RADIOLOGICAL DOSE ASSESSMENT

Introduction

Each year the potential radiological dose to the public that is attributable to operations and effluents from the West Valley Demonstration Project (WVDP) is assessed to verify that no individual could credibly have received a dose exceeding the limits established by the regulatory agencies. The results of these conservative dose calculations demonstrate that the potential maximum dose to an off-site resident was well below permissible standards and was consistent with the as-low-as-reasonably achievable (ALARA) philosophy of radiation protection.

This chapter describes the methods used to estimate the dose to the general public resulting from exposure to radiation and radionuclides originating at the Project during calendar year 2001. The resulting estimated doses are compared directly with current radiation standards established by the U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA) for protection of the public. These values are also compared with the annual dose the average resident of the U.S. receives from natural background radiation and to doses reported in previous years for the Project.

Sources of Radiation. Members of the public are routinely exposed to different sources of ionizing radiation from both natural and manmade sources. Figure 4-1 (p. 4-2) shows the relative contribution to the annual dose in millirem from these sources in comparison with the estimated calendar year 2001 maximum individual dose from the WVDP. The National Council on Radiation Protection and Measurements (NCRP) Report 93 (1987b) estimates that the average annual effective dose equivalent received by an individual living in the U.S. is about 360 mrem (3.6 mSv) from both natural and manmade sources of radiation.

While most of the radiation dose received by the general public is natural background radiation, manmade sources of radiation also contribute to the average dose. Such sources include diagnostic and therapeutic x-rays, nuclear medicine, fallout residues from atmospheric nuclear weapons tests, effluents from nuclear fuel-cycle facilities, and consumer products such as smoke detectors and cigarettes.

As can be seen in Figure 4-1 (p. 4-2), natural sources of radiation contribute 295 mrem (2.95 mSv) and manmade sources contribute 65 mrem (0.65 mSv) of the total annual U.S. average dose of 360 mrem (3.60 mSv). The WVDP contributed a very small amount (0.040 mrem [0.00040 mSv]) to the total annual manmade radiation dose to the maximally exposed off-site individual (MEOSI) residing near the WVDP. This is much less than the average dose received from using consumer products and is insignificant compared to the federal standard of 100 mrem allowed from any DOE site operations in a calendar year or the 295 mrem received annually from natural sources. The dose from WVDP operations also is small compared to the average additional dose an airline crew member typically receives from cosmic radiation (200 mrem/year).

Exposure Pathways

The radionuclides present at the WVDP site are residues from the reprocessing of commercial nuclear fuel during the 1960s and early 1970s. A very small fraction of these radionuclides is released off-site during the year through ventilation systems and liquid discharges. These releases make a negligible contribution to the radiation dose to the surrounding population through several exposure pathways.

An exposure pathway consists of a way for a source of contamination or radiation to be transported by environmental media to a receptor where exposure to contaminants may occur. For example, a member of the public could be exposed to low concentrations of radioactive particulates carried by prevailing winds.

The potential pathways of exposure from Project emissions are inhalation of gases and particulates, ingestion of locally grown food products, ingestion of fish, beef, and deer tissues, and exposure to external penetrating radiation emitted from contaminated materials. The drinking water pathway is excluded from calculations of potential maximum dose to individuals because surveys revealed that local residents do not use Cattaraugus Creek as a source of drinking water. Table 4-1 (*facing page*) summarizes the potential exposure pathways for the local off-site population.

Land Use Survey

Periodic surveys of local residents provide information about local family sizes, sources of food, and gardening practices. Information from the most recent survey, conducted in early 2002, was used to confirm the locations of the nearest residences and other population parameters. These parameters are required for computer models that are used for the annual dose assessments. (See the discussion of Dose Assessment Methodology [*facing page*] for more information on the computer models used.)

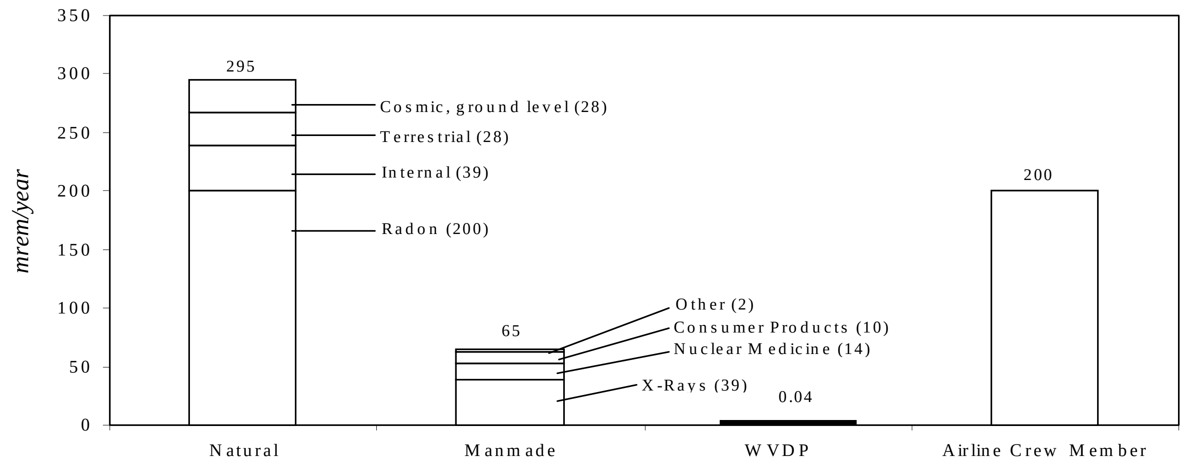

Figure 4-1. Comparison of Annual Background Radiation Dose to the Dose From 2001 WVDP Effluents

Table 4-1
Potential Local Off-Site Exposure Pathways Under Existing WVDP Conditions

Exposure Pathway and Transporting Medium	Reason for Inclusion/Exclusion
Inhalation: gases and particulates in air (included)	Off-site transport of contaminants from WVDP stacks or resuspended particulates from soils or water
Ingestion: cultivated crops (included)	Local agricultural products irrigated with contaminated surface or groundwater; foliar deposition and uptake of airborne contaminants
Ingestion: surface and groundwater (excluded)	No documented use of local surface water or downgradient groundwater wells as drinking water by local residents
Ingestion: fish, beef, venison, and milk (included)	Fish exposed to contaminants in water or sediments may be consumed; beef, venison, and milk consumption following deposition of transported airborne and surface water contaminants
External exposure: radiation emanating from particulates and gases from air or surface water (included)	Transport of air particulates and gases to off-site receptors; transport of contaminants in surface water and direct exposure during stream use and swimming

Radioactive Vitrification Operations

The start of radioactive vitrification operations in July 1996 resulted in expected increases of radioactive emissions from the main plant stack. Specifically, the release rate of iodine-129 increased from a 1993 to 1995 average of 25 microcuries (µCi) per year to 1,200 µCi in 1996 and 7,430 µCi in 1997 as a result of the processing of the high-level waste.

In 1998 the yearly release of iodine-129 fell to 4,970 µCi/yr due to the completion of Phase I of vitrification; in 1999 the total iodine-129 release was 1,900 µCi. The iodine-129 levels continued to decrease in calendar year 2000 – to 1,260 µCi, a level consistent with reduced vitrification activity. In calendar year 2001, 520 µCi of iodine-129 were released. (See Chapter 2, Special Monitoring, [p. 2-27] for a discussion of iodine-129 emissions from the main plant stack.)

Dose Assessment Methodology

The potential radiation dose to the general public from activities at the WVDP is evaluated by using a two-part methodology applied in a manner consistent with the requirements in DOE Order 5400.5. The first part uses the measurements of radionuclide concentrations in liquid and air released from the Project to determine annual total effect. The second part uses measurements of

Ionizing Radiation

Radiation can be damaging if, in colliding with other matter, the alpha or beta particles or gamma rays knock electrons loose from the absorber atoms. This process is called ionization, and the radiation that produces it is referred to as ionizing radiation because it changes an electrically neutral atom, in which the positively charged protons and the negatively charged electrons balance each other, into a charged atom called an ion. An ion can be either positively or negatively charged. Various kinds of ionizing radiation produce different degrees of damage.

Potential Effects of Radiation

The biological effects of radiation can be either somatic or genetic. Somatic effects are restricted to the person who has been exposed to radiation. For example, sufficiently high exposure to radiation can cause clouding of the lens of the eye or loss of white blood cells.

Radiation also can cause chromosomes to break or rearrange themselves or to join incorrectly with other chromosomes. These changes may produce genetic effects and may show up in future generations. Radiation-produced genetic defects and mutations in the offspring of an exposed parent, while not positively identified in humans, have been observed in some animal studies.

The effect of radiation depends on the amount absorbed within a given exposure time. The only observable effect of an instantaneous whole-body dose of 50 rem (0.5 Sv) might be a temporary reduction in white blood cell count. An instantaneous dose of 100-200 rem (1-2 Sv) might cause additional temporary effects such as vomiting but usually would have no long-lasting side effects. Assessing biological damage from low-level radiation is difficult because other factors can cause the same symptoms as radiation exposure. Moreover, the body is able to repair damage caused by low-level radiation.

The effect most often associated with exposure to relatively high levels of radiation appears to be an increased risk of cancer. However, scientists have not been able to demonstrate with certainty that exposure to low-level radiation causes an increase in injurious biological effects, nor have they been able to determine if there is a level of radiation exposure below which there are no biological effects.

Health Effects of Low-Level Radiation

Radionuclides entering the body through air, water, or food are distributed in different organs of the body. For example, isotopes of iodine concentrate in the thyroid. Strontium, plutonium, and americium isotopes concentrate in the skeleton. When inhaled, uranium and plutonium isotopes remain in the lungs for a long period of time. Some radionuclides such as tritium, carbon-14, or cesium-137 are distributed uniformly throughout the body. Thus, depending on the radionuclide, some organs may receive quite different doses. Moreover, at the same dose levels, certain organs (such as the breast) are more prone to developing a fatal cancer than other organs (such as the thyroid).

Because of the uncertainty and difficulty in measuring the incidence of increased cancer resulting from exposure to ionizing radiation, to be conservative, a linear model is used to predict health risks from low levels of radiation. This model assumes that there is a risk associated with all dose levels even though the body may effectively repair damage incurred from low levels of alpha, beta, and gamma radiations.

radioactivity in food from locations near the Project boundaries to confirm the low impact of the totals.

Radiological dose is evaluated for all major exposure pathways, including external irradiation, inhalation, and ingestion of local food products. The dose contributions from each radionuclide and pathway combination are then summed to obtain the total dose estimates reported in Table 4-2 (p. 4-6).

Measurement of Radionuclide Concentrations in Liquid and Air Releases. Because of the difficulty of distinguishing the small amount of radioactivity emitted from the site from that which occurs naturally in the environment using actual measurements of environmental samples, computer codes are used to model the environmental dispersion of radionuclides emitted from on-site monitored ventilation stacks and liquid discharge points.

First, actual data from release-monitoring samples are collected, together with annual weather measurements and the latest demographic information. (See Appendices C, D, and I.) The effective dose equivalent (EDE) to the maximally exposed off-site individual and the collective EDE to the population within a 50-mile (80-km) radius are then calculated using conservative models that have been approved by the DOE and the EPA to demonstrate compliance with radiation standards. (See Radiation Dose [*this page*] and Units of Measurement [p. 4-8].)

Measurement of Radionuclide Concentrations in Food. The second part of the dose assessment is based on actual measurements of radioactivity in samples of foodstuffs grown in the vicinity of the WVDP and the comparison of these values with measurements of samples collected from locations well beyond the potential influence of site effluents. These measurements of environmental media show that the concentrations of radioactivity are small – usually near the analytical detection limits – thereby providing additional assurance that operations at the WVDP are not adversely affecting the public.

If any of the near-site food samples were to contain radionuclide concentrations that are statistically higher than the concentrations in control

Radiation Dose

The energy released from a radionuclide is eventually deposited in matter encountered along the path of the radiation. The radiation energy absorbed by a unit mass of material is referred to as the absorbed dose. The absorbing material can be either inanimate matter or living tissue.

Alpha particles leave a dense track of ionization as they travel through tissue and thus deliver the most dose per unit-path length. However, alpha particles are not penetrating and must be taken into the body by inhalation or ingestion to cause harm. Beta and gamma radiation can penetrate the protective dead skin layer of the body from the outside, resulting in exposure of the internal organs to radiation.

Because beta and gamma radiations deposit much less energy in tissue per unit-path length relative to alpha radiation, they produce fewer biological effects for the same absorbed dose. To allow for the different biological effects of different kinds of radiation, the absorbed dose is multiplied by a quality factor to yield a unit called the dose equivalent. A radiation dose expressed as a dose equivalent, rather than as an absorbed dose, permits the risks from different types of radiation exposure to be compared with each other (e.g., exposure to alpha radiation compared with exposure to gamma radiation). For this reason, regulatory agencies limit the dose to individuals in terms of total dose equivalent.

Table 4-2
Summary of Annual Effective Dose Equivalents to an Individual and Population From WVDP Releases in 2001

Exposure Pathways	**Annual Effective Dose Equivalent**	
	Maximally Exposed Off-Site Individual[1] mrem (mSv)	***Collective Effective Dose Equivalent[2] person-rem (person-Sv)***
Airborne Releases[3]	4.6E-03 (4.6E-05)	5.9E-02 (5.9E-04)
% EPA standard (10 mrem)	0.046%	*NA*
Waterborne Releases[4]		
Effluents only	1.4E-02 (1.4E-04)	1.0E-02 (1.0E-04)
Effluents plus north plateau drainage	3.5E-02 (3.5E-04)	1.3E-01 (1.3E-03)
Total from all Pathways	4.0E-02 (4.0E-04)	1.9E-01 (1.9E-03)
% DOE standard (100 mrem) – air and water combined	0.040%	
% of natural background (295 mrem; 398,000 person-rem) – received from air and water combined	0.01%	0.00005%
Estimated Rn-220[5]	2.2E-02 (2.2E-04)[6]	7.2E-01 (7.2E-03)

Exponents are expressed as "E" in this report: a value of 1.2 x 10^{-4} in scientific notation is reported as 1.2E-04 in the text and tables.

NA – Not applicable. Numerical regulatory standards are not set for the collective EDE to the population.

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[1] *Modeled data estimates the maximum exposure to air discharges occurs at a residence 1.9 kilometers north-northwest of the main plant.*

[2] *Population of 1.35 million within 80 kilometers of the site.*

[3] *From atmospheric release non-radon point and diffuse sources. Calculated using CAP88-PC for individual and population. EPA and DOE limits for individual airborne dose are the same.*

[4] *Calculated using methodology described in Manual for Radiological Assessment of Environmental Releases at the WVDP (Spector, 2000).*

[5] *Estimated releases based on indicator measurements and vitrification processing values: dose estimates calculated using CAP88-PC.*

[6] *Estimated dose from Rn-220 specifically excluded by rule from NESHAP totals. (See p. 4-9.)*

samples, separate dose calculations would be performed to verify that the calculated foodstuff dose is within the dose range estimated by computer modeling. These calculated doses are not added to the computer-modeled estimates (Table 4-2 [*facing page*]) because the models already include contributions from all environmental pathways.

Comparison of Near-Site and Background Environmental Media Concentrations. Both near-site and control (background) samples of fish, milk, beef, venison, and local produce are collected and analyzed for various radionuclides, including tritium, cobalt-60, strontium-90, iodine-129, and cesium-137. The measured radionuclide concentrations reported in Appendix F, Tables F-1 through F-4 (pp. F-3 through F-8) are the basis for comparing near-site and background concentrations.

If differences are found between near-site and background sample concentrations, the amount by which the near-site sample concentration exceeds background is used to calculate a potential maximum individual dose for comparison with dose limits and the dose from background alone. If no statistical differences in concentrations are found, then no further assessment is conducted.

The maximum potential dose to nearby residents from the consumption of foods with radionuclide concentrations above background is calculated by multiplying the net concentrations (concentration in a sample minus background concentration) by the maximum adult annual consumption rate for each type of food and the unit dose conversion factor for ingestion of the measured radionuclide. The consumption rates are based on site-specific data and recommendations in NRC Regulatory Guide 1.109 for terrestrial food chain dose assessments (U.S. Nuclear Regulatory Commission October, 1977). The internal dose conversion factors were obtained from Internal Dose Conversion Factors for Calculation of Dose to the Public (DOE/EH-0071 [U.S. Department of Energy, July 1988]).

Note that foodstuffs are weighed when received at the laboratory and the percent moisture is determined from the difference between the mass of the dried sample weighed after preparation for radiological measurement and the original "wet" as-measured mass. Doses are calculated based on the reconstituted "wet" mass of the original sample as it would be before preparation as food.

Predicted Dose From Airborne Emissions

Airborne emissions of radionuclides are regulated by the EPA under the Clean Air Act and its implementing regulations. DOE facilities are subject to 40 CFR 61, Subpart H, National Emission Standards for Hazardous Air Pollutants (NESHAP). Subpart H constitutes the national emission standards for emissions of radionuclides other than radon from DOE facilities. The applicable standard for radionuclides is a maximum of 10 mrem (0.1 mSv) EDE to any member of the public in any year.

Releases of airborne radioactive materials from nominal ground level stacks (1 to 24 meters high) and from the main 60-meter stack are modeled using the EPA-approved CAP88-PC computer code (U.S. Environmental Protection Agency, March 1992). This air dispersion code estimates effective dose equivalents for the ingestion, inhalation, air immersion, and ground surface pathways. Site-specific data for non-radon radionuclide release rates in curies per year, wind data, and the current local population distribution are used as input parameters. Resulting output from the CAP88-PC code is then used to determine the total EDE to a maximally exposed individual and the collective dose to the population within a 50-mile (80-km) radius of the WVDP.

Units of Measurement

The unit for dose equivalent in common use in the U.S. is the rem, which stands for roentgen-equivalent-man. The international unit of dose equivalent is the sievert (Sv), which is equal to 100 rem. The millirem (mrem) and millisievert (mSv), used more frequently to report the low dose equivalents encountered in environmental exposures, are equal to one-thousandth of a rem or sievert, respectively.

The effective dose equivalent (EDE), also expressed in units of rem or sievert, provides a means of combining unequal organ and tissue doses into a single "effective" whole body dose that represents a comparable risk probability. The probability that a given dose will result in the induction of a fatal cancer is referred to as the risk associated with that dose. The EDE is calculated by multiplying the organ dose equivalent by the organ-weighting factors developed by the International Commission on Radiological Protection (ICRP) in Publications 26 (1977) and 30 (1979). The weighting factor is a ratio of the risk from a specific organ or tissue dose to the total risk resulting from an equal whole body dose. All organ-weighted dose equivalents are then summed to obtain the EDE.

The dose from internally deposited radionuclides calculated for a fifty-year period following intake is called the fifty-year committed effective dose equivalent (CEDE). The CEDE sums the dose to an individual over fifty years to account for the biological retention of radionuclides in the body. The total EDE for one year of exposure to radioactivity is calculated by adding the CEDE to the dose equivalent from external, penetrating radiation received during the year. Unless otherwise specified, all doses discussed here are total EDE values, which include the CEDE for internal emitters.

A collective population dose is expressed in units of person-rem or person-sievert because the individual doses are summed over the entire potentially exposed population. The average individual dose can therefore be obtained by dividing the collective dose by the number in the population.

As reported in Chapter 2, Environmental Monitoring, the main 60-meter stack and several shorter stacks were monitored for radioactive air emissions during 2001. The activity that was released to the atmosphere from these emission points is listed in Tables D-1 through D-11 and D-15. (See Appendix D [pp. D-3 through D-12 and D-16].) Note that these tables include data from an on-site airborne release in the fall of 2001. (See Unplanned Radiological Releases in Chapter 1 [p. 1-11].) Applicable information from these tables was used as input to the CAP88-PC code.

Wind data collected from the on-site meteorological tower during 2001 were used as input to the CAP88-PC code. Data collected at the 60-meter and 10-meter heights were used in combination with the main plant stack and near-ground-level effluent release data, respectively.

Maximum Dose to an Off-Site Individual. Based on the non-radon airborne radioactivity released from all sources at the site during 2001, it was estimated that a person living in the vicinity of the WVDP could have received a total EDE of

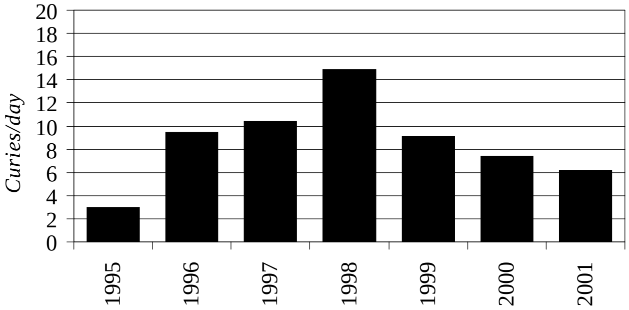
Radon-220

Radon-220 is a naturally occurring gaseous decay product of thorium-232 present in the airborne emissions from the WVDP main plant. Radon-220, also known as thoron, is associated with the THOREX-related thorium-232 and uranium-232 in the high-level waste.

As reported in Chapter 2 of the 1996 WVDP Site Environmental Report, thoron levels were observed to increase during startup of the 1996 high-level waste vitrification process. An estimate of the thoron released during each waste concentration cycle was developed and used to determine a theoretical annual release. During the vitrification phase an average of about 12 curies per day were released. In 2001, because of the substantially reduced number of concentration cycles, the average was a bit less than six and a half curies of thoron released per day.

Although large numbers of curies were released relative to other radionuclides, the calculated dose from thoron is quite small because of its short decay half-life and other characteristics. The NESHAP rule specifically excludes thoron from air emission dose calculations at the WVDP, so a dose estimate using CAP88-PC was calculated separately. The theoretical dose to the maximally exposed off-site individual (MEOSI) located 1.9 kilometers north-northwest of the site in 2001 would have been 0.022 mrem, and the collective dose to the population within an 80-kilometer radius would have been 0.72 person-rem. (See Table 4-2 [p. 4-6].) These theoretical doses are less than or about the same as doses from the manmade radionuclide WVDP effluents.

As the final stages of vitrification are completed, thoron releases are expected to decrease to below pre-vitrification levels. The figure presented here provides a relative indication of recent trends in the estimated annual thoron releases.



Estimated Radon-220 Releases from the WVDP

0.0046 mrem (0.000046 mSv). The computer model estimates that this maximally exposed off-site individual was located 1.9 kilometers north-northwest of the site and was assumed to eat only locally produced foods. Approximately 63% of the dose was from iodine-129.

The maximum total EDE of 0.0041 mrem (0.000041 mSv) from the permitted stacks and vents is far below levels that could be directly measured at the exposed individual's residence. This dose is comparable to about eight minutes of natural background radiation received by an average member of the U.S. population and is well below the 10 mrem (0.1 mSv) NESHAP limit promulgated by the EPA and required by DOE Order 5400.5.

Collective Population Dose. The CAP88-PC program was used to estimate the collective EDE to the population. Based upon the latest U.S. census population data collected in calendar year 2000, 1.35 million people were estimated to reside within 50 miles (80 km) of the WVDP. This population received an estimated 0.059 person-rem (0.00059 person-Sv) total EDE from radioactive non-radon airborne effluents released from WVDP point and diffuse sources during 2001. The resulting average EDE per individual was 0.00004 mrem (0.0000004 mSv).

Predicted Dose From Waterborne Releases

Currently there are no EPA standards establishing limits on the radiation dose to members of the public from liquid effluents except as applied in 40 CFR 141 and 40 CFR 143, Drinking Water Guidelines (U.S. Environmental Protection Agency, 1984a; 1984b). The potable-water wells sampled for radionuclides are upgradient of the WVDP and therefore are not a potential source of exposure to radiation from Project activities.

Since Cattaraugus Creek is not used as a drinking water supply, a comparison of the predicted concentrations and doses with the EPA drinking water limits established in 40 CFR 141 and 40 CFR 143 is not truly appropriate (although the values in creek samples are well below the EPA drinking water limits). The estimated radiation dose was compared to the applicable guidelines provided in DOE Order 5400.5. The EDE to the maximally exposed off-site individual and the collective EDE to the population due to routine waterborne releases and natural drainage are calculated using dose conversion factors as tabulated in the WVDP Manual for Radiological Assessment of Environmental Releases at the WVDP (Spector, 2000).

Since the Project's liquid effluents eventually reach Cattaraugus Creek, which is not used directly as a source of drinking water, the most important individual exposure pathway is the consumption of fish from this creek by local sportsmen. It is assumed that a person may consume annually as much as 46 pounds (21 kg) of fish caught in the creek. Exposure to external radiation from shoreline or water contamination also is included in the model for estimating radiation dose. Population dose estimates assume that radionuclides are further diluted in Lake Erie before reaching municipal drinking water supplies.

The computer codes GENII version 1.485 (Pacific Northwest Laboratory, 1982), which implements the models in U.S. NRC Regulatory Guide 1.109, and LADTAP II (Simpson and McGill, 1980) were used to calculate the site-specific unit dose factors for routine waterborne releases and dispersion of these effluents. Input data included local stream flow and dilution, drinking water usage, and stream usage factors. A detailed description of GENII is given in the WVDP Manual for Radiological Assessment of Environmental Releases at the WVDP (Spector, 2000).

Five planned batch releases of liquid radioactive effluents from lagoon 3 occurred during 2001. The radioactivity discharged in these effluents, listed in Appendix C, Table C-1 (p. C-3), was used with the unit dose factors to calculate the EDE to the maximally exposed off-site individual and the collective EDE to the population living within a 50-mile (80-km) radius of the WVDP.

In addition to the batch releases from lagoon 3 (WNSP001), effluents from the sewage treatment facility (WNSP007) and the french drain (WNSP008) are routinely released. The activities measured from these release points were included in the EDE calculations. The measured radioactivity concentrations from the sewage treatment facility and french drain are presented in Appendix C, Tables C-5 and C-6 (p. C-7).

Besides the three release points listed above, there are two natural drainage channels originating on the Project premises that have measurable concentrations of radioactivity in the water. These are drainages from the northeast swamp

(WNSWAMP) and north swamp (WNSW74A). The measured radioactivity from these points is reported in Tables C-7 and C-8 (pp. C-8 and C-9). Radioactivity measured at these drainage sample points is included in the EDE calculations for the maximally exposed off-site individual and the collective population.

There were no unplanned releases of waterborne radioactivity in 2001.

Maximum Dose to an Off-Site Individual. Based on the radioactivity in liquid effluents released from the WVDP (lagoon 3, the sewage treatment plant, and the french drain) during 2001 an off-site individual could have received a maximum EDE of 0.014 mrem (0.00014 mSv). Approximately 90% of this dose was from cesium-137. This 0.014 mrem (0.00014 mSv) dose is negligible in comparison to the 295 mrem (2.95 mSv) that an average member of the U.S. population receives in one year from natural background radiation.

The maximum off-site individual EDE due to drainage from the north plateau (north swamp and northeast swamp) is 0.021 mrem (0.00021 mSv). The combined EDE to the maximally exposed individual from liquid effluents and drainage is 0.035 mrem (0.00035 mSv). This annual dose is somewhat less than the 2000 estimate and is negligible in comparison to the 295 mrem (2.95 mSv) that an average member of the U.S. population receives in one year from natural background radiation.

Collective Dose to the Population. As a result of radioactivity released in liquid effluents from the WVDP (lagoon 3, the sewage treatment plant, and the french drain) during 2001, the population living within 50 miles (80 km) of the site received a collective EDE of 0.010 person-rem (0.00010 person-Sv). The collective dose to the population from the north plateau drainage is 0.12 person-rem (0.0012 person-Sv). This estimate is based on a population of 1.35 million living within the 50-mile (80-km) radius. The resulting average EDE from lagoon 3, the sewage treatment plant, the french drain, and north plateau drainage (north swamp and northeast swamp) per individual is 9.7E-05 mrem (9.7E-07 mSv). This dose of 0.000097 mrem (0.00000097 mSv) is an inconsequential addition to the dose that an average person receives in one year from natural background radiation.

Calculated Dose From Local Foodstuff Tests

Fish. Samples of fish were collected from Cattaraugus Creek from May 2001 through November 2001. Twenty fish were collected both at background locations upstream of the site and at locations downstream of the site above the Springville dam. Ten fish were collected at points downstream of the site below the dam. Edible portions of fish samples were analyzed for strontium-90 and cesium-137, and the values were compared with background values. (See Table F-4 [pp. F-6 through F-8].)

Cesium-137 concentrations in fish collected downstream of the site but above the Springville dam were not statistically higher than background.

Strontium-90 in individual fish collected downstream of the site, above the Springville dam, was detectable at slightly above the average median control sample concentrations. The calculated maximum dose to an individual from consuming 46 pounds (21 kg) of near-site fish would be 0.01 mrem (0.0001 mSv). This dose is roughly equivalent to the dose received every eighteen minutes from natural background radiation.

Milk. Milk samples were collected from various nearby dairy farms throughout 2001. Control samples were collected from farms 15 to 20 miles (25 to 30 km) to the south and north of the WVDP. Milk samples were analyzed for tritium, potassium-40, strontium-90, iodine-129, and cesium-137. (See Table F-1 [p. F-3].) Nine near-site milk samples were collected and compared with eight background samples. Average values for tritium, strontium-90, iodine-129, and cesium-137 were either below detection limits or not statistically different from control concentrations. Naturally occurring potassium-40 was used as an intrinsic reference point for the samples.

Beef. Near-site and control samples of locally raised beef were collected in 2001. These samples were analyzed for tritium, strontium-90, and cesium-137. Two samples of beef muscle tissue were collected from background locations and two from near-site locations. Individual concentrations of measured radionuclides in near-site samples were either below detection limits or not statistically different from concentrations at control locations. (See Table F-2 [p. F-4].)

Venison. Meat samples from three near-site and three control deer were collected during the fall of 2001. (See Table F-2 [p. F-4].) These samples were measured for tritium, strontium-90, cesium-137, and other gamma-emitting radionuclides. Individual concentrations of measured radionuclides in near-site venison samples were either below detection limits or not statistically different from concentrations at control locations.

Produce (Corn, Beans, and Apples). Near-site and background samples of corn, beans, and apples were collected during 2001 and analyzed for tritium, potassium-40, cobalt-60, strontium-90, and cesium-137. (See Appendix F, Table F-3 [p. F-5].) Individual concentrations of all the measured radionuclides in near-site produce samples were either below detection limits or not statistically different from concentrations at control locations.

See Appendix B (pp. B-37 through B-40) for the locations from which background biological samples are collected.

Predicted Dose From All Pathways

The potential dose to the public from both airborne and liquid effluents released from the Project during 2001 is the sum of the individual dose contributions. The calculated maximum EDE from all pathways to a nearby resident was 0.040 mrem (0.00040 mSv). This dose is 0.040% of the 100 mrem (1 mSv) annual limit in DOE Order 5400.5. The estimated dose from radon-220 to the same nearby resident was approximately 0.02 mrem.

The total collective EDE to the population within 50 miles (80 km) of the site was 0.19 person-rem (0.0019 person-Sv), with an average EDE of 0.00014 mrem (0.0000014 mSv) per individual. The estimated radon-220 dose to the population was approximately 0.72 person-rem.

Table 4-2 (p. 4-6) summarizes the dose contributions from all pathways and compares the individual doses with the applicable standards. The low doses calculated using computer modeling are corroborated by the low or non-detectable doses calculated from local foodstuff test data.

Figure 4-2 (*facing page*) shows the calculated annual dose to the hypothetical maximally exposed individual over the last fourteen years. The estimated dose for 2001 (0.040 mrem) is lower than the annual dose reported for 2000 (0.061 mrem). The decrease in dose fraction from air emissions in 2001 is attributed to the continuing decrease in iodine-129 emissions. The lower dose from the liquid pathway is mostly the result of a lower volume of releases from the water treatment system. This decrease includes the continuing effect of the migration of the gross beta plume. (See Special Groundwater Monitoring in Chapter 3 [p. 3-15].)

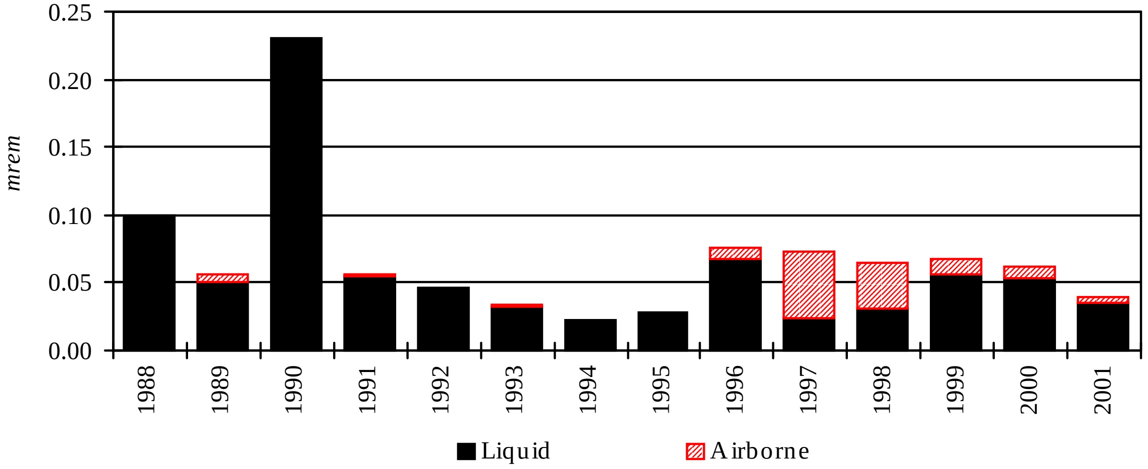


Figure 4-2. Effective Dose Equivalent from Liquid and Airborne Effluents to a Maximally Exposed Individual Residing Near the WVDP

Figure 4-3 (p. 4-14) shows the collective dose to the population over the last fourteen years. (See Fig. A-14 [p. A-16] for a map of the population sectors.) A five-year upward trend, primarily from an increase in vitrification activities, reversed in 1998 and then in 1999 through 2001 continued down towards previtrification levels.

As with the individual dose, a slight downward trend in collective dose from treated liquid effluents, directly linked to a noticeable decrease in the volume of water treated, was noted in 2001.

The overall radioactivity represented by these data confirm the continued inconsequential addition to the natural background radiation dose that the individuals and population around the WVDP receive from Project activities.

Risk Assessment

Estimates of cancer risk from ionizing radiation have been presented by the National Council on Radiation Protection and Measurements (1987b) and the National Research Council's Committee on Biological Effects of Ionizing Radiation (1990).

These reports estimate that the probability of fatal cancer induction to the public, averaged over all ages, ranges from 0.0001 to 0.0005 cancer fatalities/rem. The most recent risk coefficient of 0.0005 (International Commission on Radiological Protection 1991) was used to estimate risk to a maximally exposed off-site individual. The resulting estimated risk to this hypothetical individual from airborne and waterborne releases was a 0.000000020 probability of a cancer fatality (1 chance in 50 million). This risk is well below the range of 0.000001 to 0.00001 per year considered by the International Commission on Radiological Protection in Report 26 (1977) to be a reasonable level of risk for any individual member of the public.

Dose to Biota: Aquatic and Terrestrial Wildlife

Radionuclides from both natural and man-made sources may be found in environmental media such

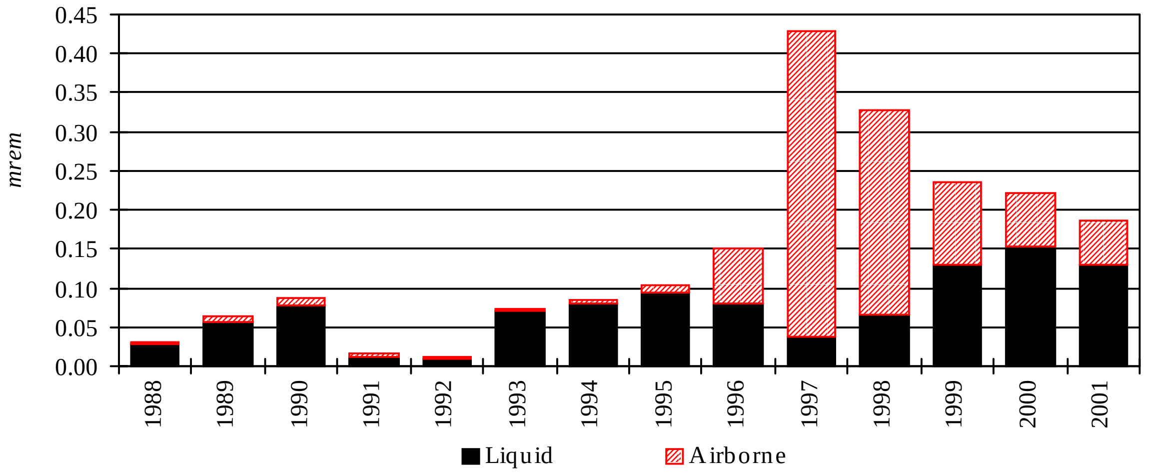


Figure 4-3. Collective Effective Dose Equivalent from Liquid and Airborne Effluents to the Population Residing Within 50 miles (80 km) of the WVDP

as water, sediments, and soils. In the past, it has been assumed that if radiological controls are sufficient to protect humans, other living things are also likely to be sufficiently protected. This assumption is no longer considered adequate, since populations of plants and animals residing in or near these media or taking food or water from these media may be exposed to a greater extent than are humans. For this reason, the DOE has prepared a technical standard which provides methods and guidance to be used to evaluate doses of ionizing radiation to populations of aquatic animals, terrestrial plants, and terrestrial animals.

Methods in this draft technical standard, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (ENVR-0011, DOE, June 2000), were used in 2001 to evaluate radiation doses to aquatic and terrestrial biota within the confines of the Western New York Nuclear Service Center (WNYNSC), which includes the WVDP. Doses were assessed for compliance with the limit in DOE Order 5400.5 for aquatic animals (1 rad per day) and for compliance with the thresholds for terrestrial plants (also 1 rad per day) and for terrestrial animals (0.1 rad per day), as proposed in ENVR-0011. Note that the absorbed dose unit (rad) is used for biota instead of the units used for indicating human risk (rem).

RAD-BCG, a calculation tool provided by the DOE for implementing ENVR-0011, was used to compare existing radionuclide concentration data from environmental sampling with biota concentration guide (BCG) limits. Data collected from surface waters, sediments, and soils on and around the WNYNSC over a ten-year period (1991 - 2000) were used in a baseline evaluation. For a more near-term assessment, a second evaluation was completed using surface water data from 2001 and sediment data from 1997 - 2001. (See Appendices A and B for maps and descriptions of monitoring and surveillance locations. Radionuclides analyzed for each medium at each location are listed in Appendix B. See Appendix C for a listing of results from these locations in 2001.)

Concentration data for radionuclides in each medium were entered to the calculation tool. The value for each radionuclide was automatically divided by the BCG in order to calculate a partial fraction for each nuclide for each medium. Partial fractions for each medium were added to produce a sum of fractions.

It was found that the isotopes with the highest sums of fractions – the radionuclides that contributed the largest component of both aquatic and terrestrial dose to biota – were strontium-90 and cesium-137. Per guidance in ENVR-0011, the populations of organisms most sensitive to strontium-90 and cesium-137 in this evaluation – that is, those populations residing on the WNYNSC that were most likely to be adversely affected via the aquatic and terrestrial pathways – were determined to be populations of the raccoon (aquatic dose) and the deer mouse (terrestrial dose). As such, this study does not pertain to pathways to humans, which are addressed elsewhere in this chapter. (See Dose Assessment Methodology [p. 4-3].)

The aquatic dose limit from DOE 5400.5 may be assumed to have been met if the sum of fractions for the water medium plus that for the sediment medium is less than 1.0. Similarly, proposed dose limits for both terrestrial plants and animals may be assumed to have been met if the sum of fractions for the water medium plus that for the soil medium is less than 1.0.

In accordance with the approach described in ENVR-0011, a general screening was first conducted using the maximum radionuclide concentrations from surface waters, sediments, and soils. Maximum radionuclide concentrations from the 10-year sampling database exceeded applicable general screening BCG limits for both aquatic and terrestrial evaluations, as did the concentrations from the 2001 surface water data and the more recent sediment data.

As recommended in ENVR-0011, a site-specific screening was then done using estimates of average radionuclide concentrations derived from measurement series in surface waters, sediments, and soils. Average concentrations for each medium, applicable BCGs, partial fractions, and sums of fractions for the ten-year baseline study are tabulated in Table 4-3 (p. 4-16).

At the site-specific screening level for the full ten-year period, the sum of fractions for the aquatic system evaluation was 0.45 and that for the terrestrial system evaluation was 0.57. The comparable sums of fraction using the more near-term data were 0.37 and 0.57, respectively. The sum of fractions for each assessment was less than 1.0, indicating that applicable BCGs were met for both the aquatic and terrestrial evaluations. It was therefore concluded that populations of aquatic and terrestrial biota (both plants and animals) on the WNYNSC are not being exposed to doses in excess of the existing DOE dose standard for aquatic organisms and the recommended standards put forth in ENVR-0011 for terrestrial biota.

Summary

Predictive computer modeling of airborne and waterborne releases resulted in estimated hypothetical doses to the maximally exposed individual that were orders of magnitude below all applicable EPA standards and DOE Orders, which place limitations on the release of radioactive materials and dose to individual members of the public. The collective population dose also was assessed and found to be orders of magnitude below the natural background radiation dose. Additionally, it was determined that biota at the WVDP are exposed at a fraction of the suggested maximum radiation levels.

Based on the overall dose assessment, the WVDP was found to be in compliance with applicable effluent radiological guidelines and standards during calendar year 2001. Table 4-4 (p. 4-17) provides a summary of WVDP releases and calculated doses in specified DOE format.

Table 4-3
Evaluation of Dose to Aquatic and Terrestrial Biota

Based on average radionuclide concentrations in waters, sediments, and soils from ten years of monitoring, the sum of fractions for the aquatic system evaluation was 0.45 and that for the terrestrial system evaluation was 0.57. Evaluations using more recent data – surface water data from 2001 and sediment data from 1997 - 2001 – resulted in aquatic and terrestrial sums of fractions of 0.37 and 0.57, respectively. Each sum of fractions was less than 1.0, indicating that applicable biota concentration guides (BCGs) were met for both the aquatic and terrestrial evaluations. The calculated sum of fractions for aquatic organisms for the near-term assessment was less than the sum of fractions calculated for the 10-year baseline. It was therefore concluded, based on both long-term and near-term results, that populations of aquatic and terrestrial biota on the WNYNSC are not being exposed to doses in excess of the existing DOE limit for aquatic organisms (U.S. Department of Energy, February 1990) and the international standards for terrestrial organisms (International Atomic Energy Agency, 1992).

Aquatic System Evaluation (Long-Term [10-Year] Data Set)

Nuclide	Water BCG* (pCi/L)	Mean Water Value (pCi/L)	Water Partial Fraction	Sediment BCG* (pCi/g)	Mean Sediment Value (pCi/g)	Sediment Partial Fraction	Water and Sediment Sum of Fractions
Cesium-137	42.6	13.0	3.05E-01	3,120	7.00	2.24E-03	0.31
Strontium-90	278	37.1	1.33E-01	582	1.76	3.02E-03	0.14
All Others	NA	NA	9.00E-03	NA	NA	3.90E-04	<0.01
Sum of Fractions (Long-Term data)			4.47E-01			5.65E-03	**0.45**
Sum of Fractions (Near-Term data)							**0.37**

Terrestrial System Evaluation (Long-Term [10-Year] Data Set)

Nuclide	Water BCG* (pCi/L)	Mean Water Value (pCi/L)	Water Partial Fraction	Soil BCG* (pCi/g)	Mean Soil Value (pCi/g)	Soil Partial Fraction	Water and Soil Sum of Fractions
Cesium-137	599,000	13.0	2.17E-05	20.8	5.95	2.87E-01	0.29
Strontium-90	54,500	37.1	6.81E-04	22.5	6.26	2.78E-01	0.28
All Others	NA	NA	1.73E-05	NA	NA	1.00E-03	<0.01
Sum of Fractions (Long-Term data)			7.20E-04			5.66E-01	**0.57**
Sum of Fractions (Near-Term data)							**0.57**

* The BCGs are calculated values. Except for the sums of fractions, which are rounded to two significant digits, all values are expressed to three significant digits.

Table 4-4
WVDP Radiological Dose and Release Summary

WVDP Radiological Dose Reporting Table CY 2001

Dose to the Maximally Exposed Individual	% of DOE 100-mrem limit	Estimated Population Dose	Population within 50 miles *2000 Projection (1990 census)*	Estimated Natural Radiation Population Dose
0.040 *mrem* 0.00040 *(mSv)*	0.040	0.19 *person-rem* 0.0019 *(person-Sv)*	1,350,000	398,000 *person-rem*

WVDP Radiological Atmospheric Releases$^+$ CY 2001 in Curies (Bq)

Tritium	Kr-85	Noble Gases ($T_{1/2}$<40 dy)	Short-Lived Fission and Activation Products ($T_{1/2}$<3 hr)	Fission and Activation Products ($T_{1/2}$>3 hr)	Total Radioiodine	Total Radiostrontium	Total Uranium*	Total Plutonium	Total Other Actinides	Other (Rn-220)
2.66E-02 (9.83E+08)	NA	NA	NA	7.89E-04 (2.92E+07)	5.30E-04 (1.96E+07)	3.28E-04 (1.21E+07)	3.02E-07 (1.12E+04)	1.11E-06 (4.10E+04)	2.12E-06 (7.86E+04)	2.27E+03 (8.40E+13)

WVDP Liquid Effluent Releases$^+$ of Radionuclide Material CY 2001 in Curies (Bq)

Tritium	Fission and Activation Products ($T_{1/2}$>3 hr)	Total Radioiodine	Total Radiostrontium	Total Uranium**	Total Plutonium	Total Other Actinides
1.20E-01 (4.43E+09)	5.76E-03 (2.13E+08)	1.55E-04 (5.73E+06)	1.37E-01 (5.09E+09)	7.52E-04 (2.78E+07)	9.27E-06 (3.43E+05)	2.35E-05 (8.70E+05)

+ The WVDP air and water releases are from point sources and controlled liquid effluent releases, respectively.
* Total uranium (grams) = 2.61E-01
** Total uranium (grams) = 4.56E+02

Note: These tables have been included to provide a standardized format for data collected from all Department of Energy sites.

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