

BACKGROUND STRONTIUM-90 CONCENTRATIONS IN ENVIRONMENTAL SAMPLES COLLECTED FROM THE HUDSON RIVER IN THE VICINITY OF THE INDIAN POINT ENERGY CENTER

The Issue

In June 2006, Entergy Nuclear Northeast, the owner of the Indian Point Energy Center (IPEC), collected fish from the Hudson River and sampled the edible portions for strontium-90 (Sr-90), in accordance with the environmental monitoring program requirements specified in its "Offsite Dose Calculation Manual." Prior to that time, Sr-90 monitoring was not required under the approved environmental monitoring program; however, Entergy added Sr-90 to its sampling plan because of the Sr-90 groundwater contamination known to be migrating toward the Hudson River.

The analysis of Sr-90 in the edible portions of fish collected from the Hudson River revealed concentrations as high as 24.5 pCi/kg. However, the fish samples in question were collected approximately 30 miles (50 kilometers) upstream from IPEC, in a location considered to be the control site for the fish sampling program. The presence of Sr-90 is expected in the Hudson River as a result of nuclear weapons testing at the Nevada Test Site. Nonetheless, over the past 25 years, analytical data have not been maintained to document the Sr-90 concentrations in fish, which might be associated with IPEC activities. As a result, no historical or current data are available for use in determining whether activities at IPEC have contributed to the Sr-90 concentrations found in fish collected from the Hudson River.

In 2007, Entergy, the State of New York, and the U.S. Nuclear Regulatory Commission (NRC) completed additional fish sampling studies to better characterize the background Sr-90 concentrations in the Hudson River. These studies included an additional sampling site in the Catskill region of New York, approximately 90 miles (145 kilometers) upstream from IPEC. In addition, to ensure objectivity, the samples from these studies were divided among Entergy, the State of New York, and the NRC, and were sent to three independent analytical laboratories. Table 1 lists the analytical results for the fish collected in 2006 (by sample location), as well as the NRC's Sr-90 analysis of the fish collected in 2007.

**Table 1. Sr-90 Concentrations in Fish Collected from the Hudson River
Near the Indian Point Energy Center, Roseton, NY, and Catskill, New York in 2006 and
2007**

Year	Site	Fish Species	pCi/kg (wet wt.)	+/-	Report Date ^a	Analysis Date
2006	Indian Point	Catfish	-1.00E+00	1.90E+00	12/18/06	12/09/2006
2006	Indian Point	American Eel	2.30E+00	2.20E+00	12/18/06	12/10/2006
2006	Indian Point	Blue Crab	4.50E+00	1.70E+00	12/18/06	12/08/2006
2006	Indian Point	Sunfish	1.02E+01	4.70E+00	12/22/07	12/15/2006
2006	Indian Point	Striped Bass	4.20E+00	2.60E+00	12/22/06	12/13/2006
2006	Indian Point	White Perch	1.88E+01	2.90E+00	1/9/07	12/27/2006
2007	Region 4	Crabs	3.00E+00	3.00E+00	8/31/07	NR
2007	Region 4	American Eel	1.00E+00	3.00E+00	8/31/07	NR
2007	Region 4	Centrarchidae	1.00E+00	2.00E+00	8/31/07	NR
2007	Region 4	White Perch	1.00E+00	3.00E+00	8/31/07	NR
2007	Region 4	Catfish	0.00E+00	3.00E+00	8/31/07	NR
2007	Region 4	Striped Bass	-1.00E+00	2.00E+00	8/31/07	NR
2007	Region 4	Carp	0.00E+00	2.00E+00	8/31/07	NR
2006	Roseton	Catfish	2.40E+00	2.30E+00	12/18/06	12/10/2006
2006	Roseton	Striped Bass	2.10E+00	1.30E+00	12/18/06	12/07/2006
2006	Roseton	American Eel	3.50E+00	1.30E+00	12/18/06	12/07/2006
2006	Roseton	White Perch	2.45E+01	2.90E+00	1/9/07	12/27/2006
2006	Roseton	Sunfish	1.71E+01	3.10E+00	1/9/07	12/28/2006
2006	Roseton	Blue Crab	1.36E+01	3.60E+00	1/9/07	12/28/2006
2007	Region 7	Catfish	-1.00E+00	3.00E+00	8/31/07	NR
2007	Region 7	Carp	3.00E+00	2.00E+00	8/31/07	NR
2007	Region 7	Striped Bass	0.00E+00	2.00E+00	8/31/07	NR
2007	Region 7	Centrarchidae	1.00E+00	3.00E+00	8/31/07	NR
2007	Region 7	Eel	1.00E+00	3.00E+00	8/31/07	NR
2007	Region 7	White Perch	0.00E+00	2.00E+00	8/31/07	NR
2007	Region 11	Carp	-1.00E+00	3.00E+00	8/31/07	NR
2007	Region 11	White Perch	3.00E+00	3.00E+00	8/31/07	NR
2007	Region 11	Catfish	2.00E+00	2.00E+00	8/31/07	NR
2007	Region 11	Centrarchidae	1.00E+00	3.00E+00	8/31/07	NR
2007	Region 11	Eel	0.00E+00	3.00E+00	8/31/07	NR

Region 4 – Indian Point Energy Center

Region 7 – Control Site (Newburgh-Beacon Bridge area, Roseton, NY), approximately 30 miles (50 km) upstream

Region 11 – Background area near Catskill, NY, approximately 90 miles (145 km) upstream

^a Report date identified at the top of the analysis report; ORISE date is the date of the memorandum to Region 1

NR – Analysis date not recorded

Strontium-90

Strontium is a naturally occurring element found in rocks, soil, dust, coal, surface and underground water, air, plants, and animals, and its background concentrations are typically in parts per million (ppm). Strontium also exists in the atmosphere as wet or dry aerosols, which are dispersed by atmospheric cycling and subsequently deposited by wet deposition. Mean concentrations in the atmosphere have steadily decreased since strontium reached its maximum concentration in 1963 (ASTDR, 2004). In water, strontium primarily exists as hydrated ions, which are relatively mobile. However, sorption of strontium via the formation of ionic complexes with other inorganic and organic substances in soils and sediments can reduce its mobility in water.

A radioactive isotope of strontium, known as Sr-90, is released into the environment as a result of anthropogenic activities. The primary source of Sr-90 in the environment is the explosions associated with the nuclear weapons testing that occurred throughout the world from 1945 through 1980. Strontium-90 is an important radionuclide from a health perspective because of its half-life (29 years) and its ability to be taken up and retained in aquatic and terrestrial plants, as well as its ability to bioaccumulate in the bones and tissues of animals. Because the beta emissions from Sr-90 have limited ability to penetrate tissues (such as skin), the key pathways for Sr-90 exposure in humans are inhalation and ingestion.

Sources of Sr-90 in the Environment

As previously noted, the majority of the Sr-90 currently found in the environment can be traced back to atmospheric nuclear weapons testing conducted throughout the world from 1945 through 1980. The majority of the aboveground testing in the United States was conducted between 1951 and 1963, but the most intensive testing occurred in 1952–1954, 1957–1958, and 1961–1962. Low-yield tests (<100 KT) conducted at the Nevada Test Site (NTS) injected almost all of their debris into the lower atmosphere (troposphere), where it was deposited primarily within the contiguous United States. A total of 1.8 PBq of Sr-90 (1 PBq = 10^{15} Bq) was deposited throughout the United States as a result of these tests (CDC, 2005). By contrast, high-yield tests, which account for more than 90% of the fission products produced, were conducted in the Pacific Ocean and at various sites in the Union of Soviet Socialist Republics (USSR). The debris from those tests was injected into an upper layer of the atmosphere (stratosphere). As a result, the long residence times associated with the transfer between the stratosphere and the troposphere allowed the debris from the high-yield tests to be dispersed throughout the atmosphere, resulting in a relatively uniform pattern of deposition across the United States. In addition, some of the Sr-90 released as a result of the Chernobyl nuclear accident in April 1986 reached the upper atmosphere, where it was transported around the world, and most was subsequently deposited as regional fallout in Eastern Europe. For that reason, the contribution of the Chernobyl accident to the Sr-90 concentration in the United States is considered insignificant (CDC, 2005).

As a result of the testing at the NTS and other sites, fission products were distributed throughout the United States and globally. Subsequent studies have concluded that 12% of the fallout from these tests was deposited close to the test sites, 10% was deposited in bands around the Earth at the latitudes of the test sites, and 78% of the fallout activity was distributed over larger areas, mostly in the same hemisphere as the given test site (UNSCEAR, 1993).

Deposition and, thus, concentrations, of radionuclides in the air decreased rapidly once atmospheric testing ceased in 1980. Moreover, any Sr-90 deposited after 1982 is presumed to be attributable to re-suspension and settlement and is considered insignificant compared to historical deposits (UNSCEAR, 2000). Figures 1a and 1b, adapted from the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 1993), illustrate the steady decrease in the annual effective dose from Sr-90 since the cessation of nuclear weapons testing.

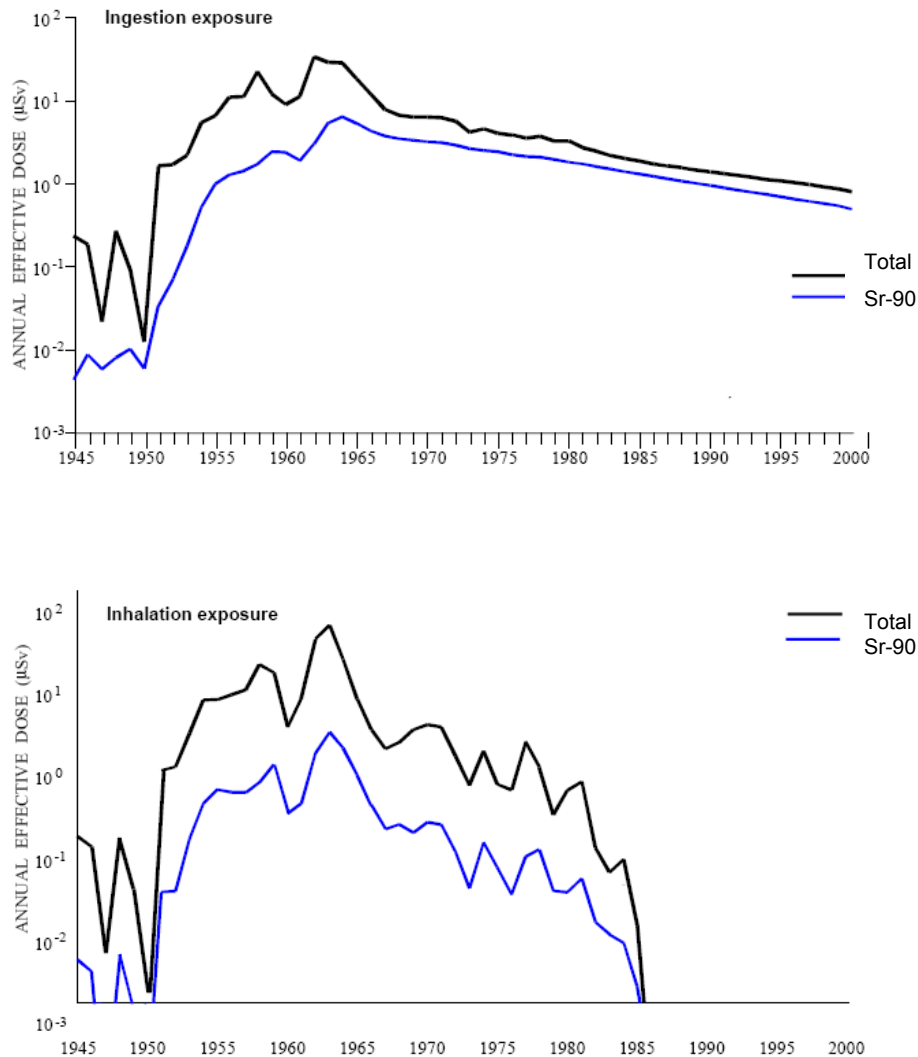


Figure 1. Worldwide average doses (μSv) from (a) ingestion and (b) inhalation of radionuclides in general, and Sr-90 in particular, as a result of atmospheric nuclear testing (adapted from UNSCEAR, 1993)

As previously noted, strontium from the atmosphere is transported and deposited on the Earth by dry or wet deposition. Dry deposition results from gravitational settling and sorption on surfaces, while wet deposition depends on conditions such as particle solubility, air concentration, rain drop size distribution, and rain fall rates (NCRP, 1984). Although the deposition density of contaminants tends to decrease with distance from the NTS, regional and local variations in deposition density are attributable to variations in meteorological conditions corresponding to the time of the tests.

During the years in which the NTS testing was being conducted (and for many years thereafter), the Environmental Measurements Laboratory (EML) maintained a network of radioactivity monitors, primarily in the form of gummed-film collectors. This monitoring network collected data on the transport and deposition of radioactive materials from the atmosphere as a result of the tests. Those data, together with detailed precipitation and wind flow records, were used to develop meteorological and deposition models that traced the fallout of radioactive materials as the clouds of debris from the nuclear weapons tests made their way across the country. Those models showed that, because of the wind flow patterns in the 1950s, the concentrations of radioactive materials tended to be higher in New York State than in the surrounding areas (Figure 2) (Beck et al., 1990, Hoecker and Machta, 1990). In the case of Test SIMON, Hoecker and Machta (1990) showed how the radioactive material was transported across the United States and deposited in New York State. Clark (1954) discussed the details of the rainout in Upstate New York that resulted in a high (albeit non-hazardous) deposition of radioactive material, including Sr-90, associated with a thunderstorm.

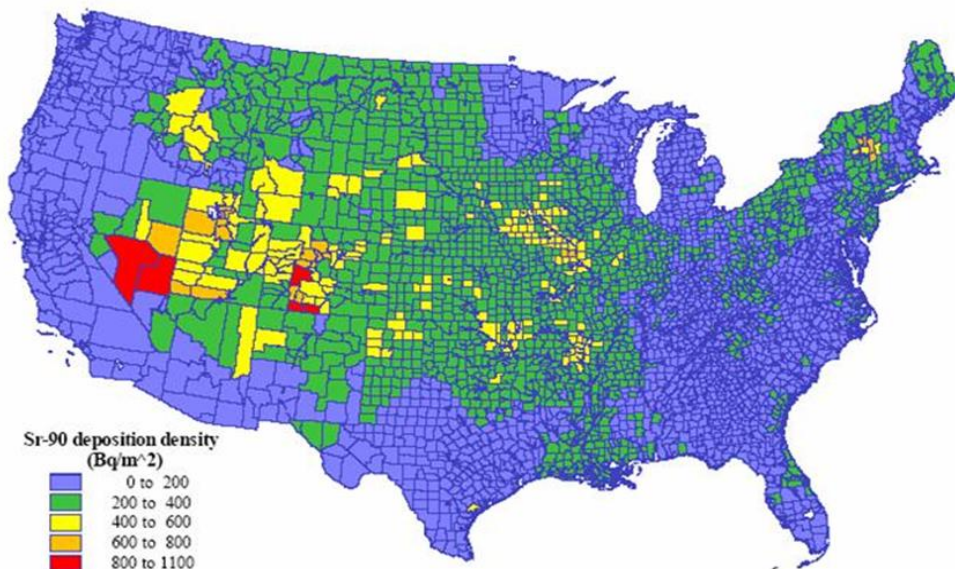


Figure 2. Cumulative Sr-90 deposition density (Bq/m²) for the continental United States as a result of nuclear weapons testing at the Nevada Test Site (from CDC, 2005)

Databases containing the data collected by EML are currently maintained and accessible through the U.S. Department of Homeland Security Web site at <http://www.eml.st.dhs.gov/databases/>. These databases can be used to determine the transport and fate of radionuclides, including Sr-90, for many years following releases associated with the NTS nuclear weapons testing. For example, analysis of the Sr-90 fallout data for New York and Florida show decreases in Sr-90 concentrations (mCi/kg) following the cessation of the NTS weapons testing; however, the concentrations in New York are consistently greater than those in Florida (Figure 3).

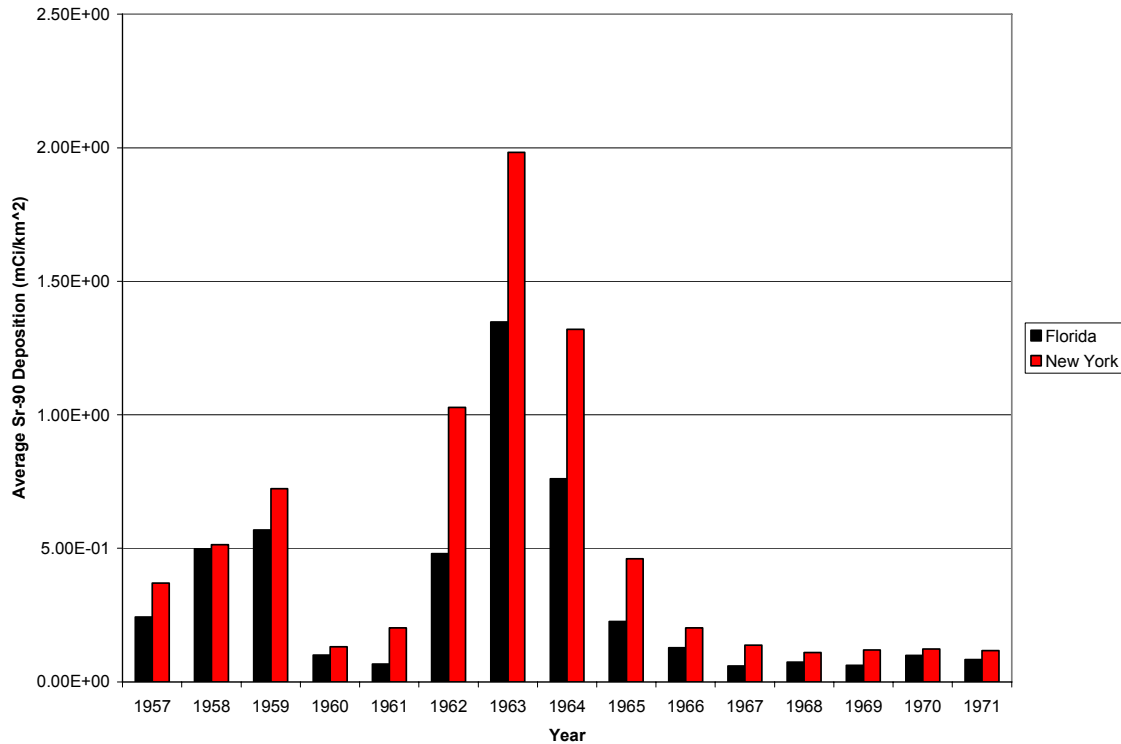


Figure 3. Average Sr-90 Deposition in New York and Florida from 1957 through 1971 (data compiled from the EML Global Fallout Deposition Database)

Similarly, UNSCEAR (1993) reported data on the time-integrated deposition of Sr-90 in each 10-degree latitude band of the globe. Notably, the 40- to 50-degree latitude band, which includes the entire State of New York, received a total of 101.6 PBq of Sr-90 — the largest integrated deposition of Sr-90 from fallout in both the northern and southern hemispheres. By contrast, the 20- to 30-degree latitude band, which includes the State of Florida, received a total of 71.2 PBq of Sr-90.

The analyses referenced above as well as the data from the EML databases and UNSCEAR reports reveal that Sr-90 background concentrations vary throughout the United States. Nonetheless, because of wind patterns and precipitation, some areas of New York State (particularly the upper reaches of the Hudson River watershed) tend to have higher background Sr-90 concentrations than other areas of the United States (CDC, 2005, Beck et al., 1990).

Although not specifically related to Sr-90, it is also important to note that a recent research study (Kenna et al., 2004) showed that sediment contamination from the Mohawk River (a tributary of the Hudson River north of Albany, New York) can be traced 124 miles (200 kilometers) downstream from the Knolls Atomic Power Laboratory (KAPL). In that study, the unique isotopic signatures associated with various nuclear contaminants were used to identify and resolve inputs from multiple sites in the Hudson River drainage basin (Kenna et al., 2004). In discussing the study by Kenna et al., an article in the *Daily Gazette* (2007) quoted the study's lead author, saying that "[t]he Mohawk River delivers about two-thirds of the sediment to the Hudson River Estuary. It's not surprising that some of the sediments contaminated by activities at KAPL [can] get deposited and removed, deposited and removed. They can get re-suspended with flooding events." The study went on to rule out IPEC as a source of this contamination (Lamendola, 2007).

Sr-90 and Fish

Sources of radioactivity in aquatic environments include naturally occurring radionuclides, fallout from the atmosphere, runoff from watersheds that received atmospheric deposition, and radioactive effluents that are released (routinely or accidentally) from a variety of sources. Depending on the element and its chemical form, a particular radionuclide may accumulate in the sediments or remain in the water column. Aquatic organisms occupying these contaminated areas may receive radiation exposure externally via the water, sediment, and other biota, or internally through ingestion and inhalation processes. For fish, adsorption and absorption through the skin and respiratory organs can also provide a means for accumulating radioactive materials.

Research conducted on the metabolism of strontium has shown that upon entering the fish, the distribution of strontium in the organs and tissues can be segregated into two general classes. Visceral organs and tissues (e.g., blood, kidney, and liver) show decreases in radioactivity shortly after exposure, while structural tissues (e.g., skeleton, gill arches, integument, and muscle) tend to concentrate and maintain higher levels of strontium for longer periods of time (Boroughs et al., 1956). Moreover, given the tendency for strontium to compete with calcium, the greatest concentration of strontium tends to be in the fish skeleton.

Numerous factors can contribute to the uptake of radionuclides (such as Sr-90) by fish. Variations in radionuclide concentrations from year-to-year tend to have a more immediate impact on fish that are lower in the food chain (e.g., plankton feeders) than those that are at a higher level (e.g., piscivorous fish) because of the lag time associated with the movement of radionuclides through the food chain. Feeding strategies, as well as the age and size of the exposed fish, can also affect uptake (Karlsson et al., 2002). Because marine fish tend to swallow more water than freshwater fish (to maintain proper osmotic balance), radionuclides dissolved in the water column are more prone to absorption in the gastrointestinal tract in marine species than in freshwater species (Karlsson et al., 2002, Boroughs et al., 1956). Moreover, the uptake of radionuclides like Sr-90 by fish in ecosystems like the Hudson River (which is tidal and has constantly changing water conditions) can be impacted by the constant shifts in salt concentrations. Nonetheless, it is important to remember that, in most cases, strontium associated with water passes directly through the visceral organs and is not retained by the fish (Boroughs et al., 1956).

Two other sites in New York, the West Valley Demonstration Project (WVDP) in West Valley, New York, and Brookhaven National Laboratory (BNL) in Upton, New York, maintain ongoing sampling and analysis programs that include measuring Sr-90 concentrations in fish as part of their environmental monitoring programs (Tables 2 and 3).

Table 2. Concentrations of Sr-90 (pCi/kg dry weight) of Fish Collected from the Control Site at Brookhaven National Laboratory, Upton, New York

Year	Sample Site	Fish Species	pCi/kg	+/-	Sample Type
2004	Lower Lake, Carmans River	Largemouth Bass	ND		
2004	Lower Lake, Carmans River	Brown Bullhead	ND		
2004	Lower Lake, Carmans River	Bluegill	6.00E+02	3.00E+02	Dry
2004	Lower Lake, Carmans River	Pumpkinseed	ND		
2004	Lower Lake, Carmans River	Golden Shiner	ND		
2003	Lower Lake, Carmans River	Golden Shiner	< MDL		Dry
2003	Lower Lake, Carmans River	Largemouth Bass	< MDL		Dry
2003	Lower Lake, Carmans River	Brown Bullhead	< MDL		Dry
2003	Lower Lake, Carmans River	Bluegill	< MDL		Dry
2003	Lower Lake, Carmans River	Brown Trout	< MDL		Dry
2002	Lower Lake, Carmans River	Brown Bullhead	< MDL		Dry
2002	Lower Lake, Carmans River	Largemouth Bass	< MDL		Dry
2002	Lower Lake, Carmans River	Bluegill	< MDL		Dry
2002	Lower Lake, Carmans River	Pumpkinseed	< MDL		Dry
2001	Lower Lake, Carmans River	Bluegill	ND		
2001	Lower Lake, Carmans River	Bluegill	ND		
2001	Lower Lake, Carmans River	Pumpkinseed	ND		
2001	Lower Lake, Carmans River	Pumpkinseed	3.00E+01	1.00E+01	Dry
2001	Lower Lake, Carmans River	Black Crappie	ND		
2001	Lower Lake, Carmans River	Bass	ND		
2001	Lower Lake, Carmans River	Golden Shiner	ND		
2001	Lower Lake, Carmans River	Golden Shiner	ND		
2001	Lower Lake, Carmans River	Black Crappie	ND		
2001	Lower Lake, Carmans River	Yellow Perch	ND		
2001	Lower Lake, Carmans River	Red-Finned Pickerel	ND		
2001	Lower Lake, Carmans River	Brown Bullhead	ND		
2000	Lower Lake, Carmans River	Golden Shiners	ND		
2000	Lower Lake, Carmans River	Bluegill	ND		
2000	Lower Lake, Carmans River	Bass	ND		
2000	Lower Lake, Carmans River	Pumpkinseed	< MDL		Dry
2000	Lower Lake, Carmans River	Brown Bullhead	< MDL		Dry

No Sr-90 data were collected from fish in 2005.

Data were collected from the annual BNL Site Environmental Reports.

Table 3. Concentrations of Sr-90 (pCi/kg Dry Weight) of Fish Collected from the Control Site at the West Valley Demonstration Project, West Valley, New York

YEAR	SITE	FISH SPECIES	pCi/kg	+/-	SAMPLE TYPE
2005	Cattaraugus Creek	Brown Trout	3.81E+00	1.67E+00	Dry
2005	Cattaraugus Creek	Brown Trout	2.99E+00	1.98E+00	Dry
2005	Cattaraugus Creek	Brown Trout	1.36E+01	2.50E+00	Dry
2005	Cattaraugus Creek	White Sucker	6.13E+00	1.77E+00	Dry
2005	Cattaraugus Creek	Hog-Nosed Sucker	7.96E+00	2.67E+00	Dry
2005	Cattaraugus Creek	White Sucker	7.14E+00	2.17E+00	Dry
2005	Cattaraugus Creek	White Sucker	1.60E+01	2.00E+00	Dry
2005	Cattaraugus Creek	Hog-nosed Sucker	7.92E+00	1.57E+00	Dry
2005	Cattaraugus Creek	White Sucker	1.43E+00	2.33E+00	Dry
2005	Cattaraugus Creek	White Sucker	4.08E+00	1.94E+00	Dry
2004	Cattaraugus Creek	White Sucker	6.83E+00	4.45E+00	Dry
2004	Cattaraugus Creek	White Sucker	2.15E+00	1.86E+00	Dry
2004	Cattaraugus Creek	White Sucker	7.43E+00	4.25E+00	Dry
2004	Cattaraugus Creek	White Sucker	2.55E+00	2.03E+00	Dry
2004	Cattaraugus Creek	White Sucker	8.27E+00	3.53E+00	Dry
2004	Cattaraugus Creek	Hog-Nosed Sucker	4.87E+00	7.32E+00	Dry
2004	Cattaraugus Creek	Brown Trout	3.12E+00	3.90E+00	Dry
2004	Cattaraugus Creek	Brown Trout	8.60E-01	3.82E+00	Dry
2004	Cattaraugus Creek	Brown Trout	-2.20E-01	4.41E+00	Dry
2004	Cattaraugus Creek	Brown Trout	1.92E+00	4.31E+00	Dry
2003	Cattaraugus Creek	White Sucker	3.90E+01	3.00E+00	Dry
2003	Cattaraugus Creek	White Sucker	1.34E+01	2.10E+00	Dry
2003	Cattaraugus Creek	Brown Trout	4.13E+00	1.96E+00	Dry
2003	Cattaraugus Creek	White Sucker	1.34E+01	1.70E+00	Dry
2003	Cattaraugus Creek	White Sucker	1.37E+01	2.70E+00	Dry
2003	Cattaraugus Creek	White Sucker	1.02E+01	3.10E+00	Dry
2003	Cattaraugus Creek	White Sucker	1.89E+01	6.30E+00	Dry
2003	Cattaraugus Creek	Hog-Nosed Sucker	2.31E+01	5.60E+00	Dry
2003	Cattaraugus Creek	Hog-Nosed Sucker	1.94E+01	4.10E+00	Dry
2003	Cattaraugus Creek	Hog-Nosed Sucker	2.00E+01	5.60E+00	Dry
2002	Cattaraugus Creek	White Sucker	1.68E+01	3.00E+00	Dry
2002	Cattaraugus Creek	White Sucker	8.17E+00	1.36E+00	Dry
2002	Cattaraugus Creek	White Sucker	1.89E+01	2.70E+00	Dry
2002	Cattaraugus Creek	White Sucker	1.11E+01	1.40E+00	Dry
2002	Cattaraugus Creek	White Sucker	1.01E+01	2.30E+00	Dry
2002	Cattaraugus Creek	White Sucker	1.57E+01	1.20E+00	Dry
2002	Cattaraugus Creek	Brown Trout	1.23E+01	1.00E+00	Dry
2002	Cattaraugus Creek	Brown Trout	1.17E+01	1.60E+00	Dry
2002	Cattaraugus Creek	Hog-Nosed Sucker	2.71E+01	1.20E+00	Dry
2002	Cattaraugus Creek	White Sucker	1.24E+01	1.10E+00	Dry

Table 3. Concentrations of Sr-90 (pCi/kg Dry Weight) of Fish Collected from the Control Site at the West Valley Demonstration Project, West Valley, New York (cont.)

Year	Site	Fish Species	pCi/kg	+/-	Sample Type
2002	Cattaraugus Creek	Brown Trout	7.37E-01	7.80E-01	Dry
2002	Cattaraugus Creek	Brown Trout	7.89E-01	8.20E-01	Dry
2002	Cattaraugus Creek	Brown Trout	1.07E+00	7.30E-01	Dry
2002	Cattaraugus Creek	Brown Trout	6.14E-01	5.49E-01	Dry
2002	Cattaraugus Creek	White Sucker	3.57E+00	1.38E+00	Dry
2002	Cattaraugus Creek	White Sucker	1.60E+01	8.80E+00	Dry
2002	Cattaraugus Creek	White Sucker	2.73E+01	7.70E+00	Dry
2002	Cattaraugus Creek	Hog-Nosed Sucker	1.82E+01	4.00E+00	Dry
2002	Cattaraugus Creek	White Sucker	1.63E+01	5.80E+00	Dry
2002	Cattaraugus Creek	White Sucker	2.47E+01	5.30E+00	Dry
2001	Cattaraugus Creek	Hog-Nosed Sucker	9.75E+00	2.95E+00	Dry
2001	Cattaraugus Creek	White Sucker	1.10E+01	2.50E+00	Dry
2001	Cattaraugus Creek	Brown Trout	1.70E+00	4.35E+00	Dry
2001	Cattaraugus Creek	White Sucker	1.47E+01	4.20E+00	Dry
2001	Cattaraugus Creek	Brown Trout	5.89E+00	7.11E+00	Dry
2001	Cattaraugus Creek	White Sucker	9.70E+00	5.48E+00	Dry
2001	Cattaraugus Creek	White Sucker	9.72E+00	3.70E+00	Dry
2001	Cattaraugus Creek	Hog-Nosed Sucker	2.27E+01	5.00E+00	Dry
2001	Cattaraugus Creek	Brown Trout	2.45E+00	4.15E+00	Dry
2001	Cattaraugus Creek	White Sucker	1.73E+01	3.80E+00	Dry
2001	Cattaraugus Creek	Hog-Nosed Sucker	8.21E+00	3.15E+00	Dry
2001	Cattaraugus Creek	Hog-Nosed Sucker	8.12E+00	2.05E+00	Dry
2001	Cattaraugus Creek	Hog-Nosed Sucker	6.27E+00	3.64E+00	Dry
2001	Cattaraugus Creek	Hog-Nosed Sucker	5.87E+00	2.27E+00	Dry
2001	Cattaraugus Creek	Brown Trout	-6.00E-02	2.75E+00	Dry
2001	Cattaraugus Creek	White Sucker	5.31E+00	1.77E+00	Dry
2001	Cattaraugus Creek	Hog-Nosed Sucker	3.85E+00	2.24E+00	Dry
2001	Cattaraugus Creek	White Sucker	3.96E+01	3.30E+00	Dry
2001	Cattaraugus Creek	Brown Trout	8.24E+00	3.52E+00	Dry
2001	Cattaraugus Creek	White Sucker	5.69E+00	2.97E+00	Dry
2000	Cattaraugus Creek	Hog-Nosed Sucker	2.00E+00	3.10E+00	Dry
2000	Cattaraugus Creek	Hog-Nosed Sucker	1.31E+01	1.60E+00	Dry
2000	Cattaraugus Creek	White Sucker	NR		Dry
2000	Cattaraugus Creek	White Sucker	NR		Dry
2000	Cattaraugus Creek	White Sucker	3.10E+00	4.80E+00	Dry
2000	Cattaraugus Creek	Brown Trout	8.40E+00	2.40E+00	Dry
2000	Cattaraugus Creek	Brown Trout	1.37E+01	1.50E+00	Dry
2000	Cattaraugus Creek	Brown Trout	7.60E+00	1.20E+00	Dry
2000	Cattaraugus Creek	Brown Trout	4.00E+00	1.04E+01	Dry
2000	Cattaraugus Creek	White Sucker	1.17E+01	1.80E+00	Dry
2000	Cattaraugus Creek	Hog-Nosed Sucker	NR		Dry
2000	Cattaraugus Creek	Brown Trout	NR		Dry

Table 3. Concentrations of Sr-90 (pCi/kg Dry Weight) of Fish Collected from the Control Site at the West Valley Demonstration Project, West Valley, New York (cont.)

Year	Site	Fish Species	pCi/kg	+/-	Sample Type
2000	Cattaraugus Creek	Brown Trout	1.63E+01	8.70E+00	Dry
2000	Cattaraugus Creek	Brown Trout	NR		Dry
2000	Cattaraugus Creek	White Sucker	-4.00E-01	1.72E+01	Dry
2000	Cattaraugus Creek	Hog-Nosed Sucker	8.50E+00	9.80E+00	Dry
2000	Cattaraugus Creek	White Sucker	8.20E+00	1.97E+01	Dry
2000	Cattaraugus Creek	White Sucker	-4.30E+00	1.57E+01	Dry
2000	Cattaraugus Creek	Brown Trout	-1.11E+01	1.89E+01	Dry
2000	Cattaraugus Creek	White Sucker	NR		Dry
1999	Cattaraugus Creek	Brown Trout	1.72E+01	1.24E+01	Dry
1999	Cattaraugus Creek	Brown Trout	1.24E+02	2.20E+01	Dry
1999	Cattaraugus Creek	Brown Trout	2.08E+01	1.70E+01	Dry
1999	Cattaraugus Creek	White Sucker	1.80E+00	1.02E+01	Dry
1999	Cattaraugus Creek	White Sucker	-3.00E+00	2.72E+01	Dry
1999	Cattaraugus Creek	Hog-Nosed Sucker	2.04E+01	8.60E+00	Dry
1999	Cattaraugus Creek	White Sucker	2.80E+00	1.19E+01	Dry
1999	Cattaraugus Creek	Hog-Nosed Sucker	8.10E+00	1.18E+01	Dry
1999	Cattaraugus Creek	Brown Trout	5.90E+00	1.60E+01	Dry
1999	Cattaraugus Creek	Brown Trout	7.70E+00	1.49E+01	Dry
1999	Cattaraugus Creek	White Sucker	4.91E+00	6.89E+00	Dry
1999	Cattaraugus Creek	White Sucker	2.70E+00	1.35E+01	Dry
1999	Cattaraugus Creek	White Sucker	1.07E+01	2.29E+01	Dry
1999	Cattaraugus Creek	White Sucker	1.73E+01	9.40E+00	Dry
1999	Cattaraugus Creek	Hog-Nosed Sucker	1.16E+01	6.10E+00	Dry
1999	Cattaraugus Creek	Brown Trout	8.10E+00	2.08E+01	Dry
1999	Cattaraugus Creek	Brown Trout	-2.00E-01	1.55E+01	Dry
1999	Cattaraugus Creek	Brown Trout	7.70E+00	1.42E+01	Dry
1999	Cattaraugus Creek	Brown Trout	2.08E+01	1.34E+01	Dry
1999	Cattaraugus Creek	Hog-Nosed Sucker	7.00E+00	1.03E+01	Dry

The WVDP operated as a fuel reprocessing facility from 1966 through 1972, and accepted radioactive waste for disposal until 1975. The site was eventually shut down as a result of costs and regulatory requirements. The Sr-90 concentrations in fish collected from the WVDP control site (Cattaraugus Creek) encompassed those found in fish collected in the Hudson River in the vicinity of IPEC and its control site in Roseton, New York (Figure 4). It should also be noted that the four samples of concern were the only samples analyzed for Sr-90 on December 27–28, 2006; all other Sr-90 analyses were conducted earlier in December 2006 or in 2007. In spite of the higher Sr-90 concentrations relative to the other samples collected in the Hudson River, Sr-90 concentrations in fish collected from the Hudson River are comparable to those that can be expected of fish in aquatic systems in New York State.

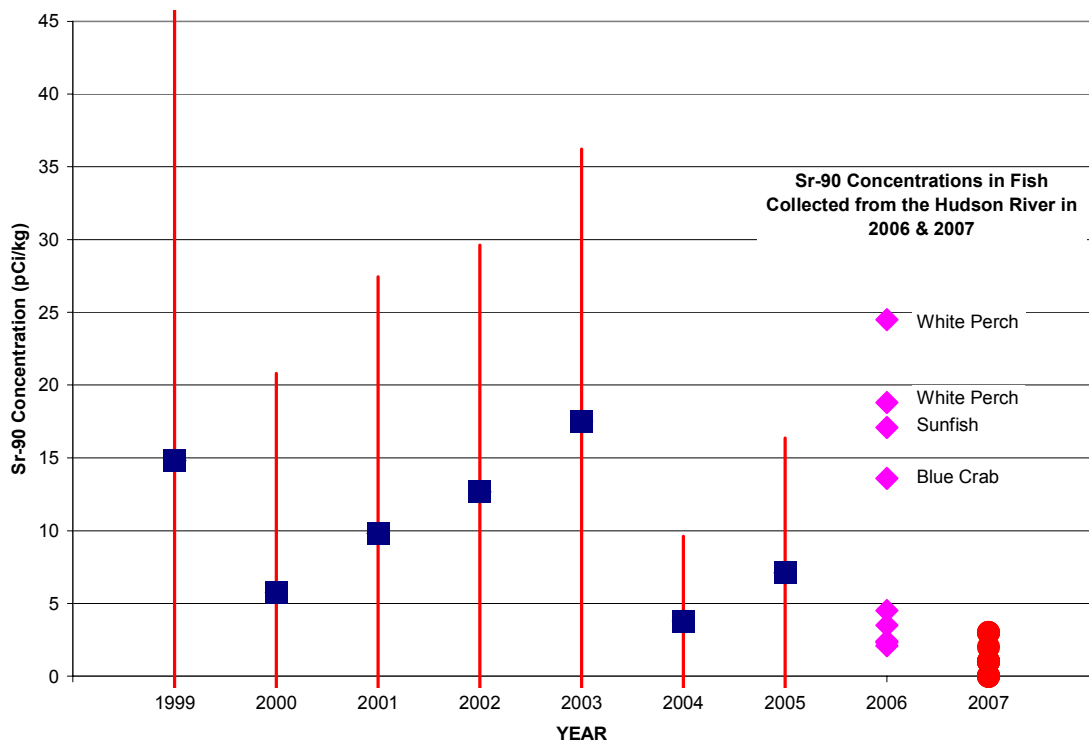


Figure 4. Mean (± 2 SD) Sr-90 concentrations (pCi/kg) measured in fish sampled from the Cattaraugus Creek, the control site for the WVDP compared to Sr-90 concentrations in fish collected from the Hudson River in the vicinity of Indian Point Energy Center and the control site near Roseton, New York

BNL is a national laboratory, administered by the U.S. Department of Energy (DOE), which conducts research in a variety of areas. In so doing, BNL released Sr-90 as a result of activities associated with reactors that previously operated at the site. The majority of fish samples collected at BNL’s fish control site in the Carmans River were determined to contain Sr-90 at levels below detection.

Dose Issues

Radiation doses received by individuals vary for a variety of reasons, including lifestyle, occupation, and time spent outdoors. In the case of nuclear weapons testing, the individuals who received the greatest exposure likely lived immediately downwind from the tests. However, smaller areas of higher and lower exposures occur throughout the United States as a result of the uneven deposition of fallout, and variations in the direction of paths taken by the clouds containing the radioactive fallout. As previously noted, inhalation and ingestion are the primary pathways for humans to be exposed to Sr-90. As a result, it is important to note that the majority of the Sr-90 that may be retained in fish is located in portions (e.g., skeleton, gills, head) that are not traditionally consumed by humans in quantities sufficient to raise an issue with regard to dose.

As part of its annual site environmental report, BNL calculates the effective dose equivalent (EDE) for the maximally exposed individual (MEI) from different exposure pathways, including the fish consumption pathway. This calculation is done for the fish that are determined to have the highest concentration of cesium-137 (Cs-137). This value is multiplied by the annual intake (kg/yr), which is estimated to be 15 pounds (6.8 kg) of fish per year (NYSDOH, 1996), and a dose conversion factor obtained from DOE/EH-0071, as follows:

$$\text{Dose (rem/year)} = \text{intake (kg/year)} \times \text{activity in flesh (\mu Ci/kg)} \times \text{dose factor (rem/\mu Ci)}$$

Using the dose conversion factor for Sr-90 found in DOE/EH-0071 (1.3E-1 rem/uCi) and the same estimated annual intake of 6.8 kg/yr, RES staff calculated the EDE for fish contaminated with Sr-90 at BNL and fish collected from the Hudson River with the highest measured Sr-90 concentrations. Notably, these calculations yielded lower EDE values for the Hudson River fish than those from BNL (Table 4). Although it is highly unlikely that a single individual would consume fish with the highest concentrations from these locations, these data provide an estimate of the potential maximum dose as a “worst-case” scenario for the MEI. Nonetheless, the calculated doses in both cases were well below the DOE dose limit of 100 mrem/year for all exposure pathways. Thus, to put this potential dose impact into perspective, the annual dose from all natural background sources and radon is approximately 300 mrem, and a diagnostic chest x-ray would result in 5–20 mrem per exposure.

Table 4. Calculated Doses from Samples with the Highest Concentrations of Sr-90 in the Vicinity of Brookhaven National Laboratory and Indian Point Energy Center

Samples Collected in the Vicinity of Brookhaven National Laboratory						
Year	Species	Sample Site	Intake (kg/year) ^A	Activity In Fish (µci/kg)	Dose Factor (rem/µci) ^B	Dose (mrem)
2004	Bluegill	Swan Pond	6.80	1.60E-03	1.30E-01	1 E+00
2003	Largemouth Bass	Donahue's Pond	6.80	1.37E-03	1.30E-01	1 E+00
2002	Bluegill	Donahue's Pond	6.80	1.42E-03	1.30E-01	1 E+00
2001	Bluegill	Donahue's Pond	6.80	1.52E-03	1.30E-01	1 E+00
2000	Largemouth Bass	Donahue's Pond	6.80	1.82E-03	1.30E-01	2 E+00

Samples Collected in the Vicinity of Indian Point Energy Center						
Year	Species	Sample Site	Intake (kg/year) ^A	Activity In Fish (µci/kg)	Dose Factor (rem/µci) ^B	Dose (mrem)
2006	White Perch	Indian Point	6.80	1.88E-05	1.30E-01	2 E-02
2006	White Perch	Roseton	6.80	2.45E-05	1.30E-01	2 E-02
2006	Sunfish	Roseton	6.80	1.71E-05	1.30E-01	2 E-02
2006	Blue Crab	Roseton	6.80	1.36E-05	1.30E-01	1 E-02

a -- Assuming consumption of 6.8 kilograms (15 lbs) of fish per year

b -- Dose factor from DOE/EH-0071, Internal Dose Conversion Factors for Calculation of Dose to the Public

References

- ASTDR, 2004. "Toxicological Profile for Strontium," U.S. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry, Atlanta, Georgia, 2004, available at <http://www.atsdr.cdc.gov/toxprofiles/tp159.html>, as of October 12, 2007.
- Beck et al., 1990. Beck, H.L., I.K. Helfer, A. Bouville, and M. Dreicer, "Estimates of Fallout in the Continental U.S. from Nevada Weapons Testing Based on Gunned-Film Monitoring Data," *Health Physics*, Vol. 59 (5), pp. 565–576.
- Boroughs et al., 1956. Boroughs, H., S.J. Townsley, and R.W. Hiatt, "The Metabolism of Radionuclides by Marine Organisms," Section I, "The Uptake, Accumulation, and Loss of Strontium ⁸⁹ by Fishes," *Biological Bulletin*, pp. 336–351, 1956, available at <http://www.biolbull.org/cqi/content/abstract/111/3/336>, as of October 12, 2007.
- Brookhaven National Laboratory, 2004. "Site Environmental Report, Volume 1," Brookhaven National Laboratory, Upton, NY. Available at <http://www.bnl.gov/ewms/ser/2004.asp> as of October 12, 2007.
- Brookhaven National Laboratory, 2003. "Site Environmental Report, Volume 1," Brookhaven National Laboratory, Upton, NY. Available at http://www.bnl.gov/bnlweb/SER/2003_SER.html as of October 12, 2007.
- Brookhaven National Laboratory, 2002. "Site Environmental Report, Volume 1," Brookhaven National Laboratory, Upton, NY. Available at http://www.bnl.gov/bnlweb/SER/2002_SER.html as of October 12, 2007.
- Brookhaven National Laboratory, 2001. "Site Environmental Report, Volume 1," Brookhaven National Laboratory, Upton, NY. Available at http://www.bnl.gov/bnlweb/SER/2001_SER.html as of October 12, 2007.
- Brookhaven National Laboratory, 2000. "Site Environmental Report, Volume 1," Brookhaven National Laboratory, Upton, NY. Available at http://www.bnl.gov/bnlweb/SER/2000_SER.html as of October 12, 2007.
- CDC, 2005. "Report on the Feasibility of a Study of the Health Consequences to the American Population from Nuclear Weapons Tests Conducted by the United States and Other Nations," Volume 1, "Technical Report," U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, Atlanta, Georgia, and the National Cancer Institute, Bethesda, Maryland, 2005, available at <http://0-www.cdc.gov.mill1.silibrary.org/nceh/radiation/fallout/default.htm>, as of October 12, 2007.
- Clark, 1954. "The Occurrence of an Unusually High-Level Radioactive Rainout in the Area of Troy, NY," *Science*, Vol. 119, pp. 619-622.
- DOE/EH-0071. "Internal Dose Conversion Factors for Calculation of Dose to the Public," U.S. Department of Energy, Washington, DC, July 1988.
- Hoecker, W.H., Machta, L., 1990. Meteorological modeling of radioiodine transport and deposition within the continental United States. *Health Physics* 59 (5), 603–617.

Karlsson et al., 2002. Karlsson, S., M. Meili, and U. Bergstrom, "Bioaccumulation Factors in Aquatic Ecosystems: A Critical Review, Swedish Nuclear Fuel and Waste Management Company, Stockholm, Sweden, 2002, available at <http://www.skb.se/upload/publications/pdf/R-02-36webb.pdf>, as of October 12, 2007.

Kenna et al., 2004. Kenna, T.C., S.N. Chillrud, D.A. Chaky, H.J. Simpson, C.M. McHugh, E.L. Shuster, and R.F. Bopp, "Determining Sources and Transport of Nuclear Contamination in Hudson River Sediments with Plutonium, Neptunium, and Cesium Isotope Ratios," *EOS Trans. AGU* 85(47), Fall Meeting Suppl., Abstract H411-05, 2004, available at <http://www.agu.org/cgi-bin/SFgate/SFgate?&listenv=table&multiple=1&range=1&directget=1&application=fm04&database=%2Fdata%2Fepubs%2Fwais%2Findexes%2Ffm04%2Ffm04&maxhits=200&=%22H411-05%22>, as of October 12, 2007.

Lamendola, 2007. Lamendola, M., "River Spreads Contamination: Study Claims KAPL Waste Carried More Than 120 Miles Downstream," *The Daily Gazette*, Schenectady, New York, March 11, 2007, p. A1, available at http://mail.energyjustice.net/pipermail/nukenet_energyjustice.net/2007-March/001895.html, as of October 12, 2007.

NCRP, 1984. Report No. 076, "Radiological Assessment: Predicting the Transport, Bioaccumulation, and Uptake by Man of Radionuclides Released to the Environment," National Council on Radiation Protection and Measurements, Bethesda, Maryland, 1984.

NYSDOH, 1996. "Radioactive Contamination in the Peconic River," New York State Department of Health, Bureau of Environmental Radiation Protection, Albany, New York, 1996.

UNSCEAR, 1993. "Sources and Effects of Ionizing Radiation," United Nations Scientific Committee on the Effects of Atomic Radiation, Vienna, Austria, 1993.

UNSCEAR, 2000. "Sources and Effects of Ionizing Radiation," United Nations Scientific Committee on the Effects of Atomic Radiation, Vienna, Austria, 2000.

West Valley Nuclear Services Company and URS Group, Inc., 2005. "West Valley Demonstration Project Annual Site Environmental Report, Calendar Year 2005," West Valley Demonstration Project, West Valley, New York. Available via <http://www.osti.gov/bridge/index.jsp> as of October 12, 2007.

West Valley Nuclear Services Company and URS Group, Inc., 2004. "West Valley Demonstration Project Annual Site Environmental Report, Calendar Year 2004," West Valley Demonstration Project, West Valley, New York. Available via <http://www.osti.gov/bridge/index.jsp> as of October 12, 2007.

West Valley Nuclear Services Company and URS Group, Inc., 2003. "West Valley Demonstration Project Annual Site Environmental Report, Calendar Year 2003," West Valley Demonstration Project, West Valley, New York. Available via <http://www.osti.gov/bridge/index.jsp> as of October 12, 2007.

West Valley Nuclear Services Company and URS Group, Inc., 2002. "West Valley Demonstration Project Annual Site Environmental Report, Calendar Year 2002," West Valley Demonstration Project, West Valley, New York. Available via <http://www.osti.gov/bridge/index.jsp> as of October 12, 2007.

West Valley Nuclear Services Company and URS Group, Inc., 2001. "West Valley Demonstration Project Annual Site Environmental Report, Calendar Year 2001," West Valley Demonstration Project, West Valley, New York. Available via <http://www.osti.gov/bridge/index.jsp> as of October 12, 2007.

West Valley Nuclear Services Company and URS Group, Inc., 2000. "West Valley Demonstration Project Annual Site Environmental Report, Calendar Year 2000," West Valley Demonstration Project, West Valley, New York. Available via <http://www.osti.gov/bridge/index.jsp> as of October 12, 2007.