# DOSE ASSESSMENT

## Sources of Radiation at the West Valley Demonstration Project (WVDP or Project)

Members of the public are routinely exposed to natural and man-made sources of ionizing radiation. An individual living in the United States (U.S.) is estimated to receive an average annual effective dose equivalent (EDE) of about 620 millirem (mrem) (6.2 millisieverts [mSv]) (National Council on Radiation Protection [NCRP] and Measurements Report 160, 2009). NCRP Report No. 160, an update of NCRP Report No. 93 (1987), noted that the average member of the U.S. population was exposed to significantly more radiation from medical procedures than from any other source, as had been observed in earlier estimates. (See the "Useful Information" Section at the end of this report for discussions of ionizing radiation. See the inset on p. 3-3 for discussions of “Radiation Dose” and “Units of Dose Measurement.”)

Half of the radiation dose to a member of the public, about 310 mrem/year, is from natural background sources of cosmic and terrestrial origin (Figure 3-1). The other half, also about 310 mrem/year, is from man-made sources, including: diagnostic and therapeutic x-rays, tomography, and fluoroscopy; nuclear medicine; consumer products such as cigarettes and smoke detectors; fallout from nuclear weapons tests; industrial, research, and educational applications; and effluents from nuclear facilities.

Radioactive materials at the WVDP are residues from the commercial reprocessing of nuclear fuel by a former site operator in the 1960s and early 1970s. Each year, very small quantities of the radioactive materials remaining at the WVDP are released to the environment. Emissions and effluents are strictly controlled so that release quantities are kept as low as reasonably achievable (ALARA).

## Exposure Pathways

An exposure pathway consists of a route for contamination to be transported by an environmental medium from a source to a receptor. Table 3-1 summarizes the potential exposure pathways to the lo-

**FIGURE 3-1**
**Comparison of Doses From Natural and Man-Made Sources to the Dose From 2010 WVDP Effluents**

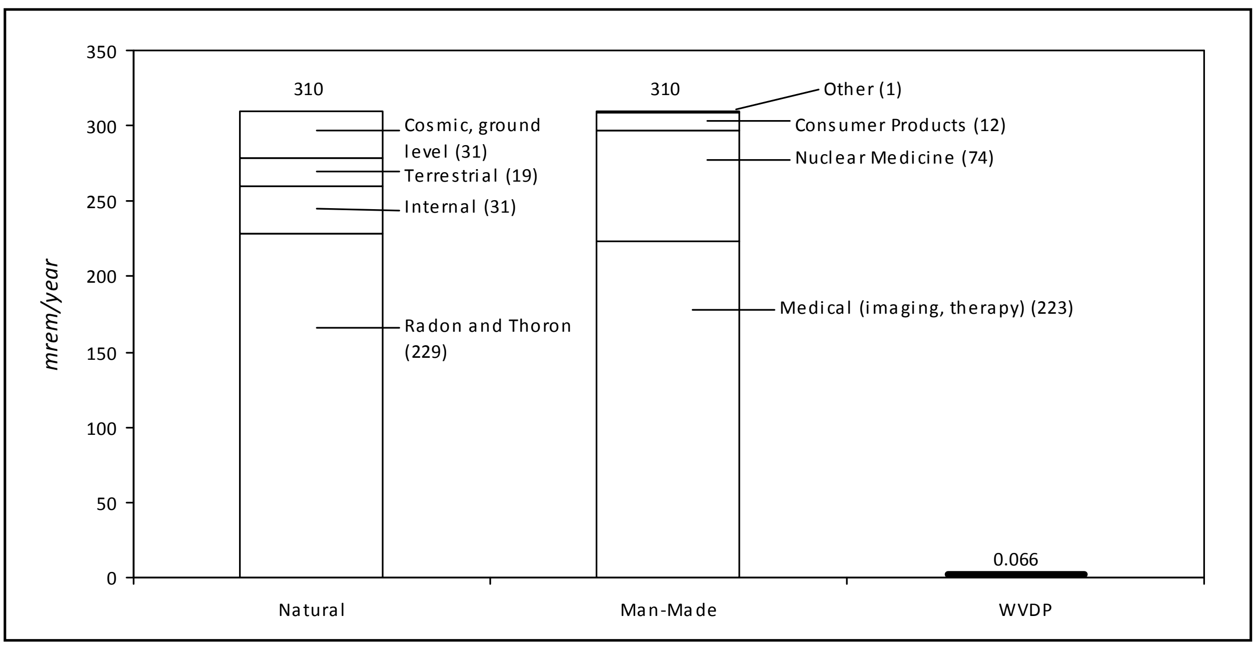


**TABLE 3-1**
**Potential Exposure Pathways from the WVDP to the Local Off-Site Population**

| *Exposure Pathway and Transporting Medium* | *Reason for Including/Excluding* |
|---|---|
| Inhalation of gases and particulates in air (included) | Off-site transport of contaminants from stacks, vents, diffuse sources, or resuspended particulates from soil or water. |
| Ingestion of vegetables, cultivated crops, venison, milk, and fish (included) | Local agricultural products irrigated with potentially contaminated surface or groundwater; airborne deposition on leaves and uptake of deposited contaminants; venison and milk from animals that have inhaled or ingested contaminants; fish that have been exposed to or ingested contaminants in surface water and sediment. |
| Ingestion of surface and groundwater (excluded) | No documented use of local surface water or downgradient groundwater wells as drinking water by local residents. |
| External exposure to radiation from particulates and gases directly from air or surface water or indirectly from surface deposition (included) | Transport of air particulates and gases to off-site receptors; transport of contaminants in surface water and direct exposure when swimming, wading, boating, or fishing. |

cal off-site population and describes the rationale for including or excluding each pathway when calculating dose from the WVDP or Project.

Potential exposure pathways that are considered include: inhalation of gases and particulates, ingestion of locally grown food products and game, and exposure to external penetrating radiation emitted from contaminated materials. Drinking water is not considered a pathway from the WVDP because surveys have determined that no public water supplies are drawn from downstream Cattaraugus Creek before Lake Erie or from groundwater in aquifers potentially affected by the WVDP.

## Land Use Survey

Periodic surveys of local residents provide information about family size, sources of food, and gardening practices. Updated population data from the calendar year (CY) 2000 census was incorporated into WVDP analyses in 2003. Population around the WVDP by sector and distance is presented on Figure A-13. Information from the most recent land use survey, conducted in early 2002, was used to update the locations of the residences nearest to the site. In 2008, a field verification was conducted to confirm the location of the nearest receptor in each sector. The Canadian population within a 50-mile (80-kilometer [km]) radius of the site (Statistics Canada, 2001) is included with the U.S. population in dose calculations. Population information is required when using computer models for annual dose assessments. An estimated 1.68 million people live within 50 miles of the site. If the WVDP becomes aware of the need to update land use information, it does so, even if full field verification for all sectors is not required.

## Dose Assessment Methodology

Dose to the public is evaluated using a two-part method consistent with the requirements of the U.S. Department of Energy (DOE) Order 5400.5. First, measurements (and/or estimates) of radionuclide concentrations in liquid and air released from the Project are assembled from the calendar year of interest. The U.S. Environmental Protection Agency (EPA)- and DOE-approved models are then used to estimate the EDE to the maximally exposed off-site individual (MEOSI) and the collective EDE to the population within a 50-mile (80-km) radius. (See the inset on "Radiation Dose" and "Units of Dose Measurement.")

Second, measurements of radioactivity in food from locations near the WVDP boundaries are taken to corroborate the results from the modeled dose calculations. Samples of vegetables, fruit, milk, venison, and fish from the vicinity of the WVDP are collected and analyzed for radiological constituents. (Biological sampling locations are shown on Figures A-9 and A-12.) Results are compared with similar measurements from samples collected at background locations far from the WVDP. If any near-site results are higher than background results, dose calculations are performed. These results are used as an independent confirmation of (not added to)

## 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. Refer to the "Useful Information" section for discussion of ionizing radiation.

## Units of Dose Measurement

The unit for dose equivalent in common use in the United States is the rem. The international unit of dose equivalent is the sievert (Sv), which is equal to 100 rem. The millirem and millisievert, used more frequently to report the low dose equivalents encountered in environmental exposures, are equal to one-thousandth of a rem or sievert, respectively. Other radioactivity unit conversions are found in the "Useful Information" section at the back of this report.

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. For waterborne releases, the EDE is calculated by multiplying the organ dose equivalent by the organ-weighting factors developed by the International Commission on Radiological Protection in Publications 26 (1977) and 30 (1979). For airborne emissions, the EDE calculation is based upon factors in Federal Guidance Report 13, and National Council on Radiation Protection report Number 123. 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 50-year period following intake is called the 50-year committed effective dose equivalent (CEDE). The CEDE sums the dose to an individual over 50 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 estimated by dividing the collective dose by the population.

the computer-modeled dose estimates (Table 3-2) because the models already take into account contributions from all environmental pathways.

**Measurement of Radionuclide Concentrations in Liquid and Air Releases.** Because it is difficult to distinguish by direct measurement the small amount of radioactivity originating from the Project or from naturally occurring radiation in the environment, computer codes are used to model the environmental dispersion of radionuclides that originate from on-site monitored ventilation stacks and liquid discharge points.

Actual data from air and water release monitoring samples are collected, together with annual weather measurements and the most recent demographic information for use in dose calculations. (See Appendices A, B, and C for details of the sampling program and for summaries of results in 2010.)

## Dose to the Public

Each year an estimate is made of the potential radiological dose to the public that is attributable to operations and effluents from the WVDP during that CY. Estimates are calculated to confirm that no individual could have received a dose that exceeded the limits for protection of the public, as established by the DOE or the EPA.

Figure 3-1 shows the estimated maximum individual dose from the WVDP in CY 2010 as compared with the average annual dose a U.S. resident receives from man-made and natural background sources. As presented, estimated dose from the WVDP would have contributed a very small amount (0.066 mrem [0.00066 mSv]) of the total annual man-made radiation dose to the MEOSI. This is much less than the average dose received from consumer products and is insignificant compared with average dose from natural sources.

Estimated dose from the Project to an off-site resident is also far below the federal standard of 100 mrem allowed from any DOE site operation in a CY, confirming that efforts at the WVDP to minimize radiological releases are consistent with the ALARA philosophy of radiation protection.

## 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 Title 40 of the Code of Federal Regulations (CFR) 61, Subpart H, National Emission Standards for Hazardous Air Pollutants (NESHAP). Subpart H contains the national emission standards for radionuclides other than radon from DOE facilities. The applicable standard is a maximum of 10 mrem (0.1 mSv) EDE to any member of the public in any year.

Releases of airborne radioactive materials in 2010 from stacks and diffuse sources on the WVDP were modeled using the EPA-approved CAP88-PC computer code (Trinity Engineering, December 2007). This air dispersion code estimates EDEs for the ingestion, inhalation, air immersion, and ground surface pathways. (See "CAP88-PC Computer Code" in the "Useful Information" section.)

Site-specific data for CY 2010 (radionuclide releases in curies per year) were used as input to the CAP88-PC code, as were wind data collected from the on-site meteorological tower during 2010 and information from the most recent local population survey. The output from the CAP88-PC code was then used to determine the total EDE from air emissions to the MEOSI and the collective EDE to the population within a 50-mile (80-km) radius of the WVDP. Results are presented in Table 3-2. Although radon is specifically excluded from the NESHAP regulation, an estimate of dose from radon at the WVDP is also included in Table 3-2 for comparison purposes. (For a detailed discussion of radon in air emissions from the WVDP, see the inset on "Radon-220.")

**Maximum Dose (Airborne) to an Off-Site Individual.** Based on the nonradon airborne radioactivity released from all site sources during 2010 (i.e., permitted stacks, stacks that do not require permits, and nonpoint sources), it was estimated that a person living in the vicinity of the WVDP could have received a total EDE of 0.0017 mrem (0.000017 mSv) from airborne releases. (See Table 3-2.) The computer model estimated that this MEOSI, who was assumed to eat only locally produced foods throughout the year, was located 1.2 mile (1.9 km) north-northwest of the site.

The dose from airborne sources is equal to about 3 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 established by the EPA and mandated by DOE Order 5400.5.

Iodine-129, a long-lived radionuclide, has routinely been found in main stack emissions. During the vitrification of high-level radioactive waste (HLW), iodine-129 releases increased because gaseous iodine was not as efficiently removed by the vitrification process off-gas treatment system as were most other radionuclides. As more HLW was removed from the tanks and converted into glass, less waste was available to emit iodine-129 and the total emitted decreased. In 2010, iodine-129 concentrations remained at (or below) pre-vitrification levels and accounted for about 25% of the dose to an off-site individual from airborne emissions. A comparison of the dose proportions from various nuclides is presented on Figure 3-2. Note that for this 2010 report, Figure 3-2 presents the primary nuclides or nuclide groups for all airborne emissions, including diffuse sources. As work activities at the WVDP progress toward decommissioning and/or facility demolition, the importance of diffuse sources to dose estimates is expected to increase, and the number of point sources amendable to normal effluent monitoring will decrease. Therefore, these diffuse sources (primarily from the low-level waste treatment facility lagoons during CY 2010) have been added to the annual totals for the purpose of this presentation.

**Unplanned Radiological Airborne Release.** Although emissions were low, there was one unplanned radiological airborne release at the WVDP during CY 2010. Heavy rainfall and a ventilation upset contributed to higher-than-typical americium-241 and plutonium discharges from the main plant process building (MPPB) stack in July and August 2010. Below stack alarm set points, these discharges were detected by stack monitoring equipment and included in the MPPB stack source term modeled in this report (the dose to the MEOSI from the main stack in CY 2010 was 0.0015% of the 10-mrem standard). Initiating conditions were determined and all personnel were briefed on the event to help in preventing recurrence. (See "MPPB Stack Ventilation - Severe Storm Event" in Chapter 2.)

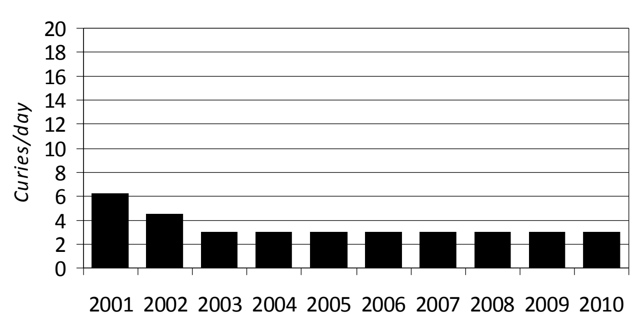
## Radon-220

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

As reported in Chapter 2 of the 1996 WVDP Site Environmental Report (West Valley Nuclear Services Company and Dames & Moore, June 1997), thoron levels were observed to increase during startup of the 1996 HLW 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 assumed to have been released. In 2010, with the vitrification process completed, the average thoron release is conservatively estimated to be about three curies 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, so a dose estimate using CAP88-PC was calculated separately. The theoretical dose to the MEOSI, located 1.2 miles (1.9 kilometers [km]) north-northwest of the site in 2010, would have been 0.027 mrem (0.00027 mSv), and the collective dose to the population within a 50-mile (80-km) radius would have been 1.8 person-rem (0.018 person-Sv). (See Table 3-2.) These theoretical doses are within the same range as historical doses from the man-made radionuclides found in WVDP effluents.

With vitrification completed, thoron releases have decreased to 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**

**FIGURE 3-2**
**Air Emissions From All Sources: Dose Percent by Radionuclide in Calendar Year (CY) 2010**

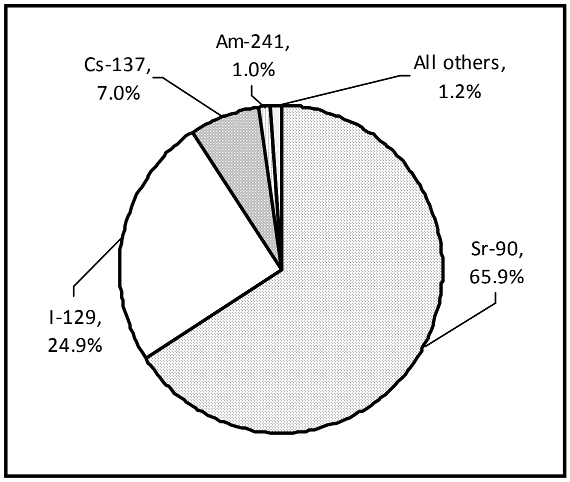



**FIGURE 3-3**
**Water Releases: Dose Percent by Radionuclide in CY 2010**

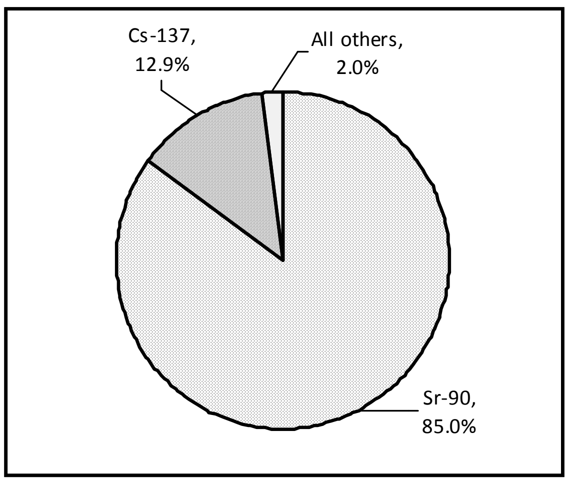
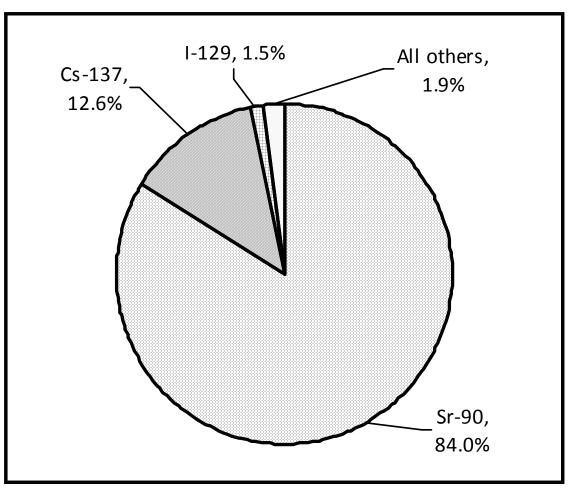



**FIGURE 3-4**
**All Sources: Dose Percent by Radionuclide in CY 2010**



**Collective Population Dose (Airborne).** About 1.68 million people were estimated to reside in the U.S. and Canada within 50 miles (80 km) of the WVDP. (See Figure A-13.) This population received an estimated 0.0077 person-rem (0.000077 person-Sv) total EDE from radioactive nonradon airborne emissions released from WVDP point and diffuse sources during 2010. The resulting average EDE per individual was 0.0000046 mrem (0.000000046 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 Parts 141 and 143, Drinking Water Guidelines (EPA, 1984a; 1984b). Corollary limits for community water supplies are set by the New York State Department of Health (NYSDOH) in the New York State Sanitary Code (Title 10 of the Official Compilation of Codes, Rules, and Regulations of the State of New York 5-1.52). Radionuclides are not regulated under the site's State Pollutant Discharge Elimination System (SPDES) permit. However, special requirements in the permit specify that the concentration of radionuclides in the discharge is subject to requirements of DOE Order 5400.5, "Radiation Protection of the Public and the Environment."

As indicated in Table 3-1, the only local private residential wells are located upgradient of the WVDP and therefore do not represent a potential source of exposure to radioactivity from Project activities. Cattaraugus Creek is not used as a drinking water supply; therefore, a comparison of estimated doses from this source with the 4-mrem/year (0.04-mSv/year) EPA and NYSDOH drinking water limits is not truly appropriate (although values are well below the drinking water limits). Population dose estimates are based on the presumption that radionuclides are even further diluted in Lake Erie before reaching any municipal water supplies.

Because the Project's liquid effluents eventually reach Cattaraugus Creek, the most important waterborne exposure pathway is the consumption of fish from the creek by local sportsmen and residents. Exposure to external radiation from contamination at the shoreline or in the water is also considered in the model for estimating radiation dose.

The computer codes GENII version 1.485 (Pacific Northwest Laboratory, 1988), which implements the models in the U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide 1.109 (NRC, 1977), and LADTAP II (Simpson and McGill, 1980) were used to calculate site-specific unit dose factors (UDFs) for routine waterborne releases and dispersion of these effluents. The UDFs derived from those codes are tabulated in the "Manual for Radiological Assessment of Environmental Releases at the WVDP," WVDP-065 (West Valley Environmental Services LLC, 2010).

Six batches of liquid effluents, totaling about 10.3 million gallons (39.1 million liters), were released from the lagoon 3 weir WNSP001 (SPDES point 001) during 2010. Measurements of the radioactivity discharged in these effluents were combined with the UDFs to calculate the EDE to the MEOSI and the collective EDE to the population living within a 50-mile (80-km) radius of the WVDP. (See Table 3-2.)

In addition to measurements from WNSP001, radioactivity measurements from sewage treatment facility effluents (WNSP007) were included in the EDE calculations. The french drain at WNSP008, a third release point that is listed in the SPDES permit for the WVDP, has been sealed off since 2001 and was therefore not considered a source of discharge in 2010.

Besides the two controlled release points at WNSP001 and WNSP007, water from two natural drainage channels on the north plateau originating on the Project premises contain measurable concentrations of radioactivity: the northeast swamp (WNSWAMP) and north swamp (WNSW74A). Although releases from WNSWAMP and WNSW74A are not considered "controlled" releases, they are well characterized and are routinely sampled and monitored. Results from these monitoring points are included in the EDE calculations for the MEOSI and the collective population. A comparison of proportions of dose attributable to specific waterborne radionuclides is shown on Figure 3-3. As presented, strontium-90 and cesium-137 account for almost all of the estimated waterborne dose, at 85.0% and 12.9%, respectively.

There were no unplanned releases of waterborne radioactivity in 2010.

**Maximum Dose (Waterborne) to an Off-Site Individual.** Based on the radioactivity in liquid effluents discharged from the WVDP (lagoon 3 and the sewage treatment plant) during 2010, an off-site individual could have received a maximum EDE of 0.0094. mrem (0.000094 mSv). (See Table 3-2.) About 81% of this dose was from cesium-137. The MEOSI EDE due to drainage from the north plateau was 0.055 mrem (0.00055 mSv).

**TABLE 3-2**
**Summary of Annual Effective Dose Equivalents (EDE) to an Individual and Population From WVDP Releases in 2010**

| *Exposure Pathways* | *Annual Effective Dose Equivalent* | |
|---|---|---|
| | *Maximally Exposed Off-Site Individual* [a] *mrem (mSv)* | *Collective Effective Dose Equivalent* [b] *person-rem (person-Sv)* |
| **Airborne Releases**[c] | **1.7E-03 (1.7E-05)** | **7.7E-03 (7.7E-05)** |
| % EPA standard (10 mrem) | 0.017% | NA |
| **Waterborne Releases**[d] | **6.4E-02 (6.4E-04)** | **3.4E-01 (3.4E-03)** |
| Effluents only | 9.4E-03 (9.4E-05) | 1.3E-02 (1.3E-04) |
| North plateau drainage | 5.5E-02 (5.5E-04) | 3.2E-01 (3.2E-03) |
| **Total From All Pathways** | **6.6E-02 (6.6E-04)** | **3.4E-01 (3.4E-03)** |
| % DOE standard (100 mrem) - air and water combined | 0.066% | NA |
| % of natural background (310 mrem; 522,000 person-rem) - received from air and water combined | 0.021% | 0.000066% |
| **Estimated Airborne Radon-220**[e] | **2.7E-02 (2.7E-04)**[f] | **1.8E+00 (1.8E-02)**[f] |

Note: Summed values may not exactly match totals due to rounding.
NA - Not applicable. Numerical regulatory standards are not set for the collective EDE to the population.

[a] The maximum exposure to air discharges is estimated to occur at a residence 1.2 miles (1.9 km) north-northwest of the main plant process building (MPPB).

[b] A population of 1.68 million is estimated to reside in the U.S. and Canada within 50 miles (80 km) of the site.

[c] Releases are from atmospheric nonradon point and diffuse sources. Calculations use CAP88-PC to estimate individual and population doses. EPA and DOE limits for individual airborne dose are the same.

[d] Estimates are calculated using the methodology described in the Manual for Radiological Assessment of Environmental Releases at the WVDP, WVDP-065 (WVES, 2010).

[e] Estimated airborne releases are based on indicator measurements and process knowledge. Dose estimates are calculated using CAP88-PC for the MPPB stack.

[f] The estimated dose from radon-220 is specifically excluded by rule from NESHAP totals.

About 98% of the north plateau dose was attributable to strontium-90, largely from the WNSWAMP drainage point.

The combined EDE to the MEOSI from liquid effluents and drainage was 0.064 mrem (0.00064 mSv). This annual dose is very small in comparison to the 310-mrem (3.10 mSv) dose that is received by an average member of the U.S. population from natural background radiation.

**Collective Population Dose (Waterborne).** As a result of radioactivity released in liquid effluents from the WVDP during 2010, the population living within 50 miles (80 km) of the site received an estimated collective EDE of 0.013 person-rem (0.00013 person-Sv). The collective dose to the population from the effluents plus the north plateau drainage was 0.34 person-rem (0.0034 person-Sv). The resulting average EDE per individual is 0.00020 mrem (0.000002 mSv), which is a very small percentage of the dose received by the average person from natural background radiation (310 mrem or 3.1 mSv).

## Predicted Dose From All Pathways

The potential dose to the public from both airborne and liquid effluents released from the Project in 2010 is the sum of the individual dose contributions. (See Table 3-2 and Figure 3-4.) The calculated maximum EDE from all pathways to a nearby resident was 0.066 mrem (0.00066 mSv). This dose is 0.066% of the 100-mrem (1-mSv) annual limit in DOE Order 5400.5. As in past years, CY 2010 results continued to demonstrate WVDP compliance with applicable radiation stan-

## TABLE 3-3
## WVDP Radiological Dose and Release Summary

| WVDP Radiological Dose Reporting Table Calendar Year (CY) 2010 | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Dose to the Maximally Exposed Individual** | | **% of DOE 100-mrem Limit** | **Estimated Population Dose** | | **Population Within 50 Miles[a] (2000 census)** | **Estimated Natural Radiation Population Dose** |
| 0.066 mrem | 0.00066 (mSv) | 0.066 | 0.34 person-rem | 0.0034 (person-Sv) | 1,684,000 | 522,000 person-rem |

| WVDP Radiological Atmospheric Emissions[b] CY 2010 in Curies and Becquerels (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[c]** | **Total Plutonium** | **Total Other Actinides** | **Other (Rn-220)** |
| 5.86E-03 (2.17E+08) | NA | NA | NA | 1.23E-04 (4.56E+06) | 3.23E-05 (1.20E+06) | 1.51E-04 (5.57E+06) | 1.66E-07 (6.13E+03) | 1.91E-06 (7.07E+04) | 2.14E-06 (7.90E+04) | 1.10E+03 (4.05E+13) |

| WVDP Liquid Effluent Releases[d] of Radionuclide Material - CY 2010 in Curies and Becquerels (Bq) | | | | | | |
|---|---|---|---|---|---|---|
| **Tritium** | **Fission and Activation Products ($T_{1/2}$>3 hr)** | **Total Radioiodine** | **Total Radiostrontium** | **Total Uranium[e]** | **Total Plutonium** | **Total Other Actinides** |
| 3.39E-02 (1.26E+09) | 6.03E-03 (2.23E+08) | 1.30E-04 (4.81E+06) | 3.65E-01 (1.35E+10) | 6.20E-04 (2.29E+07) | 7.24E-06 (2.68E+05) | 2.14E-05 (7.94E+05) |

Note: There are no known significant discharges of radioactive constituents from the site other than those reported in this table.

NA - Not applicable

[a] Total population includes the U.S. population from the 2000 census plus the Canadian population residing within a 50-mile (80-km) radius (Statistics Canada, 2001).

[b] Air releases are from point and diffuse sources.

[c] Total uranium (airborne) (grams) = 1.38E-01

[d] Water releases are from both controlled liquid effluent releases and from well-characterized site drainages.

[e] Total uranium (waterborne) (grams) = 4.66E+02

**FIGURE 3-5**
**Effective Dose Equivalent From Liquid and Airborne Effluents to a Maximally Exposed Individual Residing Near the WVDP**

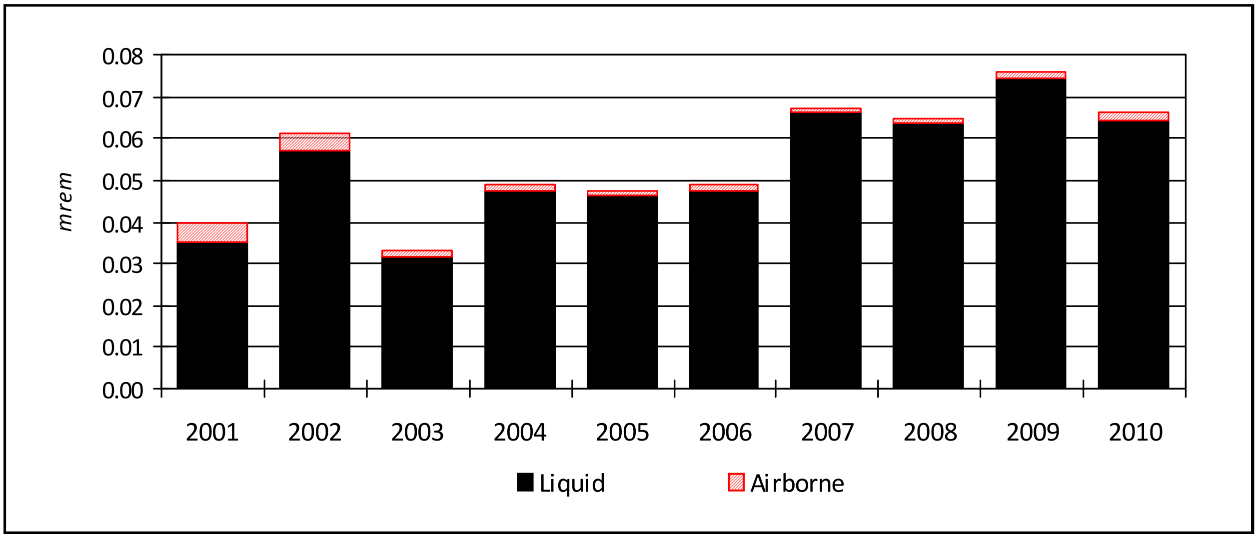
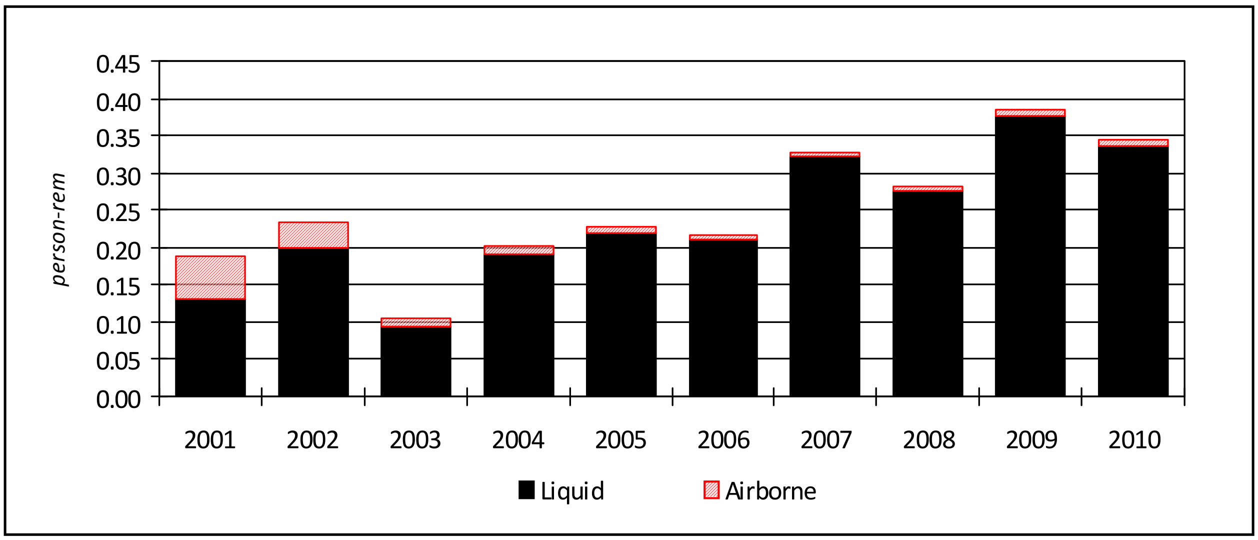



**FIGURE 3-6**
**Collective Effective Dose Equivalent From Liquid and Airborne Effluents to the Population Residing Within 50 Miles (80 km) of the WVDP**




Note: See the text box on p. 3-3 under "Units of Dose Measurement" for a discussion of mrem and person-rem.

dards for protection of the public and the environment. Table 3-3 presents the total curies released to the atmosphere from all sources at the WVDP. As presented on Figure 3-4, the largest proportion of estimated EDE to an off-site individual in 2010 was from strontium-90 via the waterborne pathway.

In CY 2010, the total collective EDE to the population within 50 miles (80 km) of the site was 0.34 person-rem (0.0034 person-Sv), with an average EDE of 0.0002 mrem (0.000002 mSv) per individual.

Figure 3-5 shows the calculated annual dose to the hypothetical MEOSI over the last 10 years. The estimated doses for 2010 were slightly lower than those in 2009. As shown by this figure, the largest portion is due to waterborne contributions.

Figure 3-6 shows the collective dose to the population over the last 10 years. The radioactivity in the human pathway represented by these data confirms the continued inconsequential addition to the natural background radiation dose that individuals and the population around the WVDP receive from Project activities.

**Calculated Dose From Food.** Most radionuclide concentrations in near-site food samples were statistically indistinguishable from concentrations in background samples. For those near-site food samples that were marginally above background, conservative dose estimates due to consuming near-site deer and milk were about 0.21 mrem/year (0.0021 mSv/year), which is about 0.03% of the dose received by an average individual due to natural and other man-made sources in 2010. (See Figure 3-1, "Comparison of Doses from Natural and Man-Made Sources to the Dose from 2010 WVDP Effluents.") This estimate assumes the individual consumes the maximum quantities of each food item. These independent estimates confirmed the low modeled dose estimates based on air and water effluents, as summarized in Table 3-2. Food crops and fish were not sampled in 2010, but will be sampled in 2012.

## Risk Assessment

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

The NCRP estimates that the probability of fatal cancer occurring is between one and five per 10,000 people who are each exposed to one rem (i.e., a risk coefficient of between 0.0001 and 0.0005). DOE guidance has, in the past, recommended using a risk coefficient of 0.0005 (International Commission on Radiological Protection [ICRP], 1991) to estimate risk to a MEOSI. Recent DOE guidance recommends using the even more conservative risk coefficient of 0.0006 provided by the Interagency Steering Committee on Radiation Standards (January 2003). The estimated risk to the hypothetical individual residing near the WVDP from airborne and waterborne releases in 2010 was about 4 per 100 million (a risk of 0.00000004). This risk is well below the range of 0.000001 to 0.00001 per year considered by the ICRP to be a reasonable risk for any member of the public (ICRP Report Number 26, 1977).

## Release of Materials Containing Residual Radioactivity

The DOE ensures protection of the public and the environment through the implementation of the standards and requirements set forth in DOE Order 5400.5. In addition to discharges to the environment, the release of property containing residual radioactive materials is considered a potential contributor to the dose received by the public.

In 2000, the Secretary of Energy placed a moratorium on the release of volumetrically contaminated metals, and suspended the unrestricted release of metals from radiological areas of DOE facilities for recycling. The moratorium and suspension currently remain in effect.

A graded approach is utilized by the WVDP for the release of equipment and materials to the public for unrestricted use. This approach considers the use of the material, the potential for internal contamination, the location the material was used, and process knowledge of the item(s) to be released. In accordance with WVDP radiological controls manuals and procedures, these criteria are assessed and documented, and the material(s) may be radiologically surveyed to verify the survey results are within the contamination limits presented in DOE Order 5400.5, Figure IV-1. Records of released property are maintained.

Presently there are no approved criteria for releasing WVDP material to the public that may have been contaminated in depth or volume; therefore, no unrestricted release of scrap metal or other material of this type has occurred. Compliance with the Secretary of Energy's suspension of unrestricted release of scrap metal for recycle continues at the WVDP.

The Secretary does encourage efforts to promote reuse and recycling of excess property for use within the DOE complex. These transfers occur only when property is transferred to individuals authorized to use such material.

## Dose to Biota

Radionuclides from both natural and man-made sources may be found in environmental media such 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, because 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 prepared a technical standard that provides methods and guidance to be used to evaluate doses of ionizing radiation to populations of aquatic animals, riparian animals (i.e., those that live along banks of streams or rivers), terrestrial plants, and terrestrial animals.

Methods in this technical standard, "A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota" (DOE-STD-1153-2002, July 2002), were used in 2010 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 native aquatic animal organisms (1 rad/day) and for compliance with the thresholds for terrestrial plants (also 1 rad/day) and for terrestrial animals (0.1 rad/day), as proposed in DOE-STD-1153-2002. Note that the absorbed dose unit (rad) is used for biota instead of the units used for indicating human risk (rem).

RESRAD-BIOTA for Windows® (November 2009), a calculation tool provided by the DOE for implementing the technical standard, was used to compare existing radionuclide concentration data from environmental sampling with biota concentration guide (BCG) screening values and to estimate upper bounding doses to biota. Data were taken from surface water samples obtained in 2010 and sediments over the most recent five years of sediment sampling (2003–2007). Soil data from the most recent 10 years (1995–2004) for which special on-site surface soil sampling was conducted and the most recent 10 years of routine on-site surface soil sampling (1998–2007) were used. Differing time periods were used because radionuclide concentrations change more rapidly over time in surface waters than in sediments and soils, as reflected in their sampling frequencies (monthly or quarterly for water, every five years for sediment and surface soil).

Concentration data for radionuclides in each medium were entered into the RESRAD-BIOTA Code. The value for each radionuclide was automatically divided by its corresponding BCG to calculate a partial fraction for each nuclide in each medium. Partial fractions for each medium were added to produce a sum of fractions.

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

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 DOE-STD-1153-2002, the populations of organisms most sensitive to strontium-90 and cesium-137 in this evaluation – that is, those most likely to be adversely affected via the aquatic and terrestrial pathways – were determined to be populations of riparian animals (such as the raccoon [aquatic dose]) and terrestrial animals (such as the deer mouse [terrestrial dose]). Populations of both animals are found on the WNYNSC.

In accordance with the graded approach described in DOE-STD-1153-2002, a general screening was first conducted using the maximum radionuclide concentrations from surface waters, sediments, and soils. Maximum radionuclide concentrations exceeded applicable BCG limits for both aquatic and terrestrial evaluations.

As recommended in DOE-STD-1153-2002, a site-specific screening was then done using estimates of average radionuclide concentrations derived from measurements in site-wide surface waters, sediments, and soils. Results are summarized in Table 3-4.

At the site-specific screening level, the sums of fractions for the aquatic and terrestrial evaluations were

**TABLE 3-4**
**2010 Evaluation of Dose to Aquatic and Terrestrial Biota**

| *AQUATIC SYSTEM EVALUATION* | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Nuclide* | *Water BCG [a] (pCi/L)* | *Mean Water Value (pCi/L)* | *Ratio* | *Sediment BCG [a] (pCi/g)* | *Mean Sediment Value (pCi/g)* | *Ratio* | *Water and Sediment Sum of Fractions* |
| **Cesium-137** | 42.7 | 1.97 | 4.60E-02 | 3,130 | 5.74 | 1.83E-03 | 0.048 |
| **Strontium-90** | 279 | 46.4 | 1.66E-01 | 583 | 1.22 | 2.09E-03 | 0.168 |
| **All Others** | NA | NA | 1.00E-03 | NA | NA | 5.20E-04 | 0.002 |
| **Sum of Fractions** | | | 2.13E-01 | | | 4.44E-03 | **0.217** |
| Estimated upper bounding dose to an aquatic animal = 0.0045 rad/day; to a riparian animal = 0.022 rad/day. | | | | | | | |

| *TERRESTRIAL SYSTEM EVALUATION* | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Nuclide* | *Water BCG [a] (pCi/L)* | *Mean Water Value (pCi/L)* | *Ratio* | *Soil BCG [a] (pCi/g)* | *Mean Soil Value (pCi/g)* | *Ratio* | *Water and Soil Sum of Fractions* |
| **Cesium-137** | 599,000 | 1.97 | 3.28E-06 | 20.8 | 4.64 | 2.23E-01 | 0.223 |
| **Strontium-90** | 54,500 | 46.4 | 8.51E-04 | 22.5 | 1.01 | 4.47E-02 | 0.046 |
| **All Others** | NA | NA | 7.20E-07 | NA | NA | 1.30E-03 | 0.001 |
| **Sum of Fractions** | | | 8.55E-04 | | | 2.69E-01 | **0.270** |
| Estimated upper bounding dose to a terrestrial plant = 0.0025 rad/day; to a terrestrial animal = 0.027 rad/day. | | | | | | | |

NA - Not applicable

[a] The biota concentration guides (BCGs) are calculated values. Except for the sums of fractions and dose estimates, which are rounded to two significant digits, all values are expressed to three significant digits.

0.22 and 0.27, 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.

Upper bounding doses associated with the aquatic system evaluation were 0.0045 rad/day to an aquatic animal and 0.022 rad/day to a riparian animal, far below the 1 rad/day standard from DOE Order 5400.5 for dose to a native aquatic animal. Upper bounding doses associated with the terrestrial system evaluation were 0.027 rad/day to a terrestrial animal and 0.0025 rad/day to a terrestrial plant, again well below the guidance thresholds (0.1 and 1 rad/day, respectively).

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 native aquatic animals (DOE, February 1990) and the international standards for terrestrial organisms (International Atomic Energy Agency [IAEA], 1992).

## Summary

Tables 3-2, 3-3, and 3-4 summarize radiological dose and release information for CY 2010.

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 that place limitations on the release of radioactive materials and dose to individual members of the public. The collective population dose was also assessed and found to be orders of magnitude below the natural background radiation dose. Additionally, estimates indicated that populations of biota at the WVDP are exposed at a fraction of the DOE and IAEA guidelines for dose to biota.

Based on the overall dose assessment, the WVDP was found to be in compliance with applicable effluent radiological guidelines and standards during CY 2010.

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