APPENDIX C
EVALUATION OF HUMAN HEALTH IMPACTS FROM NORMAL OPERATIONS

APPENDIX C
EVALUATION OF HUMAN HEALTH IMPACTS FROM NORMAL OPERATIONS

This appendix provides a brief general discussion of radiation and its effects on human health, as well as the methods and assumptions used for estimating the potential impacts and risks to individuals, workers, and the general public from exposure to releases of radioactivity and hazardous chemicals during normal operations at Los Alamos National Laboratory (LANL). It also discusses methods used to safely control biological material during research activities.

This appendix addresses the methods used to assess human health impacts from normal operations at LANL. To do so, it considers: (1) radionuclides potentially released into the air from Key Facilities as a function of the three alternatives considered in this site-wide environmental impact statement (SWEIS); and (2) radionuclides and chemicals that may be present in environmental pathways (such as ground and surface water and game animals) in and around the LANL environs. In addition, background information is presented regarding the effects on human health from exposure to radiation, biological agents, and hazardous chemicals. Both the methods used to assess impacts and the impacts themselves from the proposed projects that may be implemented at LANL as part of the Expanded Operations Alternative are addressed elsewhere in this SWEIS (see Appendices G, H, I, and J).

The release of pollutants to ambient air is the focus in these analyses because they are projected to dominate possible exposures to the public as a result of future LANL operations. Other releases such as those through outfalls into surface water bodies are not expected to be dominant contributors to future exposures because of the significant reduction in the use of outfalls and the extensive implementation of environmental controls such as those of the National Pollutant Discharge Elimination System. Past releases, however, have resulted in some radiological and chemical contamination in several environmental media, and impacts from this contamination are addressed in this appendix. This approach for evaluating human health impacts from normal operations is consistent with the approach used for the 1999 *Site-Wide Environmental Impact Statement for Continued Operation of the Los Alamos National Laboratory, Los Alamos, New Mexico (1999 SWEIS).*

C.1 Impacts on Human Health from Radiological Exposure

Radiation exposure and its consequences are of interest to the public. For this reason, this section provides information on the nature of radiation, emphasizes the consequences of exposure to radiation, and explains the basic concepts used to evaluate radiation health effects.

C.1.1 About Radiation and Radioactivity

C.1.1.1 What Is Radiation?

Radiation is energy transferred in the form of particles or waves. Globally, human beings are exposed constantly to radiation from the solar system and the Earth's rocks and soil. This

radiation contributes to the natural background radiation that always surrounds us. Manmade sources of radiation also exist, including medical and dental x-rays, household smoke detectors, and materials released from nuclear and coal-fired power plants.

All matter in the universe is composed of atoms. Radiation comes from the activity of tiny particles within an atom. An atom consists of a positively charged nucleus (central part of an atom) with a number of negatively charged electron particles in various orbits around the nucleus. There are two types of particles in the nucleus: neutrons that are electrically neutral and protons that are positively charged. All atoms of a given chemical element have the same number of protons in their nuclei. There are more than 100 natural and manmade elements. Atoms that have the same number of protons in their nuclei, but different numbers of neutrons, are called isotopes of an element. Elements may have one or more stable isotopes and others that are unstable (decay with time).

Unstable isotopes undergo spontaneous change known as radioactive disintegration or radioactive transformation. The process of continuously undergoing spontaneous transformation is called radioactivity. The radioactivity (number of transformations per second) of a given amount of material decreases with time. Each radioactive isotope is distinguished by the time it takes for a given quantity of the material to lose half of its original radioactivity. This time is its half-life, and is characteristic of the isotope. For example, an isotope with a half-life of 8 days will lose one-half of its radioactivity in that amount of time. In 8 more days, the radioactivity will again decrease by half, to one-fourth of the original value. The half-lives of various radioactive elements can vary from millionths of a second to millions of years.

As unstable isotopes change into more stable forms, they emit electrically-charged particles. The particle may be either an alpha particle (a helium nucleus) or a beta particle (an electron) and have various levels of kinetic energy. Sometimes these particles are emitted in conjunction with gamma rays. The alpha and beta particles and gamma rays are frequently referred to as “ionizing radiation”, a term that reflects the fact that the charged particle or gamma ray can strip or displace electrons away from atoms of matter through which they pass, leaving those atoms with an electrical charge. The ionization caused by radiation can change the chemical composition of many substances, including living tissue, which can affect the way they function.

Ionizing radiation is used in a variety of ways, many of which are familiar to us in our everyday lives. The machines used by doctors to diagnose and treat medical patients typically use x-rays, which are a form of ionizing radiation. The process by which a television displays a picture is by ionizing coatings on the inside of the screen with electrons. Most home smoke detectors use a small source of ionizing radiation to detect smoke particles in room air.

When a radioactive isotope of an element emits a particle, it changes to an entirely different element, one that may or may not be radioactive. Eventually, a stable element is formed. This transformation, which may take several steps, is known as a decay chain. For example, radium, which is a member of the radioactive decay chain of uranium, has 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 first to polonium, then through a series of further decay steps to bismuth, and ultimately to a stable isotope of lead. Meanwhile, the decay products will build up and eventually disappear as time progresses.

The characteristics of various forms of ionizing radiation are briefly described below and in the box to the right.

Alpha (α)—Alpha particles are the heaviest type of ionizing radiation. They can travel only a few centimeters in air. Alpha particles lose their energy almost as soon as they collide with anything. They can be stopped easily by a sheet of paper or by the surface of one's skin.

Radiation Type	***Typical Travel Distance in Air***	***Barrier***
α	Few inches	Sheet of paper or skin's surface
β	Few feet	Thin sheet of aluminum foil or glass
γ	Very large	Thick wall of concrete, lead, or steel
n	Very large	Water, paraffin, graphite

Beta (β)—Beta particles are much (7,330 times) lighter than alpha particles. They can travel a longer distance than alpha particles in the air. A high-energy beta particle can travel a few feet in the air. Beta particles can pass through a sheet of paper, but can be stopped by a thin sheet of aluminum or glass.

Gamma (γ)—Gamma rays (and x-rays), unlike alpha or beta particles, are waves of pure energy. Gamma rays travel at the speed of light. Gamma radiation is very penetrating and requires concrete, lead, or steel shielding to stop it.

Neutrons (n)—The most prolific source of neutrons is a nuclear reactor. Neutrons produce ionizing radiation indirectly by collision with hydrogen nuclei (protons) and when gamma rays and alpha particles are emitted following neutron capture in matter. A neutron has about one-quarter the weight of an alpha particle. It will travel in the air until it is absorbed in another nucleus.

C.1.1.2 Units of Radiation Measure

During the early days of radiological experience, there was no precise unit of radiation measurement. Therefore, a variety of units was used to measure the amount, type, and intensity of radiation. Just as heat can be measured in terms of its intensity or effects using units of calories or degrees, amounts of radiation or its effects can be measured in units of curies, radiation absorbed dose (rad), or dose equivalent (roentgen equivalent man, or rem). The following summarizes these units.

Curie—The curie, named after the French scientists Marie and Pierre Curie, describes the "intensity" (activity) of a sample of radioactive material. The rate of decay of 1 gram of radium was the basis for this unit of measure. Because the measured decay rate kept changing slightly as measurement techniques became more accurate, the curie was subsequently defined as exactly 3.7×10^{10} disintegrations (decays) per second.

Radiation Units and Conversions to International System of Units	
1 curie	= 3.7×10^{10} disintegrations per second
	= 3.7×10^{10} becquerels
1 becquerel	= 1 disintegration per second
1 rad	= 0.01 gray
1 rem	= 0.01 sievert
1 gray	= 1 joule per kilogram

Rad—The rad is used to measure the physical absorption of radiation. The total energy absorbed per unit quantity of tissue is referred to as absorbed

dose (or simply dose). As sunlight heats pavement by giving up energy to it, radiation similarly gives up energy to objects in its path. 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.

Rem (roentgen equivalent man)—A rem is a measurement of the dose equivalent from radiation based on its biological effects. The rem is used to measure the effects of radiation on the body as degrees centigrade are used to measure the effects of sunlight heating pavement. Thus, 1 rem of one type of radiation is presumed to have the same biological effects as 1 rem of any other kind of radiation. This allows comparison of the biological effects of radionuclides that emit different types of radiation.

The units of radiation measurement in the International System of Units are becquerels (a measure of source intensity [activity]), grays (a measure of absorbed dose), and sieverts (a measure of dose equivalent).

An individual may be exposed to ionizing radiation externally (from a radioactive source outside the body) or internally (from ingesting or inhaling radioactive material). The external dose is different from the internal dose because an external dose is delivered only during the actual time of exposure to the external radiation source, while an internal dose continues to be delivered as long as the radioactive source is in the body. The dose from internal exposure is calculated over 50 years following the initial exposure. Both radioactive decay and elimination of the radionuclide by ordinary metabolic processes decrease the dose rate with the passage of time.

C.1.1.3 Sources of Radiation

The average American receives a total of approximately 360 millirem per year from all sources of radiation, both natural and manmade, of which approximately 300 millirem per year are from natural sources. A person living in Los Alamos receives an average background dose between 300 and 500 millirem, depending on where they live (LANL 2004d). The sources of radiation can be divided into six different categories: cosmic radiation, terrestrial radiation, internal radiation, consumer products, medical diagnosis and therapy, and other sources (NCRP 1987). These categories are discussed in the following paragraphs.

Cosmic Radiation—Cosmic radiation is ionizing radiation resulting from energetic charged particles from space continuously hitting the Earth's atmosphere. Cosmic radiation comprises these particles and the secondary particles and photons they create. Because the atmosphere provides some shielding against cosmic radiation, the intensity of this radiation increases with the altitude above sea level. The average dose to people in the United States from this source is approximately 27 millirem per year. Doses from cosmic radiation range from 50 millirem per year at lower elevations near the Rio Grande River to about 90 millirem per year in the mountains near Los Alamos (LANL 2004d).

External Terrestrial Radiation—External terrestrial radiation is the radiation emitted from the radioactive materials in the Earth's rocks and soils. The average dose from external terrestrial radiation is approximately 28 millirem per year. Doses from terrestrial radiation in Los Alamos range from about 50 to 150 millirem a year, depending on the amounts of natural uranium, thorium, and potassium in the soil (LANL 2004d).

Internal Radiation—Internal radiation results from radioactive material that has entered the body by inhalation or ingestion and is retained by the affected organs or tissues. Natural radionuclides in the body include isotopes of uranium, thorium, radium, radon, polonium, bismuth, 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 approximately 200 millirem per year. The average dose from other internal radionuclides is approximately 40 millirem per year.

Consumer Products—Consumer products also contain sources of ionizing radiation. In some products, such as smoke detectors and airport x-ray machines, the radiation source is essential to the product's operation. In other products, such as televisions and tobacco, the radiation source is a byproduct of the product's function. The average dose from consumer products is approximately 10 millirem per year.

Radiation Source	***Average Annual Dose (millirem)***
Cosmic	50-90
External Terrestrial	50-150
Internal	240
Consumer Products	10
Medical Diagnostic and Treatment	50
Other	1 +

Medical Diagnosis and Therapy—Radiation is an important diagnostic medical tool and cancer treatment. Diagnostic x-rays result in an average exposure of 50 millirem per year. Nuclear medical procedures result in an average exposure of 14 millirem per year.

Other Sources—There are a few additional sources of radiation that contribute minor doses to individuals in the United States. The dose from nuclear fuel cycle facilities (for example, uranium mines, mills, and fuel processing plants) and nuclear power plants has been estimated to be less than 1 millirem per year. Radioactive fallout from atmospheric atomic bomb tests, emissions from certain mineral extraction facilities, and transportation of radioactive materials contribute less than 1 millirem per year to the average dose to an individual. Air travel contributes approximately 1 millirem per year to the average dose.

C.1.1.4 Exposure Pathways

As stated earlier, an individual may be exposed to ionizing radiation both externally and internally. The different ways that an individual can be exposed to radiation are called exposure pathways. Each type of exposure is discussed separately in the following paragraphs.

External Exposure—External exposure can result from a number of different pathways where the exposure is external to the body. These pathways include exposure to a cloud of radiation passing over the receptor (an exposed individual), standing on ground that is contaminated with radioactivity, and swimming or boating in contaminated water. If the receptor leaves the source of radiation exposure, the dose rate will be reduced. It is assumed that external exposure occurs uniformly during the year. The appropriate dose measure is called the effective dose equivalent.

Internal Exposure—Internal exposure results from a radiation source entering the human body through either inhalation of contaminated air or ingestion of contaminated food or water. In contrast to external exposure, once a radiation source enters the body, it remains there for a period of time that varies depending on its physical decay and biological half-life. The absorbed

dose to each organ of the body is calculated for a period of 50 years following the intake. The calculated absorbed dose is called the committed dose equivalent. Various organs have different susceptibilities to damage from radiation. The committed effective dose equivalent takes these different susceptibilities into account and provides a broad indicator of risk to the health of an individual from radiation. The committed effective dose equivalent is a weighted sum of the committed dose equivalent in each major organ or tissue. The concept of committed effective dose equivalent applies only to internal pathways.

C.1.1.5 Limits of Radiation Exposure

Limits of exposure to members of the public and radiation workers are derived from International Commission on Radiological Protection recommendations. The U.S. Environmental Protection Agency (EPA) uses the National Council on Radiation Protection and Measurements and the International Commission on Radiological Protection recommendations to set specific annual exposure limits (usually less than those specified by the Commission) 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 the U.S. Department of Energy (DOE) and EPA for radiation workers and members of the public are given in **Table C–1**.

Table C–1 Exposure Limits for Members of the Public and Radiation Workers

Guidance Criteria (Organization)	*Public Exposure Limits at the Site Boundary*	*Worker Exposure Limits*
10 CFR Part 835 (DOE)	Not applicable	5,000 millirem per year [a]
DOE Order 5400.5 (DOE) [b]	10 millirem per year (all air pathways) 4 millirem per year (drinking water pathway) 100 millirem per year (all pathways)	Not applicable
40 CFR Part 61 (EPA)	10 millirem per year (all air pathways)	Not applicable
40 CFR Part 141 (EPA)	4 millirem per year (drinking water pathways)	Not applicable

CFR = *Code of Federal Regulations*, EPA = U.S. Environmental Protection Agency.

[a] Although this limit (or level) is enforced by DOE, worker doses must be managed in accordance with as low as reasonably achievable (ALARA) principles. An annual limit of 2,000 millirem per year was established by DOE to assist in achieving its goal to maintain radiological doses at ALARA levels (DOE 1999b).

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

C.1.2 Health Effects

To provide a background for discussing impacts, this section explains the basic concepts used to evaluate radiation effects.

Radiation can cause a variety of damaging health effects in people. The most significant effects are induced cancer fatalities. These effects are referred to as "latent" cancer fatalities because the cancer may take many years to develop. In the discussions that follow, all fatal cancers are considered latent; therefore, the term "latent" is not used.

The National Research Council prepared a series of reports to advise the U.S. Government on the health consequences of radiation exposures. The most recent of these, *Health Effects from Exposure to Low Levels of Ionizing Radiation, BEIR VII-Phase 2* (National Research Council 2005), provides current estimates for excess mortality from leukemia and other cancers that are expected to result from exposure to ionizing radiation. Biological Effects of Ionizing

Radiation (BEIR) VII provides estimates that are not significantly different from those in its predecessor, BEIR V, and recent United Nations Scientific Committee on the Effects of Atomic Radiation and International Commission on Radiological Protection reports. The report, however, concludes that recent data and analyses have reduced the uncertainties associated with the risk estimates. BEIR V developed models in which the excess relative risk was expressed as a function of age at exposure, time after exposure, and sex for each of several cancer categories. The models were based on the assumption that the relative risks are comparable between the atomic bomb survivors and the U.S. population.

The models and risk coefficients in BEIR VII are derived through review of the most current information on the biological mechanisms of radiation tumorigenesis as well as analyses of relevant epidemiologic data that includes the Japanese atomic bomb survivors, medically-exposed persons, and large-scale occupational radiation studies. The BEIR VII Committee concluded that the balance of evidence tends to support a simple proportionate relationship at low doses between radiation dose and risk. This conclusion essentially affirms the Linear-No-Threshold model that has long been the basis for the regulation and control of occupational and environmental radiation exposure in the United States.

The National Council on Radiation Protection and Measurements (NCRP 1993), based on the radiation risk estimates provided in BEIR V and the International Commission on Radiological Protection (ICRP 1991), estimates the total detriment resulting from low dose[1] or low dose rate exposure to ionizing radiation to be 0.00076 per rem for the working population and 0.00083 per rem for the general population. The total detriment includes fatal and nonfatal cancers as well as severe hereditary (genetic) effects. The major contribution to the total detriment is from fatal cancer, estimated to be 0.0006 per rem for both radiation workers and the general population. For comparison, the BEIR VII Committee's preferred estimates of lifetime attributable risk of mortality for all solid cancers and leukemia are 0.00048 for males and 0.00066 for females. The breakdowns of the risk estimators for both workers and the general population are given in **Table C–2**. Nonfatal cancers and genetic effects are less probable consequences of radiation exposure.

Table C–2 Nominal Health Risk Estimators Associated with Exposure to 1 Rem of Ionizing Radiation

Exposed Individual	*Fatal Cancer* [a, c]	*Nonfatal Cancer* [b]	*Genetic Disorders* [b]	*Total*
Worker	0.0006	0.00008	0.00008	0.00076
Public	0.0006	0.0001	0.00013	0.00083

[a] For fatal cancer, the health effect coefficient is the same as the probability coefficient. When applied to an individual, the units are the lifetime probability of a cancer fatality per rem of radiation dose. When applied to a population of individuals, the units are the excess number of fatal cancers per person-rem of radiation dose. These factors are from DOE 2003a.

[b] In determining a means of assessing health effects from radiation exposure, the International Commission on Radiological Protection has developed a weighting method for nonfatal cancers and genetic effects. These factors are from NCRP 1993.

[c] For high individual exposures (greater than or equal to 20 rem), the health factors are multiplied by a factor of 2.

Sources: NCRP 1993, DOE 2003a.

[1] *Low dose is defined as the dose level where deoxyribonucleic acid (DNA) repair can occur in a few hours after irradiation-induced damage. Currently, a dose level of about 0.2 grays (20 rad), or a dose rate of 0.1 milligrays (0.01 rad) per minute is considered low enough to allow the DNA to repair itself in a short period (EPA 1994).*

EPA, in coordination with other Federal agencies involved in radiation protection, issued *Federal Radiation Guidance Report No. 13, Cancer Risk Coefficients for Environmental Exposure to Radionuclides*, in September 1999 (EPA 1999). This document is a compilation of risk factors for doses from external gamma radiation and internal intakes of radionuclides. *Federal Radiation Guidance Report No. 13* is the basis for the radionuclide risk coefficients used in the EPA Health Effects Assessment Summary Tables (EPA 2001) and in computer dose codes. The Interagency Steering Committee on Radiation Standards (ISCORS) issued a technical report entitled, *A Method for Estimating Radiation Risk from TEDE* (DOE 2003a). ISCORS technical reports are guidance to Federal agencies to assist them in preparing and reporting the results of analyses and implementing radiation protection standards in a consistent and uniform manner. This report provides dose-to-risk conversion factors where doses are estimated using total effective dose equivalent (TEDE). It is recommended for use by DOE personnel and contractors when computing potential radiation risk from calculated radiation dose for comparison purposes. For situations in which a radiation risk assessment is required for making risk management decisions, however, the radionuclide-specific risk coefficients in Federal Guidance Report No. 13 should be used.

DOE and other agencies regularly conduct dose assessments using models and codes that calculate radiation dose from exposure or intake using dose conversion factors and do not compute risk directly. In those cases where it is necessary or desirable to estimate risk for comparative purposes (for example, comparing the risk associated with alternative actions), it is common practice to simply multiply the calculated TEDE by a risk-to-dose factor. DOE previously recommended a TEDE-to-fatal cancer risk factor of 0.0005 per rem for the public and 0.0004 per rem for working-age populations. ISCORS recommends that agencies use a conversion factor of 0.0006 fatal cancers per TEDE (rem) for mortality and 0.0008 cancers per rem for morbidity when making qualitative or semi-quantitative estimates of risk from radiation exposure to members of the general public[2] (DOE 2003a).

The ISCORS report notes that the recommended risk coefficients used with TEDE dose estimates generally produce conservative radiation risk estimates (they overestimate risk). Regarding the ingestion pathway for the 11 radionuclides included in the report, the risks are overestimated compared to the values in Federal Radiation Guidance Report No. 13 for about 8 radionuclides and significantly overestimated (by up to a factor of 6) for 4 of these. The Office of Environmental Policy and Guidance also compared the TEDE-to-cancer risk conversion factor approach to Federal Radiation Guidance Report No. 13 for the inhalation pathway and found a bias toward overestimating risk, although it was not as severe as for ingestion. For 16 radionuclides and chemical states evaluated, 7 were overestimated (by more than a factor of 2) and 5 were underestimated. The remainder agreed within about a factor of two. Generally, these differences were within the uncertainty of transport and the uptake portions of dose or risk modeling; therefore, the approach recommended is fully acceptable for comparative assessments. It is recommended, however, that the more rigorous approach using Federal Radiation Guidance Report No. 13 cancer risk coefficients be employed wherever possible (DOE 2003a).

Different methods of extrapolation to the low-dose region could yield higher or lower numerical estimates of fatal cancers. Studies of human populations exposed to low doses are inadequate to

[2] *Such estimates should not be stated with more than one significant digit.*

demonstrate the actual level of risk. There is scientific uncertainty about cancer risk in the low-dose region below the range of epidemiologic observation, and the possibility of no risk cannot be excluded (CIRRPC 1992).

C.1.2.1 Health Effect Risk Estimators Used in this SWEIS

Health impacts from radiation exposure, whether from external or internal sources, generally are identified as "somatic" (affecting the exposed individual) or "genetic" (affecting descendants of the exposed individual). Radiation is more likely to produce somatic effects than genetic effects. The somatic risks of most importance are induced cancers. Except for leukemia, which can have an induction period (the time between exposure to a carcinogen and a cancer diagnosis) of as little as 2 to 7 years; most cancers, however, have an induction period of more than 20 years.

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. Such cancers, however, also produce relatively low mortality rates because they are relatively amenable to medical treatment. Because fatal cancer is the most probable serious effect of environmental and occupational radiation exposures, estimates of cancer fatalities rather than cancer incidence are presented in this new SWEIS. The numbers of fatal cancers can be used to compare the risks among the various alternatives.

The fatal cancer estimators are used to calculate the statistical expectation of the effects of exposing a population to radiation. For example, if 100,000 people were each exposed to a one-time radiation dose of 100 millirem (0.1 rem), the collective dose would be 10,000 person-rem. The exposed population would then be expected to experience 6 additional cancer fatalities from the radiation (10,000 person-rem times 0.0006 lifetime probability of cancer fatalities per person-rem = 6 cancer fatalities).

Calculations of the number of excess fatal cancers associated with radiation exposure do not always yield whole numbers. These calculations may yield numbers less than 1, especially in environmental impact applications. For example, if a population of 100,000 were exposed to a total dose of only 0.001 rem per person, the collective dose would be 100 person-rem (100,000 persons times 0.001 rem = 100 person-rem). The corresponding estimated number of cancer fatalities would be 0.06 (100 person-rem times 0.0006 cancer fatalities per person-rem = 0.06 cancer fatalities). This estimate of 0.06 cancer fatalities means that there is 1 chance in 16.6 that the exposed population would experience 1 fatal cancer. In other words, 0.06 cancer fatalities is the *expected* 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 would incur a fatal cancer from the 0.001 rem dose each member would have received. In a small fraction of the groups, 1 cancer fatality would result; in exceptionally few groups, 2 or more cancer fatalities would occur. The *average* expected number of deaths over all the groups would be 0.06 cancer fatalities (just as the average of 0, 0, and 0 added to 1 is 1/4, or 0.25). The most likely outcome is no cancer fatalities.

C.1.2.2 Material of Interest at Los Alamos National Laboratory

LANL scientists have a large involvement in nuclear science and its applications. Therefore, many types of radioactive materials and radiation sources are in use at LANL; however, many of these uses require only very small amounts of material. Note that all radioactive materials are considered in this new SWEIS, but three radionuclides tend to dominate the human health effects at LANL due to their particular radioactive and biological characteristics, the quantities of material being used, or the potential for dispersion in an accident. These radionuclides are plutonium, uranium, and tritium.

Plutonium is a manmade element that has several applications in weapons, nuclear reactors, and space exploration. There are several types of plutonium atoms, called isotopes, which are distinguished by the different numbers of neutrons in their nucleus. (Note that isotopes of a particular element all behave the same chemically.) In most cases, the isotopes of plutonium decay by alpha particle emission and have radioactive half-lives ranging from tens to thousands of years. Plutonium that is taken into the body tends to be deposited in certain organs (notably the bone, liver and lung) and is excreted very slowly. Because alpha particles have a very short range in tissue, the radiation dose from plutonium in the body is largely delivered to the organs where the material is deposited.

Uranium is a naturally-occurring radioactive element. The discovery that an atom of uranium could be fissioned with neutrons was the starting point of the Nuclear Age. Uranium-235 is one of several fissile materials that fission with the release of energy. Various applications require the use of different isotopes of uranium. Because isotopes cannot be chemically separated, processes have been developed to enrich uranium to various isotopic ratios. Natural uranium consists mostly of uranium-238, with very small amounts of uranium-234 and uranium-235. Enriched uranium is enhanced in the isotope uranium-235 above its natural concentration of 0.72 percent. Highly enriched uranium has a greater than 20 percent concentration of uranium-235 or greater. Depleted uranium results from the enrichment process, where most of the uranium-235 is removed.

Most uranium isotopes of interest here have very long half-lives and are alpha-emitters. Their half-lives are much longer than plutonium isotopes; as a result, uranium is generally of lower radiological concern than plutonium. Its actual radiological concern, however, varies with its enrichment. As a heavy metal, uranium can be chemically toxic to the kidneys. Depending on the enrichment and chemical form, either chemical or radiological considerations dominate.

Tritium is a radioactive isotope of hydrogen. It is generated at low levels in the environment by interactions of cosmic radiation with the upper atmosphere, but for practical applications, it is normally produced in a nuclear reactor. The radioactive properties of tritium are very useful. By mixing tritium with a chemical that emits light in the presence of radiation, a phosphor, a continuous light source, is created. This can be applied to situations where a dim light is needed but using batteries or electricity is not possible. Rifle sights and exit signs are common applications. Tritium has a half-life of around 12 years and decays by emitting a low-energy beta particle that cannot penetrate the outer layer of human skin. The main hazard associated with tritium is internal exposure. Because tritium is an isotope of hydrogen, it can be incorporated into a water molecule, forming tritiated water. In the environment, tritium is most often found in

its elementary form as a gas, or as water. Tritiated water is a concern to the human body because the body is composed mostly of water. Tritiated water will easily and rapidly enter the body and irradiate it rather uniformly; however, it also is removed from the body rather quickly because it can be easily displaced with regular water and has a biological half-life of about 12 days under normal conditions.

C.1.3 Methods Used to Estimate Radiological Impacts from Normal Operations

Dose assessments for members of the public were performed at LANL to determine the incremental doses that would be associated with the alternatives addressed in this SWEIS. This section provides supplemental information regarding those assessments. Incremental doses for members of the public were calculated for the following types of receptors:

- *Facility-Specific Maximally Exposed Individual (MEI)*—The facility-specific MEI represents a location near a facility where the greatest modeled dose to a hypothetical public individual would be received from all modeled emissions.

- *LANL Site-Wide MEI*—The LANL MEI represents the location where the single highest modeled dose would be received by a hypothetical public individual. The highest facility-specific MEI becomes the LANL MEI.

- Collective dose to the population within a 50-mile (80-kilometer) radius from LANL.

C.1.3.1 Key Facilities Modeled

Several facilities at LANL release radioactive materials to the ambient air through stacks, vents, or diffuse emissions. The facilities modeled for this SWEIS are listed in **Table C–3**. Those facilities not modeled were eliminated from detailed analysis because they either have historically low emission rates or would not be expected to operate during the period analyzed in this SWEIS. In addition, all of the facilities modeled in the *1999 SWEIS* as non-Key Facilities (High Pressure Tritium Facility [Technical Area (TA) 33] and Nuclear Safeguards Research Facilities [TA-35]) no longer have facility emissions. The following are changes from the *1999 SWEIS* to the list of Key Facilities:

- The Pajarito Site (TA-18) was removed from the LANL Key Facility list in both the Reduced and Expanded Operations Alternatives of this SWEIS (see Chapter 3, Section 3.1.3.9). Because the normal operational releases will still be applicable for the No Action Alternative at the Pajarito Site, a dose assessment was performed for this SWEIS.

- The Tritium Facilities in TA-21 were removed from the LANL Key Facilities list in the Expanded Operations Alternative. The buildings will continue to have radioactive air emissions until the decontamination, decommissioning, and demolition process has begun. Since these air emissions will result in potential doses to the MEI and public, a dose assessment was performed for the Tritium Facilities in TA-21 in this SWEIS.

Table C–3 Los Alamos National Laboratory Key Facilities

Technical Area	*Facility Name*
TA-3-29	Chemistry and Metallurgy Research Building
TA-3-66	Sigma Complex
TA-3-102	Machine Shops
TA-11	High Explosives Processing Facilities
TA-15 and TA-36	High Explosives Testing Facilities
TA-16	Tritium Facility [a]
TA-18	Pajarito Site [b]
TA-48	Radiochemistry Facility
TA-53	Los Alamos Neutron Science Center
TA-54	Waste Management Operations [c]
TA-55	Plutonium Facility Complex
Non-Key (TA-21)	TA-21 Non-Key Facilities [a]

[a] The Tritium Facility includes the Weapons Engineering Tritium Facility at TA-16. The non-Key Facilities at TA-21 were formerly part of the Tritium Facilities and include the Tritium Science and Fabrication Facility and the Tritium Systems Test Assembly that will continue to produce emissions while awaiting decontamination, decommissioning, and demolition and are under non-Key Facilities.

[b] A LANL Key Facility in the No Action Alternative, it will continue to produce emissions until the Solution High-Energy Burst Assembly moves to another DOE site.

[c] Area G and the Decontamination and Volume Reduction System.

The new LANL Key Facilities were reviewed for potential radiological air releases. It was determined that no significant air emissions from these facilities would produce doses that could affect the public. In addition, the radiological air emissions from the Radioactive Liquid Waste Treatment Facility at TA-50 were considered in the *1999 SWEIS* to be minimal (DOE 1999a) relative to other sources at LANL and therefore were not modeled. It was anticipated that the replacement Radioactive Liquid Waste Treatment Facility also would have minimal radiological air emissions; therefore, it was not modeled in this SWEIS (Appendix G).

As part of LANL's zero liquid discharge program, two concrete basins located at the east end of TA-53 are used to evaporate radioactive liquid discharge from the Los Alamos Neutron Science Center (LANSCE) facility. LANSCE radioactive liquid is first placed in a collection tank for decay. Measurement of the radioisotope concentration of the liquid in this tank after decay is used to determine when it can be released to one of the evaporation basins. Each basin has a 125,000-gallon (473,125-liter) capacity and is lined with a nonpermeable material. The measured radioisotope concentrations in liquid released to the evaporation basin in 2006 were used to calculate the dose to the MEI residing at the East Gate at State Highway 502 located 800 meters (2,625 feet) from the evaporation basins. The calculation used the Clean Air Act Assessment Package – 1988 (CAP88) computer code (EPA 2002) and assumed that all radioisotopes present in the liquid in the evaporation basin during the year, regardless of physical form, were released to the air. The resulting calculated dose to the MEI was 0.035 millirem per year. This 0.035 millirem evaporation basin MEI dose is less than 0.5 percent of the LANL MEI dose of 7.8 millirem for the No Action Alternative. The effect of these evaporation basins on the 50-mile (80-kilometer) population dose from normal operations was calculated to be 0.0278 person-rem per year, which is small (0.13 percent) compared to the population dose from LANSCE emissions (22 person-rem per year).

C.1.3.2 Clean Air Act Assessment Package – 88 Model

CAP88-PC Version 3.0 computer code was used for this SWEIS to calculate population radiation doses from normal releases of radioisotopes (EPA 2002). There were significant changes in dose calculations between the (CAP88-PC) DOS Version 1.0 used in the *1999 SWEIS* and the Version 3.0 used here, including:

- Incorporation of the new Federal Guidance Report No. 13 dose and risk factors;
- Incorporation of options to choose different chemical forms for each radionuclide;
- Addition of pathways, such as drinking water ingestion and external exposure from multiple depths of soil contamination;
- Ability to account for the effect of humidity; and
- Addition of more than 800 isotopes, consistent with those in Federal Guidance Report No. 13.

C.1.3.3 Model Input Parameters

The CAP88 model requires many input parameters to perform dose calculations. Most of these parameters are built into the model and require no input from the user. The user-defined inputs are discussed below, along with how the data were derived.

Population Data

The evaluation of collective offsite dose considers the population living within 50 miles (80 kilometers) of LANL. Potential doses to the local population from airborne radioactive emissions at each Key Facility at LANL were estimated using a 50-mile radius centered on the facility whose emissions were being analyzed. The 50-mile radius is typically used in EISs to evaluate impacts from both emissions from normal operations and releases from postulated accidents. Dose calculations using emissions from LANSCE were performed to support the use of the 50-mile distance. In this analysis, in addition to the dose to the MEI, the dose to an individual was calculated in the direction of the highest dose (north-northeast) for various distances out to 50 miles. As shown in **Figure C–1**, the dose dropped dramatically with increasing distance from the source, due primarily to the dispersion of the emitted contaminants, which reduced their concentrations. Therefore, anywhere beyond 50 miles in any direction, the dose would be smaller than the dose at 50 miles (0.035 millirem per year).

The Sector Population, Land Fraction, and Economic Estimation Program (NRC 2003) was used to create population distribution files that were then configured to work as data input files for CAP88. The SECPOP2000 software can calculate estimated population and economic data about any point (specified by longitude and latitude) that lies within the continental United States. SECPOP2000 used the latest (2000) census data. Population estimates were made using block level census data.

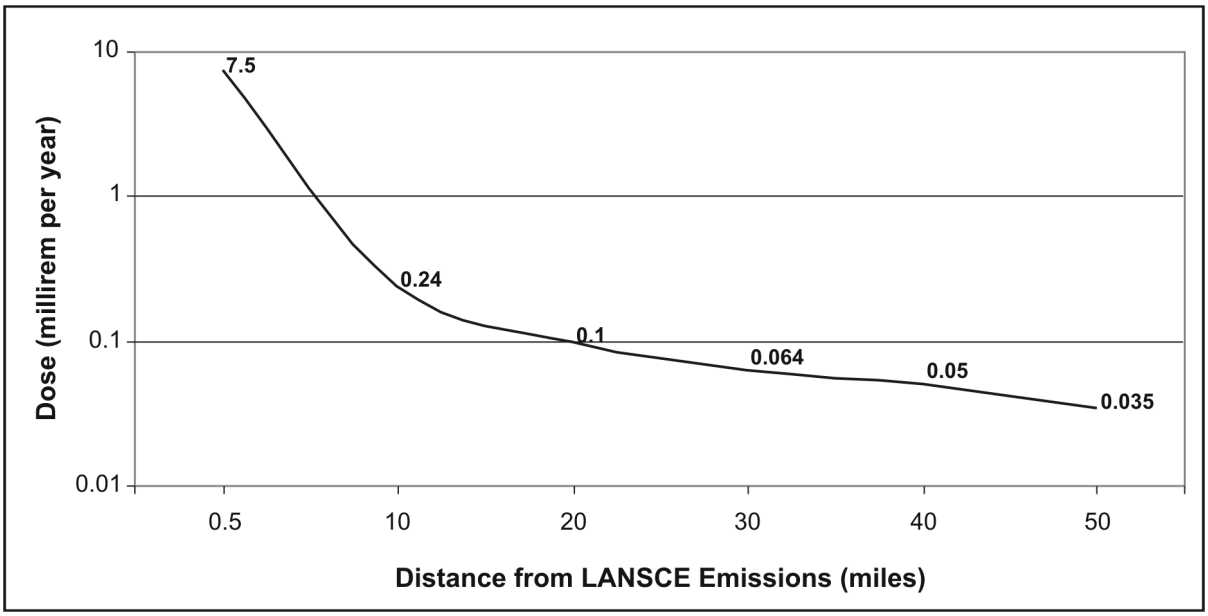

Figure C–1 Maximum Dose to an Individual at Selected Distances

In its population files, CAP88 uses edgepoints for each sector, which are entered in the population file in kilometers. The edgepoints used for CAP88 were consistent with those used for the accident analyses (1, 2, 3, 4, 5, 10, 20, 30, 40, 50 miles). Each CAP88 population file was subsequently analyzed for residents inappropriately listed as residing on LANL property. One block of 184 individuals was consistently listed on a LANL-only sector. Those 184 individuals were manually moved to the adjoining sector to ensure no individuals were assessed as living on LANL property.

Maximally Exposed Individual Locations

The facility-specific MEI represents the location near a specific facility where a hypothetical person receives the greatest dose. These locations do not represent actual residences or individuals, but rather a hypothetical receptor (see Chapter 5, Section 5.6). Some points at the LANL boundary do have residences close to them. This is especially true for those TAs located in the northern part of the LANL site, such as TA-3 and TA-53.

The facility-specific MEI locations remained the same in this SWEIS as those in the *1999 SWEIS*. Due to the expected changes in LANL boundaries near TA-21 and TA-54, the MEIs for TA-21 and TA-54 were reviewed. The review of the TA-21 MEI location included the conveyance of segments A-5-1, A-6, A-8, A-9, A-10, A-11, and A-15. The review of the TA-54 MEI location included the conveyance of segments A-19-1, A-19-2, A-19-3, B-1 and C-1, all of which are near White Rock (LANL 2006a). Since the highest dose for TA-54 in the *1999 SWEIS* was located northeast of the site at the boundary with San Ildefonso Pueblo, the conveyance of land near White Rock, further away, did not affect the TA-54 MEI location.

For some Key Facilities, there are areas nearby that are not populated by LANL workers (such as the Los Alamos County Landfill). These areas were not considered populated by public receptors. Some modeled facilities share the same MEI location. The Chemistry and Metallurgy

Research Building (TA-3-29) and the Sigma Complex (TA-3-66) share the same MEI location, as do the Radiochemistry Facility (TA-48) and the Plutonium Facility Complex (TA-55).

Meteorological Data

There are six towers that gather meteorological data. Four of the towers are located on mesa tops and are used with the CAP88 model to estimate air dispersion of emitted nuclides. The data used for each tower covered an average of 9 years (January 1, 1995 through December 31, 2003) of actual meteorological data. Using average meteorological data over a period of time better reflects conditions than data from any individual year. The tower nearest to the modeled facility was used for data input.

Tower	***Key Facility Locations***
TA-6	TA-3, TA-16, TA-48, TA-55
TA-49	TA-11, TA-15, TA-36
TA-53	TA-21, TA-53
TA-54	TA-18, TA-54

The other meteorological data used in CAP88 is listed below. Previous versions of CAP88 used a default value of 8 grams per cubic meter for the Average Absolute Humidity. For this SWEIS, a value of 3.85 grams per cubic meter (LANL 2004a) was used. All other parameters were confirmed from the *1999 SWEIS.*

- Annual precipitation = 19 inches (48 centimeters) per year.
- Annual ambient temperature = 48 degrees Fahrenheit (8.8 degrees Celsius).
- Height of lid (atmosphere mixing level) = 5,000 feet (1,525 meters).
- Average absolute humidity = 4 grams per cubic meter (3.85 grams per cubic meter rounded up by CAP88).

Emissions Data

For this SWEIS, all actual emissions from 1999 through 2004 (LANL 2000, 2001, 2002a, 2003a, 2004c, 2005a) were reviewed and analyzed to ensure that the projected emissions from the *1999 SWEIS* were bounding. Based on the above review and additional data from LANL, some changes were made to the projected air emissions. Specific changes can be found in the appropriate Radiological Air Emissions **Tables C–4** through **C–15**. In addition, each Key Facility's activities were reviewed for the three alternatives considered in this SWEIS (No Action, Reduced Operations, and Expanded Operations). The projected releases are based on those activities. A complete description of the alternatives can be found in Chapter 3.

Changes to CAP88 Version 3.0 included the ability of the user to choose the specific chemical form and type. The chemical form used in the assessments was based on each facility's process knowledge. For example, LANSCE produces a variety of materials generated through the process of activation; consequently, emissions occur as gaseous mixed activation products. Other activation products occur in particulate and vapor form.

Gaseous mixed activation product emissions included argon-41, carbon-11, nitrogen-13, nitrogen-16, oxygen-14, and oxygen-15. Various radionuclides such as mercury-193, mercury-197, germanium-68, and bromine-82 made up the majority of the particulate and vapor form emissions (LANL 2004c). Tritium can be released in different forms, either as tritium oxide (vapor) or as elemental tritium (gas), at each facility where it is present. Area G at TA-54, for instance, is a known source of diffuse emissions of tritium vapor (LANL 2004c). These forms are noted in Tables C–4 through C–15.

At some Key Facilities, the emissions were modeled using the most conservative radioisotope. For example, actinide emissions at the Chemistry and Metallurgy Research Building include plutonium, uranium, thorium, and americium isotopes. Of these isotopes, plutonium-239 was used for modeling purposes to conservatively represent all of the actinides released. By using plutonium-239, the estimated dose for members of the public presented in this SWEIS is higher than would be experienced if the actual actinides were used in the model calculations.

Some Key Facility projected emissions included radionuclides that are not in the dose conversion factor database of CAP88 Version 3.0. Impacts from these radionuclides would be minimal due to their extremely short half-lives and small inventory amounts. All of the radionuclides omitted from the dose assessment have half-lives of less than 2 minutes. Chlorine-39, whose portion among the LANSCE air emissions was negligible (less than 0.01 percent per year), also was omitted from the dose assessment.

Table C–4 Radiological Air Emissions (curies per year) from the Chemistry and Metallurgy Research Building (Technical Area 3-29) [a]

Radionuclide	*No Action*	*Reduced Operations*	*Expanded Operations*
Stack ES-14 Height (meters) = 15.9 Diameter (meters) = 1.07 Exit velocity (meters per second) = 6.8			
Actinides [b]	0.00076	0.00003	Same as No Action
Stack ES-46 [c] Height (meters) = 16.5 Diameter (meters) = 1.88 Exit velocity (meters per second) = 1.9			
Krypton-85	100	Same as No Action	Same as No Action
Xenon-131m	45	Same as No Action	Same as No Action
Xenon-133	1,500	Same as No Action	Same as No Action

[a] Projected emission rates are from the *CMRR EIS* (DOE 2003b). For the No Action and Expanded Operations Alternatives, because of the start of the Chemistry and Metallurgy Research Replacement Facility Project, there would be no emissions from the Chemistry and Metallurgy Research Building after approximately 2014. The actinide processes and resulting emissions would move to a new facility near TA-55 and the Wing 9 processes would move to the Radiological Sciences Institute. The support for hydrodynamic testing and tritium separation activities would remain at TA-55.

[b] Actinides were not broken down by isotope and were represented by plutonium-239. Actinides are emitted from almost all wings. The most conservative stack (ES-14) was chosen to model these emissions. The most conservative lung absorption rate for plutonium-239 (moderate) was chosen.

[c] Fission products are emitted from Wing 9. The most conservative stack (ES-46) was chosen for modeling.

Note: To convert meters to feet, multiply by 3.2808.

Table C–5 Radiological Air Emissions (curies per year) from the Sigma Complex (Technical Area 3-66)

Radionuclide	*No Action*	*Reduced Operations*	*Expanded Operations*
All Stacks [a] Height (meters) = 15.2 Diameter (meters) = 1.2 Exit velocity (meters per second) = 1			
Uranium-234 [b]	0.0000660	Same as No Action	Same as No Action
Uranium-238 [b, c]	0.0018	Same as No Action	Same as No Action

[a] Stacks are no longer monitored. Emissions now based on process knowledge and inventory. Depleted uranium is considered as uranium-238 and enriched uranium is considered as uranium-234.
[b] The most conservative lung absorption rate (slow) was chosen for all uranium and thorium isotopes. A moderate lung absorption rate was used for protactinium.
[c] All uranium-238 is assumed to be in equilibrium with thorium-234 and protactinium-234m.
Note: To convert meters to feet, multiply by 3.2808.

Table C–6 Radiological Air Emissions (curies per year) from the Machine Shops (Technical Area 3-102)

Radionuclide	*No Action*	*Reduced Operations*	*Expanded Operations*
Stack ES-22 Height (meters) = 13.4 Diameter (meters) = 0.91 Exit velocity (meters per second) = 0.8			
Uranium-238 [a]	0.00015	Same as No Action	Same as No Action

[a] Uranium-238 was used to model all uranium. Protactinium-234m and thorium-234 are in equilibrium with uranium-238. The most conservative lung absorption rate (slow) was chosen for uranium and thorium. A moderate lung absorption rate was used for protactinium.
Note: To convert meters to feet, multiply by 3.2808.

Table C–7 Radiological Air Emissions (curies per year) from High Explosives Processing Facilities (Technical Area 11)

Radionuclide	*No Action*	*Reduced Operations* [a]	*Expanded Operations*
Area size (square meters) = 10,000 [b]			
Uranium-234 [c]	3.71×10^{-7}	2.97×10^{-7}	3.71×10^{-7}
Uranium-235 [d, c]	1.89×10^{-8}	1.51×10^{-8}	1.89×10^{-8}
Uranium-238 [e, c]	9.96×10^{-7}	7.97×10^{-7}	9.96×10^{-7}

[a] For Reduced Operations, a 20 percent reduction in operations was assumed to result in a 20 percent reduction in air emissions.
[b] No stack emissions. This is an area source.
[c] The most conservative lung absorption rate (slow) was chosen for all uranium and thorium. A moderate lung absorption rate was used for protactinium.
[d] Thorium-231 is in equilibrium with uranium-235.
[e] Thorium-234 and protactinium-234m are in equilibrium with uranium-238.
Note: To convert square meters to square feet, multiply by 10.764.

Table C–8 Radiological Air Emissions (curies per year) from High Explosives Testing Facilities (Technical Area 15 and Technical Area 36) [a]

Radionuclide	*No Action*	*Reduced Operations* [b]	*Expanded Operations*
Area size (square meters) = 100 [c]			
Uranium-234 [f]	0.0345	0.0276	0.0345
Uranium-235 [d, f]	0.0015	0.0012	0.0015
Uranium-238 [e, f]	0.114	0.0912	0.114

[a] Depleted uranium was modeled as 27 percent uranium-234, 1 percent uranium-235, and 72 percent uranium-238 per curie of release, per LANL guidance in *Dose Assessment Using CAP88*, RRES-MAQ-501, R6 (LANL 2003b).
[b] For Reduced Operations, a 20 percent reduction in operations was assumed to result in a 20 percent reduction in air emissions. The reduction of experiments with special nuclear material at the Dual Axis Radiographic Hydrodynamic Test Facility was assumed to have no effect on air emissions.
[c] No stack emissions. This is an area source.
[d] Thorium-231 is in equilibrium with uranium-235.
[e] Thorium-234 and protactinium-234m are in equilibrium with uranium-238.
[f] The most conservative lung absorption rate (slow) was chosen for all uranium and thorium. A moderate lung absorption rate was used for protactinium.
Note: To convert square meters to square feet, multiply by 10.764.

Table C–9 Radiological Air Emissions (curies per year) from the Tritium Facility (Technical Area 16)

Radionuclide	*No Action*	*Reduced Operations*	*Expanded Operations*
Stack FE-04 Height (meters) = 18.3 Diameter (meters) = 0.46 Exit velocity (meters per second) = 19.3			
Tritium (gas)	300	Same as No Action	Same as No Action
Tritium (water vapor)	500	Same as No Action	Same as No Action

Note: To convert meters to feet, multiply by 3.2808.

Table C–10 Radiological Air Emissions (curies per year) from the Pajarito Site (Technical Area 18)

Radionuclide	*No Action*	*Reduced Operations* [a]	*Expanded Operations* [a]
Area size (square meters) = 45,200 [b]			
Argon-41	102	Same as No Action	Same as No Action

[a] Under reduced and expanded operations, the Solution High-Energy Burst Assembly would be removed from TA-18 in about 2009, thereafter there would be no radiological air emissions.
[b] No stack emissions. This is an area source from operations that activate argon atoms in the air surrounding the assembly.
Note: To convert square meters to square feet, multiply by 10.764.

Table C–11 Radiological Air Emissions (curies per year) from the Radiochemistry Facility (Technical Area 48)

Radionuclide [a]	*No Action*	*Reduced Operations*	*Expanded Operations*
Fan Exhaust FE-51/54 [b] Height (meters) = 13.1 Diameter (meters) = 0.91 Exit velocity (meters per second) = 7.9			
Plutonium-239 [c]	0.0000121	Same as No Action	Same as No Action
Uranium-235 [c]	0.000000484	Same as No Action	Same as No Action
Mixed Fission Products [d]	0.000154	Same as No Action	Same as No Action
Fan Exhaust FE-63/64 [e] Height (meters) = 13.4 Diameter (meters) = 0.3 Exit velocity (meters per second) = 12.5			
Arsenic-72 [f]	0.000121	Same as No Action	Same as No Action
Arsenic-73 [f]	0.00255	Same as No Action	Same as No Action
Arsenic-74 [f]	0.00133	Same as No Action	Same as No Action
Beryllium-7 [f]	0.0000165	Same as No Action	Same as No Action
Bromine-77 [f]	0.000935	Same as No Action	Same as No Action
Germanium-68 [f, h]	0.00897	Same as No Action	Same as No Action
Rubidium-86 [g]	0.000000308	Same as No Action	Same as No Action
Selenium-75 [g]	0.000385	Same as No Action	Same as No Action
Other Activation Products [i]	0.00000558	Same as No Action	Same as No Action

[a] All radionuclides at TA-48 were increased 10 percent (over *1999 SWEIS* amounts or highest actual emission rate, whichever was higher).
[b] Actinides are emitted through several unmonitored stacks at TA-48. The most conservative stack (Fan Exhaust FE-51/54 exits through stack 54) was chosen to model emissions from these stacks.
[c] The most conservative lung absorption rates (moderate for plutonium and slow for uranium) were chosen.
[d] Mixed Fission Products were not broken down by isotopes and were represented by strontium-90 and yttrium-90 in equilibrium. The default lung absorption rate (moderate) was used.
[e] Activation products are emitted through several stacks at TA-48. The most conservative stack (Fan Exhaust FE-63/64 exits through stack 7) was chosen to model emissions from these stacks.
[f] The lung absorption rate (moderate) was used.
[g] The default lung absorption rate (fast) was used
[h] Germanium-68 was assumed to be in equilibrium with gallium-68.
[i] Other Activation Products are a mixed group of activation products represented by strontium-90 and yttrium-90 in equilibrium. The default lung absorption rate (moderate) was used.
Note: To convert meters to feet, multiply by 3.2808.

Table C–12 Radiological Air Emissions (curies per year) from the Los Alamos Neutron Science Center (LANSCE) (Technical Area 53) [a, b]

Radionuclide	*No Action*	*Reduced Operations*	*Expanded Operations*
Stack ES-2 Height (meters) = 13.1 Diameter (meters) = 0.91 Exit velocity (meters per second) = 7			
Argon-41	453	0	453
Carbon-11 (dioxide)	18,400	0	18,400
Mercury-193	30.1	0	30.1
Nitrogen-13	2,860	0	2,860
Oxygen-15	3,820	0	3,820
Stack ES-3 [c] Height (meters) = 33.5 Diameter (meters) = 0.91 Exit velocity (meters per second) = 12.5			
Argon-41	431	0	431
Carbon-11[d] (dioxide)	4,090	0	4,090
Nitrogen-13	240	0	240
Oxygen-15	60	0	60
Area size (square meters) = 1,432 [e]			
Argon-41	3.2	0	3.2
Carbon-11 (dioxide)	76.8	0	76.8

[a] The total curies emitted changed from the *1999 SWEIS* emission rates based on a revised curie per microamp-hour ratio. Under the Reduced Operations Alternative, there would be no emissions due to the shutdown of all activity at LANSCE.

[b] Carbon-10 and oxygen-14 were not modeled. They both are very short-lived nuclides (less than 2 minutes) and have no published dose conversion factor. They would have minimal health impacts.

[c] Emission projections for the Isotope Production Facility were modeled as being released from stack ES-3 in addition to evacuations from experimental areas A, B, and C and associated lines B and C tunnels. Expanded Operations include emissions for up to 100 irradiated targets for medical isotope processing.

[d] Total carbon-11 from stack ES-3 and the Isotope Production Facility.

[e] These are fugitive sources created at the accelerator target cells that have migrated into room air and into the environment.

Note: To convert meters to feet, multiply by 3.2808.

Table C–13 Radiological Air Emissions (curies per year) from Waste Management Operations (Technical Area 54)

Radionuclide	*No Action*	*Reduced Operations*	*Expanded Operations*
Area size (square meters) = 5,000 [a]			
Tritium (water vapor)	60.9	Same as No Action	Same as No Action
Americium-241 [b]	6.6×10^{-7}	Same as No Action	Same as No Action
Plutonium-238 [c]	4.80×10^{-6}	Same as No Action	Same as No Action
Plutonium-239 [c]	6.80×10^{-7}	Same as No Action	Same as No Action
Uranium-234 [c]	8.00×10^{-6}	Same as No Action	Same as No Action
Uranium-235 [c]	4.10×10^{-7}	Same as No Action	Same as No Action
Uranium-238 [c]	4.00×10^{-6}	Same as No Action	Same as No Action
Stack 54-412 (DVRS) Height (meters) = 10.7 Diameter (meters) = 0.69 Exit velocity (meters per second) = 16.6			
Americium-241 [b]	3.53×10^{-6}	Same as No Action	Same as No Action
Plutonium-238 [c]	1.76×10^{-5}	Same as No Action	Same as No Action
Plutonium-239 [c]	7.78×10^{-6}	Same as No Action	Same as No Action

DVRS = Decontamination and Volume Reduction System.

[a] These emissions are from an area source. They are conservatively based on a 5-year average plus two standard deviations of nearby environmental concentration measurements.

[b] The default lung absorption rate (moderate) was used.

[c] The most conservative lung absorption rates (moderate for plutonium and slow for uranium) were chosen.

Note: To convert meters to feet, multiply by 3.2808; to convert square meters to square feet, multiply by 10.764.

Table C–14 Radiological Air Emissions (curies per year) from the Plutonium Facility Complex (Technical Area 55)

Radionuclide	*No Action*	*Reduced Operations*	*Expanded Operations* [a]
Stack ES-15 Height (meters) = 9.5 Diameter (meters) = 0.93 Exit velocity (meters per second) = 6.8			
Plutonium-239 [b]	0.0000025	Same as No Action	Same as No Action
Stack ES-16 Height (meters) = 9.5 Diameter (meters) = 0.94 Exit velocity (meters per second) = 10.8			
Plutonium-239 [b]	0.000017	Same as No Action	0.000036
Tritium (gas)	250	Same as No Action	Same as No Action
Tritium (water vapor)	750	Same as No Action	Same as No Action

[a] Expanded operations include pit production (80 pits), pit surveillance (65 pits), actinide processing 1,764 pounds (800 kilograms), and pit disassembly capacity (500 pits).

[b] No isotopic breakdown of particulates was available; therefore all particulates were represented by plutonium-239. The most conservative lung absorption rate (moderate) was chosen.

Note: To convert meters to feet, multiply by 3.2808.

Table C–15 Radiological Air Emissions (curies per year) from Non-Key Facilities (Technical Area 21)

Radionuclide	*No Action* [a]	*Reduced Operations* [a]	*Expanded Operations* [a]
Stack ES-1 (TA-21 Tritium Science and Fabrication Facility) Height (meters) = 22.9 Diameter (meters) = 1.22 Exit velocity (meters per second) = 10.3			
Tritium (water vapor) [b]	50	Same as No Action	Same as No Action
Stack ES-5 (TA-21 Tritium Systems Test Assembly) Height (meters) = 29.9 Diameter (meters) = 0.79 Exit velocity (meters per second) = 7.8			
Tritium (gas)	100	Same as No Action	Same as No Action
Tritium (water vapor) [c]	400	Same as No Action	Same as No Action

TA = technical area.

[a] Emissions from TA-21 stacks were stopped in September 2006 as part of TA-21 shutdown activities. Decontamination, decommissioning, and demolition of TA-21 under the Expanded Operations Alternative would permanently eliminate this potential source of emissions.

[b] Tritium emissions are based on LANL estimates of neutron target tube loading operations through the end of 2006 while awaiting decontamination, decommissioning, and demolition. The more conservative water vapor form of tritium was used.

[c] Tritium emissions (water vapor) were increased from the *1999 SWEIS* based on actual emission data (1999 through 2004) and expected emission rate while awaiting decontamination, decommissioning, and demolition.

Note: To convert meters to feet, multiply by 3.2808.

Stack Parameters

The height and diameter measurements of monitored stacks were taken from the 2003 LANL Radionuclide Air Emissions Report (LANL 2004c). The same exit velocities for those stacks were used as in the *1999 SWEIS*. The parameters used for unmonitored stacks were obtained from LANL staff (LANL 2006a). Stack parameters are listed in Tables C–4 through C–15.

Agricultural Data

One pathway of exposure modeled by CAP88 is emission of radionuclides to the air and their subsequent ingestion through food crops. CAP88 uses average agricultural productivity data for New Mexico based on the address of LANL when determining the agricultural data. The EPA Food Source Scenario used in CAP88 describes the fraction of vegetables, milk, and meat produced in the area. The ingestion (consumption) rates are the same for all scenarios. The "rural" scenario was used and included the following fractions.

Fraction	***Vegetable***	***Milk***	***Meat***
Produced at home	0.7	0.399	0.442
From the region (not imported)	0.3	0.601	0.558

C.1.3.4 Results of Analyses

The sequence of analyses performed to generate the radiological impact estimates from normal operations included selection of normal operational modes, estimation of source terms, estimation of environmental transport and uptake of radionuclides, calculation of radiation doses to exposed individuals, and estimation of health effects. There are uncertainties associated with each of these steps. Uncertainties exist in the way the physical systems being analyzed are represented by the computational models and in the data required to exercise the models (due to measurement, sampling, or natural variability).

The analysis was designed to ensure—through judicious selection of release scenarios, models, and parameters—that the results represent the potential risks. This was accomplished by making conservative assumptions in the calculations at each step. The models, parameters, and release scenarios used in the calculations were selected such that most intermediate results and, consequently, final estimates of impacts, were greater than would be expected. As a result, even though the range of uncertainty in a quantity might be large, the value calculated for any one modeled dose would be close to one of the extremes in the range of possible values, so the chance of the actual dose being greater than the calculated value would be low. The goal of the radiological assessment for normal operations in this SWEIS is to produce conservative results in order to capture any uncertainties in normal operations.

Maximally Exposed Individual

The facility-specific MEI represents a location near a facility that was modeled as having the greatest dose to a hypothetical public individual from all modeled emissions. This location was determined for each Key Facility and was calculated based on meteorological data for the site, as well as the type and amount of radiological air emissions from the Key Facility. For the purposes of this analysis, it was very conservatively assumed that the MEI is a person who stays in the same location 24 hours a day, 365 days a year. Furthermore, it was assumed that this person is not shielded from emissions by clothing or shelter (for example, a building, auto, home, etc.).

The doses were then calculated at each facility-specific MEI location from all other modeled facilities; thus, the facility-specific MEI represents the estimated dose to an individual near the specified facility from all modeled facilities. **Table C–16** summarizes the dose to each facility MEI from emissions from all modeled facilities. **Tables C–17** through **C–19** compare the facility-specific MEI for each of the three alternatives considered in this SWEIS. Each facility-specific MEI was totaled and the facility-specific MEI with the highest total dose was designated the LANL site-wide MEI for that alternative. Therefore any facility-specific MEI dose would be less than the LANL site-wide MEI for that alternative.

Table C–16 Summary of Facility-Specific Maximally Exposed Individual Dose (millirem per year) [a, b]

	No Action Alternative	*Reduced Operations Alternative*	*Expanded Operations Alternative*
Chemistry and Metallurgy Research Building and Sigma Complex [c]	0.46	0.13	0.46
Machine Shops	0.37	0.08	0.37
High Explosives Processing Facilities	0.38	0.11	0.38
High Explosives Testing Facilities	2.9	0.78	2.9
Tritium Facility	0.32	0.09	0.32
Pajarito Site [d]	2.9	0.78	2.9
Radiochemistry Facility and Plutonium Facility Complex [e]	0.78	0.20	0.78
Los Alamos Neutron Science Center [f]	14	0.24	14
Waste Management Operations	1.2	0.33	1.2
Non-Key Facilities (TA-21) [g]	1.9	0.29	1.9

TA = technical area.

[a] Doses are from all modeled facilities.

[b] Under the No Action Alternative and the Expanded Operations Alternative, the LANL site-wide MEI would be located near LANSCE. Under the Reduced Operations Alternative, the LANL site-wide MEI would be located near the Firing Sites at TA-36.

[c] Chemistry and Metallurgy Research Building and Sigma Complex had the same MEI location.

[d] Under the Reduced and Expanded Operations Alternatives, Pajarito Site (TA-18) would not be operational after about 2009, thereby eliminating the need for a designated facility-specific MEI dose.

[e] Radiochemistry Facility and Plutonium Facility Complex had the same MEI location.

[f] As a mitigating measure, operational controls at LANSCE would limit their portion of the MEI dose to 7.5 millirem, resulting in lower doses.

[g] Emissions from TA-21 stacks were stopped in September 2006 as part of TA-21 shutdown activities. Decontamination, decommissioning, and demolition of TA-21 under the Expanded Operations Alternative would permanently eliminate this potential source of radiation dose.

LANL site-wide MEI dose impacts for the No Action (Table C–17) and Expanded Operations (Table C–19) Alternatives reflect the change in location of the actinide processes at the Chemistry and Metallurgy Research Building to the new Chemistry and Metallurgy Research Replacement Facility near TA-55. These impacts on the doses were determined by calculating the net dose (removal of the dose from operations at the Chemistry and Metallurgy Research Building and addition of the dose from operations at the new Chemistry and Metallurgy Research Replacement Facility). These impacts to the MEI were minimal. For the Reduced Operations Alternative (Table C–18), LANL site-wide MEI dose impacts reflect the continued operations at the existing Chemistry and Metallurgy Research Building in TA-3.

Under the No Action and Expanded Operations Alternatives, operational controls at LANSCE would limit the amount of radiological air emissions. It is assumed that there is a dose limit of 7.5 millirem to the MEI from LANSCE emissions. This dose limit, when added to the doses from operations at all other Key Facilities, would result in a LANL site-wide MEI dose of 7.8 millirem under the Expanded Operations Alternative. The regulatory limit of 10 millirem per year (Title 40 *Code of Federal Regulations* [CFR] 61.92) to a member of the public, therefore, would not be exceeded under any of the SWEIS alternatives. The highest estimated dose to the MEI from normal LANL operations, 8.2 millirem per year, would be under the Expanded Operations Alternative and includes the additional dose (0.42 millirem per year) from remediation activities (see Chapter 5, Section 5.6 and Appendix I, Section I.5.6).

Table C–17 Maximally Exposed Individual Dose for the No Action Alternative (millirem per year)

Source	*CMR/ Sigma MEI*	*Machine Shop MEI*	*TA-11 MEI*	*TA-15/ TA-36 MEI*	*TA-16 MEI*	*TA-18 MEI*	*TA-48/ TA-55 MEI*	*TA-53 MEI*	*TA-54 MEI*	*Non-Key (TA-21) MEI*
CMR Building	0.0639	0.0435	0.00540	0.0158	0.00513	0.0111	0.0549	0.0113	0.00609	0.0158
Sigma Complex	0.0262	0.0114	0.00206	0.00598	0.00135	0.00411	0.0243	0.00412	0.00225	0.00598
Machine Shops	0.00225	0.00225	0.000165	0.000450	0.000165	0.000315	0.00165	0.000315	0.000180	0.000450
High Explosives Processing Facilities	0.00000118	0.00000127	0.0000212	0.00000230	0.00000736	0.00000212	0.00000281	0.00000134	0.00000109	0.00000142
High Explosives Testing Facilities	0.0866	0.0551	0.102	0.899	0.0716	0.809	0.131	0.247	0.304	0.292
Tritium Facility	0.00522	0.00491	0.0184	0.00447	0.0243	0.00455	0.00478	0.00362	0.00375	0.00393
Pajarito Site	0.000551	0.000520	0.000683	0.00796	0.000530	0.0979	0.000898	0.00704	0.0194	0.00326
Radiochemistry Facility	0.000192	0.000161	0.0000778	0.000496	0.0000703	0.000304	0.00194	0.000289	0.000151	0.000350
LANSCE	0.269	0.240	0.241	1.88	0.209	1.97	0.516	13.3 [a]	0.81	1.57
Waste Management Operation	0.00107	0.00106	0.00107	0.00116	0.00106	0.00121	0.00107	0.00117	0.0520	0.00110
Plutonium Facility Complex	0.00715	0.00663	0.00530	0.0240	0.00496	0.0145	0.0399	0.0117	0.00856	0.0153
TA-21 Non-Key Facilities	0.00266	0.00252	0.00242	0.00705	0.00209	0.00478	0.00374	0.0115	0.00277	0.0223
Total	**0.46**	**0.37**	**0.38**	**2.85**	**0.32**	**2.92**	**0.78**	**13.56 [a, b]**	**1.21**	**1.93**

CMR = Chemistry and Metallurgy Research, MEI = maximally exposed individual, TA = technical area, LANSCE = Los Alamos Neutron Science Center.

[a] As a mitigating measure, operational controls at LANSCE would limit their portion of the MEI dose to 7.5 millirem resulting in a LANL site-wide MEI dose of 7.8 millirem.

[b] After approximately 2014, actinide emissions will move from the Chemistry and Metallurgy Research Building to the Chemistry and Metallurgy Research Replacement Facility near TA-55. The resulting dose (an additional 0.0023 millirem) will have minimal impact on the LANL MEI dose.

Table C–18 Maximally Exposed Individual Dose for the Reduced Operations Alternative (millirem per year)

Source	*CMR/ Sigma MEI*	*Machine Shop MEI*	*TA-11 MEI*	*TA-15/ TA-36 MEI*	*TA-16 MEI*	*TA-18 MEI*	*TA-48/ TA-55 MEI*	*TA-53 MEI*	*TA-54 MEI*	*Non-Key (TA-21) MEI*
CMR Building	0.0135	0.00921	0.00117	0.00342	0.00111	0.00235	0.0119	0.00250	0.00134	0.00342
Sigma Complex	0.0262	0.0114	0.00206	0.00598	0.00135	0.00411	0.0243	0.00412	0.00225	0.00598
Machine Shops	0.00225	0.00225	0.000165	0.000450	0.000165	0.000315	0.00165	0.000315	0.000180	0.000450
High Explosives Processing Facilities	0.000000947	0.00000102	0.0000169	0.00000184	0.00000589	0.00000169	0.00000225	0.00000107	0.000000872	0.00000114
High Explosives Testing Facilities	0.0693	0.0441	0.0816	0.720	0.0573	0.648	0.105	0.198	0.243	0.234
Tritium Facility	0.00522	0.00491	0.0184	0.00447	0.0243	0.00455	0.00478	0.00362	0.00375	0.00393
Pajarito Site [a]	0.000551	0.000520	0.000683	0.00796	0.000530	0.0979	0.000898	0.00704	0.0194	0.00326
Radiochemistry Facility	0.000192	0.000161	0.0000778	0.000496	0.0000703	0.000304	0.00194	0.000289	0.000151	0.000350
LANSCE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Waste Management Operation	0.00107	0.00106	0.00107	0.00116	0.00107	0.00121	0.00107	0.00117	0.0520	0.00110
Plutonium Facility Complex	0.00715	0.00663	0.00530	0.0240	0.00496	0.0145	0.0399	0.0117	0.00856	0.0153
TA-21 Non-Key [b] Facilities	0.00266	0.00252	0.00242	0.00705	0.00209	0.00478	0.00374	0.0115	0.00277	0.0223
Total (millirem per year)	**0.13**	**0.08**	**0.11**	**0.78**	**0.09**	**0.78**	**0.20**	**0.24**	**0.33**	**0.29**

CMR = Chemistry and Metallurgy Research, MEI = maximally exposed individual, TA = technical area, LANSCE = Los Alamos Neutron Science Center.

[a] Pajarito Site (TA-18) would not be operational after 2009 under this alternative and would therefore not produce emissions. These values are potentially applicable for the first few years.

[b] Emissions from TA-21 stacks were stopped in September 2006 as part of TA-21 shutdown activities. However, some emissions are assumed until decontamination, decommissioning, and demolition are complete.

Table C–19 Maximally Exposed Individual Dose for the Expanded Operations Alternative (millirem per year)

Source	*CMR/ Sigma MEI*	*Machine Shop MEI*	*TA-11 MEI*	*TA-15/ TA-36 MEI*	*TA-16 MEI*	*TA-18 MEI*	*TA-48/ TA-55 MEI*	*TA-53 MEI*	*TA-54 MEI*	*Non-Key (TA-21) MEI*
CMR Building	0.0639	0.0435	0.00540	0.0158	0.00513	0.0111	0.0549	0.0113	0.00609	0.0158
Sigma Complex	0.0262	0.0114	0.00206	0.00598	0.00135	0.00411	0.0243	0.00412	0.00225	0.00598
Machine Shops	0.00225	0.00225	0.000165	0.000450	0.000165	0.000315	0.00165	0.000315	0.000180	0.000450
High Explosives Processing Facilities	0.00000118	0.00000127	0.0000212	0.00000230	0.00000736	0.00000212	0.00000281	0.00000134	0.00000109	0.00000142
High Explosives Testing Facilities	0.0866	0.0551	0.102	0.899	0.0716	0.809	0.131	0.247	0.304	0.292
Tritium Facility	0.00522	0.00491	0.0184	0.00447	0.0243	0.00455	0.00478	0.00362	0.00375	0.00393
Pajarito Site [a]	0.000551	0.000520	0.000683	0.00796	0.000530	0.0979	0.000898	0.00704	0.0194	0.00326
Radiochemistry Facility	0.000192	0.000161	0.0000778	0.000496	0.0000703	0.000304	0.00194	0.000289	0.000151	0.000350
LANSCE	0.269	0.240	0.241	1.88	0.209	1.97	0.516	13.3 [b]	0.81	1.57
Waste Management Operation	0.00107	0.00106	0.00107	0.00116	0.00106	0.00121	0.00107	0.00117	0.0520	0.00110
Plutonium Facility Complex	0.00729	0.00675	0.00538	0.0248	0.00503	0.0149	0.0412	0.0120	0.00874	0.0157
TA-21 Non-Key Facilities [a]	0.00266	0.00252	0.00242	0.00705	0.00209	0.00478	0.00374	0.0115	0.00277	0.0223
Total (millirem per year)	**0.46**	**0.37**	**0.38**	**2.85**	**0.32**	**2.92**	**0.78**	**13.56** [b, c]	**1.21**	**1.93**

CMR = Chemistry and Metallurgy Research, MEI = maximally exposed individual, TA = technical area, LANSCE = Los Alamos Neutron Science Center.

[a] TA-18 and TA-21 are expected to be decontaminated, decommissioned, and demolished under this alternative and would not produce emissions after that time. These values are applicable for the first few years.

[b] As a mitigating measure, operational controls at LANSCE would limit their portion of the MEI dose to 7.5 millirem resulting in a LANL site-wide MEI dose of 7.8 millirem.

[c] After approximately 2014, actinide emissions will move from the Chemistry and Metallurgy Research Building to the Chemistry and Metallurgy Research Replacement Facility near TA-55. The resulting dose (an additional 0.0023 millirem) will have minimal impact on the LANL MEI dose.

Collective Population Dose

The collective dose to the population living within a 50-mile (80-kilometer) radius from normal operations at LANL was calculated based on emissions from all modeled facilities. The population doses from emissions at each Key Facility were compared and then totaled in **Table C–20**. The majority of the population dose comes from emissions at the High Explosives Testing Facilities and LANSCE under both the No Action and Expanded Operations Alternatives. Under the Reduced Operations Alternative, LANSCE would not be operating; therefore, it would produce no emissions contributing to a population dose.

Table C–20 Collective Population Dose Summary (person-rem per year)

Source	*No Action Alternative Estimated Dose*	*Reduced Operations Alternative Estimated Dose*	*Expanded Operations Alternative Estimated Dose*
Chemistry and Metallurgy Research Building [a]	0.43	0.11	0.43
Sigma Complex	0.16	0.16	0.16
Machine Shops	0.01	0.01	0.01
High Explosives Processing Facilities	0.00005	0.00004	0.00005
High Explosives Testing Facilities	6.4	5.2	6.4
Tritium Facility	0.09	0.09	0.09
Pajarito Site	0.23	0.23 [b]	0.23 [b]
Radiochemistry Facility	0.01	0.01	0.01
Los Alamos Neutron Science Center	22	0.00	22
Waste Management Operations	0.04	0.04	0.04
Plutonium Facilities Complex	0.19	0.19	0.20
Non-Key Facilities (TA-21)	0.09	0.09	0.09 [b]
Total Dose (person-rem per year)	**30**	**6.1**	**36.2** [c]

TA = technical area.

[a] For the No Action and Expanded Operations Alternatives, because of the start of the Chemistry and Metallurgy Research Replacement project there would be no emissions from the Chemistry and Metallurgy Research Building after approximately 2014. The actinide processes and resulting emissions would move to a new facility near TA-55 and the Wing 9 processes would move to the Radiological Sciences Institute. There would be no change in the population dose impact from this move.

[b] TA-18 and TA-21 would be decontaminated, decommissioned, and demolished under these alternatives and would not produce emissions after that time. These values are applicable for the first few years.

[c] The population dose includes 6.2 person-rem that is the maximum annual contribution that may occur from material disposal area remediation (see Appendix I).

Minority and Low-Income Population Dose

Radiological impacts of normal operations on minority, Hispanic, American Indian[3], and low-income populations are determined by applying a methodology similar to that used to determine dose to the total population. This approach is discussed in detail in Section C.1.3. It should be noted that the exposure scenario used to model the minority, Hispanic, American Indian, and low-income populations assumes that these individuals would be exposed in the same manner as

[3] *The term American Indian is used in this environmental justice analysis to reflect definitions used in the 2000 Census. The term Native American is used elsewhere in this SWEIS.*

the general population, that is, by external exposure to a radioactive plume and deposited radioactive materials and by internal exposure from inhalation and from ingestion of foodstuffs.

For purposes of evaluating potential for disproportionately high and adverse impacts caused by radiological emissions from normal operations, an annual collective dose was calculated for each of the subsets of the population being evaluated (minority, Hispanic, American Indian, and low-income) within 50 miles (80 kilometers) of the emission source. **Table C–21** shows the population estimates used for this environmental justice analysis. The average dose to an individual of the minority or low-income population is then calculated to compare to the average dose to an individual from the remainder of the population. The average dose to an individual of the population subset being evaluated is derived by dividing the annual collective dose for the subset by the number of people in the subset.

Table C–21 Potentially Affected Populations

Source Location	*Total Population*	*Total Minority Population*	*Hispanic Population*	*American Indian Population*	*Low-Income Population*
TA-53	283,766	155,261	127,641	17,811	35,826
TA-36	375,495	185,474	151,110	21,263	39,206

The result is then compared to the average dose to an individual who is not a member of the subset being evaluated. The average dose to a member of the remaining population is derived by dividing the annual collective dose to the remainder of the population (collective dose to the total population minus the collective dose to the subset population) by the number of people within 50 miles (80 kilometers) that are not in the population subset. The total minority population includes all Hispanic persons regardless of race. In addition, the American Indian population may include persons who indicated that they were of Hispanic ethnicity in the 2000 Census.

As shown in Table C–20, the total population within 50 miles (80 kilometers) of LANL is projected to receive an annual dose of about 30 person-rem under the No Action Alternative, and 36 person-rem under the Expanded Operations Alternative. Because the majority of these doses (22 person-rem) result from operations at LANSCE, the environmental justice analysis for these alternatives uses the 50-mile (80-kilometer) population centered on LANSCE in TA-53. For the Reduced Operations Alternative, the majority of the collective dose of 6.4 person-rem results from operations at the High-Explosive Testing firing sites at TA-36, therefore, the environmental justice analysis for this alternative uses the 50-mile (80-kilometer) population centered on TA-36.

Table C–22 shows the collective and annual average individual doses used to examine the potential for disproportionately high and adverse impacts on minority, Hispanic, American Indian, and low-income populations. The collective population dose is highest for those populations with the highest number of individuals. Under all alternatives, the largest population is associated with the white, non-Hispanic, and non-low-income populations. The differences, if any, would be most evident on the basis of average individual doses to members of the different population groups. As shown in Table C–22, there are no appreciable differences between the average dose to any minority, Hispanic, American Indian, or low-income individual and the comparable non-minority or non-low-income individual under any of the alternatives. Therefore,

these alternatives would not pose disproportionately high and adverse impacts on minority and low-income populations or individuals surrounding each facility site.

Table C–22 Comparison of Total Minority, Hispanic, American Indian and Low-income Population and Average Individual Annual Doses

	No Action [a] Alternative	*Reduced [a] Operations Alternative*	*Expanded [a] Operations Alternative*
Collective Population Dose (person-rem) [b]	29.2	4.9	29.2
Average Individual Dose (millirem)	0.10	0.013	0.10
White (non-Hispanic) Population Dose (person-rem)	15.0	2.7	15.0
Non-Minority Average Individual Dose (millirem)	0.11	0.014	0.11
Minority Population Dose (person-rem)	14.1	2.2	14.1
Minority Average Individual Dose (millirem)	0.088	0.012	0.088
Hispanic Population Dose (person-rem) [c]	11.3	1.9	11.3
Hispanic Average Individual Dose (millirem)	0.086	0.012	0.086
American Indian Population Dose (person-rem) [d]	1.8	0.20	1.8
American Indian Average Individual Dose (millirem)	0.092	0.0094	0.092
Non-low-income Population Dose (person-rem)	25.9	4.4	25.9
Non-low-income Average Individual Dose (millirem)	0.10	0.013	0.10
Low-Income Population Dose (person-rem)	3.0	0.44	3.0
Low-Income Average Individual Dose (millirem)	0.082	0.011	0.082

[a] The collective population dose displayed in this table, accounts for the estimated dose from LANSCE at TA-53 and the High Explosive Testing firing sites at TA-36 for the No Action and Expanded Operations Alternatives, and the firing sites at TA-36 for the Reduced Operations Alternative.

[b] The collective population doses for this environmental justice analysis differ by plus or minus 3 to 6 percent from those in Table C–20. This difference is due to different models used to estimate the populations; both estimates are based on data drawn from the 2000 decennial census. The SECPOP computer program used for the analysis for Table C–20 does not allow for the identification of minority and low-income populations. Therefore an alternate method that uses a more refined distribution of the population is used for this analysis. The minor differences do not affect the conclusions supported by the analyses.

[c] The total Hispanic population includes all Hispanic persons regardless of race.

[d] The American Indian population may include persons who indicated that they were of Hispanic ethnicity in the 2000 census.

Under all alternatives, the annual population and average individual dose would be highest for the white (non-Hispanic) population. Similarly the projected annual population and average individual dose for persons living above the poverty level (non-low-income populations) would be higher than for those living below the poverty threshold. These data indicate that under all alternatives there would not be disproportionately high and adverse impacts on minority, Hispanic, American Indian, and low-income populations surrounding LANL.

C.1.4 Impacts to Offsite Resident, Recreational User, and Special Pathways Receptors from Radionuclides and Chemical Contaminants in the Environment

C.1.4.1 Methodology

Earlier investigation of exposure pathways in the vicinity of LANL (DOE 1999a) concluded that ingestion of foodstuffs and water and incidental ingestion of soil and sediment were of primary interest. Several other contact exposure pathways (including dermal absorption of contaminants from clays used in pottery, bathing or ceremonial use of springs, and smoking of native vegetation) were examined at that time and were not found to be significant contributors to risk. Recent environmental surveillance results and other reports on conditions following the 2000 Cerro Grande Fire indicated that diet, land use, and cultural practices remain largely unchanged from conditions noted in the *1999 SWEIS* analysis, and that, apart from inhalation, ingestion continues to be the only significant pathway by which people in the region adjacent to LANL might be exposed to radioactive and other contaminants resulting from operations at the site. Risks from radionuclides and chemicals in the environment, therefore, were evaluated for three receptors and ingestion exposure scenarios, collectively referred to as "specific receptors." The specific receptors and the rationale for the selection of ingestion exposure parameters for this analysis are as follows:

- **Offsite Resident.** This receptor represents the resident of Los Alamos County whose living habits and diet tend to produce higher than average exposures to radioactive materials and chemicals in the local environment. The resident also was assumed to use water from the Los Alamos County water supply and to have a garden at their home that produced the fruit and vegetables that they consumed. The resident also was assumed to consume local game animals, game fish, honey, and pinyon nuts, as well as beef and milk produced on local farms and ranches. Accordingly, the pathways considered for this resident include ingestion of groundwater and the above-listed foods, plus inadvertent ingestion of soils and sediments on produce, such as leafy greens and root vegetables. The assumption that the offsite resident consumes all components of the diet and that all the foodstuffs are produced locally (that is no dilution by store-bought or processed foods from outside the area) tends to raise the intake of contaminants well above that of the average person living near LANL. In fact, at the 95th percentile consumer (high-intake) rates published by EPA for each foodstuff, a diet consisting of locally-raised beef, milk, fruits, and vegetables, plus local big game animals and fish, fairly approximates a "subsistence" diet (over 4 pounds [1.83 kilograms] of fruits and vegetables, 1.2 pounds [0.55 kilograms] of meat and fish, and 1.7 pints [0.8 liters] of milk per day), particularly when combined with the additional foods described under "specials pathways". The 95th percentile consumer eats these foodstuffs at a rate greater than 95 percent of the population.

- **Recreational User of Wildlands.** The recreational user represents a hypothetical outdoor enthusiast who regularly uses the canyons on and near LANL for recreation (as a hiker, rockhound, photographer, etc.). This receptor was assumed to make an average of two visits per month to the canyons, spending 8 hours per visit. This receptor was assumed to be exposed to environmental contaminants by consumption of surface water

and the incidental ingestion of soils and sediments at concentrations typical of the LANL canyons. Ingestion of sediments and soils occurs from consuming surface water and from swallowing inhaled dust. It is reasonable to assume that the recreational user is a local resident and that, in the extreme case, exposures received in the course of outdoor recreation might be *additional to* those depicted by the offsite resident.

- **Special Pathways – Subsistence Consumption of Fish and Wildlife**. Section 4–4 of Executive Order 12898 directs that "Federal agencies whenever practicable and appropriate, shall collect, maintain, and analyze information on the consumption patterns of populations who principally rely on fish and/or wildlife for subsistence" and that "Federal agencies shall communicate to the public the risks of those consumption patterns." Therefore, special exposure and diet pathways were evaluated to assess the potential impacts to Native American, Hispanic, and other residents whose traditional living habits and diets could cause larger exposures to environmental contaminants than those experienced by the hypothetical offsite resident. The foodstuffs and pathways of specific interest for this group are ingestion of game animals, including consumption of some organ meats not assumed for the "resident" receptor, ingestion of game fish and other fish taken from local waters, and ingestion of native vegetation through use of Indian Tea (Cota). In general, these intakes can be assumed to be *in addition to* the meat, milk, produce, water, and soil and sediment consumption reflected in the offsite resident plus recreational user pathway assumptions.

The types and amounts of foods represented in the offsite resident diet package suggested that consumption of all items at the *high* intake rates, plus the three additional special pathways components (non-game fish, herbal teas, organ meats), approximates a subsistence diet for someone living in the vicinity of LANL. To confirm that proposition, a trial was done in which the combined intakes (offsite resident plus recreational user plus special pathways) were adjusted to create a model diet consisting entirely of items that would likely be staple foods for a person living a subsistence life near Los Alamos. Milk, beef, and game fish were removed from the offsite resident diet package and groundwater was replaced by surface (stream) water as the sole source of drinking water. The intakes of the remaining foods – deer, elk, non-game fish; produce (beans, corn, squash, and greens); fruit (plums, apricots, and apples); honey and pinyon nuts – were then scaled up to deliver a total of 2,700 calories per day. The radiation dose from consumption of this subsistence diet was determined to be 9.1 millirem per year, consistent with the special pathways consumer at the high intake rates.

Concentrations of radionuclides and chemicals in environmental media reported in LANL Environmental Surveillance Reports for 2001 through 2004 (LANL 2002b, 2004b, 2004d, 2005b) were used in the dose and risk analysis except where noted in the table (see Tables C–24 through C–40). Chemical and radionuclide concentrations in the *2005 LANL Environmental Surveillance Report* (LANL 2006b) were reviewed and found to be enveloped by the 2001 through 2004 measurements. For each environmental medium, the mean and 95 percent upper confidence limit[4] of the reported values were calculated. Data from locations near the LANL boundary, identified in the reports as "perimeter" locations, were used to calculate dose and risk to the offsite resident receptor. For the special pathways receptor, data from bottom-feeder fish

[4] *Calculated using the methodology described in Appendix F.*

taken at locations downstream from LANL were used to represent the maximum impact of LANL emissions and runoff. Data from the limited number of published LANL analysis results for elk heart and liver and Indian Tea (Cota) were used to complete the intake for the special pathways receptor. For the recreational user receptor, soil, sediment and surface water analysis results for onsite locations accessible to the public were used.

Because of the small number of samples reported for some media (all items are not necessarily sampled every year) calendar year 1999 and 2000 results for foodstuffs were also considered, thereby increasing the number of data points used to develop the 95 percent upper confidence limit values and reducing uncertainty. Uncertainties associated with measured contaminant concentrations in environmental media may be quite large, and the 95 percent upper confidence limit values were used when calculating dose to hypothetical individuals to help ensure that the dose and risk estimates were conservative. For radionuclides, additional conservatism was introduced by calculating the 95 percent upper confidence limit values using only those reported values that were greater than zero. This was performed for several reasons. First, the same method was used to develop the 95 percent upper confidence limit values for calculating ingestion doses in the *1999 SWEIS.* By using the same approach, the results of the current analysis can be compared directly with the 1999 results for each pathway component. Second, concentrations of the radionuclides of interest in environmental media are typically quite low (near the threshold of detection) and, when corrected for counting background radiation, negative concentrations of some radionuclides were reported. Setting the negative values to zero or to the limit of detection for a particular radionuclide is complicated by the fact that analytical methods, detection limits, and data reporting formats may vary from year to year. Finally, the ingestion pathway doses are quite small even when they are biased upwards by eliminating the zero and negative sample results. When calculating 95 percent upper confidence limit values for nonradioactive contaminants, a similar conservatism was introduced by using a value *equal to the lower limit of detection* for all samples reported as below the detection limit.

Based on a review of LANL environmental surveillance data and the results of ingestion pathway exposure calculations published in the *1999 SWEIS*, it was determined that consumption of water, soil, sediment, fish, and produce would account for essentially all ingestion exposure to nonradioactive contaminants. Accordingly, only those five pathway components were analyzed for contribution to nonradiological risk. **Table C–23** summarizes the ingestion exposure pathway components that were evaluated for each receptor.

The consumption rate of each component of the ingestion pathway was assumed to equal the average adult daily intake. The average adult daily intake of each foodstuff is defined as the 50^{th} percentile. The "high" daily consumer is defined as the 95^{th} percentile consumer. In other words, 95 percent of the population eats at a rate less than the high daily consumption rate. These rates and doses are typically 2-3 times higher than for the average case. The intake rates, their sources, and the doses for both intake rates are reported in the notes following the dose calculation tables for the various components of the ingestion pathway. For chemicals, the health hazard index and cancer risk were calculated using the most current Reference Doses and Slope Factors published by EPA Region 6 (EPA 2005b).

Table C–23 Ingestion Exposure Pathway Components Evaluated for Offsite Resident, Recreational User, and Special Pathways Receptors

Exposure Pathway Component	*Offsite Resident* [a]	*Recreational User* [b]	*Special Pathways* [c]
Produce	✓	✓	✓
Meat (free-range beef)	✓	✓	✓
Milk	✓	✓	✓
Fish (game)	✓	✓	✓
Elk	✓	✓	✓
Deer	✓	✓	✓
Honey	✓	✓	✓
Pinyon nuts	✓	✓	✓
Groundwater	✓	✓	✓
Soil	✓	✓	✓
Sediment	✓	✓	✓
Surface water		✓	✓
Soil [d]		✓	✓
Sediment [d]		✓	✓
Fish (non-game)			✓
Elk (heart, liver)			✓
Indian Tea (Cota)			✓

[a] A hypothetical person who is conservatively assumed to intake various foodstuffs, water, soil and sediments with concentrations of contaminants at the 95 percent upper confidence limit for each contaminant.
[b] Assumed to visit the canyons on and near LANL 24 times per year, 8 hours per visit.
[c] Assumed to have traditional Native American or Hispanic lifestyles and diet.
[d] Soil and sediments from onsite locations.

C.1.4.2 Estimates of Ingestion Pathway Radiation Dose and Risk

The results of the radiation dose calculations for each of the receptors and components of the ingestion pathway are summarized in **Tables C–24** through **C–40**. Except where noted, all intake rates are in grams dry weight per year. The total doses from all pathway components are presented in **Table C–41**.

Table C–24 Dose from the Consumption of Produce

Exposure Pathway: Produce Ingestion				
Intake (grams per year)	***Nuclide***	***Concentration (picocuries per gram)***	***Dose Conversion Factor (rem per picocurie)***	***Dose (rem per year)***
32,200	Americium-241	0.000858	4.50×10^{-6}	0.000124
32,200	Cesium-137	0.0175	5.00×10^{-8}	0.0000282
32,200	Plutonium-238	0.00128	3.80×10^{-6}	0.000156
32,200	Plutonium-239, Plutonium-240	0.000430	4.30×10^{-6}	0.0000595
32,200	Strontium-90	0.129	1.30×10^{-7}	0.000541
32,200	Tritium	1.04	6.30×10^{-11}	2.11×10^{-6}
32,200	Uranium	0.0167	2.60×10^{-7}	0.000140
Total		–	–	**0.00105**

Notes: Average annual intakes are (4.5 grams per kilogram-day for vegetables + 3.7 grams per kilogram-day for fruits) × (a dry to wet weight ratio of 0.15) × 71.8-kilogram adult × (365 days per year) = 32,200 grams dry weight per year (EPA 2003). The *1999 SWEIS* reported 0.00162 rem per year (average intake) from combined fruit and vegetable consumption. High intake is 25.5 grams wet weight per kilogram-day. Thus, dose at high intake is (25.5/8.2) × 0.00105 or 0.00327 rem per year. To convert grams to ounces, multiply by 0.035274. To convert grams to ounces, multiply by 0.035274.

Table C–25 Dose from the Consumption of Free Range Beef

Exposure Pathway: Meat Ingestion				
Intake (grams per year)	***Nuclide***	***Concentration (picocuries per gram)***	***Dose Conversion Factor (rem per picocurie)***	***Dose (rem per year)***
14,900	Americium-241	0.000301	4.50×10^{-6}	0.0000202
14,900	Cesium-137	0.0560	5.00×10^{-8}	0.0000417
14,900	Plutonium-238	0.000230	3.80×10^{-6}	0.0000130
14,900	Plutonium-239, Plutonium-240	0.000218	4.30×10^{-6}	0.0000140
14,900	Strontium-90	0.0843	1.30×10^{-7}	0.000163
14,900	Tritium	0.00	6.30×10^{-11}	0.00
14,900	Uranium	0.00105	2.60×10^{-7}	4.07×10^{-6}
Total		–	–	**0.000256**

Notes: Average annual intake is 2.1 grams per kilogram-day × 0.27 dry to wet ratio × 71.8 kilogram adult × 365 days per year = 14,900 grams dry weight per year (EPA 1997). Concentration values are from the 1999 LANL Environmental Surveillance Report, Table 6-14 (mean plus 2 sigma). The *1999 SWEIS* reported 0.00027 rem per year from this source and pathway. High intake is 5.1 grams per kilogram-day. Thus, dose at high intake is (5.1/2.1) × 0.000256 or 0.000622 rem per year. To convert grams to ounces, multiply by 0.035274.

Table C–26 Dose from the Consumption of Milk

Exposure Pathway: Milk Ingestion				
Intake (liters per year)	***Nuclide***	***Concentrations (picocuries per liter)***	***Dose Conversion Factor (rem per picocurie)***	***Dose (rem per year)***
110	Americium-241	0.0785	4.50×10^{-6}	0.0000388
110	Cesium-137	25.8	5.00×10^{-8}	0.000142
110	Plutonium-238	0.00710	3.80×10^{-6}	2.97×10^{-6}
110	Plutonium-239, Plutonium-240	0.0856	4.30×10^{-6}	0.0000405
110	Strontium-90	3.76	1.30×10^{-7}	0.0000538
110	Tritium	450	6.30×10^{-11}	3.12×10^{-6}
110	Uranium	0.120	2.60×10^{-7}	3.43×10^{-6}
Total		–	–	**0.000284**

Notes: Average annual intake is 0.3 liters per day × 365 days per year 110 liters per year. Uranium total is 0.065 (U-234) + 0.013 (U-235) + 0.042 (U-238) = 0.120 picocuries per liter. The *1999 SWEIS* reported 0.0000733 rem per year (0.000195 for high intake) from this source and pathway. High intake is 0.8 liters per day. Thus, dose at high intake is (0.8/0.3) × 0.000284 or 0.000757 rem per year (DOE 1999a). To convert liters to gallons, multiply by 0.26418.

Table C–27 Dose from the Consumption of Fish

Exposure Pathway: Fish Ingestion				
Intake (grams per year)	***Nuclide***	***Concentration (picocuries per gram)***	***Dose Conversion Factor (rem per picocurie)***	***Dose (rem per year)***
1,880	Americium-241	0.000764	4.50×10^{-6}	6.46×10^{-6}
1,880	Cesium-137	0.0226	5.00×10^{-8}	2.13×10^{-6}
1,880	Plutonium-238	0.000517	3.80×10^{-6}	3.69×10^{-6}
1,880	Plutonium-239, Plutonium-240	0.000315	4.30×10^{-6}	2.55×10^{-6}
1,880	Strontium-90	0.0462	1.30×10^{-7}	0.0000113
1,880	Tritium	0.669	6.30×10^{-11}	7.92×10^{-8}
1,880	Uranium	0.00678	2.60×10^{-7}	3.31×10^{-6}
Total		–	–	**0.0000295**

Notes: Average annual intake is 20.1 grams per day (5.15 grams per day dry weight × 365 days = 1,880 grams per year dry weight). High intake is 53 grams per day (13.6 grams per day dry weight). Thus, dose at high intake is (53/20.1) × 0.0000295 or 0.0000778 rem per year (EPA 1997). The *1999 SWEIS* reported 0.0000542 rem per year (average intake) from this source and pathway (DOE 1999a). Uranium concentration of 9.55 nanograms per gram dry weight (0.00955 micrograms per gram dry weight) equates to 0.00678 picocuries per gram. Applying the reported 0.23 picocuries per milliliter tritium concentration value to the water fraction (1-0.256) yields: 0.744/0.256 or 2.91 grams water per gram dry weight × 0.23 picocuries per milliliter × 1 milliliter per gram water = 0.669 picocuries tritium per gram dry weight. To convert grams to ounces, multiply by 0.035274.

Table C–28 Dose from the Consumption of Elk

Exposure Pathway: Elk Ingestion				
Intake (grams per year)	***Nuclide***	***Concentration (picocuries per gram)***	***Dose Conversion Factor (rem per picocurie)***	***Dose (rem per year)***
2,420	Americium-241	0.000221	4.50×10^{-6}	2.40×10^{-6}
2,420	Cesium-137	0.0208	5.00×10^{-8}	2.52×10^{-6}
2,420	Plutonium-238	0.0000518	3.80×10^{-6}	4.76×10^{-7}
2,420	Plutonium-239, Plutonium-240	0.000210	4.30×10^{-6}	2.18×10^{-6}
2,420	Strontium-90	0.0315	1.30×10^{-7}	9.92×10^{-6}
2,420	Tritium	1.00	6.30×10^{-11}	1.52×10^{-7}
2,420	Uranium	0.00570	2.60×10^{-7}	3.59×10^{-6}
Total		–	–	**0.0000212**

Notes: Average annual intake is 26 grams per day × 0.255 dry to wet ratio × 365 days per year = 2,420 grams per year. Uranium concentration of 8.04 nanograms per gram dry weight (0.00804 micrograms per gram) equates to 0.00570 picocuries per gram. The *1999 SWEIS* reported 0.0000773 rem per year (average intake) from this source and pathway. High intake is 63 grams per day . Thus, dose at high intake is 63/26 × 0.0000212 or 0.0000514 rem per year (DOE 1999a). To convert grams to ounces, multiply by 0.035274.

Table C–29 Dose from the Consumption of Deer

Exposure Pathway: Deer Ingestion				
Intake (grams per year)	***Nuclide***	***Concentration (picocuries per gram)***	***Dose Conversion Factor (rem per picocurie)***	***Dose (rem per year)***
2,370	Americium-241	0.000150	4.50×10^{-6}	1.60×10^{-6}
2,370	Cesium-137	0.0351	5.00×10^{-8}	4.16×10^{-6}
2,370	Plutonium-238	0.000132	3.80×10^{-6}	1.19×10^{-6}
2,370	Plutonium-239, Plutonium-240	0.000297	4.30×10^{-6}	3.03×10^{-6}
2,370	Strontium-90	0.0386	1.30×10^{-7}	0.0000119
2,370	Tritium	4.86	6.30×10^{-11}	7.26×10^{-7}
2,370	Uranium	0.00162	2.60×10^{-7}	9.98×10^{-7}
Total		–	–	**0.0000236**

Notes: Average annual intake is 26 grams per day × 0.25 dry to wet ratio × 365 days per year = 2,370 grams per year (dry weight). High intake is 63 grams per day. Thus, dose at high intake is 63/26 × 0.0000236 or 0.0000572 rem per year. Uranium concentration of 2.28 nanograms per gram dry weight (0.00228 micrograms per gram) equates to 0.00162 picocuries per gram. Tritium concentration on a dry weight basis equals picocuries per milliliter of water × milliliters of water per gram dry weight. If the dry to wet ratio is 0.25, 0.75 grams water (0.75 milliliter) is present for each 0.25 grams dry weight. Tritium concentration is 1.62 picocuries per milliliter × 0.75 milliliters/0.25 grams or 4.86 picocuries per gram dry weight. The *1999 SWEIS* reported 0.0000181 rem per year (average intake) from this source and pathway (DOE 1999a). To convert grams to ounces, multiply by 0.035274.

Table C–30 Dose from the Consumption of Honey

Exposure Pathway: Honey Ingestion				
Intake (milliliters per year)	***Nuclide***	***Concentration (picocuries per milliliter)***	***Dose Conversion Factor (rem per picocurie)***	***Dose (rem per year)***
989	Americium-241	0.000599	4.50×10^{-6}	2.67×10^{-6}
989	Cesium-137	0.0177	5.00×10^{-8}	8.73×10^{-7}
989	Plutonium-238	0.0000294	3.80×10^{-6}	1.10×10^{-7}
989	Plutonium-239, Plutonium-240	0.0000728	4.30×10^{-6}	3.10×10^{-7}
989	Strontium-90	0.00406	1.30×10^{-7}	5.22×10^{-7}
989	Tritium	2.07	6.30×10^{-11}	1.29×10^{-7}
989	Uranium	0.00712	2.60×10^{-7}	1.83×10^{-6}
Total		–	–	**6.44×10^{-6}**

Notes: Average intake is 3.84 grams per day. At a specific gravity of 1.4171 (18 percent water, 20 degrees centigrade) this equates to 2.71 milliliters per day or 989 milliliters per year. High intake is 13.7 grams per day or 3,528 milliliters per year. Thus, dose at high intake is $13.7/3.84 \times 6.44 \times 10^{-6}$ or 0.0000230 rem per year. Uranium value is 0.00356 (uranium-234) plus 0.000394 (uranium-235) plus 0.00317 (uranium-238) = 0.00712 picocuries per milliliter. The *1999 SWEIS* reported 7.37×10^{-7} rem per year from this source and pathway (average intake), but addressed only tritium and did not include the contributions from the other nuclides reported here (DOE 1999a).

Table C–31 Dose from the Consumption of Pinyon Nuts

Exposure Pathway: Pinyon Nut Ingestion				
Intake (grams per year)	***Nuclide***	***Concentration (picocuries per gram)***	***Dose Conversion Factor (rem per picocurie)***	***Dose (rem per year)***
1,410	Beryllium-7	0.140	1.10×10^{-10}	2.17×10^{-8}
1,410	Americium-241	0.00	4.50×10^{-6}	0.00
1,410	Cesium-137	0.0200	5.00×10^{-8}	1.41×10^{-6}
1,410	Plutonium-238	0.0170	3.80×10^{-6}	0.0000911
1,410	Plutonium-239, Plutonium-240	0.0130	4.30×10^{-6}	0.0000788
1,410	Strontium-90	0.230	1.30×10^{-7}	0.0000422
1,410	Tritium	0.364	6.30×10^{-11}	3.23×10^{-8}
1,410	Uranium	0.0568	2.60×10^{-7}	0.0000208
Total		–	–	**0.000234**

Notes: Calculated using concentrations from *1999 SWEIS* Table D.3.3-50 corrected for dry to wet ratio of 0.94 versus 0.06 (NutritionData 2006). Average intake of 1,500 grams per year corresponds to 1,410 grams per year dry weight. Tritium concentration is (0.06/0.94) × (1 milliliter per gram water) × (5.7 picocuries per milliliter) = 0.364 picocuries per gram. The *1999 SWEIS* reported 0.0000155 rem per year for from this source and pathway (DOE 1999a). No high intake was found. Thus, dose at high intake equals dose at average intake. To convert grams to ounces, multiply by 0.035274.

Table C–32 Dose from the Consumption of Groundwater

Exposure Pathway: Groundwater Ingestion				
Intake (liters per year)	***Nuclide***	***Concentration (picocuries per liter)***	***Dose Conversion Factor (rem per picocurie)***	***Dose (rem per year)***
551	Americium-241	0.0551	4.50×10^{-6}	0.000137
551	Cesium-137	6.49	5.00×10^{-8}	0.000179
551	Plutonium-238	0.0127	3.80×10^{-6}	0.0000267
551	Plutonium-239, Plutonium-240	0.0244	4.30×10^{-6}	0.0000577
551	Strontium-90	0.101	1.30×10^{-7}	7.26×10^{-6}
551	Tritium	311	6.30×10^{-11}	1.08×10^{-5}
551	Uranium	0.866	2.60×10^{-7}	0.000124
Total		–	–	**0.000542**

Notes: Average intake is 1.51 liters per day (551 liters per year). High intake is 2.44 liters per day. Thus, dose at high intake is (2.44/1.51) × 0.000542 or 0.000876 rem per year. Calculated using groundwater composite data (95 percent upper confidence limit) for 2001-2004 for "Water Supply Wells" (see Appendix F of this SWEIS). The *1999 SWEIS* reported 0.00234 rem per year for the offsite Los Alamos County resident from this source and pathway (DOE 1999a). To convert liters to gallons, multiply by 0.26418.

Table C–33 Dose from the Consumption of Soil

Exposure Pathway: Soil Ingestion				
Intake (grams per year)	***Nuclide***	***Concentration (picocuries per gram)***	***Dose Conversion Factor (rem per picocurie)***	***Dose (rem per year)***
36.5	Americium-241	0.0126	4.50×10^{-6}	2.07×10^{-6}
36.5	Cesium-137	0.346	5.00×10^{-8}	6.31×10^{-7}
36.5	Plutonium-238	0.00358	3.80×10^{-6}	4.96×10^{-7}
36.5	Plutonium-239, Plutonium-240	0.0671	4.30×10^{-6}	0.0000105
36.5	Strontium-90	0.177	1.30×10^{-7}	8.39×10^{-7}
36.5	Tritium	1.04	6.30×10^{-11}	2.39×10^{-9}
36.5	Uranium	2.39	2.60×10^{-7}	0.0000227
Total		–	–	**0.0000372**

Notes: Average intake is 36.5 grams per year. High intake is 146 grams per year. Thus, dose at high intake is (146/36.5) × 0.0000372 or 0.000149 rem per year. Calculated using 2001-2004 composite data (95 percent upper confidence limit) for perimeter stations (see Appendix F of this SWEIS). The *1999 SWEIS* reported 0.000313 rem per year for the offsite resident from this source and pathway (DOE 1999a). To convert grams to ounces, multiply by 0.035274.

Table C–34 Dose from the Consumption of Sediment

Exposure Pathway: Sediment Ingestion				
Intake (grams per year)	***Nuclide***	***Concentration (picocuries per gram)***	***Dose Conversion Factor (rem per picocurie)***	***Dose (rem per year)***
36.5	Americium-241	0.365	4.50×10^{-6}	0.0000600
36.5	Cesium-137	0.327	5.00×10^{-8}	5.97×10^{-7}
36.5	Plutonium-238	0.220	3.80×10^{-6}	3.05×10^{-5}
36.5	Plutonium-239, Plutonium-240	0.947	4.30×10^{-6}	0.000149
36.5	Strontium-90	0.244	1.30×10^{-7}	1.16×10^{-6}
36.5	Tritium	127	6.30×10^{-11}	2.92×10^{-7}
36.5	Uranium	1.77	2.60×10^{-7}	0.0000168
Total		–	–	**0.000258**

Notes: Average intake is 36.5 grams per year. High intake is 146 grams per year. Thus, dose at high intake is (146/36.5) × 0.000258 or 0.00103 rem per year. Calculated using 2001-2004 composite data (95 percent upper confidence limit) for perimeter stations (see Appendix F of this SWEIS). The *1999 SWEIS* reported 0.00262 rem per year for the offsite resident from this source and pathway (DOE 1999a). To convert grams to ounces, multiply by 0.035274.

Table C–35 Dose to the Recreational User Receptor from the Consumption of Surface Water

Exposure Pathway: Surface Water Ingestion (Recreational User)				
Intake (liters per year)	***Nuclide***	***Concentration (picocuries per liter)***	***Dose Conversion Factor (rem per picocurie)***	***Dose (rem per year)***
5.34	Americium-241	17.7	4.50×10^{-6}	0.000426
5.34	Cesium-137	13.9	5.00×10^{-8}	3.72×10^{-6}
5.34	Plutonium-238	20.4	3.80×10^{-6}	0.000415
5.34	Plutonium-239, Plutonium-240	14.6	4.30×10^{-6}	0.000336
5.34	Strontium-90	3.97	1.30×10^{-7}	2.75×10^{-6}
5.34	Tritium	380	6.30×10^{-11}	1.28×10^{-7}
5.34	Uranium	16.6	2.60×10^{-7}	0.0000230
Total		–	–	**0.00121**

Notes: Average intake is 5.34 liters per year. High intake is 8.64 liters per year. Thus, dose at high intake is (8.64/5.34) × 0.00121 or 0.00195 rem per year. Calculated using surface water onsite stations 2001-2004 composite data (95 percent upper confidence limit). The *1999 SWEIS* reported 0.000740 rem per year for the "resident recreational user" from this source and pathway (DOE 1999a). To convert liters to gallons, multiply by 0.26418.

Table C–36 Dose to the Recreational User Receptor from the Consumption of Soil

Exposure Pathway: Soil Ingestion (Recreational User)				
Intake (grams per year)	***Nuclide***	***Concentration (picocuries per gram)***	***Dose Conversion Factor (rem per picocurie)***	***Dose (rem per year)***
1.07	Americium-241	0.0176	4.50×10^{-6}	8.49×10^{-8}
1.07	Cesium-137	0.365	5.00×10^{-8}	1.95×10^{-8}
1.07	Plutonium-238	0.00236	3.80×10^{-6}	9.60×10^{-9}
1.07	Plutonium-239, Plutonium-240	0.0669	4.30×10^{-6}	3.08×10^{-7}
1.07	Strontium-90	0.154	1.30×10^{-7}	2.14×10^{-8}
1.07	Tritium	1.14	6.30×10^{-11}	7.71×10^{-11}
1.07	Uranium	2.34	2.60×10^{-7}	6.51×10^{-7}
Total		–	–	**1.09×10^{-6}**

Notes: Average intake is 1.07 grams per year. High intake is 4.27 grams per year. Thus, dose at high intake is (4.27/1.07) × 1.09×10^{-6} or 4.37×10^{-6} rem per year. Calculated using 2001-2004 composite data (95 percent upper confidence limit) for onsite stations (see Appendix F of this SWEIS). The *1999 SWEIS* reported 0.0000125 rem per year for the "resident recreational user" from this source and pathway (DOE 1999a). To convert grams to ounces, multiply by 0.035274.

Table C–37 Dose to the Recreational User Receptor from the Consumption of Sediment

Exposure Pathway: Sediment Ingestion (Recreational User)				
Intake (grams per year)	***Nuclide***	***Concentration (picocuries per gram)***	***Dose Conversion Factor (rem per picocurie)***	***Dose (rem per year)***
1.07	Americium-241	0.696	4.50×10^{-6}	3.35×10^{-6}
1.07	Cesium-137	1.48	5.00×10^{-8}	7.89×10^{-8}
1.07	Plutonium-238	0.422	3.80×10^{-6}	1.72×10^{-6}
1.07	Plutonium-239, Plutonium-240	0.692	4.30×10^{-6}	3.18×10^{-6}
1.07	Strontium-90	0.286	1.30×10^{-7}	3.98×10^{-8}
1.07	Tritium	352	6.30×10^{-11}	2.37×10^{-8}
1.07	Uranium	1.86	2.60×10^{-7}	5.17×10^{-7}
Total		–	–	**8.91×10^{-6}**

Notes: Average intake is 1.07 grams per year. High intake is 4.27 grams per year. Thus, the dose at high intake is (4.27/1.07) $\times$ 8.91×10^{-6} or 0.0000356 rem per year. Calculated using 2001-2004 composite data (95 percent upper confidence limit) for onsite stations (see Appendix F of this SWEIS). The *1999 SWEIS* reported 0.000176 rem per year for the "resident recreational user" from this source and pathway (DOE 1999a). To convert grams to ounces, multiply by 0.035274.

Table C–38 Dose to the Special Pathways Receptor from the Consumption of Fish

Exposure Pathway: Fish Ingestion (Special Pathways)				
Intake (grams per year)	***Nuclide***	***Concentration (picocuries per gram)***	***Dose Conversion Factor (rem per picocurie)***	***Dose (rem per year)***
6,540	Americium-241	0.000482	4.50×10^{-6}	0.0000142
6,540	Cesium-137	0.00866	5.00×10^{-8}	2.83×10^{-6}
6,540	Plutonium-238	0.000653	3.80×10^{-6}	0.0000162
6,540	Plutonium-239, Plutonium-240	0.000210	4.30×10^{-6}	5.90×10^{-6}
6,540	Strontium-90	0.0450	1.30×10^{-7}	0.0000382
6,540	Tritium	1.16	6.30×10^{-11}	4.78×10^{-7}
6,540	Uranium	0.0184	2.60×10^{-7}	0.0000313
Total		–	–	**0.000109**

Notes: Calculated using average intake of 70 grams per day (17.92 grams per day dry weight). High intake is 170 grams per day (43.52 grams per day dry weight.). Thus, dose at high intake is (170/70) $\times$ 0.000109 or 0.000265 rem per year (EPA 1997). The *1999 SWEIS* reported 0.000189 rem per year (average intake) from this source and pathway. Uranium concentration of 24.5 nanograms per gram dry weight. (0.0245 micrograms per gram) equates to 0.0174 picocuries per gram. Applying the reported 0.40 picocuries per milliliter tritium concentration value to the water fraction (1-0.256) yields: 0.744 grams water per 0.256 grams dry weight $\times$ 0.40 picocuries per milliliter $\times$ 1 milliliter per gram water = 1.163 picocuries per gram dry weight. To convert grams to ounces, multiply by 0.035274.

Table C–39 Dose to the Special Pathways Receptor from the Consumption of Elk Heart and Liver

Exposure Pathway: Elk Ingestion (Special Pathways)				
Intake (grams per year)	***Nuclide***	***Concentration (picocuries per gram)***	***Dose Conversion Factor (rem per picocurie)***	***Dose (rem per year)***
436	Americium-241	0.00	4.50×10^{-6}	0.00
436	Cesium-137	0.0679	5.00×10^{-8}	1.48×10^{-6}
436	Plutonium-238	0.00	3.80×10^{-6}	0.00
436	Plutonium-239, Plutonium-240	0.000655	4.30×10^{-6}	1.23×10^{-6}
436	Strontium-90	0.00650	1.30×10^{-7}	3.68×10^{-7}
436	Tritium	0.00	6.30×10^{-11}	0.00
436	Uranium	0.0347	2.60×10^{-7}	3.93×10^{-6}
Heart Total		–	–	**7.01×10^{-6}**
763	Americium-241	0.00	4.50×10^{-6}	0.00
763	Cesium-137	0.596	5.00×10^{-8}	0.0000227
763	Plutonium-238	0.0000750	3.80×10^{-6}	2.17×10^{-7}
763	Plutonium-239, Plutonium-240	0.0000950	4.30×10^{-6}	3.12×10^{-7}
763	Strontium-90	0.00820	1.30×10^{-7}	8.13×10^{-7}
763	Tritium	0.00	6.30×10^{-11}	0.00
763	Uranium	0.0160	2.60×10^{-7}	3.17×10^{-6}
Liver Total		–	–	**0.0000273**
Heart + Liver Total		–	–	**0.0000343**

Notes: This represents consumption of heart and liver in addition to the meat consumption calculated for the resident. Average heart intake is based on 3.2 pounds per year for an individual × 454 grams per pound × 0.30 (wet to dry ratio). Average liver intake is based on 5.6 pounds per year for an individual × 454 grams per pound × 0.30 (wet to dry ratio). The *1999 SWEIS* reported 0.0000343 rem per year from this source and pathway (no new data were found – same data and consumption rates were used here as for *1999 SWEIS*) (DOE 1999a). To convert grams to ounces, multiply by 0.035274.

Table C–40 Dose to the Special Pathways Receptor from the Consumption of Indian Tea (Cota)

Exposure Pathway: Indian Tea (Cota) Ingestion (Special Pathways)				
Intake (liters per year)	***Nuclide***	***Concentration (picocuries per liter)***	***Dose Conversion Factor (rem per picocurie)***	***Dose (rem per year)***
213	Americium-241	0.0362	4.50×10^{-6}	0.0000347
213	Cesium-137	21.2	5.00×10^{-8}	0.000226
213	Plutonium-238	0.0250	3.80×10^{-6}	0.0000202
213	Plutonium-239, Plutonium-240	0.0302	4.30×10^{-6}	0.0000277
213	Strontium-90	0.642	1.30×10^{-7}	0.0000178
213	Tritium	117	6.30×10^{-11}	1.58×10^{-6}
213	Uranium	0.780	2.60×10^{-7}	0.0000432
Total		–	–	**0.000371**

Notes: Average intake is 0.58 liters per day (213 liters per year). High intake is 2.03 liters per day (741 liters per year). Thus, dose at high intake is (2.03/0.58) × 0.000371 or 0.00130 rem per year. The *1999 SWEIS* reported 0.000749 rem per year (average intake) from this source and pathway (DOE 1999a). To convert liters to gallons, multiply by 0.26418.

Table C–41 Summary of Ingestion Pathway Doses for Offsite Resident, Recreational User, and Special Pathways Receptors

Exposure Pathway	*Dose to Receptor (rem per year)*		
	Offsite Resident [a]	*Recreational User* [b]	*Special Pathways* [c]
Produce	0.00105	0.00105	0.00105
Meat (free-range beef)	0.000256	0.000256	0.000256
Milk	0.000284	0.000284	0.000284
Fish (game)	0.0000294	0.0000294	0.0000294
Elk	0.0000212	0.0000212	0.0000212
Deer	0.0000236	0.0000236	0.0000236
Honey	6.44×10^{-6}	6.44×10^{-6}	6.44×10^{-6}
Pinyon nuts	0.000234	0.000234	0.000234
Groundwater	0.000542	0.000542	0.000542
Soil	0.0000372	0.0000372	0.0000372
Sediment	0.000258	0.000258	0.000258
Surface water	–	0.00121	0.00121
Soil [d]	–	1.09×10^{-6}	1.09×10^{-6}
Sediment [d]	–	8.91×10^{-6}	8.91×10^{-6}
Fish (non-game)	–	–	0.000109
Elk (heart, liver)	–	–	0.0000343
Indian Tea (Cota)	–	–	0.000371
Totals	**0.00274**	**0.00396**	**0.00448**

[a] A hypothetical person who is conservatively assumed to intake various foodstuffs, water, soil and sediments with concentrations of contaminants at the 95 percent upper confidence limit for each contaminant.
[b] Assumed to visit the canyons on and near LANL 24 times per year, 8 hours per visit.
[c] Assumed to have traditional Native American or Hispanic lifestyles and diet.
[d] Soil and sediments from onsite locations.

The offsite resident receptor was estimated to receive a dose of about 0.00274 rem, or about 2.7 millirem, per year from the ingestion exposures reported here. Eliminating all zero and negative values when calculating the 95 percent upper confidence limit concentration from the reported environmental surveillance results adds a degree of conservatism. It is also quite unlikely that any given individual would derive all of their diet from local sources, as was assumed in this consumption model. Additional exposures to a person whose diet and activities reflect those of the recreational user and special pathways receptors would bring their total doses to about 4.0 and 4.5 millirem per year, respectively. Using a risk estimator value of 0.0006 lifetime probability of fatal cancer per person-rem, 4.5 millirem (0.0045 rem) per year would equate to a probability of fatal cancer of 2.7×10^{-6}, or just under a 3 in 1 million chance of developing a fatal cancer from the ingestion pathway. The high consumption rates for all components of the ingestion pathway are detailed in their respective tables (C–24 through C–40). The total doses to each receptor as a result of potential consumption at these higher rates would be increased by less than a factor of three. Using the high consumption rates, the lifetime probability of developing a fatal cancer would be about 4.3×10^{-6} for the offsite resident total dose of 0.0072 rem; 5.5×10^{-6} for the recreational user total dose of 0.0091 rem; and 6.4×10^{-6} for the special pathways receptor total dose of 0.0107 rem per year of exposure.

For perspective, the ingestion pathway doses of 2.7 to 10.7 millirem per year calculated here for the offsite resident and other specific receptors should be viewed against the dose of about 400 millirem (dose ranges from 300 to 500 millirem) per year that the average Los Alamos resident receives from all background radiation sources (see Section C.1.1.3). That average includes about 240 millirem from radioactive material that has entered the body by inhalation or ingestion. The largest fraction of the internal dose (about 200 millirem on average) is due to the short-lived decay products of naturally-occurring radon gas. It is also important to compare these ingestion pathway doses to the more significant inhalation pathway dose, where the bulk of the radiological air emissions and resulting dose come from LANSCE and the High Explosives Testing Key Facility (see Chapter 5, Section 5.6).

As shown in Table C–41, the highest estimated ingestion pathway dose to any specific receptor is about 4.5 millirem per year from radionuclides in the environment resulting from past LANL operations, global fallout, and naturally-occurring geologic sources. If a particular specific receptor also were to receive the maximum impact from projected future radionuclide LANL emissions to the atmosphere (see Tables C–19, C–20, and C–21), that specific receptor might receive a total annual dose from past and future site operations ranging from about 5.3 millirem (4.5 millirem plus the dose to the MEI of 0.79 millirem) for the Reduced Operations Alternative to about 12.3 millirem (4.5 millirem plus the dose to the MEI of 7.8 millirem) for the No Action and Expanded Operations Alternatives. The fatal cancer risk associated with these doses ranges from about 3 in 1 million to 7 in 1 million. To place these doses in perspective, that same individual would be expected to receive an annual dose from background sources of about 400 millirem. In addition, these are conservatively calculated doses because no one person would actually consume such a large concentration from each pathway component. These large concentrations are found at scattered locations around LANL.

When calculating ingestion pathway radiation doses, river surface water was considered as a potential dose source for certain recreational user and special pathways receptors. Surface water radioisotope concentrations were measured at locations both upstream and downstream of LANL on the Rio Grande and Jemez River during 2005 (LANL 2006b). The 95 percent upper confidence limit values of these measurements were used to calculate the radiation dose to an individual that consumed all their drinking water, at the rate of 2 liters per day, from these surface water sources. The total surface drinking water doses are presented in **Table C–42**. This table shows the location of the sampling station relative to LANL (that is, upstream or downstream), as well as the fraction of the EPA 4 millirem per year drinking water limit that the calculated dose at each location represents. Consumption of all drinking water from all of the river locations around LANL resulted in doses of less than 10 percent of the EPA limit. There was no trend between upstream and downstream locations relative to LANL.

The doses calculated here are generally lower than those reported in the *1999 SWEIS* for the same ingestion pathway components. Only 5 of the 17 pathway component doses are greater than those reported in the *1999 SWEIS*. The dose from honey consumption is greater than that reported in the *1999 SWEIS* because the 1999 dose calculation considered only the dose from tritium, whereas this calculation includes the dose from tritium and all other radionuclides reported in the LANL environmental surveillance data for honey. The dose from pinyon nut consumption reported here is higher because this calculation makes use of a higher dry to wet weight ratio than was assumed in the *1999 SWEIS* calculation. The doses from consumption of

surface water (recreational user), milk, and deer are also higher, but not remarkably so. The calculated dose from consumption of elk heart and liver is unchanged from the *1999 SWEIS* because no more current radionuclide concentration data were found. The lower doses calculated here for the other 12 pathway components are due to lower average radionuclide concentrations in environmental media reported during the 2001 through 2004 period compared to the 1991 through 1996 data used in the *1999 SWEIS* calculations.

Table C–42 Total Los Alamos National Laboratory River Surface Water Consumption Radiation Doses

Surveillance Sample River Site	*Location Upstream or Downstream of LANL*	*Total Annual (2 liters per day) Drinking Water Dose (millirem)*	*Percent of Annual EPA Drinking Water Dose Limit of 4 Millirem*
Jemez River	Upstream	0.384	9.6%
Embudo at Rio Grande	Upstream	0.118	3.0%
Otowi at Rio Grande	Upstream	0.159	4.0%
Chamita at Rio Grande	Upstream	0.236	5.9%
Frijoles at Rio Grande	Downstream	0.297	7.4%
Cochiti at Rio Grande	Downstream	0.172	4.3%

C.2 Impacts on Human Health from Nonradioactive Contaminants in the Environment

Many nonradioactive substances (chemical elements, compounds, and mixtures) found in the environment are potentially harmful to human health. Some substances, small amounts of which are beneficial or necessary for good health, may be harmful in larger amounts or higher concentrations (examples: iron, selenium, zinc). Even at very low concentrations or levels of intake, exposure to some substances may cause long-term health effects or increase the likelihood of developing certain diseases, particularly when the exposure continues over a long period of time (that is, chronic exposure). The health impact (harmful effect) of taking any substance into the body depends on the toxicity of the material (a measure of the amount needed to produce a given harmful effect) and the dose or intake (the rate at which the substance was taken into the body). For many substances, humans have the capacity to metabolize, excrete, or otherwise detoxify small quantities or small chronic intakes without showing ill effects. Substances that accumulate in the body over time, however, may cause harm that becomes evident only after many years of exposure.

Humans may be exposed to toxic substances in their environment by several different routes, of which ingestion, inhalation, and skin contact are usually most important. At concentrations typically found in the general living environment, acute health effects (those having a rapid onset followed by a short, severe course of symptoms) are seldom observed. Elevated levels of some contaminants in air, water, soil, and other environmental media, however, have been linked statistically to the occurrence rate (or frequency) of specific health problems in populations exposed to those media. The health effects from exposure to carcinogenic substances are evaluated using risk factors from the EPA Integrated Risk Information System database (EPA 2005a). The risk factor for a substance is an estimate of the upper-bound lifetime probability, per unit oral intake or concentration in the air, of an individual developing cancer from exposure to the substance. The potential for noncancer health effects from exposure to a toxic substance is evaluated by dividing the estimated average daily intake of that substance by

its Oral Reference Dose value (RfD) to obtain a hazard index. The Oral Reference Dose is an estimate of the average daily oral intake that is believed to pose no appreciable risk of harmful health effects (EPA 2005b). If the calculated hazard index is greater than 1, the individual is considered to be at some risk of adverse health effects as a result of exposure to the substance.

C.2.1 Methods Used to Estimate Risks from Ingestion of Nonradioactive Contaminants

Environmental media and foodstuffs collected on and near LANL are regularly analyzed for various nonradioactive contaminants. Measured concentrations of contaminants in food, water, soils and sediments are used here to calculate the health risks to residents and special pathways receptors from the ingestion of those materials. The same dietary intake assumptions used to calculate radiation dose and risk were used to estimate health risk from a range of nonradioactive contaminants, some of which occur naturally in the LANL environment and others that are a result of past LANL operations, natural processes, or human activities in the region.

Naturally-occurring contaminants with possible health implications for residents include metals derived from local soil and rock that are consumed via ingestion of groundwater, surface water, soil, sediment and various foodstuffs. As part of this group, arsenic and beryllium are known to be present in concentrations that represent a significant increment of ingestion risk. Contaminants known to have been released to the environment from site operations include nitrates and perchlorate, as well as various high explosives and organics. These materials are present in groundwater and surface water on and near LANL, and therefore represent a potential direct impact on the health of the current population from past LANL operations. Finally, residues from environmentally persistent pesticides used in the surrounding forests and agricultural land can be detected in various media, as can organic contaminants of natural (such as wildland fires) or undetermined origin. These substances and others have been monitored, either regularly or episodically as part of the LANL Environmental Surveillance Program.

Groundwater Ingestion

To estimate human health impacts to the public, only contaminants that could be ingested by the postulated receptors were included in the impact calculations. For the groundwater component of the ingestion pathway, only analysis results from the water supply wells were used to calculate the 95 percent upper confidence limit concentration.

Groundwater at LANL occurs as a regional aquifer at depths ranging from 600 to 1,200 feet (180 to 370 meters) and as perched groundwater of limited thickness and horizontal extent, either in canyon alluvium or at intermediate depths of a few hundred feet. All water produced by the Los Alamos County water supply system comes from the regional aquifer and meets Federal and state drinking water standards. No drinking water is supplied from the alluvial and intermediate groundwater sources. Water supply wells are present in Guaje Canyon, Pueblo Canyon, upper Los Alamos Canyon, Mortandad Canyon, Pajarito Canyon, and White Rock Canyon.

Liquid effluent disposal is the primary means by which LANL contaminants have had an effect, albeit limited, on the regional aquifer. Liquid effluent disposal at LANL has significantly degraded the quality of alluvial groundwater in some canyons. Because flow through the underlying approximately 900-foot-thick (270-meter-thick) zone of unsaturated rock is slow, the

impact of effluent disposal is seen to a lesser degree in intermediate-depth perched groundwater and is only seen in a few wells that draw from the regional aquifer. In general, groundwater quality would improve as outfalls are eliminated, the volume of liquid discharges is reduced, and the water quality (concentrations of contaminants) of the discharges is improved.

During the last decade, EPA has recognized the potential for perchlorate toxicity at concentrations in the parts per billion range. No EPA regulatory limit exists for perchlorate in drinking water, though several states have set limits in the range of 10 to 20 parts per billion. EPA Region VI has established a level of 3.7 parts per billion.

LANL and the New Mexico Environment Department DOE Oversight Bureau have found perchlorate in most groundwater samples analyzed from across northern New Mexico at concentrations below 1 part per billion. At LANL, perchlorate was the byproduct of the perchloric acid used in nuclear chemistry research. Water samples from most LANL locations show low perchlorate concentrations, but samples taken downstream from inactive perchlorate release sites show distinctly higher values.

As indicated by the LANL environmental surveillance program (LANL 2005b), the presence of high metal values (compared with regulatory standards) in groundwater samples is believed to be due to ubiquitous well-sampling-related issues rather than to contamination resulting from LANL operations. Well-drilling fluids; the metal in well casings, fittings, and pump housings; dissolved surface minerals from the aquifer's rock framework; and alterations to aquifer water chemistry due to the presence of a well all may contribute to increases of some metal values.

Arsenic was detected in measurable amounts in some water supply wells. As noted in Appendix D of the *1999 SWEIS*, the primary sources of arsenic in food and water sources in the LANL area are naturally-occurring soil and basalt. The concentrations of arsenic in groundwater supply wells are not significantly different between Los Alamos and San Ildefonso. The main use of arsenic in the United States is pesticide formulation, and LANL does not use large amounts of arsenic in any of its research and development or processing activities.

Some supply wells have shown elevated levels of nitrate. LANL environmental surveillance program results (LANL 2005b) indicate that a possible source of these contaminants is effluent from a local sewage treatment plant. In addition, some past effluent discharges from the Radioactive Liquid Waste Treatment Facility contained high levels of nitrates (LANL 2004b).

The LANL environmental surveillance program analyzed samples from selected springs and wells for organic constituents. Samples were analyzed for some or all of the following types of organics: volatile organic compounds, semivolatile organic compounds, polychlorinated biphenyls, pesticides, diesel-range organics, and high explosives (HMX, RDX, TNT). Certain organic compounds used in analytical laboratories are frequently detected in samples, probably as a result of contamination introduced by the laboratory process. These compounds include acetone, methylene chloride, 2-butanone, and bis(2-ethylhexyl)phthalate. Since there was no definitive evidence that these compounds were introduced as part of the laboratory process, they were conservatively retained as part of the group of organics considered as contributing to risk from ingestion of groundwater.

Volatile and semi-volatile organic compounds were not found in any of the water supply wells in significant concentrations; therefore, they were not included in the group of compounds that contribute to risk from groundwater consumption.

High-explosive compounds also were not found in statistically significant quantities in the water supply wells. They have been found in other regional aquifer wells, however, and are a known contaminant in surface waters and sediments. As a result, any supply well sample results containing high-explosive compounds were conservatively retained for consideration.

In August 2004, the LANL environmental surveillance program identified several positive pesticide results, notably results for 4,4'-DDT and 4,4'-DDE, in LANL samples. These results were not supported by previous data or by process knowledge at the sample locations. Subsequent examination of the data revealed that some glassware used in the process was only rinsed, without further cleaning, between uses. This finding meant that pesticide contamination could be transferred from one sample to another during the sample preparation. As a result, all pesticide results for 2004 are considered unusable (LANL 2005b).

Table C–43 shows the contribution to health risk to the offsite resident receptor from ingestion of trace metals, nitrates, perchlorate, and organic compounds in groundwater. Arsenic, the contaminant with the highest Hazard Index and cancer risk, occurs naturally at relatively high concentrations in soil and groundwater throughout northern New Mexico. Arsenic is not known to have been used in significant quantities at LANL and the elevated groundwater concentrations do not appear to be related to any past or current LANL operations or effluents. Vanadium, the contaminant with the second-highest Hazard Index, is also a naturally-occurring trace element in the region. Elevated concentrations of vanadium seen in surface water and groundwater samples do not appear to be related to any past or current LANL operations or effluents. See Section C.2 for additional information.

Surface Water and Sediment Ingestion

LANL personnel monitor surface water and stream sediments in northern New Mexico and southern Colorado to evaluate the potential environmental effects of LANL operations. LANL personnel analyze samples for radionuclides, high explosives, metals, a wide range of organic compounds, and (for surface water) general chemistry.

Watercourses that drain from LANL property are dry most of the year. No perennial surface water extends completely across LANL in any canyon. The canyons consist of over 85 miles (140 kilometers) of watercourses located within LANL and Los Alamos Canyon upstream of the site. Of the 85 (140 kilometers) miles of watercourse, approximately 2 miles (3.2 kilometers) are naturally perennial, and approximately 3 miles (4.8 kilometers) are perennial waters created by effluent. The remaining 80 or more miles (130 kilometers) of watercourse dry out for varying lengths of time. The driest segments may flow only in response to local precipitation or snowmelt. Although most of the watercourses are dry throughout the year, occasional floods can redistribute sediment in a streambed to locations far downstream from where a release or spill occurs.

Table C–43 Hazard Index and Cancer Risk to the Offsite Resident Receptor from the Ingestion of Nonradioactive Contaminants in Groundwater

Groundwater Consumption: 1.51 Liters per Day Average, 2.44 Liters per Day High Intake

Analytes	*95% UCL Concentration (µg/L)*	*Average Chronic Daily Intake (mg/kg-day)*	*High Chronic Daily Intake (mg/kg-day)*	*Oral RfD (mg/kg-day)*	*Oral Slope Factor (per mg/kg-day)*	*Average Case Hazard Index*	*High Intake Hazard Index*	*Average Case Cancer Risk*	*High Intake Cancer Risk*
Silver	1.08	0.0000227	0.0000367	0.005		0.00454	0.00735		
Aluminum	176	0.0037	0.00599	1.00		0.0037	0.00599		
Arsenic	13	0.00027	0.000443	0.0003	1.5	0.912	1.48	0.00041	0.000664
Boron	1,350	0.0283	0.0459	0.2		0.142	0.229		
Barium	182	0.00383	0.0062	0.2		0.0192	0.0310		
Beryllium	0.229	4.80×10^{-6}	7.77×10^{-6}	0.002	4.3	0.0024	0.0039	0.0000206	0.0000334
Cadmium	0.164	3.43×10^{-6}	5.56×10^{-6}	0.0005	0.0018	0.00687	0.0111	6.18×10^{-9}	1.00×10^{-8}
Perchlorate	2.88	0.00006	0.0000987	0.0007		0.0863	0.140		
Cobalt	2.95	0.0000619	0.0001	0.02		0.00309	0.00501		
Chromium	8.48	0.000178	0.00029	1.5		0.000119	0.000192		
Copper	22.9	0.000481	0.00079	0.037		0.013	0.021		
Mercury	0.248	5.21×10^{-6}	8.43×10^{-6}	0.0003		0.0174	0.0281		
Manganese	12.6	0.000265	0.000429	0.047		0.00564	0.00912		
Molybdenum	33.3	0.0007	0.00113	0.005		0.14	0.227		
Nickel	4.45	0.0000935	0.00015	0.02		0.00468	0.00757		
Nitrate	1,910	0.0402	0.065	1.6		0.0251	0.0406		
Lead	5.21	0.00011	0.000177	0.0014		0.0781	0.126		
Antimony	0.419	8.79×10^{-6}	0.0000142	0.0004		0.022	0.0356		
Selenium	6.55	0.00014	0.000223	0.005		0.0275	0.0446		
Tin	5.46	0.00012	0.000186	0.6		0.000191	0.00031		
Strontium	835	0.0175	0.0284	0.6		0.0292	0.0473		
Thallium	0.318	6.68×10^{-6}	0.0000108	0.00008		0.0835	0.135		
Uranium	0.875	0.0000184	0.0000298	0.0006		0.0306	0.0496		
Vanadium	3.65	0.00077	0.00124	0.001		0.766	1.24		
Zinc	189	0.00397	0.00643	0.3		0.0132	0.0214		

Analytes	*95% UCL Concentration (µg/L)*	*Average Chronic Daily Intake (mg/kg-day)*	*High Chronic Daily Intake (mg/kg-day)*	*Oral RfD (mg/kg-day)*	*Oral Slope Factor (per mg/kg-day)*	*Average Case Hazard Index*	*High Intake Hazard Index*	*Average Case Cancer Risk*	*High Intake Cancer Risk*
Acetone	10.6	0.00022	0.00036	0.9		0.000246	0.00399		
Bis(2-ethylhexyl)phthalate	1.59	0.0000334	0.0000541	0.02	0.014	0.00167	0.0027	4.67×10^{-7}	7.57×10^{-7}
Butanone(2)	0.36	7.56×10^{-6}	0.0000122	0.6		0.0000126	0.0000204		
Chloromethane	1.22	0.0000256	0.0000415	0.026	0.0063	0.000985	0.0016	1.61×10^{-7}	2.61×10^{-7}
Heptachlor epoxide	0.01	2.10×10^{-7}	3.40×10^{-7}	0.0000130	9.1	0.0162	0.0262	1.91×10^{-6}	3.09×10^{-6}
Methylene chloride	3.7	0.0000777	0.000126	0.06	0.0075	0.0013	0.0021	5.83×10^{-7}	9.44×10^{-7}
RDX	0.25	5.25×10^{-6}	8.50×10^{-6}	0.003	0.11	0.00175	0.00283	5.78×10^{-7}	9.35×10^{-7}
Styrene	0.78	0.0000164	0.0000265	0.2		0.0000819	0.000133		
Tetrachloroethene	0.92	0.0000193	0.0000313	0.06	0.2	0.000322	0.000521	3.86×10^{-6}	6.26×10^{-6}
Tetryl	0.04	8.40×10^{-7}	1.36×10^{-6}	0.004		0.000210	0.000340		

kg = kilogram, L = liter, mg = milligram, µg = microgram, RDx = hexahydro-1, 3, 5-trinitro-1, 3, 5-triazine, RfD = Reference Dose, UCL = upper confidence limit.
Notes: Chronic Intake (mg/kg-day) = Water Concentration (µg/L) × Consumption rate (L/day) × 1×10^{-3} (mg/µg) × 1/Body Weight (1/71.8 kg). Shaded cells in Slope Factor and Cancer Risk columns indicate no known human chemical cancer risk.

The overall quality of most surface water in the Los Alamos area is very good, with very low levels of dissolved solutes. Of the more than 100 analytes tested in sediment and surface water within LANL, most are at concentrations far below regulatory standards or risk-based advisory levels. Nearly every major watershed, however, shows indications of some effect from LANL operations, often for just a few analytes.

Although many of the above-background results in sediment and surface water are from the major liquid effluent discharges, other possible sources include isolated spills, former photographic-processing facilities, highway runoff, and residual ash from the Cerro Grande Fire. At monitoring locations below other industrial or residential areas, particularly in the Los Alamos and Pueblo Canyon watersheds, above-background contaminant levels reflect contributions from non-LANL sources such as urban runoff.

Guaje Canyon is a major tributary in the Los Alamos Canyon watershed that heads in the Sierra de los Valles and lies north of LANL. The canyon has not received any effluent from LANL activities. Concentrations of metals, organics, and radionuclides in Guaje Canyon base flow and sediments were below regulatory limits or screening levels. Active channel sediments contained background ranges of metals and radionuclides.

Los Alamos Canyon, including Bayo, Acid, Pueblo, and DP Canyons, has a large drainage that heads in the Sierra de los Valles. Land in the Los Alamos Canyon watershed has been continuously used since the mid-1940s, with operations conducted at some time in all of the subdrainages. Each of the canyons draining the watershed also receives urban runoff from the Los Alamos town site.

Nonradiological contaminants detected at significant concentrations in the Los Alamos Canyon watershed include polychlorinated biphenyls, benzo(a)pyrene, mercury, copper, lead, and zinc. Analysis detected benzo(a)pyrene in sediment samples from Acid Canyon above Pueblo; the LANL environmental surveillance staff concluded that the major source of benzo(a)pyrene in the drainage was urban runoff rather than a LANL-related source (LANL 2005b).

Mercury was detected in Los Alamos Canyon above DP Canyon. LANL sources of mercury and polychlorinated biphenyls are known to exist in the drainage system, and erosion control features have been installed near the sources to minimize downstream movement. Elevated concentrations of copper, lead, and zinc were detected in DP Canyon above LANL facilities and are likely derived from urban runoff sources rather than LANL operations.

Sandia Canyon begins on the Pajarito Plateau within TA-3 and has a total drainage area of about 5.5 square miles. This relatively small drainage extends eastward across the central part of LANL and crosses San Ildefonso Pueblo land before joining the Rio Grande. Effluent discharges primarily from power plant blowdown support perennial flow conditions along a 2-mile (3.2-kilometer) reach. The upper portion of the canyon contains some of the highest polychlorinated biphenyl concentrations of any watercourse within LANL boundaries. Downstream sediment concentrations of polychlorinated biphenyls decline quickly and are near background ranges at the LANL downstream boundary. Along an approximately 2-mile (3.2-kilometer) segment are found above-background concentrations of chromium, copper,

mercury, and zinc in surface water and sediments. Measurements in 2004 also found concentrations of dissolved copper and lead above regulatory standards.

Mortandad Canyon begins on the Pajarito Plateau near the main complex at TA-3. The canyon crosses San Ildefonso Pueblo land before joining the Rio Grande. Analysis detected dissolved copper concentrations and benzo(a)pyrene above screening levels; potential sources are many and include road runoff, ash from the Cerro Grande Fire, and industrial sources.

Pajarito Canyon begins on the flanks of the Sierra de los Valles on U.S. Forest Service lands. The canyon crosses the south-central part of LANL before entering Los Alamos County lands in White Rock. Dissolved copper concentrations greater than the regulatory standards were detected in channels throughout the Pajarito Canyon watershed. A review of sediment data from the drainage did not indicate a LANL source for the copper. In 2004, a sediment sample from Pajarito Canyon contained many metals and radionuclides at concentrations two to five times above background levels (LANL 2005b). Concentrations of organic compounds in sediments from Pajarito Canyon are far below EPA residential soil screening levels, with the exception of benzo(a)pyrene. Low levels of polychlorinated biphenyls were detected in sediments. Polychlorinated biphenyls were not detected in stormwater runoff samples.

Water Canyon heads on the flanks of the Sierra de los Valles on U.S. Forest Service land and extends across LANL to the Rio Grande. Water Canyon and its tributary Cañon de Valle pass through the southern portion of LANL where explosives development and testing has been conducted in the past and continues to take place. Elevated concentrations of barium, HMX, and RDX have been measured in sediment and surface water.

Tables C–44 and **C–45** show the contribution to health risk to the recreational user receptor from ingestion of metals, nitrates, perchlorate, and organic compounds in surface water and sediment. **Table C–46** shows the health risk to the offsite resident receptor from ingestion of contaminants in sediment that may be transported offsite by streams and seasonal runoff.

Soil Ingestion

In the past, soils within and around LANL were analyzed for 22 light, heavy, and nonmetal trace elements (occurrence in amounts less than 1,000 micrograms per gram in soil) and 3 light and heavy abundant elements (occurrence in amounts greater than 1,000 micrograms per gram in soil). Most of these elements, with the exception of barium, beryllium, mercury, and lead, were either below the limits of detection or within the regional statistical reporting limits. Therefore, recent analyses only address the four metals that were consistently detected above the limit of detection in past years (barium, beryllium, mercury, and lead). In general, very few individual sites from either perimeter or onsite areas had barium, beryllium, mercury, or lead concentrations above the regional statistical reporting limits, and these concentrations were far below the screening action levels.

Table C–44 Hazard Index and Cancer Risk to the Recreational User Receptor from the Ingestion of Nonradioactive Contaminants in Surface Water

Surface Water Consumption: 5.34 Liters per Year Average, 8.64 Liters per Year High Intake

Analytes	*95% UCL Concentration (µg/L)*	*Average Chronic Daily Intake (mg/kg-day)*	*High Chronic Daily Intake (mg/kg-day)*	*Oral RfD (mg/kg-day)*	*Oral Slope Factor (per mg/kg-day)*	*Average Case Hazard Index*	*High Intake Hazard Index*	*Average Case Cancer Risk*	*High Intake Cancer Risk*
Silver	5.19	1.06×10^{-6}	1.71×10^{-6}	0.005		0.000212	0.0003		
Aluminum	129,000	0.0263	0.0426	1.00		0.0263	0.0426		
Arsenic	2.89	5.89×10^{-6}	9.53×10^{-6}	0.0003	1.50	0.0196	0.0318	8.84×10^{-6}	0.0000143
Boron	231	0.0000471	0.0000762	0.2		0.000236	0.0004		
Barium	3,270	0.000666	0.00108	0.2		0.00333	0.00539		
Beryllium	13.4	2.72×10^{-6}	4.41×10^{-6}	0.002	4.30	0.00136	0.0022	0.0000117	0.0000189
Cadmium	10.4	2.11×10^{-6}	3.42×10^{-6}	0.0005	0.0018	0.00423	0.00684	3.80×10^{-9}	6.15×10^{-9}
Perchlorate	16.8	3.42×10^{-6}	5.53×10^{-6}	0.0007		0.00489	0.00791		
Cobalt	54.2	0.0000111	0.0000179	0.02		0.000553	0.00089		
Chromium	117	0.0000238	0.0000385	1.5		0.0000159	0.0000257		
Copper	115	0.0000234	0.0000378	0.037		0.000632	0.00102		
Mercury	0.389	7.94×10^{-8}	1.28×10^{-7}	0.0003		0.000265	0.000428		
Manganese	11,200	0.0029	0.00371	0.047		0.0488	0.0789		
Molybdenum	23.5	4.80×10^{-6}	7.76×10^{-6}	0.005		0.000959	0.00155		
Nickel	73.8	0.0000151	0.0000243	0.02		0.000753	0.00122		
Nitrate	21,200	0.0043	0.007	1.60		0.0027	0.00437		
Lead	191	0.0000390	0.0000631	0.0014		0.0278	0.045		
Antimony	72	0.0000147	0.0000238	0.0004		0.0367	0.0594		
Selenium	9.36	1.91×10^{-6}	3.09×10^{-6}	0.005		0.000382	0.0006		
Tin	8.98	1.83×10^{-6}	2.96×10^{-6}	0.6		3.05×10^{-6}	4.94×10^{-6}		
Strontium	711	0.000145	0.0002	0.6		0.000242	0.0004		
Thallium	9.20	1.88×10^{-6}	3.04×10^{-6}	0.00008		0.0235	0.0379		
Uranium	79.3	0.0000162	0.0000262	0.0006		0.0270	0.0436		
Vanadium	150	0.0000306	0.0000496	0.001		0.0306	0.0496		

Analytes	*95% UCL Concentration (µg/L)*	*Average Chronic Daily Intake (mg/kg-day)*	*High Chronic Daily Intake (mg/kg-day)*	*Oral RfD (mg/kg-day)*	*Oral Slope Factor (per mg/kg-day)*	*Average Case Hazard Index*	*High Intake Hazard Index*	*Average Case Cancer Risk*	*High Intake Cancer Risk*
Zinc	862	0.000176	0.000284	0.3		0.00586	0.000948		
Acetone	78.3	0.000016	0.0000258	0.9		0.0000177	0.0000287		
AROCLOR 1260	0.5	1.02×10^{-7}	1.65×10^{-7}		2.00			2.04×10^{-7}	3.30×10^{-7}
Benzo(a)pyrene	3.85	7.85×10^{-7}	1.27×10^{-6}		7.30			5.73×10^{-6}	9.27×10^{-6}
Bis(2-ethylhexyl)phthalate	10.9	2.23×10^{-6}	3.61×10^{-6}	0.02	0.014	0.000111	0.00018	3.12×10^{-8}	5.05×10^{-8}
HMX	150	0.0000307	0.0000496	0.05		0.000613	0.000992		
RDX	7.78	1.59×10^{-6}	2.57×10^{-6}	0.003	0.11	0.000529	0.000856	1.75×10^{-7}	2.82×10^{-7}
Trinitrotoluene	0.35	7.14×10^{-8}	1.16×10^{-7}	0.0005	0.03	0.000143	0.000231	2.14×10^{-9}	3.47×10^{-9}

HMx = octahydro-1, 3, 5, 7-tetranitro-3, 5, 7-tetrazocine, kg = kilogram, L = liter, mg = milligram, µg = microgram, RfD = Reference Dose, UCL = upper confidence limit.
Notes: Chronic Intake (mg/kg-day) = Water Concentration (µg/L) × Consumption rate (L/day) × 1×10^{-3} (mg/µg) × 1/Body Weight (1/71.8 kg). Shaded cells in Slope Factor and Cancer Risk columns indicate no known human chemical cancer risk.

Table C–45 Hazard Index and Cancer Risk to the Recreational User Receptor from the Ingestion of Nonradioactive Contaminants in Sediment

Sediment Consumption: 1.07 g per Year Average, 4.27 g per Year High Intake

Analytes	*95% UCL Concentration (µg/g)*	*Average Chronic Daily Intake (mg/kg-day)*	*High Chronic Daily Intake (mg/kg-day)*	*Oral RfD (mg/kg-day)*	*Oral Slope Factor (per mg/kg-day)*	*Average Case Hazard Index*	*High Intake Hazard Index*	*Average Case Cancer Risk*	*High Intake Cancer Risk*
Silver	1.95	7.97×10^{-8}	3.18×10^{-7}	0.005		0.0000159	0.0000636		
Aluminum	16,400	0.00067	0.00268	1		0.00067	0.00268		
Arsenic	3.75	1.53×10^{-7}	6.11×10^{-7}	0.0003	1.5	0.00059	0.00204	2.29×10^{-7}	9.16×10^{-7}
Boron	5.9	2.41×10^{-7}	9.61×10^{-7}	0.2		1.20×10^{-6}	4.81×10^{-6}		
Barium	244	9.95×10^{-6}	0.0000398	0.2		0.0000498	0.000199		
Beryllium	1.1	4.49×10^{-8}	1.79×10^{-7}	0.002	4.3	0.0000225	0.0000897	1.93×10^{-7}	7.72×10^{-7}
Cadmium	0.841	3.43×10^{-8}	1.37×10^{-7}	0.0005	0.0018	0.0000686	0.00274	6.17×10^{-11}	2.47×10^{-10}
Cobalt	5.37	2.19×10^{-7}	8.75×10^{-7}	0.02		0.0000110	0.0000438		
Chromium	30.7	1.25×10^{-6}	5.01×10^{-6}	1.5		8.35×10^{-7}	3.34×10^{-6}		
Copper	19.4	7.92×10^{-7}	3.16×10^{-6}	0.037		0.0000214	0.0000855		

Analytes	*95% UCL Concentration (µg/g)*	*Average Chronic Daily Intake (mg/kg-day)*	*High Chronic Daily Intake (mg/kg-day)*	*Oral RfD (mg/kg-day)*	*Oral Slope Factor (per mg/kg-day)*	*Average Case Hazard Index*	*High Intake Hazard Index*	*Average Case Cancer Risk*	*High Intake Cancer Risk*
Mercury	0.103	4.21×10^{-9}	1.68×10^{-8}	0.0003		0.0000140	0.0000561		
Manganese	824	0.0000336	0.000134	0.047		0.000715	0.00286		
Molybdenum	1.88	7.69×10^{-8}	3.07×10^{-7}	0.005		0.0000154	0.0000614		
Nickel	10.8	4.41×10^{-7}	1.76×10^{-6}	0.02		0.0000221	0.0000882		
Lead	24.9	1.02×10^{-6}	4.06×10^{-6}	0.00140		0.000726	0.0029		
Antimony	0.197	8.04×10^{-9}	3.21×10^{-8}	0.0004		0.0000201	0.0000803		
Selenium	3.80	1.55×10^{-7}	6.20×10^{-7}	0.005		0.0000310	0.000124		
Tin	8.89	3.63×10^{-7}	1.45×10^{-6}	0.6		6.04×10^{-7}	2.41×10^{-6}		
Strontium	51.9	2.12×10^{-6}	8.45×10^{-6}	0.6		3.53×10^{-6}	0.0000141		
Thallium	0.232	9.48×10^{-9}	3.79×10^{-8}	8.00×10^{-5}		0.000118	0.000473		
Vanadium	23.9	9.77×10^{-7}	3.90×10^{-6}	0.001		0.000977	0.0039		
Zinc	148	6.04×10^{-6}	0.0000241	0.3		0.0000201	0.0000804		
AROCLOR 1260	165	6.72×10^{-6}	0.0000268		2.00			0.0000134	0.0000537
Benzo(a)anthracene	1,010	0.0000413	0.000165		0.73			0.0000302	0.000121
Benzo(a)pyrene	741	0.0000303	0.000121		7.3			0.000221	0.000882
Benzo(b)fluoranthene	982	0.0000401	0.000160		0.73			0.0000293	0.000117
Bis(2-ethylhexyl)phthalate	2,310	0.0000945	0.000377	0.02	0.014	0.00472	0.0189	1.32×10^{-6}	5.28×10^{-6}
HMX	1,100	0.0000448	0.000179	0.05		0.000896	0.00358		
RDX	1,130	0.0000460	0.000184	0.003	0.11	0.0153	0.0612	5.06×10^{-6}	0.0000202
Trinitrotoluene	199	8.14×10^{-6}	0.0000325	0.0005	0.03	0.0163	0.065	2.44×10^{-7}	9.75×10^{-7}

g = grams, HMx = octahydro-1, 3, 5, 7-tetranitro-3, 5, 7-tetrazocine, kg = kilogram, L = liter, mg = milligram, µg = microgram, RDx = hexahydro-1, 3, 5-trinitro-1, 3, 5-triazine, RfD = Reference Dose, UCL = upper confidence limit.

Notes: Chronic Intake (mg/kg-day) = Sediment Concentration (µg/g) × Consumption rate (g/day) × 1×10^{-3} (mg/µg) × 1/Body Weight (1/71.8 kg). Shaded cells in Slope Factor and Cancer Risk columns indicate no known human chemical cancer risk.

Table C–46 Hazard Index and Cancer Risk to the Offsite Resident Receptor from the Ingestion of Nonradioactive Contaminants in Sediment

Sediment Consumption: 36.5 g per Year Average, 146 g per Year High Intake

Analytes	*95% UCL Concentration (µg/g)*	*Average Chronic Daily Intake (mg/kg-day)*	*High Daily Intake (mg/kg-day)*	*Oral RfD (mg/kg-day)*	*Oral Slope Factor (per mg/kg-day)*	*Average Case Hazard Index*	*High Intake Hazard Index*	*Average Case Cancer Risk*	*High Intake Case Cancer Risk*
Silver	0.921	1.28×10^{-6}	5.13×10^{-6}	0.005		0.000256	0.00103		
Aluminum	40,000	0.0556	0.223	1		0.056	0.223		
Arsenic	6.28	8.73×10^{-6}	0.0000350	0.0003	1.5	0.0291	0.117	0.0000131	0.0000525
Boron	15.3	0.0000212	0.0000851	0.2		0.000106	0.000426		
Barium	371	0.0005	0.00207	0.2		0.00258	0.0103		
Beryllium	2.00	2.78×10^{-6}	0.0000111	0.002	4.3	0.00139	0.0056	0.0000119	0.0000478
Cadmium	1.08	1.50×10^{-6}	6.03×10^{-6}	0.0005	0.0018	0.00301	0.0121	2.71×10^{-9}	1.08×10^{-8}
Cobalt	11.5	0.0000160	0.0000643	0.02		0.000802	0.00321		
Chromium	24.7	0.0000343	0.000138	1.5		0.0000229	0.0000917		
Copper	26.0	0.0000361	0.000145	0.037		0.000976	0.00391		
Mercury	0.143	1.99×10^{-7}	7.96×10^{-7}	0.0003		0.000662	0.00265		
Manganese	1,370	0.0019	0.00761	0.047		0.0404	0.162		
Molybdenum	0.809	1.13×10^{-6}	4.51×10^{-6}	0.005		0.000225	0.000902		
Nickel	22.8	0.0000316	0.000127	0.02		0.00158	0.00634		
Lead	26.8	0.0000372	0.000149	0.0014		0.0266	0.106		
Antimony	0.14	1.94×10^{-7}	7.79×10^{-7}	0.0004		0.000486	0.00195		
Selenium	1.55	2.15×10^{-6}	8.63×10^{-6}	0.005		0.000431	0.00173		
Tin	2.74	3.81×10^{-6}	0.0000153	0.6		6.35×10^{-6}	0.0000254		
Strontium	212	0.000294	0.00118	0.6		0.000490	0.00196		
Thallium	0.400	5.57×10^{-7}	2.23×10^{-6}	0.00008		0.00696	0.0279		
Vanadium	51.1	0.000071	0.000285	0.001		0.071	0.285		
Zinc	96.6	0.000134	0.000538	0.3		0.000447	0.00179		
AROCLOR 1260	12.0	0.0000167	0.0000668		2.00			0.0000334	0.000134
Bis(2-ethylhexyl)phthalate	198	0.000275	0.0011	0.02	0.014	0.00138	0.055	3.85×10^{-6}	0.0000154

g = grams, kg = kilogram, L = liter, mg = milligram, µg = microgram, RfD = Reference Dose, UCL = upper confidence limit.

Notes: Chronic Intake (mg/kg-day) = Sediment Concentration (µg/g) × Consumption rate (g/day) × 1×10^{-3} (mg/µg) × 1/Body Weight (1/71.8 kg). Shaded cells in Slope Factor and Cancer Risk columns indicate no known human chemical cancer risk.

A comparison of the means of these elements collected in soils from perimeter and onsite areas with those from regional areas shows that the concentrations of beryllium, mercury, and lead in soils collected from onsite areas were significantly higher than concentrations from regional soils. Although beryllium, mercury, and lead concentrations in soils from onsite areas were statistically higher than in regional soils, the differences were very small.

Tables C–47 and **C–48** show the contribution to health risk to the offsite resident and the recreational user receptors from the ingestion of trace metals in surface soil.

Produce and Fish Ingestion

A wide variety of wild and domestic edible vegetable, fruit, grain, and animal products are harvested in the area surrounding LANL. Ingestion of foodstuffs constitutes an important pathway by which nonradioactive contaminants can be transferred to humans. Therefore, foodstuff samples are routinely collected (fruits, vegetables, grains, fish, milk, eggs, honey, herbal teas, mushrooms, pinyon nuts, domestic animals, and large and small game animals) from the surrounding area and communities to determine the impacts of LANL operations on the human food chain.

The metal elements analyzed in food were either those that have been consistently detected above the limit of detection in past years, those that have a history of use at LANL, or those that have been detected in significantly higher concentrations in soils. Of the five metals analyzed in produce collected from perimeter and onsite areas, only three (barium, lead, and selenium) were found to be above their limits of detection; beryllium and mercury were below the limits of detection. Of the three elements that were found to be above their limits of detection, all were within regional statistical reporting limits. As a group, the levels of all of the metal elements analyzed in produce from all perimeter and onsite areas were not significantly higher than those in produce collected from regional areas. Of special note is that beryllium and lead were found at significantly higher levels in soils collected in perimeter and onsite areas, but were not found at significantly higher levels in produce collected from perimeter or onsite areas than in produce collected from around the region.

Monitoring results reported in 2002 (LANL 2004b) show trace elements in produce collected before and after the Cerro Grande Fire. From almost all sites, only selenium was present in higher concentrations in produce collected after the Cerro Grande Fire than in produce collected before the fire. It is hard to say that selenium concentrations in produce collected from these sites increased because of the Cerro Grande Fire because (1) no other trace elements were elevated after the fire, and (2) selenium concentrations in soil samples collected from these same sites in 2000 and 2002 were not significantly higher than in soils collected in 1999.

The 2003 Environmental Surveillance Report presents the results of a special study on perchlorates found in vegetables and irrigation waters (LANL 2004d). Perchlorates are used at LANL in explosive and actinide research and were released into the environment as treated and untreated effluent discharges. They are highly soluble, mobile, and long-lived, and they have migrated from shallow depths to deeper groundwater levels within LANL lands. Perchlorates are

Table C–47 Hazard Index and Cancer Risk to the Offsite Resident Receptor from the Ingestion of Nonradioactive Contaminants in Soil

Soil Consumption: 36.5 g per Year Average, 146 g per Year High Intake

Analytes	*95% UCL Concentration (µg/g)*	*Average Chronic Daily Intake (mg/kg-day)*	*High Chronic Daily Intake (mg/kg-day)*	*Oral RfD (mg/kg-day)*	*Oral Slope Factor (per mg/kg-day)*	*Average Case Hazard Index*	*High Intake Hazard Index*	*Average Case Cancer Risk*	*High Intake Cancer Risk*
Barium	164	0.000229	0.001	0.2		0.00114	0.00458		
Beryllium	0.924	1.28×10^{-6}	5.15×10^{-6}	0.002	4.3	0.000642	0.00257	5.52×10^{-6}	0.0000221
Mercury	0.0222	3.08×10^{-8}	1.24×10^{-7}	0.0003		0.000103	0.000412		
Lead	23.5	0.0000326	0.000131	0.0014		0.0233	0.0934		
Selenium	0.13	1.81×10^{-7}	7.24×10^{-7}	0.005		0.0000361	0.000145		

g = grams, kg = kilogram, L = liter, mg = milligram, µg = microgram, RfD = Reference Dose, UCL = upper confidence limit.

Notes: Chronic Intake (mg/kg-day) = Soil Concentration (µg/g) × Consumption rate (g/day) × 1×10^{-3} (mg/µg) × 1/Body Weight (1/71.8 kg). Shaded cells in Slope Factor and Cancer Risk columns indicate no known human chemical cancer risk.

Table C–48 Hazard Index and Cancer Risk to the Recreational User Receptor from the Ingestion of Nonradioactive Contaminants in Soil

Soil Consumption: 1.07 g per Year Average, 4.27 g per Year High Intake

Analytes	*95% UCL Concentration (µg/g)*	*Average Chronic Daily Intake (mg/kg-day)*	*High Chronic Daily Intake (mg/kg-day)*	*Oral RfD (mg/kg-day)*	*Oral Slope Factor (per mg/kg-day)*	*Average Case Hazard Index*	*High Intake Hazard Index*	*Average Case Cancer Risk*	*High Intake Cancer Risk*
Barium	184	7.52×10^{-6}	0.0000301	0.2		0.0000376	0.000150		
Beryllium	0.932	3.80×10^{-8}	1.52×10^{-7}	0.002	4.3	0.0000190	0.0000760	1.64×10^{-7}	6.53×10^{-7}
Mercury	0.0242	9.87×10^{-10}	3.94×10^{-9}	0.0003		3.29×10^{-6}	0.0000131		
Lead	18.3	7.48×10^{-7}	2.99×10^{-6}	0.0014		0.000534	0.00213		

g = grams, kg = kilogram, L = liter, mg = milligram, µg = microgram, RfD = Reference Dose, UCL = upper confidence limit.

Notes: Chronic Intake (mg/kg-day) = Soil Concentration (µg/g) × Consumption rate (g/day) × 1×10^{-3} (mg/µg) × 1/Body Weight (1/71.8 kg). Shaded cells in Slope Factor and Cancer Risk columns indicate no known human chemical cancer risk.

readily taken up by plants, and the major source of water for home garden irrigation in the Los Alamos vicinity is from deep groundwater sources. Perchlorates inhibit thyroid function, but there is no current Federal standard for protection of human health. Therefore, a special study was conducted to evaluate the possible existence of perchlorates in locally grown foods. Results showed no perchlorate concentrations in any of the vegetable samples or water samples above the minimum reporting level or the minimum detection level.

The 2004 Environmental Surveillance Report (LANL 2005b) discussed the results of a special monitoring study to identify polychlorinated biphenyls in the Rio Grande. Polychlorinated biphenyls are extensively distributed worldwide and are ubiquitous in the environment. Concern has existed for years that LANL has released polychlorinated biphenyls into the environment that may have reached the Rio Grande. From 1997 to 2002, studies were conducted on polychlorinated biphenyls in fish taken from the Rio Grande and from Cochiti and Abiquiu reservoirs. One of the goals of the studies was to determine whether LANL has contributed to the polychlorinated biphenyl burdens. Results showed only a small amount of similarity between the type of aroclors indicated in the Rio Grande below LANL and aroclors known to exist at LANL. In addition, the studies concluded that, for the particular time period studied, LANL was not likely contributing polychlorinated biphenyls to the Rio Grande as indicated by the statistically similar total polychlorinated biphenyls concentrations at the two stations above LANL and the station immediately below LANL. This same conclusion was made in reports on the previous fish studies.

Fish normally collected each year include two types: predators and bottom-feeders. In any given year, predator fish may include the following: northern pike (*Esox lucius*), largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieui*), white crappie (*Pomoxis annularis*), brown trout (*Salmo trutta*), white bass (*Morone chrysops*), and walleye (*Stizostedion vitreum*). Similarly, bottom-feeding fish may include the following: white sucker (*Catostomus commersoni*), channel catfish (*Ictalurus punctatus*), carp (*Cyprinus carpio*), and carp sucker (*Carpiodes carpio*). Bottom-feeding fish are better indicators of environmental contamination than predator game fish because the bottom-feeding fish forage on the bottom where contaminants readily bind to sediments.

In general, most of the trace elements in both predator and bottom-feeding fish collected upstream and downstream of LANL were below the limit of detection. Concentrations of the elements that were above the limit of detection (barium, mercury, and selenium) were within historical regional background concentrations and were statistically similar to concentrations in fish from other bodies of water in the region. Mercury concentrations, a major problem in New Mexico fisheries, were statistically significant in most fish collected. The levels of mercury in predator and bottom-feeding fish muscle (fillets) collected were still below the U.S. Food and Drug Administration's ingestion limit.

Tables C–49 and **C–50** show the contributions to health risk to the offsite resident from the ingestion of trace metals in produce and predator fish. **Table C–51** shows the contribution to health risk to the special pathways receptor from ingestion of trace metals in non-predator (bottom-feeding) fish.

Table C–49 Hazard Index and Cancer Risk to the Offsite Resident Receptor from the Ingestion of Nonradioactive Contaminants in Produce

Produce Consumption: 8.2 g/kg-day Average, 25.5 g/kg-day High Intake

Analytes	*95% UCL Concentration (µg/g wet weight)*	*Average Chronic Daily Intake (mg/kg-day)*	*High Chronic Daily Intake (mg/kg-day)*	*Oral RfD (mg/kg-day)*	*Oral Slope Factor (per mg/kg-day)*	*Average Case Hazard Index*	*High Intake Hazard Index*	*Average Case Cancer Risk*	*High Intake Cancer Risk*
Barium	4.48	0.0367	0.114	0.2		0.184	0.571		
Beryllium	0.03	0.000246	0.000765	0.002	4.3	0.123	0.383	0.00106	0.00329
Mercury	0.0117	0.0000957	0.000297	0.0003		0.319	0.992		
Lead	0.658	0.00540	0.0168	0.00140		3.86	12		
Selenium	0.103	0.000844	0.00263	0.005		0.169	0.525		

g = grams, kg = kilogram, L = liter, mg = milligram, µg = microgram, RfD = Reference Dose, UCL = upper confidence limit.

Notes: Chronic Intake (mg/kg-day) = Produce Concentration (µg/g) × Consumption rate (g/day) × 1×10^{-3} (mg/µg) × 1/Body Weight (1/71.8 kg). Shaded cells in Slope Factor and Cancer Risk columns indicate no known human chemical cancer risk.

Table C–50 Hazard Index and Cancer Risk to the Offsite Resident Receptor from the Ingestion of Nonradioactive Contaminants in Fish

Fish Consumption: 20.1 g/day Average, 53 g/day High Intake

Analytes	*95% UCL Concentration (µg/g)*	*Average Chronic Daily Intake (mg/kg-day)*	*High Chronic Daily Intake (mg/kg-day)*	*Oral RfD (mg/kg-day)*	*Oral Slope Factor (per mg/kg-day)*	*Average Case Hazard Index*	*High Intake Hazard Index*	*Average Case Cancer Risk*	*High Intake Cancer Risk*
Silver	1.42	0.000399	0.00105	0.005		0.0797	0.21		
Arsenic	0.5	0.00014	0.000369	0.0003	1.5	0.467	3.5	0.00021	0.00158
Barium	0.536	0.00015	0.000396	0.2		0.000751	0.00198		
Beryllium	0.264	0.0000738	0.000195	0.002	4.3	0.0369	0.0973	0.000317	0.000837
Cadmium	0.25	0.0000700	0.000185	0.0005	0.0018	0.14	0.369	1.26×10^{-7}	3.32×10^{-7}
Chromium	0.5	0.00014	0.000369	1.5		0.0000933	0.00246		
Mercury	0.6	0.000168	0.000443	0.00003		0.56	1.48		
Nickel	1	0.00028	0.000738	0.02		0.014	0.0369		
Lead	0.15	0.0000420	0.000111	0.001		0.03	0.0791		
Antimony	0.4	0.000112	0.000295	0.0004		0.28	0.738		
Selenium	1.10	0.000309	0.000814	0.005		0.0617	0.163		

g = grams, kg = kilogram, L = liter, mg = milligram, µg = microgram, RfD = Reference Dose, UCL = upper confidence limit.

Notes: Chronic Intake (mg/kg-day) = Fish Concentration (µg/g wet weight) × Consumption rate (g/day) × 1×10^{-3} (mg/µg) × 1/Body Weight (1/71.8 kg). Shaded cells in Slope Factor and Cancer Risk columns indicate no known human chemical cancer risk.

Table C–51 Hazard Index and Cancer Risk to the Special Pathways Receptor from the Ingestion of Nonradioactive Contaminants in Fish

Fish Consumption: 70 g per Day Average, 170 g per Day High Intake

Analytes	*95% UCL Concentration (µg/g)*	*Average Chronic Daily Intake (mg/kg-day)*	*High Chronic Daily Intake (mg/kg-day)*	*Oral RfD (mg/kg-day)*	*Oral Slope Factor (per mg/kg-day)*	*Average Case Hazard Index*	*High Intake Hazard Index*	*Average Case Cancer Risk*	*High Intake Cancer Risk*
Silver	0.5	0.000488	0.00119	0.005		0.0975	0.237		
Arsenic	0.526	0.000513	0.00125	0.0003	1.50	1.71	4.16	0.000770	0.00187
Barium	1.20	0.00117	0.00285	0.2		0.00587	0.0143		
Beryllium	0.264	0.000257	0.0006	0.002	4.30	0.129	0.312	0.0011	0.00269
Cadmium	0.25	0.000244	0.000593	0.0005	0.0018	0.488	1.19	4.39×10^{-7}	1.07×10^{-6}
Chromium	0.5	0.000488	0.00119	1.5		0.000325	0.000790		
Mercury	0.398	0.000388	0.000944	0.003		1.29	3.15		
Nickel	1.00	0.000975	0.00237	0.02		0.0488	0.119		
Lead	0.168	0.000163	0.000397	0.0014		0.117	0.284		
Antimony	0.4	0.00039	0.000948	0.0004		0.975	2.37		
Selenium	0.866	0.000844	0.00205	0.005		0.169	0.41		

g = grams, kg = kilogram, L = liter, mg = milligram, µg = microgram, RfD = Reference Dose, UCL = upper confidence limit.

Notes: Chronic Intake (mg/kg-day) = Fish Concentration (µg/g wet weight) × Consumption rate (g/day) × 1×10^{-3} (mg/µg) × 1/Body Weight (1/71.8 kg). Shaded cells in Slope Factor and Cancer Risk columns indicate no known human chemical cancer risk.

C.3 Impacts on Human Health from Biological Agents

C.3.1 Introduction

The research capacity of LANL deals with a multitude of world-class scientific topics and is focused on advancing environmental and biomedical knowledge and supporting both the DOE mission and the national bio-defense mission. Current biological research covers a range of topics including, but not limited to, genomic (or genetic) and proteomic (the study of proteins generated by the genes of a particular cell) science, measurement science and diagnostics, molecular synthesis, structural biology, cell biology, computational biology, and environmental microbiology. All of these divisions are focused on understanding the interaction between humans, the microbial world, and the environment. This task is accomplished by the detailed study of microorganisms and their characteristics using technology specific to each of the groups mentioned above. Microorganisms are found naturally in the environment; they are living things that have or can develop the ability to act or function independently. There are different categories of microorganisms, including bacteria, viruses, and fungi. Bacteria are single-celled organisms that can multiply rapidly and live anywhere in the environment. Only a very small percentage of these can cause infection and mild-to-severe disease in humans. Bacteria are also capable of producing toxins that can be harmful to humans, animals, and plants. A virus is an acellular organism (that is, a single particle) that depends on the host cell's metabolic functions to multiply. Most but not all viruses can infect humans. Fungi are plant-like organisms that lack chlorophyll; a small number of these organisms are capable of causing disease in humans.

C.3.2 Principles of Biosafety

All laboratories within the United States, including LANL, follow a specific set of guidelines for all laboratory practices that is issued by the Centers for Disease Control and Prevention and the National Institutes of Health. These guidelines are safety protocols that provide a baseline for all laboratory work.

The term "containment" is used to describe safe methods of managing infectious materials in the laboratory environment where they are being handled or maintained. The purpose of containment is to reduce or eliminate exposure of laboratory workers, other persons, and the outside environment to potentially hazardous agents (HHS 2007).

Primary containment, the protection of personnel and the immediate laboratory environment from exposure to infectious agents, is provided by both good microbiological technique and the use of appropriate safety equipment. Secondary containment, the protection of the environment external to the laboratory from exposure to infectious materials, is provided by a combination of facility design and operational practices. Therefore, the three elements of containment include laboratory practice and technique, safety equipment, and facility design. The risk assessment of the work to be performed with a specific agent will determine the appropriate combination of these elements (HHS 2007).

C.3.2.1 Safety Equipment (Primary Barriers)

Safety equipment includes biological safety cabinets, enclosed containers, and other engineering controls designed to remove or minimize exposures to hazardous biological materials. The biological safety cabinet is the principal device used to provide containment of infectious splashes or aerosols generated by many microbiological procedures. Three types of biological safety cabinets (Class I, II, and III) are used in microbiological laboratories. Open-fronted Class I and Class II biological safety cabinets are primary barriers that offer significant levels of protection to laboratory personnel and the environment when used with good microbiological techniques. The Class II biological safety cabinet also provides protection from external contamination of the materials (for example, cell cultures, microbiological stocks) being manipulated inside the cabinet. The gas-tight Class III biological safety cabinet provides the highest attainable level of protection to personnel and the environment. Safety equipment also may include items for personal protection such as gloves, coats, gowns, shoe covers, boots, respirators, face shields, safety glasses, or goggles. Personal protective equipment is often used in combination with biological safety cabinets and other devices that contain the agents, animals, or materials being handled (HHS 2007).

C.3.2.2 Facility Design and Construction (Secondary Barriers)

The design and construction of the facility contributes to laboratory workers' protection, provides a barrier to protect persons outside the laboratory, and protects persons or animals in the community from infectious agents that may be accidentally released from the laboratory. Laboratory management is responsible for providing facilities commensurate with the laboratory's function and the recommended biosafety level for the agents being manipulated.

The recommended secondary barrier(s) will depend on the risk of transmission of specific agents. For example, the exposure risks for most laboratory work in Biosafety Level 1 and 2 facilities will be direct contact with the agents or inadvertent contact exposures through contaminated work environments. Secondary barriers in these laboratories may include separation of the laboratory work area from public access, availability of a decontamination facility, and handwashing facilities. When the risk of infection by exposure to an infectious aerosol is present, higher levels of primary containment and multiple secondary barriers may be necessary to prevent infectious agents from escaping into the environment. Such design features include specialized ventilation systems to ensure directional airflow, air treatment systems to decontaminate or remove agents from exhaust air, controlled access zones, airlocks at laboratory entrances, or separate buildings or modules to isolate the laboratory. Design engineers for laboratories may refer to specific ventilation recommendations such as those found in the Applications Handbook for Heating, Ventilation, and Air-Conditioning published by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (HHS 2007).

C.3.2.3 Waste

Biological waste being removed from a laboratory is disinfected with a 10 percent Clorox solution or by autoclaving (a process using temperature and pressure to produce steam) regardless of the safety level. These processes, when implemented correctly, ensure that all waste is decontaminated before it leaves the confinement of the facility (HHS 2007). Normal

laboratory waste is handled in an appropriate manner in accordance with the type of waste being discarded via the LANL Safety Plan.

C.3.2.4 Biological Release

LANL operates Biosafety Level 1 and 2 (see the discussion of Biosafety Levels in Section C.3.3) facilities as discussed in Chapter 3, Section 3.1.3.11, of this SWEIS. If released into the environment, Biosafety Level 1 material at LANL would pose little to no risk to the workers, public, or environment in general because this biological material is not known to consistently cause disease and is not contagious. Biosafety Level 2 facilities use an extensive set of procedures, safety equipment, and containment facilities that prevent any releases of Biosafety Level 2 agents that would affect workers or the public. Laboratory personnel are still subject to non-biological hazards that are associated with all workplaces and are subject to Occupational Safety and Health Administration regulations.

C.3.3 Biosafety Levels

Four biosafety levels represent combinations of laboratory practices and techniques, safety equipment, and laboratory facilities. Each combination is specifically appropriate for the operations performed, the documented or suspected routes of transmission of the infectious agents, and the laboratory function or activity. The recommended biosafety level(s) for specific organisms represent those conditions under which the agent(s) ordinarily can be safely handled. When specific information is available to suggest that the human body's ability to resist the type, strength, and rate of infection is insufficient, or that antibiotic resistance patterns, vaccine and treatment availability, or other factors are significantly altered, more (or less) stringent practices may be specified (HHS 2007).

C.3.3.1 Biosafety Level 1

Biosafety Level 1 practices, safety equipment, and facility design and construction are appropriate for undergraduate and secondary educational training and teaching laboratories, as well as other laboratories in which work is performed with defined and characterized strains of viable microorganisms that are not known to consistently cause disease in healthy adult humans. *Bacillus subtilis, Naegleria gruberi,* infectious canine hepatitis virus, and exempt organisms under the National Institutes of Health Recombinant DNA Guidelines represent microorganisms that meet these criteria. Vaccine strains that have undergone multiple in vivo (that is, within a living organism) passages should not be considered infectious simply because they are vaccine strains. Biosafety Level 1 represents a basic level of containment that relies on standard microbiological practices with no special primary or secondary barriers recommended, other than a sink for handwashing (HHS 2007).

C.3.3.2 Biosafety Level 2

Biosafety Level 2 practices, equipment, and facility design and construction are applicable to clinical, diagnostic, teaching, and other laboratories in which work is performed with the broad spectrum of naturally occurring moderate-risk agents that are present in the community and associated with human disease of varying severity. With good microbiological techniques, these

agents can be used safely in activities conducted on the open bench, provided the potential for producing splashes or aerosols is low. Hepatitis B virus, HIV, *salmonellae*, and *Toxoplasma spp.* (a parasite that spreads from animals to humans) are representative of microorganisms assigned to this containment level. Biosafety Level 2 is appropriate when work is performed with any human-derived blood, body fluids, tissues, or primary human cell lines where the presence of an infectious agent may be unknown. (Laboratory personnel working with human-derived materials should refer to the Occupational Safety and Health Administration Bloodborne Pathogen Standard for specific required precautions.) Primary hazards to personnel working with these agents relate to accidental skin absorption, mucous membrane exposures, or ingestion of infectious materials. Extreme caution should be taken with contaminated needles or sharp instruments. Even though organisms routinely manipulated at Biosafety Level 2 are not known to be transmissible by the aerosol route, procedures with aerosol or high splash potential that may increase the risk of such personnel exposure must be conducted in primary containment equipment or in devices such as a biological safety cabinet. Other primary barriers should be used as appropriate, such as splash shields, face protection, gowns, and gloves. Secondary barriers such as handwashing sinks and waste decontamination facilities must be available to reduce potential environmental contamination (HHS 2007).

C.3.3.3 Biosafety Level 3

Biosafety Level 3 practices, safety equipment, and facility design and construction are applicable to clinical, diagnostic, teaching, research, or production facilities in which work is performed with indigenous or exotic agents with a potential for respiratory transmission, and thus may cause serious and potentially lethal infection. *Mycobacterium tuberculosis*, St. Louis encephalitis virus, and *Coxiella burnetii* are representative of the microorganisms assigned to this level. Primary hazards to personnel working with these agents relate to autoinoculation (that is, inoculation with a vaccine made from microorganisms obtained from the recipient's own body), ingestion, and exposure to infectious aerosols. At Biosafety Level 3, more emphasis is placed on primary and secondary barriers to protect personnel in contiguous areas, the community, and the environment from exposure to potentially infectious aerosols. For example, all laboratory manipulations should be performed in a biological safety cabinet or other enclosed equipment such as a gas-tight aerosol generation chamber. Secondary barriers for this level include controlled access to the laboratory and ventilation requirements that minimize the release of infectious aerosols from the laboratory (HHS 2007). The Biosafety Level 3 work being proposed for LANL is being addressed in a separate environmental impact statement and is not addressed in this SWEIS.

C.3.3.4 Biosafety Level 4

Biosafety Level 4 practices, safety equipment, and facility design and construction are applicable to work with dangerous and exotic agents that pose a high individual risk of life-threatening disease, may be transmitted via the aerosol route, and have no available vaccine or therapy. Agents with similar genetics to Biosafety Level 4 agents also should be handled at this level. When sufficient data are obtained, work with these agents may continue at this level or at a lower level. Viruses such as Marburg or Congo-Crimean hemorrhagic fever are manipulated at Biosafety Level 4 (HHS 2007). No Biosafety Level 4 work is currently performed or proposed to

be performed at LANL. **Table C–52** delineates containment design practices and levels of biological agents for each Biosafety Level Facility.

Table C–52 Containment Design Practices and Levels of Biological Agents for Each Biosafety Level Facility

Biosafety Level	*Agents*	*Practices*	*Safety Equipment (Primary Barriers)*	*Facilities (Secondary Barriers)*
1	Not known to consistently cause disease in healthy adults.	Standard Microbiological Practices	None required.	Open bench top sink required.
2	Associated with human disease; hazard = percutaneous injury (that is, injury obtained through the skin or skin puncture), ingestion, and mucous membrane exposure.	Biosafety Level 1 practices plus: - Limited access, - Biohazard warning signs, - "Sharps" precautions, and - Biosafety manual defining any needed waste decontamination or medical surveillance policies	Primary barriers = Class I or II biological safety cabinets or other physical containment devices used for all manipulations of agents that cause splashes or aerosols of infectious materials; personal protective equipment: laboratory coats; gloves; and face protection as needed.	Biosafety Level 1 plus: - Autoclave (a strong, pressurized, steam-heated vessel, used for sterilization).
3	Indigenous or exotic agents with potential for aerosol transmission; disease may have serious or lethal consequences.	Biosafety Level 2 practices plus: - Controlled access, - Decontamination of all waste, - Decontamination of lab clothing before laundering, and - Baseline serum.	Primary barriers = Class I or II biological safety cabinets or other physical containment devices used for all open manipulations of agents; personal protective equipment: protective lab clothing; gloves; and respiratory protection as needed.	Biosafety Level 2 plus: - Physical separation from access corridors; - Self-closing, double-door access; - Exhausted air not recirculated; and - Negative airflow into laboratory.
4	Dangerous or exotic agents which pose high risk of life-threatening disease from aerosol-transmitted lab infections or related agents with unknown risk of transmission.	Biosafety Level 3 practices plus: - Clothing change before entering, - Shower on exit, and - All material decontaminated on exit from facility.	Primary barriers = All procedures conducted in Class III biological safety cabinets or Class I or II biological safety cabinets in combination with full-body, air-supplied, positive pressure personnel suit.	Biosafety Level 3 plus: - Separate building or isolated zone; - Dedicated supply and exhaust, vacuum, and decontamination systems; and - Other requirements outlined in Section C.3.3.3.

Source: HHS 2007.

C.3.4 Detection

Unlike chemical or radiological hazards, biological organisms cannot be recognized instantaneously due to the complexity of differentiating normal background organisms from potentially deadly organisms. Therefore, the scientific community has been working diligently to develop methods and assays that will allow collection and identification of an organism within any sample within an acceptable time. The detection of a biological agent starts with being able to collect samples from surfaces, air, water, soil, or bodily fluids that contain the potentially harmful organism. The next step in detection is identifying the presence of a harmful organism and its identification. These assays must be capable of utilizing specificity, time, and accuracy to identify the unknown agent; the more specific assays take a longer period of time. The methods

that are most commonly used are Polymerase Chain Reaction, Enzyme-Linked Immunosorbent Assay, and Culturing. Polymerase Chain Reaction is a method in which specific DNA sequences are amplified to identify the presence or absence of a given organism. Enzyme-Linked Immunosorbent Assay is a method that determines the presence of antibodies to a foreign substance. Culturing, the gold standard method for many reference laboratories, is a method in which a given sample is spread on a nutrient culture plate containing the appropriate media for the organism of interest and allowed to grow for a given length of time at a given temperature. This method allows investigators to identify all living organisms within a sample, unlike the previous methods that cannot distinguish between living or dead organisms. All of these methods together are being developed to help protect the public from a biological attack.

C.3.5 Select Biological Agents

Select agents are specifically regulated pathogens and toxins as defined in 42 CFR Part 73, including pathogens and toxins regulated by both the U.S. Department of Health and Human Services and U.S. Department of Agriculture (specifically overlapping agents or toxins). These agents are select agents because they have been or could be used by a nation state or terrorist group to attack the United States in the form of biological warfare; therefore they are a risk to national security. These select agents are a concern because:

- They can be easily or moderately disseminated or transmitted from person to person;
- They result in high mortality rates, moderate morbidity rates, and have the potential for a major public health impact;
- They might cause public panic and social disruption;
- They require special action for public health preparedness;
- They require specific enhancements of the Center for Disease Control and Prevention's diagnostic capacity and enhanced disease surveillance;
- Their ease of production and dissemination; and
- They can be engineered for mass dissemination in the future.

C.3.6 Transmission

These different types of agents are also categorized by route of infection or transmission; that is, how they are passed via an animal (zoonotic), a host – mosquito (vector-borne), or a human. A "zoonotic disease is a disease caused by infectious agents that can be transmitted between (or are shared by) animals and humans" (Olsen 2000). These categories of agents also can be described by whether or not they just cause infection in the person that had contact with that organism (infectious) and whether the infection is passed from person to person (contagious).

C.4 Key Differences Between Biological, Radiological, and Chemical Agents

Although each is always present in our environment and can be both beneficial and detrimental to human health, there are several important distinctions between biological, radiological, and chemical agents, including those listed below:

- Biological organisms have the capability to survive and replicate within a given environment, whereas both radiological and chemical agents will decay or remain constant over time.
- Detection time for chemicals and ionizing radiation is faster than for biological materials (minutes versus hours).
- Only biological materials are capable of contagious spread from person to person.
- There are levels of radiation and concentrations of chemicals below which there are no discernible health effects; but even at minute concentrations, certain biological agents may cause health effects ranging from mild illness (morbidity) to fatal illness (mortality).
- All chemical agents and some biological agents can be neutralized by the use of other chemicals, but radiation cannot be neutralized; it can only be shielded or contained.

C.5 References

CIRRPC (Committee on Interagency Radiation Research and Policy Coordination), 1992, *Use of BEIR V and UNSCEAR 1988 in Radiation Risk Assessment, Lifetime Total Cancer Mortality Risk Estimates at Low Doses and Low Dose Rates for Low-LET Radiation*, ORAU 92/F-64, Science Panel Report No. 9, Office of Science and Technology Policy, Executive Office of the President, Washington, DC, December.

DOE (U.S. Department of Energy), 1999a, *Site-Wide Environmental Impact Statement for Continued Operation of the Los Alamos National Laboratory, Los Alamos, New Mexico*, DOE/EIS-0238, Albuquerque Operations Office, Albuquerque, New Mexico, January.

DOE (U.S. Department of Energy), 1999b, *DOE Standard, Radiological Control*, DOE-STD-1098-99, Washington, DC, July.

DOE (U.S. Department of Energy), 2003a, *Estimating Radiation Risk from Total Effective Dose Equivalent (TEDE), ISCORS Technical Report No. 1*, DOE/EH-412/0015/0802, Rev. 1, Office of Environmental Policy and Guidance, Washington, DC, January.

DOE (U.S. Department of Energy), 2003b, *Final Environmental Impact Statement for the Chemistry and Metallurgy Research Building Replacement Project at Los Alamos National Laboratory, Los Alamos, New Mexico*, DOE/EIS-0350, Los Alamos, New Mexico, November.

EPA (U.S. Environmental Protection Agency), 1994, *Estimating Radiogenic Cancer Risks*, EPA 402-R-93-076, Office of Radiation and Indoor Air, Washington, DC, June.

EPA (U.S. Environmental Protection Agency), 1997, *Exposure Factors Handbook*, National Center for Environmental Assessment, Office of Research and Development, Washington, DC, August.

EPA (U.S. Environmental Protection Agency), 1999, *Cancer Risk Coefficients for Environmental Exposure To Radionuclides*, Federal Guidance Report, No. 13, EPA 402-R-99-001, Office of Radiation and Indoor Air, Washington, DC, September.

EPA (U.S. Environmental Protection Agency), 2001, *Office of Radiation and Indoor Air, Health Effects Assessment Summary Tables (HEAST) - Radionuclides Table*, April 16.

EPA (U.S. Environmental Protection Agency), 2002, *CAP88-PC Version 3.0 User Guide, Draft Revision 1*, Office of Radiation and Indoor Air, Washington, DC, August.

EPA (U.S. Environmental Protection Agency), 2003, *CSFII Analysis of Food Intake Distributions*, EPA/600/R-03/029, National Center for Environmental Assessment–Washington Office, Office of Research and Development, Washington, DC, March.

EPA (U.S. Environmental Protection Agency), 2005a, *Integrated Risk Information System, IRIS Substance List*, (accessed at www.epa.gov/IRIS).

EPA (U.S. Environmental Protection Agency), 2005b, *Region 6 Human Health Medium-Specific Screening Levels 2006,* (accessed at *www.epa.gov/earth1r6/6pd/rcra_c/pd-n/screen.htm),* EPA Region 6, Dallas, TX, December.

HHS (U.S. Department of Health and Human Services), 2007, *Biosafety in Microbiological and Biomedical Laboratories,* Centers for Disease Control and Prevention, National Institutes of Health, Health and Human Services, Fifth Edition, February.

ICRP (International Commission on Radiological Protection), 1991, *1990 Recommendations of the International Commission on Radiological Protection,* Annals of the ICRP, ICRP Publication 60, Vol. 21, No. 1-3, Pergamon Press, New York, New York, November.

LANL (Los Alamos National Laboratory), 2000, *U.S. Department of Energy Report, 1999 LANL Radionuclide Air Emissions,* LA-13732-ENV, Los Alamos, New Mexico, July.

LANL (Los Alamos National Laboratory), 2001, *U.S. Department of Energy Report, 2000 LANL Radionuclide Air Emissions*, LA-13839-MS, Los Alamos, New Mexico, August.

LANL (Los Alamos National Laboratory), 2002a, *U.S. Department of Energy Report, 2001 LANL Radionuclide Air Emissions*, LA-13957-PS, Office of Los Alamos Site Operations, Los Alamos, New Mexico, June.

LANL (Los Alamos National Laboratory), 2002b, *Environmental Surveillance at Los Alamos during 2001*, LA-13979-ENV, Los Alamos, New Mexico, September.

LANL (Los Alamos National Laboratory), 2003a, *U.S. Department of Energy Report, 2002 LANL Radionuclide Air Emissions,* LA-14058-PR, Los Alamos, New Mexico, June.

LANL (Los Alamos National Laboratory), 2003b, *Dose Assessment Using CAP88,* RRES-MAQ-501, R6, Meteorology and Air Quality, August 26.

LANL (Los Alamos National Laboratory), 2004a, *Air-Sampling Data from Area G: A Radioactive-Waste Management Site,* LA-14090, January.

LANL (Los Alamos National Laboratory), 2004b, *Environmental Surveillance at Los Alamos during 2002*, LA-14085-ENV, Los Alamos, New Mexico, January.

LANL (Los Alamos National Laboratory), 2004c, *U.S. Department of Energy Report, 2003 LANL Radionuclide Air Emissions*, LA-14155-PR, Los Alamos Site Office, Los Alamos, New Mexico, June.

LANL (Los Alamos National Laboratory), 2004d, *Environmental Surveillance at Los Alamos during 2003*, LA-14162-ENV, Los Alamos, New Mexico, September.

LANL (Los Alamos National Laboratory), 2005a, *U.S. Department of Energy Report, 2004 LANL Radionuclide Air Emissions*, LA-14233, Los Alamos Site Office, Los Alamos, New Mexico, June.

LANL (Los Alamos National Laboratory), 2005b, *Environmental Surveillance at Los Alamos during 2004*, LA-14239-ENV, Los Alamos, New Mexico, September.

LANL (Los Alamos National Laboratory), 2006a, *Los Alamos National Laboratory Site-Wide Environmental Impact Statement Information Document*, Data Call Materials, Los Alamos, New Mexico.

LANL (Los Alamos National Laboratory), 2006b, *Environmental Surveillance at Los Alamos during 2005*, LA-14304-ENV, Los Alamos, New Mexico, September.

National Research Council, 2005, Free Executive Summary, *Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII – Phase 2, Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation*, (accessed February 28, 2006 at www.nap.edu/catalog/11340.html).

NCRP (National Council on Radiation Protection and Measurements), 1987, *Ionizing Radiation Exposure of the Population of the United States*, NCRP Report No. 93, Bethesda, Maryland, September 1.

NCRP (National Council on Radiation Protection and Measurements), 1993, *Risk Estimates for Radiation Protection*, NCRP Report No. 115, Bethesda, Maryland, December 31.

NRC (U.S. Nuclear Regulatory Commission), 2003, *SECPOP2000: Sector Population, Land Fraction, and Economic Estimation Program*, NUREG/CR-6525, Rev. 1, Washington, DC, August.

NutritionData, 2006, "Nutritional Summary for Nuts, pine nuts, pinyon, dried," (accessed at www.nutritiondata.com/ facts-001-02s02f2.html), Nutrition Facts and Calorie Counter, New York, New York.

Olsen, C., 2000, "Zoonotic Diseases Tutorial," (accessed February 28, 2006, www.vetmed.wisc.edu/pbs/zoonoses), Department of Pathobiological Sciences, School of Veterinary Medicine, University of Wisconsin, Madison, Wisconsin.