated that the total dose associated with Y-12 operations could be reduced to approximately 2 person-rem (Gorman 2009). For the bounding analysis, this SWEIS assumes the average worker dose would be reduced by 50 percent, but acknowledges that the dose could be even smaller.

Source: REMS 2007, Gorman 2009.

D.5 RISK ESTIMATES AND HEALTH EFFECTS FOR POTENTIAL RADIATION EXPOSURES TO MEMBERS OF THE PUBLIC

D.5.1 Airborne Radionuclides

The release of radiological contaminants, primarily uranium, into the atmosphere at Y-12 occurs almost exclusively as a result of plant production, maintenance, and waste management activities. NESHAP regulations for radionuclides require continuous emission sampling of major sources (a “major source” is considered to be any emission point that potentially can contribute more than 0.1 mrem per year EDE to an off-site individual). During 2004, 42 of the 55 stacks suitable for continuous monitoring were judged to be major sources. Eighteen of the stacks with the greatest potential to emit significant amounts of uranium are equipped with alarmed breakthrough detectors, which alert operations personnel to process-upset conditions or to a decline in filtration-system efficiencies, allowing them to investigate and correct the problem before a significant release occurs. As of January 1, 2004, Y-12 had continuous monitoring capability on a total of 55 stacks, 46 of which were active and 9 of which were temporarily shut down. Emissions from unmonitored process and laboratory exhausts, categorized as minor emission sources, are estimated according to calculation methods approved by the EPA. In 2004, there were 46 unmonitored processes operated by Y-12. These are included as minor sources in the Y-12 source term.

Uranium and other radionuclides are handled in millicurie quantities at facilities within the boundary of Y-12. Twenty-nine minor emission points were identified from laboratory activities at facilities within the boundary of Y-12. In addition, the Y-12 Analytical Chemistry Organization laboratory is operated in a leased facility that is not within the ORR boundary; it is located approximately a mile east of Y-12, on Union Valley Road. The emissions from the Analytical Chemistry Organization Union Valley laboratory are included in the Y-12 Complex source term. Eight minor emission points were identified at the laboratory. The releases from these emission points are minimal, however, and have a negligible impact on the total Y-12 dose.

Emissions from Y-12 room ventilation systems are estimated from radiation control data collected on airborne radioactivity concentrations in the work areas. Areas where the monthly average concentration exceeded 10 percent of the DOE derived air concentration worker-protection guidelines are included in the annual emission estimate. An estimated 0.01 Ci (2.17 kilograms) of uranium was released into the atmosphere in 2007 as a result of Y-12 activities. The specific activity of enriched uranium is much greater than that of depleted uranium, and about 80.0 percent of the curie release was composed of emissions of enriched uranium particulate, even though approximately 6.0 percent of the total mass of uranium released was enriched material.

Summary of Health Effects from Airborne Radionuclides. The dose received by the hypothetical MEI for Y-12 under the No Action Alternative was calculated to be 0.15 mrem based on both monitored and estimated emissions data (DOE 2008). This dose would be well below the NESHAP standard of 10 mrem for protection of the public (DOE 2008). The major radionuclide emissions from Y-12 are U-234, U-235, U-236, and U-238. The total dose to the population residing within 50 miles of ORR during 2007 (approximately 1,040,041 people) from Y-12 air emissions under the No Action Alternative was calculated to be about 1.5 person-rem (DOE 2008). For the Upgrade in-Place Alternative, the radiological airborne emissions and resulting impacts from upgraded enriched uranium (EU) facilities would remain unchanged from the No Action Alternative.

Although the design for a UPF is not completed, it is anticipated that implementation of the UPF Alternative would reduce the airborne emissions concentrations for Y-12 from those under the No Action Alternative and Upgrade-in Place Alternative. NNSA has estimated that uranium emissions from the UPF would be reduced by approximately 30 percent compared to the No Action Alternative. Under the Capability-sized UPF Alternative and the No Net Production/Capability-sized UPF Alternative, activities that release radiological emissions would be reduced, resulting in lower emission levels relative to the No Action Alternative. NNSA estimates that uranium emissions would decrease by approximately 40 percent for the Capability-sized UPF Alternative and approximately 50 percent for the No Net Production/Capability-sized UPF Alternative. The potential radiological doses and impacts to the MEI of the public and the population within 50 miles from Y-12 air emissions for all alternatives are presented in Tables D.5.1-1 and D.5.1-2.

Table D.5.1–1. Annual Radiation Doses from Y-12 Air Emissions.

	Alternatives				
	No Action	UPF	Upgrade in-Place	Capability-sized UPF	No Net Production/Capability-sized UPF
Dose to the MEI (mrem/year)	0.15	0.1	0.15	0.09	0.08
Offsite Population Dose (person-rem/year) [ab]	1.5	1.0	1.5	1.0	0.8

[a] Population residing within 50 miles of ORR
[b] Based on total of airborne emissions and liquid effluents

Table D.5.1–2. Annual Radiation Health Impacts from Y-12 Air Emissions.

	Alternatives				
	No Action	UPF	Upgrade in-Place	Capability-sized UPF	No Net Production/Capability-sized UPF
Latent Cancer Fatality to the MEI	9.0×10^{-8}	6.0×10^{-8}	9.0×10^{-8}	5.0×10^{-8}	4.0×10^{-8}
Latent Cancer Fatalities in the Offsite Population [ab]	0.0009	0.0006	0.0009	0.0005	0.0005

[a] Population residing within 50 miles of ORR.
[b] Based on total of airborne emissions and liquid effluents

D.5.2 Waterborne Radionuclides

D.5.2.1 *Effluent Monitoring*

A radiological monitoring plan is in place at the Y-12 Complex to address compliance with DOE orders and NPDES Permit TN002968. The permit, issued in 1995, required the Y-12 Complex to reevaluate its radiological monitoring plan and to submit results from the monitoring program quarterly as an addendum to the NPDES discharge monitoring report. There were no discharge limits set by the NPDES permit for radionuclides; the requirement is to monitor and report.

The radiological monitoring plan also addresses monitoring of the sanitary sewer. The Y-12 Complex is permitted to discharge domestic wastewater to the city of Oak Ridge publicly owned treatment works under Industrial and Commercial User Wastewater Discharge Permit No. 1-91. As required by the discharge permit, radiological monitoring of this discharge is conducted and reported to the city of Oak Ridge, although there are no city-established limits. Potential sources of radionuclides discharging to the sanitary sewer have been identified in previous studies at the Y-12 Complex as part of an initiative to meet the “as low as reasonably achievable” goals.

Radiological monitoring of storm water is also required by the NPDES permit. A comprehensive monitoring plan has been designed to fully characterize pollutants in storm water runoff. The most recent revision of the plan incorporates radiological-monitoring requirements. There are 75 storm water outfalls and monitoring points located at the Y-12 Complex, and the NPDES permit requires characterization of a minimum of 25 storm water outfalls per year.

D.5.2.2 *Results*

In 2004, the total mass of uranium and associated curies released from the Y-12 Complex at the easternmost monitoring station, Station 17 on Upper East Fork Poplar Creek (UEFPC), and at the westernmost monitoring station, at Bear Creek kilometer (BCK) 4.55 (the former NPDES outfall 304), was 303 kilograms, or 0.200 curies (Table D.5.2.2-1). The total release is calculated by multiplying the average concentration (grams per liter) by the average flow (million gallons per day). Converting units and multiplying by 365 days per year yields the calculated discharge.

The City of Oak Ridge Industrial and Commercial User Wastewater Discharge Permit allows the Y-12 Complex to discharge wastewater to be treated at the Oak Ridge publicly owned treatment works through the East End Sanitary Sewer Monitoring Station, also identified as SS6. Compliance samples are collected there. Results of radiological monitoring are reported to the city of Oak Ridge in quarterly monitoring reports.

Uranium remains the dominant radiological constituent and increases during storm flow. This increase is likely due to increased groundwater flow and storm water runoff from historically contaminated areas.

Table D.5.2.2-1. Release of Uranium from the Y-12 Complex to the Off-site Environment as a Liquid Effluent, 2000–2004.

Year	Quantity released	
	Ci	kg
Station 17		
2000	0.063	126
2001	0.043	82
2002	0.062	140
2003	0.073	167
2004	0.067	161
Outfall 304		
2000	0.093	168
2001	0.065	136
2002	0.070	141
2003	0.078	179
2004	0.133	142

Summary of Health Effects from Waterborne Radionuclides

For liquid effluents, the MEI dose to a member of the public from consumption of fish, drinking water, and participation in other water uses from the Clinch River would not be expected to change for all alternatives. For liquid effluents, the MEI dose to a member of the public would be approximately 0.006 mrem per year (DOE 2008). Statistically, an annual dose of 0.006 mrem would result in a latent cancer fatality (LCF) risk of 4.0×10^{-9}. The committed collective EDE to the population residing within a 50-mile radius of ORR from liquid effluents would be about 6.3 person-rem per year (DOE 2008). Statistically, a dose of 6.3 person-rem would result in 0.004 LCFs annually.

D.6 HAZARDOUS CHEMICAL IMPACTS TO HUMAN HEALTH

D.6.1 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.6.1.1 *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 sub-chronic) 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.

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.6.1.2 *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 animals studies are a set of guidelines that serve as the basis for the development of noncarcinogenic toxicity values.

D.6.1.3 *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.

D.6.2 How Does DOE Regulate Chemical Exposures?

D.6.2.1 *Environmental Protection Standards*

DOE Order 450.1 requires implementation of sound stewardship practices that are protective of the air, water, land, and other natural and cultural resources impacted by the DOE operations and by which DOE cost-effectively meets or exceeds compliance with applicable environmental; public health; and resource protection laws, regulations, executive orders, and DOE requirements. The objective is accomplished by implementing Environmental Management Systems (EMSs) at DOE sites. An EMS is a continuing cycle of planning, implementing, evaluating, and improving processes and actions undertaken to achieve environmental goals. Applicable Federal and state environmental acts/agreements include:

- *Resource Conservation and Recovery Act* (RCRA)
- *Comprehensive Environmental Response, Compensation, and Liability Act* (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.6.2.2 *Regulated Occupational Exposure Limits*

Occupational limits for hazardous chemicals are regulated by DOE by the adoption and imposition of certain Occupational Safety and Health Act regulations. The permissible exposure limits (PELs) represent the legal concentration levels, according to the Occupational Health and Safety Administration (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.7 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.7.1 Department of Energy Regulation of Worker Safety

10 CFR Part 851, *Worker Safety and Health Program*, 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 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 Part 1910 and 29 CFR Part 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.7.2 Y-12 Injury/Illness Rates

The Y-12 worker non-fatal injury/illness rates for Federal, Management and Operating (M&O) contractor, site security, and subcontractor personnel were used to calculate the 4-year average (2005–2008) injury/illness rate per 100 workers (or 200,000 hours). These 4-year averages are expressed in terms of Total Recordable Cases (TRCs) and Days Away, Restricted or on Job Transfer (DART) (formerly Lost Workdays (LWDs)). At Y-12, from 2005 through 2008, there was an average of almost 116 TRCs and 3,571 DARTs each year (DOE 2009a). Dividing the TRCs each year by the total number hours worked and then multiplying by 200,000, the TRC Rate (TRCR) was obtained for each year and then the average TRCR was derived for the 4-year period. The average TRCR for Y-12 is 2.02; which means that 2.02 TRCs may be expected per 100 workers each year. Using a similar calculation for DARTs, the average DART Rate for Y-12 from 2005 through 2008 is 63.18 per 100 workers each year.

The 4-year average injury/illness rate was used to calculate the total number of Y-12 worker non-fatal injury/illness per year, assuming the 4-year average rate would remain constant. Table D.7.2-1 presents the recordable cases of injuries that would be expected for the entire Y-12 workforce under each of the alternatives during operations.

During the 4-year averaging period there were no fatalities at Y-12, although there was one fatality reported for Oak Ridge Operations, which includes Y-12 (DOE 2009a). So, while the calculated annual fatality rate per 100 workers at Y-12 is zero, the calculated rate for Oak Ridge Operations is 0.00035 fatalities per year per 100 workers. Because there is always the potential for a worker fatality, Table D.7.2-1 shows less than one worker fatality per year.

Table D.7.2-1. Annual Calculated Nonfatal TRCs and DARTs for the Y-12 Workforce During Operations.

	No Action Alternative	UPF Alternative	Upgrade in-Place Alternative	Capability-sized UPF Alternative	No Net Production/ Capability-sized UPF Alternative
Number of Workers	6,500	5,950	6,500	3,900	3,400
Total Recordable Cases	131	120	131	79	69
DART	4,107	3,759	4,107	2,464	2,148
Fatalities	<1	<1	<1	<1	<1

During construction, the UPF would have the highest potential for occupational injuries due to the fact that the UPF would require the greatest construction workforce. For the total construction duration, approximately 2,900 worker-years would be required to construct the UPF. The TRCR for construction in the state of Tennessee during 2007 was 5.2 and the DART rate was 2.7 (BLS 2009). The worker fatality rate for construction in Tennessee during 2007 was 10.5 per 100,000 workers (BLS 2009a); that would be equivalent to 0.011 fatalities per 100 workers. Table D.7.2-2 presents the TRC, DART, and worker fatality rates that would be expected based on statewide statistics during construction based on the largest applicable workforce for each alternative. It should be noted that the worker fatality record for Y-12 for construction is significantly better than for the state as a whole, given that there have been no construction-related fatalities during construction of the HEUMF.

Table D.7.2-2. Annual Calculated Nonfatal TRCs and DARTs for the Y-12 Construction Workforce.

	No Action Alternative	UPF Alternative	Upgrade in-Place Alternative	Capability-sized UPF Alternative	No Net Production/ Capability-sized UPF Alternative
Number of Workers	0	950	300	850	850
Total Recordable Cases[a]	0	49	16	44	44
DART[a]	0	26	8	23	23
Fatalities[a]	0	0.105	0.033	0.093	0.093

[a] TRC, DART, and fatalities rates for construction in the state of Tennessee in 2007 were 5.2, 2.7, and 0.011, respectively (BLS 2009, BLS 2009a).

D.8 EPIDEMIOLOGIC STUDIES

Several epidemiologic studies have been completed on Y-12 workers to evaluate potential health effects from radiation and chemical exposures. Y-12 workers have also been included in many site-wide Oak Ridge Operations (ORO) health studies. In addition to these reviews, community-wide health patterns have been studied in Anderson and Roane counties. A synopsis of many of these studies is presented in this section.

D.8.1 Background

Epidemiology is the study of the distribution and determinants of disease in a population. In epidemiologic studies, the distribution of disease is considered in relation to time, place, and person. Populations may be characterized by age, race, and gender distributions, as well as by social characteristics related to health (e.g., income and education), occupation, susceptibility to disease, and exposure to specific agents. Determinants of disease include the causes of disease, and factors that influence the risk of disease. Epidemiologic studies often lead to an understanding of the causes of disease.

The study of the health effects associated with ionizing radiation was first published in the 1930s to evaluate the incidence of cancer among painters who had used radium to paint watch dials from 1910 to 1920. The research and manufacture of nuclear weapons and subsequent radiation exposure occurred beginning in the late 1930s. Since that time, because of the concern with potential adverse health effects, numerous epidemiologic studies have been conducted among workers involved in the manufacture and testing of nuclear weapons. More recently, concerns about the effects of radiological contaminants on public health have resulted in health studies among communities that surround DOE facilities.

D.8.2 Types of Epidemiologic Studies

Ecological Studies. Ecological studies compare associations between people living in geographical areas with disease frequency. A group of people, rather than the individual, is the unit of comparison. Groups can be chosen by neighborhood, city, county, or region where demographic information and incidence and mortality data are available. The differences in the rates of disease between geographical areas can be correlated to certain distinct factors, such as the proximity to a paper factory. An example of an ecological study is the comparison of lung cancer mortality rates among communities with respect to distance from chemical industries.

The major disadvantage of ecological studies is that the measure of exposure is based on the average level of exposure in the community, when what is really of interest is each individual's exposure. Ecological studies do not take into account other factors such as age, race, and individual behaviors that may also be related to disease. As such, these types of studies may lead to incorrect conclusions. For example, the cause of lung cancer in the example above may be explained by a higher percentage of cigarette smoking among individuals in a community with the chemical industries rather than the industrial pollutants themselves. These incorrect conclusions are called an "ecologic fallacy." Due to these limitations, ecological studies are helpful only as initial steps in an investigation to determine the cause of disease.

Cohort Studies. Cohort studies include an identified population that can be classified as being exposed or not exposed to an agent of interest. Occupational studies fit well with a cohort study because workers have an individual work history which can provide the data on exposure for the pattern of disease (or mortality) of interest. Characterization of the exposure may be qualitative (e.g., high, low, or no exposure) or very quantitative (e.g., chemicals in milligrams per cubic meter [mg/m^3]). Job titles and area measurements are often used to estimate exposure in the absence of personal data.

In the cohort study, individuals are tracked for a period of time, and cause of death recorded. In general, overall rates of death and cause-specific rates of death have been assessed for workers at Y-12, and data sources are available from the DOE Comprehensive Epidemiologic Data Resource (CEDR) Program (CEDR 2000). Death rates for the exposed population are compared with death rates of workers who did not have the exposure (internal comparison), or they are compared with expected death rates based on the U.S. population or state death rates (external comparison). If the death rates vary from what is expected, an association is said to exist between the disease and exposure.

Most cohort studies at Y-12 have been historical cohort studies or studies of past exposures. This type of study can be a problem if the exposure records are incomplete. Y-12 studies often have used internal and external estimates of radiation exposure by job classification to approximate missing exposure data. Cohort studies require extremely large populations and are expensive to conduct. While they are not appropriate for studying rare diseases, they may, however, provide a direct estimate of the risk of death from a specific disease and allow an investigator to evaluate many disease end points.

Case-Control Studies. Case-control studies begin with the identification of individuals with a disease (cases) and match them with individuals without the disease (controls). The choice of controls is important because they must be individuals who are at risk for the disease and are representative of the population that generated the cases. Cases and controls are then compared by the proportion of individuals exposed to the agent of interest. Case-control studies are also called “retrospective studies” because they start with people with the disease and look back in their history for exposure. These studies are well suited for rare disease and are generally used to examine the relationship between a specific disease and exposure.

D.8.3 Community Health Studies

A number of health studies have been conducted in the city of Oak Ridge and its surrounding communities, particularly the Scarboro Community, located approximately 2 miles from Y-12. In the fall of 1998, the Joint Center for Political and Economic Studies, a policy research institution, was tasked by DOE to help the Scarboro residents interpret some of these health studies. The Center reviewed the following studies:

- Oak Ridge Health Agreement Steering Panel Study on the health effects of ORR pollutants
- Oak Ridge Reservation Annual Site Environmental Report, 1998
- Scarboro Community Environmental Study
- Analysis of Respiratory Illnesses Among Children in the Scarboro Community

The Joint Center completed the work in October 2000 with the issuance of five summary publications. While these summaries generated no new epidemiological analyses, they served to help the community understand the purpose and results of the studies.

D.8.4 Oak Ridge Health Studies

The State of Tennessee and DOE signed an agreement in July 1991, allowing the Tennessee Department of Health to sponsor the Oak Ridge Health Studies. An independent group was formed to identify the important historical materials and emission sources from the Oak Ridge sites and to identify any adverse health effects caused by these materials to the surrounding communities. To provide direction and to ensure the independence of the studies, the Oak Ridge Health Agreement Steering Panel was formed, including a panel of experts and local citizens. Project oversight was provided through the Tennessee Department of Health.

A dose reconstruction feasibility study (Phase I) was initiated in 1992 and the contract was awarded to ChemRisk by the State of Tennessee. They reviewed documents and concluded that there was enough information available to reconstruct past releases and offsite doses caused by radioactive and hazardous materials. They also indicated that potential harm to the surrounding population may have occurred from releases of the following contaminants: (1) mercury releases from Y-12, (2) PCBs from all sites, (3) radioactive iodine from ORNL, and (4) radionuclide releases from ORNL. A full-dose, in-depth reconstruction study was initiated in 1994 to investigate these priority contaminants, the quantity released to the environment, and the potential adverse effects to the health of the surrounding population. The Steering Panel added further study of uranium releases because of the historical role of Oak Ridge's uranium work. The mercury, PCB, and uranium investigations are included in this document, since they are relevant to Y-12.

Mercury Health Studies. The Health Studies' investigators reported that the past estimated mercury releases for Y-12 were too low. According to the researchers' estimates, Y-12 released about 70,000 pounds of mercury into the atmosphere from vents and 280,000 pounds into the EFPC between 1950 and 1982. The total of these, about 350,000 pounds, exceeded by about 60,000 pounds previously published estimate by DOE's 1980s Mercury Task Force. The investigators evaluated the toxic effects from elemental mercury, inorganic mercury and organic mercury. The concluded that the greatest potential health risk from the elemental mercury releases was to children in the Scarboro community, living one-half mile from Y-12, and to farm residents along EFPC who may have inhaled enough to cause damage to the central nervous system between 1953 and 1959. The hazard from organic mercury, specifically methyl mercury, was estimated to be most toxic to people who ate large amounts of fish from Poplar Creek, the Clinch River, or Watts Bar Lake during this period. Pregnant women who ate fish from these sources between the late 1950s and early 1960s risked brain damage to their fetuses. They estimated that the number of fetuses exposed at a potentially toxic level was likely nearer to 100 than 1,000.

PCB Health Studies. The Health Studies reported that the estimates of PCB releases from ORR were difficult to quantify since PCBs were not considered hazardous prior to the early 1970s, so releases were not monitored. In 1977, the manufacture of PCBs was banned in the United States. People eating fish from the Clinch River were reported as being at the greatest risk for illness from the PCB releases from ORR. The report cited the Y-12 releases into EFPC on the east side of the plant as being of particular concern since the creek flows directly through the Oak Ridge community after leaving the plant. The researchers concluded that some fishermen at the Clinch

River and Watts Bar Reservoir have eaten enough fish from these sources to affect their health, but estimates of how many have been affected are not possible at this time. The investigators estimated that fewer than three excess cancers have been caused by PCBs from ORR. They recommend further studies of fish and turtle consumption, PCB blood levels in people consuming fish, PCB levels in core samples from the Clinch River and the Watts Bar Reservoir, PCB levels in the soils near EFPC, and PCB levels in cattle grazing near the creek.

Uranium Health Studies. The Health Studies investigators reported that the DOE reports of uranium releases have been understated. The study estimates Y-12 released about 50,000 kg of uranium to the air from 1944 to 1995, more than seven times the 6,535 kg previously acknowledged by DOE. Using the new data, the investigators calculated health risks to nearby residents, using a conservative screening method so as not to underestimate the risks. The new risk for cancer for residents included residents of the Scarboro community. The analyses reported career screening indexes that were slightly lower than the investigator’s decision guide for carcinogens, but with a great deal of uncertainty. In response to this information, investigators have recommended a more extensive screening of uranium on ORR.

D.8.5 Agency for Toxic Substances and Disease Registry PCB Studies

The Agency for Toxic Substances and Disease Registry (ATSDR) is a governmental agency established to conduct public health assessments of Federal facilities and to carry out any needed follow-up health activities. These activities include health studies, registries, medical monitoring, and health education. To help characterize environmental contamination in the Oak Ridge area, ATSDR screened more than 500 persons for PCB and blood mercury levels in September 1997. Blood samples were obtained from 116 persons who met the criteria and volunteered, including 13 residents of the Scarboro community. Participants were interviewed, and blood samples were obtained for PCBs and mercury in the blood. The study found the participants had PCB levels and blood mercury levels comparable to levels found in the general population. Only 5 (4 percent) of the persons tested had elevated PCB levels (> 20 μg per cubic meter). Four of the five had PCB levels between 20 and 30 μg per cubic meter and one had a serum PCB level of 103.8 μg per cubic meter, which is higher than levels generally found. As for blood mercury, only one individual had their total blood mercury greater than 10 μg per cubic meter, which is considered elevated. The remaining participants had total blood mercury levels similar to the general population.

D.8.6 Cancer Mortalities in Children

In response to a British study reporting increased leukemia and lymphoma in children living near nuclear plants in the United Kingdom, the National Cancer Institute (NCI) initiated a study of cancer mortality in the areas surrounding U.S. nuclear facilities (Jablon et al. 1991) cancer deaths were compared in counties surrounding nuclear facilities with control counties from the same region. They also compared cancer deaths before start-up of the nuclear facility with cancer deaths after start-up. The study areas included nine DOE facilities, including Oak Ridge Operations, 52 commercial nuclear electric plants, and one former commercial fuel reprocessing plant. Anderson County and Roane County were included in the review and were compared locally to Blount, Bradley, Coffee, Jefferson, and Hamblen counties in Tennessee, and

Henderson County in North Carolina. Three comparison counties were matched with each county studies. For childhood leukemia, when compared to the control counties, there were fewer leukemia deaths after start-up than before. For the DOE facilities, operations began before the study time period, the year 1950, but there was no facility with significantly elevated childhood leukemia mortality. The same results were obtained for mortality due to leukemia for all ages. The relative risk (in this study, the comparison of ratios of the standardized mortality ratios (SMRs) for the study and control counties) for the DOE sites for mortality due to all types of cancer, except leukemia, were significantly high (1.04) after start-up but smaller than the rate-ratio before start-up (1.06). The study did report a significant increased incidence of childhood leukemia for one commercial site, but it predated the start-up of the nuclear facility. The authors concluded that the results do not prove the absence of an effect, but if an effect is present, it is too small to be observed by these methods.

Tennessee Medical Management, Inc. compared Tennessee, Oak Ridge, Anderson County, and Roane County cancer mortality and incidence data with the expected deaths and incidence rates for the U.S. for 1990 and for the interval 1988 through 1990. Actual deaths in Oak Ridge, as well as cancer deaths, were fewer than expected. Anderson County deaths from all causes and cancer deaths were equivalent to expected rates, as were Roane County deaths. The study also compared new cancer cases. Anderson County showed a higher incidence of lung and bronchial cancer than expected, and fewer than expected leukemias, stomach and small intestine cancers, and colon cancers.

D.8.7 Site-wide Studies of Oak Ridge Workers

D.8.7.1 *Mortality of Nuclear Workers in Oak Ridge*

A 1997 report, titled *A Mortality Study of Employees of the Nuclear Industry in Oak Ridge, Tennessee* (Frome et al. 1997), expanded on an earlier study of the health of workers employed at the nuclear plants in Oak Ridge. The previous study had only included white males employed exclusively at ORNL and had excluded workers moving between plants. This study included 106,020 workers, employed for at least 30 days at any of the Oak Ridge nuclear facilities between 1943 and 1984 whose records were without critical errors (e.g., unknown sex, race, date of birth, or employment dates). The objectives of the expanded study were to include individuals omitted from the earlier study to compare the mortality patterns of workers among the Oak Ridge facilities, to address errors of redundancy when workers employed at more than one facility were included in the analysis, and to conduct dose-response analyses for workers exposed to external radiation. The most significant excess cancer mortality associated with external radiation was found in lung cancer for white males, with an SMR of 1.18 (1,849 deaths). An SMR of 1.12 (1,568 deaths) was reported for nonmalignant respiratory disease. The study reported a strong socioeconomic effect with the lung cancer results, and baseline rates were higher for Y-12 workers and workers employed at more than one facility. The authors acknowledged that information on cigarette smoking for this cohort of workers was not available for analysis and may have been a confounder.

D.8.7.2 *Lung Cancer Mortality Study*

A case-control study (Dupree et al. 1995) of 787 lung cancer deaths from four uranium processing operations, including Y-12, Fernald Feed Materials and Production Center, and the Mallinckrodt Chemical Works, was conducted to investigate the relationship between lung cancer and uranium dust exposure. The cases consisted of workers who were employed in the facilities for at least 183 days, died before January 1, 1983, and had lung cancer listed anywhere on the death certificate. Each case was matched with a control by facility, race, gender, and birth and hire dates within 3 years. Included in the history of the cohort was information on smoking, first pay code (to estimate socioeconomic status), complete work histories, and occupational radiation monitoring records. Annual radiation dose to the lungs from deposited uranium was estimated for each individual and annual external dose was determined for workers who had dosimetry measurements available. Smoking (ever/never used tobacco) and pay code (monthly/ nonmonthly) were potential confounders considered in the analysis. The odds ratios for lung cancer mortality for seven cumulative internal dose groups did not demonstrate increasing risk with increasing dose. An odds ratio of 2.0 was estimated for those exposed to 25 rads or more, but the 95 percent confidence interval of -.20 to 20 exhibited great uncertainty in the estimate. The study also suggested workers hired at age 45 years or older showed an exposure effect.

D.8.8 Y-12 Worker-Specific Studies

D.8.8.1 *Y-12 Worker Cohort Study*

Polednak and Frome reported a study of 18,869 white male workers employed at Y-12 between 1943 and 1947 and followed through 1974. The cohort included workers exposed to internal (alpha) and external (beta) radiation through the inhalation of uranium dusts, electrical workers who performed maintenance in the exposure areas, and other workers who were not exposed. The study did not include personnel monitoring for exposures to uranium dust, but inferred monitoring results were matched with the work area and job. The SMR for lung cancer was elevated among workers employed for 1 year or more compared with workers employed less than 1 year and was more pronounced in workers hired at 45 years of age or older (SMR - 1.51; 95 percent CI 1.01-2.31). Among the workers employed after the age of 44, the SMR for lung cancer was greatest for electrical workers (SMR - 1.55, 7 observed), alpha chemistry workers (SMR - 3.02, 7 observed), and beta process workers (SMR - 1.51, 11 observed). SMRs were also elevated for mental psychoneurotic, personality disorders (SMR - 1.36, 36 observed), emphysema (SMR - 1.16, 100 observed), diseases of the bones and organs of movement (SMR - 1.22, 11 observed), and external causes of death (SMR - 1.09, 623 observed).

D.8.8.2 *Cancer Mortality Among Y-12 Rad Workers*

In 1988, a study was conducted of Y-12 white male workers employed for at least 30 days from 1947 to 1979 (Checkoway et al. 1988). The study included exposures to alpha and gamma radiation from insoluble uranium compounds. A statistically significant increase in deaths from lung cancer (SMR-1.36, 89 observed; 95 percent CI -1.09-1.67) was observed when compared with the U.S. lung cancer rates, but not when compared with Tennessee lung cancer rates (SMR-1.18, 95 percent CI - 0.95-1.45). Positive dose-response trends were seen for lung cancer mortality with respect to cumulative alpha and gamma radiation, with the most notable trend occurring for gamma radiation among workers who received greater than or equal to 5 rem of alpha radiation. When a 10-year latency assumption was applied, these trends diminished. The authors noted the observed dose-response trends, while based only on small numbers, point to a potential carcinogenic effect to the lung from relatively low-dose radiation. In addition, nonstatistically significant increases were observed for all cancers (SMR - 1.01, 196 observed), diseases of the blood-forming organs (SMR - 1.48, 3 observed), kidney cancer (SMR - 1.22, 6 observed), and other lymphatic cancers (SMR -1.86, 9 observed). Brain and central nervous system cancer mortality was also higher than expected, but without a dose-response trend.

D.8.8.3 *Cancer Mortality Among Minority Rad Workers*

Loomis and Wolf updated the Checkoway study to include the years through 1990 and to include African-American and white female workers and men of other races (Loomis and Wolf 1996). The exposures for the cohort included low dose, internal, alpha radiation and external, penetrating radiation plus beryllium, mercury, solvents, and other industrial compounds. The authors reported a low total mortality for all Y-12 workers and a total cancer mortality as expected. For the entire cohort, nonstatistically significant excesses were observed for pancreatic cancer (SMR - 1.36, 34 observed), skin cancer (SMR - 1.07, 11 observed), breast cancer (females only, SMR - 1.21, 11 observed), prostate cancer (SMR - 1.31, 36 observed), kidney cancer (SMR - 1.30, 16 observed), brain cancer (SMR -1.29, 20 observed), cancers of other lymphatic tissues (SMR - 1.32, 22 observed), and diseases of the blood-forming organs (SMR-1.23, 6 observed). The lung cancer mortality was statistically significant (SMR - 1.17, 202 observed; 95 percent CI 1.01-1.34), especially for white males (SMR - 1.20, 194 observed; 95 percent CI - 1.04-1.38). The lung cancer excess was greatest among those workers hired prior to 1954 (SMR - 1.27, 161 observed), with 5 to 20 years of employment and with 10 to 30. Another finding was evidence of excess breast cancer mortality among the 1,073 female workers (SMR 1.21; 95 percent CI - 0.60-2.17). The authors suggested more work needed to be done on lung cancer mortality due to radiation exposure and to the potential link between beryllium and lung cancer.

D.8.9 Health Effects of Mercury Exposure

A study of mortality patterns of all workers employed at least 5 months at Y-12 between January 1, 1953, and April 30, 1958 was published in 1984 (Cragle et al. 1984). Mercury was used during this timeframe to produce enriched lithium. The group was divided into mercury-exposed and nonmercury-exposed by results of urinalysis supplied by the site. Vital status follow-up was complete through the end of 1978 and SMRs were calculated. There were no differences in mortality patterns for the mercury-exposed, when compared to the nonmercury exposed. Excesses of lung cancer mortality were observed in both groups of workers and were not related to the mercury exposure (exposed SMR=1.34; 42 observed, 31.36 expected; nonexposed SMR=1.34, 71 observed, 52.9 expected). The authors stated that mortality is not the optimal end point to assess mercury-related health effects.

Another study of mercury workers (Albers et al. 1988) assessed neurological function and mercury exposure. The clinical study examined 502 Y-12 workers, 247 of whom worked in the mercury process 20 to 35 years prior to the examination. Several correlations between increasing mercury exposure and declining neurological function were discovered. An exposure assessment was determined for each mercury worker during the time of employment in the mercury process. Workers with at least one urinalysis equal to or greater than 0.6 mg/L of mercury showed decreased strength, coordination, and sensation along with increased tremor and prevalence of Babinski and snout reflexes when compared to the 255 non-exposed workers. Clinical polyneuropathy was associated with the level of the highest exposure but not with the duration of exposure.

D.8.10 Ongoing Studies of Y-12 Workers and the Community

DOE, along with U.S. Department of Health and Human Services, has published a *Draft Agenda for Public Health Activities for Fiscal Years 1999 and 2000 at U.S. Department of Energy Sites* (DOE 1999a). Included in this report are several ongoing occupational health studies dealing with Y-12.

Public Health Assessment. The ATSDR is involved in an ongoing study of the public health impact from releases of hazardous materials from ORR. This assessment will help identify and characterize both the current and past exposures of offsite populations to radiologic and chemical contaminants. Morbidity and mortality data to identify increased rates of health outcomes associated with these materials are also included in this study.

DOE Beryllium Worker Medical Surveillance Program. Y-12 beryllium workers are included in the DOE Beryllium Worker Medical Surveillance Program currently under way to detect and diagnose chronic beryllium disease. Information from this program is being used to evaluate worker protection and control measures, to monitor trends in chronic beryllium disease frequency, and to strengthen work planning to minimize worker exposures. A communication effort to educate workers about chronic beryllium disease is included.

DOE's Former Worker Program. Under DOE's Former Worker Program, Dr. Eula Bingham of the University of Cincinnati, in cooperation with the United Brotherhood of Carpenters Health and Safety Fund and several other groups, is directing the Former Construction Workers Project. Phase I of the project has identified approximately 800 former construction workers. Phase II will focus on medical screening of workers exposed to asbestos, beryllium, noise, silica, solvents, and heavy metals.

Mortality Among Female Nuclear Weapons Workers. NIOSH is sponsoring the State University of New York in a study of mortality among female nuclear weapons workers. This includes female workers from 12 DOE sites and will be the largest study of mortality among the 80,000 females employed by DOE. Risk estimates will be developed for exposure to ionizing radiation and chemical hazards.

Lung Cancer and Leukemia Case-Control Studies. NIOSH has two ongoing case-control studies combining multiple DOE sites, including Oak Ridge, to answer specific cancer questions. One study is attempting to define the relationship between lung cancer and external radiation exposure. The second study, the largest of its kind, is exploring the relationship between external radiation and leukemia risk among 250 workers with leukemia compared to similar workers without leukemia.

Chemical Laboratory Workers Mortality Study. NIOSH has an ongoing cohort mortality study assessing potential worker exposures to groups of chemicals and ionizing radiation and their relationship to mortality patterns. This is in response to other studies, outside DOE, indicating an increased risk of cancers among chemical laboratory workers.

D.9 FACILITY RADIOLOGICAL ACCIDENT SCENARIOS

This section presents the estimated consequences of accidents that could occur at Y-12 as required by the *National Environmental Policy Act* (NEPA). The scenarios described here define the bounding envelope of accidents—that is, any other reasonably foreseeable accident at Y-12 would be expected to have similar or smaller consequences. These accident analyses are conservative, with little or no credit taken for existing preventative and mitigating features in each building or operation analyzed or the safety procedures that are mandatory at Y-12.

This section describes how locations or operations were selected for analysis, the computer codes used to estimate consequences, the development of the scenarios and assumptions about source terms, the selection of computer modeling and a description of the results, and predicted health effects.

D.9.1 Approach to the Analysis of Potential Accidents

D.9.1.1 *Overview*

Accident scenarios have been developed to reflect the broad range of accidents that might occur at Y-12. The scenarios are specific to particular buildings and operations. The following terms are used to define the scenarios:

- A reasonably foreseeable accident could include an accident with "impacts which have catastrophic consequences, even if their probability of occurrence is low, provided that the analysis of the impacts is supported by credible scientific evidence, is not based on pure conjecture, and is within the rule of reason" (40 CFR 1502.22). "Credible" means having reasonable grounds for believability, and the "rule of reason" means that the analysis is based on scientifically sound judgment.
- An accident is bounding if no reasonably foreseeable accident with greater consequences can be identified. A bounding envelope is a set of individual bounding accidents covering the range of probabilities and possible consequences.

A deterministic, nonprobabilistic approach was used to develop the accident scenarios, including those scenarios without a specific initiating cause. The wide range of postulated accidents characterizes the range of impacts associated with the operation of Y-12. The postulated accident scenario for radioactive material can be reasonably evaluated in terms of the effective dose equivalent, and from this, the bounding scenario can be determined.

D.9.1.2 *Selection of Buildings and Operations for Accident Scenarios*

Developing accident scenarios began with reviewing the all Y-12 facilities with emphasis on building hazard classification and radionuclide inventories (including type, quantity, and physical form) and storage and use conditions. First, administrative buildings without radioactive materials were excluded. Then, buildings ranked as low hazard and those without radioactive materials were eliminated from consideration. The potential offsite consequences of facilities screened out would be well bounded by Y-12's bounding accident scenarios.

The next step in the selection process was to identify the most current documentation describing/quantifying the hazards associated with each facility's operation. Current safety documentation, which is either classified or contains Unclassified Controlled Nuclear Information that is not releasable to the general public, was obtained for these facilities, and reviewed to determine a reasonable range of bounding accidents for Y-12. These documents included the following:

- Safety Analysis Report for the 9215 Complex, Y/MA-7886, Rev. 4, Effective 12/08/2005
- Safety Analysis Report for the 9204-2E Facility, Y/SAR-003, Rev. 4, Effective 12/01/2005
- Safety Analysis Report for the 9204-2 Facility, Y/SM-SAR-005, Rev. 4, Effective 12/20/2005
- Safety Analysis Report for the 9204-4 Facility, Y/SAR-004, Rev. 4, Effective 02/24/2005
- Safety Analysis Report for the Nuclear Material Safeguarded Shipping and Storage Facility, Y/SAR-10, Rev. 5, Effective 12/21/2005
- Preliminary Documented Safety Analysis for the Highly Enriched Uranium Materials Facility, Y/HEU-0091 Rev. 0, 08/17/04
- Basis for Interim Operation for the Enriched Uranium Operations Complex, Y/MA-7254, Rev. 18, Effective 09/23/2004
- Safety Analysis Report for 9212 Complex, Y/MA-7926, Rev. 1, 11/18/05 (Approved not yet effective)
- Safety Analysis Report for Building 9995, Y/ENG/SAR-79, Rev. 4, 05/20/2005, Effective 06/22/2005
- Safety Analysis Report for Building 9201-5/5E, Y/NA-1836, Rev. 3, 05/16/2005, Effective 06/30/2005
- Safety Analysis Report for Buildings 9201-5N/5W, Y/NA-1839, Rev. 3, 05/16/2005, Effective 06/30/2005

Section D.9.3 uses unclassified and publicly-releasable data derived from these safety documents to define the accident scenarios for each facility. Section D.9.4 presents the impacts from these accidents.

In developing the accident analyses for this SWEIS, malevolent acts (theft, sabotage, terrorism) were considered (see Appendix E, Section E.2.14). Although it is not possible to predict whether intentional attacks would occur at Y-12, or the nature of the types of attacks that might be made, NNSA has evaluated scenarios involving malevolent, terrorist, or intentionally destructive acts at Y-12 in an effort to assess potential vulnerabilities and identify improvements to security procedures and response measures in the aftermath of the attacks of September 11, 2001. Those evaluations are classified. Security at NNSA facilities is a critical priority for the NNSA, and NNSA continues to identify and implement measures designed to defend against and deter attacks at its facilities.

In this appendix, NNSA also considers the impacts of a non-malevolent, non-intentional aircraft crash into Y-12 facilities. [Note: this aircraft crash is separate from a malevolent, intentionally destructive act with an aircraft, which was considered in the deliberate scenarios discussed above]. This analysis considered the potential for aircraft crashes involving all types of aircraft, including general aviation, air carriers, air taxis, and military aircraft. Of these categories, the probability that an air carrier, air taxi, or military aircraft could crash into a Y-12 facility is so low (less than 1×10^{-7} chance of occurring annually) as to not be considered as a credible accident scenario. Therefore, aircraft crashes at Y-12 involving aircraft other than general aviation were not considered reasonably foreseeable. Therefore, the aircraft crash accident scenarios discussed in this appendix are for general aviation aircraft.

General aviation includes the subcategories of single-engine piston, multiengine aircraft, and helicopter aircraft. Helicopter velocities are generally lower than that of fixed-wing aircraft and single-engine aircraft engines are generally heavier than multiengine aircraft engines for equivalent performance. Therefore, the consequences of a large single-engine piston aircraft impacting facilities at the Y-12 site bound the reasonably foreseeable accidents into Y-12 facilities.

The frequency evaluation for an aircraft crash uses a formula which considers the following factors:

1. The number of operations (N)
2. The probability that the plane will crash (P)
3. Given a crash, the probability that it will occur in a 1-square-mile area where the facility is located (f)
4. The effective area of the facility (A)

Site-specific values for each of these factors were determined and used to derive the frequency values listed in Table D.9.3-1.

D.9.2 Consequence Analysis

Y-12 uses radioactive materials in a wide variety of operations including scientific research and development, machining and inspection, chemical processing, analytical chemistry metallurgy, weapon component processing, and as calibration and irradiation sources. Radioactive materials are collected as waste products in forms varying from contaminated materials and equipment to contaminated trash and liquids.

This section analyzes postulated accidents that could result in radioactive material releases. It describes how bounding scenarios were selected for analysis, discusses the computer code that was used in the analysis as well as assumptions about weather conditions and atmospheric dispersion, presents the bounding scenarios, and estimates the potential health effects.

D.9.2.1 *Atmospheric Dispersion Modeling*

Consequences of accidental radiological releases were determined using the MACCS2 computer code (Chanin and Young 1998). MACCS2 is a United States Department of Energy/Nuclear Regulatory Commission (DOE/NRC) sponsored computer code that has been widely used in support of probabilistic risk assessments for the nuclear power industry and in support of safety and NEPA documentation for facilities throughout the DOE complex.

The MACCS2 code uses three distinct modules for consequence calculations: The ATMOS module performs atmospheric transport calculations, including dispersion, deposition, and decay. The EARLY module performs exposure calculations corresponding to the period immediately following the release; this module also includes the capability to simulate evacuation from areas surrounding the release. The EARLY module exposure pathways include inhalation, cloudshine, and groundshine. The CHRONC module considers the time period following the early phase; i.e., after the plume has passed. CHRONC exposure pathways include groundshine, resuspension inhalation, and ingestion of contaminated food and water. Land use interdiction (e.g., decontamination) can be simulated in this module. Other supporting input files include a meteorological data file and a site data file containing distributions of the population and agriculture surrounding the release site.

Because of assumptions used in this SWEIS analysis, not all of the code’s capabilities were used. It was conservatively assumed that no special actions would be taken to avoid or mitigate exposure to the general population following an accidental release of radionuclides. For example, there would be no evacuation or protection of the surrounding population nor would there be interdiction to prevent ingestion of food grown downwind of the release.

Ten radial rings and 16 uniform direction sectors were used to calculate the collective dose to the offsite population. The radial rings were every 1 mile to 5 miles, a ring at 10 miles, and every 10 miles, from 10 to 50 miles starting at the distribution center. Due to the small expanse of the Y-12 site, a single center of distribution, located at the Y-12 West meteorological tower was used to represent all releases. The location of the offsite MEI was assumed to be along the emergency response boundary (ERB) or, for elevated or buoyant releases, at the point of greatest offsite consequence. In practice, all elevated or buoyant release MEIs were in fact located at the ERB. Similarly, the noninvolved onsite worker location was taken as 100 meters from the release in any direction.

Population and individual doses were statistically sampled by assuming an equally likely accident start time during any hour of the year. All hours were sampled. The results from each of these samples were then sorted to obtain a distribution of results (radiation dose), from which the results were extracted and presented in this Y-12 SWEIS.

MEI and noninvolved worker doses were calculated using conservative assumptions, such as the wind blowing toward the MEI and locating the receptor along the plume centerline. The doses (50-year committed effective dose equivalent) were converted into LCFs using the factor of 6×10^{-4} LCFs per person-rem for both members of the public and workers (DOE 2002d); calculated LCFs were doubled for individual doses greater than 20 rem (NCRP 1993a). The MEI and non-involved worker are assumed to be exposed for the duration of the release; they or DOE would take protective or mitigative actions thereafter if required by the size of the release. Exposure to the general population continues after the release as a result of resuspension and inhalation, external exposure and ingestion of deposited radionuclides.

D.9.2.2 *Mitigation Measures*

Mitigations to exposure and therefore mitigations to dose that would affect the postulated results of the accident scenarios are discussed below. In general, no mitigation was assumed for emergency response in the consequence analysis.

Emergency Response and Protective Actions

Y-12 has detailed plans for responding to accidents of the type described here, and the response activities would be closely coordinated with those of local communities such as Alameda County. Y-12 personnel are trained and drilled in the protective actions to be taken if a release of radioactive or otherwise toxic material occurs. Refer to Appendix I for further details on Y-12 emergency planning and response information.

The underlying principle for the protective action guides (PAGs) is that under emergency conditions all reasonable measures should be taken to minimize the radiation exposure of the general public and emergency workers. In the absence of significant constraints, protective actions could be implemented when projected doses are lower than the ranges given in the PAGs. No credit was taken for emergency response and protective actions in the consequence analysis.

High Efficiency Particulate Air Filtration

In all areas where unconfined plutonium or other radioactive materials can be handled and can exist in a dispersible form, high-efficiency particulate air (HEPA) filters provide a final barrier against the inadvertent release of radioactive aerosols into the outside environment. However, these filters would not trap volatile fission products such as the noble gases and iodine; such gases would be released into the outside environment.

HEPA filter efficiencies are 99.99 percent or greater with the minimum efficiency of 99.97 percent for 0.3-micron particles, the size most easily passed by the filter. To maximize containment of particles and provide redundancy, two HEPA filters in series are used. These HEPA filters are protected by building design features against the consequences of an earthquake or fire. Credit was taken for filtration in the consequence analysis when ventilation and building containment were shown by analysis to survive during the accident.

D.9.3 Description of Accident Scenarios

From the safety documents obtained through the process described in Section D.9.1.2, the next step was to identify potential accident scenarios and source terms (release rates and frequencies) associated with those facilities. Table D.9.3–1 lists the results of this process, and contains the accident name, its frequency, and its source term. Tables D.9.3-2 and D.9.3-3 lists the source term released to the environment following a Uranium solution. Table D.9.3-4 lists the estimated direct radiation dose from an unshielded criticality accident.

Table D.9.3-1. Potential Facility Accident Scenarios.

Accident	Frequency	Source Term or Hazard	Notes/Assumptions
EU Metal Fabrication Complex			
Local fire	$10^{-2} – 10^{-4}$	N/A, No radiological consequences	
Uranium Metal Criticality	$10^{-2} – 10^{-4}$	See Table D.9.3-2 and Table D.9.3-4	$1.0×10^{18}$ fissions
Major fire	$10^{-4} – 10^{-6}$	EU = 17.9 kg (sum of metal and chips) DU = 452 kg (sum of metal and chips)	Release height = ground level Release duration = 1 hour
Aircraft Crash – Initiator for major fire	$1.5×10^{-5} – 2.2×10^{-5}$	See major fire	
Tanker Truck Accident – Initiator for major fire	$10^{-4} – 10^{-6}$	See major fire	
Earthquake	$10^{-2} – 10^{-4}$	Same as criticality	
High Winds	$10^{-2} – 10^{-4}$	Same as earthquake	
Rain/Snow	$10^{-2} – 10^{-4}$	Same as earthquake	
Assembly			
Uranium Metal Criticality	$10^{-2} – 10^{-4}$	See Table D.9.3-2 and Table D.9.3-4	$1.0×10^{18}$ fissions
Explosion	$10^{-4} – 10^{-6}$	2 kg EU (sum of metal and chips) 0.04 kg DU (sum of metal and chips)	Release height = 7.6 m Release duration =1 hour
Fire	$10^{-4} – 10^{-6}$	Same as explosion	Release height = 7.6 m Release duration = 2 hours
Earthquake	$10^{-2} – 10^{-4}$	Bounded by fire	
Wind	$10^{-1} – 10^{-2}$	None	
Flood	$10^{-2} – 10^{-4}$	None	
Aircraft crash	$\sim 2×10^{-5}$	Bounded by fire	
Manufacturing QE			
Uranium Metal Criticality	$10^{-2} – 10^{-4}$	See Table D.9.3-2 and Table D.9.3-4	$1.0×10^{18}$ fissions
Local fires	$10^{-2} – 10^{-4}$	No radiological releases	
Large Building Fire	$10^{-4} – 10^{-6}$	2.6 kg EU 54 kg DU 172 kg Th	Release height =<10 m Release duration = 1 hour
Aircraft Crash – Initiator for large building fire	$4.5×10^{-5} – 5.0×10^{-5}$	See large building fire	
Tanker Truck explosion – Initiator for large building fire	$10^{-4} – 10^{-6}$	See large building fire	
Earthquake	$10^{-2} – 10^{-4}$	Bounded by criticality	
Wind	$10^{-2} – 10^{-4}$	Bounded by criticality	
Rain/Snow	$10^{-2} – 10^{-4}$	Bounded by criticality	

Table D.9.3-1. Potential Facility Accident Scenarios (*continued*).

Accident	Frequency	Source Term or Hazard	Notes/Assumptions
EU Warehouse			
Uranium Metal Criticality	10^{-2} – 10^{-4}	See Table D.9.3-2 and Table D.9.3-4	1.0×10^{18} fissions
Fire	10^{-4} – 10^{-6}	EU = 22.6 kg DU = 20.1 kg U-233 = 0.0066 kg Th = 0.13 kg (the above all represent the sum of metals, oxides, and combustibles) Pu = 1.0×10^{-6} kg Np-237 = 1.6×10^{-5} kg	Release height = 4 m Release duration = 1 hour
Aircraft crash – Initiator of fire	1.2×10^{-5}	Same as fire	
Earthquake-induced loss of confinement	10^{-2} – 10^{-4}	EU = 1.3 kg DU = 0.06 kg Th = 0.03 kg (the above all represent the sum of metals, oxides, and combustibles)	Release height = ground level Release duration = 15 min
Wind	10^{-2} – 10^{-4}	Bounded by criticality and fire	
Flood	10^{-2} – 10^{-4}	Bounded by criticality	
Lightning	10^{-4} – 10^{-6}	Bounded by fire	
Design-basis fires[1]	10^{-2} – 10^{-4}	EU = 2.58 kg DU = 0.55 kg	Release height = 11.3 m Release duration = 1 hour
HEUMF			
Uranium Metal Criticality	10^{-2} – 10^{-4}	See Table D.9.3-2 and Table D.9.3-4	1.0×10^{18} fissions
Earthquake	10^{-2} – 10^{-4}	None	
Wind	10^{-2} – 10^{-4}	None	
Rain/Snow	10^{-2} – 10^{-4}	None	
Flood	10^{-2} – 10^{-4}	Bounded by criticality	
EU Operations			
Uranium Metal Criticality	10^{-2} – 10^{-4}	See Table D.9.3-2 and Table D.9.3-4	1.0×10^{18} fissions
Uranium Solution Criticality	10^{-2} – 10^{-4}	See Table D.9.3-3 and Table D.9.3-4	3.28×10^{18} fissions
Local fires	10^{-2} – 10^{-4}	8 kg EU (includes aqueous and organic solutions	Release height = ground level Release duration = 15 min

---

[1] The source term for a design-basis fire at the HEUMF has been identified as the bounding (largest possible) source term, and reasonably bounds the source term that might result from any aircraft crash, whether malevolent or non-malevolent.

Table D.9.3-1. Potential Facility Accident Scenarios (*continued)*.

Accident	Frequency	Source Term or Hazard	Notes/Assumptions
EU Operations (continued)			
Large fire	$10^{-4} – 10^{-6}$	14.8 kg EU (includes metals, oxides, and aqueous and organic solutions)	Release height = “roof level” Release duration = 1 hour
Explosions	$10^{-2} – 10^{-4}$	None – localized effects only	
Aircraft crash	$10^{-4} – 10^{-6}$	37.8 kg EU (includes metals, chips, oxides, and aqueous and organic solutions)	Release height = “roof level” Release duration = 15 min
Earthquake-induced fire	$10^{-2} – 10^{-4}$	Same as large fire	
Wind	$10^{-2} – 10^{-4}$	Bounded by earthquake	
Rain/Snow	$10^{-2} – 10^{-4}$	Bounded by earthquake	
Lightning	$10^{-2} – 10^{-4}$	Same as local fire	
Analytical Laboratory			
Uranium Metal Criticality	$10^{-2} – 10^{-4}$	See Table D.9.3-2 and Table D.9.3-4	1.0×10^{18} fissions
Large fire	$10^{-2} – 10^{-4}$	0.06 kg EA (includes solutions, metals, oxides, etc.)	
Aircraft crash	1.4×10^{-5}	Same as large fire	
Machine Shop Special Materials			
Large fire	$10^{-4} – 10^{-6}$	96.6 kg DU (includes metals, fines, and oxides)	Release height = ground level Release duration = 1 hour
Inadvertent water leak into furnace	$10^{-2} – 10^{-4}$	32 kg DU	Release height = ground level Release duration = “short” (assume 15 min)
Machine Shop DU/Binary			
Large fire	$10^{-4} – 10^{-6}$	31.3 kg DU (includes bulk metal, chips, and fines)	Release height = “elevated” Release duration = 1 hour
Uranium Metal Criticality	$10^{-2} – 10^{-4}$	See Table D.9.3-2 and Table D.9.3-4	1.0×10^{18} fissions
Earthquake	$10^{-2} – 10^{-4}$	Bounded by large fire	
High wind/tornado	$10^{-2} – 10^{-4}$	Bounded by large fire	
Rain/Snow	$10^{-2} – 10^{-4}$	Bounded by large fire	

Table D.9.3-2. Source Term (Ci) released to the environment following a Uranium Metal Criticality (1.0×10^{18} fissions).

Radionuclide	Half Life	Curies released
Kr-83m	1.8 hr	8.00E+00
Kr-85m	4.5 yr	7.50E+00
Kr-84	1.7 yr	8.00E-05
Kr-87	76.3 min	4.95E+01
Kr-88	2.8 hr	3.25E+01
Kr-89	3.2 min	2.10E+03
Xe-131m	11.9 day	4.10E-03
Xe-133m	2.0 day	9.00E-02
Xe-133	5.2 day	1.35E+00
Xe-135m	15.6 min	1.10E+02
Xe-135	9.1 hr	1.80E+01
Xe-137	3.8 min	2.45E+03
Xe-138	14.2 min	6.50E+02
I-131	8.1 day	4.35E-02
I-132	2.3 hr	5.50E+00
I-133	0.8 hr	8.00E-01
I-134	52.6 min	2.25E+01
I-135	6.6 hr	2.35E+00

Table D.9.3-3. Source Term (Ci) released to the environment following a Uranium Solution Criticality (3.28×10^{18} fissions).

Radionuclide	Half Life	Curies released
Kr-83m	1.8 hr	5.25E+01
Kr-85m	4.5 yr	4.92E+01
Kr-84	1.7 yr	5.25E-04
Kr-87	76.3 min	3.25E+02
Kr-88	2.8 hr	2.13E+02
Kr-89	3.2 min	1.38E+04
Xe-131m	11.9 day	2.69E-02
Xe-133m	2.0 day	5.90E-01
Xe-133	5.2 day	8.86E+00
Xe-135m	15.6 min	7.22E+02
Xe-135	9.1 hr	1.18E+02
Xe-137	3.8 min	1.61E+04
Xe-138	14.2 min	4.26E+03
I-131	8.1 day	7.13E-01
I-132	2.3 hr	9.02E+01
I-133	0.8 hr	1.31E+01
I-134	52.6 min	3.69E+02
I-135	6.6 hr	3.85E+01

Table D.9.3-4. Estimated Direct Radiation Dose from an Unshielded Criticality Accident.

Downwind Distance (m)	Direct Radiation Dose (rem)	
	Uranium metal criticality	Uranium solution criticality
100	5.7	18.6
200	0.88	2.9
300	0.25	0.81
350	0.14	0.47
400	0.088	0.29
450	0.056	0.18
500	0.036	0.12
550	0.024	0.079
600	0.016	0.053
650	0.011	0.036
700	0.0077	0.025
750	0.0054	0.018
800	0.0039	0.013
850	0.0028	0.0091
900	0.0020	0.0066
950	0.0015	0.0048
1000	0.0011	0.0036

D.9.4 Estimated Health Effects

Tables D.9.4-1 and D.9.4-2 show the frequencies and consequences of the postulated set of accidents for a noninvolved worker and the public (maximally exposed offsite individual and the general population living within 50 miles of Y-12).

Table D.9.4-1. Radiological Accident Frequency and Consequences: All Alternatives.

		Maximally Exposed Individual [a]		Offsite Population [b]		Noninvolved Worker [c]	
Accident	Frequency (per year)	Dose (rem)	Latent Cancer Fatalities	Dose (Person-rem)	Latent Cancer Fatalities	Dose (rem)	Latent Cancer Fatalities
Major fire	$10^{-4} – 10^{-6}$	0.59	0.00036	520	0.31	16.3	0.0098
Explosion	$10^{-4} – 10^{-6}$	0.058	0.000035	51.2	0.031	1.18	0.00071
Fire in UPF Warehouse	$10^{-4} – 10^{-6}$	0.69	0.00041	608	0.36	17.4	0.010
Design-basis fires for HEU Storage	$10^{-2} – 10^{-4}$	0.073	0.000044	66.1	0.04	1.08	0.00065
Aircraft crash	$10^{-4} – 10^{-6}$	0.3	0.0002	665	0.4	0.388	0.00023

Source: Tetra Tech 2008.

[a] At site boundary, approximately 1.3 miles from release.

[b] Based on a projected future population (year 2030) of approximately 1,548,207 persons residing within 50 miles of Y-12 location.

[c] At 1000 meters from release.

Table D.9.4-2. Annual Cancer Risks: All Alternatives.

Accident	Maximally Exposed Individual [a]	Offsite Population[b]	Noninvolved Worker [c]
Major fire	3.6×10^{-8}	3.1×10^{-5}	9.8×10^{-7}
Explosion	3.5×10^{-9}	3.1×10^{-6}	7.1×10^{-8}
Fire in UPF Warehouse	4.1×10^{-8}	3.6×10^{-5}	1.0×10^{-6}
Design-basis fires for HEU Storage	4.4×10^{-7}	4.0×10^{-4}	6.5×10^{-6}
Aircraft crash	2.0×10^{-8}	4.0×10^{-5}	2.3×10^{-8}

Source: Tetra Tech 2008.

[a] At site boundary, approximately 1.3 miles from release.

[b] Based on a projected future population (year 2030) of approximately 1,548,207 persons residing within 50 miles of Y-12 location.

[c] At 1000 meters from release.

The accident with the highest potential consequences to the offsite population (see Table 5.14.1-1) is the aircraft crash into the EU facilities. Approximately 0.4 LCFs in the offsite population could result from such an accident in the absence of mitigation. An offsite MEI would receive a maximum dose of 0.3 rem. Statistically, this MEI would have a $2\text{x}10^{-4}$ chance of developing a LCF, or about 1 in 5,000. This accident has a probability of occurring approximately once every 100,000 years. When probabilities are taken into account (see Table 5.14.1-2), the accident with the highest risk is the design-basis fire for HEU storage. For this accident, the maximum LCF risk to the MEI would be $4.4\text{x}10^{-7}$, or about 1 in 2 million. For the population, the LCF risk would be $4\text{x}10^{-4}$, or about 1 in 2,500.

D.9.5 Involved Worker Impacts

Workers in the facility where the accident occurs would be particularly vulnerable to the effects of the accident because of their location. For all of the accidents, there is a potential for injury or death to involved workers in the vicinity of the accident. However, prediction of latent potential health effects becomes increasingly difficult to quantify for facility workers as the distance between the accident location and the worker decreases. This is because the individual worker exposure cannot be precisely defined with respect to the presence of shielding and other protective features. The worker also may be injured or killed by physical effects of the accident itself.

The facility ventilation system would control dispersal of the airborne radiological debris from the accident. Following initiation of accident/site emergency alarms, workers would evacuate the area in accordance with site emergency operating procedures and would not be vulnerable to additional radiological injury.

The bounding case radiological accident for involved workers is a uranium solution criticality in EU Building. Severe worker exposures could occur inside the facility as a result of a criticality, due primarily to the effects of prompt neutrons and gammas. A criticality would be detected by the criticality alarm system, and an evacuation alarm would be sounded. All personnel would immediately evacuate the building.

Personnel close to the criticality event (within the building) may incur prompt external exposures. Depending on distance and the amount of intervening shielding material, lethal doses composed of neutron and gamma radiation could be delivered. The dose due to prompt gamma and neutron radiation at a distance can be evaluated by the following formulas:

$$\text{Prompt gamma dose: } D_g = 2.1 \times 10^{-20}\ N\ d^{-2}\ \exp^{-3.4d}$$

$$\text{Prompt neutron dose: } D_n = 7.0 \times 10^{-20}\ N\ d^{-2}\ \exp^{-5.2d}$$

Where:

D_g = gamma dose (rem)

D_n = neutron dose (rem) (neutron quality factor = 20)

N = number of fissions

d = distance from source (km)

At a distance of 10 meters, the combined prompt gamma and neutron radiation dose to personnel from a criticality in a powder, solution, or slurry of uranium or plutonium (3.28×10^{18} fissions) would be 2,845 rem (Dg = 665 rem plus Dn = 2,180 rem), which is greater than the average lethal radiation dose to humans of approximately 450 rem. Thus, the potential for lethal exposure exists. On average, there could be two workers in a room who could be exposed to this radiation.

In EU Building, the laboratory interior concrete walls would provide substantial shielding, except through the doors. In the event of a criticality, this shielding and rapid evacuation from the laboratories would reduce doses to personnel not in the immediate vicinity of the criticality excursion.

Direct exposure to airborne fission products produced during the criticality event would contribute only a small fraction to the total dose to a worker. Because of ventilation system operation, other personnel inside the building would not likely incur radiation dose resulting from the inhalation of airborne radioactive materials or immersion in the plume. If the ventilation system were unavailable, this dose would be small in comparison to the direct dose received at the time of the burst. The worker immediately involved would act appropriately according to training and emergency procedures.

D.9.6 Secondary Impacts

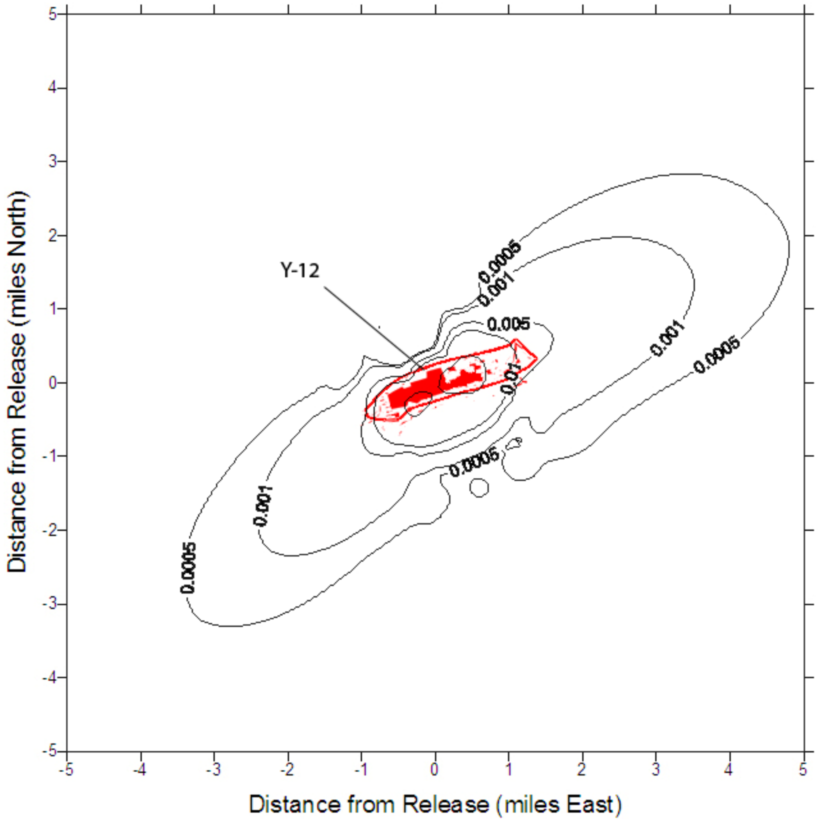
The main focus of the accident analysis has been to determine the impacts to public and worker health and safety. However, NNSA recognizes that accidents involving releases of radioactivity and chemical substances can also adversely affect the surrounding environment. For the purposes of this analysis, postulated impacts upon the environment from potential accident scenarios are referred to as "secondary impacts."

To determine the greatest impact that could occur to the environment from the postulated accidents considered in the appendix, each accident scenario was evaluated to determine potential secondary impacts. Since the main pathway for contamination from the accidents discussed above is via airborne released, NNSA expects only limited contamination of surface water or groundwater on or off site. Therefore, adverse impacts on water quality and aquatic biota from the postulation accident scenarios considered in this EIS would not be expected.

It is expected that contamination of the environment from most of the accidents postulated in this EIS would be limited to the immediate area surrounding the facility where the accident occurs. However, for some of the accident scenarios, contamination could extend off of the Y-12 site. For the accident with the largest offsite radiological consequences (aircraft crash into the EU Operations Complex), Figures D.9.6-1, D.9.6-2 and D.9.6-3 depict the dispersion plume from this accident and give an indication of the area of radiological contamination, both on and off of the Y-12 site. Figures D.9.6-1, D.9.6-2 and D.9.6-3 show mean deposition isopleths that would result if the maximum risk accident were to occur. The isopleths are presented for three scales: 0-5 miles, 0-10 miles, and 0-50 miles from the release. The depositions are compared with EPA soil Preliminary Remediation Goals (PRGs) for perspective. These PRGs are typically used as site screening tools to help determine whether CERCLA (i.e., Superfund) sites require soil remediation actions.

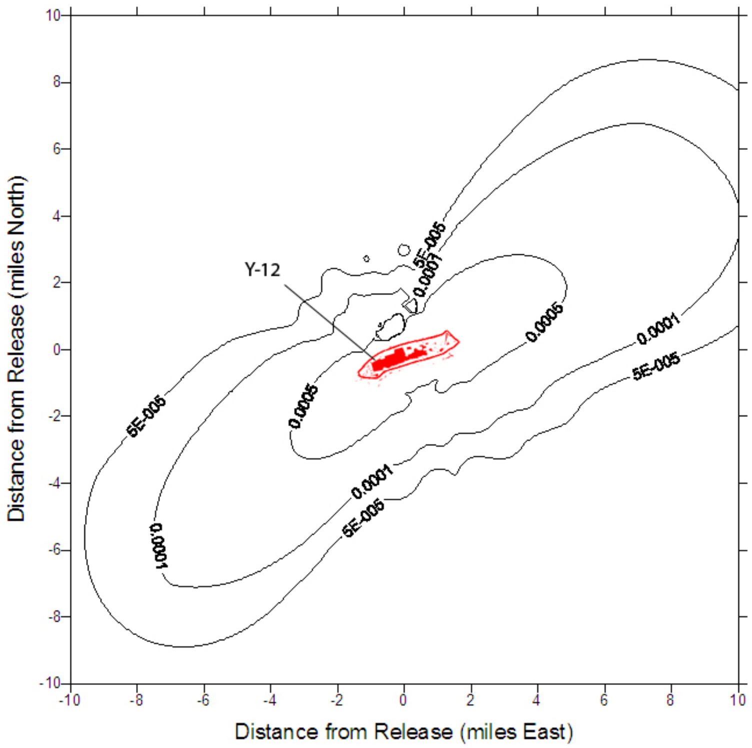
The soil screening level PRGs for each nuclide were combined into a single PRG for agricultural land usage (0.21 pCi per gram) and residential land usage (4.8 pCi per gram). These concentrations were converted to equivalent agriculture and residential deposition levels, 0.008 μCi per square meter and 0.18 μCi per square meter, respectively, assuming a typical soil density (1.5 grams per cubic centimeter) and mixing of deposited material in the upper inch of soil.

These screening levels are limited to the area close to the release, as seen in Figure D.9.6-1 (0-5 mile scale). The agriculture (ingestion of fruit and vegetables grown at this location) screening level is exceeded only within approximately one-third of a mile from the release. The residential (inhalation of suspended material, soil ingestion, external exposure) screening level is exceeded only within approximately 1.5 miles from the release.



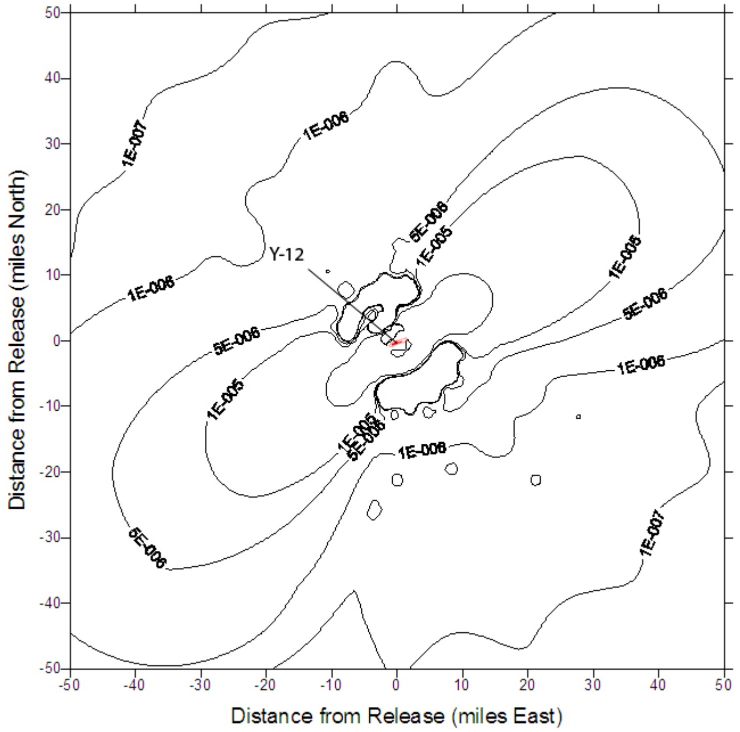
Note: units of measure for the isopleth lines are micro-curies/square meter.

Figure D.9.6-1. Dispersion Plume: 0 – 5 Mile Scale.



Note: units of measure for the isopleth lines are micro-curies/square meter.

Figure D.9.6-2. Dispersion Plume: 0 – 10 Mile Scale.



Note: units of measure for the isopleth lines are micro-curies/square meter.

Figure D.9.6-3. Dispersion Plume: 0 – 50 Mile Scale.

D.9.7 Chemical Accidents

Under all alternatives, Y-12 would store and use a variety of hazardous chemicals. The quantities of chemicals vary, ranging from small amounts in individual laboratories to bulk amounts in processes and specially designed storage areas. In addition, the effects of chemical exposure on personnel would depend upon its characteristics and could range from minor to fatal. Minor accidents within a laboratory room, such as a spill, could result in injury to workers in the immediate vicinity. A catastrophic accident such as a large uncontrolled fire, explosion, earthquake, or aircraft crash could have the potential for more serious impacts to workers and the public.

The adverse effects of exposure vary greatly among chemicals. They range from physical discomfort and skin irritation to respiratory tract tissue damage and, at the extreme, death. For this reason, allowable exposure levels differ from substance to substance. For this analysis, ERPG values are used to develop hazard indices for chemical exposures. Emergency Response Planning Guide (ERPG) definitions are provided below.

EPRG DEFINITIONS

ERPG-1 *is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor*.

ERPG-2 *is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.*

ERPG-3 *is the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.*

NNSA estimated the impacts of the potential release of the most hazardous chemicals used at Y-12. Potential chemical accidents were obtained from review of the Y-12 chemical accident scenarios reported in previous NEPA documents. A chemical's vapor pressure, acceptable concentration (ERPG-2), and quantity available for release were factors used to rank a chemical's hazard. Determination of a chemical's hazardous ranking takes into account quantities available for release, protective concentration limits (ERPG-2) and evaporation rate. The accident scenario postulates a major leak, such as a pipe rupture, and the released chemical forming a pool about one inch in depth in the area around the point of release. The chemical analyzed for release was nitric acid.

Table D.9.7-1 show the impact of an accidental release of nitric acid as measured in terms of ERPG-2 protective concentration limits given in parts per million. The distance at which the limit is reached is also provided for the ERPG-2 limit. The concentration of the chemical at 1,000 meters (3,281 feet) from the accident is shown for comparison with the concentration limit for ERPG-2. The distance to the site boundary and the concentration at the site boundary are also shown for comparison with the ERPG-2 concentration limits and for determining if the limits are exceeded offsite.

Both Gaussian Plume and ALOHA methodologies were used to evaluate the potential consequences associated with a release of each chemical in an accident situation. The impacts of a nitric acid release are measured in terms of ERPG-2 protective concentration limits given in ppm. The distances at which the limit is reached are also provided for the ERPG-2 limit. The concentration of the chemical at 1,000 meters (3,281 feet) from the accident is shown for comparison with the concentration limit for ERPG-2. The distance to the site boundary and the concentration at the site boundary are also shown for comparison with the ERPG-2 concentration limits and for determining if the limits are exceeded offsite. Conservative modeling of chemical release over the period of 1-hour was based on a spill and subsequent pool with evaporation resulting calculated down-wind concentrations.

Table D.9.7-1. Chemical Accident Frequency and Consequences: All Alternatives.

Chemical Released	Quantity Released (kg)	ERPG-2		Concentration		Frequency
		Limit (ppm)	Distance to Limit (km)	At 1,000 m (ppm)	At Site Boundary (ppm)[a]	
Nitric acid	10,500	6	0.28	0.5	0.01	10^{-4}

Source: Tetra Tech 2008.

[a] Site boundary is at a distance of approximately 1.3 miles.

References Specific to Appendix D

Albers et al.1988	Albers, J.W., L.R. Kallenbach, L.J. Fine, G.D. Langolf, R.A. Wolfe, P.D. Donofrio, A.G. Alessi, K.A. Stolp-Smith, M.B. Bromberg, and Mercury Workers Study Group, "Neurological Abnormalities Associated with Remote Occupational Elemental Mercury Exposure," Annals of Neurological Science, 24(5):651-659, November 1988.
BLS 2009	Bureau of Labor Statistics (BLS), "Incidence Rates of Nonfatal Occupational Injuries and Illnesses by Industry and Case Types, 2007," Table 6, 2009. Available at: http://www.bls.gov/iif/oshstate.htm, Accessed on August 12 2009.
BLS 2009a	BLS, "Fatal Occupational Injuries, Employment, and Rates of Fatal Occupational Injuries by Selected Worker Characteristics, Occupations, and Industries, 2007," Bureau of Labor Statistics, 2009. Available at: http://www.bls.gov/iif/oshwc/cfoi/cfoi_rates_2007.pdf, Accessed on August 18, 2009.
CEDR 2000	Comprehensive Epidemiologic Data Resource (CEDR), "A Digital Collection of Public Use Data Sets," U.S. Department of Energy, 2000. Available at: http://cedr.lbl.gov, Accessed on February 2000.
Checkoway et al.1988	Checkoway, H., N. Pearce, D.J. Crawford-Brown, D.L. Cragle, "Radiation-Doses and Cause-Specific Mortality Among Workers at a Nuclear-Materials Fabrication Plant," American Journal of Epidemiology, 127(2): 255-266, February 1988.
Cragle et al.1984	Cragle, D.L., D.R. Hollis, J.R. Qualters, W.G. Tankersley, and S.A. Fry, "A Mortality Study of Men Exposed to Elemental Mercury," Journal of Occupational Medicine, 26(11): 817-821, November 1984.
DOE 1999a	U.S. Department of Energy (DOE), "Draft Agenda for Public Health Activities for Fiscal Years 1999 and 2000 U.S. Department of Energy Sites," U.S. Department of Energy and U.S. Department of Health and Human Services, Washington D.C., April 1999.
DOE 2002d	DOE, "Radiation Risk Estimation from Total Effective Dose Equivalents (TEDEs)," Office of Environmental Policy and Guidance, Washington, D.C., August 9, 2002.

DOE 2005a	DOE, “Oak Ridge Reservation Annual Site Environmental Report for 2004,” DOE/ORR/2204, U.S. Department of Energy, September 2005.
DOE 2005g	DOE, “DOE and Contractor Injury and Illness Experience By Year and Quarter, 2000 through 2005, 3rd Qtr, Data extracted 12/10/2005,” Office of Environment, Safety, and Health, Washington D.C., 2005. Available at: http://www.eh.doe.gov/cairs/cairs/dataqtr/q053.xls, Accessed on January 24, 2007.
DOE 2008	DOE, “Oak Ridge Reservation Annual Site Environmental Report for 2007,” DOE/ORO/2261, Oak Ridge Reservation, Oak Ridge, TN, September 2008.
DOE 2009a	DOE, “DOE and Contractor Injury and Illness Experience by Field Organization by Year and Quarter, 2004 through 2009, 1st Qtr (rev. 4/27/2009),” Office of Environment, Safety, and Health, Washington D.C., 2009. Available at: http://www.eh.doe.gov/cairs/cairs/, Accessed on August 12, 2009.
Dupree et al.1995	Dupree, E. A., J.P. Watkins, J.N. Ingle, P.W. Wallace, C.M. West, and W.G. Tankersley,“ Uranium Dust Exposure and Lung Cancer Risk in Four Uranium Processing Operations,” Epidemiology, 6(4): 370-5, July 1995.
EPA 1989	U.S. Environmental Protection Agency (EPA), “Risk Assessments Methodology, Environmental Impact Statement, NESHAPs for Radionuclides,” Background Information, Vol. 1, EPA/520/1-89-005, U.S. Environmental Protection Agency, Washington D.C., 1989.
EPA 2008	EPA, “Radiation Risk Assessment Software: CAP88 and CAP88 PC,” Washington D.C. 2008. Available at: http://www.epa.gov/radiation/assessment/CAP88/index.html, Accessed on June-July 2008.
Frome et al. 1997	Frome_ E. L., D.L. Cragle, J.P. Watkins, S.B. Wing, C.M. Shy, W.G. Tankersley, and C.M. West, “A Mortality Study of Employees of the Nuclear Industry in Oak Ridge, Tennessee,” Oak Ridge National Laboratory, Oak Ridge, TN, July 1997.
ICRP 1975	International Commission on Radiological Protection (ICRP), “Reference Man: Anatomical, Physiological and Metabolic Characteristics, ICRP Publication 23, Pergamon Press, New York, New York, 1975.

Jablon et al.1991	Jablon, S., Z, Hrubec., and Boice J.D. Jr., “Cancer in Populations Living Near Nuclear Facilities, A Survey of Mortality Nationwide and Incidence in Two States,” Journal of the American Medical Association, Volume 265, No. 11, March 1991.
Loomis and Wolf 1996	Loomis, D.P. and S.H. Wolf, “American Journal of Industrial Medicine,” 29(2): 131-41, February 1996.
NCRP 1993a	National Council on Radiation Protection (NCRP), “Risk Estimates for Radiation Protection,” NCRP Report No. 115, Bethesda, MD, 1993.
NRC 1977	U.S. Nuclear Regulatory Commission (NRC), “Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes,” NUREG-0170, Washington, D.C., December 1977.
Ries et al. 2002	Ries, LAG., M.P. Eisner, C.L. Kosary, B.F. Hankey, B.A. Miller, L. Clegg and B.K. Edwards(eds), “SEER Cancer Statistics Review, 1973-1999,” National Cancer Institute. Bethesda, MD, 2002.
Tetra Tech 2008	Tetra Tech, Inc., “Topical Report Supporting Documentation for the Accident Impacts and Normal Operation Presented in the Y-12 Site-wide Environmental Impact Statement,” 2008.