"This increased flow can influence the distribution of radionuclides released from White Oak
 Creek and the deposition of the radionuclides in the Clinch River" (Blaylock 2004). See Figure 1
 for the locations of CRM 20.8 and 14, Melton Hill Dam, Watts Bar Reservoir, Clinch River, and
 White Oak Creek.

## 5 **II.B. Operational History**

Beginning in the early 1940s, the ORR used radioactive material for various processes, such as
uranium enrichment, plutonium production, plutonium separation, and the development of
separation processes for additional radionuclides (ChemRisk 1993b; Jacobs Engineering Group
Inc. 1996).

10 The X-10 site was built in 1943 as a "pilot plant" to demonstrate plutonium production and 11 chemical separation. The government had intended to operate the facility for only 1 year. This 12 initial time period was, however, extended indefinitely as operations were continued and 13 expanded at X-10 (ChemRisk 1993b; ChemRisk 1999a; TDOH 2000). Because X-10 was developed to produce and separate plutonium, the main plant contained two parts that were both 14 15 built in 1943: 1) a plutonium production plant called the "Clinton Pile" and later referred to as 16 the ORNL graphite reactor, and 2) a chemical pilot plant developed to separate and purify 17 plutonium. The chemical pilot plant focused on recovering small amounts of plutonium from fuel 18 that was irradiated in the Clinton Pile (ChemRisk 1993b).

19 After World War II, the facility broadened its focus to include non-weapons related activities,

20 such as the physical and chemical separation of nuclear products, the creation and assessment of

21 nuclear reactors, and the production of a range of radionuclides for global use in the medicinal,

22 industrial, and research disciplines (ChemRisk 1993b; U.S. DOE 1994a). In the 1950s and

23 1960s, the X-10 site became a worldwide research center to study nuclear energy and to

24 investigate the physical and life sciences that are related to nuclear energy. From 1958 to 1987,

25 the Oak Ridge Research Reactor operated to support various scientific experiments at X-10. For

a long period of time, this reactor was the main radionuclide supplier to the "free world" for

27 medical, research, and industrial purposes (Johnson & Schaffer 1992, Stapleton 1992, and

28 Thompson 1963).



1 Following the establishment of the U.S. DOE in the 1970s, the research focus at X-10 was extended to include the study of energy transmission, conservation, and production (UT-Battelle 2 3 2003). For more than 50 years, the ORR has been the site for extensive scientific investigation by 4 scores of ecologists and environmental scientists. The ORR is a natural haven for wildlife and 5 plants with many rare and endangered species. Today, the X-10 site receives worldwide 6 recognition as a facility for extensive research and development in several areas of science and 7 technology. In addition, the X-10 site produces numerous radioactive isotopes that have 8 significant uses in medicine and research (TDEC 2002). See Figure 5 for a time line of the major 9 processes at the X-10 site.

10 The operational history of X-10 is described in greater detail in the 1993 Dose Reconstruction

11 Feasibility Study (ChemRisk 1993b). The main processes and activities that are associated with

12 off-site releases of contaminants from X-10 include: 1) production of radioactive lanthanum

13 (RaLa processing) (1944–1956), 2) Thorex processing of short-decay irradiated thorium

14 (approximately 1954–1960), 3) graphite reactor operations (1943–1963), 4) processing of

15 graphite reactor fuel for plutonium recovery (1943–1945), and 5) waterborne and airborne waste

16 disposal (1943–present). For additional details, please see Section 2.1 and 2.3 of *Oak Ridge* 

17 *Health Studies Phase I Report—Volume II—Part A—Dose Reconstruction Feasibility Study.* 

18 Tasks 1 & 2: A Summary of Historical Activities on the Oak Ridge Reservation with Emphasis on

19 Information Concerning Off-Site Emission of Hazardous Material (ChemRisk 1993b).

20 Because the government had planned to run the X-10 site for only 1 year, minimal waste had

21 been expected from the facility's chemical separation processes (ChemRisk 1993b; ChemRisk

22 1999a; Jacobs Engineering Group Inc. 1996). As a result, the intended waste disposal practices

23 quickly proved insufficient for the amount of wastes generated at X-10. When X-10 began

24 operating in 1943, liquid wastes were put into several underground "gunite" tanks (ChemRisk

25 1999a; Jacobs Engineering Group Inc. 1996; ORHASP 1999; Spalding and Boegly 1985). These

26 tanks, which are divided into the North Tank Farm and the South Tank Farm, are located in

27 Bethel Valley within the center of X-10's main facility area (SAIC 2002). Please see Figure 6 for

the location of the tanks.

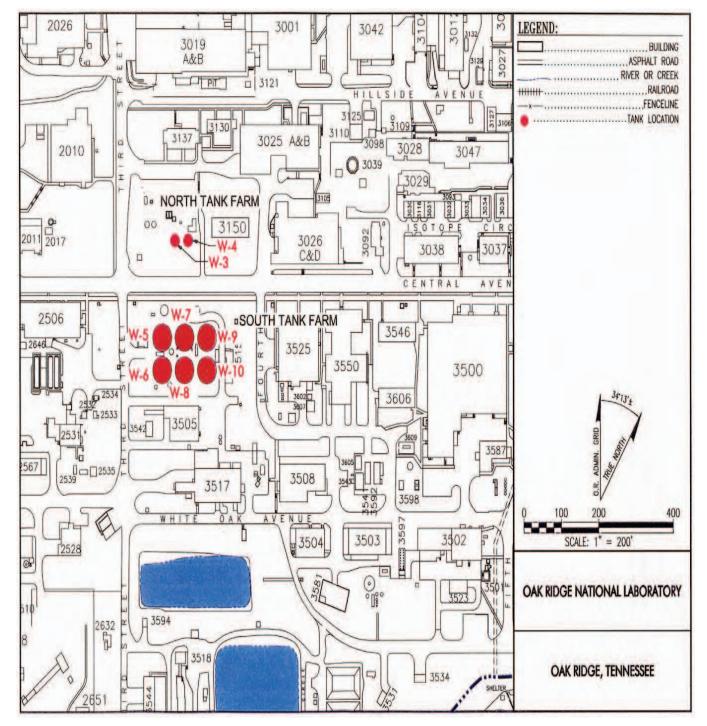
## Figure 5. X-10 Facility Time Line



## X-10 Facility Time Line

	5111/10	011151		-	_			_	_	_	
	1944-46, Radioactivity in White Oak Dam	ONMEN	ITAL DA		_	-	-	-	_	-	-
-	1944-present, Radionucli	des, Metals, Tritium in Wh									
Water	• 1947, Radioa	ctivity in Clinch River		1960-64, Radionuclides, Chemicals in Clinch River	1970, Mercary in Mellon	Hill Reserveir		1984	<ul> <li>1986. Cs-137 in Watts E</li> <li>1988-pre</li> <li>1988-</li> </ul>	clides in White Oak Lake	, White Oak Creeks Ionuclides, in Clinch
	1944-45, Radioactivity in Creek Lake, White Oak Cr			• 1962, SR-90 in Clin	ch River Fish	📻 1972, Tritium in Wi	tite Oak Lake Fish 1976-77, Mercury i				
		1948-49, Badios Oak Creek, Whit	activity/Radionuclides in White te Oak Lake, Clinch River Fish	1962-63, Radionucl River, White Oak Co	lides in Clinch leek Fish		= 1977-present, R	dionuclides in ORR Deer			
			1951, Radioactivities in	Waterlowl on White Dak La	ike 1957-p nd SR-90 in Cows' Milk with		lionuclides, in Clinch River	fish			
					Cattle Thyroid within 50 m						
								ouride, Radionuclides in Gras 79, Metals, in White Oak Cree			
Biota								= 198 Lake	4. Metals, PCBs, Radionucli e, Clinch River, Melton Hill C 1985-present, Metals, Org. White Oak Creek, Clinch fri 1986-88, Radionuclide Waterfowl on White Oa 1986-89, Metals, Pest Melton Hill and Watts I Melton Hill and Watts I	des in White Oak Creek, W Jam Fish, Frogs, Turlles, a anics in White Oak Creek, I ar Fish k Lake cides, PCBs, in Sar Reservoir Fish ficactivity in Geese from O	delton Branch, Fifth ( RNL Settling Ponds
									Radi	, Metals, PCBs, Pesticides onuclides in Clinch and Ter	nessee River Fish
	1944-52-61, Radioactivity	in White Oak Lake Sedim	ents 10, 72, Radionuclides in White		ove White Oak Lake Bed Se		n White Oak Creek, Clinch	979, PCBs in Clinch River	1985, 1989-90, Metals, On Radionuclides in Clinch Ri	ganics, ver Sediments	
			lides in Clinch River and Tenn	essee River Sediments		River, Melton Hil	Reservoir Sediments			d Radionuclides in Clinch F ury in First, Fifth, White Os	
ŧ.				1960-64, Radionuclides an Clinch and Tennessee Rive	r Sediments	1970, Mercury in Melton Hill Reservoir sediment	in Wh	85, Radionuclides ite Dak Creek Gravel			a creek addiment
Sediment				= 1962, Ruthenium in V	Phite Oak Lake Bed Sedime		982, PCBs, Metals in Watts alton Hill Reservoir Sedimen		4, Mercury, Radionuclides Iton Hill Reservoir, Tenness	in White Oak Creek, ee River Sediments	
Sed							- 1975-present, Metals in	Clinch River Sediment		1990-91, Metals, Organics in White Oak Creek Emba 1990, Metals, Organics, Hill, Norris, and Watte Ba	
			1947-present, Particle Num	nber, Beta Radioactivity, OR	NL Local Area						
Air			• 1955-present, Particle Nun		er. Beta Radioactivity, Beta			e Gamma Emitters, SR-90 OR		er and Remote Locations (	12-120 miles)
								1980, Tritium, ORNL Local	Ares		
~			•1	159-present, Radionuclides i	n Water trons Clinch River	Water Intakes		e 1981, 83, Radionuclides, Metals in Residential Well	Inorganics in Resi	ty in Residential Well Wate ly, Radiomuclides, dential Well Water Metals, Organics, Radiom	
Water			TH ACT	WITIES	-				Distant water	_	
Water	DUBLI	C HEAL	THACT	IVIIIES		_			_	_	_
Water	PUBLI	CONTRACTOR AND								_	
Water	9 1942-93, Phase I Oak Rid										
Water	1942-93, Phase I Oak Rid 1942-93, Phase II Oak Rid - Iodine-131 do - Radiene-161	dge Health Studies (7/99) se reconstruction report 194 eleases to Clinch River 194	44-56 3-66								
Water	1942-93, Phase I Oak Rid 1942-93, Phase II Oak Rid - liedine 131 do - Radiamutide r - PCB dose reco	lige Health Studies (7/99) se reconstruction report 19 eleases to Clinch River 1942 instruction report 1942-99		r Studies (7.86)						-	
Water	1942-93, Phase I Oak Rid 1942-93, Phase II Oak Rid - liedine 131 do - Radiamutide r - PCB dose reco	lige Health Studies (7/99) se reconstruction report 19 eleases to Clinch River 1942 instruction report 1942-99	44-56 3-06 el: Feasibility el Epidemiologi	ic Studies (7/96)				• 1980-92, Health Statistics			
Water	1942-93, Phase I Oak Rid 1942-93, Phase II Oak Rid - liedine 131 do - Radiamutide r - PCB dose reco	lige Health Studies (7/99) se reconstruction report 19 eleases to Clinch River 1942 instruction report 1942-99		ic Studies (7/96)					1985-95, Health Consultat 1988-9 Addres	ion on Lower Watts Bar Re D. Health Statistics Review s Dak Ridge Physician's Co	to ncerns (10/19/92)
Water	1942-93, Phase I Oak Rid 1942-93, Phase II Oak Rid - liedine 131 do - Radiamutide r - PCB dose reco	lige Health Studies (7/99) se reconstruction report 19 eleases to Clinch River 1942 instruction report 1942-99		c Studies (7/96)					1985-95, Health Consultat 1988-9 Addres	ion on Lower Watts Bar Re 0. Health Statistics Review Data Ridge Physician's Co 1990-92, Review of Clinic Living in or near Oak Ridg 1990-95, Health Assessm Tennessen Region, Secor	to neerns (10/19/92) cal Information on Pe ge, Tennessee (9/92) ent of the East of Edition (1995)
Water	1942-93, Phase I Oak Rid 1942-93, Phase II Oak Rid - liedine 131 do - Radiamutide r - PCB dose reco	lige Health Studies (7/99) se reconstruction report 19 eleases to Clinch River 1942 instruction report 1942-99		n: Studies (7/66)					1985-95, Health Consultat 1988-9 Addres	ion on Lower Watts Bar Ree D. Hearth Statistics: Review Dak Ridge Physician's Cn 1990-92, Review of Clinic Living in or near Oak Ridd 1990-95, Cemmunity Dia Reports—Anderson Coun 1990-96, Community Dia Reports—Anderson Coun	to ncerns (10/19/92) tal Information on Pe je, Tennessee (9/92) ent of the East of Edition (1995) gnosis Status by (1996)







Source: SAIC 2002

Each gunite tank held 170,000 gallons, but the amount of liquid wastes and sludges quickly filled 1 2 up the tanks. The sludges were kept in the gunite tanks; however, the liquid wastes were held 3 until enough radioactivity was lost through decay before the liquid waste (combined with 4 diluting water) could be released to White Oak Creek (ChemRisk 1999a; Jacobs Engineering 5 Group Inc. 1996; ORHASP 1999; Spalding and Boegly 1985; U.S. DOE 1996a). The creek 6 received the liquid wastes from the tanks and storm water drainage as it flowed through the X-10 7 facilities. In June 1944, the 3513 Pond was created as a supplementary settling basin for gunite 8 tank liquids and as a basin where short-lived radionuclides could further decay before being 9 released to White Oak Creek (Jacobs Engineering Group Inc. 1996; Spalding and Boegly 1985). 10 Prior to emptying into the Clinch River, White Oak Creek flows through several contaminated 11 areas in Melton Valley (for example, the old hydrofracture facility) before it runs into White Oak 12 Lake (on-site) (TDOH 2000). This lake was used as a final "settling basin" since 1943 for 13 radionuclides released from X-10 (Blaylock et al. 1993; ChemRisk 1999a; TDOH 2000; U.S. 14 DOE 2002a). See Figure 7 for a photograph (1991) of the X-10 site, White Oak Lake, the X-10 15 disposal area, and the Clinch River. White Oak Lake was made when White Oak Dam was built 16 across White Oak Creek in 1943. This dam was used as a basin for further settling of the solids 17 that remained (Jacobs Engineering Group Inc. 1996). Please see Figure 4 for the location of 18 White Oak Dam. But some waste products did not settle into the 3513 Pond or White Oak Lake; 19 instead, the waste traveled over White Oak Dam and reached the Clinch River (TDOH 2000). 20 Most of the waste product releases to White Oak Creek are associated with former operations at 21 X-10. This waste includes but is not limited to radionuclides. The X-10 site began discharging 22 radioactive waste to the Clinch River via White Oak Creek in 1943. Thus, the Tennessee

23 Department of Health (TDOH) conducted *Task 4 of the Reports of the Oak Ridge Dose* 

24 Reconstruction, Radionuclide Releases to the Clinch River From White Oak Creek on the Oak

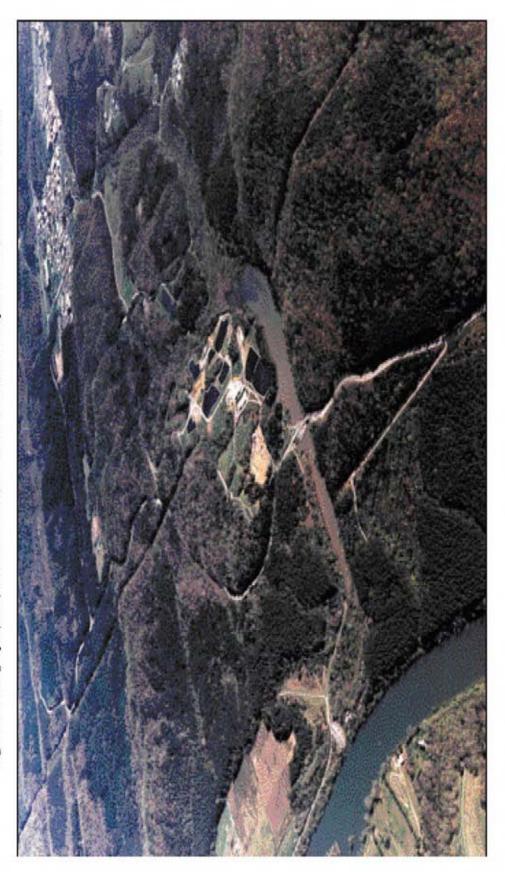
25 *Ridge Reservation* to evaluate whether off-site populations have been exposed to radioactive

26 waste from X-10 between 1944 and 1991 (the Task 4 dose reconstruction is used to examine past

27 exposures in this public health assessment).



Figure 7. Photograph (1991) of the X-10 Site, White Oak Lake, X-10 Disposal Areas, and the Clinch River



The above photograph from 1991 shows X-10/ORNL (upper right), White Oak Lake (lower center), X-10/ORNL disposal area (above White Oak Lake), and the Clinch River (lower left).

Source: TDOH 2000

Oak Ridge Reservation: White Oak Creek Radionuclide Releases Public Health Assessment - Public Comment Release - Do not cite, quote, or release

- 1 Since 1944, solid wastes generated by X-10 were disposed of at six solid waste storage areas
- 2 (SWSAs) (U.S. DOE 1994a as cited in Jacobs Engineering Inc. 1996). The first three SWSAs (1-
- 3 3) are located in Bethel Valley and the remaining three SWSAs (4-6) are located in Melton
- 4 Valley (ChemRisk 1993b; ChemRisk 1999a). For a map of these solid waste storage areas,
- 5 please see Figure 8. Between 1955 and 1963, these waste storage areas were allocated as the
- 6 Southern Regional Burial Ground by the Atomic Energy Commission. Throughout this time
- 7 period, the X-10 site functioned as a main disposal location for wastes from more than 50 off-site
- 8 installations (e.g., Knolls Atomic Power Laboratory, Battelle Memorial Institute), various
- 9 research facilities, small contractors, several isotope consumers, and Atomic Energy
- 10 Commission installations (Lockheed Martin Marietta Energy Systems, Inc. 1998). Please see
- 11 Table 1 for additional information on these disposal areas.
- 12

## Table 1. Solid Waste Disposal Areas at the X-10 Site

Disposal Area	Period of Operation	Status	Acreage
1	1943–1944	Closed	1
2	1944–1946	Closed	4
3	1946–1951	Closed	6
4	1951–1959	Closed	23
5	1959–1973	Open for retrievable storage only past 1973.	50
6	1969–Unknown	Current status is not indicated.	68 (14.5 acres are usable)

<sup>13</sup> 14

Source: Bates 1983 as cited in ChemRisk 1993b

While X-10's operations continued, the amount of wastes generated at the site continued to increase. During X-10's early years of operation, after liquid radioactive wastes were initially

17 treated they were pumped into an Intermediate Holding Pond (IHP) adjacent to the east side of

18 SWSA 4 (see Figure 8 for the general location of the IHP next to SWSA 4 and Section II.C.2. for

19 IHP-related remedial activities). The "hottest" radioactive substances decayed in the pond; the

20 radionuclides that did not settle into the pond flowed downstream to the Clinch River (TDEC

21 2003a). In addition, between 1951 and 1976 the facility alternately used seven "earthen pits" for

22 liquid waste disposal (Spalding and Boegly 1985). A wastewater treatment process plant was

23 built in 1957 to retrieve fission products from these (and additional) liquid wastes before their

24 disposal (a more advanced facility replaced this in 1976) (U.S. DOE 1994a). In 1960, the

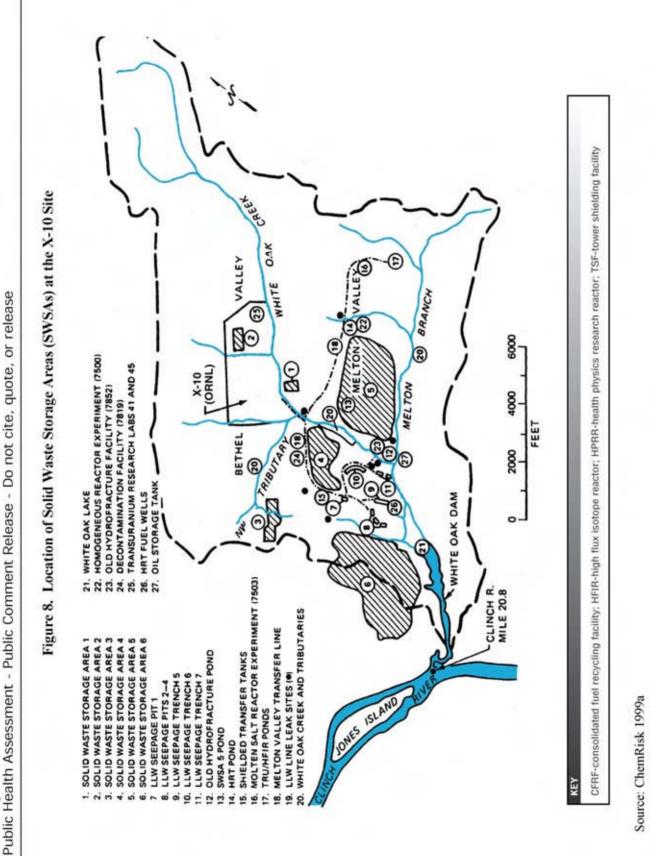


"earthen pit" was changed to an "earth-covered trench" to reduce inadvertent radiation exposure
and rainwater buildup. Over time, leaks occurred at several of these pits, which resulted in the
releases of various radionuclides (Spalding and Boegly 1985).

Trenches were used until 1966, when "hydrofracture technology"<sup>2</sup> was initiated for liquid waste
disposal (Spaulding and Boegly 1985). The first hydrofracture facility operated between 1964
and 1979; 26 injections were made during this time period. A newer facility started performing
injections in June 1982, but this operation was discontinued in 1984 because of uncertainties
related to potential leaching into deep groundwater (Boyle et al. 1982; Ohnesorge 1986).
ATSDR will evaluate hydrofracture technology in its future public health assessment on
groundwater.

11 In addition to releases from disposal areas, radioactive substances were discharged when White 12 Oak Lake was partially drained in October 1955 (Blaylock et al. 1993). The lake was drained to 13 give X-10 a greater capacity to handle large discharges and to lessen the chance that ducks would 14 live in the contaminated water (Blaylock et al. 1993). Before it could revegetate, severe rains in 1956 caused a flood that eroded the bottom sediment of White Oak Lake (Blaylock et al. 1993; 15 16 ChemRisk 1999a). This resulted in the largest discharge of Cs 137 at the lake and also caused 17 radionuclides in particulate form to deposit in the White Oak Creek Embayment. In the early 18 1990s, a coffer cell dam was built at the mouth of White Oak Creek to prohibit water backflow 19 to the White Oak Creek Embayment. After this dam was completed, the natural scouring of 20 sediment at the embayment was prevented (ChemRisk 1999a).

<sup>&</sup>lt;sup>2</sup> Hydrofracture technology uses hydraulic pressure to create cracks in the shale bedrock layers that are below the disposal area. Low-level waste alkaline solutions are combined with cement and infused with pressure into the fracture zone. This grout mixture seals the cracks and stagnates wastes that are in the deep shale formation.



Oak Ridge Reservation: White Oak Creek Radionuclide Releases



DOE predicted that 70% to 80% of radioactive substances released from X-10 to surface waters 1 2 resulted from seepage at waste disposal areas (U.S. DOE 1988). Mainly because of these 3 disposal practices at X-10 and the heavy rains in 1956, approximately 200,000 curies of 4 radioactive waste were discharged from White Oak Creek into the Clinch River between 1944 5 and 1991 (ATSDR et al. 2000; TDOH 2000). Please see Table 2 for the estimated discharges of 6 radionuclide releases to the Clinch River via White Oak Creek (Jacobs Engineering Group Inc. 7 1996). Table 3 is a summary of peak annual releases from White Oak Dam for the eight "key" 8 radionuclides-those that were identified for further evaluation based on a pathway and disease 9 incidence analysis of 24 radionuclides (ChemRisk 2000). For additional details regarding the 10 radioactive waste disposal history of the X-10 site, please see Section 2.1.5 of Oak Ridge Health 11 Studies Phase I Report—Volume II—Part A—Dose Reconstruction Feasibility Study. Tasks 1 & 12 2: A Summary of Historical Activities on the Oak Ridge Reservation with Emphasis on Information 13 Concerning Off-Site Emission of Hazardous Material (ChemRisk 1993b) and also Section 2.0 14 of Task 4 of the Reports of the Oak Ridge Dose Reconstruction, Radionuclide Releases to the 15 Clinch River From White Oak Creek on the Oak Ridge Reservation—an Assessment of Historical 16 Quantities Released, Off-Site Radiation Doses, and Health Risks (ChemRisk 1999a). For 17 information on current remedial activities, see Sections II.C.1. (Bethel Valley Watershed), 18 II.C.2. (Melton Valley Watershed), and II.C.3. (Off-Site Locations) in this document.

Year	Cs 137	Ru 106	Sr 90	TRE <sup>b</sup>	Ce 144	Zr 95	I 131	Co 60	H 3	TR
1949	77	110	150	77	18	180	77			0.04
1950	19	23	38	30		15	19			0.04
1951	20	18	29	11		5	18			0.08
1952	10	15	72	26	23	19	20			0.03
1953	6	26	130	110	7	8	2			0.08
1954	22	11	140	160	24	14	4			0.07
1955	63	31	93	150	85	5	7	7		0.25
1956	170	29	100	140	59	12	4	46		0.28
1957	89	60	83	110	13	23	1	5		0.15
1958	55	42	150	240	30	6	8	9		0.08
1959	76	520	60	94	48	27	1	77		0.68
1960	31	1,900	28	48	27	38	5	72		0.19
1961	15	2,000	22	24	4	20	4	31		0.07
1962	6	1,400	9	11	1	2	0.4	14		0.06
1963	4	430	8	9	2	0.3	0.4	14		0.17
1964	6	190	7	13	0.3	0.2	0.3	15	1,900	0.08
1965	2	69	3	6	0.1	0.3	0.2	12	1,200	0.50
1966	2	29	3	5	0.1	0.7	0.2	7	3,100	0.16
1967	3	17	5	9	0.2	0.5	0.9	3	13,300	1.03
1968	1	5	3	4	0.03	0.3	0.3	1	9,700	0.04
1969	1	2	3	5	0.02	0.2	0.5	1	12,200	0.20
1970	2	1	4	5	0.06	0.02	0.3	1	9,500	0.40
1971	1	0.5	3	3	0.05	0.01	0.2	1	8,900	0.05
1972	2	0.5	6	5	0.03	0.01	0.3	1	10,600	0.07
1973	2	0.7	7		0.02	0.05	0.5	1	15,000	0.08
1974	1	0.2	6		0.02	0.02	0.2	0.6	8,600	0.02
1975	0.6	0.3	7				0.3	0.5	11,000	0.02
1976	0.2	0.2	5				0.03	0.9	7,400	0.01
1977	0.2	0.2	3				0.03	0.4	6,200	0.03
1978	0.3	0.2	2				0.04	0.4	6,300	0.03
1979	0.2	0.1	2.4				0.04	0.4	7,700	0.03
1980	0.6	0	1.5				0.04	0.4	4,600	0.04
1981	0.2	0.1	1.5				0.04	0.7	2,900	0.04
1982	1.5	0.2	2.7				0.06	1.0	5,400	0.03
1983	1.2	0.2	2.1				0.004	0.3	5,600	0.05
1984	0.6	0.2	2.6				0.05	0.2	6,400	0.03
1985	0.4	0.007	3.0					0.6	3,700	0.00
1986	1.0	0	1.8					0.54	2,600	0.02
1987	0.6	0	1.2					0.12	2,500	0.00
1988	0.4	0	1.1					< 0.07	1,700	
1989	1.2	0	2.9					0.13	4,100	
1990	1.1	0	3.1					0.12	3,100	
1991	1.7		2.7					0.12	2,100	
1992	0.6		2.1					0.04	1,900	
1993	0.5		2.1					0.04	1,700	
1994	0.5		2.8					0.07	2,200	
Total	699.6	6,931.6	1,214.6	1,295	341.93	376.61	175.33	325.58	183,100	5.24

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1

Systems, Inc. 1993, and DOE 1988 as cited in Jacobs Engineering Group Inc. 1996 a All digits were carried through to avoid any errors from rounding numbers. Only the first two are significant.

b Total of rare earth elements, excluding cerium.

c Transuranic radionuclides.

Blank cells indicate that no data were reported.

The four radionuclides expected to be of most concern are highlighted in gray.