5.0 Direct Radiation Pathway and Radiation Dose

> **Results in Brief: 2010 Estimated Doses**
>
> **Direct Radiation**—The estimated 2010 effective dose equivalent at the southeastern boundary of the site was 10 mrem/yr (0.10 mSv/yr). This is 10 percent of the 100-mrem/yr (1-mSv/yr) DOE limit.
>
> **Dose to the MEI**—The dose to the MEI for 2010 was estimated to be 10 mrem/yr (0.10 mSv/yr) at the southeastern boundary of the site. This is 10 percent of the 100-mrem/yr (1-mSv/yr) DOE limit.

This section provides the 2010 results for direct radiation monitoring and the estimated dose to the public from the direct radiation pathway. It also addresses biotic dose to aquatic organisms from remedial actions associated with the groundwater restoration program.

In the past, the Fernald Preserve demonstrated compliance with the DOE effective dose limit of 100 millirem per year (mrem/yr) (1 millisievert per year [mSv/yr]) from exposure pathways (excluding radon) using direct radiation measurements and data collected from samples of airborne emissions to estimate the total dose to the maximally exposed individual (MEI). In consultation with EPA, DOE ended air monitoring for particulate emissions on January 4, 2010, because 3 years of post-remediation data indicated emissions are at or near background. Therefore, the 2010 dose estimate reflects the incremental dose above background that is attributed to direct radiation.

This section also provides an assessment of dose to aquatic organisms that may be affected by the site's effluent to nearby streams and rivers. An assessment of dose to biota (i.e., aquatic and terrestrial organisms) is one of the requirements of DOE Order 5400.5. By limiting the dose to aquatic organisms, DOE Order 5400.5 seeks to limit the severity and likelihood of off-site environmental impacts attributable to the aquifer restoration effort at the Fernald Preserve. The dose assessment to biota is performed through the use of a computer model that estimates dose from measured radionuclide concentrations in Paddys Run and effluent discharged to the Great Miami River.

5.1 Monitoring for Direct Radiation

Direct radiation originates from sources such as cosmic radiation, naturally occurring radionuclides in soil and food, and anthropogenic radioactive materials. Gamma rays and X-rays are the dominant types of radiation that create a public exposure concern because they penetrate into the deep tissues of the body. The largest historical source of direct radiation at the Fernald Preserve was waste material associated with the Silos Project. The last waste material associated with the Silos Project was removed from the site in 2006. Presently, there are no significant sources for direct radiation at the Fernald Preserve. During 2010, direct radiation levels at the Fernald Preserve were continuously measured at four trail locations, the Visitors Center, five boundary locations, and one background location with optically stimulated luminescence (OSL) dosimeters. The background location is 3.2 miles from the center of the Fernald Preserve (Figure 5–1).

Table 5–1 provides the annual range of direct radiation measurements for 2009 and 2010, and Figure 5–2 illustrates the quarterly results for 2010. Each quarterly result is the average of three measurements obtained from three separate dosimeters placed at each location (except for the first quarter result for OSL-54 because the three dosimeters registered negative values, and the use of zero for this quarter results in the lack of a first-quarter bar on the plot). In general, the first-quarter results are less than other quarters because the first quarter had fewer exposure days,

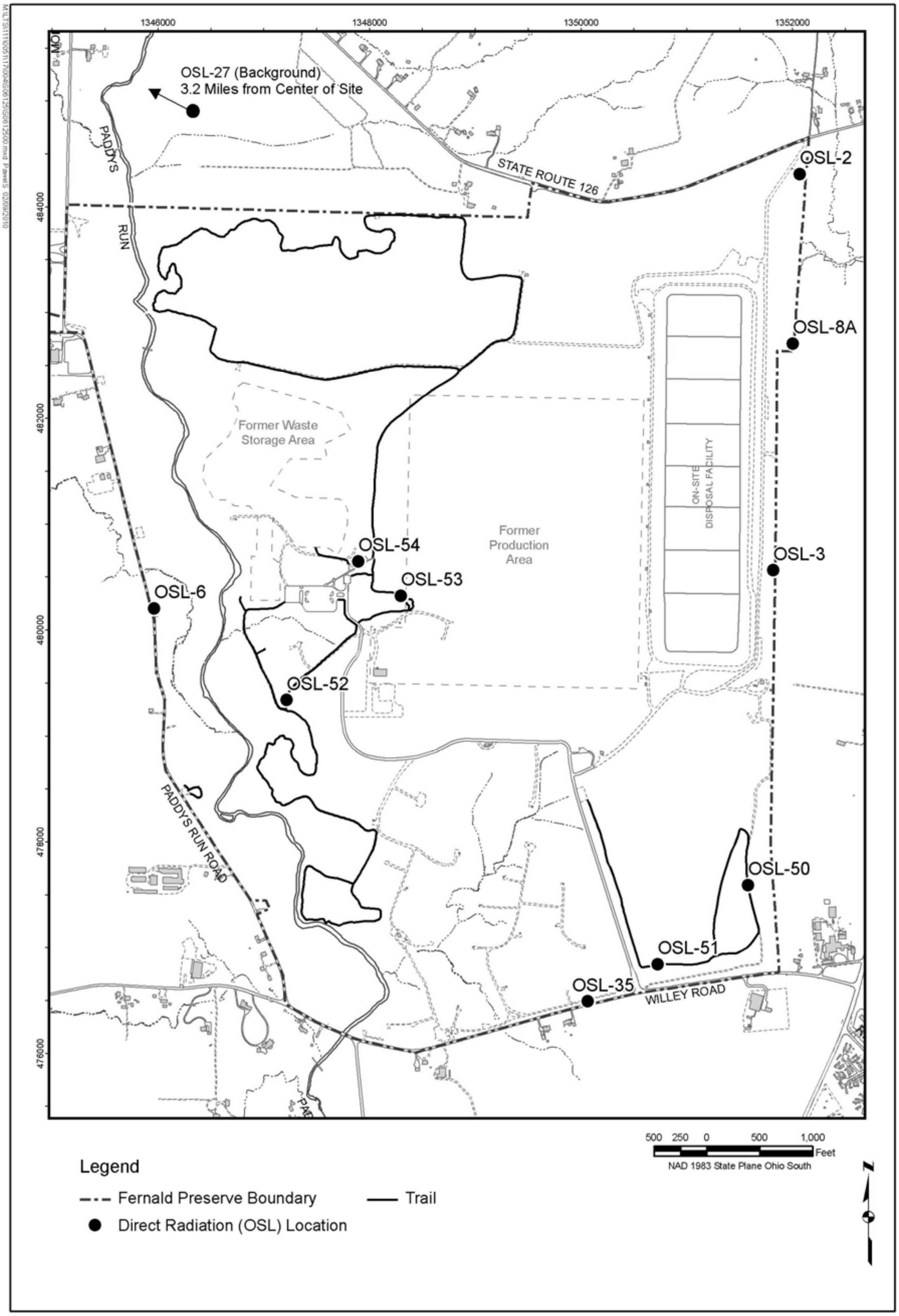

Figure 5–1. Direct Radiation (OSL) Monitoring Locations

and the winter months may hold more moisture in the ground, which can attenuate radiation emitted from soil particles. Compared to background results, many of the on-site results are slightly higher, and the Visitors Center results are lower due to the shielding provided by the building materials. However, as noted in Appendix C, Attachment C.1, the mean of the quarterly boundary measurements is similar to background when statistical variability is evaluated, which is in agreement with removal of the last direct radiation waste sources in 2006.

Table 5–1. Direct Radiation (OSL) Measurement Summary

	Direct Radiation (mrem)	
Location	**Sum of 2010 Quarterly Results**	**Sum of 2009 Quarterly Results**
On Site		
Minimum	18	20
Maximum	28	29
Background[a]		
Minimum	18	20
Maximum	18	20

[a] The minimum and maximum results are identical because there is only one background dosimeter.

5.2 Direct Radiation Dose

Direct radiation dose to deep tissue is primarily the result of gamma and X-ray emissions from radionuclides. The largest historical source of direct radiation at the site was the waste materials stored in the silos. This and all other significant surface radiation sources were removed from the site in 2006. Remaining surface sources for radiation are soil, which contains radium, thorium, and uranium isotopes at activities that are below the FRLs established in the OU5 ROD (DOE 1996), and small pieces of debris that are exposed by soil erosion.

In past years, an estimate of direct radiation dose was calculated for the resident living nearest to the boundary location with the highest measurement. This dose was estimated by using the net measurement at the location and accounting for the distance between the boundary location and the residence, which lowered the direct radiation dose because dose decreases with distance from the radiation source. The boundary fence was removed in late 2006, and direct radiation is now assessed at the monitor location, because there is no fence to prevent an individual from standing at this location. Calculation of dose at the monitor location accounts for the higher doses in 2007 through 2010, relative to dose reported in the *Fernald Preserve 2006 Site Environmental Report* (DOE 2007).

From the data in Table 5-1, the maximum measurement is 28 mrem/yr (0.28 mSv/yr) at OSL-51 (Figure 5–1), and the background dose is 18 mrem/yr (0.18 mSv/yr). The difference in the OSL dose between OSL-51 dosimeter and the background dosimeter is 10 mrem/yr (0.10 mSv/yr), which is assumed to be the direct radiation dose for a hypothetical individual who stands at the OSL-51 location for one year. This is a very conservative estimate of the dose, as an individual would not spend an entire year at OSL-51. Additionally, Appendix C, Attachment C.1 shows that the present quarterly measurements at the boundary are indistinguishable from background results when statistical variability is considered.

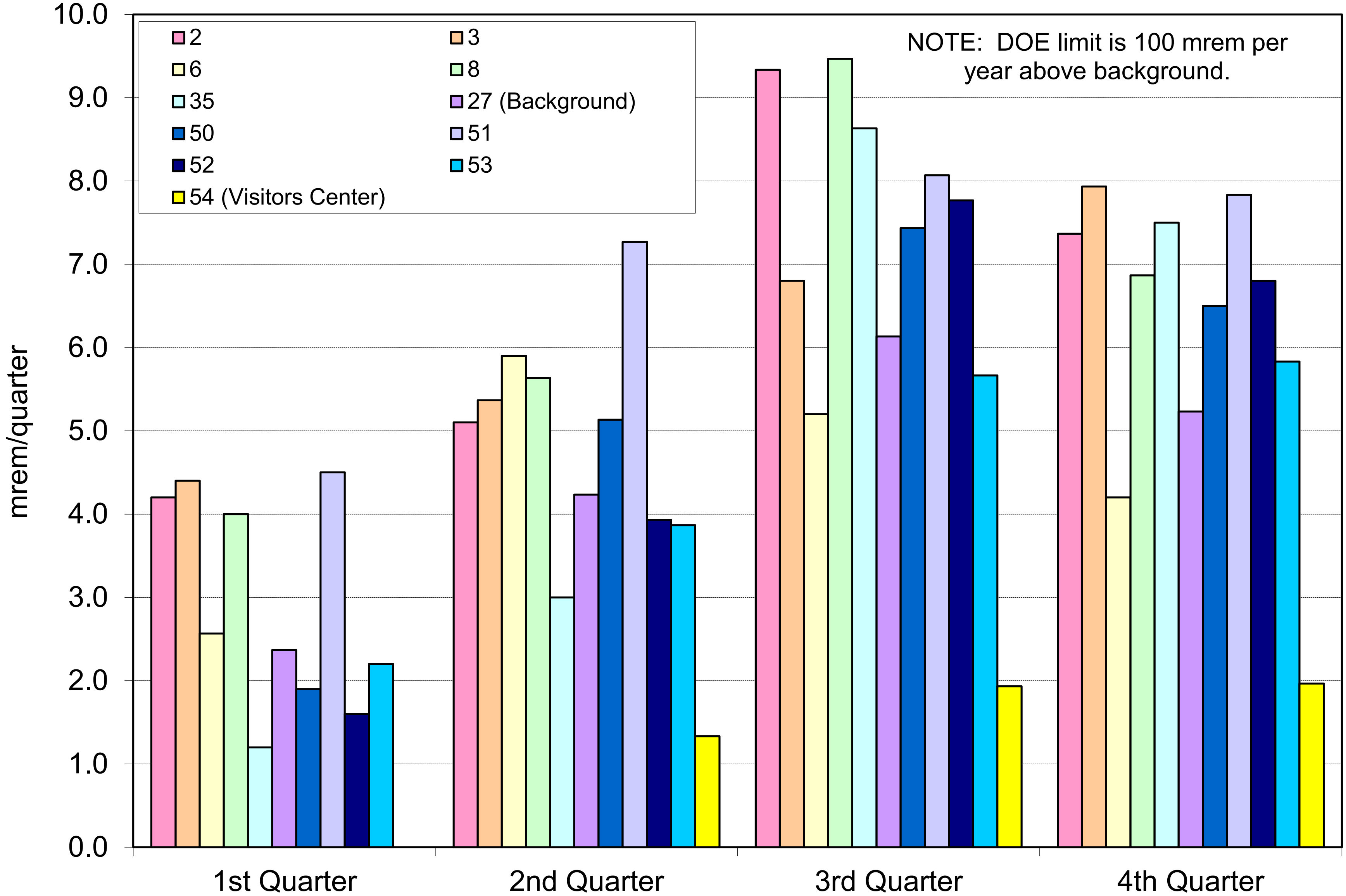

Figure 5–2. Quarterly Results for OSL Monitoring Locations

5.3 Total of Doses to the Maximally Exposed Individual

The MEI is the member of the public who receives the highest estimated effective dose based on the sum of the individual pathway doses (as noted above, direct radiation is the only pathway considered in 2010). It is the maximum dose because the MEI is assumed to spend 24 hours a day, 365 days a year at the site boundary where maximum direct radiation is measured. As shown in Table 5–2, the 2010 dose to the MEI is 10 mrem/yr (0.10 mSv/yr) and represents the sum of the estimated dose from direct radiation at OSL-51. The conservative exposure assumptions used to estimate the dose ensures that the dose to the MEI is the maximum possible dose any member of the public could receive.

Table 5–2. Dose to MEI

Pathway	Dose Attributable to the Fernald Preserve	Applicable Limit
Direct radiation at OSL-51	10 mrem/yr	100 mrem/yr (total for all pathways)
MEI	10 mrem/yr	100 mrem/yr (total for all pathways)

The estimate represents the incremental dose above background attributable to the Fernald Preserve, exclusive of the dose received from radon. (Radon monitoring was eliminated at the end of 2008 because it was at background levels.) Figure 5–3 provides a comparison between the average background radiation dose at the background location (18 mrem/yr [0.18 mSv/yr]) and the dose to the MEI (10 mrem/yr [0.10 mSv/yr]), relative to the annual DOE limit (100 mrem/yr [1 mSv/yr]).

5.4 Significance of Estimated Radiation Doses for 2010

One method of evaluating the significance of the estimated doses is to compare them with doses received from background radiation. Background radiation delivers an annual dose of approximately 100 mrem/yr (1 mSv/yr) from natural sources, excluding radon. For example, the dose received each year from cosmic and terrestrial background radiation contributes approximately 26 mrem/yr (0.26 mSv/yr) and 28 mrem/yr (0.28 mSv/yr), respectively. This sum (54 mrem/yr) is three times greater than the direct radiation dose of 18 mrem/yr at the background location, and it is about five times greater than the 10-mrem/yr-above-background dose estimated for the individual at OSL-51. The 100 mrem/yr per person background also includes dose from the ingestion of food and medical X-rays (about 46 mrem/yr), which is not recorded by the direct radiation OSLs at the boundary and background locations. In addition, the background radiation dose will vary in different parts of the country. Living in the Cincinnati, Ohio, area contributes an annual dose of approximately 110 mrem/yr (1.1 mSv/yr), whereas living in Denver, Colorado, increases the background to approximately 125 mrem/yr (1.25 mSv/yr) (NAS 1980, NCRP 1984).

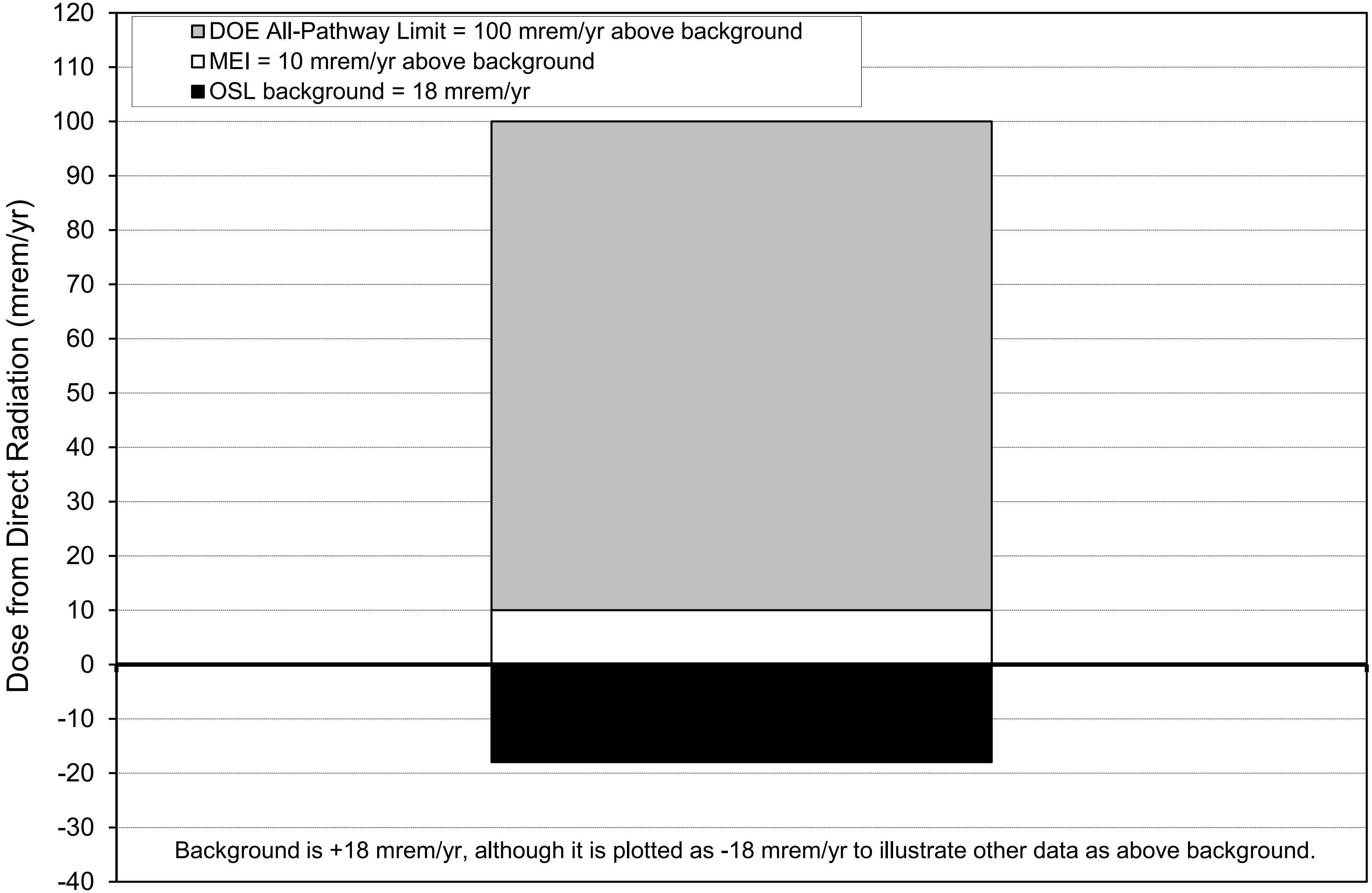

Figure 5–3. Comparison of 2010 All-Pathway Doses and Allowable Limits

Another method of determining the significance of the estimated dose is to compare it with dose limits developed to protect the public. The International Commission on Radiological Protection has recommended that members of the public receive less than 100 mrem/yr (1 mSv/yr) above background. As a result of this recommendation, DOE has incorporated 100 mrem/yr (1 mSv/yr) above background as the limit in DOE Order 5400.5. The sum of all estimated doses from 2010 site operations (10 mrem/yr [0.10 mSv/yr]) is considerably below this limit (Figure 5–3).

5.5 Estimated Dose to Biota

DOE Order 5400.5 requires that populations of aquatic biota be protected at a dose limit of 1 rad/day (10 milligray per day [mGy/day]). DOE has issued a technical standard entitled *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE 2002b) and supporting software (RAD-BCG) for use in the evaluation and reporting of biota dose limits.

In general, the dose and compliance assessment process involves comparing radionuclide concentrations measured in surface water or sediment samples to biota concentration guides (BCGs) established by researchers. The BCGs are set so that biota exposed at the BCG level would not be expected to exceed the biota dose limit of 1 rad/day (10 mGy/day) during a calendar year. The measured radionuclide concentration in water or sediment is divided by the appropriate BCG value, and if the resulting fraction is less than 1.0, compliance with the biota dose limit is demonstrated for that nuclide. BCGs have been established for radionuclides that are relatively common constituents in past releases to the environment from DOE facilities. At facilities such as the Fernald Preserve, where multiple contaminants (e.g., radium, thorium, and uranium) can be released, a “sum-of-the-fractions” rule applies. The sum-of-the-fractions rule means each radionuclide fraction (i.e., the measured concentration divided by the BCG for that nuclide) must be summed, and the sum of all nuclide fractions must be less than 1.0.

For 2010, compliance with the dose limit to aquatic biota was determined by using the maximum concentration of each radionuclide found in Paddys Run at Willey Road (SWP-03) and effluent discharged from PF 4001 to the Great Miami River (refer to Section 4). The maximum concentration in water delivered from the Parshall Flume and Paddys Run is multiplied by the annual volume of water discharged from the Parshall Flume and Paddys Run to obtain a net mass for each nuclide delivered to the Great Miami River. The net mass is divided by the sum of the discharge volumes and low-flow volume from the Great Miami River to derive input concentrations to the RAD-BCG computer model. The results of this assessment indicate that the sum of the fractions for radium, technetium, thorium, and uranium isotopes is 0.007, which is well below the compliance threshold value of 1.0. Appendix C, Attachment C.2 provides additional information on the biota dose assessment.

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