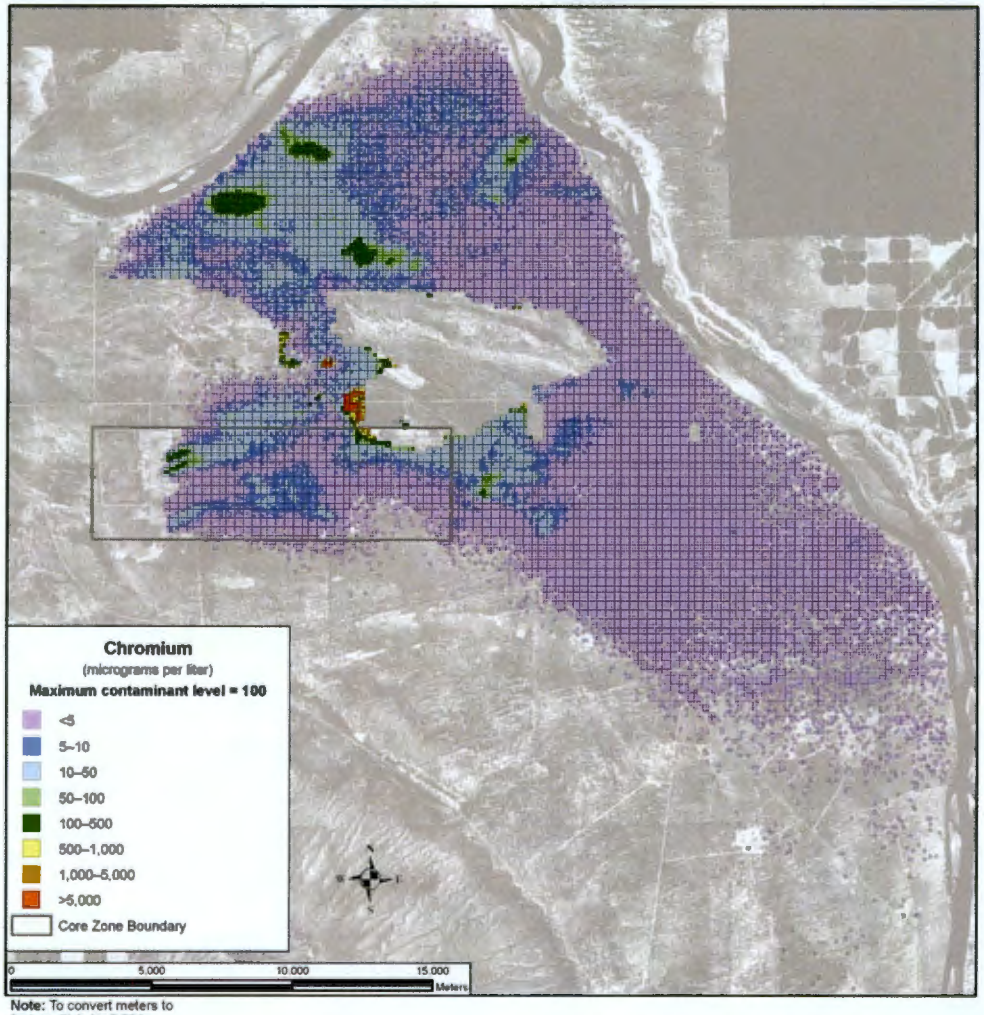
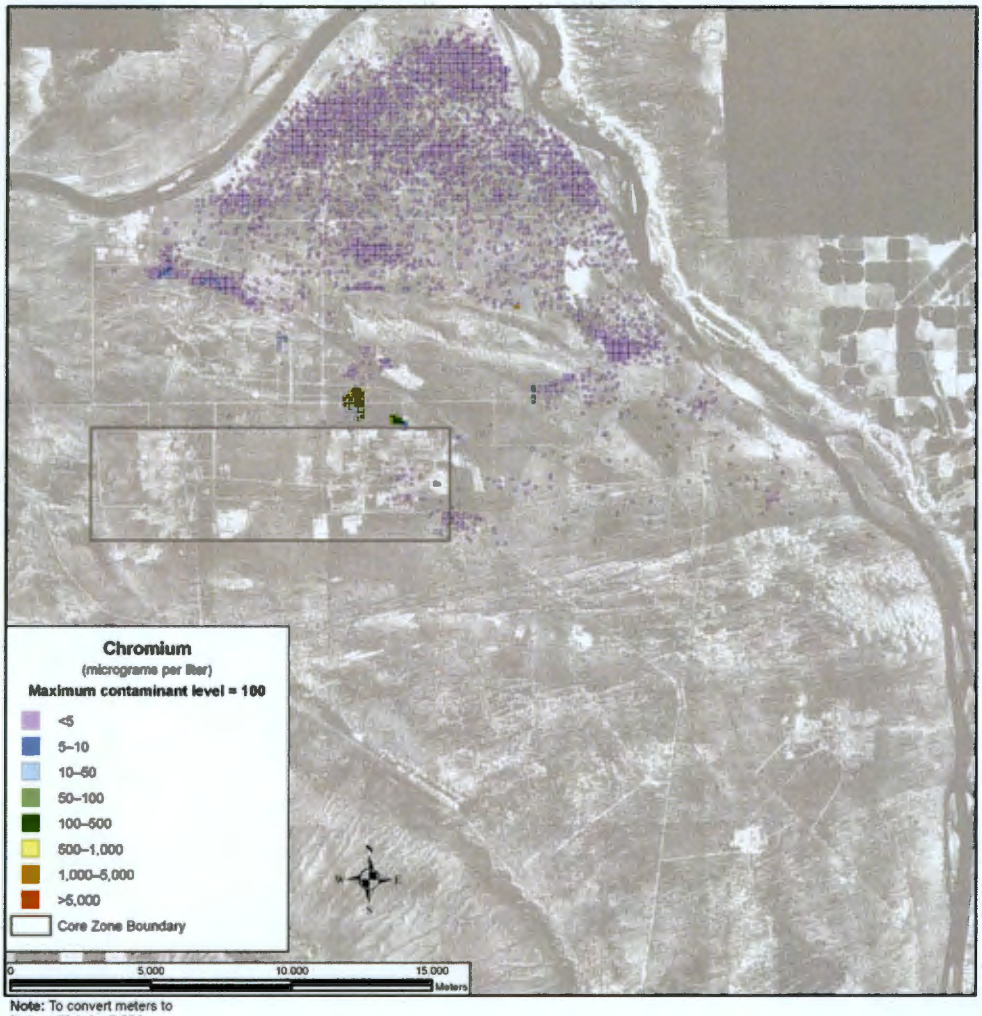
SECTION

6 OF 11



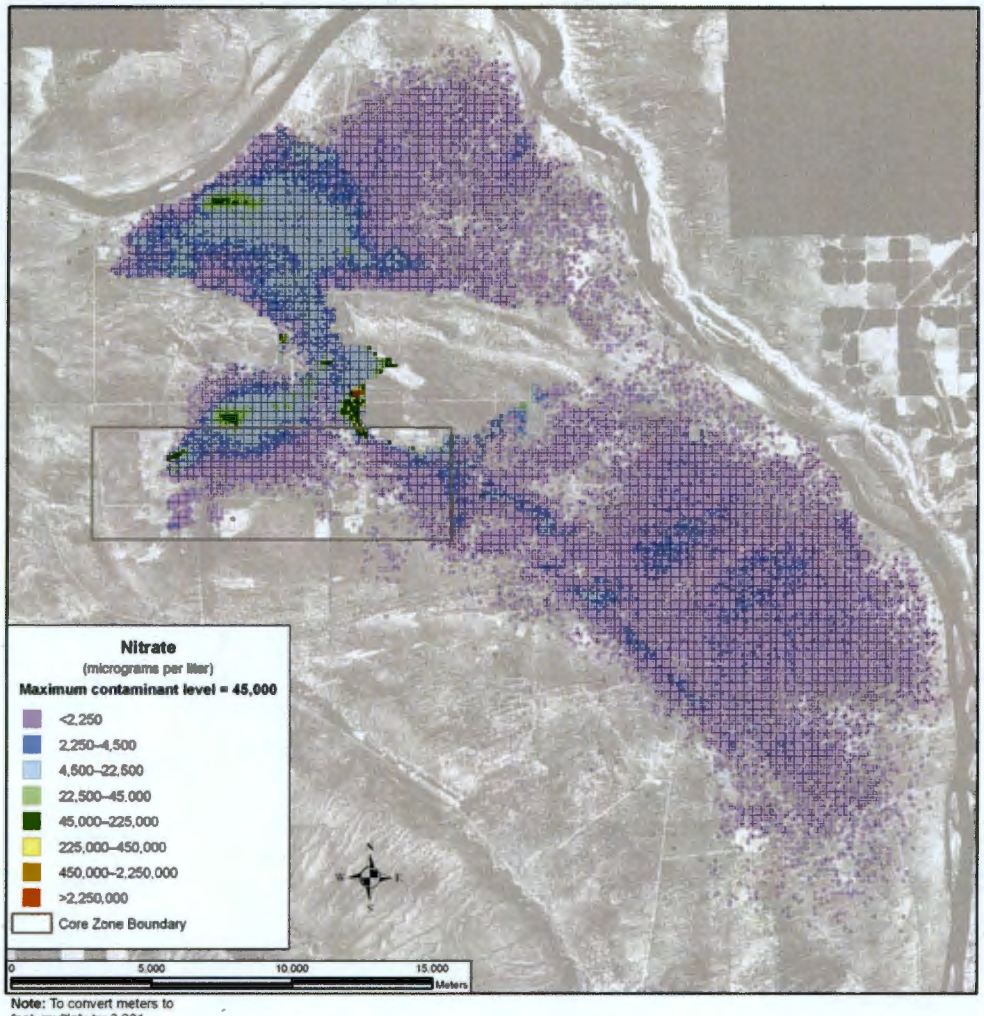
Note: To convert meters to feet, multiply by 3.281

Figure 5–232. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 2135



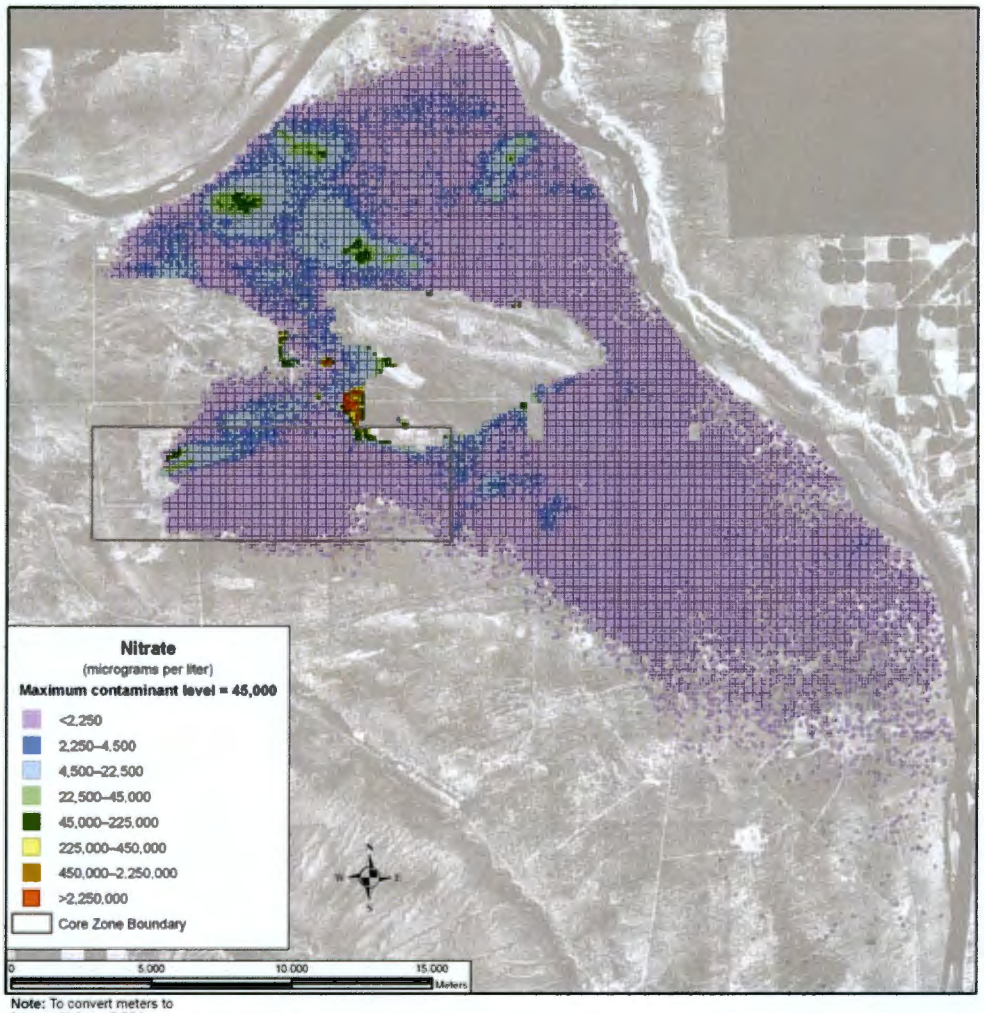
Note: To convert meters to feet, multiply by 3.281

Figure 5–233. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 7140



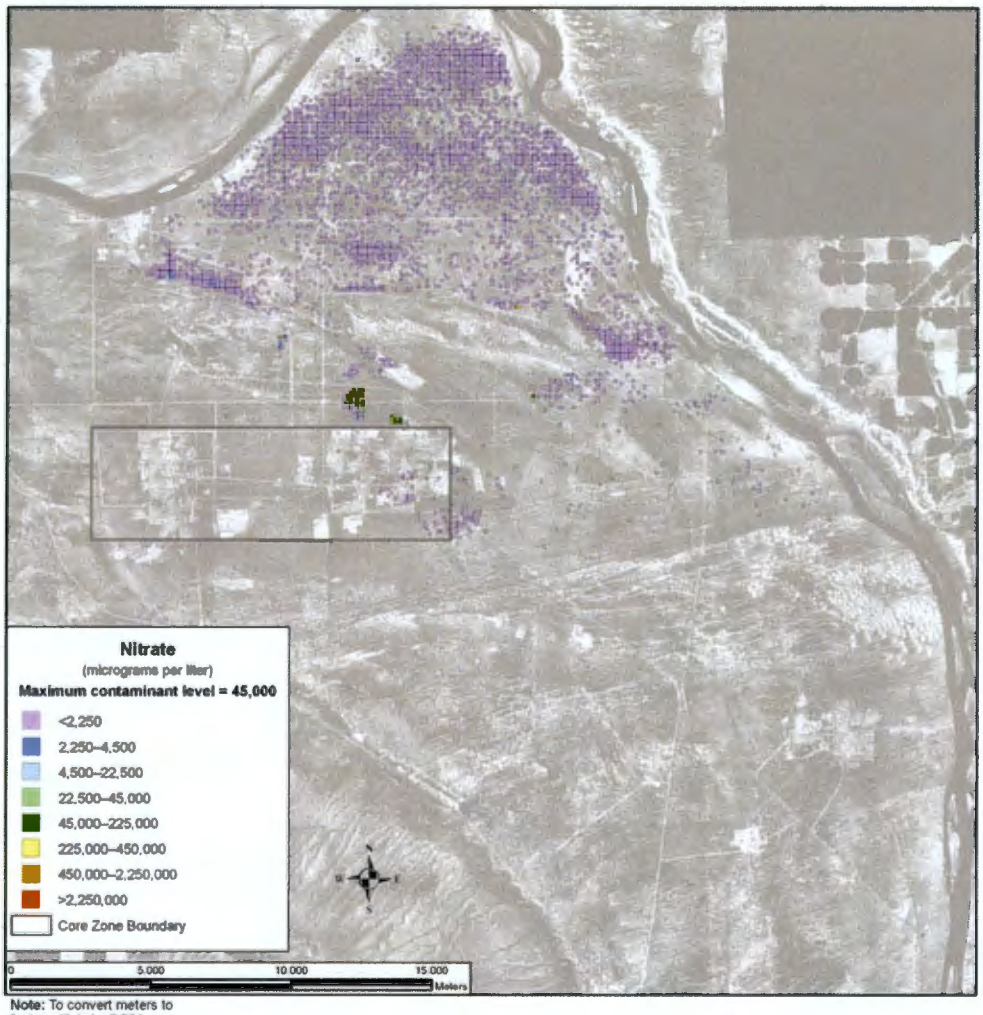
Note: To convert meters to feet, multiply by 3.281

Figure 5–234. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

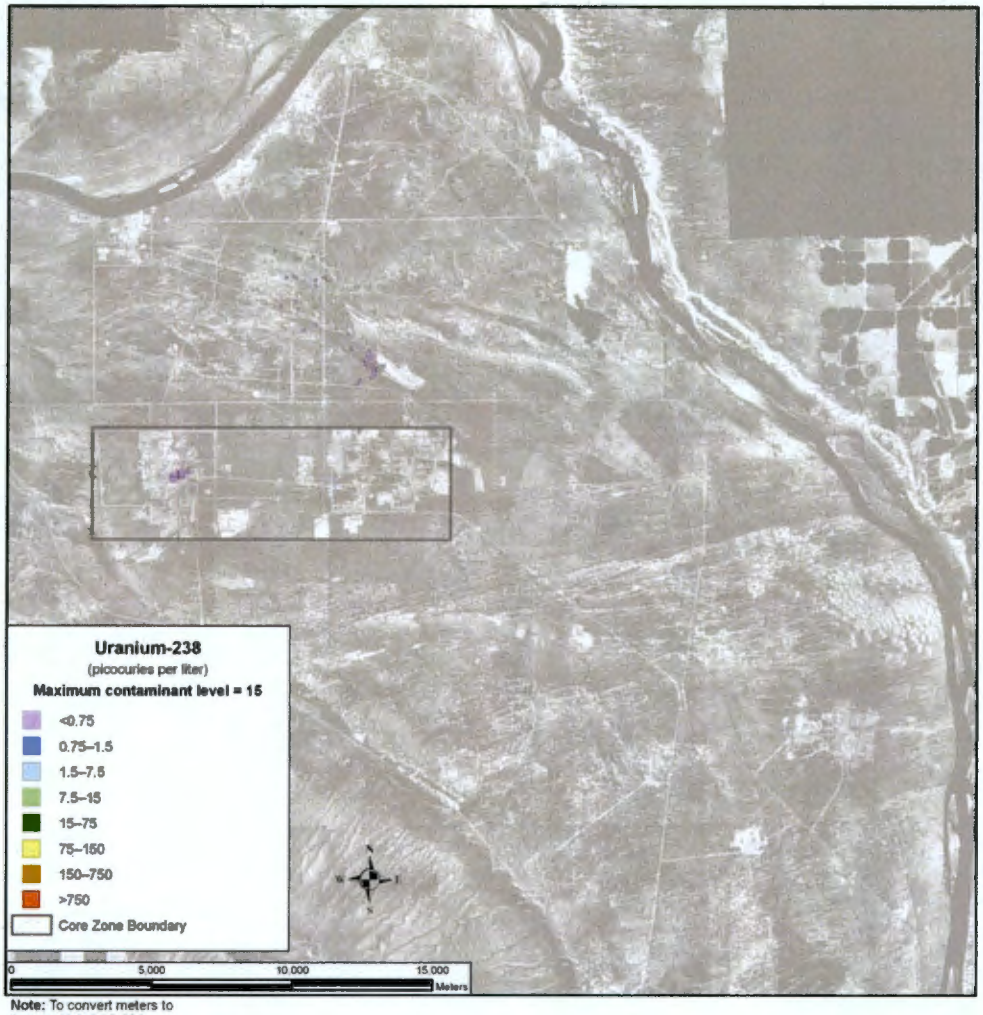
Figure 5–235. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281

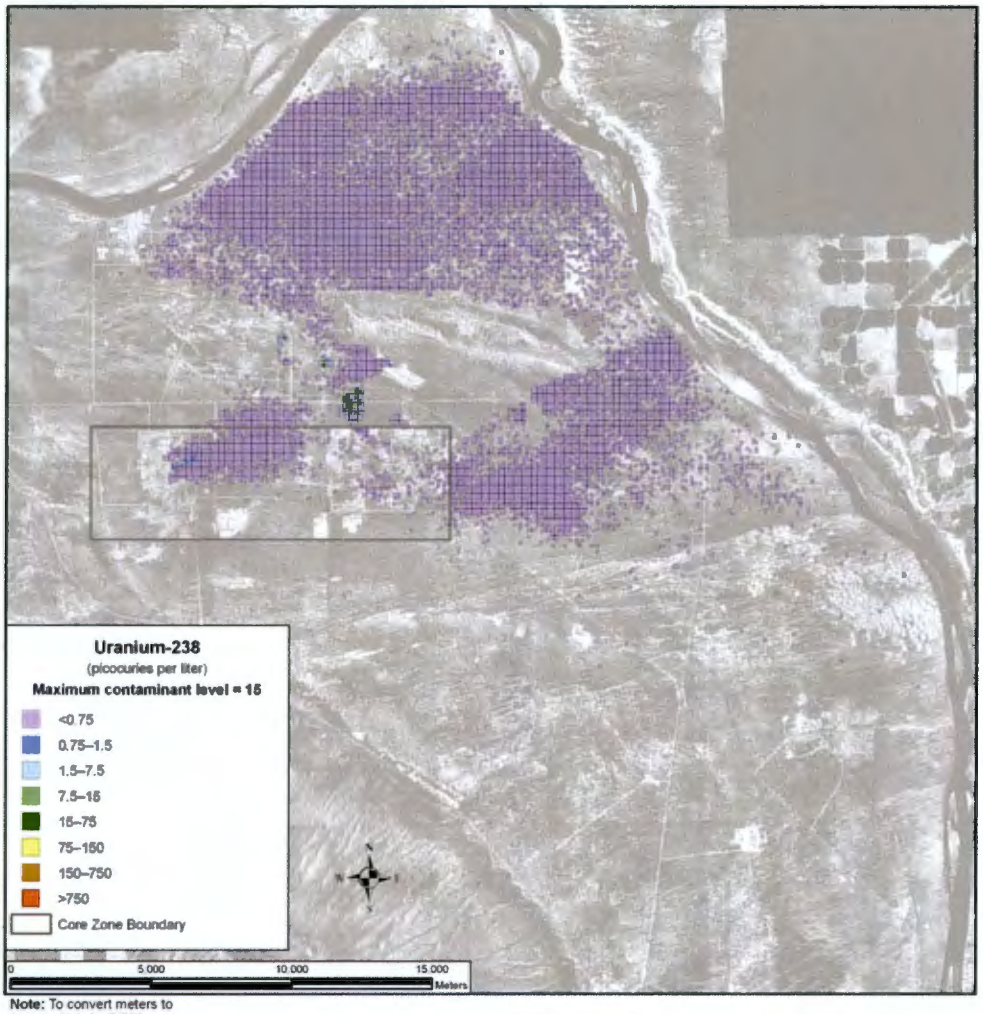
Figure 5–236. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 7140

Uranium-238 and total uranium under the Base Case are not as mobile as those COPCs discussed above, moving about seven times slower than the pore water velocity. As a result, travel times through the vadose zone are longer, release to the aquifer is delayed, and travel times through the aquifer to the Columbia River are longer. Figure 5–237 shows the distribution of uranium-238 during CY 2005. There is a small plume associated with cribs and trenches (ditches) and past leaks at the T Barrier that is less than one-twentieth of the benchmark concentration and is contained within the Core Zone Boundary. By CY 7140, the area of the plume has grown and extended to the Columbia River (see Figure 5–238). Most of the plume is significantly below the benchmark except for a small pocket with high concentrations in the southern region of Gable Gap extending north from the B Barrier. At CY 11,885, the greatest development of the plume during the analysis period is seen (see Figure 5–239). The only area with a significant level of contaminant concentration is the area in the southern region of Gable Gap that originates from the B Barrier. Figures 5–240 through 5–242 show similar results for total uranium.



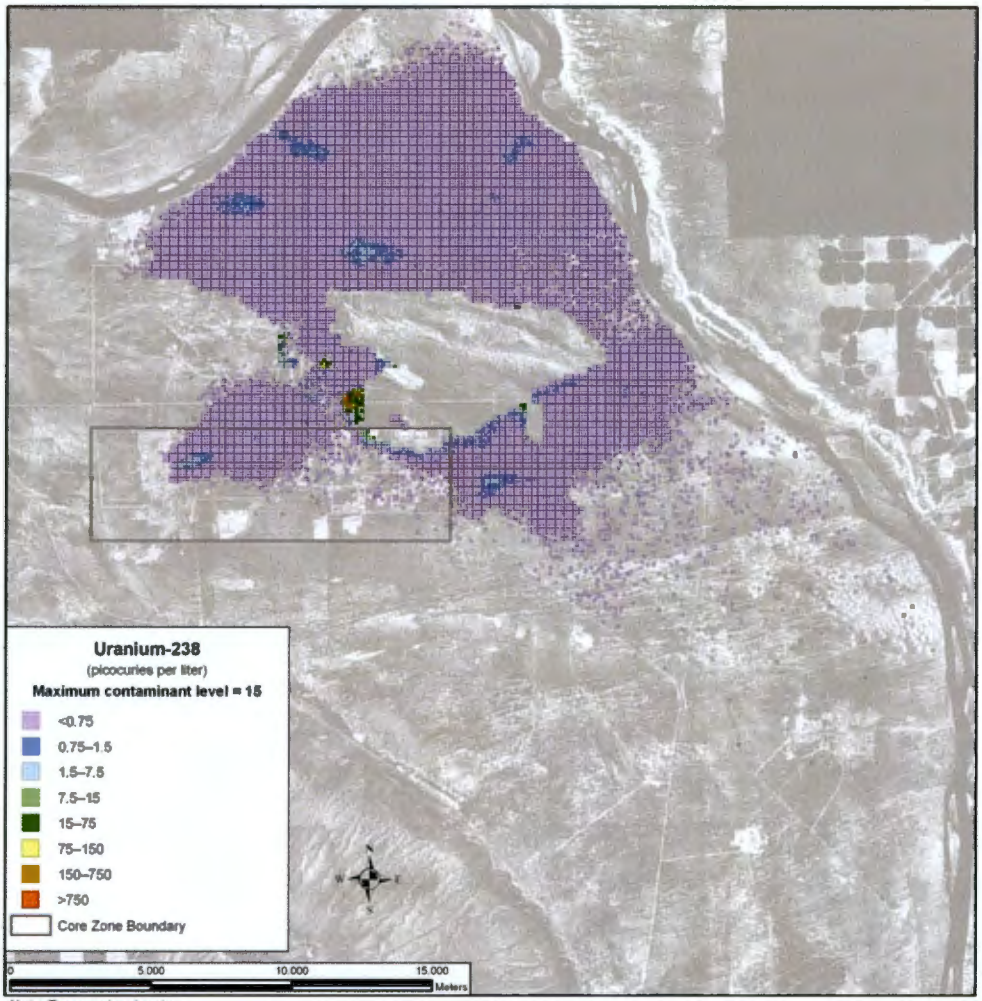
Note: To convert meters to feet, multiply by 3.281

Figure 5–237. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 2005



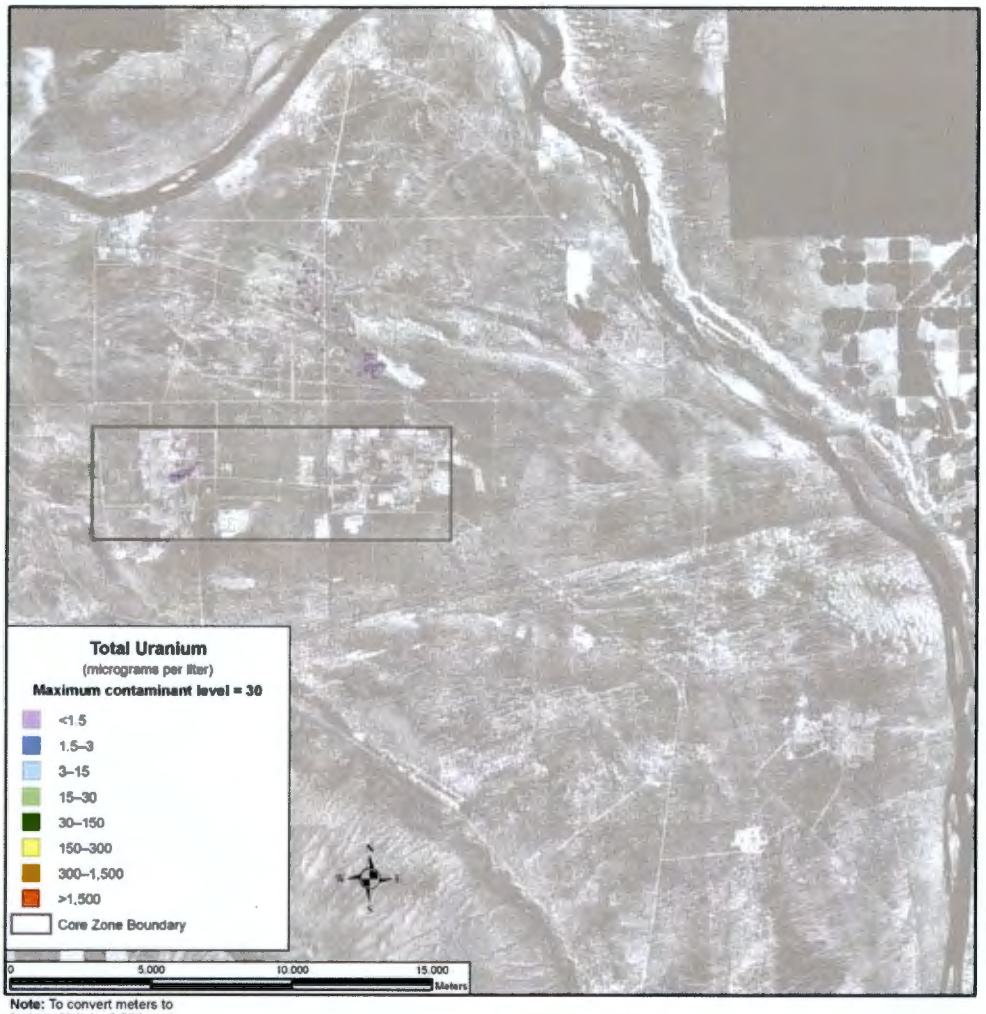
Note: To convert meters to feet, multiply by 3.281

Figure 5–238. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 7140



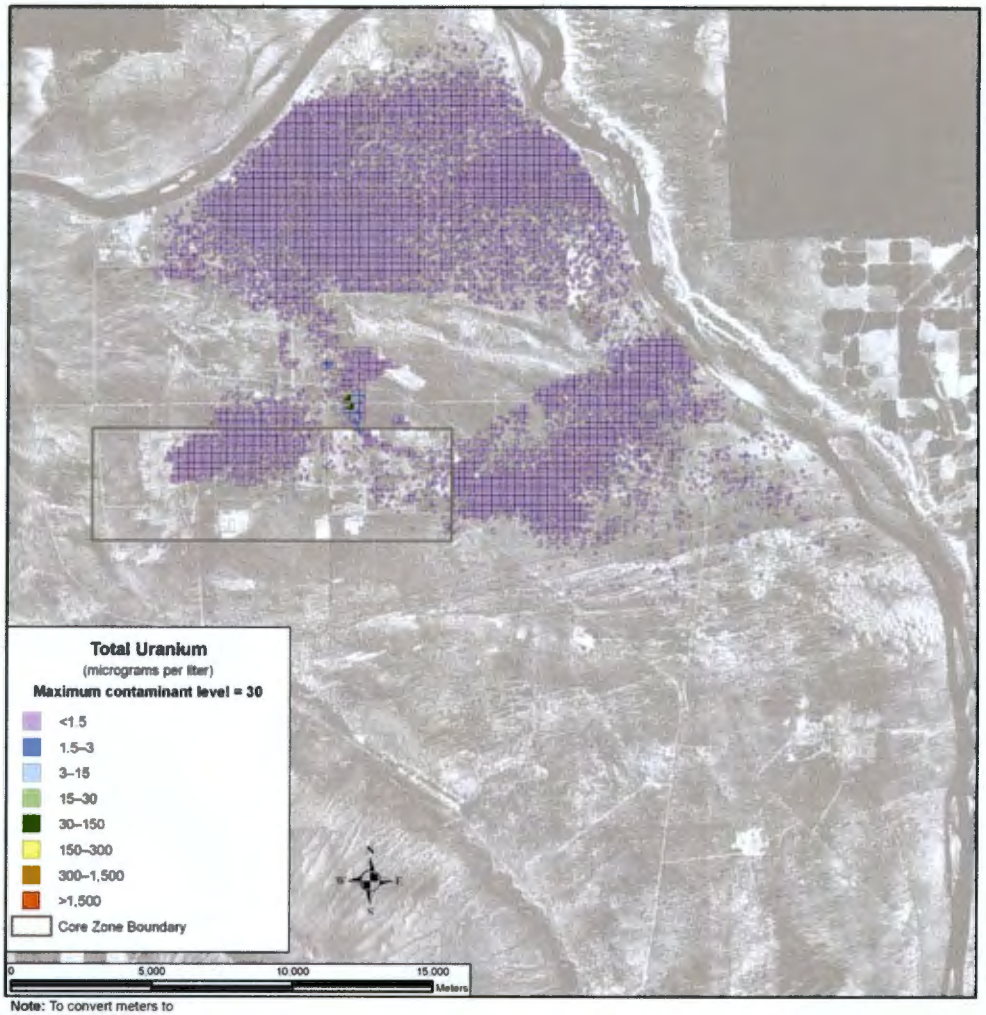
Note: To convert meters to feet, multiply by 3.281

Figure 5–239. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 11,885



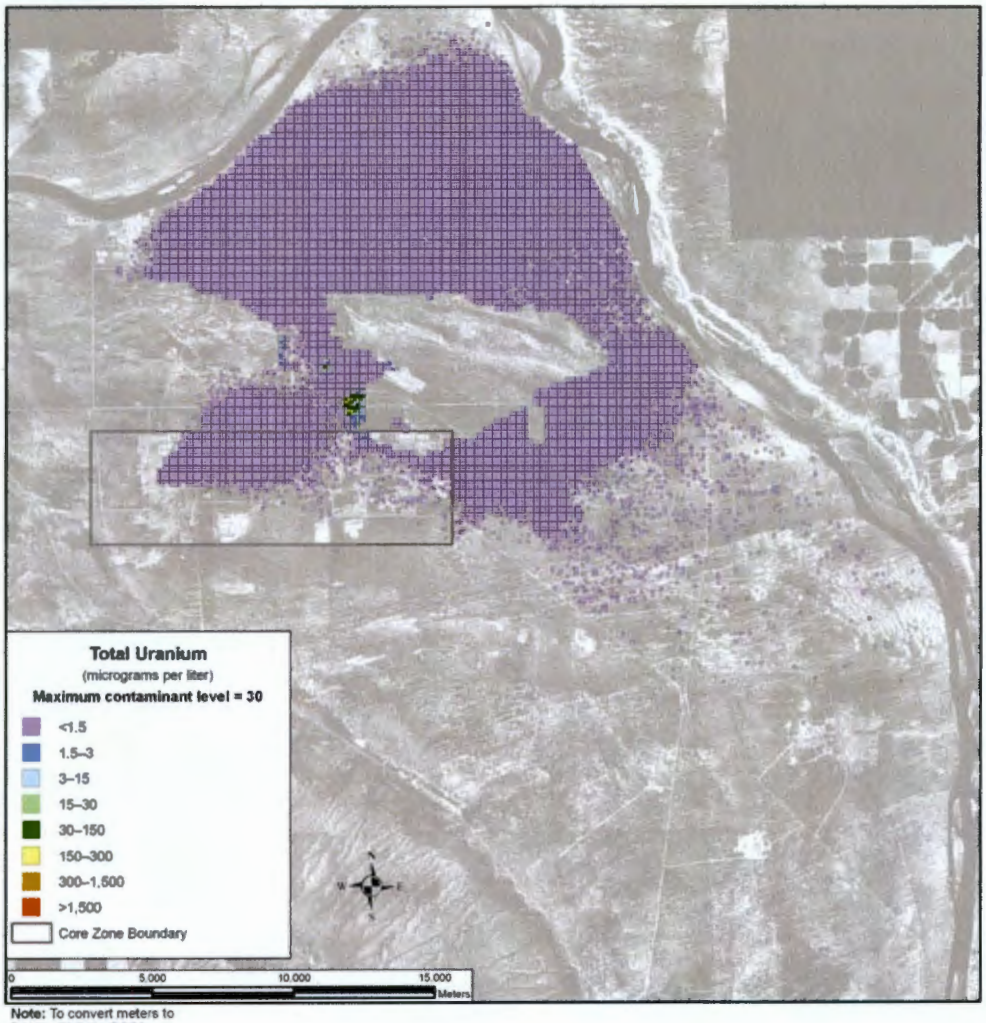
Note: To convert meters to feet, multiply by 3.281

Figure 5–240. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

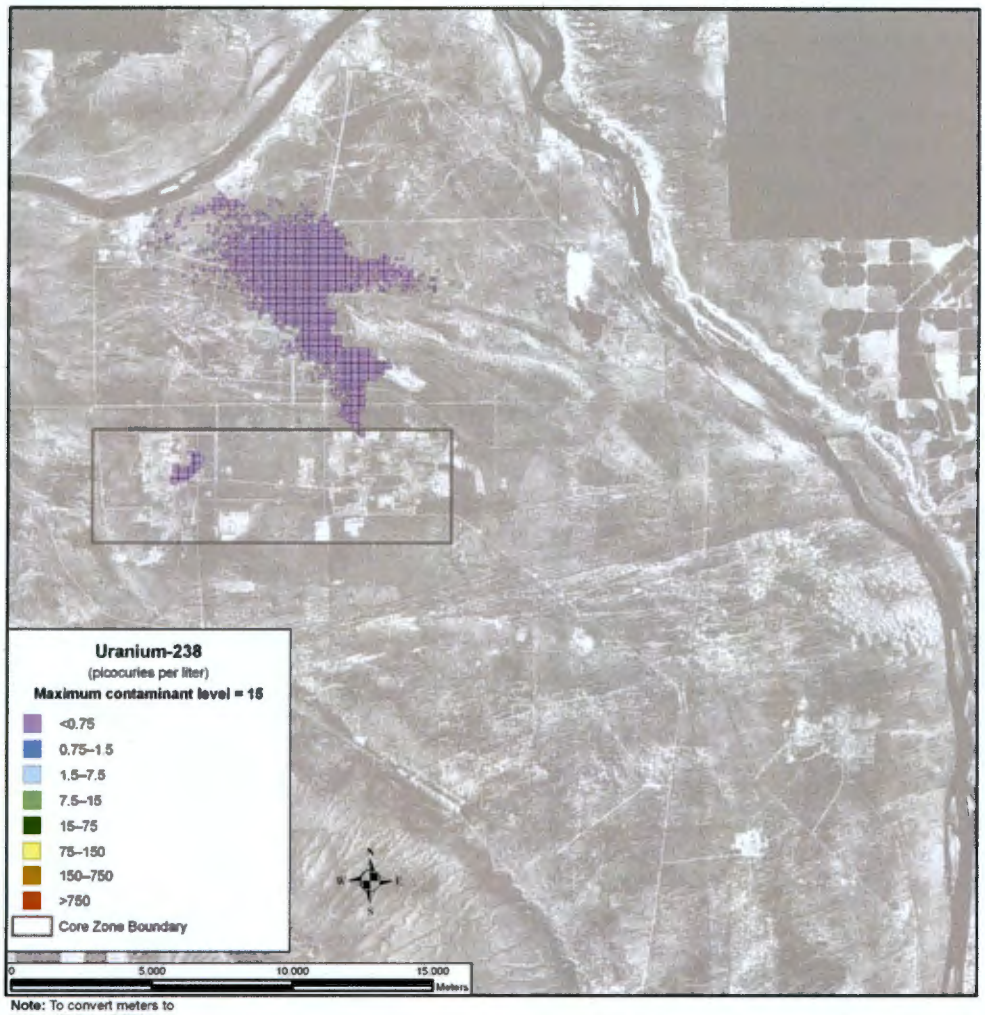
Figure 5–241. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281

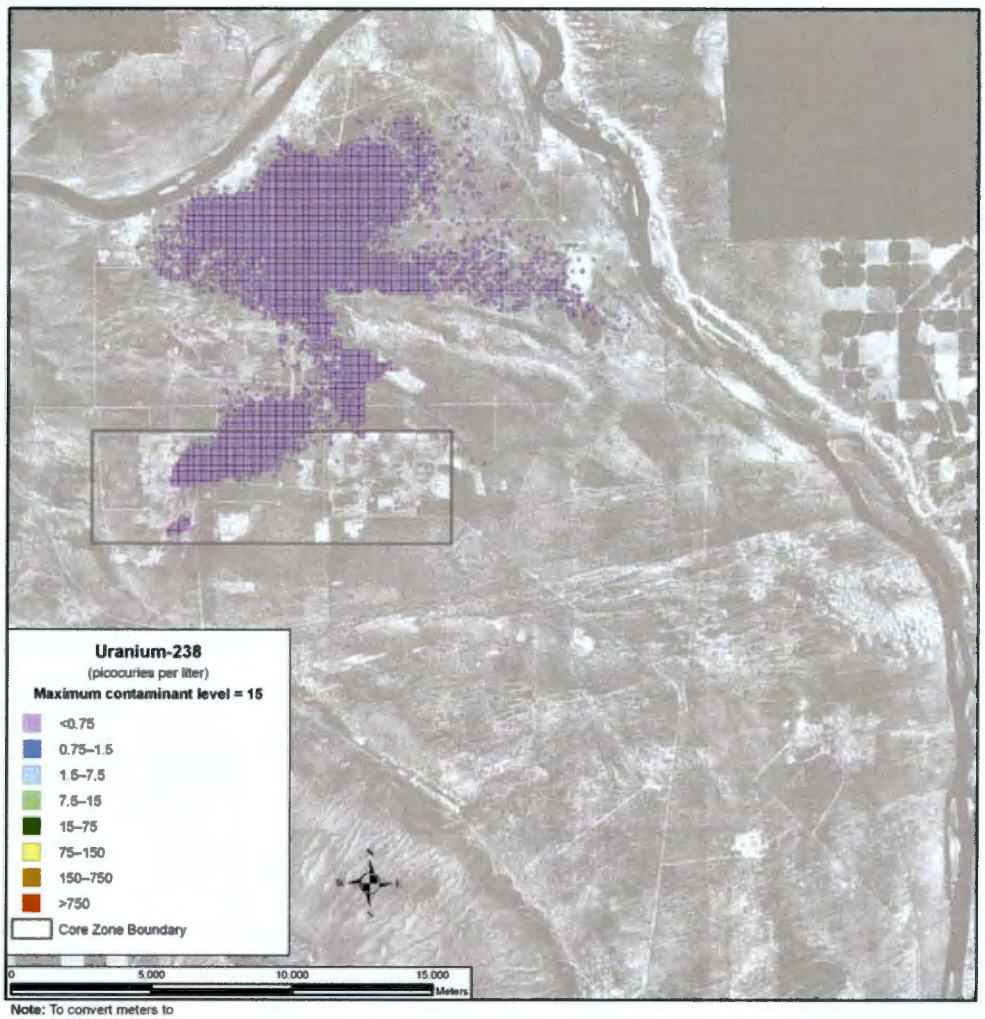
Figure 5–242. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 11,885

Figure 5–243 shows the distribution of uranium-238 during CY 2005 under the Option Case. There are two plumes associated with this case, one originating from the T Barrier and the other from the B Barrier. Although there are no significant contaminant concentrations, the plumes under the Option Case are much larger than under the Base Case. By CY 2135, the contaminant plume has grown and reached the Columbia River, but there are still no significant peaks in concentration levels (see Figure 5–244). By CY 11,885, while the greatest development of the plume occurred under the Base Case, the contaminant plume under the Option Case has begun to recede (see Figure 5–245). This recession is due to the removal of the six sets of cribs and trenches (ditches) and the remediation of their contaminant plumes. Figures 5–246 through 5–248 show similar results for total uranium.



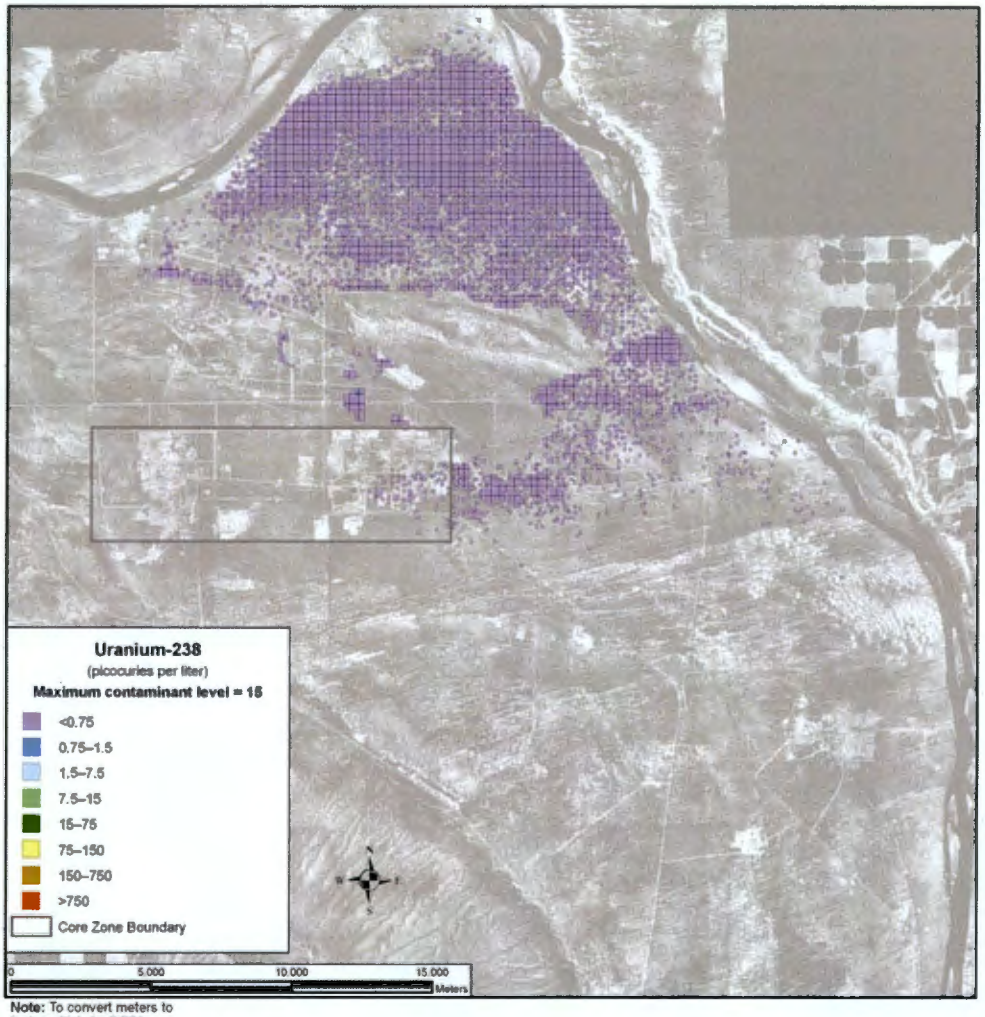
Note: To convert meters to feet, multiply by 3.281

Figure 5–243. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 2005



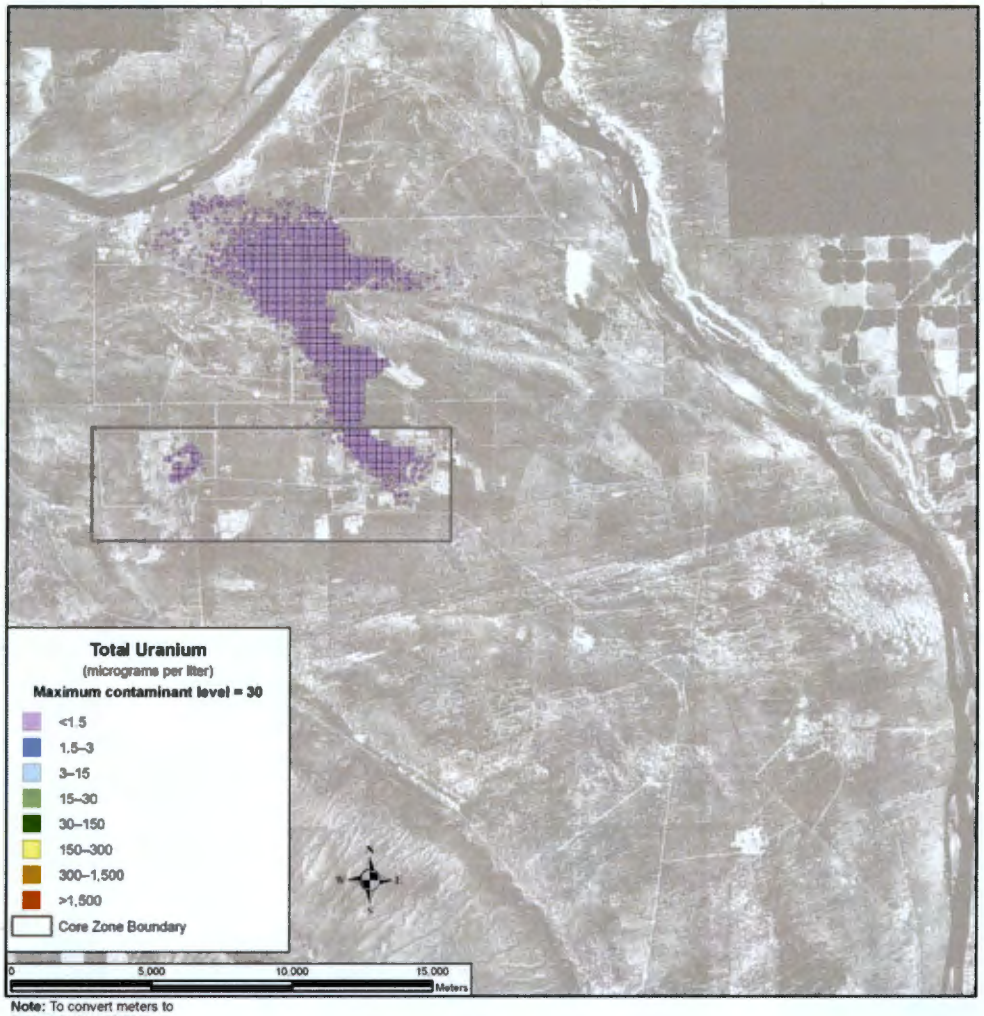
Note: To convert meters to feet, multiply by 3.281

Figure 5–244. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 2135



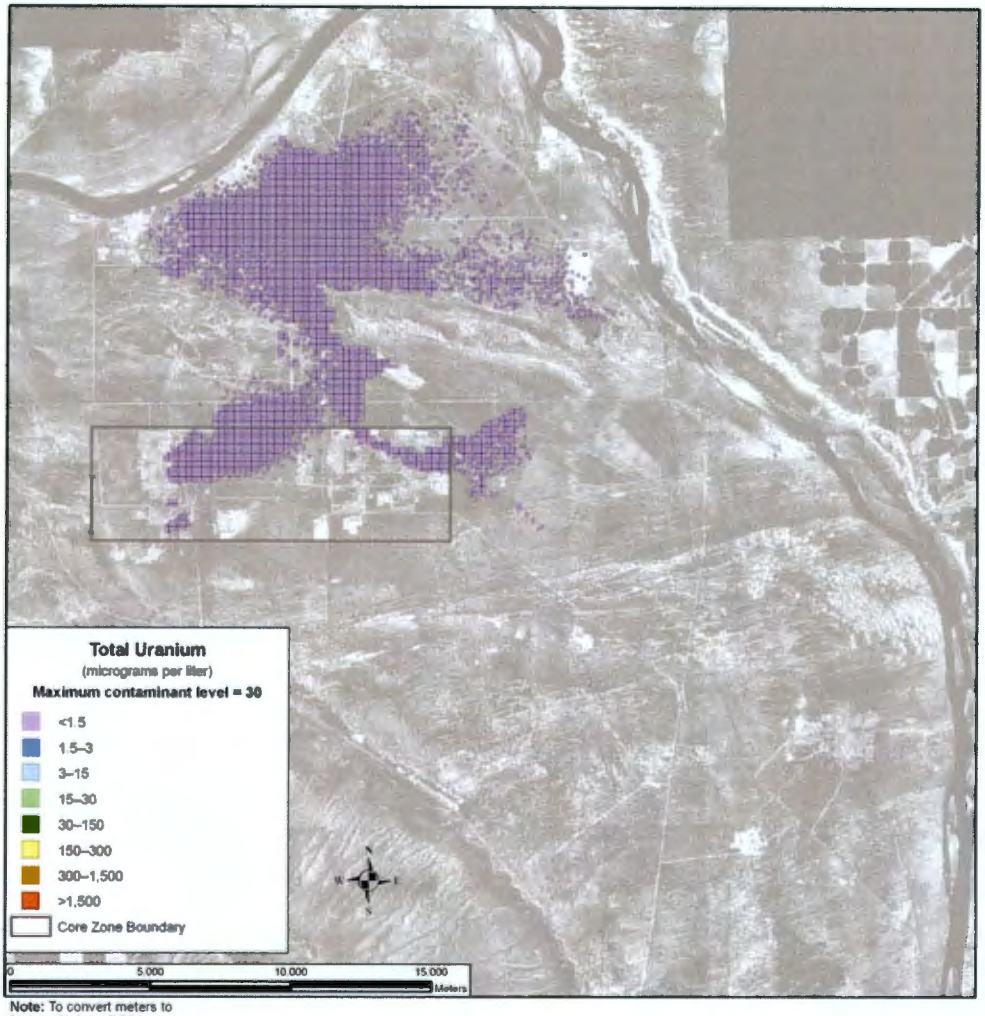
Note: To convert meters to feet, multiply by 3.281

Figure 5–245. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 11,885



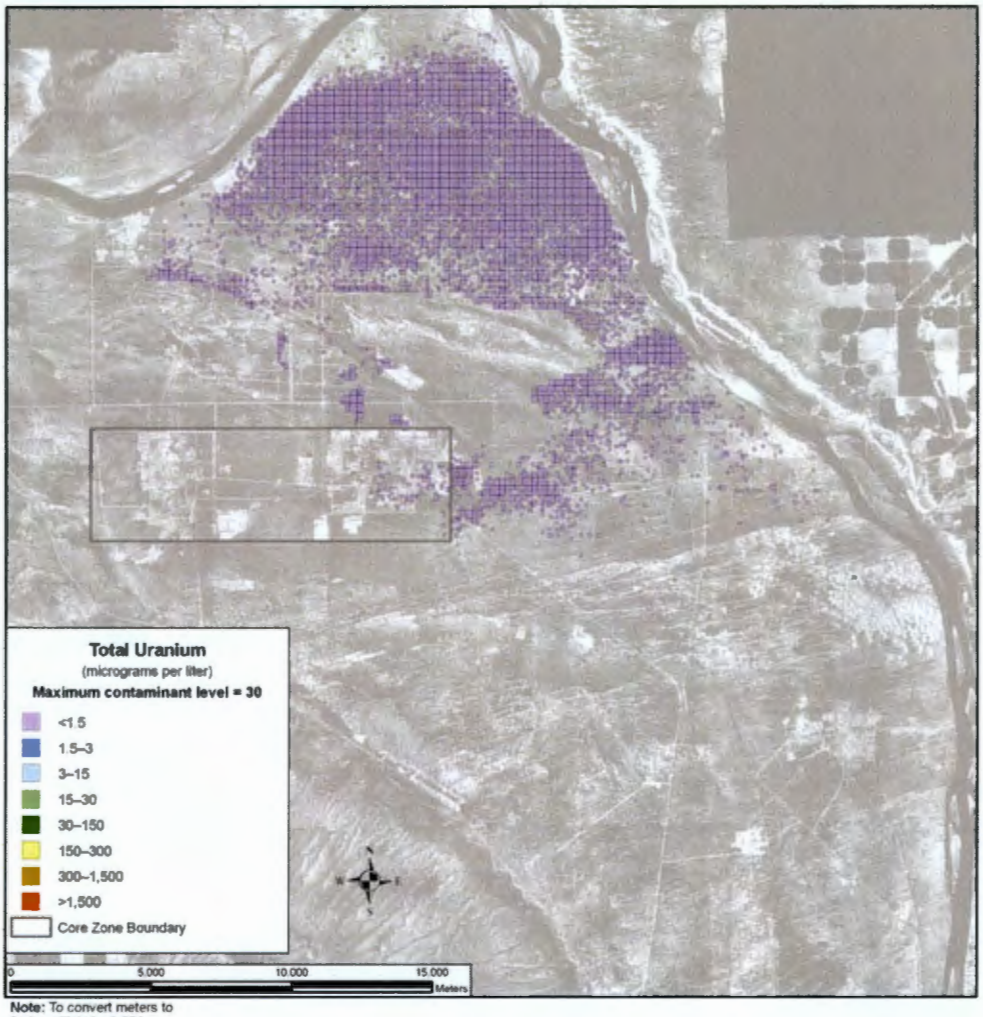
Note: To convert meters to feet, multiply by 3.281

Figure 5–246. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

Figure 5–247. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281

Figure 5–248. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 11,885

Figure 5–249 shows the area in square kilometers in which groundwater concentrations of technetium-99 exceed the benchmark concentration in the analysis as a function of time under the Base Case. A peak of almost 4.5 square kilometers (1.7 square miles) occurs around CY 2135, followed by a fairly sharp decrease. By about CY 4000, the area with a concentration above the benchmark begins to level out around 0.5 square kilometers (0.19 square miles). Iodine-129 shows a similar pattern (see Figure 5–250), as both constituents are conservative tracers.

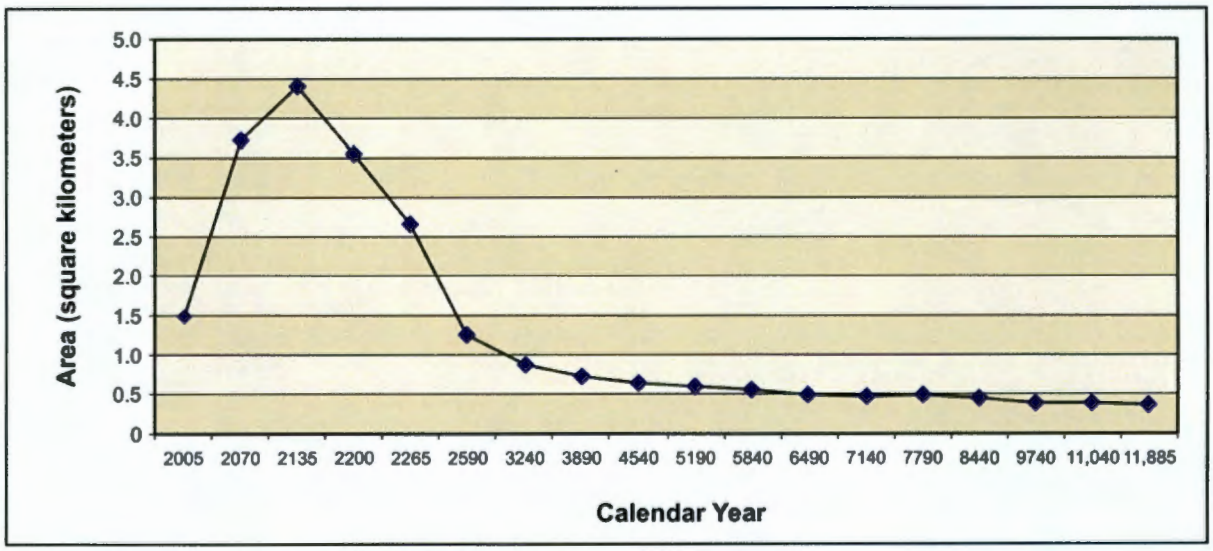


Figure 5–249. Tank Closure Alternative 6A, Base Case, Total Area of Groundwater Technetium-99 Concentration Exceeding the Benchmark Concentration as a Function of Time

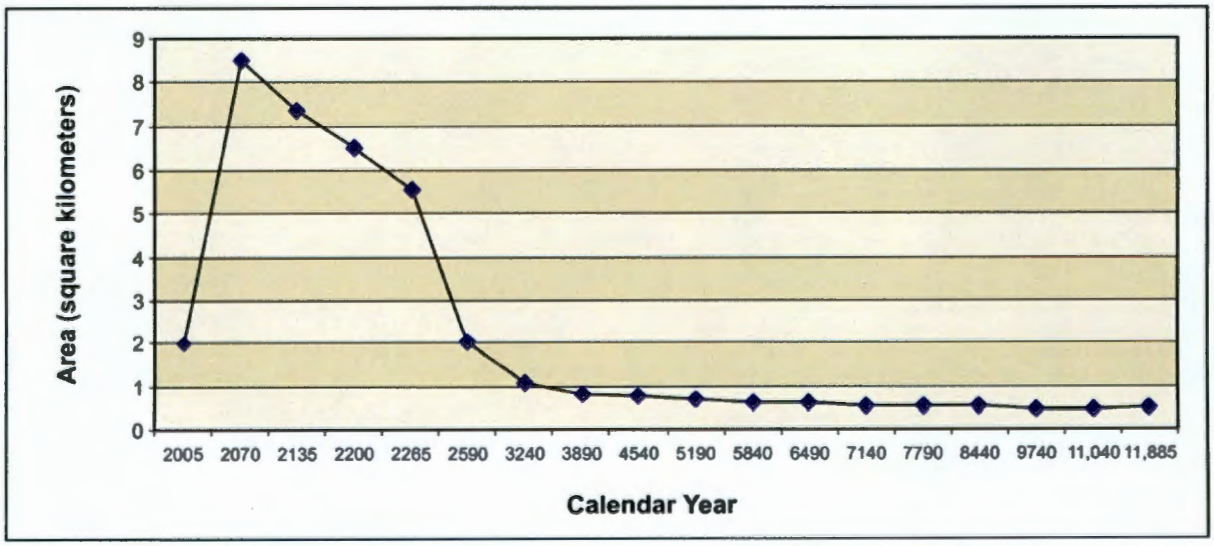


Figure 5–250. Tank Closure Alternative 6A, Base Case, Total Area of Groundwater Iodine-129 Concentration Exceeding the Benchmark Concentration as a Function of Time

Under the Option Case, the areas with concentrations of technetium-99 and iodine-129 above the benchmarks are essentially identical to those under the Base Case (see Figures 5–251 and 5–252).

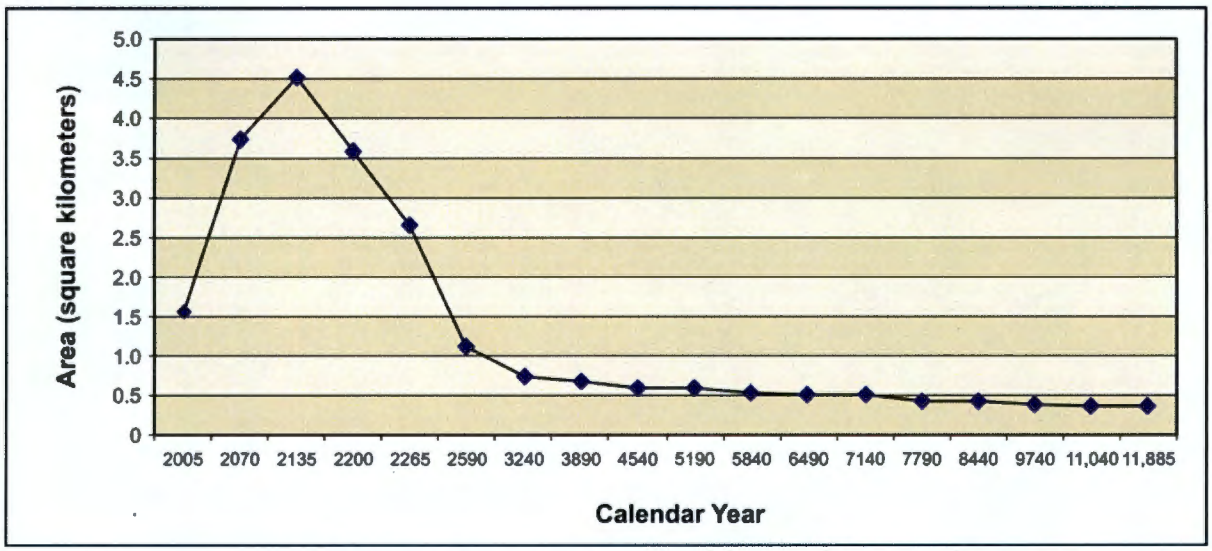


Figure 5–251. Tank Closure Alternative 6A, Option Case, Total Area of Groundwater Technetium-99 Concentration Exceeding the Benchmark Concentration as a Function of Time

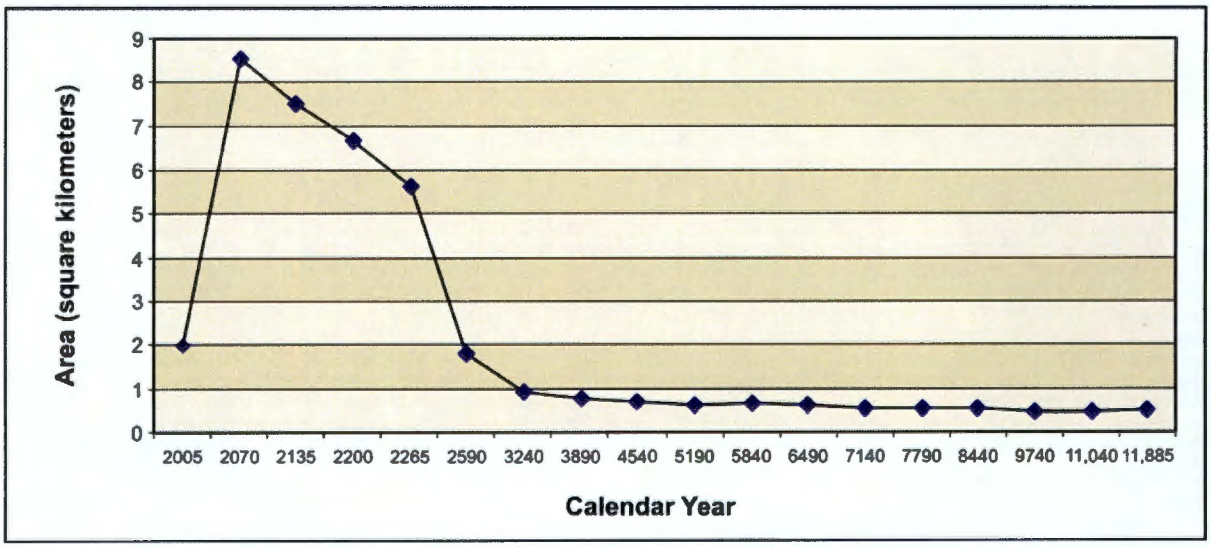


Figure 5–252. Tank Closure Alternative 6A, Option Case, Total Area of Groundwater Iodine-129 Concentration Exceeding the Benchmark Concentration as a Function of Time

Under the Base Case, uranium-238 did not register above the benchmark concentration in any area until after CY 5840 (see Figure 5–253). A sharp increase in area with concentrations above the maximum contaminant level occurs after CY 5840 and continues to rise through the end of the period of analysis (CY 11,940). It is expected that the majority of the uranium-238 would continue to migrate through the vadose zone after the period of analysis is over.

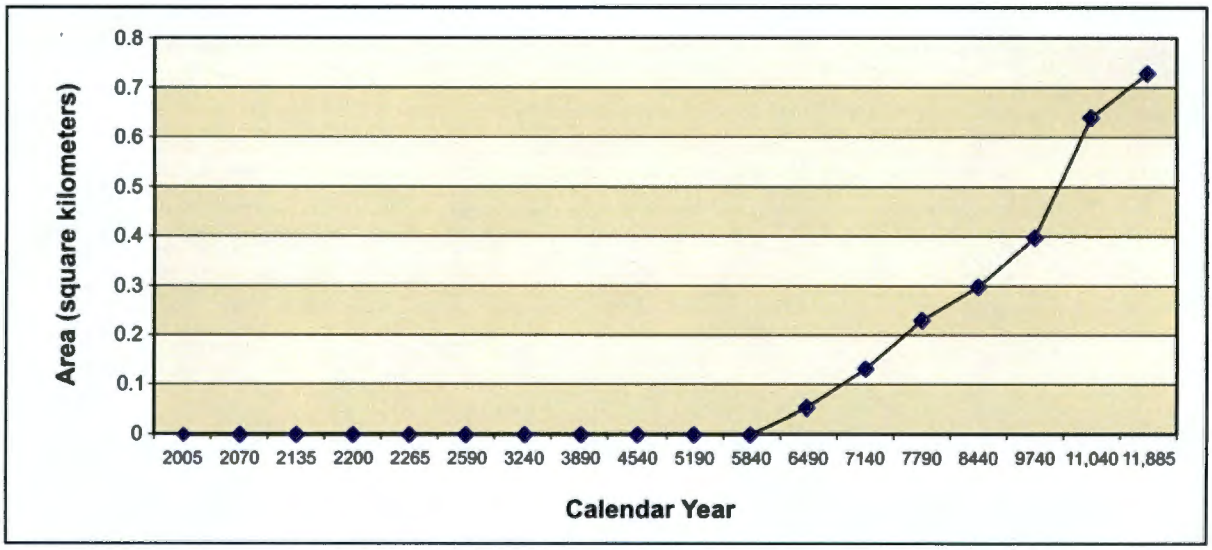


Figure 5–253. Tank Closure Alternative 6A, Base Case, Total Area of Groundwater Uranium-238 Concentration Exceeding the Benchmark Concentration as a Function of Time

Under the Option Case, uranium-238 did not register above the benchmark concentration in any area during the period of analysis. This is a result of the high retardation rate and the removal and remediation of the cribs and trenches (ditches).

5.1.1.9.6 Summary of Impacts

For the conservative tracers under the Base Case, concentrations at the Core Zone Boundary exceeded the benchmark standards by about two orders of magnitude during the early part of the period of analysis, around CY 1956. Columbia River nearshore concentrations never reached the benchmark concentration and peaked at about one-half to one order of magnitude below it. The intensities and areas of these groundwater plumes peaked around CY 1956.

The concentrations of iodine-129, technetium-99, chromium, and nitrate (the conservative tracers) under the Option Case are essentially identical to those under the Base Case.

For tritium under the Base Case, concentrations at the Core Zone Boundary exceed the benchmark by about two orders of magnitude for a short period of time during the early part of the period of analysis, around CY 1956. During the same period of time, the Columbia River nearshore concentrations peaked at about one order of magnitude below the benchmark. Attenuation by radioactive decay is a predominant mechanism that limits the intensity and duration of groundwater impacts of tritium.

The concentrations of tritium under the Option Case are essentially identical to those under the Base Case.

For uranium-238 and total uranium under the Base Case, limited mobility is an important factor governing the timeframes and scale of groundwater impacts. The concentrations of these retarded species began to approach the benchmark at the Core Zone Boundary toward the latter part of the period of

analysis but never reached it. The concentration levels of uranium-238 and total uranium at the Columbia River nearshore never came to within about two orders of magnitude below the benchmark. The intensity and area of the contaminant plumes peaked at the end of the period of analysis.

Under the Option Case, uranium-238 concentrations in the Core Zone Boundary generally stayed about three to four orders of magnitude below the benchmark, except for a short spike in the Core Zone Boundary to about one order of magnitude below the benchmark at the beginning of the period of analysis. The Columbia River nearshore concentrations stayed fairly constant at about four orders of magnitude below the benchmark. Total uranium concentrations at the Core Zone Boundary generally stayed about three to four orders of magnitude below the benchmark. The Columbia River nearshore concentrations remained fairly constant at around four and a half orders of magnitude below the benchmark.

5.1.1.10 Tank Closure Alternative 6B: All Vitrification with Separations; Clean Closure, Base and Option Cases

This section describes the groundwater analysis results for Tank Closure Alternative 6B, including long-term groundwater impacts of contaminant sources within the tank farm barriers. Impacts of sources removed from within the tank farm barriers and disposed of in an IDF and the RPPDF are presented in Section 5.3, which discusses waste management impacts.

Tank Closure Alternative 6B, Base and Option Cases, resembles Tank Closure Alternative 6A, Base and Option Cases, except that waste retrieval and processing would proceed at a faster rate and closure would occur at an earlier date.

Under Tank Closure Alternative 6B, Base Case, tank waste would be retrieved to a volume corresponding to 99.9 percent retrieval; all tank farms would be clean-closed by removing the tanks, ancillary equipment, and soils to a depth of 3 meters (10 feet) below the tank base. Where necessary, deep soil excavation would also be conducted to remove contamination plumes within the soil column. The adjacent cribs and trenches (ditches) would be covered with an engineered modified RCRA Subtitle C barrier.

Under Tank Closure Alternative 6B, Option Case, tank waste would be retrieved to a volume corresponding to 99.9 percent retrieval; all tank farms would be clean-closed by removing the tanks, ancillary equipment, and soils to a depth of 3 meters (10 feet) below the tank base. Where necessary, deep soil excavation would also be conducted to remove contamination plumes within the soil column. In addition, the adjacent cribs and trenches (ditches) would be clean-closed.

5.1.1.10.1 Actions and Timeframes Influencing Groundwater Impacts

Summaries of the proposed actions and timelines for Tank Closure Alternative 6B are provided in Chapter 2, Section 2.5. For the long-term groundwater impact analysis, three major periods were identified for Tank Closure Alternative 6B, as follows:

- The past-practice period was assumed to start with the onset of tank farm operations in 1944 and continue through 2007, when tank and infrastructure upgrades were complete. Releases to the vadose zone occurred during the past-practice period from past leaks at the SST farms and discharges to the cribs and trenches (ditches) associated with the B, BX, BY, T, TX, and TY tank farms. The groundwater impacts during the past-practice period under Tank Closure Alternative 6B that are presented in this section are common to all of the Tank Closure alternatives.

- The retrieval period was assumed to start in 2008 and end in CY 2101. During this period, 99.9 percent of the waste would be retrieved from the tanks and all tank farms would be clean-closed.

- The post–administrative control period was assumed to start in CY 2102 and continue through the 10,000-year period of analysis until CY 11,940.

5.1.1.10.2 COPC Drivers

A total of 19 COPCs were analyzed for Tank Closure Alternative 6B. Complete results for all 19 COPCs are tabulated in Appendices M, N, and O. The discussion in this section of long-term impacts associated with Tank Closure Alternative 6B is focused on the following COPC drivers:

- Radiological risk drivers: tritium, iodine-129, technetium-99, and uranium-238
- Chemical risk drivers: none
- Chemical hazard drivers: chromium, nitrate, and total uranium

The COPC drivers for Tank Closure Alternative 6B were selected by evaluating the risk or hazard associated with all 19 COPCs during the year of peak risk or hazard at the Core Zone Boundary during the 10,000-year period of analysis and selecting the major contributors. This process is described in Appendix Q. Uranium-238 and total uranium were added to the COPC drivers, although their contribution to risk and hazard are not dominant during the year of peak risk or hazard. Tritium was added to the list of COPC drivers because of its contribution to risk during the early part of the period of analysis. The radiological risk drivers account for essentially 100 percent of the radiological risk. The only predicted chemical risk is from 2,4,6-trichlorophenol, calculated as 1×10^{-11}, which is negligible for purposes of this discussion. The chemical hazard drivers account for 100 percent of the chemical hazard associated with Tank Closure Alternative 6B.

The COPC drivers that are discussed in detail in this section fall into three categories. Iodine-129, technetium-99, chromium, and nitrate are all mobile (i.e., move with groundwater) and long-lived (relative to the 10,000-year period of analysis), or stable. They are essentially conservative tracers. Tritium is also mobile, but short-lived. The half-life of tritium is about 13 years, and tritium concentrations are strongly attenuated by radioactive decay during travel through the vadose zone and groundwater systems. Finally, uranium-238 and total uranium are long-lived, or stable, but are not as mobile as the other COPC drivers. These constituents move about seven times more slowly than groundwater. As the analyses of release, concentration versus time, and spatial distribution of the COPC drivers are presented, the distinct behavior of these three groups will become apparent.

The other COPCs that were analyzed do not significantly contribute to drinking water risk at the Core Zone Boundary during the period of analysis because of limited inventories, high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of these factors.

5.1.1.10.3 Analysis of Release and Mass Balance

This section presents the impacts of Tank Closure Alternative 6B in terms of total amount of COPCs released to the vadose zone, groundwater, and the Columbia River during the 10,000-year period of analysis. Releases of radionuclides are totaled in curies, chemicals in kilograms (see Figures 5–254 through 5–265). Two subtotals are plotted representing releases from cribs and trenches (ditches) and from past leaks. Amounts released from other tank farm sources are negligible for the purposes of this discussion. Note that the release amounts are plotted on a logarithmic scale to facilitate visual comparison of releases that vary over four orders of magnitude.

Figure 5–254 shows the estimated release to the vadose zone for the radiological risk drivers under the Base Case, which would include use of a modified RCRA Subtitle C barrier, and Figure 5–255, the chemical hazard drivers. The predominant sources for tritium, chromium, and nitrate are the cribs and trenches (ditches) associated with the B, BX, BY, T, TX, and TY tank farms. For all other COPC drivers the predominant sources are from past leaks. This suggests that past leaks, which were released during the past-practice period, as well as the cribs and trenches (ditches) are both important impact drivers under Tank Closure Alternative 6B, Base Case.

Figure 5–256 shows the estimated release to the vadose zone for the radiological risk drivers under the Option Case, which would include clean closure of cribs and trenches (ditches), and Figure 5–257, the chemical hazard drivers. The predominant sources for tritium, the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), uranium-238, and total uranium are similar to those in the vadose zone under the Base Case.

Figure 5–258 shows the estimated release to groundwater for the radiological risk drivers under the Base Case and Figure 5–259, the chemical hazard drivers. In addition to the total inventory released, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), the amount released to groundwater is essentially equal to the amount released to the vadose zone.

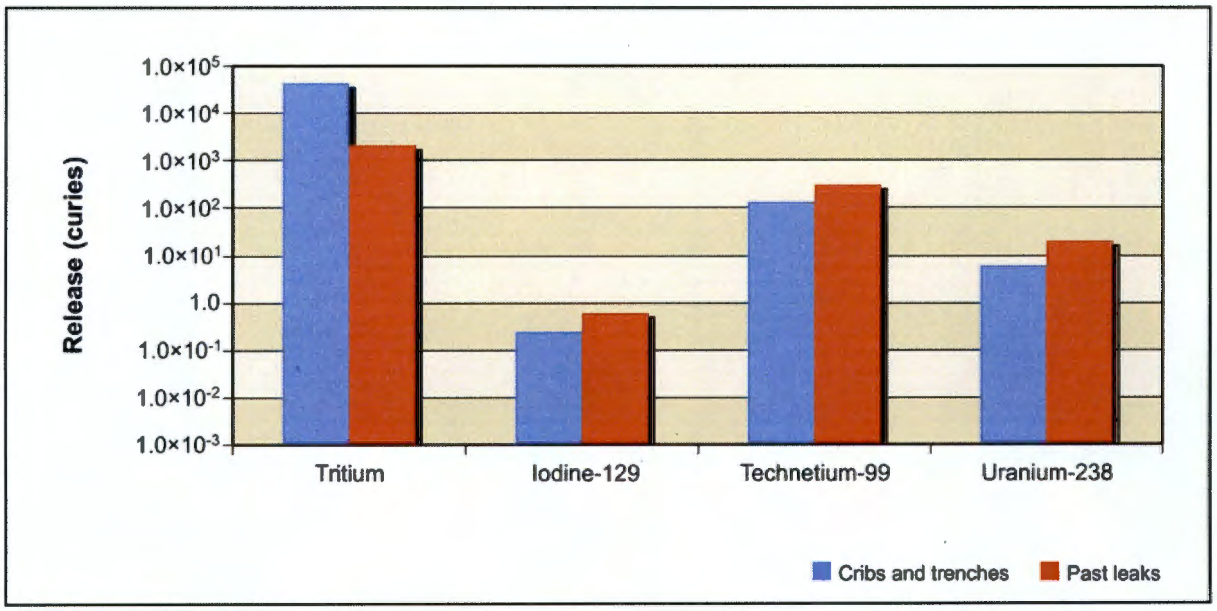


Figure 5–254. Tank Closure Alternative 6B, Base Case, Releases of Radiological Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

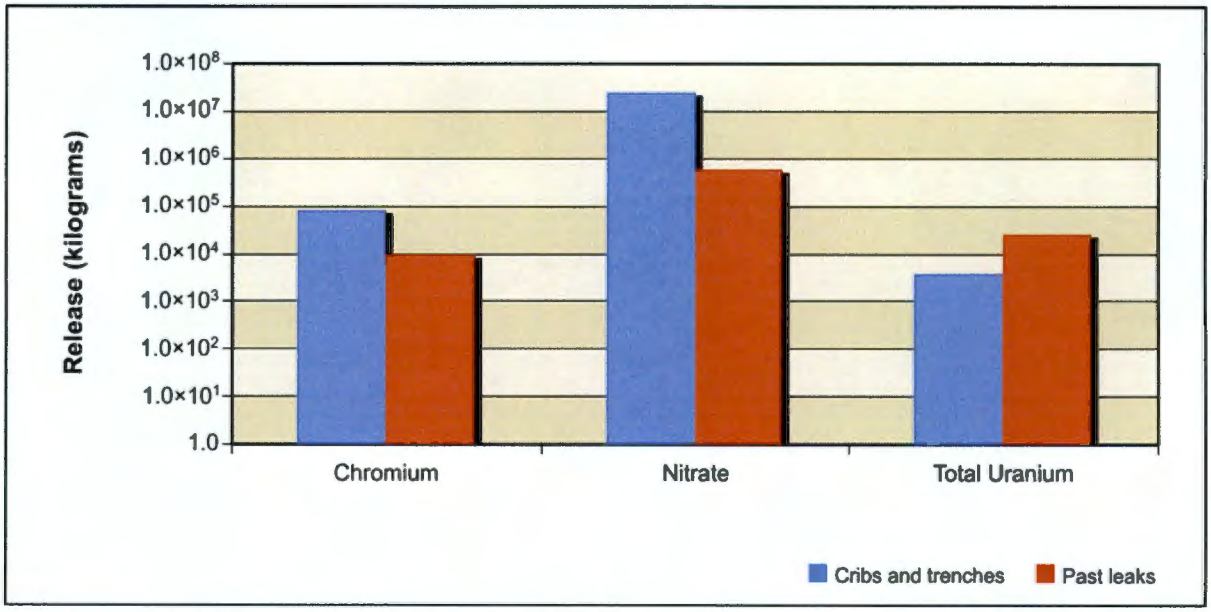


Figure 5–255. Tank Closure Alternative 6B, Base Case, Releases of Chemical Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

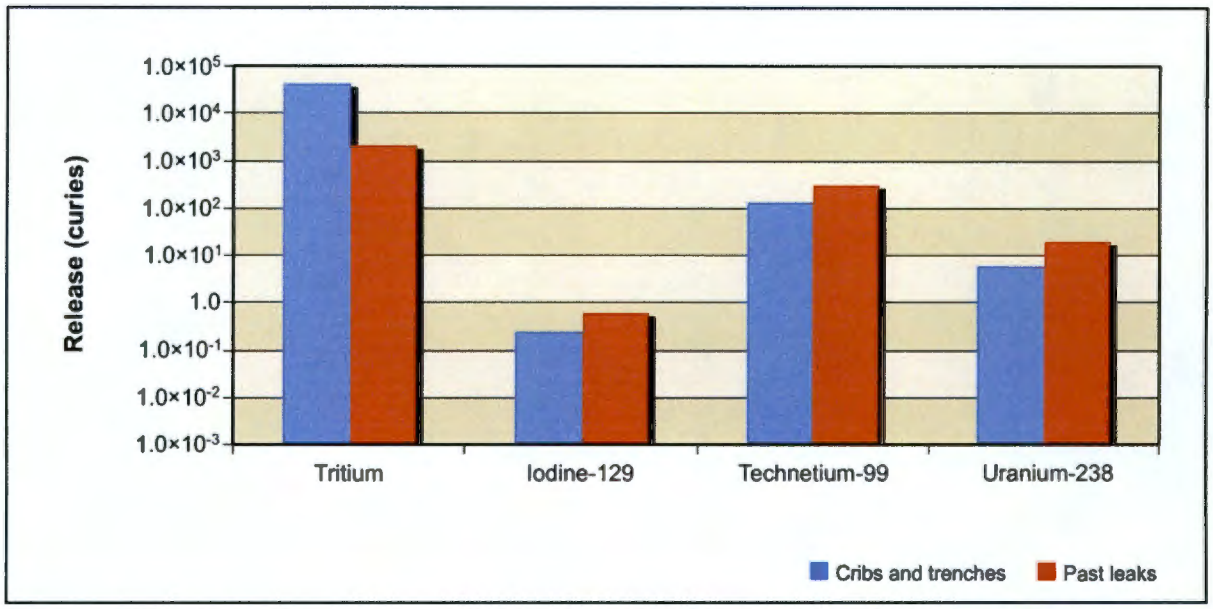


Figure 5–256. Tank Closure Alternative 6B, Option Case, Releases of Radiological Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

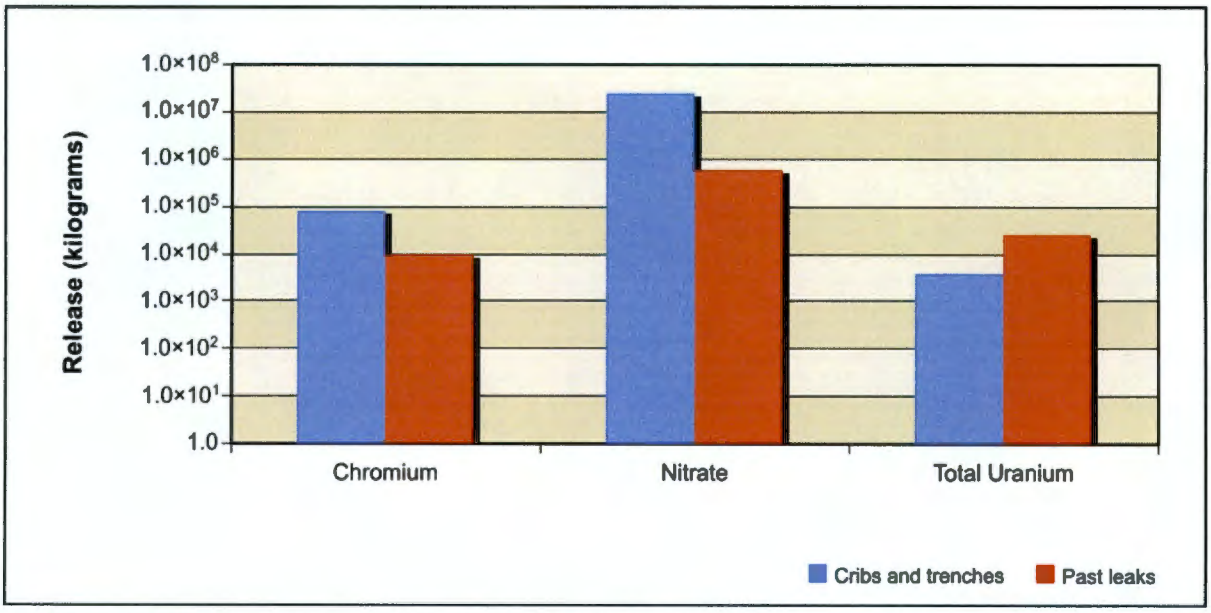


Figure 5–257. Tank Closure Alternative 6B, Option Case, Releases of Chemical Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

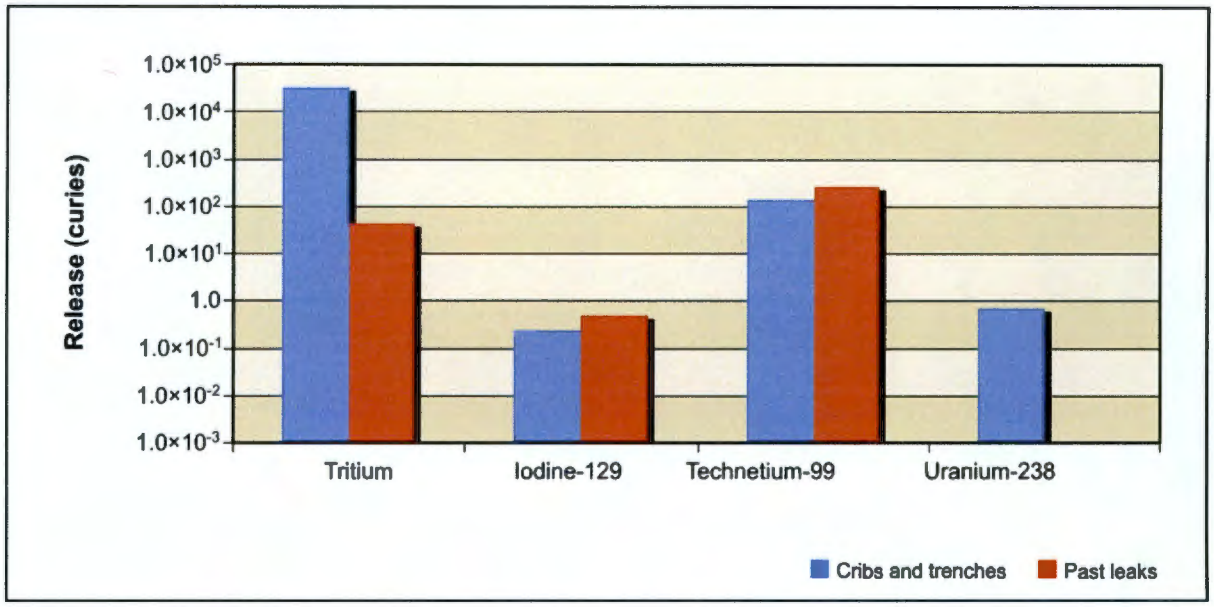


Figure 5–258. Tank Closure Alternative 6B, Base Case, Releases of Radiological Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

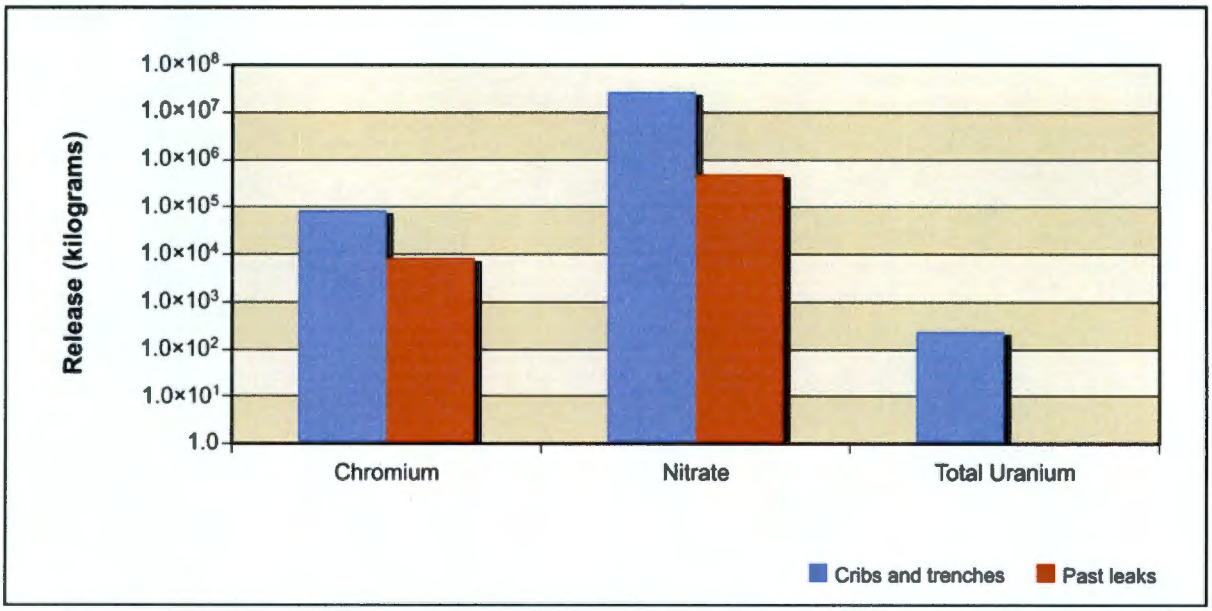


Figure 5–259. Tank Closure Alternative 6B, Base Case, Releases of Chemical Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

For tritium, the amount released to groundwater is attenuated by radioactive decay. For cribs and trenches (ditches), about 74 percent of the total inventory reached groundwater in the analysis; for past leaks, only 2 percent reached groundwater. These results suggest that tritium impacts on groundwater are dominated by releases from cribs and trenches (ditches), and that radioactive decay of tritium is an important attenuation process. They also suggest that uranium-238 and total uranium impacts would occur later in the post–administrative control period because of the long travel times in the vadose zone for these COPCs.

Figure 5–260 shows the estimated release to groundwater for the radiological risk drivers under the Option Case and Figure 5–261, the chemical hazard drivers. In addition to the total inventory released, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), the amount released to groundwater is about 7 percent less than the amount released to the vadose zone.

For uranium-238 and total uranium, the amount released to groundwater is less than that of the release to the vadose zone because of vadose zone retention. The amount of this retention depends on the type of contaminant source, specifically volume and timing of moisture movement through the vadose zone. For cribs and trenches (ditches), where moisture movement through the vadose zone is relatively rapid (because of the volume of water associated with the source), essentially none of the total inventory reached groundwater during the period of analysis. For past leaks, essentially none of the total inventory reached groundwater during the period of analysis.

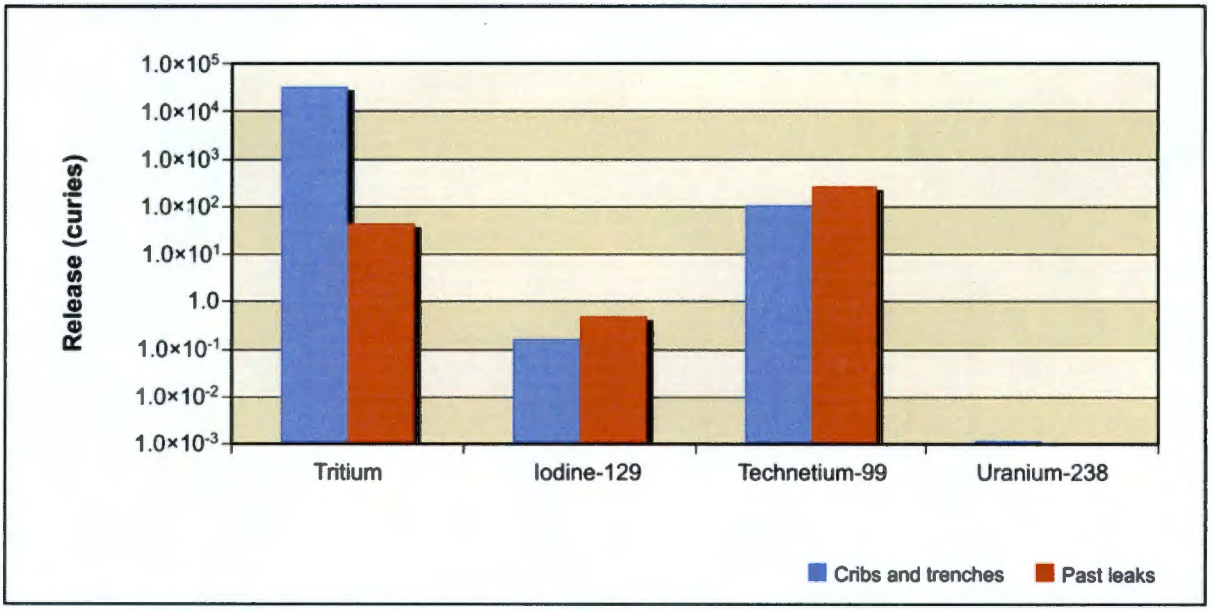


Figure 5–260. Tank Closure Alternative 6B, Option Case, Releases of Radiological Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

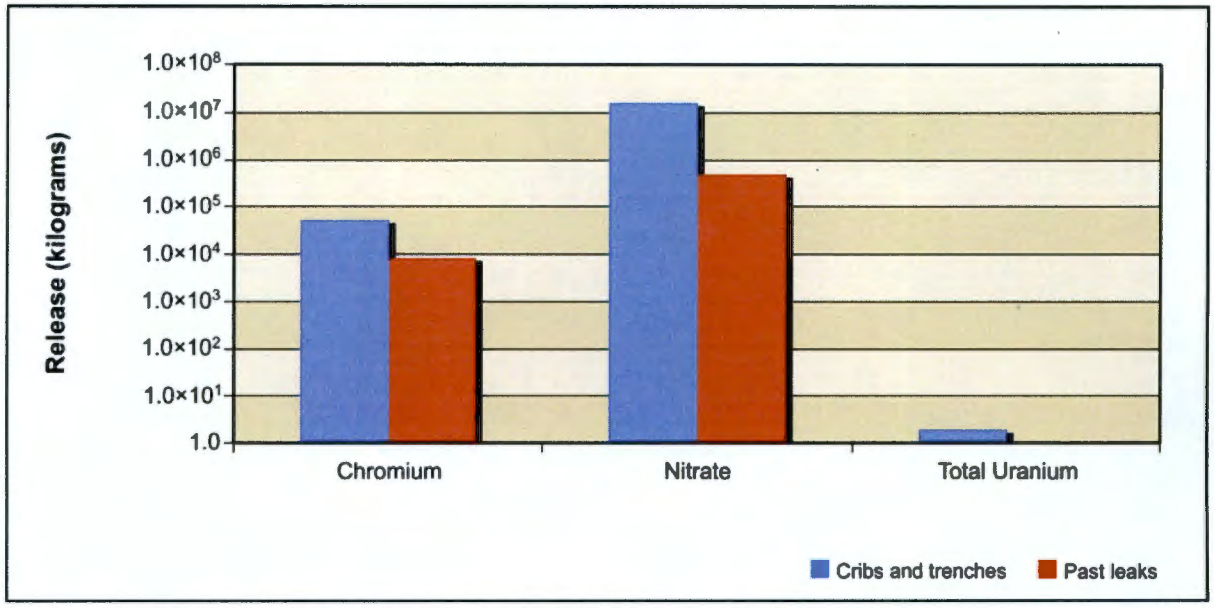


Figure 5–261. Tank Closure Alternative 6B, Option Case, Releases of Chemical Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

For tritium, the amount released to groundwater is attenuated by radioactive decay. For cribs and trenches (ditches), about 85 percent of the total inventory reached groundwater in the analysis; for past leaks, only 2 percent reached groundwater. These results suggest that tritium impacts on groundwater are dominated by releases from cribs and trenches (ditches), and that radioactive decay of tritium is an important attenuation process. They also suggest that uranium-238 and total uranium impacts would decrease over time because the long travel times in the vadose zone for these COPCs allow much of what was released to be collected and treated when the cribs and trenches (ditches) are removed and their deep plumes remediated.

Figure 5–262 shows the estimated release to the Columbia River for the radiological risk drivers under the Base Case and Figure 5–263, the chemical hazard drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers. For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), the amount released to the Columbia River is essentially equal to the amount released to groundwater.

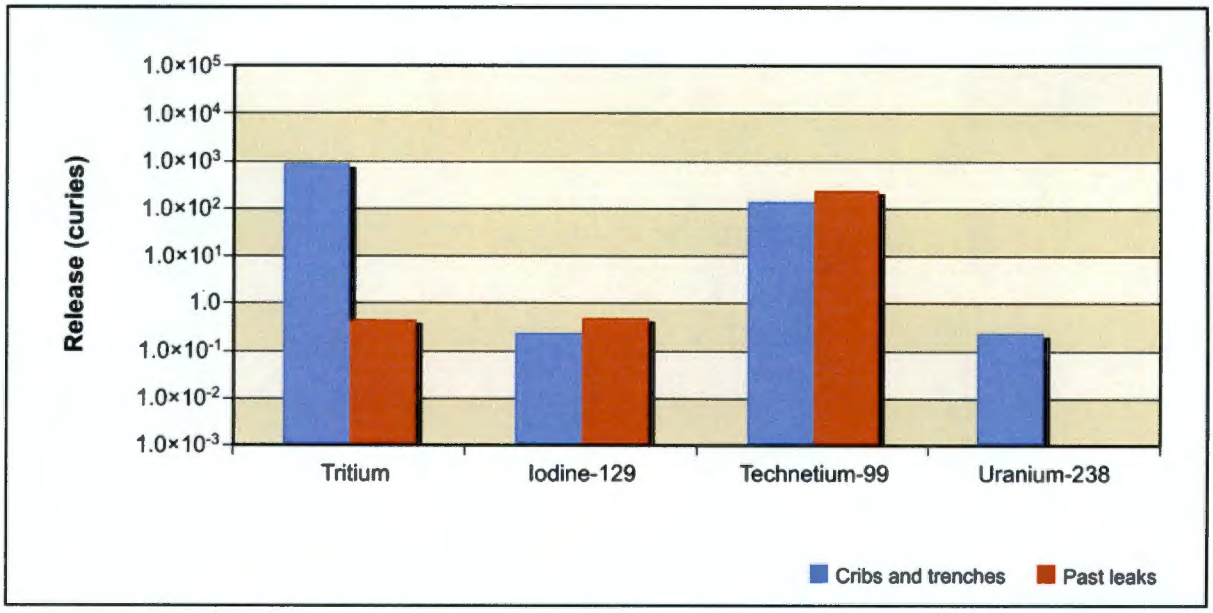


Figure 5–262. Tank Closure Alternative 6B, Base Case, Releases of Radiological Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

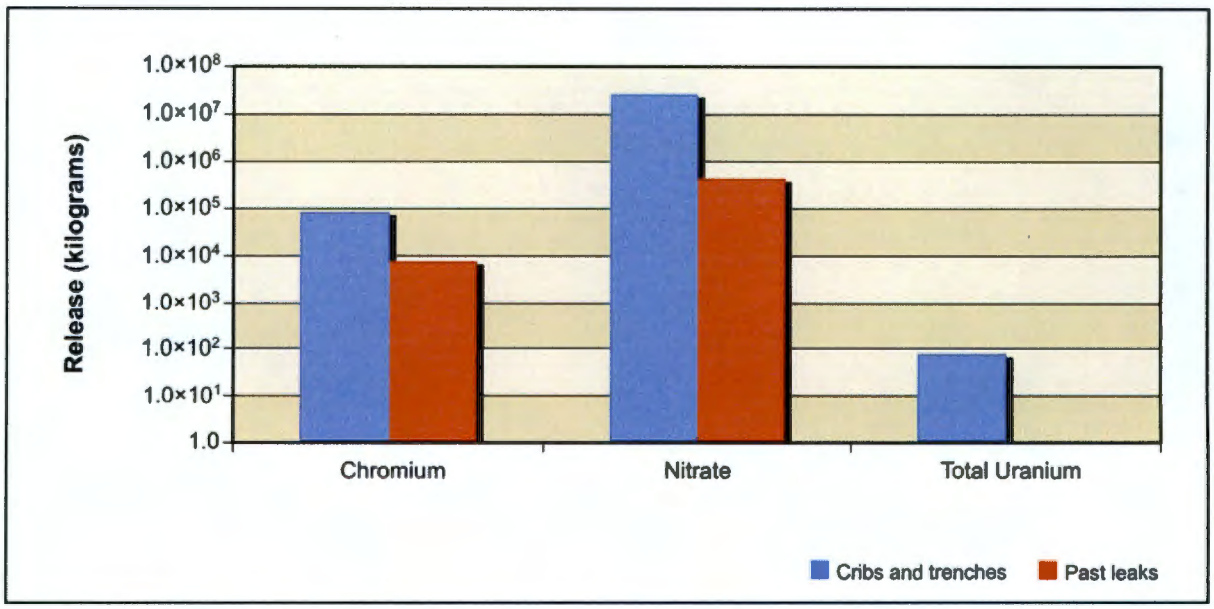


Figure 5–263. Tank Closure Alternative 6B, Base Case, Releases of Chemical Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

For uranium-238 and total uranium, the amount released to the Columbia River is less than that of the release to groundwater because of retardation. For cribs and trenches (ditches), about 40 percent of the amount released to groundwater during the period of analysis reached the Columbia River.

For tritium, the amount released to the Columbia River is attenuated by radioactive decay. For cribs and trenches (ditches), only about 3 percent of the tritium released to groundwater reached the Columbia River during the period of analysis. For past leaks, only about 1 percent of the tritium released to groundwater reached the Columbia River. These results suggest that tritium impacts on the Columbia River are strongly attenuated by radioactive decay. They also suggest that uranium-238 and total uranium impacts on the Columbia River would occur later in the post–administrative control period because of the long travel times in the vadose zone and through the groundwater system for these COPCs.

Figure 5–264 shows the estimated release to the Columbia River for the radiological risk drivers under the Option Case and Figure 5–265, the chemical hazard drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers. For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), the amount released to the Columbia River is essentially equal to the amount released to groundwater.

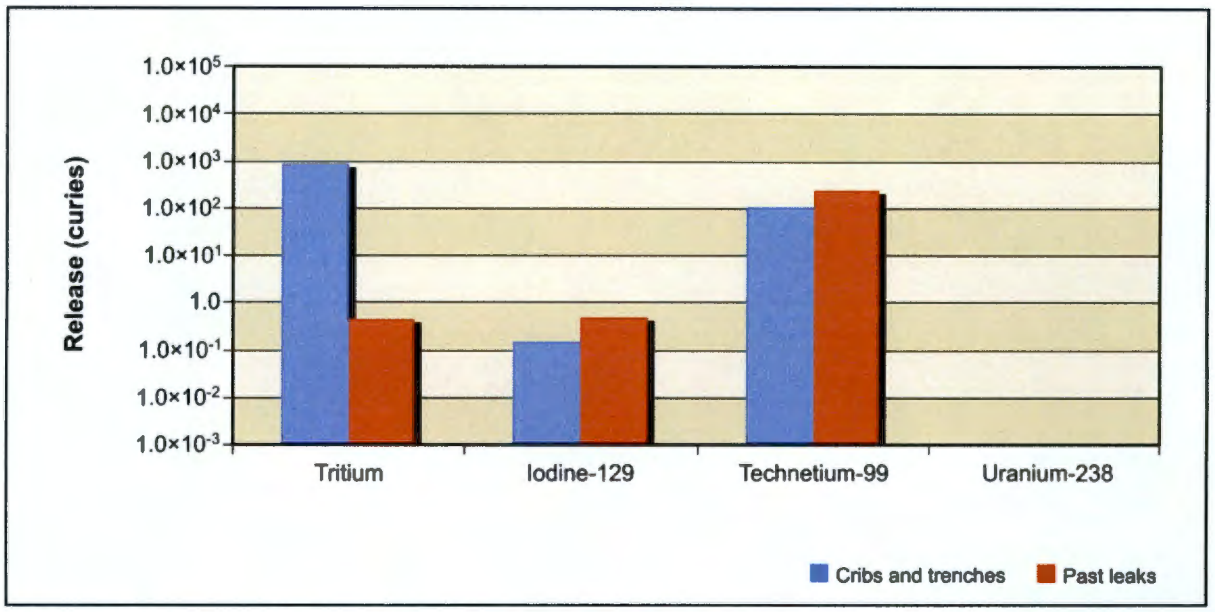


Figure 5–264. Tank Closure Alternative 6B, Option Case, Releases of Radiological Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

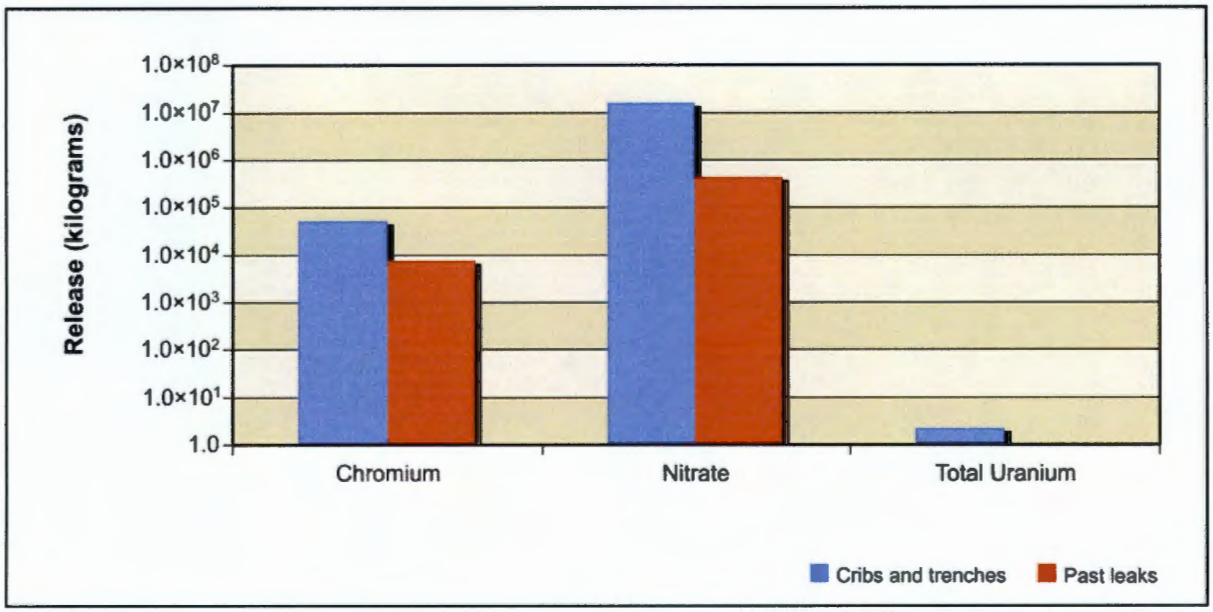


Figure 5–265. Tank Closure Alternative 6B, Option Case, Releases of Chemical Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

For uranium-238 and total uranium, the amount released to the Columbia River from the groundwater is effectively zero, as essentially no uranium reached the groundwater from the vadose zone. For tritium, the amount released to the Columbia River is attenuated by radioactive decay. For cribs and trenches (ditches), only about 3 percent of the tritium released to groundwater reached the Columbia River during the period of analysis. For past leaks, only about 1 percent of the tritium released to groundwater reached the Columbia River. These results suggest that tritium impacts on the Columbia River are strongly attenuated by radioactive decay. They also suggest that uranium-238 and total uranium would not impact the Columbia River, as much of what was released is to be collected when the cribs and trenches (ditches) are removed and their deep plumes remediated.

5.1.1.10.4 Analysis of Concentration Versus Time

This section presents the analysis of Tank Closure Alternative 6B impacts in terms of groundwater concentration versus time at the Core Zone Boundary and the Columbia River. Concentrations of radionuclides are in picocuries per liter, chemicals in micrograms per liter (see Tables 5–8 and 5–9 and Figures 5–266 through 5–279). The benchmark concentration for each radionuclide and chemical is also shown. Because of the discrete nature of the concentration carried across a barrier or the river, a line denoting the 95th percentile upper confidence limit of the concentration is included on a few graphs. This confidence interval was calculated to show when the actual concentration over a certain time interval is likely (95 percent of the time) to be at or below this value. The confidence interval is basically a statistical aid to interpreting data with a significant amount of random fluctuation (noise). The confidence interval was calculated when the concentration had a reasonable degree of noise, the concentration's trend was level, and the concentrations were near the benchmark. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over five orders of magnitude. Tables 5–8 and 5–9 list the maximum concentrations under the Base and Option Cases of the COPCs in the peak year after CY 2050 at the tank farm barriers, Core Zone Boundary, and Columbia River nearshore.

Figure 5–266 shows the concentration versus time for tritium under the Base Case. Releases from cribs and trenches (ditches) cause the groundwater concentrations at the Core Zone Boundary to exceed the benchmark concentrations by about two orders of magnitude for a short period of time during the early part of the period of analysis, around CY 1956. During the same period of time, the Columbia River nearshore concentrations peaked at about one order of magnitude below the benchmark concentration. Because the half-life of tritium is less than 13 years, radioactive decay rapidly attenuates groundwater concentration.

The concentrations of tritium versus time under the Option Case are essentially identical to those under the Base Case (see Figure 5–267).

Figures 5–268 through 5–271 show concentration versus time for iodine-129, technetium-99, chromium, and nitrate (the conservative tracers) under the Base Case. All of the conservative tracers show similar patterns. Releases from cribs and trenches (ditches) cause groundwater concentrations in the Core Zone Boundary to exceed benchmark concentrations by about two orders of magnitude during the early part of the period of analysis in CY 1956. The Columbia River nearshore concentrations never met or exceeded the benchmark concentration, but came to within about one-half to one order of magnitude.

The concentrations of iodine-129, technetium-99, chromium, and nitrate (the conservative tracers) versus time under the Option Case are essentially identical to those under the Base Case (see Figures 5–272 through 5–275).

Table 5–8. Tank Closure Alternative 6B, Base Case, Maximum COPC Concentrations in the Peak Year at the Tank Farm Barriers, Core Zone Boundary, and Columbia River Nearshore

Contaminant	A Barrier	B Barrier	S Barrier	T Barrier	U Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclide in picocuries per liter								
Hydrogen-3 (tritium)	30	5,010	46	7,300	13	6,000	178	20,000
	(2051)	(2054)	(2050)	(2055)	(2052)	(2054)	(2050)	
Technetium-99	**1,390**	**29,300**	**2,560**	**15,500**	140	**24,800**	168	900
	(2050)	(2050)	(2050)	(2051)	(2060)	(2050)	(2214)	
Iodine-129	**3**	**39**	**5**	**29**	0.3	**31**	0.3	1
	(2050)	(2057)	(2050)	(2050)	(2054)	(2057)	(2319)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	0	**34**	0	13	0	10	0	15
	(1940)	(11,742)	(1940)	(11,780)	(1940)	(11,758)	(11,844)	
Chemical in micrograms per liter								
Chromium	7	**3,180**	**283**	**771**	9	**1,660**	33	100
	(2050)	(2055)	(2050)	(2050)	(2050)	(2050)	(2695)	
Nitrate	511	**1,540,000**	8,650	**133,000**	624	**1,010,000**	8,420	45,000
	(2059)	(2050)	(2050)	(2051)	(2057)	(2050)	(2450)	
Total uranium	0	10	0	4	0	7	0	30
	(1940)	(11,678)	(1940)	(11,755)	(1940)	(11,678)	(11,508)	

Note: Corresponding calendar years shown in parentheses. Concentrations that would exceed the benchmark value are indicated in **bold** text.
Key: COPC=constituent of potential concern.

Table 5–9. Tank Closure Alternative 6B, Option Case, Maximum COPC Concentrations in the Peak Year at the Tank Farm Barriers, Core Zone Boundary, and Columbia River Nearshore

Contaminant	A Barrier	B Barrier	S Barrier	T Barrier	U Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclide in picocuries per liter								
Hydrogen-3 (tritium)	30	4,870	46	6,680	13	5,190	172	20,000
	(2051)	(2073)	(2050)	(2067)	(2052)	(2073)	(2088)	
Technetium-99	**1,390**	**27,000**	**2,560**	**15,500**	140	**22,700**	162	900
	(2050)	(2058)	(2050)	(2051)	(2060)	(2058)	(2304)	
Iodine-129	**3**	**38**	**5**	**29**	0.3	**30**	0.3	1
	(2050)	(2051)	(2050)	(2050)	(2054)	(2052)	(2319)	
Chemical in microgram per liter								
Chromium	7	**3,770**	**283**	**778**	9	**1,760**	28	100
	(2050)	(2087)	(2050)	(2050)	(2050)	(2061)	(2166)	
Nitrate	511	**1,690,000**	8,650	**154,000**	624	**1,230,000**	7,110	45,000
	(2059)	(2053)	(2050)	(2084)	(2057)	(2053)	(2056)	

Note: Corresponding calendar years shown in parentheses. Concentrations that would exceed the benchmark value are indicated in **bold** text.
Key: COPC=constituent of potential concern.

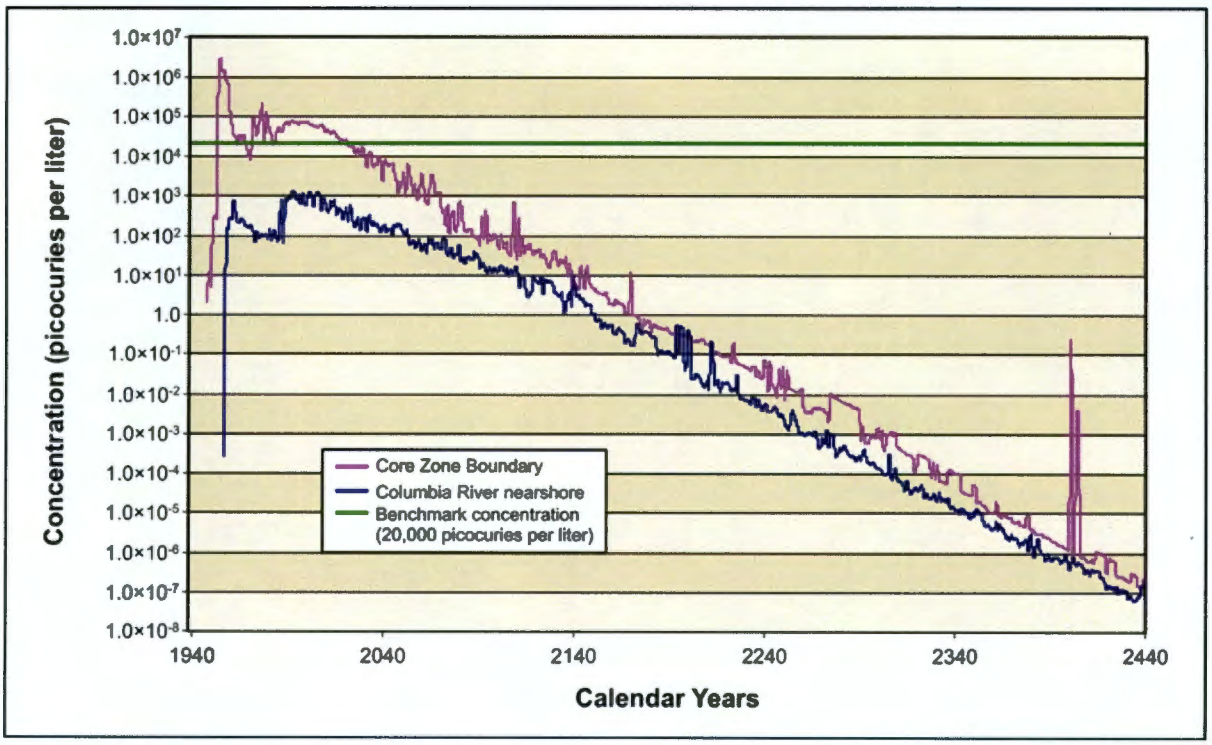


Figure 5–266. Tank Closure Alternative 6B, Base Case, Hydrogen-3 (Tritium) Concentration Versus Time

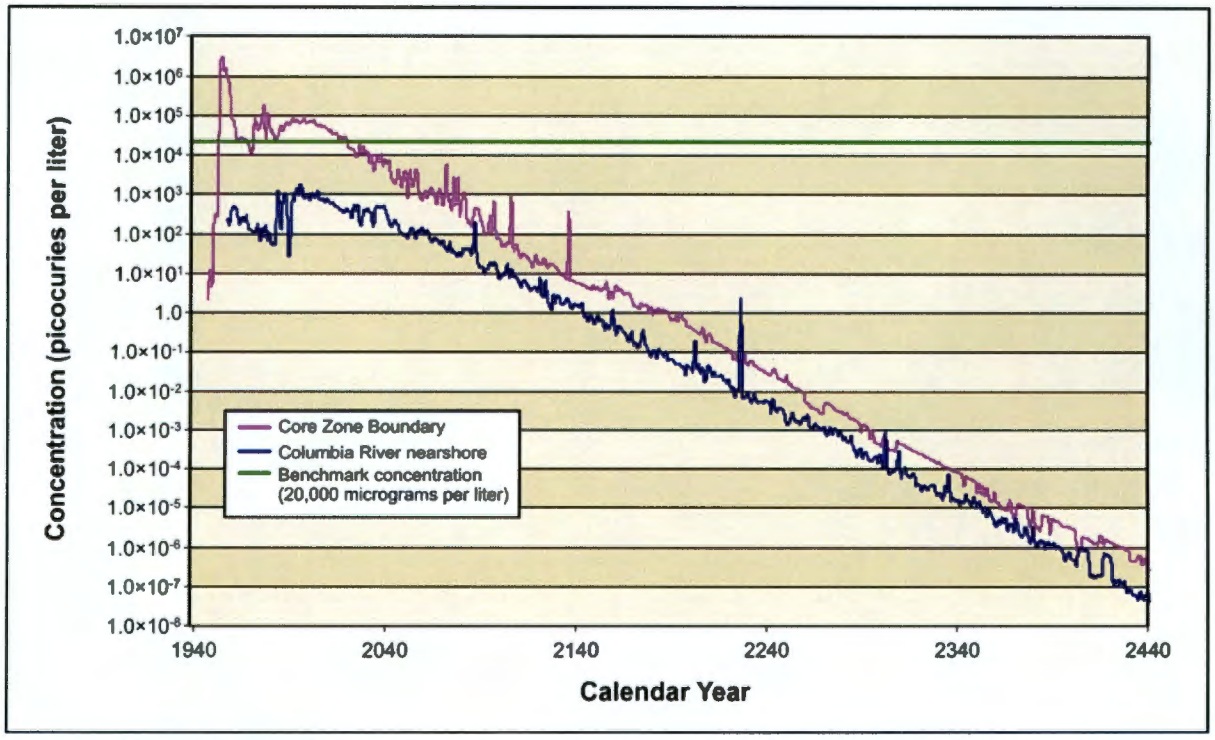


Figure 5–267. Tank Closure Alternative 6B, Option Case, Hydrogen-3 (Tritium) Concentration Versus Time

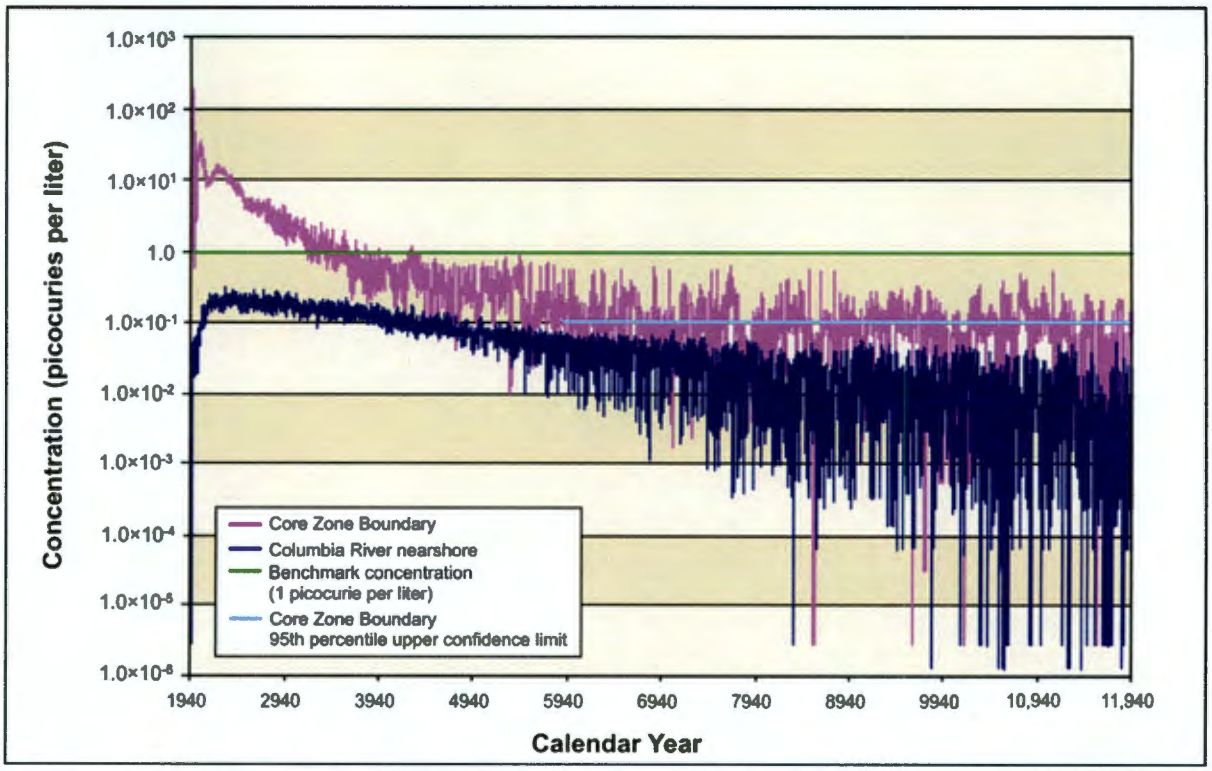


Figure 5–268. Tank Closure Alternative 6B, Base Case, Iodine-129 Concentration Versus Time

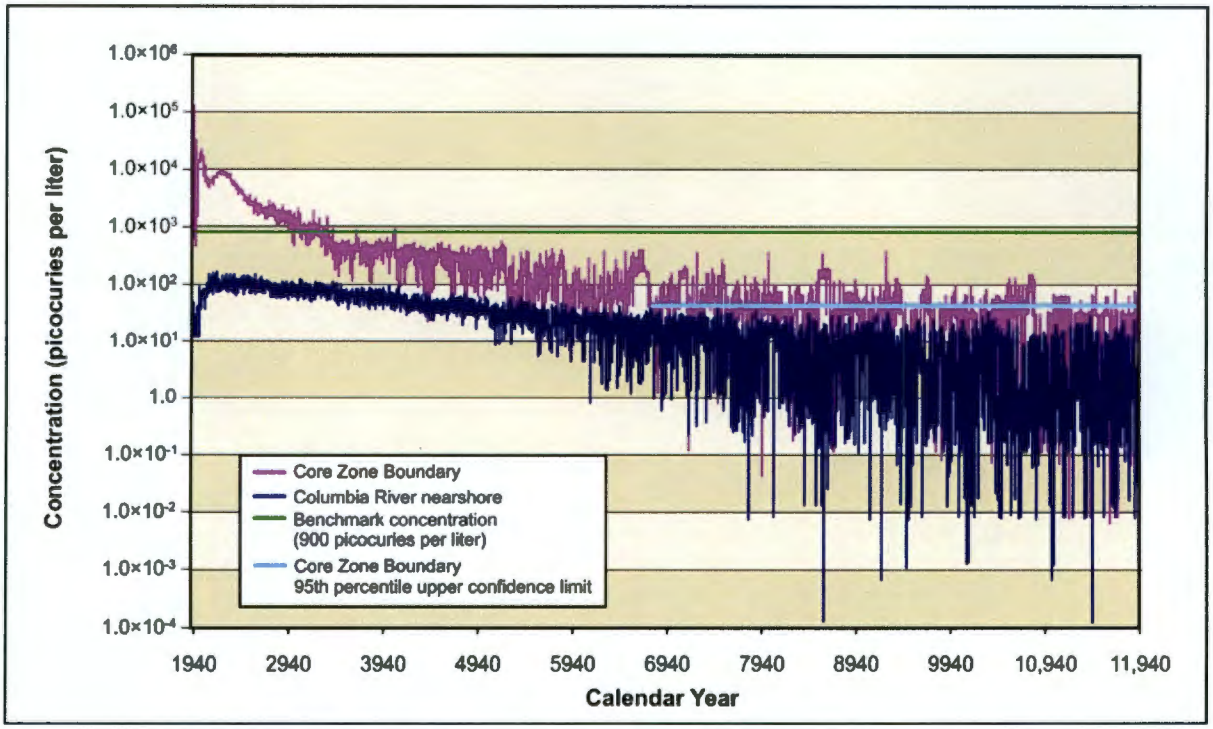


Figure 5–269. Tank Closure Alternative 6B, Base Case, Technetium-99 Concentration Versus Time

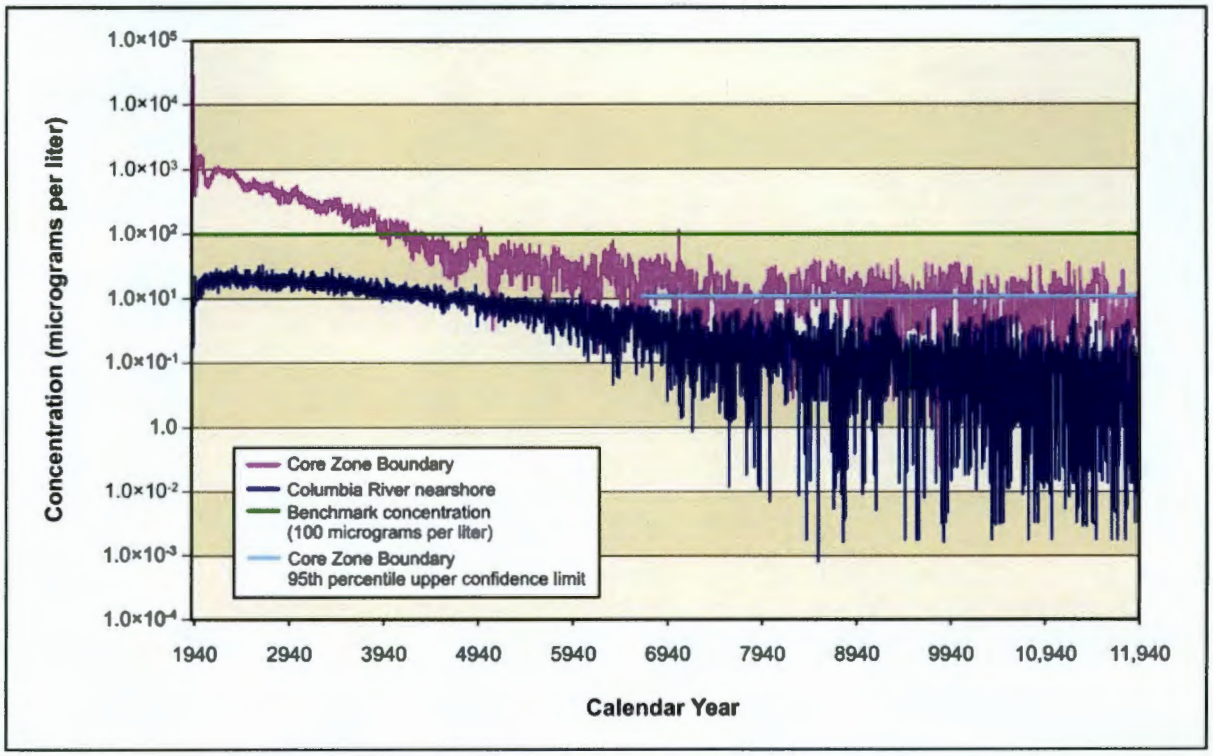


Figure 5–270. Tank Closure Alternative 6B, Base Case, Chromium Concentration Versus Time

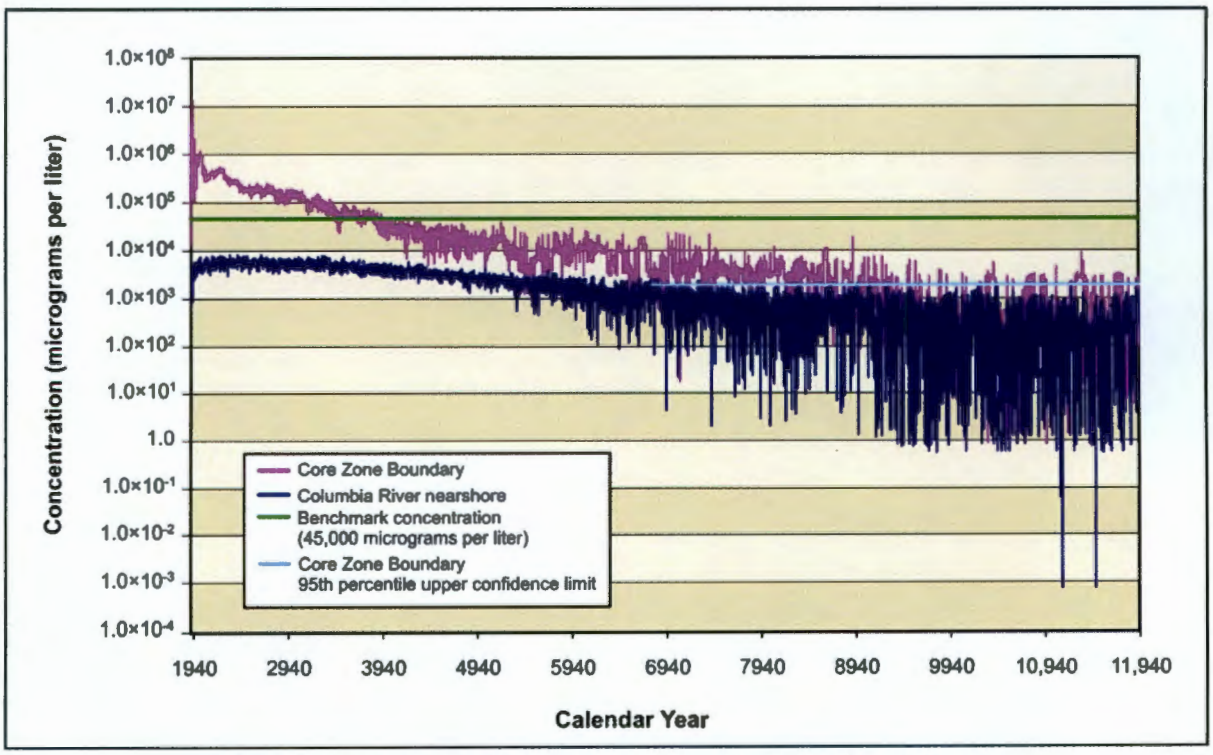


Figure 5–271. Tank Closure Alternative 6B, Base Case, Nitrate Concentration Versus Time

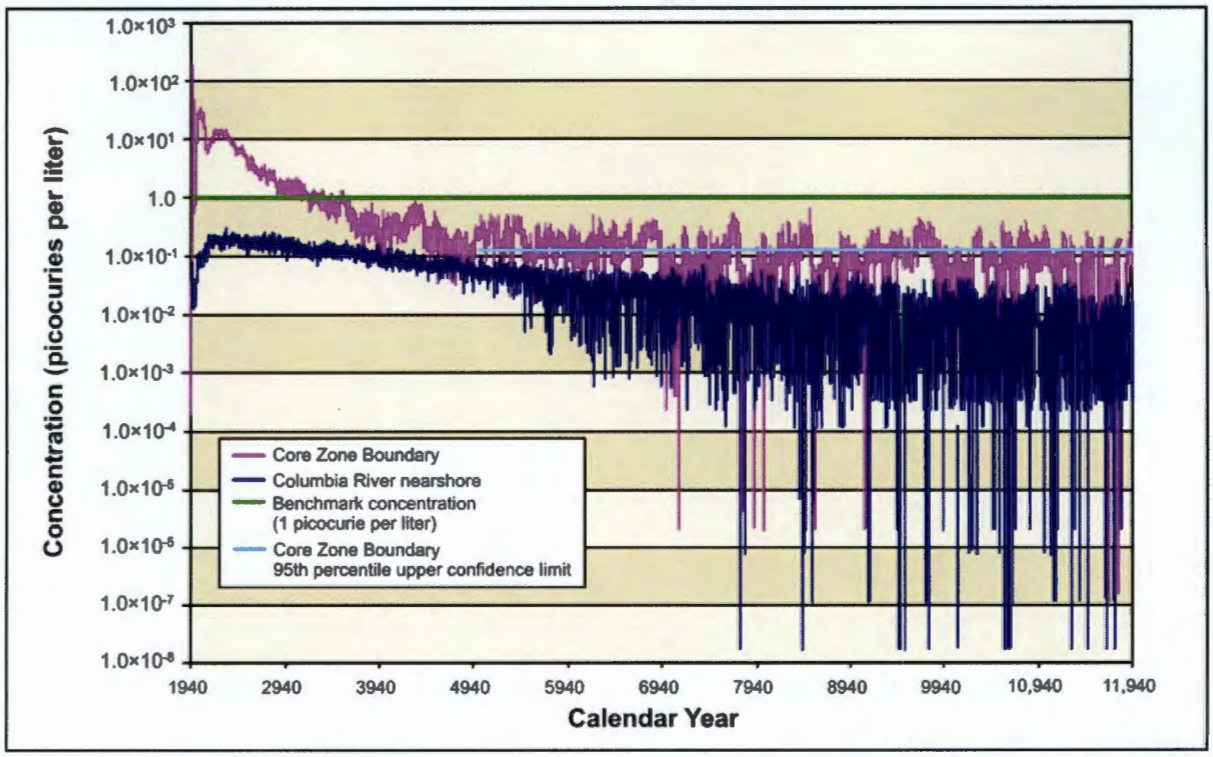


Figure 5–272. Tank Closure Alternative 6B, Option Case, Iodine-129 Concentration Versus Time

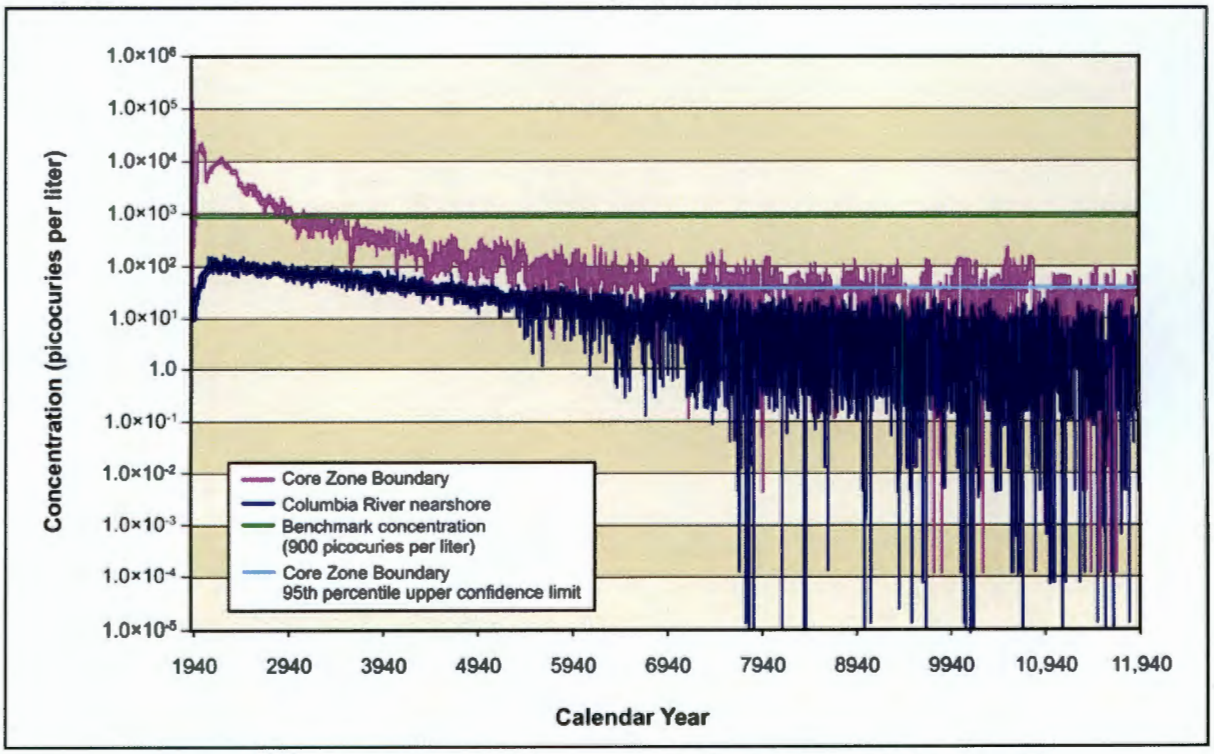


Figure 5–273. Tank Closure Alternative 6B, Option Case, Technetium-99 Concentration Versus Time

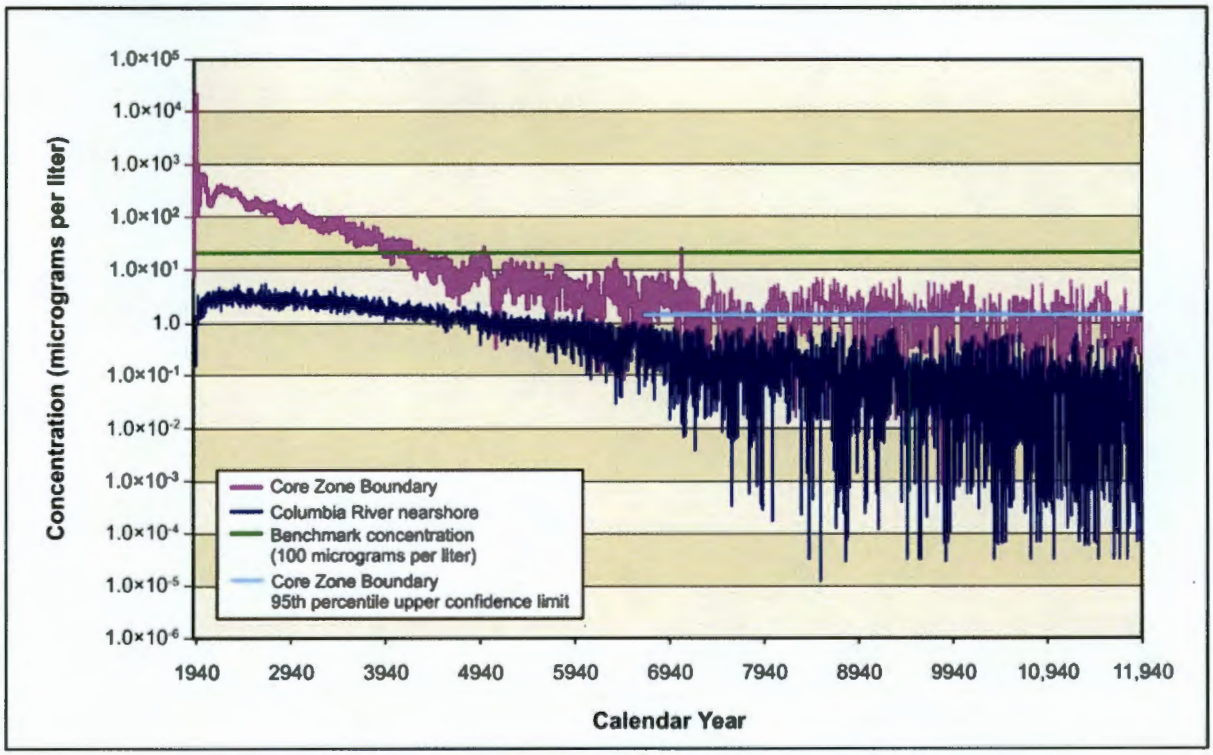


Figure 5–274. Tank Closure Alternative 6B, Option Case, Chromium Concentration Versus Time

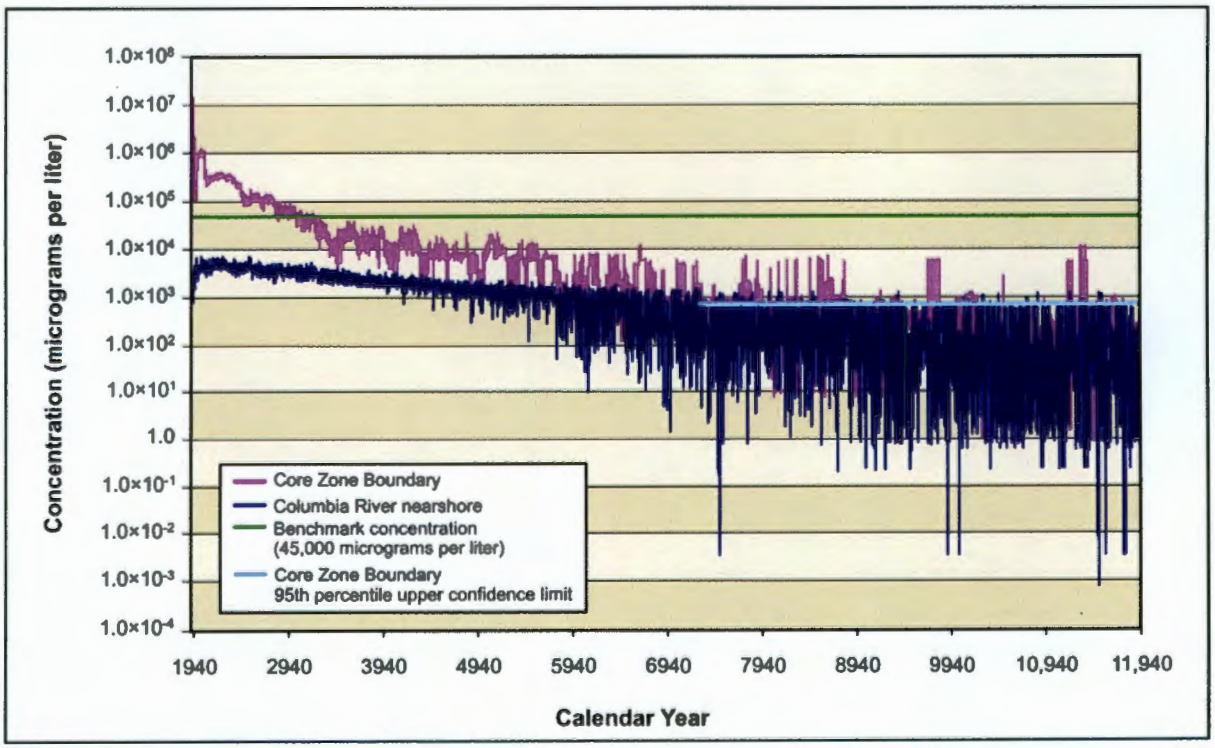


Figure 5–275. Tank Closure Alternative 6B, Option Case, Nitrate Concentration Versus Time

Figures 5–276 and 5–277 show concentration versus time for uranium-238 and total uranium under the Base Case. Although uranium-238 concentrations in the Core Zone Boundary began to approach the benchmark toward the latter part of the period of analysis, they never reached it. Total uranium concentrations at the Core Zone Boundary also began to increase toward the end of the period of analysis but never came to within one order of magnitude of the benchmark. The concentration levels of uranium-238 and total uranium at the Columbia River nearshore never came to within about two orders of magnitude below the benchmark.

Under the Option Case, uranium-238 concentrations in the Core Zone Boundary generally stayed about three to four orders of magnitude below the benchmark concentration, except for a short spike to about one order of magnitude below the benchmark at the beginning of the period of analysis (see Figure 5–278). At around CY 7500, the uranium-238 Core Zone Boundary concentrations fell to about four orders of magnitude below the benchmark. The Columbia River nearshore concentrations of uranium-238 stayed fairly constant at about four orders of magnitude below the benchmark. Total uranium concentrations at the Core Zone Boundary generally stayed about three to four orders of magnitude below the benchmark (see Figure 5–279). The Columbia River nearshore concentrations of total uranium remained fairly constant at around four and a half orders of magnitude below the benchmark.

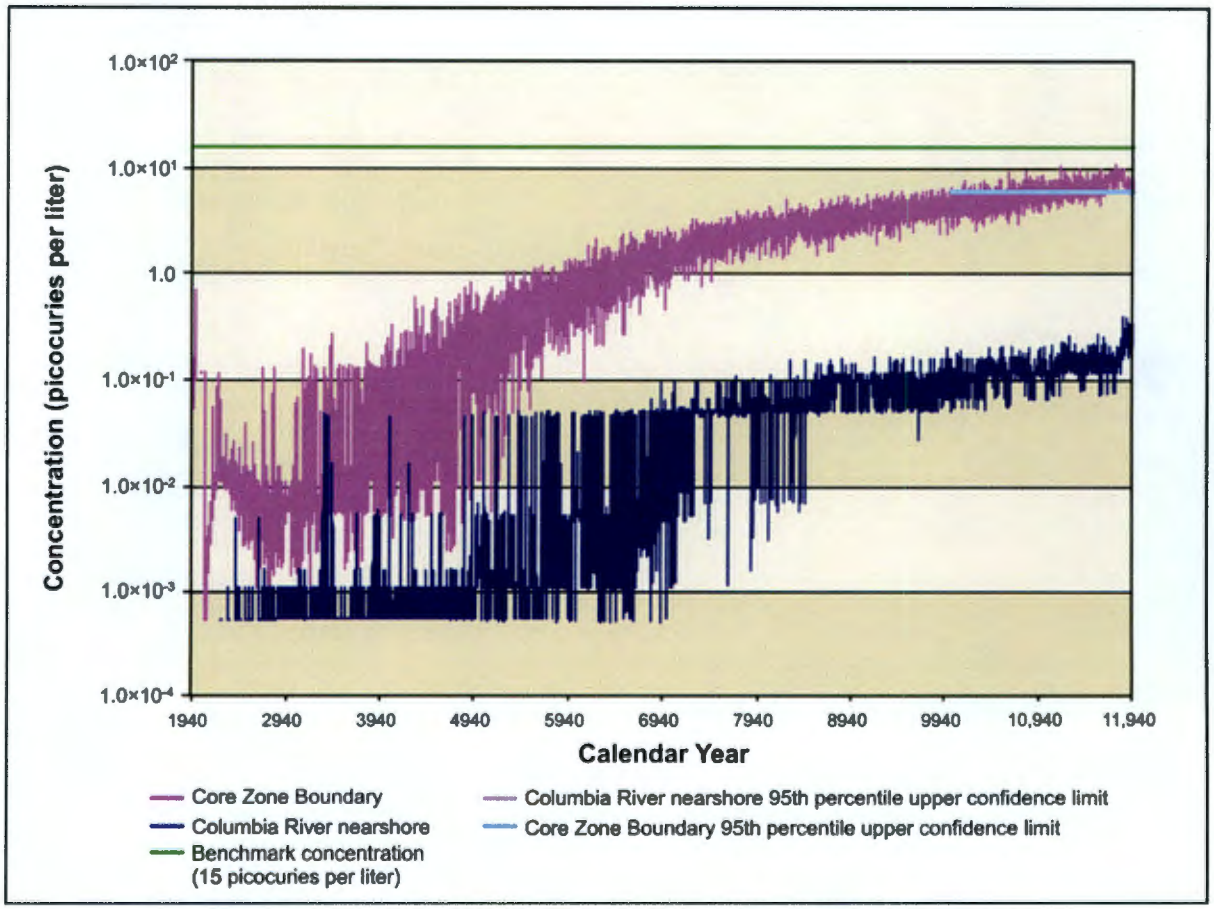


Figure 5–276. Tank Closure Alternative 6B, Base Case, Uranium-238 Concentration Versus Time

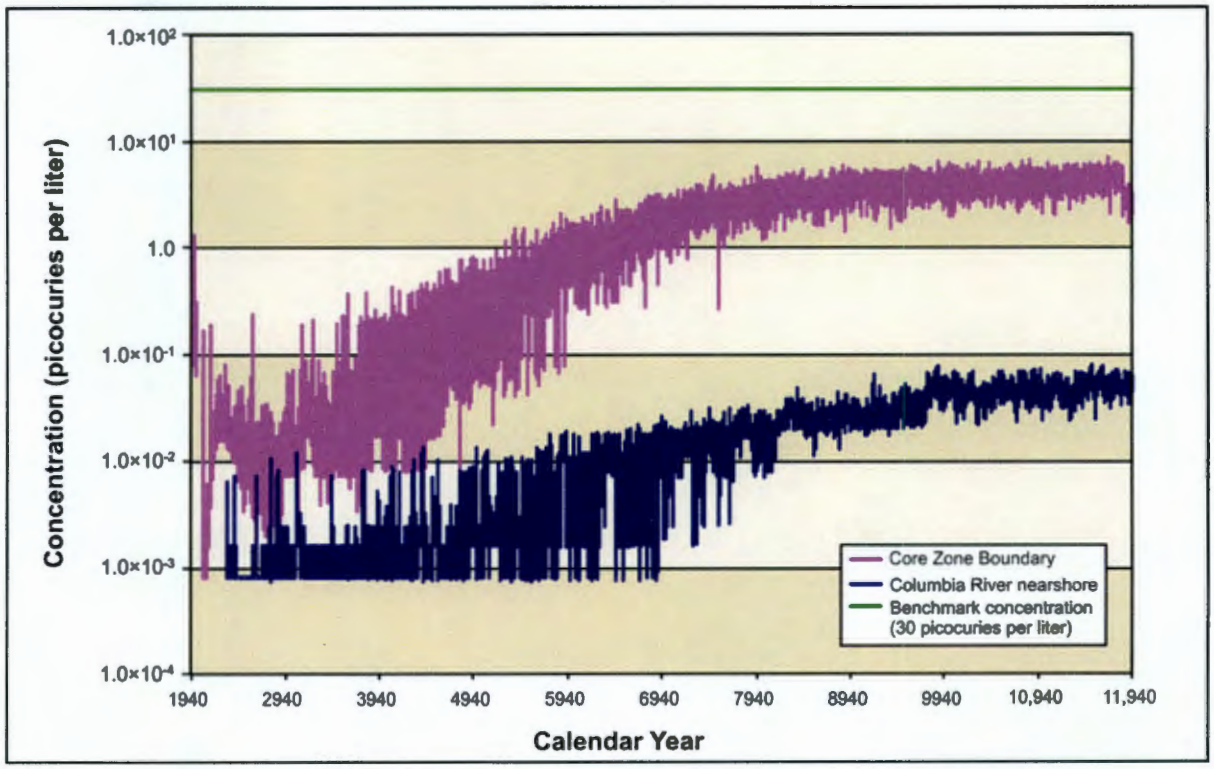


Figure 5–277. Tank Closure Alternative 6B, Base Case, Total Uranium Concentration Versus Time

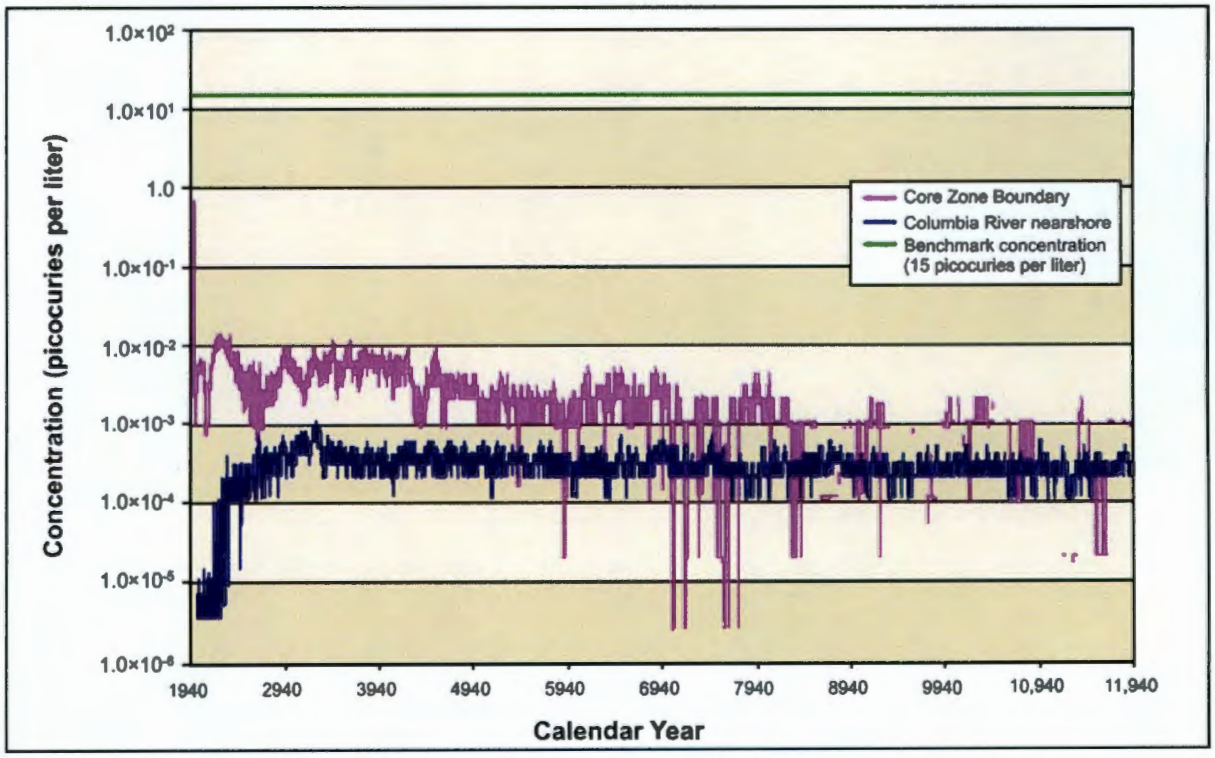


Figure 5–278. Tank Closure Alternative 6B, Option Case, Uranium-238 Concentration Versus Time

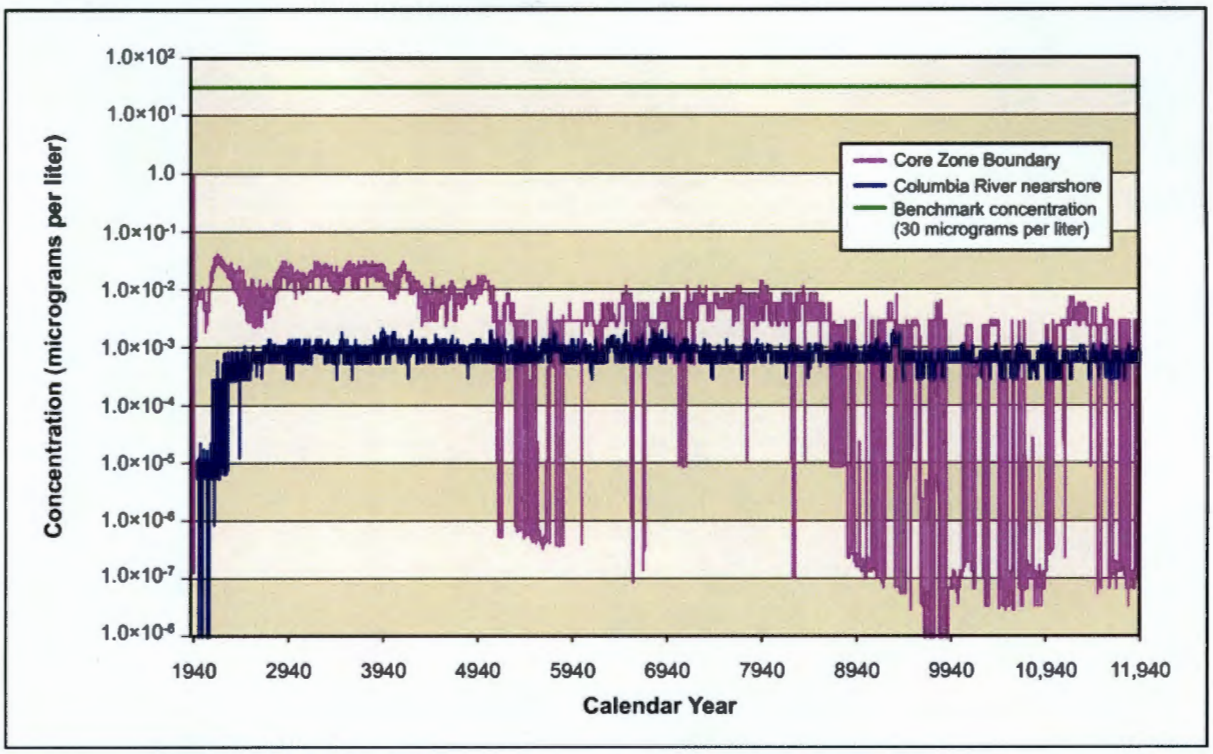
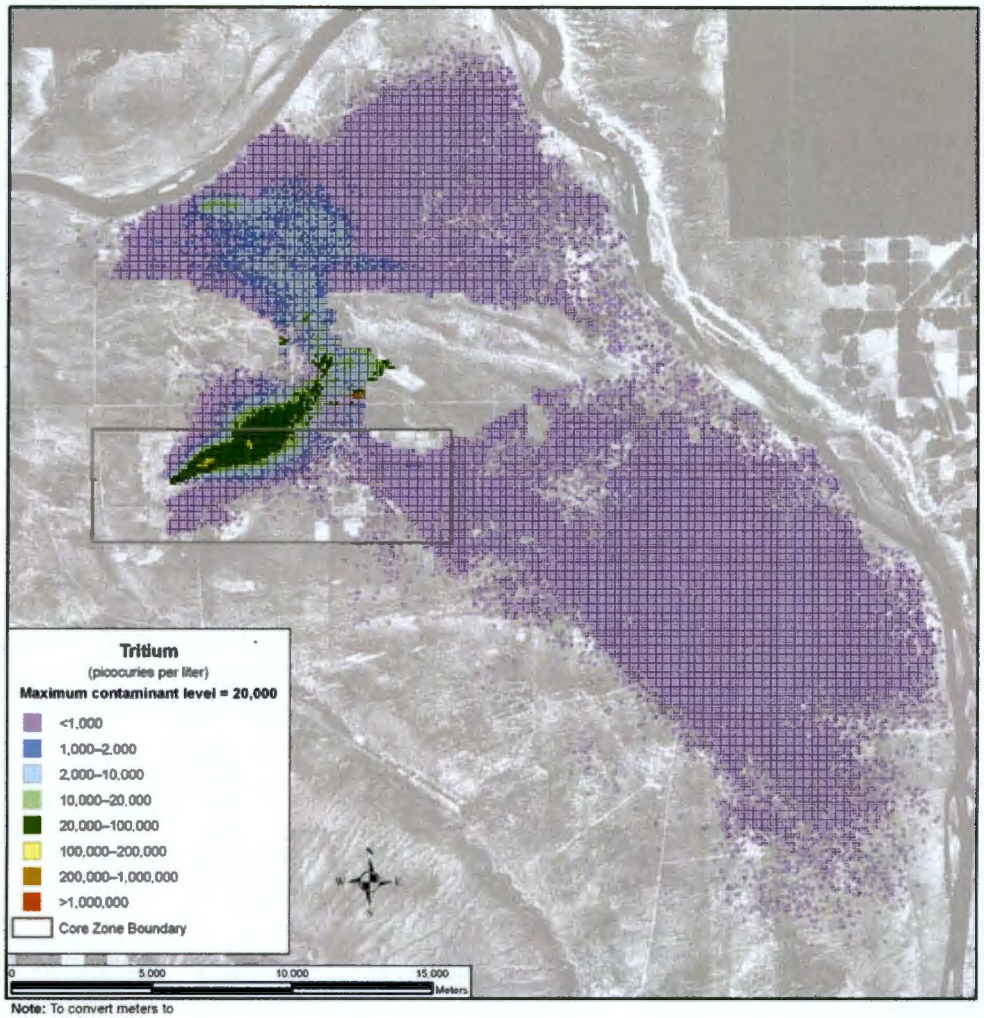


Figure 5–279. Tank Closure Alternative 6B, Option Case, Total Uranium Concentration Versus Time

5.1.1.10.5 Analysis of Spatial Distribution of Concentration

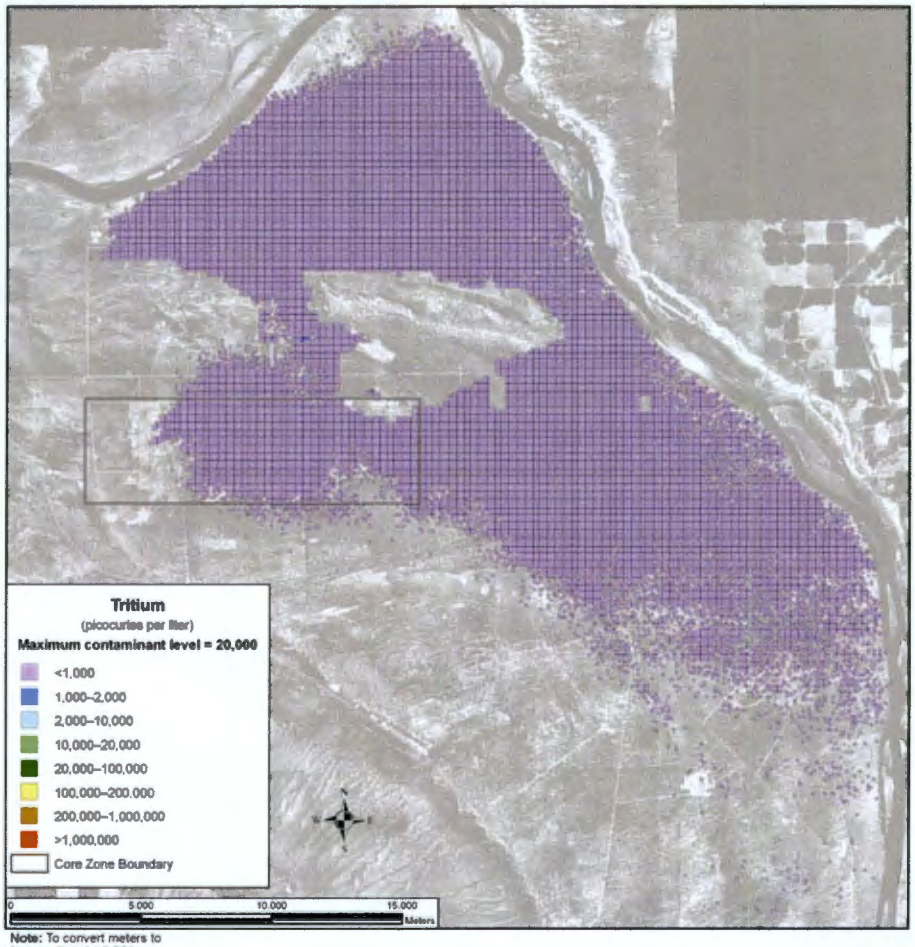
This section presents the impacts of Tank Closure Alternative 6B in terms of the spatial distribution of groundwater concentration at selected times. Concentrations of radionuclides are in picocuries per liter, chemicals in micrograms per liter (see Figures 5–280 through 5–324). Concentrations for each radionuclide and chemical are indicated by a color scale that is relative to the benchmark concentration. Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations less than the benchmark concentration are indicated by the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude.

Figure 5–280 shows the spatial distribution of groundwater concentration for tritium during CY 2005 under the Base Case. Releases from cribs and trenches (ditches) and past leaks, associated primarily with the T, TX, and TY tank farms, result in a groundwater concentration plume (exceeding the benchmark concentration) that extends from the center part of the 200-West Area northeast, crossing the Core Zone Boundary, and extending toward Gable Gap. Peak concentrations in this plume are about 10 to 20 times greater than the benchmark, and mostly contained within the Core Zone Boundary. The overall tritium concentrations are attenuated by radioactive decay to levels less than one-twentieth of the benchmark concentration by CY 2135, although a few minor traces from about one-twentieth to one-tenth below the benchmark can be found in Gable Gap (see Figure 5–281).



Note: To convert meters to feet, multiply by 3.281

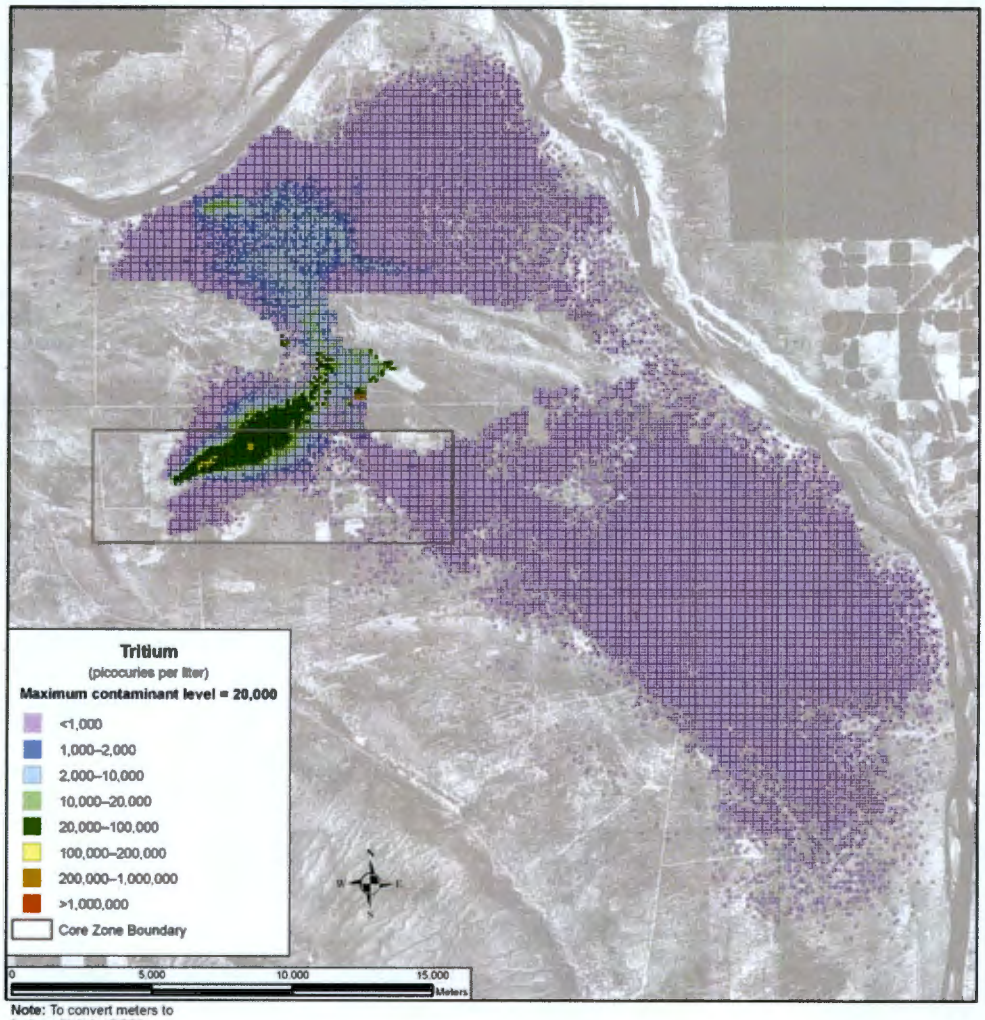
Figure 5–280. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

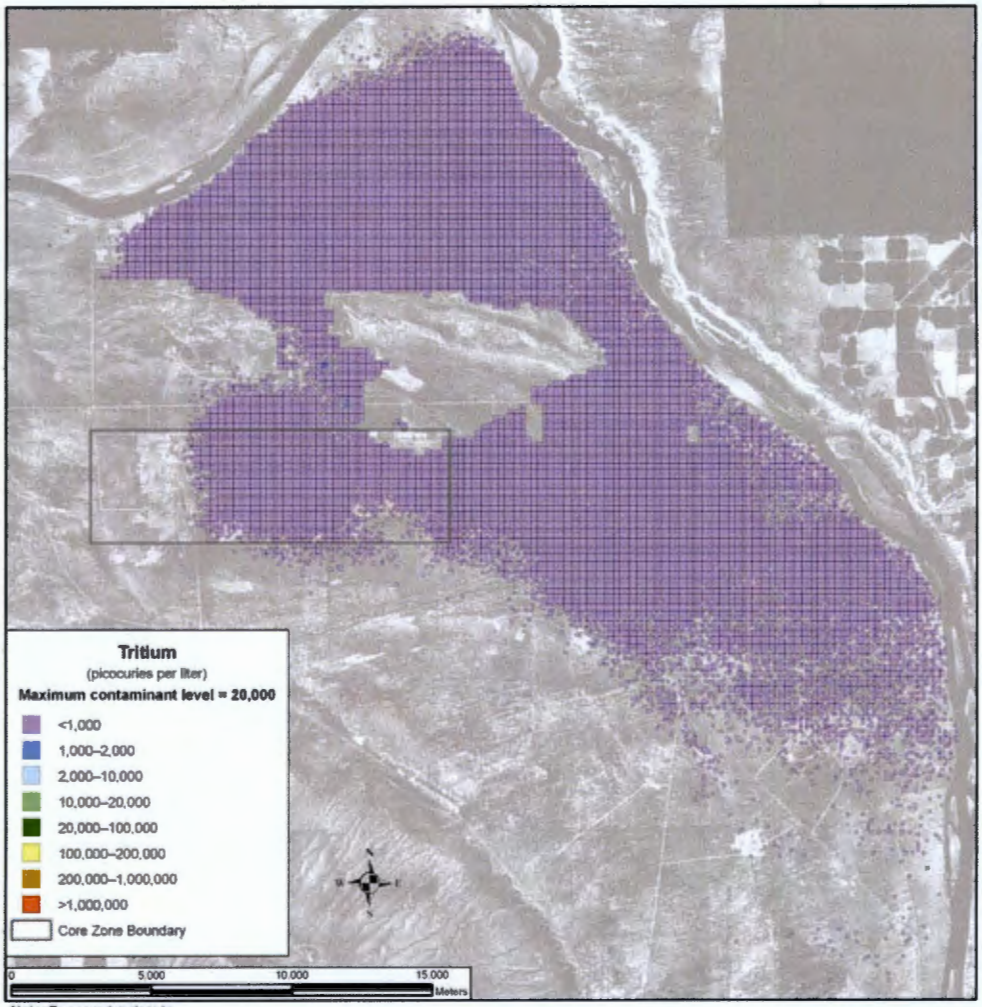
Figure 5–281. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2135

The spatial distribution of groundwater concentrations for tritium under the Option Case, which would include removal of the six sets of cribs and trenches (ditches) and remediation of their plumes within the vadose zone, is essentially identical to that under the Base Case (see Figures 5–282 and 5–283).



Note: To convert meters to feet, multiply by 3.281

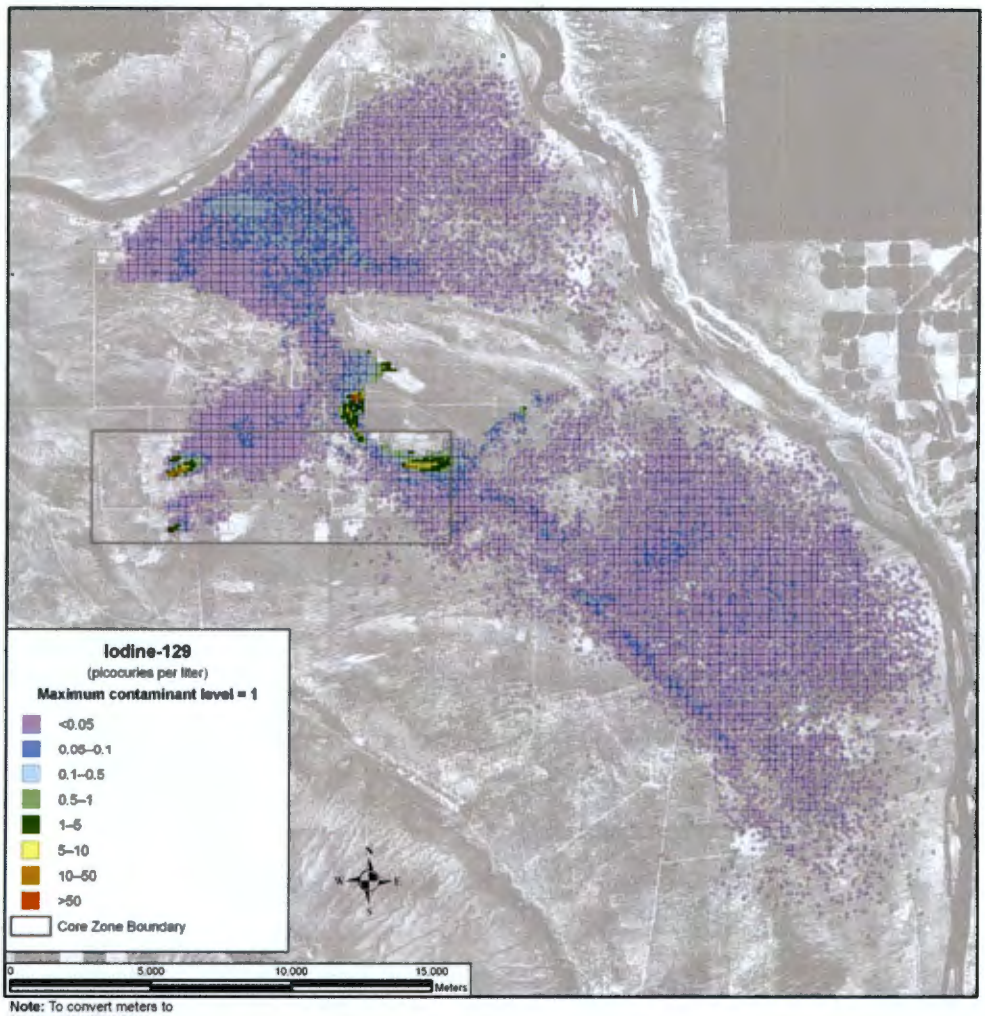
Figure 5–282. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

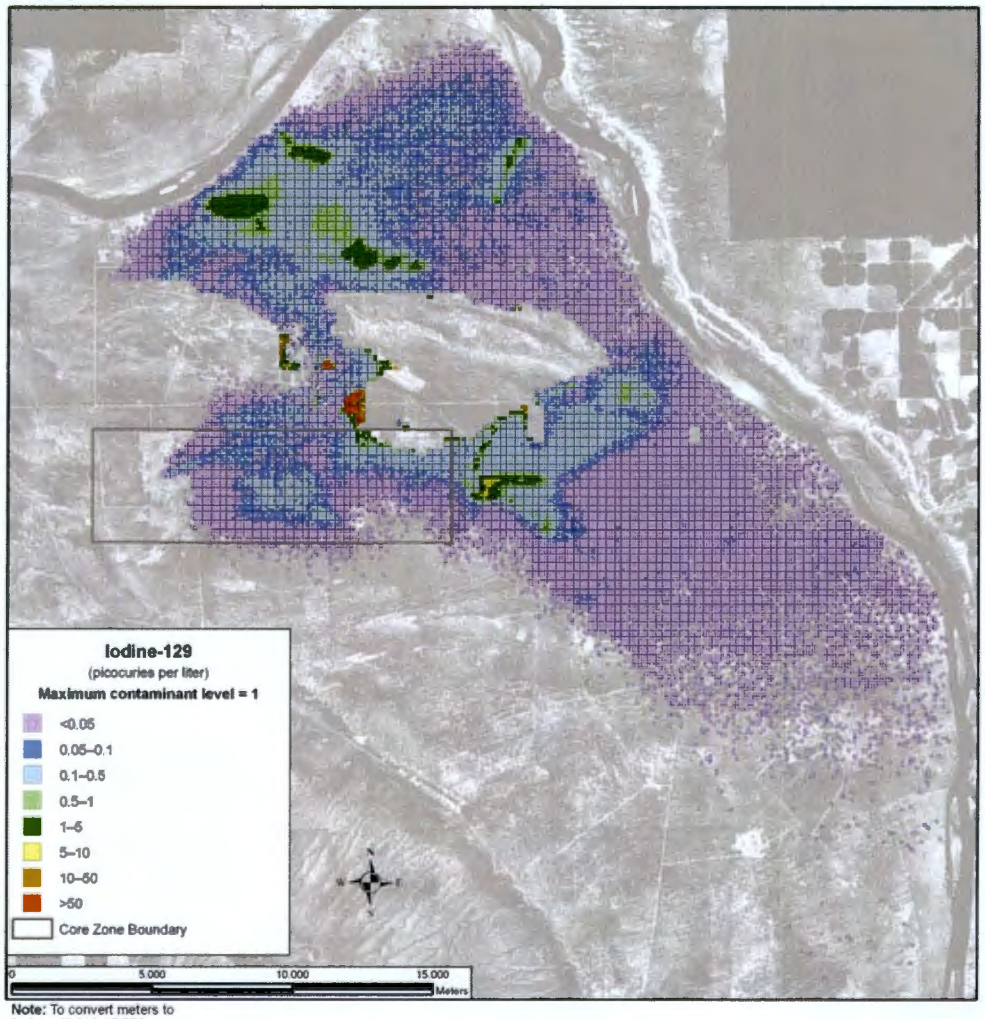
Figure 5–283. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2135

Figure 5–284 shows the spatial distribution of groundwater concentration for iodine-129 during CY 2005 under the Base Case. Analysis releases from cribs and trenches (ditches) and past leaks result in groundwater concentration plumes that exceed the benchmark concentration associated with the T Barrier, B Barrier, and A Barrier. Peak concentrations in this plume are about 10 to 30 times greater than the benchmark, and mostly contained within the Core Zone Boundary. By CY 2135, the contaminant plumes have spread further north through Gable Gap and further east toward the Columbia River (see Figure 5–285). In the plume north of Gable Gap, contaminant levels have begun to meet the benchmark. In the east, just outside of the Core Zone Boundary, levels have risen 5 to 10 times above the benchmark. By CY 7140, most of the mass in the plume has reached the Columbia River, with only a small pocket with high concentrations in the southern region of Gable Gap extending north from the B Barrier (see Figure 5–286). Technetium-99, chromium, and nitrate (see Figures 5–287 through 5–295) show similar spatial distributions at selected times. Iodine-129, technetium-99, chromium, and nitrate are all conservative tracers (i.e., move at the rate of the pore water velocity).



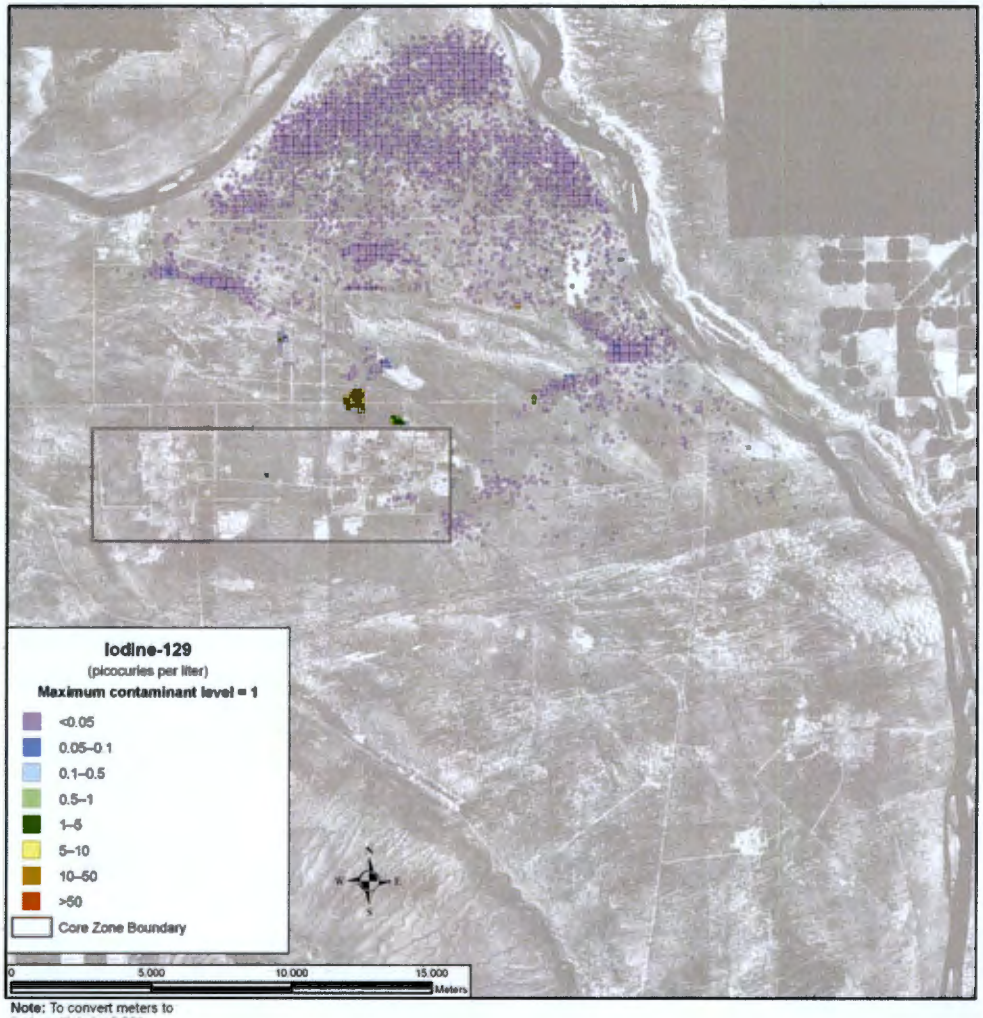
Note: To convert meters to feet, multiply by 3.281

Figure 5–284. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2005



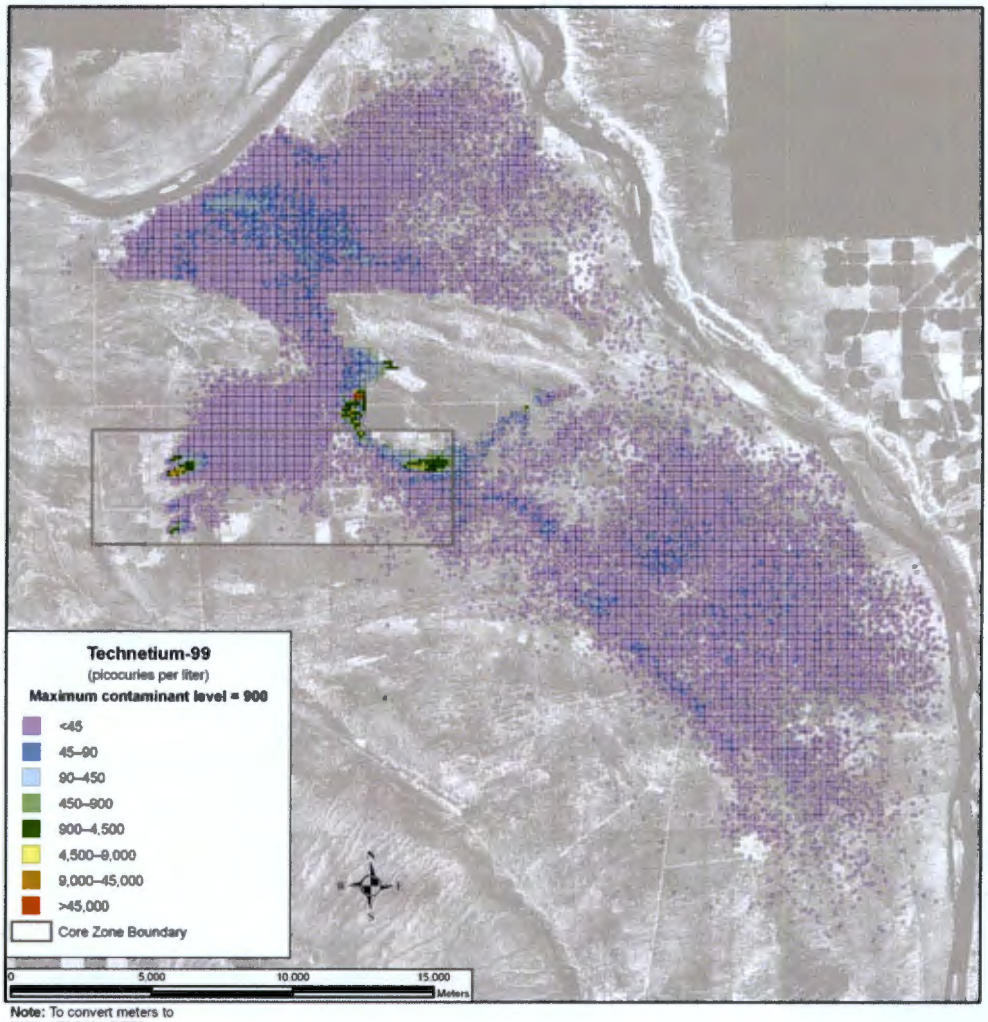
Note: To convert meters to feet, multiply by 3.281

Figure 5–285. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2135



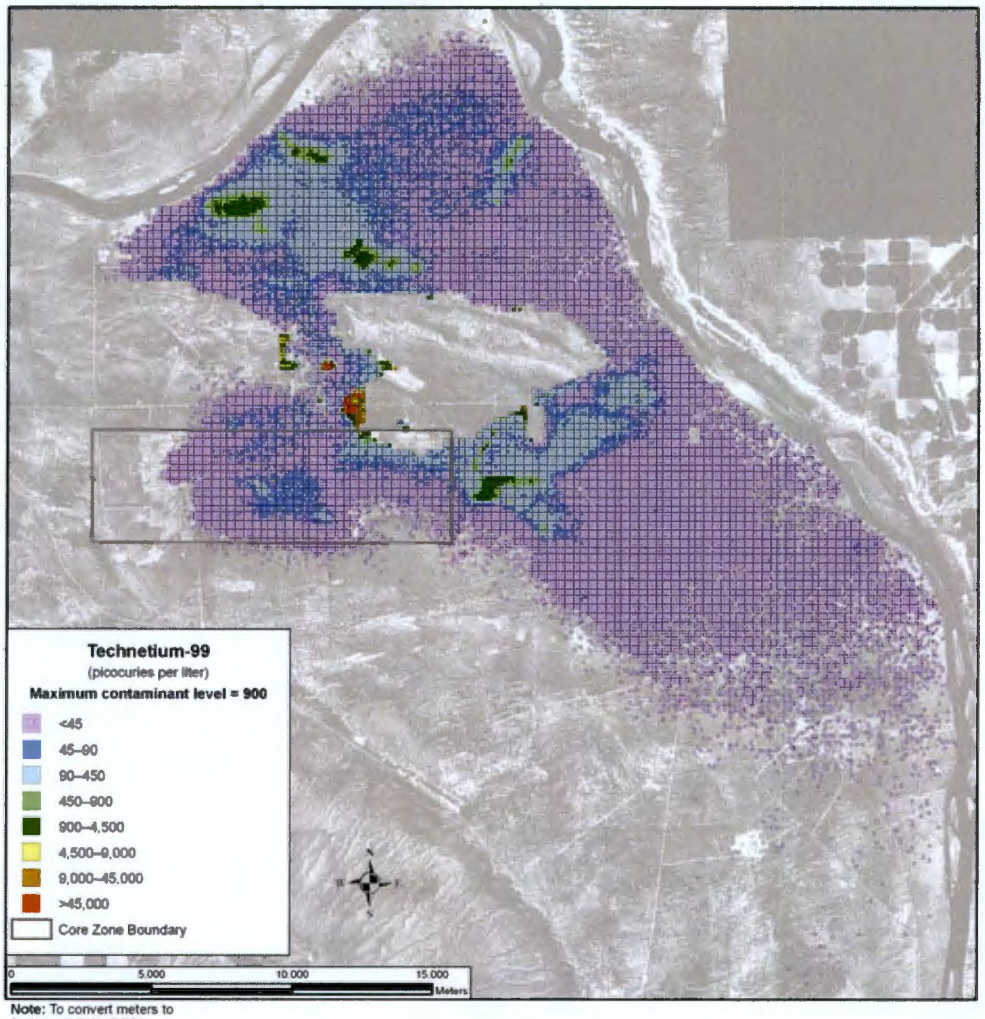
Note: To convert meters to feet, multiply by 3.281

Figure 5–286. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140



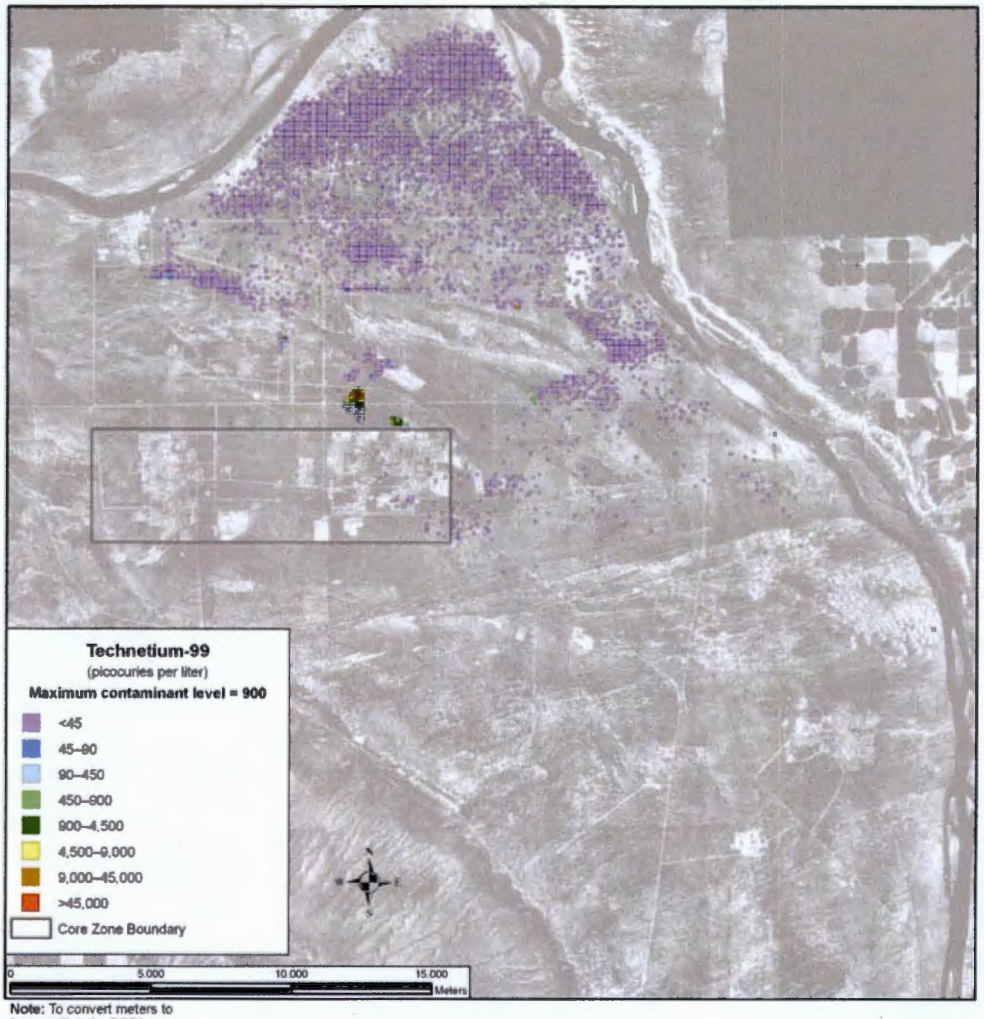
Note: To convert meters to feet, multiply by 3.281

Figure 5–287. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2005



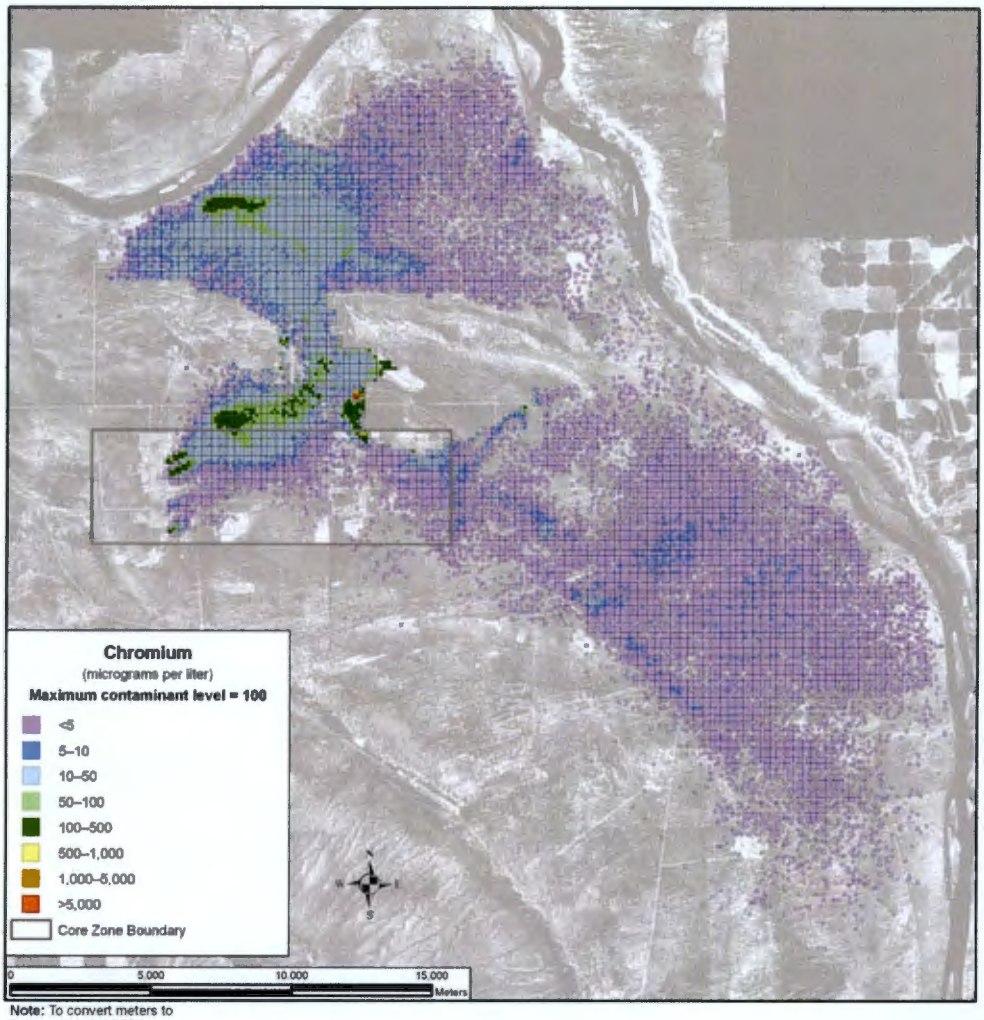
Note: To convert meters to feet, multiply by 3.281

Figure 5–288. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2135



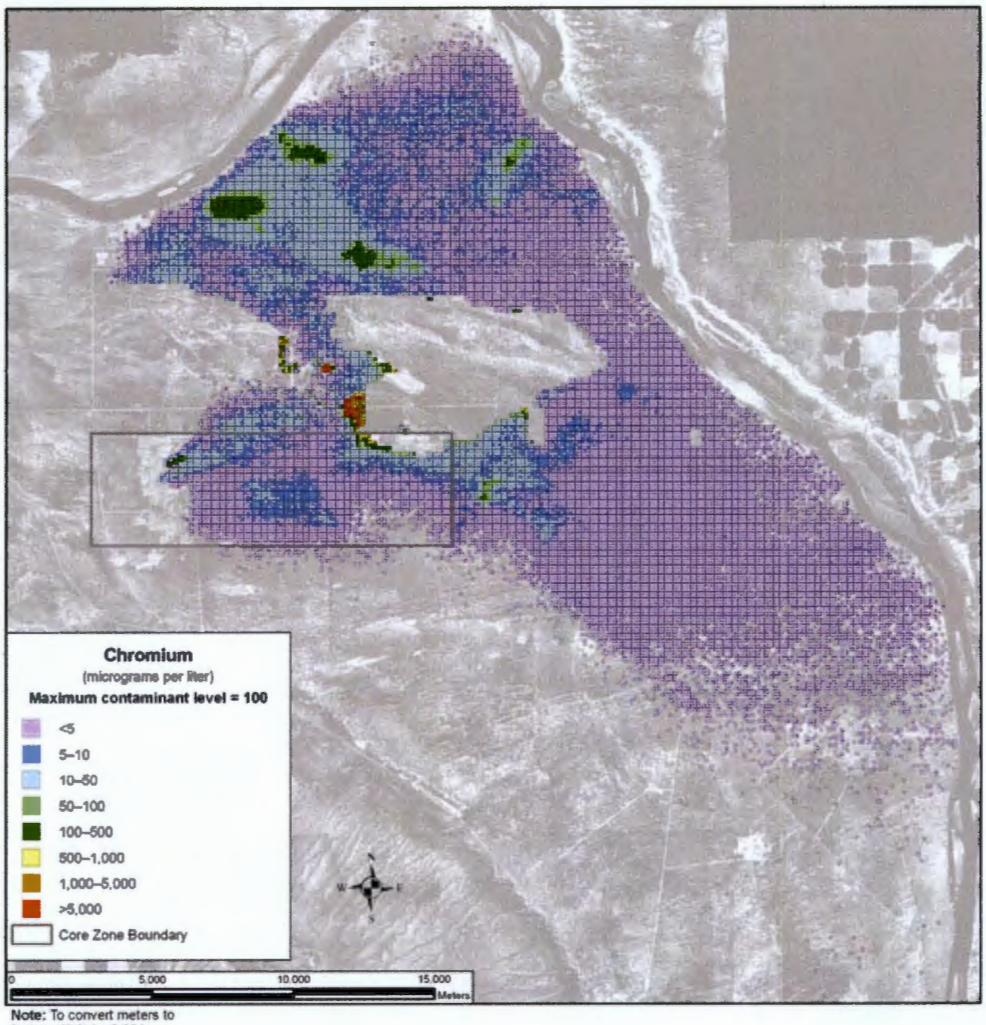
Note: To convert meters to feet, multiply by 3.281

Figure 5–289. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140



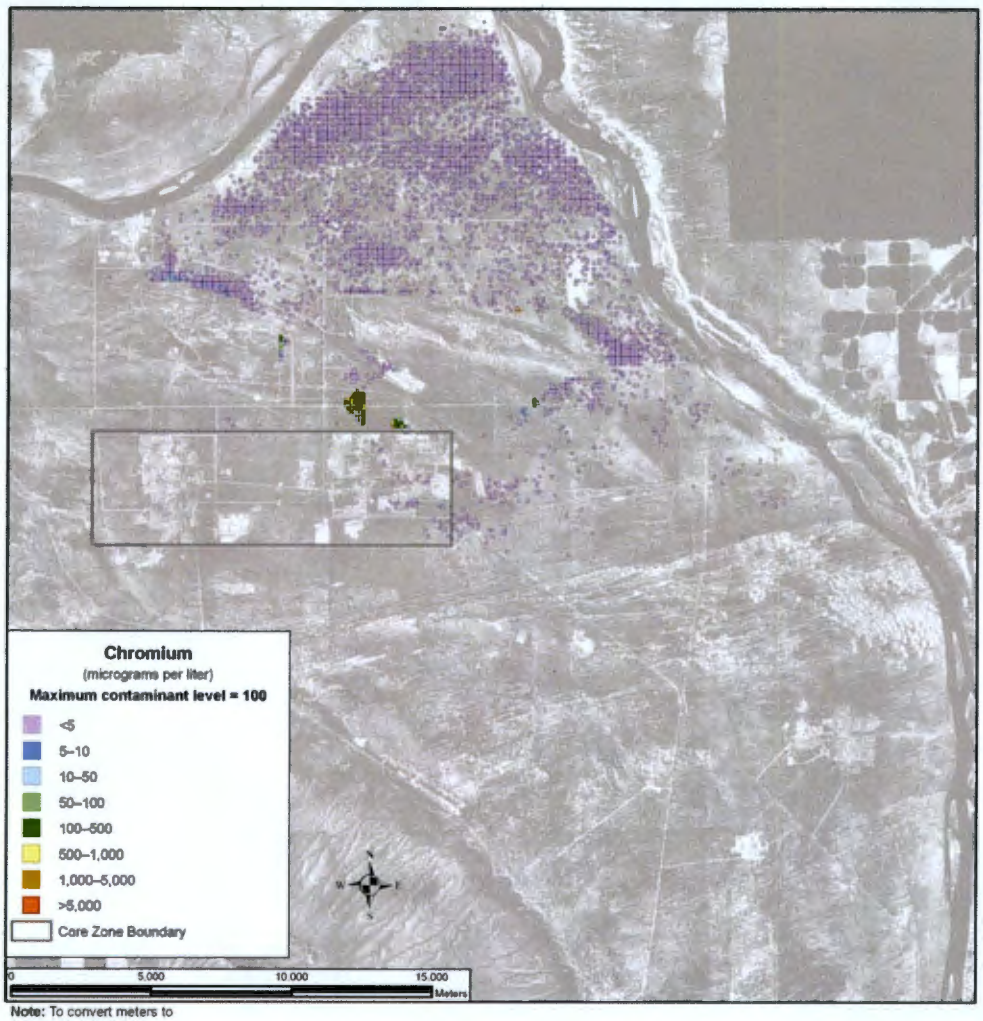
Note: To convert meters to feet, multiply by 3.281

Figure 5–290. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 2005



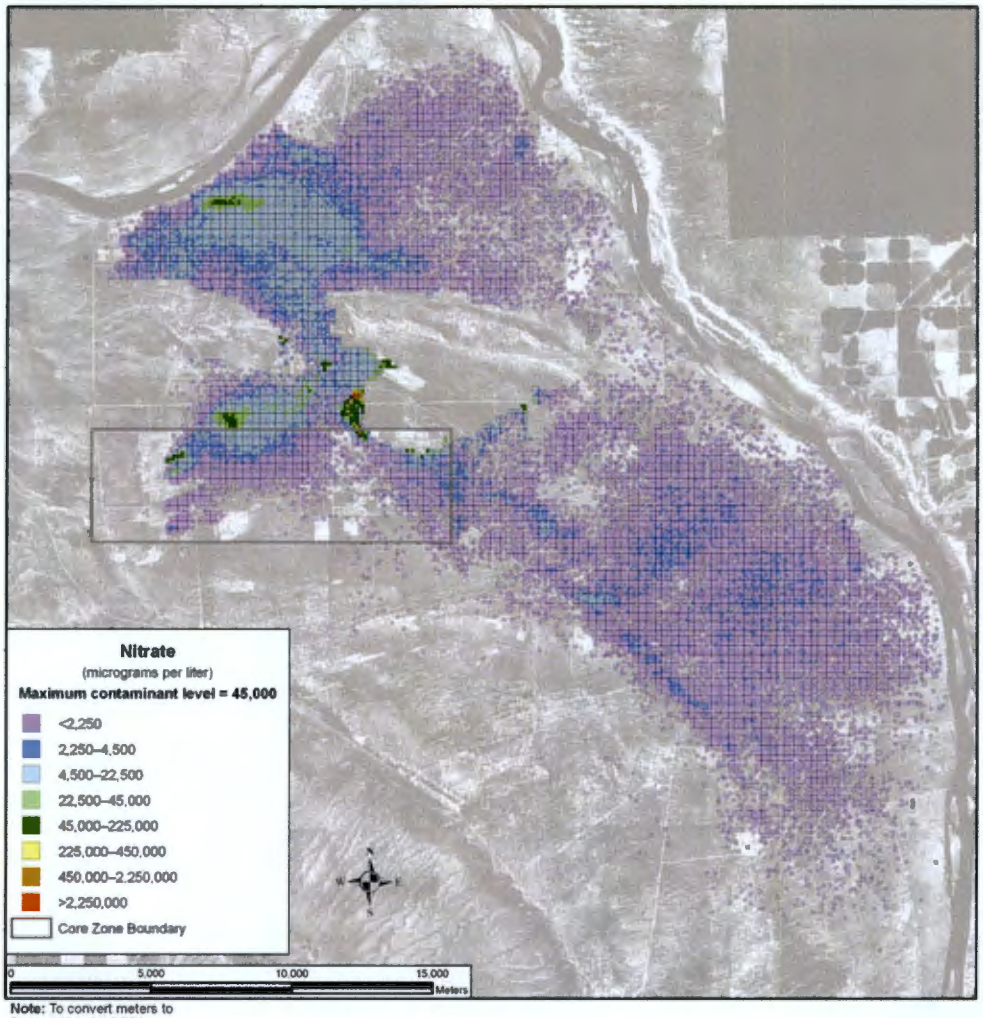
Note: To convert meters to feet, multiply by 3.281

Figure 5–291. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 2135



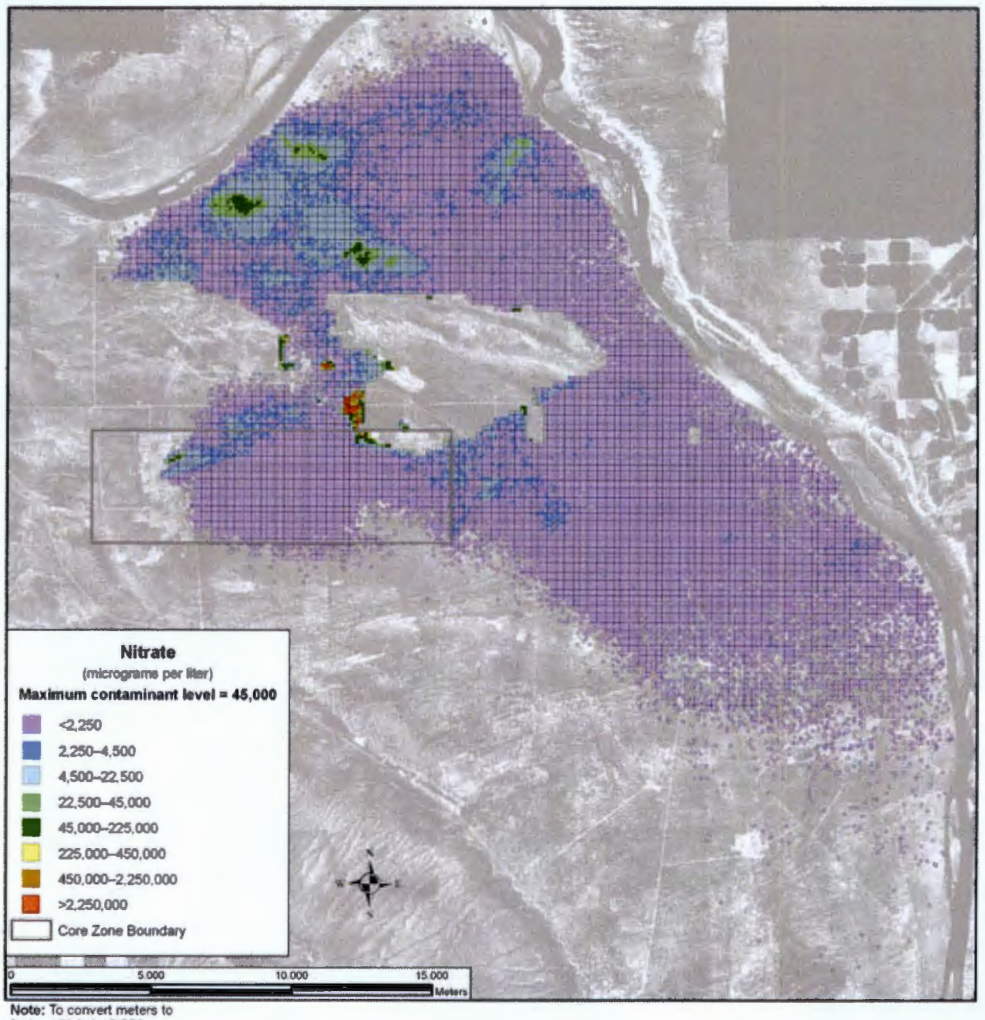
Note: To convert meters to feet, multiply by 3.281

Figure 5–292. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 7140



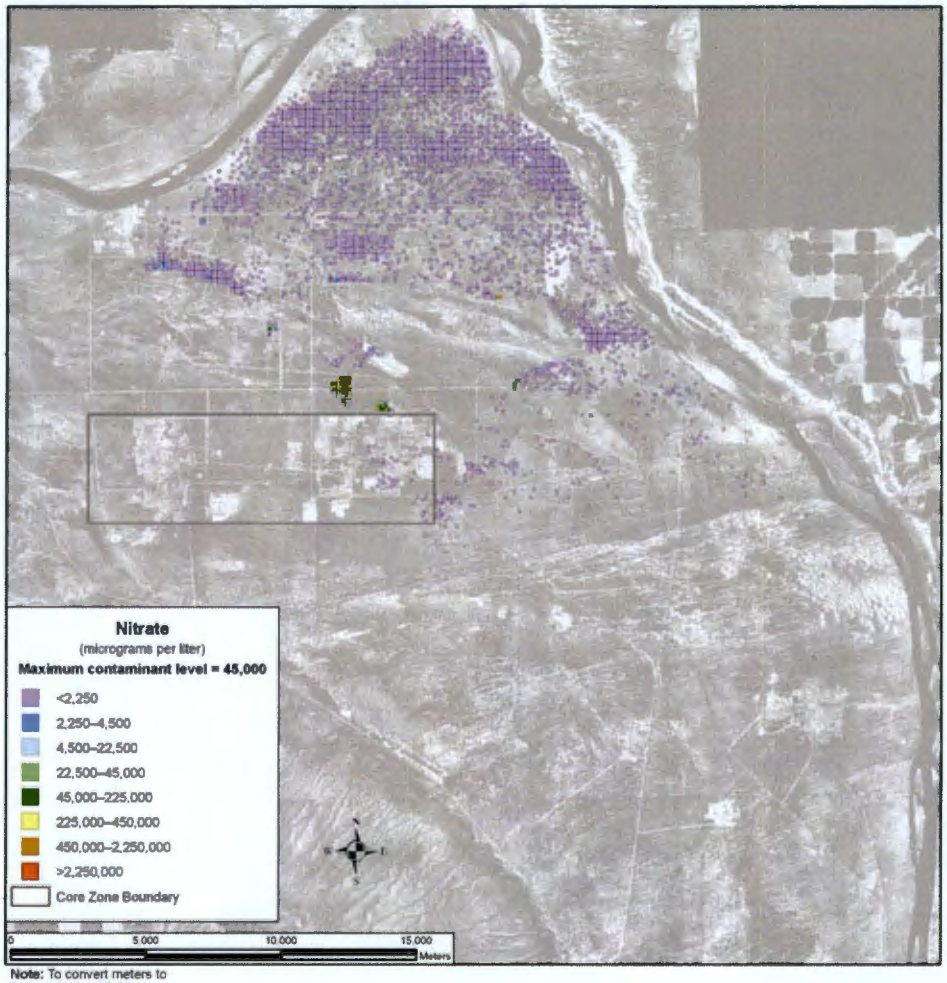
Note: To convert meters to feet, multiply by 3.281

Figure 5–293. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

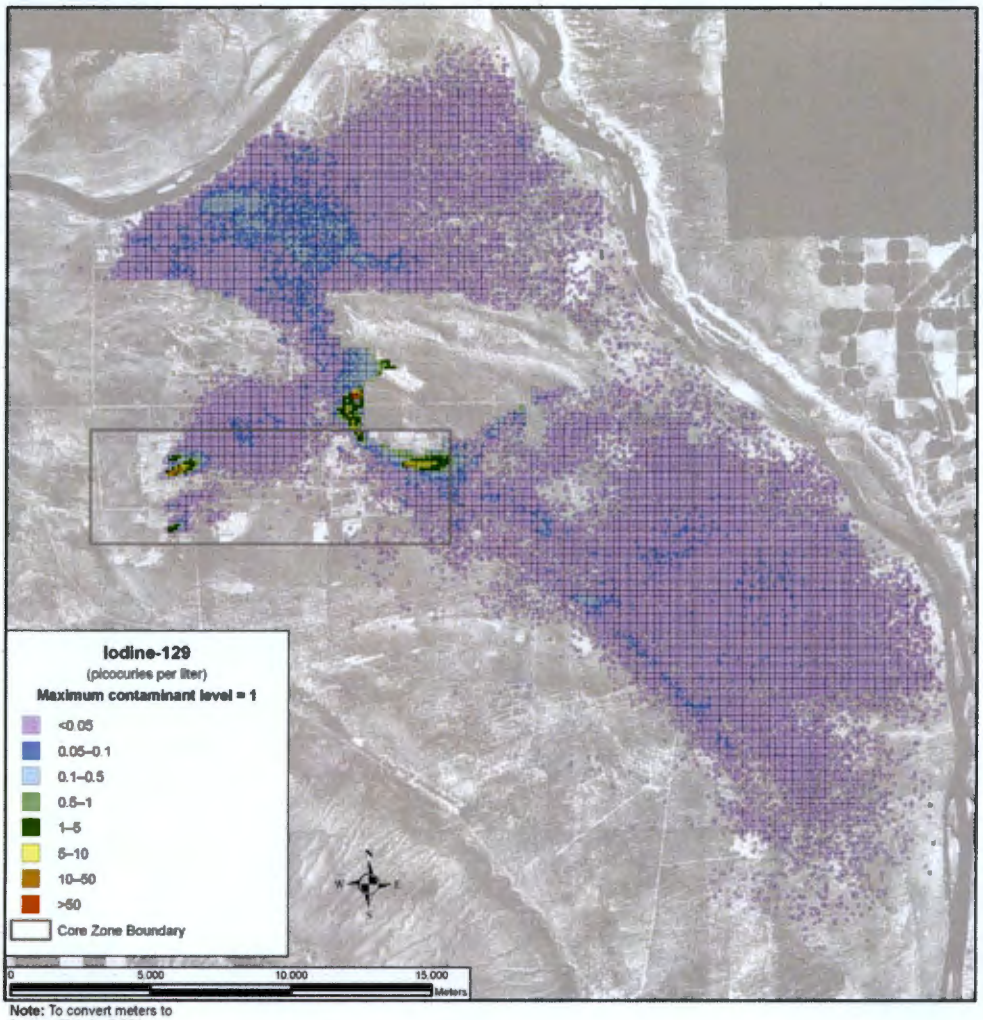
Figure 5–294. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281

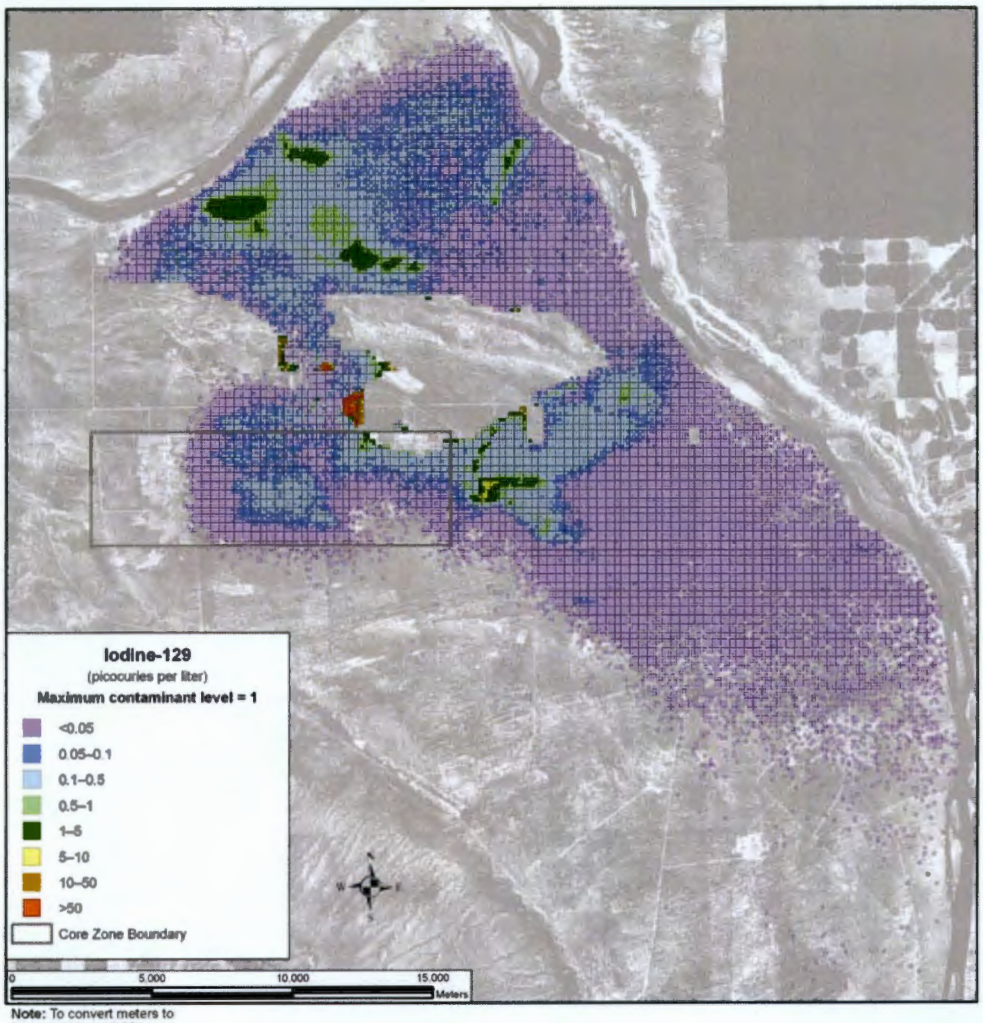
Figure 5–295. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 7140

The spatial distribution of groundwater concentrations for the conservative tracers under the Option Case is essentially identical to that under the Base Case (see Figures 5–296 through 5–307).



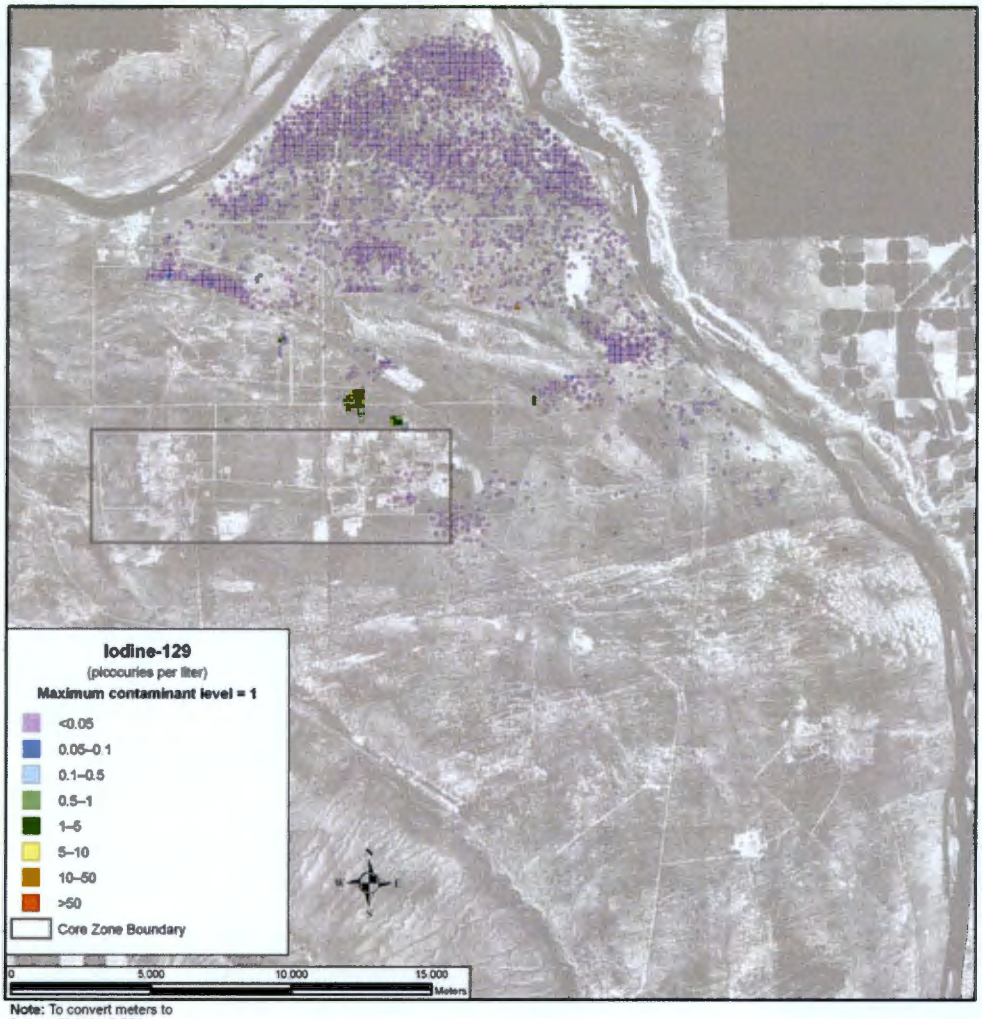
Note: To convert meters to feet, multiply by 3.281

Figure 5–296. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2005



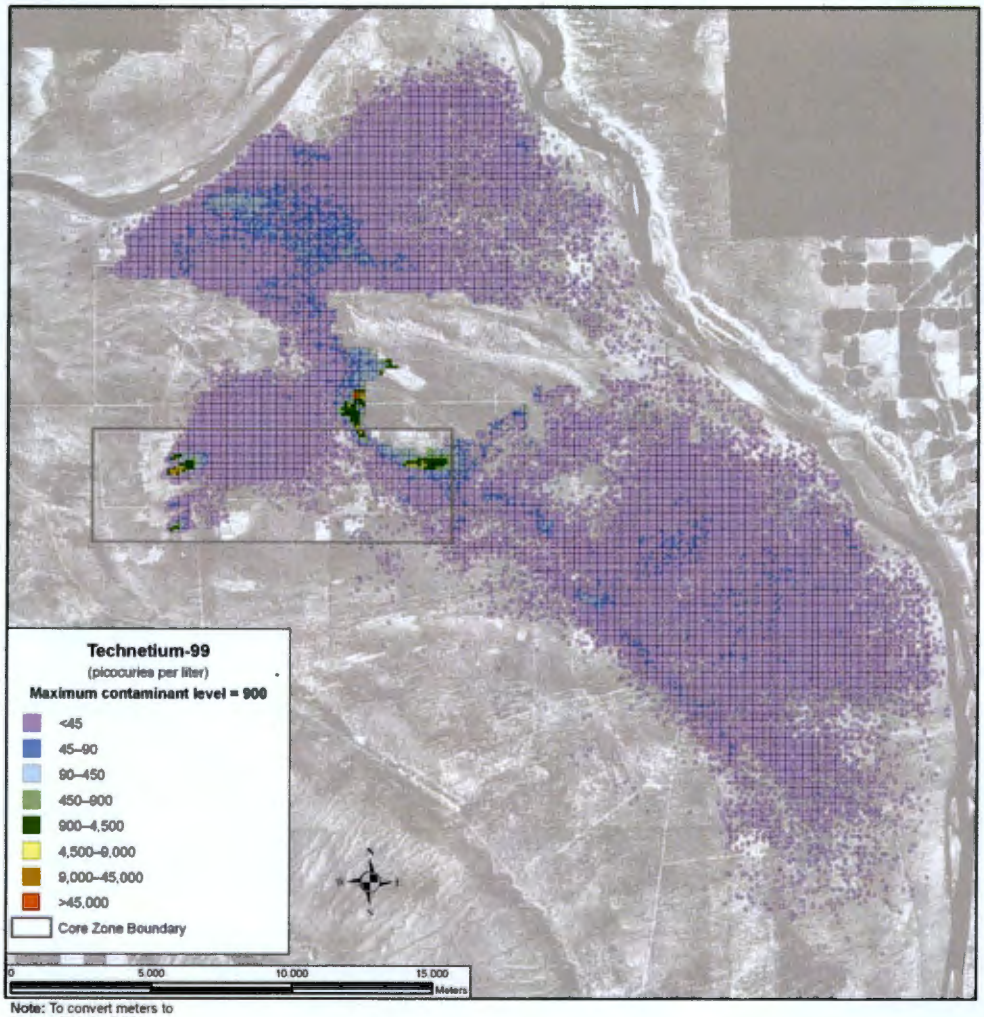
Note: To convert meters to feet, multiply by 3.281

Figure 5–297. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2135



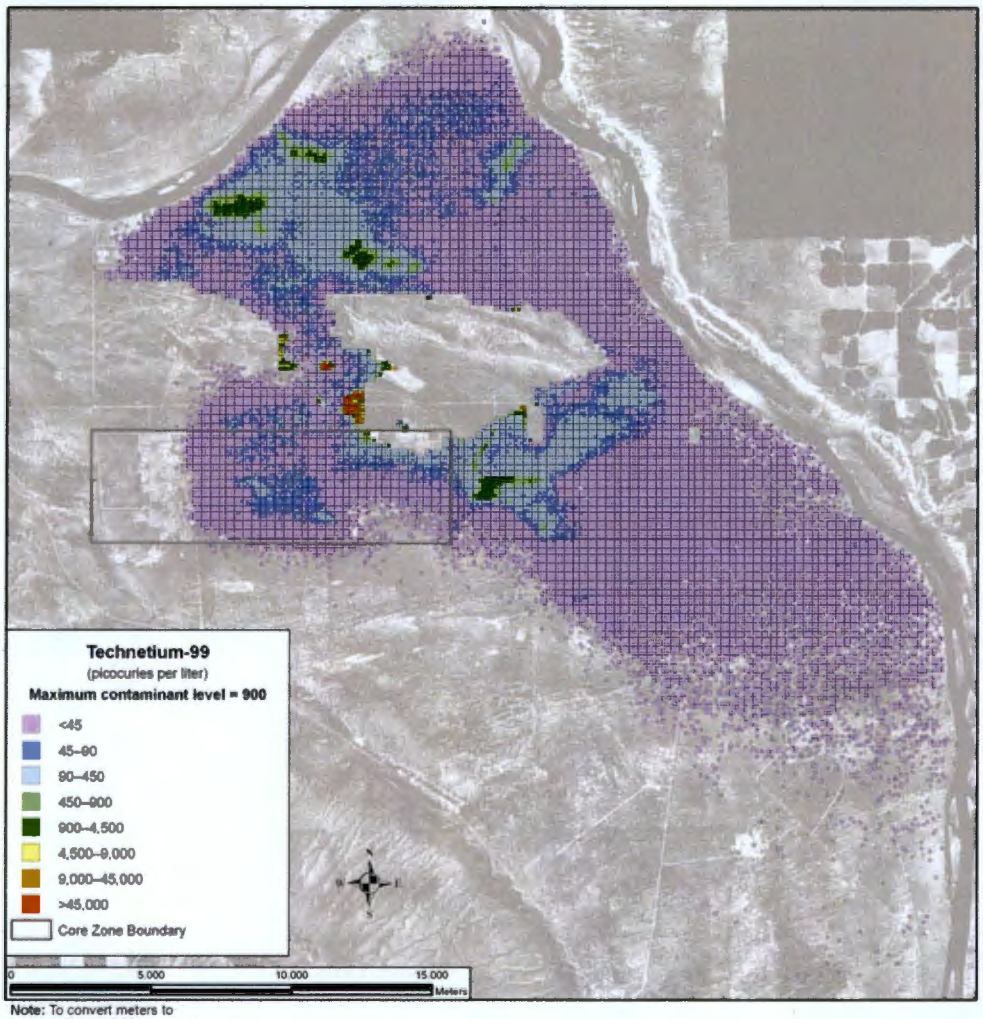
Note: To convert meters to feet, multiply by 3.281

Figure 5–298. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140



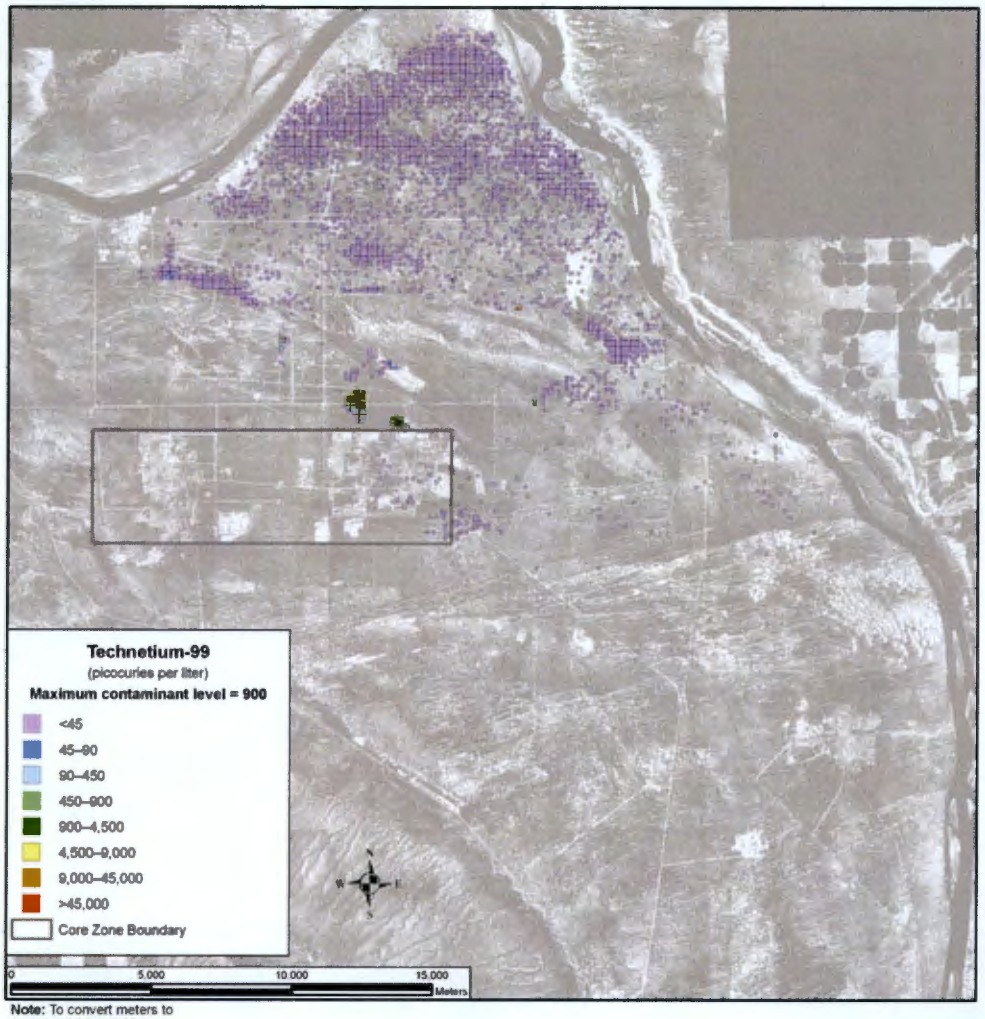
Note: To convert meters to feet, multiply by 3.281

Figure 5–299. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2005



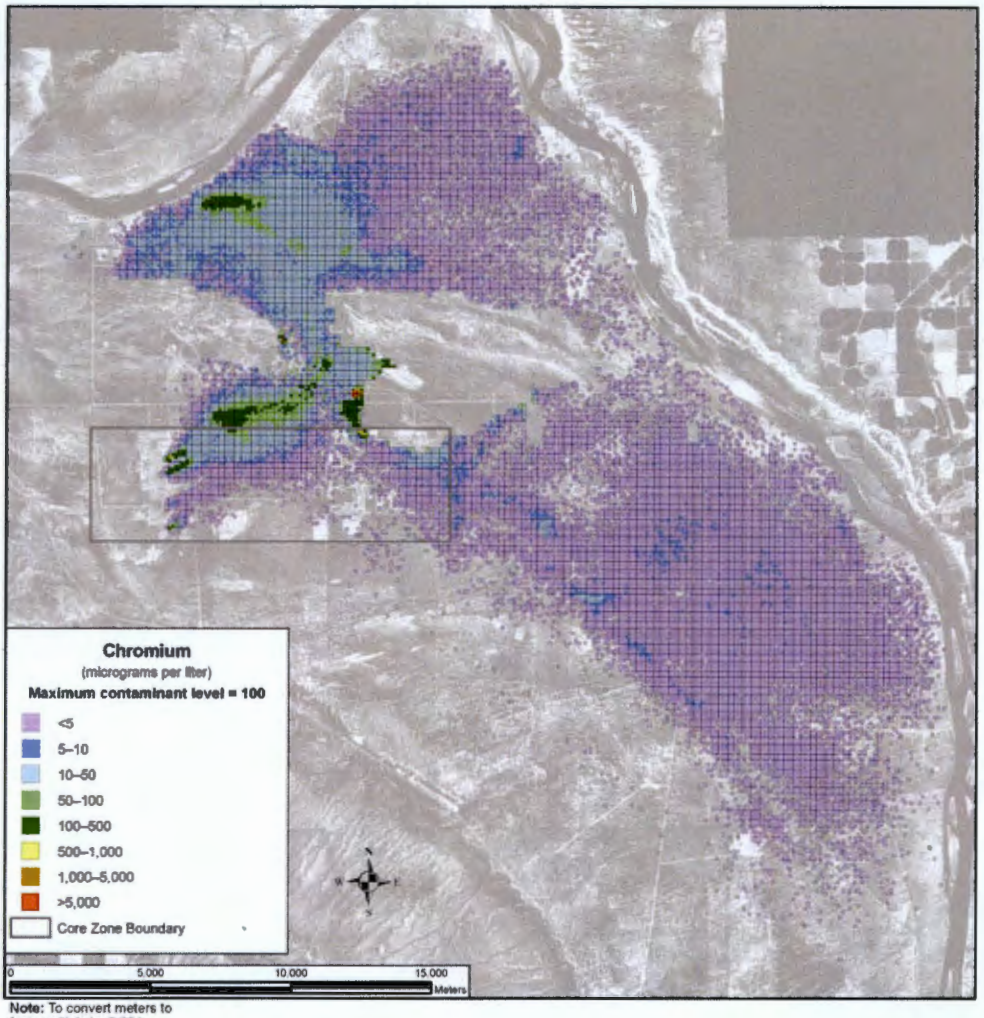
Note: To convert meters to feet, multiply by 3.281

Figure 5–300. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2135



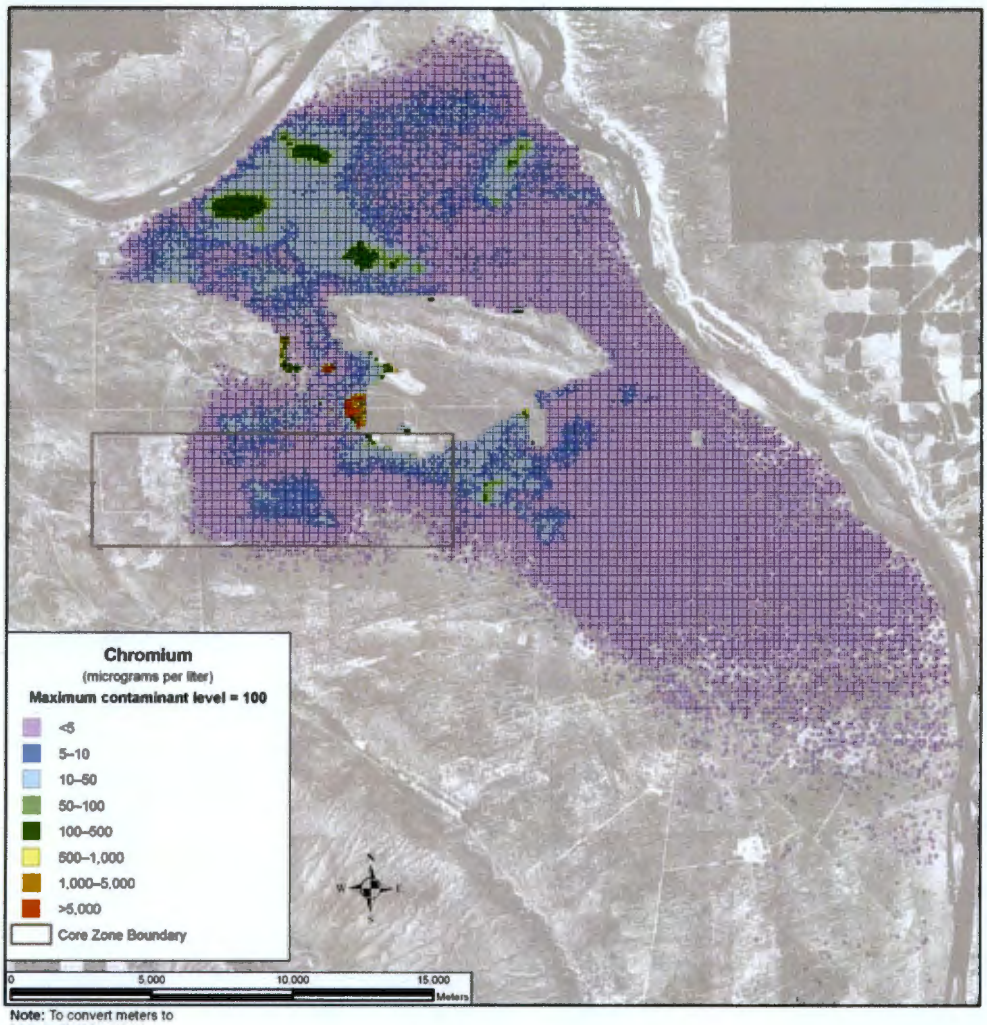
Note: To convert meters to feet, multiply by 3.281

Figure 5–301. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140



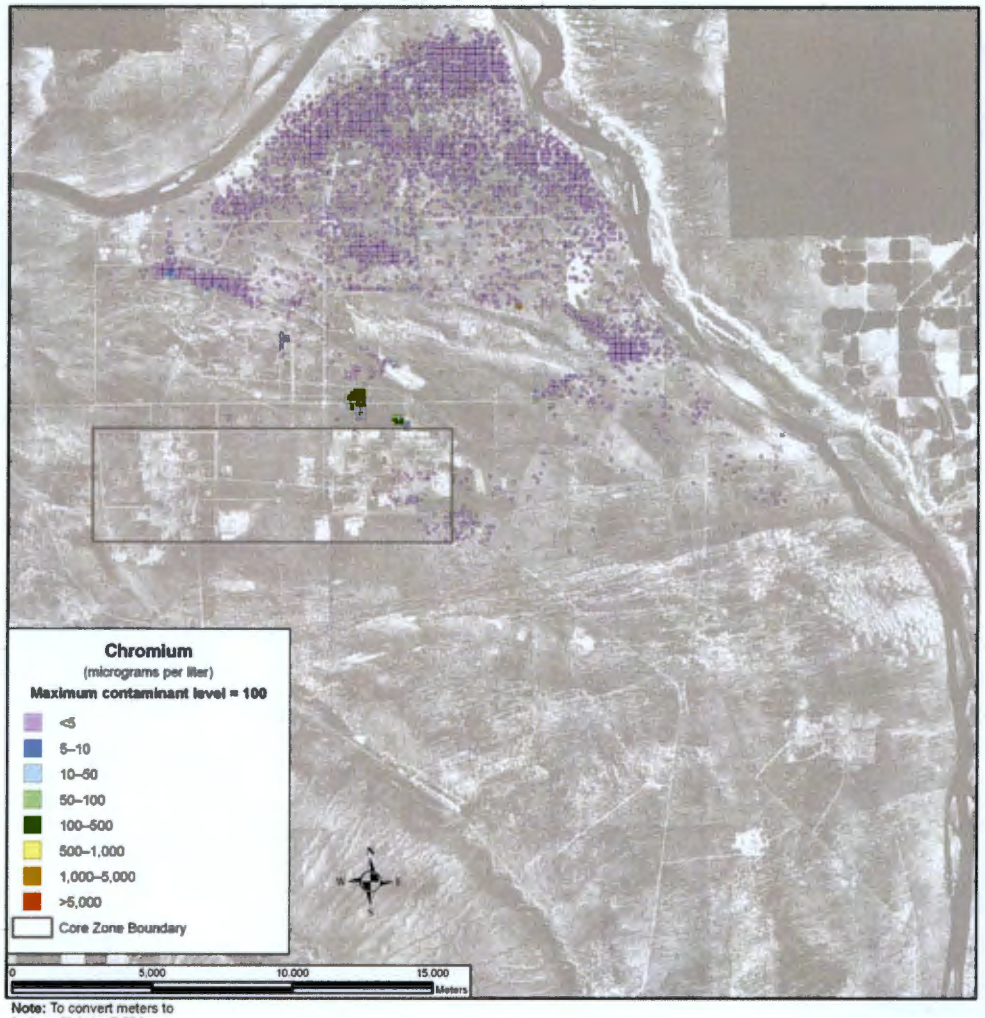
Note: To convert meters to feet, multiply by 3.281

Figure 5–302. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 2005



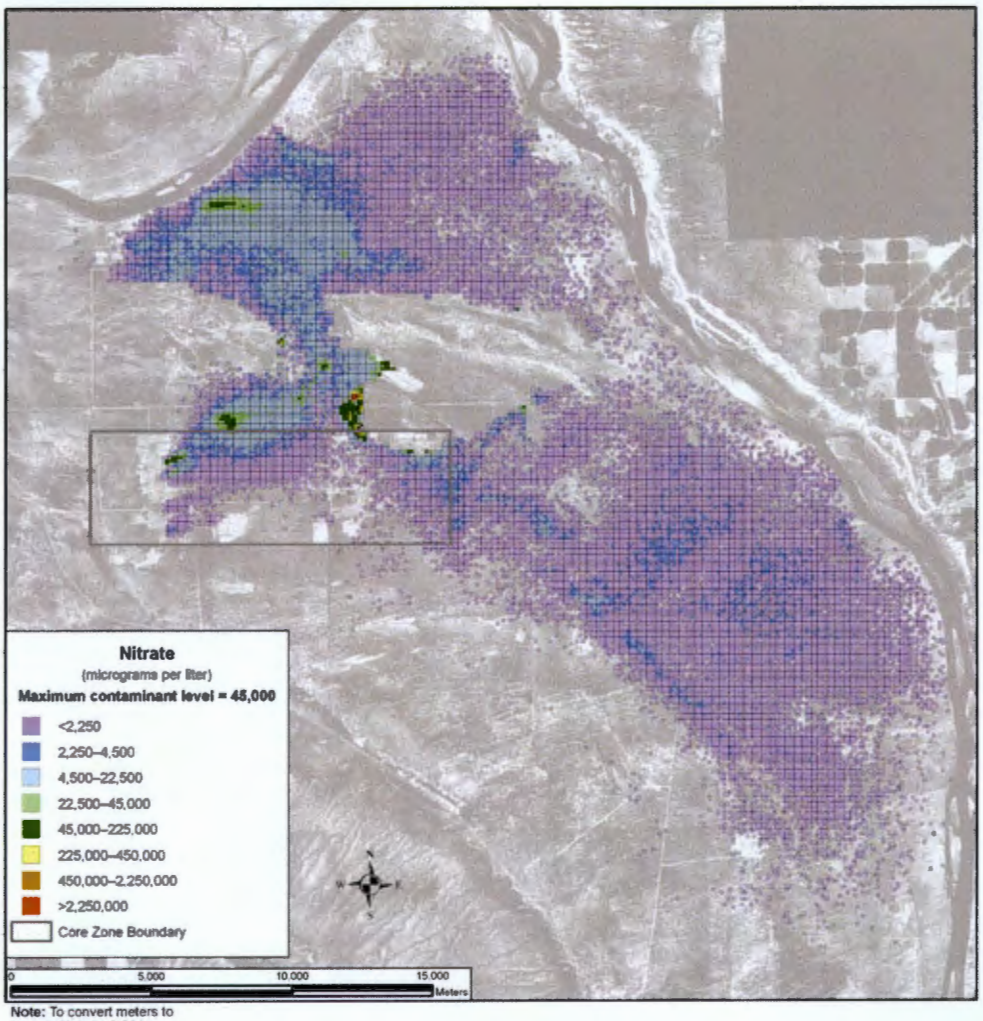
Note: To convert meters to feet, multiply by 3.281

Figure 5–303. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 2135



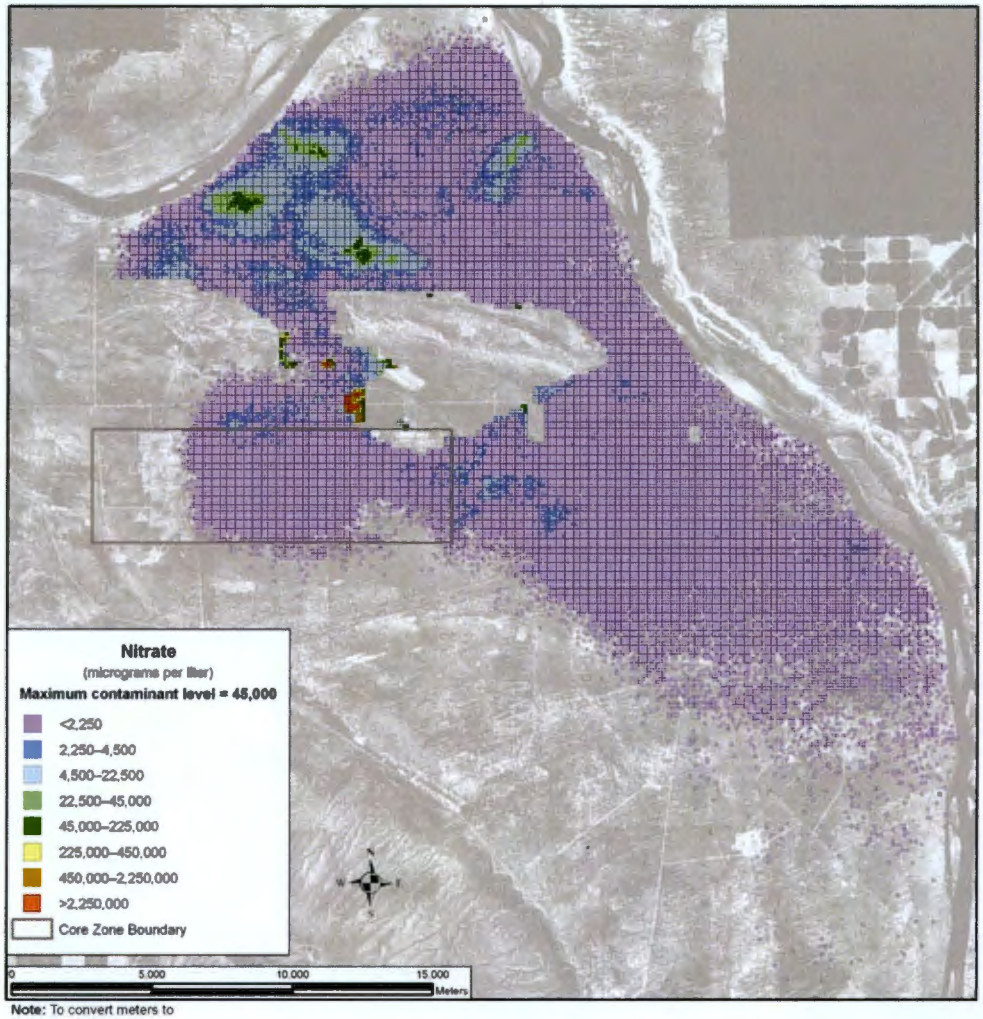
Note: To convert meters to feet, multiply by 3.281

Figure 5–304. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 7140



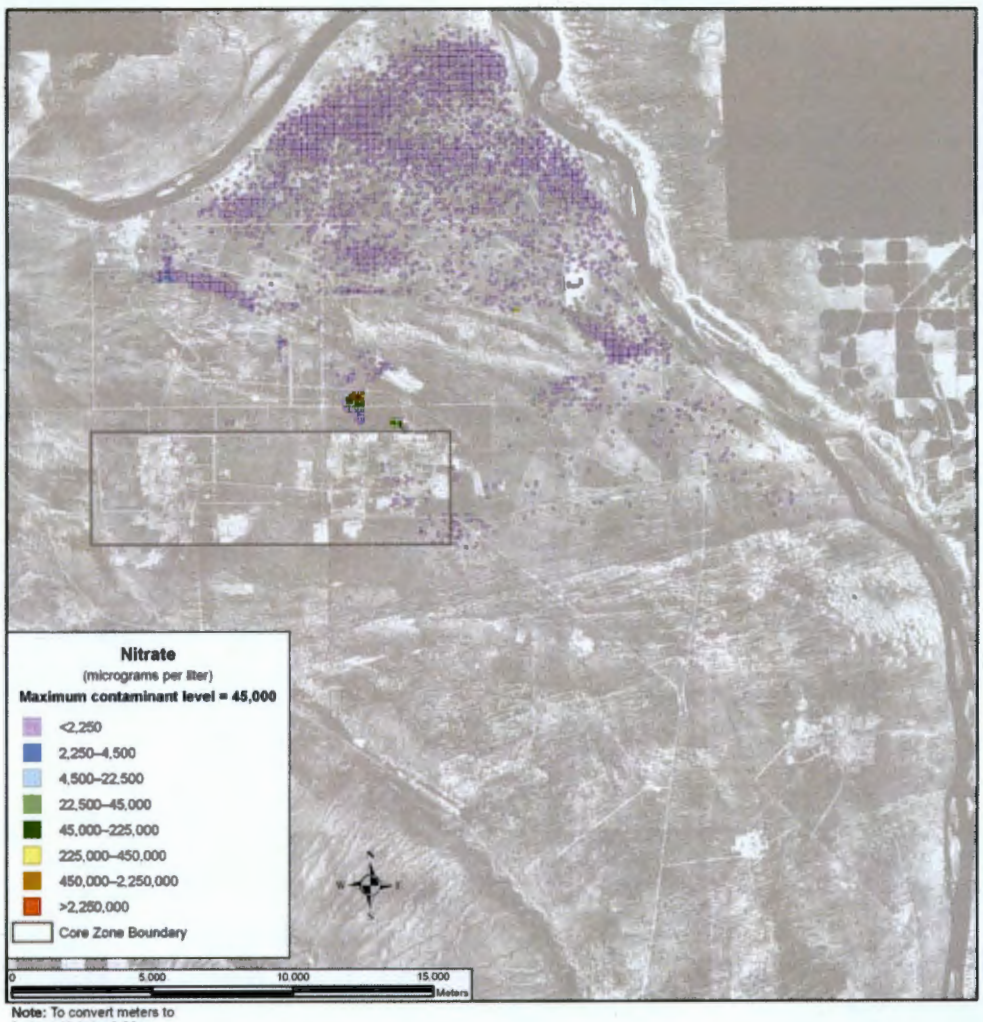
Note: To convert meters to feet, multiply by 3.281

Figure 5–305. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

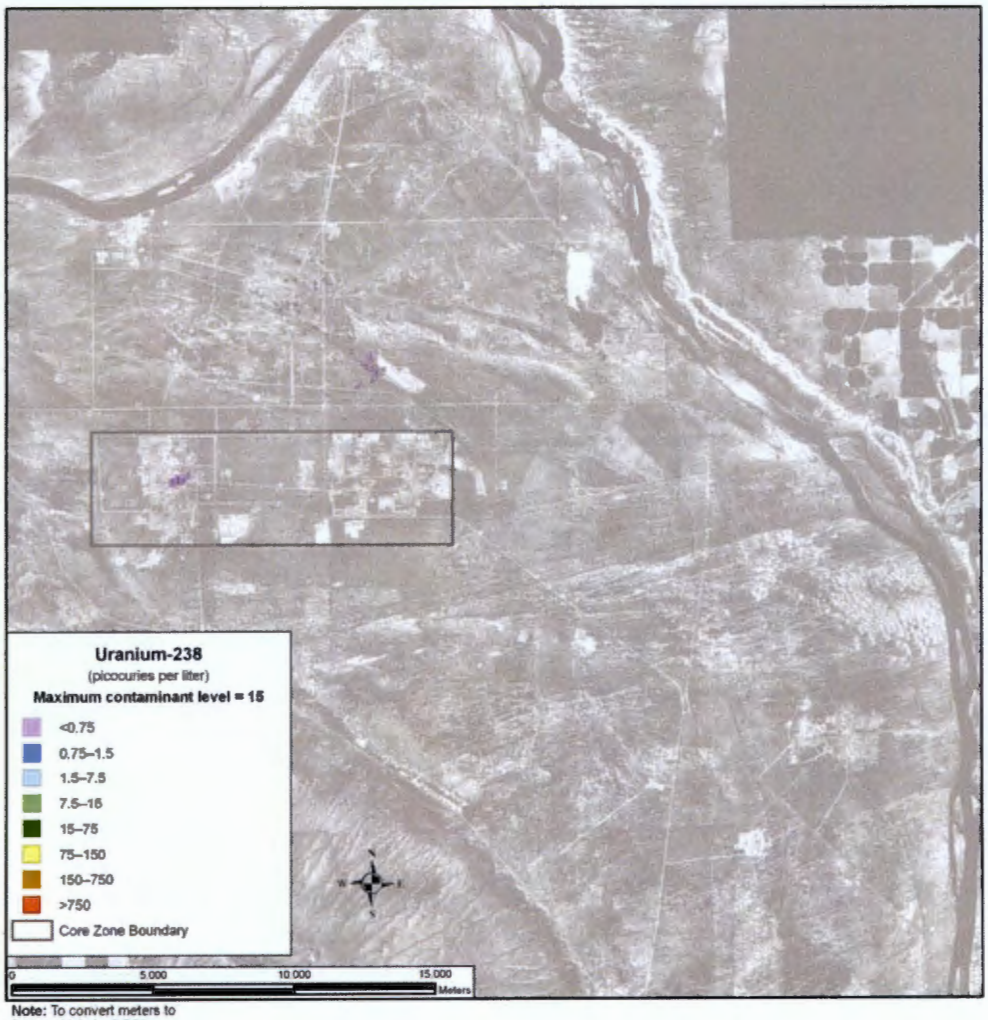
Figure 5–306. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281

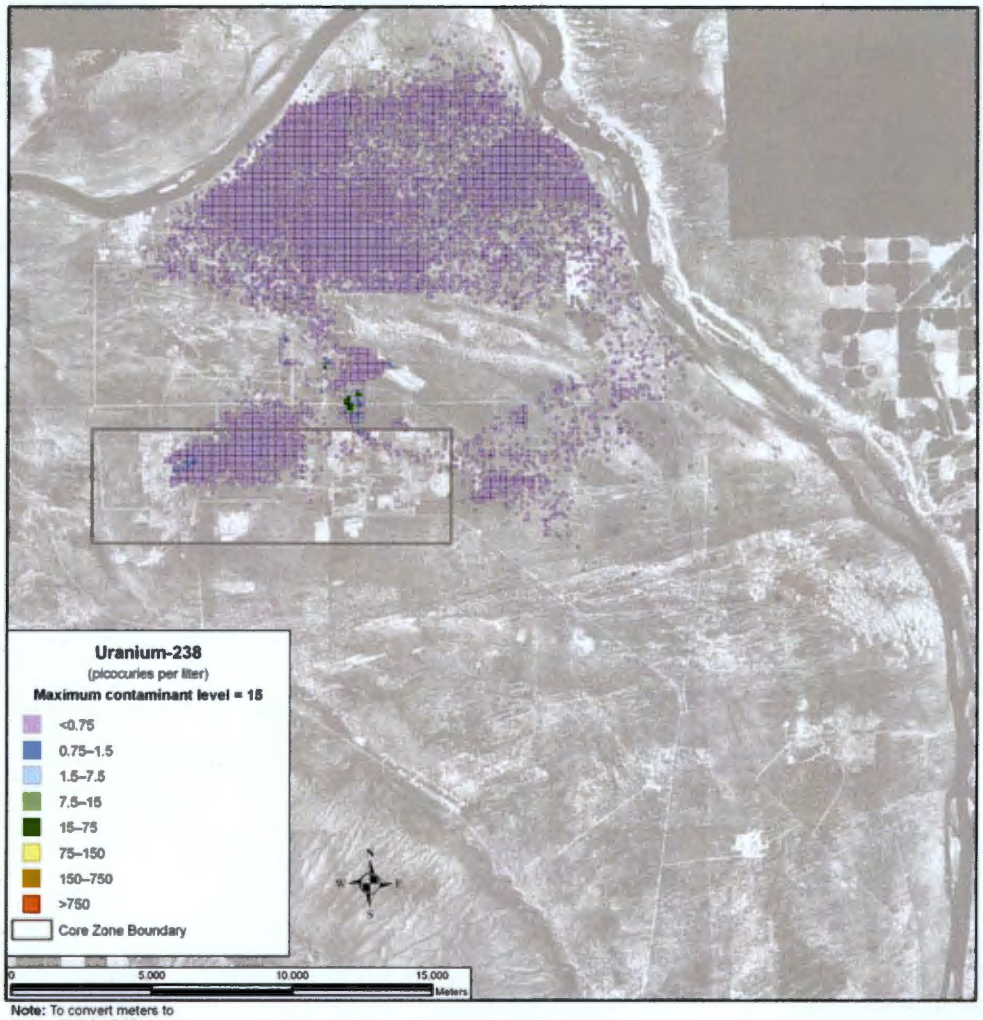
Figure 5–307. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 7140

Uranium-238 and total uranium under the Base Case are not as mobile as those COPCs discussed above, moving about seven times slower than the pore water velocity. As a result, travel times through the vadose zone are longer, release to the aquifer is delayed, and travel times through the aquifer to the Columbia River are longer. Figure 5–308 shows the distribution of uranium-238 during CY 2005. There is a small plume associated with cribs and trenches (ditches) and past leaks at the T Barrier that is less than one-twentieth of the benchmark concentration and is contained within the Core Zone Boundary. By CY 7140, the area of the plume has grown and extended to the Columbia River (see Figure 5–309). Most of the plume is significantly below the benchmark except for a small pocket with high concentrations in the southern region of Gable Gap extending north from the B Barrier. At CY 11,885, the greatest development of the plume during the analysis period is seen (see Figure 5–310). The only area with a significant level of contaminant concentration is the area in the southern region of Gable Gap that originates from the B Barrier. Figures 5–311 through 5–313 show similar results for total uranium.



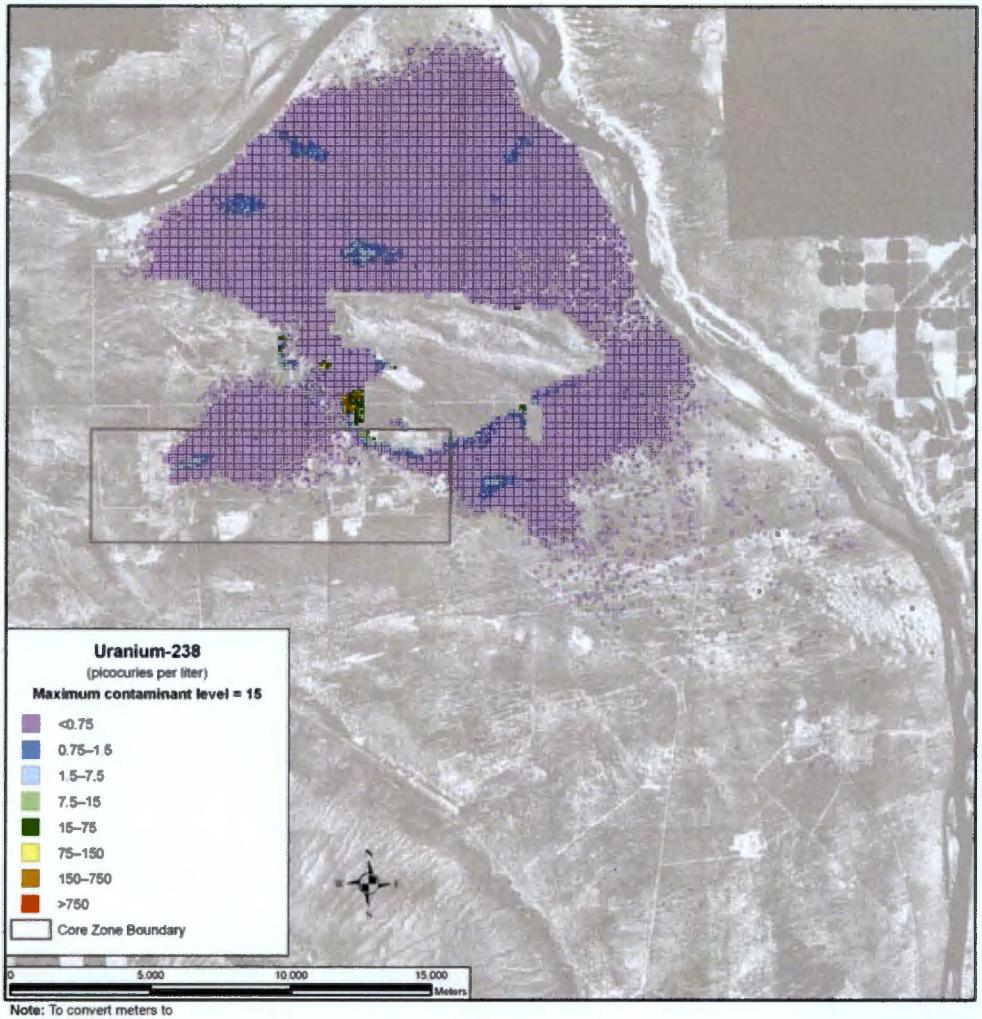
Note: To convert meters to feet, multiply by 3.281

Figure 5–308. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

Figure 5–309. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 7140

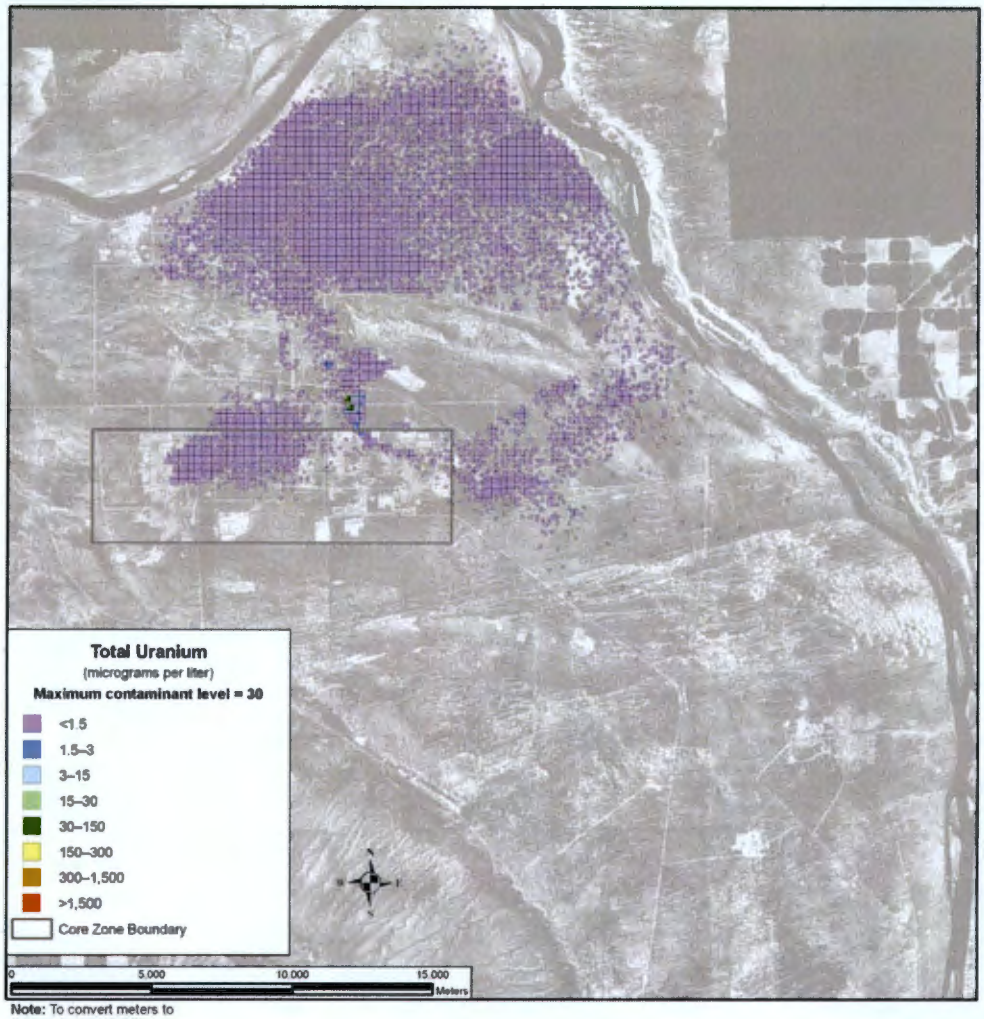


Note: To convert meters to feet, multiply by 3.281

Figure 5–310. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 11,885

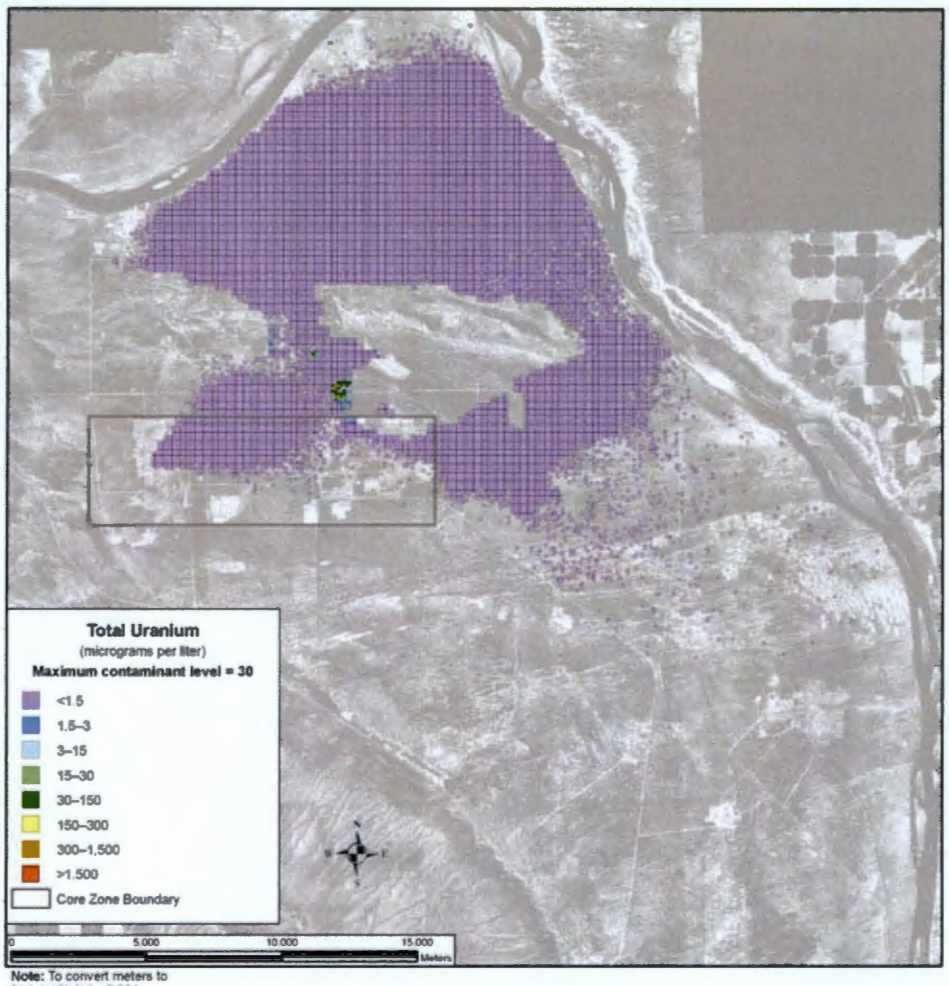
Note: To convert meters to feet, multiply by 3.281

Figure 5–311. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

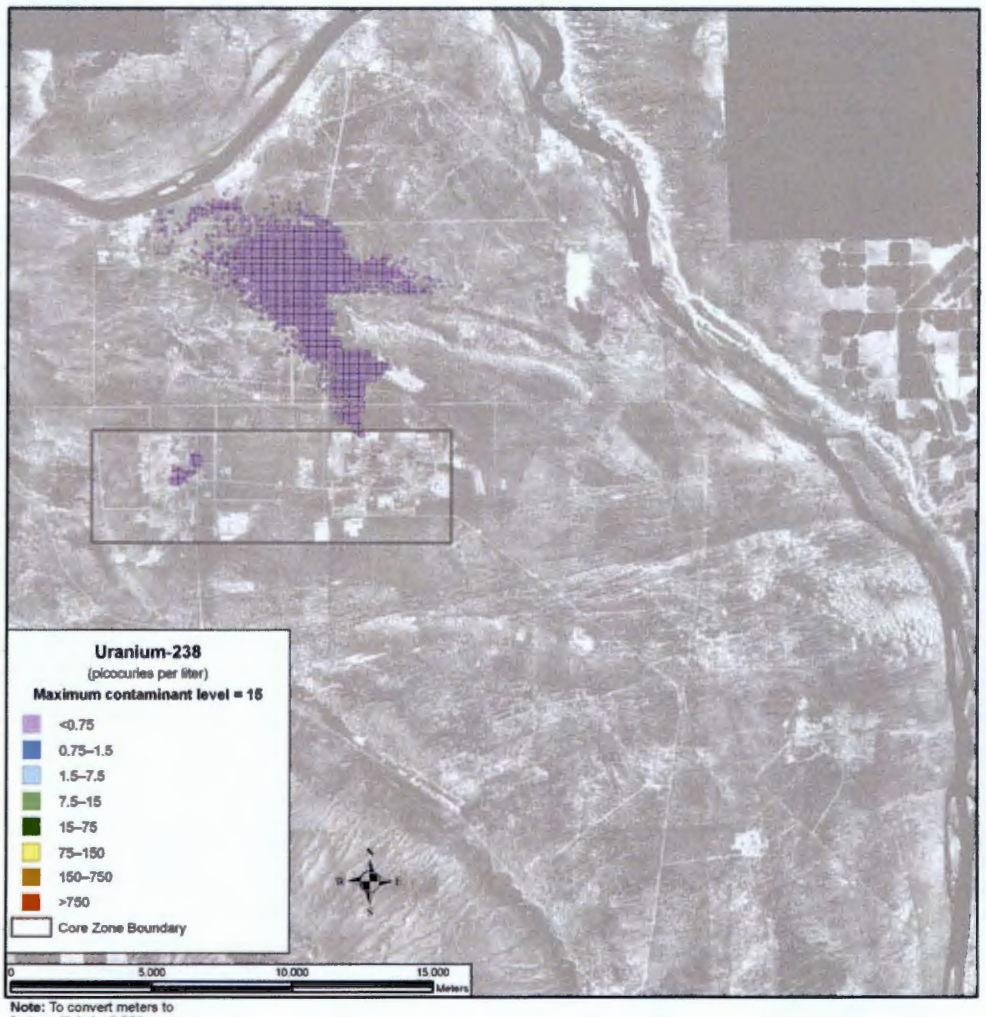
Figure 5–312. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281

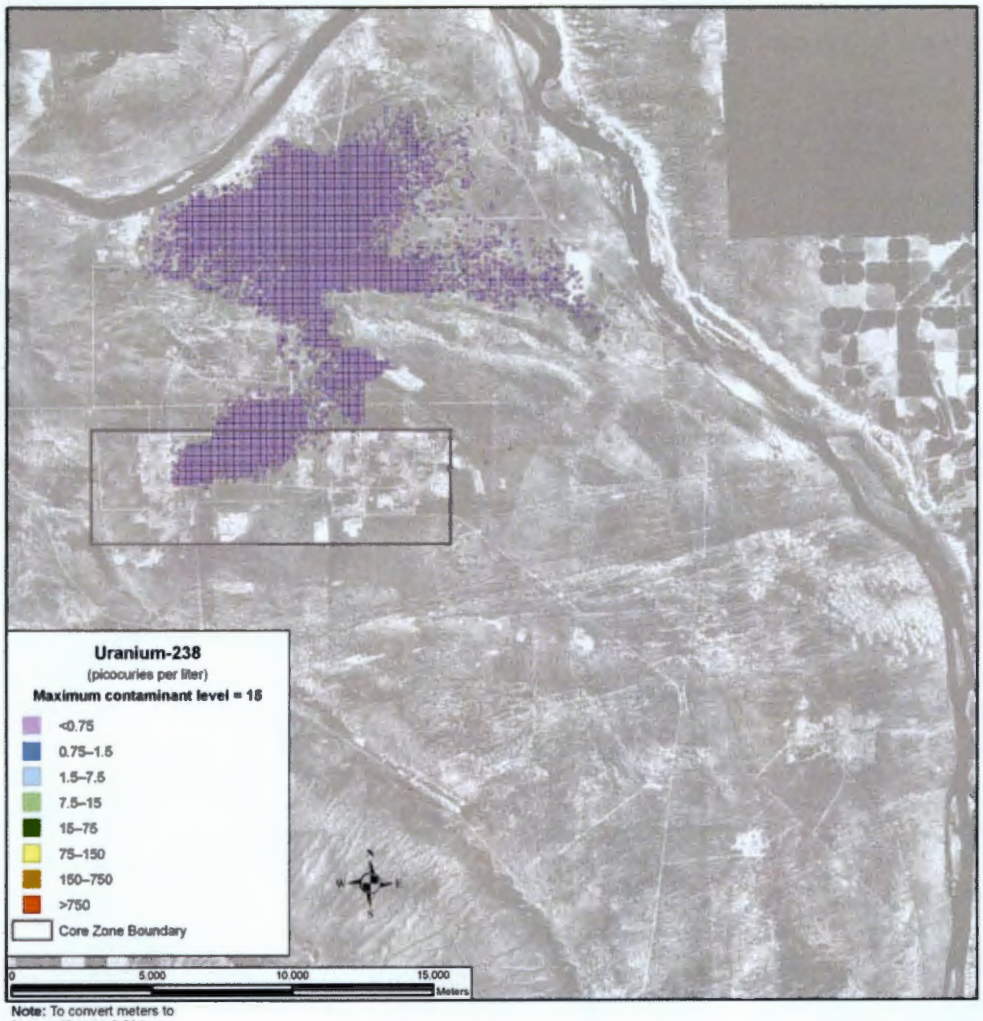
Figure 5–313. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 11,885

Figure 5–314 shows the distribution of uranium-238 during CY 2005 under the Option Case. There are two plumes associated with this case, one originating from the T Barrier and the other from the B Barrier. Although there are no significant contaminant concentrations, the plumes under the Option Case are much larger than those under the Base Case. By CY 2135, the contaminant plume has grown and reached the Columbia River, but there are still no significant peaks in concentration levels (see Figure 5–315). By CY 11,885, while the greatest development of the plume occurred under the Base Case, the contaminant plume under the Option Case has begun to recede (see Figure 5–316). This recession is due to the removal of the six sets of cribs and trenches (ditches) and the remediation of their contaminant plumes. Figures 5–317 through 5–319 show similar results for total uranium.



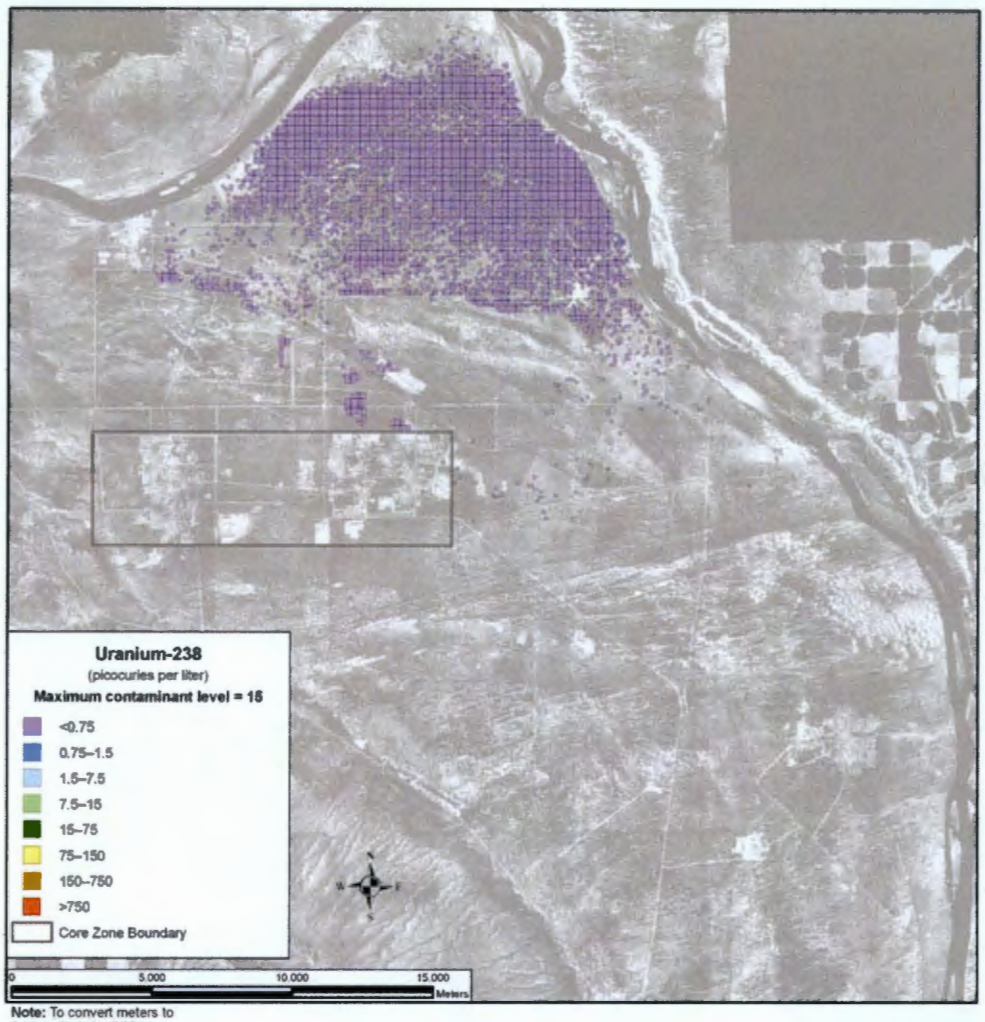
Note: To convert meters to feet, multiply by 3.281

Figure 5–314. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 2005



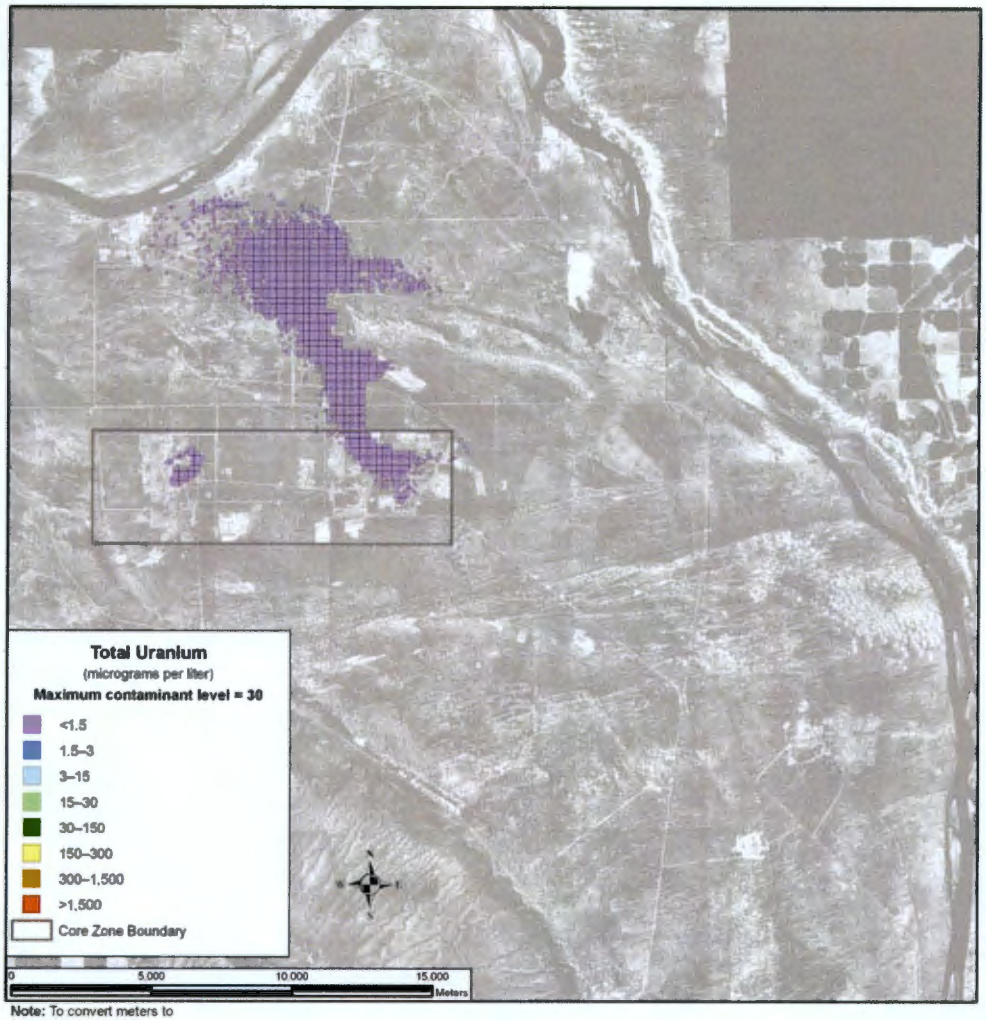
Note: To convert meters to feet, multiply by 3.281

Figure 5–315. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 2135



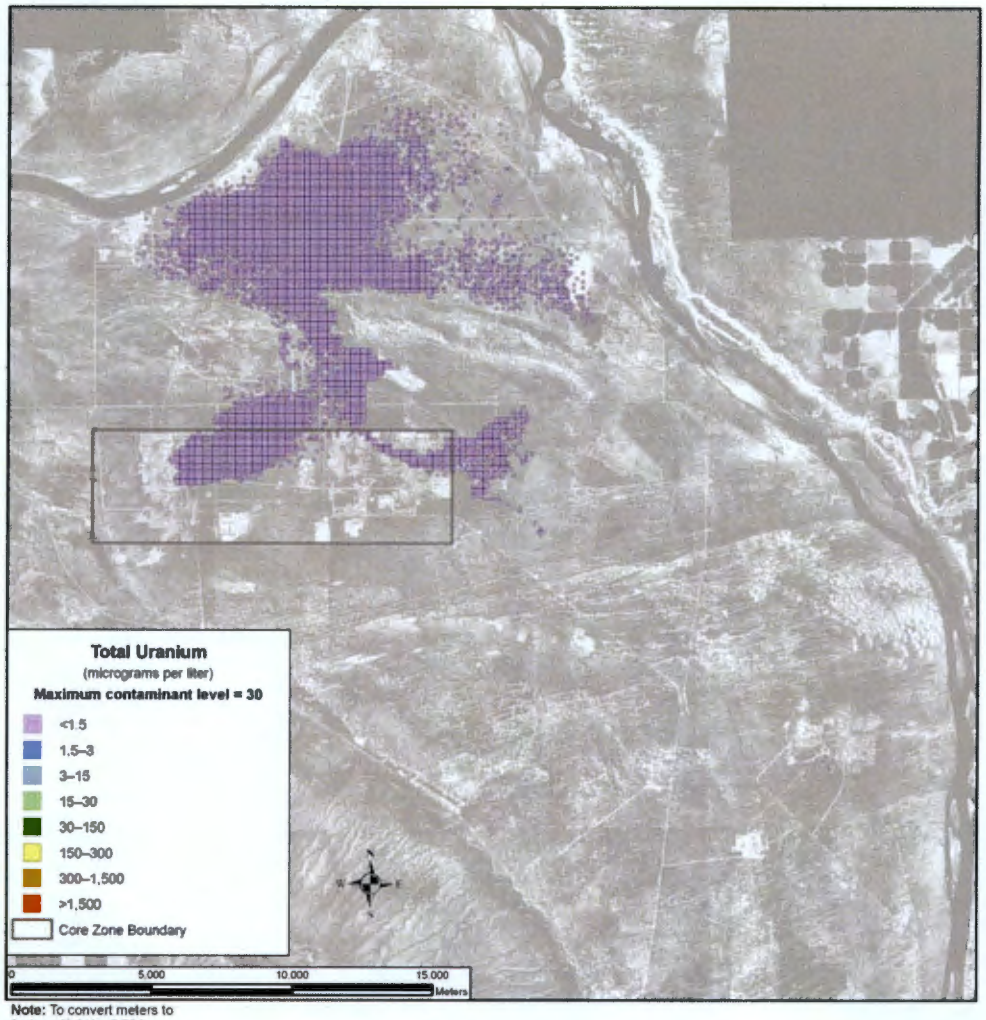
Note: To convert meters to feet, multiply by 3.281

Figure 5–316. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 11,885



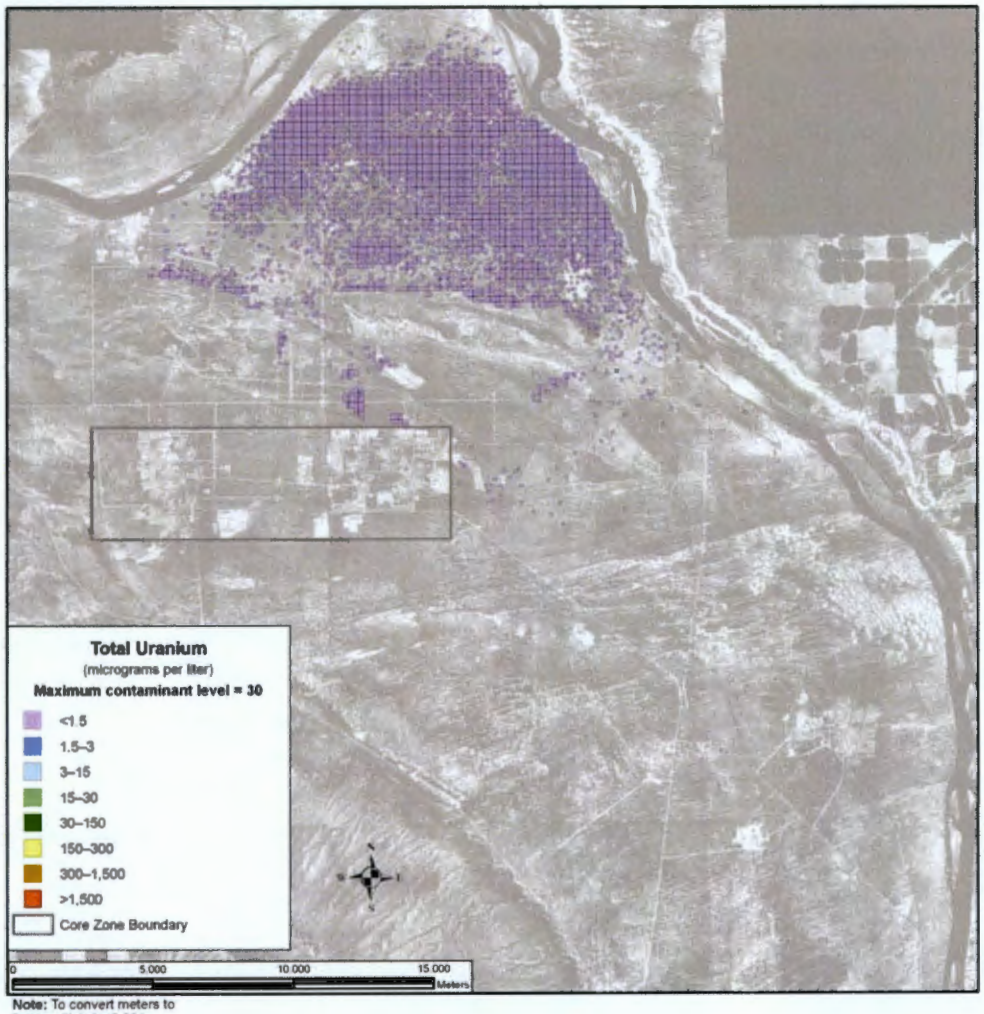
Note: To convert meters to feet, multiply by 3.281

Figure 5–317. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

Figure 5–318. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281

Figure 5–319. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 11,885

Figure 5–320 shows the area in square kilometers in which groundwater concentrations of technetium-99 exceed the benchmark concentration in the analysis as a function of time under the Base Case. A peak of almost 4.0 square kilometers (1.7 square miles) occurs around CY 2135, followed by a fairly sharp decrease. By about CY 4000, the area with a concentration above the benchmark begins to level out around 0.5 square kilometers (0.19 square miles). Iodine-129 shows a similar pattern (see Figure 5–321), as both constituents are conservative tracers.

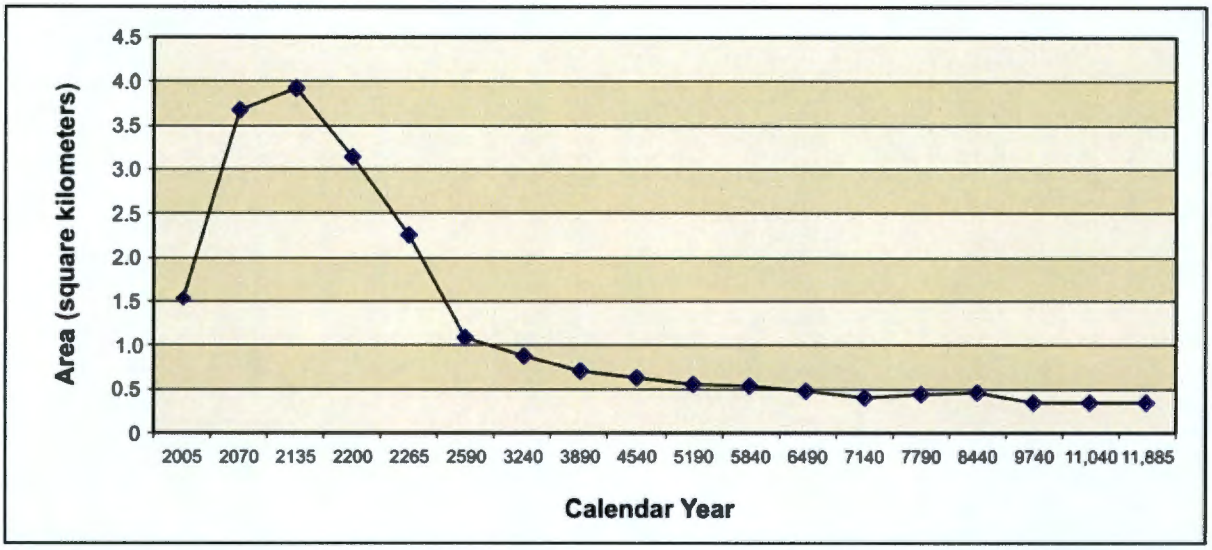


Figure 5–320. Tank Closure Alternative 6B, Base Case, Total Area of Groundwater Technetium-99 Concentration Exceeding the Benchmark Concentration as a Function of Time

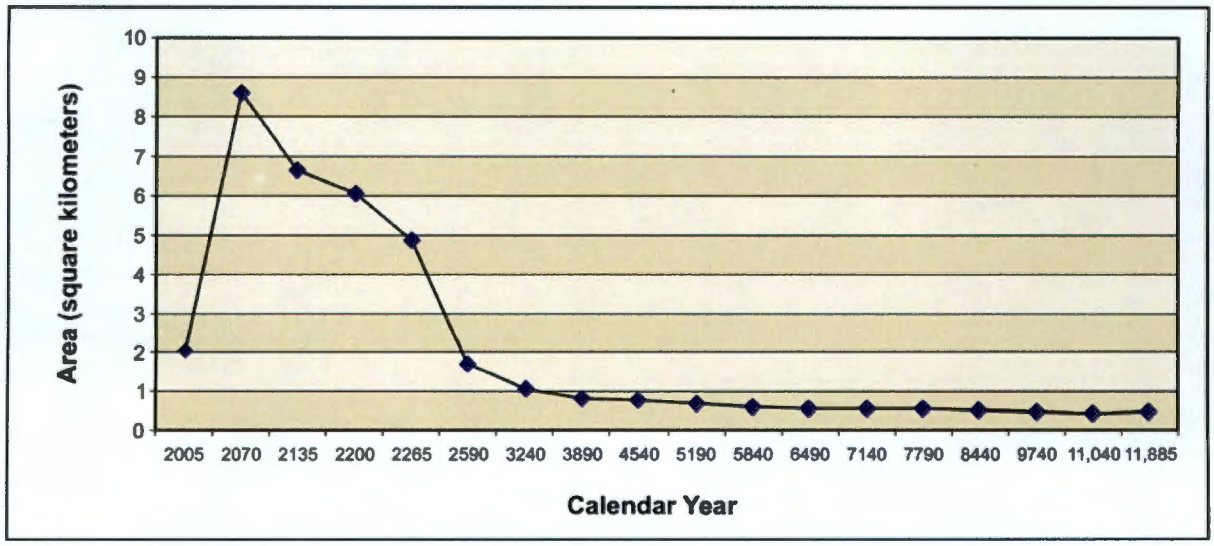


Figure 5–321. Tank Closure Alternative 6B, Base Case, Total Area of Groundwater Iodine-129 Concentration Exceeding the Benchmark Concentration as a Function of Time

Under the Option Case, the areas with concentrations of technetium-99 and iodine-129 above the benchmarks are essentially identical to those under the Base Case (see Figures 5–322 and 5–323).

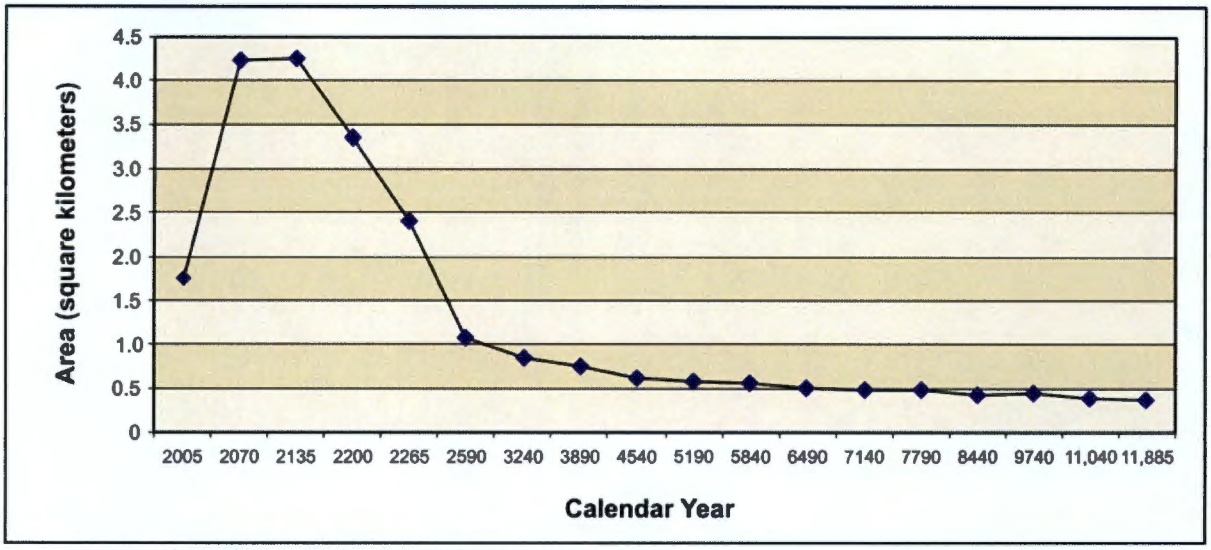


Figure 5–322. Tank Closure Alternative 6B, Option Case, Total Area of Groundwater Technetium-99 Concentration Exceeding the Benchmark Concentration as a Function of Time

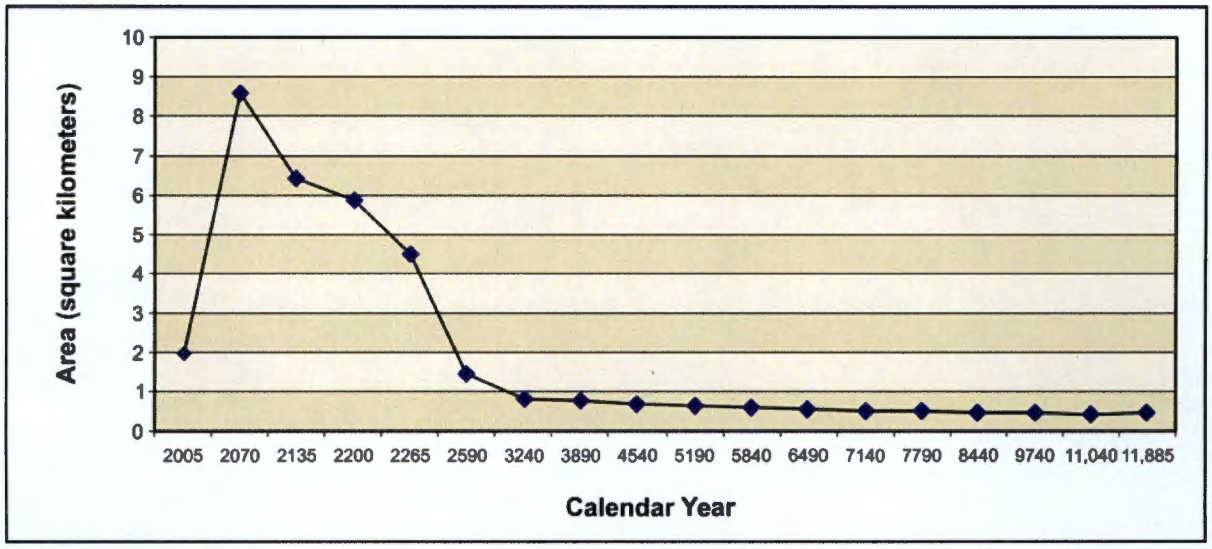


Figure 5–323. Tank Closure Alternative 6B, Option Case, Total Area of Groundwater Iodine-129 Concentration Exceeding the Benchmark Concentration as a Function of Time

Under the Base Case, uranium-238 did not register above the benchmark in any area until after CY 5840 (see Figure 5–324). A sharp increase in area with concentrations above the maximum contaminant level is seen after CY 5840 and continues to rise through the end of the period of analysis (CY 11,940). It is expected that the majority of the uranium-238 would continue to migrate through the vadose zone after the period of analysis is over.

Under the Option Case, uranium-238 did not register above the benchmark in any area during the period of analysis. This is a result of the high retardation rate and the removal and remediation of the cribs and trenches (ditches).

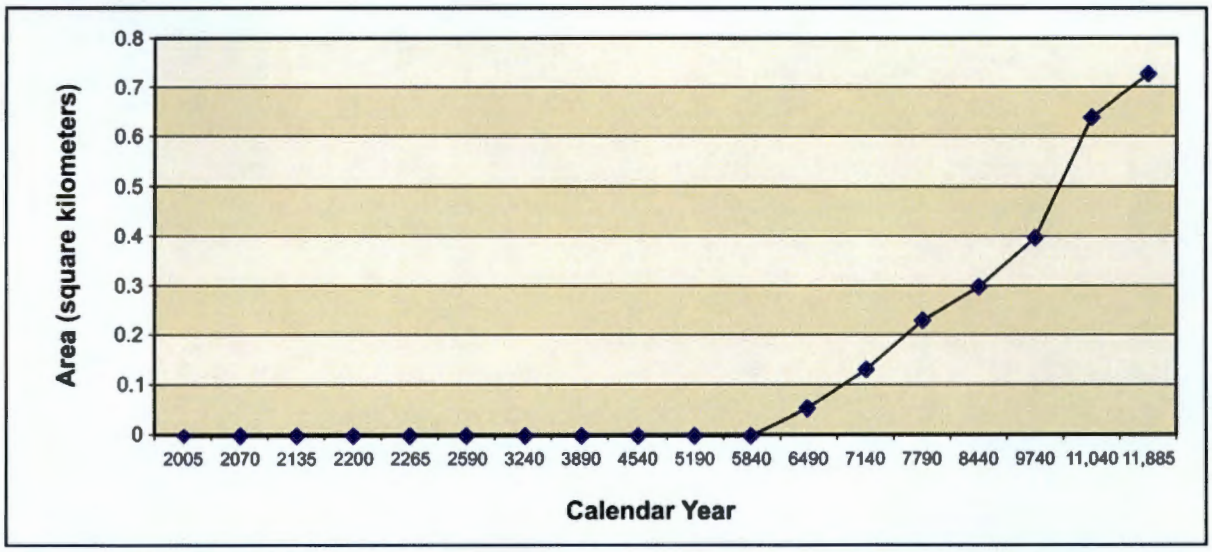


Figure 5–324. Tank Closure Alternative 6B, Base Case, Total Area of Groundwater Uranium-238 Concentration Exceeding the Benchmark Concentration as a Function of Time

5.1.1.10.6 Summary of Impacts

For the conservative tracers under the Base Case, concentrations at the Core Zone Boundary exceeded the benchmark standards by about two orders of magnitude during the early part of the period of analysis, around CY 1956. Columbia River nearshore concentrations never reached the benchmark concentration and peaked at about one-half to one order of magnitude below it. The intensities and areas of these groundwater plumes peaked around CY 1956.

The concentrations of iodine-129, technetium-99, chromium, and nitrate (the conservative tracers) under the Option Case are essentially identical to those under the Base Case.

For tritium under the Base Case, concentrations at the Core Zone Boundary exceeded the benchmark by about two orders of magnitude for a short period of time during the early part of the period of analysis, around CY 1956. During the same period of time, the Columbia River nearshore concentrations peaked at about one order of magnitude below the benchmark. Attenuation by radioactive decay is a predominant mechanism that limits the intensity and duration of groundwater impacts of tritium.

The concentrations of tritium under the Option Case are essentially identical to those under the Base Case.

For uranium-238 and total uranium under the Base Case, limited mobility is an important factor governing the timeframes and scale of groundwater impacts. The concentrations of these retarded species began to approach the benchmark at the Core Zone Boundary toward the latter part of the period of analysis but never reached it. The concentration levels of uranium-238 and total uranium at the Columbia River nearshore never came to within about two orders of magnitude below the benchmark. The intensity and area of the contaminant plumes peaked at the end of the period of analysis.

Under the Option Case, uranium-238 concentrations at the Core Zone Boundary generally stayed about three to four orders of magnitude below the benchmark concentration, except for a short spike at the Core Zone Boundary to about one order of magnitude below the benchmark at the beginning of the period of analysis. The Columbia River nearshore concentrations stayed fairly constant at about four orders of magnitude below the benchmark. Total uranium concentrations at the Core Zone Boundary generally stayed about three to four orders of magnitude below the benchmark. The Columbia River nearshore

concentrations remained fairly constant at around four and a half orders of magnitude below the benchmark.

5.1.1.11 Tank Closure Alternative 6C: All Vitrification with Separations; Landfill Closure

Activities under Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C would be similar in scope and timing. Tank waste would be retrieved to a volume corresponding to 99 percent retrieval, and residual material in tanks would be stabilized in place. The tank farms and six sets of adjacent cribs and trenches (ditches) would be covered with an engineered modified RCRA Subtitle C barrier. From the long-term groundwater impact perspective, the results from the analyses of these alternatives are identical. Refer to Section 5.1.3 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 6C.

5.1.1.11.1 Actions and Timeframes Influencing Groundwater Impacts

Refer to Section 5.1.1.3.1 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 6C.

5.1.1.11.2 COPC Drivers

Refer to Section 5.1.1.3.2 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 6C.

5.1.1.11.3 Analysis of Release and Mass Balance

Refer to Section 5.1.1.3.3 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 6C.

5.1.1.11.4 Analysis of Concentration Versus Time

Refer to Section 5.1.1.3.4 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 6C.

5.1.1.11.5 Analysis of Spatial Distribution of Concentration

Refer to Section 5.1.1.3.5 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 6C.

5.1.1.11.6 Summary of Impacts

Refer to Section 5.1.1.3.6 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 6C.

5.1.2 Human Health Impacts

Potential human health impacts due to release of radionuclides are estimated as dose and as lifetime risk of incidence of cancer. For long-term performance assessment, radiological dose and risk are estimated consistent with the recommendations of *Cancer Risk Coefficients for Environmental Exposure to Radionuclides*, Federal Guidance Report No. 13 (Eckerman et al. 1999), including use of radionuclide-specific dose factors and risk coefficients. Potential human health effects due to release of chemical constituents include both carcinogenic effects and other forms of toxicity. Impacts of carcinogenic chemicals are estimated as lifetime risk of incidence of cancer. Noncarcinogenic effects are estimated as Hazard Quotient, the ratio of the long-term intake of a single chemical to intake that produces no observable effect, and as Hazard Index, the sum of the Hazard Quotients of a group of chemicals. Further information on the nature of human health effects in response to exposure to radiological and chemical constituents is provided in Appendix K. Screening analysis identified 14 radionuclide and 26 chemical constituents as contributing the greatest risk of adverse impacts. Appendix Q provides more information on the screening analysis, including time of occurrence of peak impacts and constituent- and location-specific impacts under each Tank Closure, FFTF Decommissioning, and Waste Management alternative.

Four measures of human health impacts are considered in this analysis—lifetime risks of developing cancer from radiological and chemical constituents, dose from radiological constituents, and Hazard Index from chemical constituents. These measures are calculated for each year for 10,000 years for receptors at eight specific locations (i.e., A, B, S, T, and U Barriers, Core Zone Boundary, Columbia River nearshore, and Columbia River surface water). This is a large amount of information that must be summarized to allow interpretation of results. The method chosen is to present dose for the year of maximum dose, risk for the year of maximum risk, and Hazard Index for the year of maximum Hazard Index. This choice is based on regulation of radiological impacts as dose, and the observation that peak risk and peak noncarcinogenic impacts expressed as Hazard Index may occur at times other than that of peak dose.

Three types of release are considered under the Tank Closure alternatives. The first type of release is the past practice of direct discharge of liquid to cribs and trenches (ditches). The second type of release is due to past leaks from damaged tanks. The third type of release identified in the following text and figures as "other tank farm sources" is due to future activities and includes leaks during retrieval of waste from the tanks, as well as long-term leaching of waste material in tanks and ancillary equipment.

Onsite locations are the boundaries of the tank farms, Core Zone Boundary, and Columbia River nearshore. Offsite locations are access points to Columbia River surface water near the site and at population centers downstream of the site. Estimates of concentration of constituents in the Columbia River surface water are used to calculate impacts for both the offsite location points of analysis. Total offsite population is 5 million people. Four types of receptor are considered. The first type, a drinking-water well user, uses groundwater as a source of drinking water. The second type, a resident farmer, uses groundwater for drinking-water consumption and irrigation of crops. Garden size and crop yield are assumed adequate to produce approximately 25 percent of average requirements of crops and animal products. The third type, an American Indian resident farmer, also uses groundwater for drinking-water consumption and irrigation of crops. Garden size and crop yield are assumed adequate to produce the entirety of average requirements of crops and animal products. The fourth type, an American Indian hunter-gatherer, is impacted by both groundwater and surface water because he uses surface water for drinking-water consumption and consumes both wild plant materials, which use groundwater, and game animals, which use surface water. In Appendix Q, estimates of impacts are presented in two sets of tables, one set for receptors using groundwater and one set for users of surface water. To facilitate presentation, estimates of impacts on the American Indian hunter-gatherer are presented in the set of tables for surface water users in Appendix Q. However, in this section and in subsequent sections, the

impacts on the American Indian hunter-gatherer are presented under the Columbia River nearshore location.

The significance of dose impacts is evaluated by comparison with the 100-millirem-per-year all-exposure-modes standard specified for protection of the public and the environment in DOE Order 5400.5, *Radiation Protection of the Public and the Environment.* The level of protection provided for the drinking-water pathway is evaluated by comparison with applicable drinking-water standards presented in Section 5.1.1. Population doses are compared with the total effective dose equivalent from background sources of 365 millirem per year for a member of the population of the United States (NCRP 1987). The significance of noncarcinogenic chemical impacts is evaluated by comparison with a guideline value of unity for Hazard Index.

5.1.2.1 Tank Closure Alternative 1: No Action

Under Tank Closure Alternative 1, the tank farms would be maintained in the current condition indefinitely but, for the purpose of analysis, the structural integrity of the tanks is assumed to fail after an administrative control period of 100 years. The salt cake in the SSTs is assumed available at this time for leaching into the vadose zone, and the liquid contents of the DSTs are assumed to be discharged directly to the vadose zone. Potential human health impacts under Tank Closure Alternative 1 are detailed in Appendix Q and summarized in Tables 5–10 through 5–15; those related to cribs and trenches (ditches) after CY 1940 are in Tables 5–10 and 5–11; to past leaks after CY 1940 in Tables 5–12 and 5–13; and to the combination of cribs and trenches (ditches), past leaks, and other tank farm sources after CY 2050 in Tables 5–14 and 5–15.

Due to the large magnitude of the liquid release in the analysis, transport through the vadose zone is rapid, and impacts exceeding dose standards are estimated for onsite locations. The largest contributors are the cribs and trenches (ditches) and the presence of tritium, technetium-99, iodine-129, uranium-238, chromium, nitrates, and total uranium. Due to large dilution in the Columbia River, offsite impacts on individuals are small. The population dose was estimated as 3.39 person-rem per year for the year of maximum impact. This corresponds to 1.85×10^{-4} percent of the annual population dose due to background exposure.

Table 5–10. Tank Closure Alternative 1 Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	6.39×10^{2}	7.88×10^{2}	1.24×10^{-2}	0.00	1.24×10^{-2}	1.24×10^{3}	8.86×10^{2}	3.48×10^{-2}	1.98×10^{-7}	3.48×10^{-2}
T Barrier	1.44×10^{3}	1.23×10^{2}	1.37×10^{-2}	0.00	1.37×10^{-2}	2.30×10^{3}	1.35×10^{2}	2.40×10^{-2}	3.54×10^{-8}	2.40×10^{-2}
Core Zone Boundary	6.39×10^{2}	5.12×10^{2}	1.24×10^{-2}	0.00	1.24×10^{-2}	1.24×10^{3}	5.88×10^{2}	3.48×10^{-2}	1.13×10^{-7}	3.48×10^{-2}
Columbia River nearshore	2.51×10^{-1}	4.57×10^{-1}	4.89×10^{-6}	0.00	4.89×10^{-6}	4.40×10^{-1}	5.04×10^{-1}	1.58×10^{-5}	1.28×10^{-10}	1.58×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	1.93×10^{-4}	1.60×10^{-4}	5.88×10^{-9}	3.39×10^{-14}	5.88×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–11. Tank Closure Alternative 1 American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	2.37×10^{3}	1.50×10^{3}	7.43×10^{-2}	9.10×10^{-3}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
T Barrier	4.22×10^{3}	2.22×10^{2}	4.79×10^{-2}	1.62×10^{-3}	4.79×10^{-2}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	2.37×10^{3}	1.02×10^{3}	7.43×10^{-2}	5.17×10^{-3}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	8.29×10^{-1}	8.33×10^{-1}	3.44×10^{-5}	5.86×10^{-6}	3.44×10^{-5}	5.44×10^{-1}	8.17×10^{-1}	6.69×10^{-6}	2.93×10^{-6}	7.94×10^{-6}
Off Site										
Columbia River	5.59×10^{-4}	2.10×10^{-1}	1.80×10^{-8}	1.56×10^{-9}	1.88×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–12. Tank Closure Alternative 1 Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	2.87×10^{1}	6.34×10^{-1}	8.23×10^{-4}	0.00	8.23×10^{-4}	6.39×10^{1}	6.58×10^{-1}	2.55×10^{-3}	2.30×10^{-10}	2.55×10^{-3}
B Barrier	2.05×10^{1}	1.26	6.00×10^{-4}	0.00	6.00×10^{-4}	4.62×10^{1}	1.35	1.87×10^{-3}	4.04×10^{-10}	1.87×10^{-3}
S Barrier	9.13	4.19	2.64×10^{-4}	0.00	2.64×10^{-4}	2.04×10^{1}	4.26	8.19×10^{-4}	1.65×10^{-9}	8.19×10^{-4}
T Barrier	5.36×10^{1}	5.81	1.54×10^{-3}	0.00	1.54×10^{-3}	1.19×10^{2}	6.03	4.76×10^{-3}	2.12×10^{-9}	4.76×10^{-3}
U Barrier	9.86×10^{-1}	1.39×10^{-1}	1.11×10^{-5}	0.00	1.11×10^{-5}	1.02	1.42×10^{-1}	3.14×10^{-5}	5.29×10^{-11}	3.14×10^{-5}
Core Zone Boundary	1.20×10^{1}	4.55	3.57×10^{-4}	0.00	3.57×10^{-4}	2.74×10^{1}	4.63	1.12×10^{-3}	1.76×10^{-9}	1.12×10^{-3}
Columbia River nearshore	3.14×10^{-1}	4.19×10^{-2}	9.45×10^{-6}	0.00	9.45×10^{-6}	7.24×10^{-1}	4.32×10^{-2}	2.97×10^{-5}	1.60×10^{-11}	2.97×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	3.27×10^{-5}	2.15×10^{-6}	1.32×10^{-9}	7.48×10^{-16}	1.32×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–13. Tank Closure Alternative 1 American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.24×10^{2}	1.01	5.48×10^{-3}	1.05×10^{-5}	5.48×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	8.99×10^{1}	2.15	4.02×10^{-3}	1.85×10^{-5}	4.02×10^{-3}	N/A	N/A	N/A	N/A	N/A
S Barrier	3.96×10^{1}	6.36	1.76×10^{-3}	7.55×10^{-5}	1.76×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	2.31×10^{2}	9.26	1.02×10^{-2}	9.70×10^{-5}	1.02×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	1.51	2.15×10^{-1}	6.76×10^{-5}	2.42×10^{-6}	6.76×10^{-5}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	5.36×10^{1}	6.95	2.41×10^{-3}	8.09×10^{-5}	2.41×10^{-3}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.42	6.56×10^{-2}	6.41×10^{-5}	7.34×10^{-7}	6.41×10^{-5}	7.64×10^{-3}	1.86×10^{-2}	9.87×10^{-8}	3.67×10^{-7}	4.44×10^{-7}
Off Site										
Columbia River	1.32×10^{-4}	1.05×10^{-3}	4.72×10^{-9}	3.43×10^{-11}	4.74×10^{-9}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–14. Tank Closure Alternative 1 Drinking-Water Well User and Resident Farmer Long-Term Human Health Impact Summary

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.43×10^{2}	4.13	4.45×10^{-3}	2.40×10^{-11}	4.45×10^{-3}	3.39×10^{2}	4.66	1.42×10^{-2}	1.12×10^{-9}	1.42×10^{-2}
B Barrier	3.69×10^{2}	6.95×10^{1}	1.13×10^{-2}	0.00	1.24×10^{-2}	8.60×10^{2}	7.94×10^{1}	3.56×10^{-2}	1.98×10^{-8}	3.56×10^{-2}
S Barrier	8.33×10^{1}	1.73×10^{1}	2.51×10^{-3}	1.36×10^{-11}	2.51×10^{-3}	1.92×10^{2}	1.78×10^{1}	7.89×10^{-3}	6.49×10^{-9}	7.89×10^{-3}
T Barrier	3.52×10^{1}	1.18×10^{1}	1.00×10^{-3}	0.00	1.37×10^{-2}	7.80×10^{1}	1.28×10^{1}	3.10×10^{-3}	3.58×10^{-9}	2.40×10^{-2}
U Barrier	3.43×10^{1}	3.42	9.87×10^{-4}	0.00	9.87×10^{-4}	7.63×10^{1}	3.59	3.06×10^{-3}	1.21×10^{-9}	3.06×10^{-3}
Core Zone Boundary	7.44×10^{2}	1.31×10^{2}	2.26×10^{-2}	2.99×10^{-11}	2.26×10^{-2}	1.73×10^{3}	1.35×10^{2}	7.12×10^{-2}	4.79×10^{-8}	7.12×10^{-2}
Columbia River nearshore	1.19×10^{1}	1.88	3.40×10^{-4}	6.19×10^{-13}	3.40×10^{-4}	2.62×10^{1}	1.98	1.07×10^{-3}	6.47×10^{-10}	1.07×10^{-3}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	6.77×10^{-4}	4.39×10^{-5}	2.76×10^{-8}	1.24×10^{-14}	2.76×10^{-8}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–15. Tank Closure Alternative 1 American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impact Summary

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	6.72×10^{2}	7.87	3.07×10^{-2}	5.12×10^{-5}	3.07×10^{-2}	N/A	N/A	N/A	N/A	N/A
B Barrier	1.70×10^{3}	1.37×10^{2}	7.70×10^{-2}	9.10×10^{-4}	7.70×10^{-2}	N/A	N/A	N/A	N/A	N/A
S Barrier	3.77×10^{2}	2.71×10^{1}	1.70×10^{-2}	2.97×10^{-4}	1.70×10^{-2}	N/A	N/A	N/A	N/A	N/A
T Barrier	1.51×10^{2}	2.08×10^{1}	6.66×10^{-3}	1.64×10^{-4}	4.79×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	1.48×10^{2}	5.59	6.57×10^{-3}	5.56×10^{-5}	6.57×10^{-3}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	3.40×10^{3}	2.08×10^{2}	1.54×10^{-1}	2.20×10^{-3}	1.54×10^{-1}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	5.11×10^{1}	3.10	2.30×10^{-3}	2.97×10^{-5}	2.30×10^{-3}	7.31×10^{-2}	1.14	3.49×10^{-6}	1.48×10^{-5}	1.77×10^{-5}
Off Site										
Columbia River	2.61×10^{-3}	3.94×10^{-2}	9.42×10^{-8}	5.68×10^{-10}	9.47×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

For releases from the cribs and trenches (ditches), peak impacts at the B and T Barriers are estimated to occur in the past, prior to CY 2000. For past leaks, peak impacts at the tank farm barriers are estimated to occur in the vicinity of, or prior to, CY 2050. As shown in Figure 5–325, peak impacts at the Core Zone Boundary due to all sources are the result primarily of assumed tank failure and occur as a narrow, early peak and as a broad pulse extending between CYs 2500 and 5000. An elevated level of risk due to tank failure extends over the entire period of analysis. At the Core Zone Boundary, peak risk due to tank failure is approximately a factor of 20 greater than peak risk due to cribs and trenches (ditches) and a factor of 100 greater than peak risk due to past leaks.

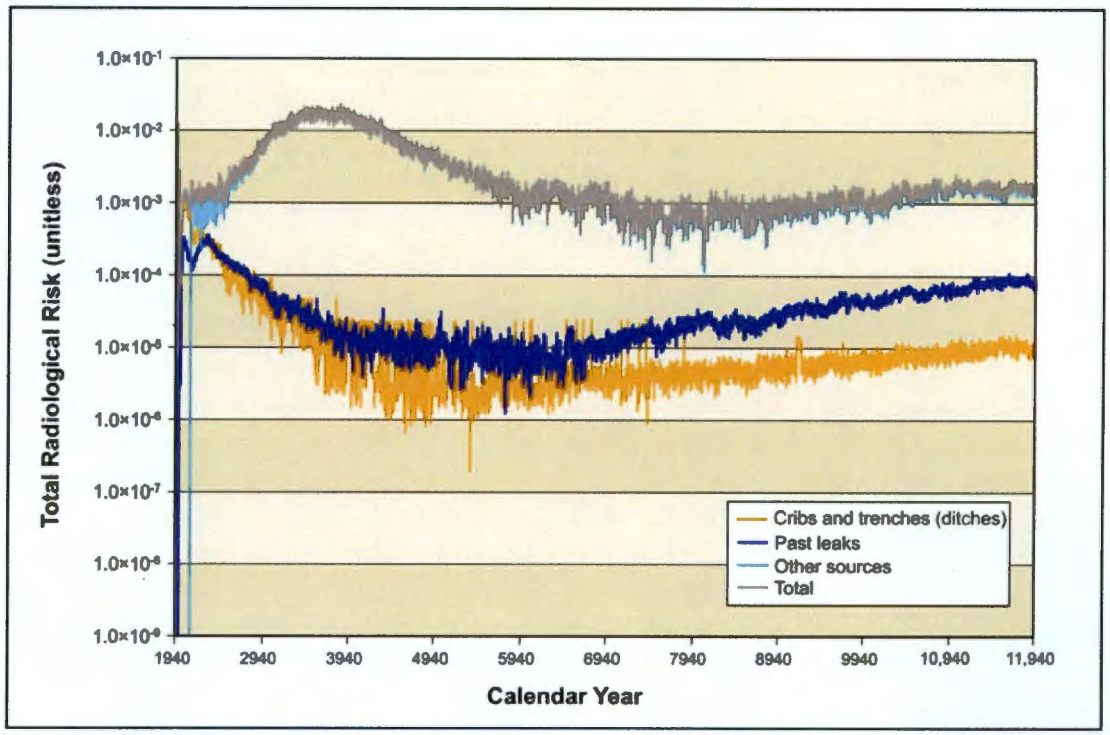


Figure 5–325. Tank Closure Alternative 1 Time Series of Radiological Risk for the Drinking-Water Well User at the Core Zone Boundary

5.1.2.2 Tank Closure Alternative 2A: Existing WTP Vitrification; No Closure

Under Tank Closure Alternative 2A, tank waste would be retrieved to a volume corresponding to 99 percent retrieval, but the residual material in tanks would not be stabilized. After an administrative control period of 100 years, salt cake in the tanks was assumed available for dissolution in infiltrating water and the liquid contents of the DSTs are assumed to be discharged directly to the vadose zone. Potential human health impacts under Tank Closure Alternative 2A are detailed in Appendix Q and summarized in Tables 5–16 through 5–21; those related to cribs and trenches (ditches) after CY 1940 are in Tables 5–16 and 5–17; to past leaks after CY 1940 in Tables 5–18 and 5–19; and to the combination of cribs and trenches (ditches), past leaks, and other tank farm sources after CY 2050 in Tables 5–20 and 5–21.

The dose standard would be exceeded at the B Barrier, T Barrier, and Core Zone Boundary for the drinking-water well user, resident farmer, and American Indian resident farmer due to the presence of tritium, technetium-99, and iodine-129 released from the cribs and trenches (ditches), but would not be exceeded at the other locations. For the drinking-water well user, resident farmer, and American Indian resident farmer, the Hazard Index guideline would be exceeded at the B Barrier, T Barrier, and Core Zone Boundary due primarily to release of chromium and nitrate from the cribs and trenches (ditches).

Table 5–16. Tank Closure Alternative 2A Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	6.61×10^{2}	7.60×10^{2}	1.29×10^{-2}	0.00	1.29×10^{-2}	1.28×10^{3}	8.63×10^{2}	3.59×10^{-2}	1.80×10^{-7}	3.59×10^{-2}
T Barrier	1.43×10^{3}	1.25×10^{2}	1.36×10^{-2}	0.00	1.36×10^{-2}	2.28×10^{3}	1.37×10^{2}	2.39×10^{-2}	3.58×10^{-8}	2.39×10^{-2}
Core Zone Boundary	6.61×10^{2}	5.00×10^{2}	1.29×10^{-2}	0.00	1.29×10^{-2}	1.28×10^{3}	5.76×10^{2}	3.59×10^{-2}	1.07×10^{-7}	3.59×10^{-2}
Columbia River nearshore	2.16×10^{-1}	3.97×10^{-1}	4.24×10^{-6}	0.00	4.24×10^{-6}	3.83×10^{-1}	4.39×10^{-1}	1.35×10^{-5}	1.15×10^{-10}	1.35×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	1.88×10^{-4}	1.60×10^{-4}	5.67×10^{-9}	3.49×10^{-14}	5.67×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–17. Tank Closure Alternative 2A American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	2.45×10^{3}	1.47×10^{3}	7.67×10^{-2}	8.27×10^{-3}	7.67×10^{-2}	N/A	N/A	N/A	N/A	N/A
T Barrier	4.19×10^{3}	2.25×10^{2}	4.76×10^{-2}	1.64×10^{-3}	4.76×10^{-2}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	2.45×10^{3}	1.00×10^{3}	7.67×10^{-2}	4.89×10^{-3}	7.67×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	7.20×10^{-1}	7.27×10^{-1}	2.92×10^{-5}	5.29×10^{-6}	2.92×10^{-5}	4.37×10^{-1}	6.78×10^{-1}	5.38×10^{-6}	2.65×10^{-6}	6.85×10^{-6}
Off Site										
Columbia River	5.55×10^{-4}	2.09×10^{-1}	1.77×10^{-8}	1.60×10^{-9}	1.85×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–18. Tank Closure Alternative 2A Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	2.79×10^{1}	6.31×10^{-1}	7.95×10^{-4}	0.00	7.95×10^{-4}	6.18×10^{1}	6.55×10^{-1}	2.46×10^{-3}	2.30×10^{-10}	2.46×10^{-3}
B Barrier	2.07×10^{1}	1.55	6.17×10^{-4}	0.00	6.17×10^{-4}	4.74×10^{1}	1.57	1.93×10^{-3}	3.75×10^{-10}	1.93×10^{-3}
S Barrier	9.08	4.08	2.62×10^{-4}	0.00	2.62×10^{-4}	2.03×10^{1}	4.15	8.12×10^{-4}	1.60×10^{-9}	8.12×10^{-4}
T Barrier	5.30×10^{1}	5.73	1.52×10^{-3}	0.00	1.52×10^{-3}	1.18×10^{2}	5.95	4.70×10^{-3}	2.08×10^{-9}	4.70×10^{-3}
U Barrier	1.24	1.44×10^{-1}	1.40×10^{-5}	0.00	1.40×10^{-5}	1.29	1.48×10^{-1}	3.14×10^{-5}	5.48×10^{-11}	3.14×10^{-5}
Core Zone Boundary	1.37×10^{1}	4.95	3.30×10^{-4}	0.00	3.30×10^{-4}	2.54×10^{1}	5.03	1.03×10^{-3}	1.95×10^{-9}	1.03×10^{-3}
Columbia River nearshore	3.08×10^{-1}	4.11×10^{-2}	9.27×10^{-6}	0.00	9.27×10^{-6}	7.10×10^{-1}	4.23×10^{-2}	2.92×10^{-5}	1.61×10^{-11}	2.92×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	3.29×10^{-5}	2.26×10^{-6}	1.32×10^{-9}	7.74×10^{-16}	1.32×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–19. Tank Closure Alternative 2A American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.20×10^{2}	1.01	5.28×10^{-3}	1.05×10^{-5}	5.28×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	9.27×10^{1}	2.16	4.17×10^{-3}	1.72×10^{-5}	4.17×10^{-3}	N/A	N/A	N/A	N/A	N/A
S Barrier	3.93×10^{1}	6.20	1.75×10^{-3}	7.33×10^{-5}	1.75×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	2.28×10^{2}	9.15	1.01×10^{-2}	9.53×10^{-5}	1.01×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	1.51	2.25×10^{-1}	6.77×10^{-5}	2.51×10^{-6}	6.77×10^{-5}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	4.95×10^{1}	7.49	2.22×10^{-3}	8.95×10^{-5}	2.22×10^{-3}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.39	6.43×10^{-2}	6.30×10^{-5}	7.39×10^{-7}	6.30×10^{-5}	1.06×10^{-2}	1.71×10^{-2}	1.38×10^{-7}	3.70×10^{-7}	4.28×10^{-7}
Off Site										
Columbia River	1.35×10^{-4}	1.08×10^{-3}	4.78×10^{-9}	3.55×10^{-11}	4.81×10^{-9}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–20. Tank Closure Alternative 2A Drinking-Water Well User and Resident Farmer Long-Term Human Health Impact Summary

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	3.60	3.16×10^{-1}	1.05×10^{-4}	1.16×10^{-13}	7.95×10^{-4}	8.09	3.80×10^{-1}	3.26×10^{-4}	4.73×10^{-11}	2.46×10^{-3}
B Barrier	6.83×10^{1}	6.89×10^{1}	2.05×10^{-3}	0.00	1.29×10^{-2}	1.57×10^{2}	7.78×10^{1}	6.45×10^{-3}	1.67×10^{-8}	3.59×10^{-2}
S Barrier	6.31	2.94	1.85×10^{-4}	0.00	2.62×10^{-4}	1.43×10^{1}	2.99	5.78×10^{-4}	1.14×10^{-9}	8.12×10^{-4}
T Barrier	3.53×10^{1}	9.90	1.01×10^{-3}	0.00	1.36×10^{-2}	7.82×10^{1}	1.06×10^{1}	3.11×10^{-3}	3.14×10^{-9}	2.39×10^{-2}
U Barrier	1.33	2.60×10^{-1}	3.57×10^{-5}	0.00	3.57×10^{-5}	2.74	2.93×10^{-1}	1.12×10^{-4}	6.66×10^{-11}	1.12×10^{-4}
Core Zone Boundary	5.92×10^{1}	3.78×10^{1}	1.80×10^{-3}	4.67×10^{-14}	1.29×10^{-2}	1.37×10^{2}	4.38×10^{1}	5.66×10^{-3}	7.69×10^{-9}	3.59×10^{-2}
Columbia River nearshore	4.39×10^{-1}	4.36×10^{-1}	1.32×10^{-5}	1.53×10^{-15}	1.32×10^{-5}	1.01	4.80×10^{-1}	4.15×10^{-5}	1.26×10^{-10}	4.15×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	4.37×10^{-5}	2.00×10^{-5}	1.77×10^{-9}	3.91×10^{-15}	5.67×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–21. Tank Closure Alternative 2A American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impact Summary

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.57×10^{1}	6.87×10^{-1}	7.02×10^{-4}	2.17×10^{-6}	5.28×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	3.08×10^{2}	1.32×10^{2}	1.39×10^{-2}	7.68×10^{-4}	7.67×10^{-2}	N/A	N/A	N/A	N/A	N/A
S Barrier	2.78×10^{1}	4.49	1.25×10^{-3}	5.23×10^{-5}	1.75×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	1.51×10^{2}	1.70×10^{1}	6.68×10^{-3}	1.44×10^{-4}	4.76×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	5.36	4.96×10^{-1}	2.41×10^{-4}	3.05×10^{-6}	2.41×10^{-4}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	2.70×10^{2}	7.67×10^{1}	1.22×10^{-2}	3.53×10^{-4}	7.67×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.98	7.91×10^{-1}	8.96×10^{-5}	5.78×10^{-6}	8.96×10^{-5}	4.36×10^{-2}	3.99×10^{-1}	5.66×10^{-7}	2.89×10^{-6}	6.85×10^{-6}
Off Site										
Columbia River	1.72×10^{-4}	2.93×10^{-2}	6.19×10^{-9}	1.79×10^{-10}	1.85×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

The dose standard would be exceeded at the A Barrier for the American Indian resident farmer and at the T Barrier for the resident farmer and American Indian resident farmer due to the presence of tritium, technetium-99, and iodine-129 released in past leaks. The Hazard Index guideline would be exceeded for the drinking-water well user, resident farmer, and American Indian resident farmer at the B Barrier, S Barrier, T Barrier, and the Core Zone Boundary primarily due to release of chromium and nitrate from past leaks. The Hazard Index guideline would also be exceeded for the resident farmer at the A Barrier primarily due to chromium and nitrate. The Hazard Index guideline would be exceeded for the American Indian resident farmer at the T Barrier primarily due to release of nitrate from past leaks. After CY 2050, the dose standard would be exceeded at the B Barrier and Core Zone Boundary for the resident farmer and American Indian resident farmer due to the presence of tritium, technetium-99, and iodine-129, and the dose standard would be exceeded at the T Barrier for the American Indian resident farmer due to the presence of tritium, technetium-99, iodine-129, and uranium-238. The Hazard Index guideline would be exceeded at the B Barrier, S Barrier, T Barrier, and Core Zone Boundary for the drinking-water well user, resident farmer, and American Indian resident farmer primarily due to chromium, nitrate, and total uranium. The population dose was estimated as 2.18×10^{-1} person-rem per year for the year of maximum impact. This corresponds to 1.20×10^{-5} percent of the annual population dose due to background exposure.

For releases from cribs and trenches (ditches) and past leaks, estimates of the magnitude and time series of impacts are substantially the same as those reported for Tank Closure Alternative 1. As shown in Figure 5–326, peak impacts at the Core Zone Boundary due to tank salt cake or liquid release are reduced by approximately a factor of 100 due to tank retrieval activity. A substantial peak due to tank failure remains centered on CY 3200, but the major contributor for long-term impacts shifts to past leaks under Tank Closure Alternative 2A.

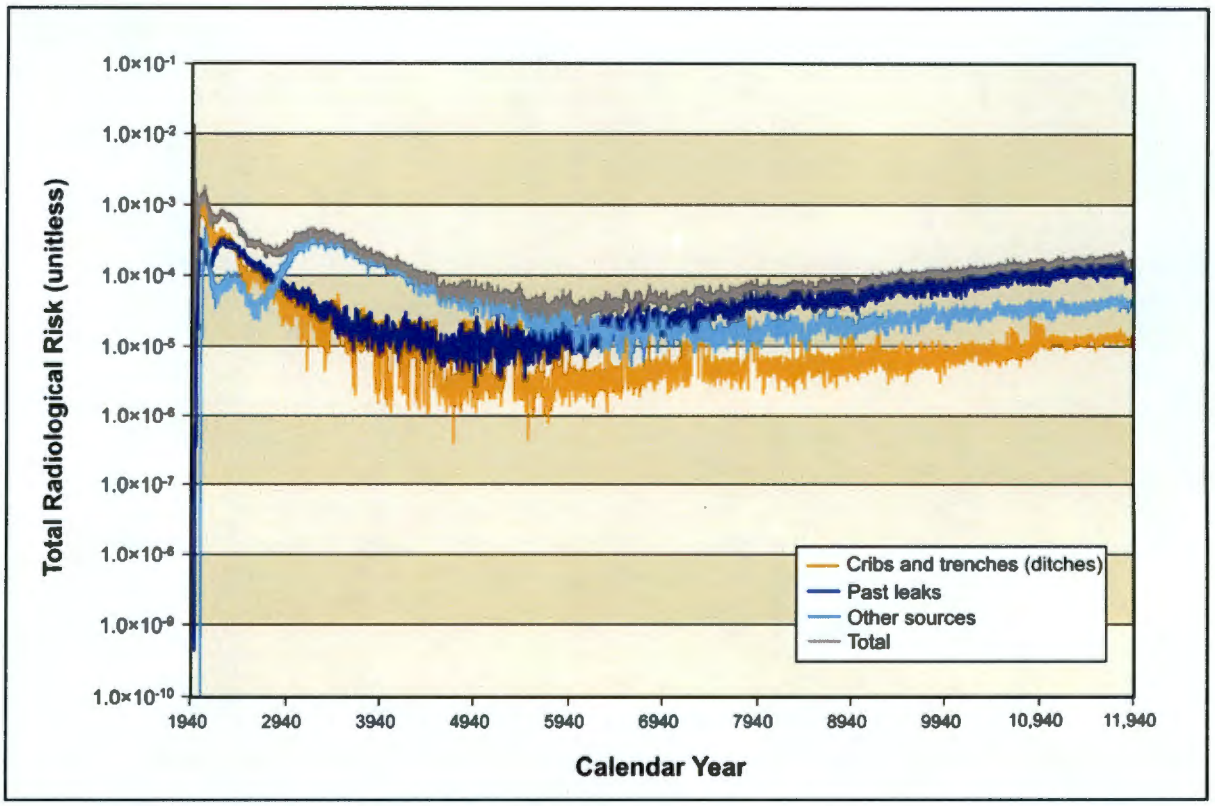


Figure 5–326. Tank Closure Alternative 2A Time Series of Radiological Risk for the Drinking-Water Well User at the Core Zone Boundary

5.1.2.3 Alternative 2B: Expanded WTP Vitrification; Landfill Closure

Activities under Tank Closure Alternative 2B would be similar to those under Tank Closure Alternative 2A, except that residual material in tanks would be stabilized in place. Soil would be removed down to 4.6 meters (15 feet) for the BX and SX tank farms and replaced with clean soils from onsite sources. The tank farms and six sets of adjacent cribs and trenches (ditches) would be covered with an engineered modified RCRA Subtitle C barrier. Potential human health impacts under Tank Closure Alternative 2B are detailed in Appendix Q and summarized in Tables 5–22 through 5–27; those related to cribs and trenches (ditches) after CY 1940 are in Tables 5–22 and 5–23; to past leaks after CY 1940 in Tables 5–24 and 5–25; and to the combination of cribs and trenches (ditches), past leaks, and other tank farm sources after CY 2050 in Tables 5–26 and 5–27.

The risk and hazard drivers are tritium, technetium-99, iodine-129, uranium-238, chromium, nitrate, and total uranium. Impacts would be slightly less than those under Tank Closure Alternative 2A, and standards would be exceeded, as under Alternative 2A. The population dose was estimated as 1.95×10^{-1} person-rem per year for the year of maximum impact. This corresponds to 1.07×10^{-5} percent of the annual population dose due to background exposure.

For releases from cribs and trenches (ditches) and past leaks, estimates of the magnitude and time series of impacts are substantially the same as those reported for Tank Closure Alternatives 1 and 2A. As shown in Figure 5–327, radiological risks at the Core Zone Boundary due to cribs and trenches (ditches) and past leaks prior to CY 3000 are nearly identical to those under Tank Closure Alternative 2A, while long-term risks are reduced slightly due to placement of caps under Tank Closure Alternative 2B. As in the case of Tank Closure Alternative 2A, peak impacts are due to releases from cribs and trenches (ditches) for the early time period, to leaching from other tank farm sources for the intermediate time period, and to past leaks for the long-term time period.

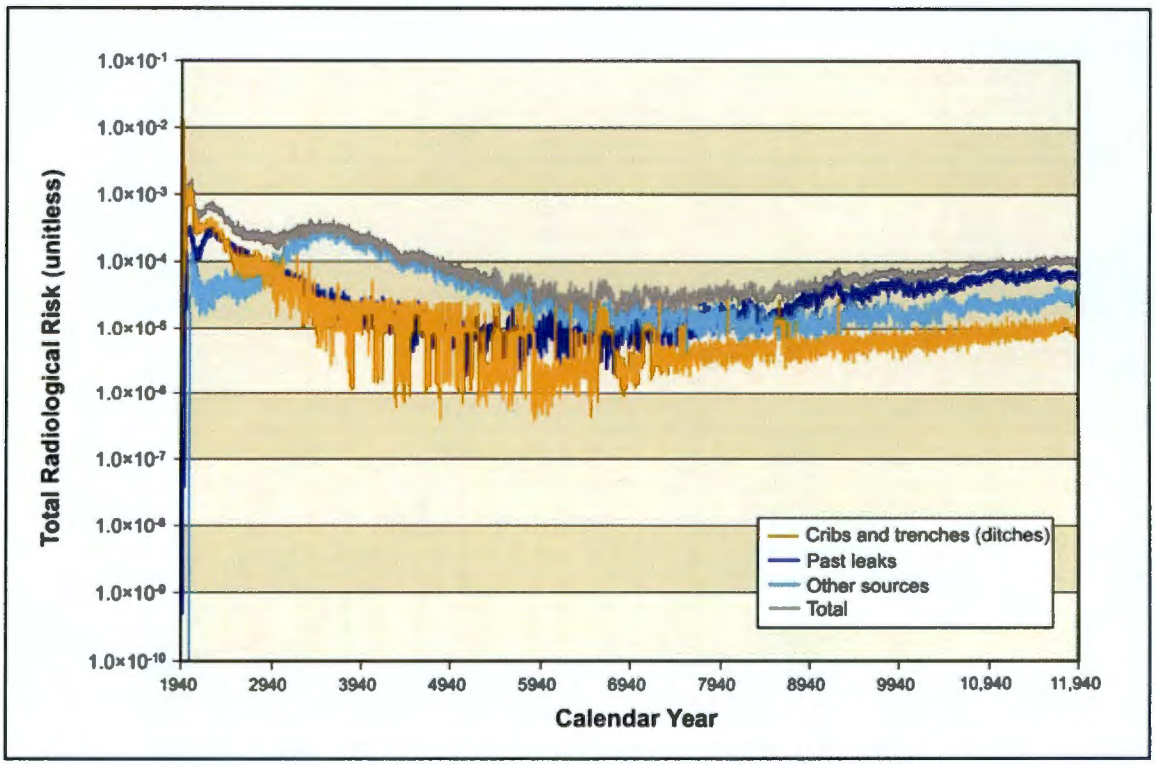


Figure 5–327. Tank Closure Alternative 2B Time Series of Radiological Risk for the Drinking-Water Well User at the Core Zone Boundary

Table 5–22. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	6.36×10^{2}	7.95×10^{2}	1.24×10^{-2}	0.00	1.24×10^{-2}	1.24×10^{3}	8.94×10^{2}	3.48×10^{-2}	2.00×10^{-7}	3.48×10^{-2}
T Barrier	1.46×10^{3}	1.27×10^{2}	1.39×10^{-2}	0.00	1.39×10^{-2}	2.32×10^{3}	1.39×10^{2}	2.43×10^{-2}	3.66×10^{-8}	2.43×10^{-2}
Core Zone Boundary	6.36×10^{2}	4.97×10^{2}	1.24×10^{-2}	0.00	1.24×10^{-2}	1.24×10^{3}	5.70×10^{2}	3.48×10^{-2}	1.10×10^{-7}	3.48×10^{-2}
Columbia River nearshore	2.08×10^{-1}	4.02×10^{-1}	5.89×10^{-6}	0.00	5.89×10^{-6}	4.79×10^{-1}	4.35×10^{-1}	1.85×10^{-5}	1.23×10^{-10}	1.85×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	1.91×10^{-4}	1.63×10^{-4}	5.83×10^{-9}	3.52×10^{-14}	5.83×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–23. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	2.36×10^{3}	1.51×10^{3}	7.43×10^{-2}	9.16×10^{-3}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
T Barrier	4.27×10^{3}	2.27×10^{2}	4.85×10^{-2}	1.68×10^{-3}	4.85×10^{-2}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	2.36×10^{3}	9.85×10^{2}	7.43×10^{-2}	5.05×10^{-3}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	9.53×10^{-1}	7.03×10^{-1}	4.01×10^{-5}	5.66×10^{-6}	4.01×10^{-5}	4.04×10^{-1}	7.14×10^{-1}	4.97×10^{-6}	2.83×10^{-6}	6.40×10^{-6}
Off Site										
Columbia River	5.59×10^{-4}	2.11×10^{-1}	1.80×10^{-8}	1.61×10^{-9}	1.88×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–24. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	2.75×10^{1}	6.52×10^{-1}	7.79×10^{-4}	0.00	7.79×10^{-4}	6.07×10^{1}	6.76×10^{-1}	2.40×10^{-3}	2.38×10^{-10}	2.40×10^{-3}
B Barrier	1.92×10^{1}	1.22	5.57×10^{-4}	0.00	5.57×10^{-4}	4.30×10^{1}	1.32	1.73×10^{-3}	3.76×10^{-10}	1.73×10^{-3}
S Barrier	9.42	4.15	2.72×10^{-4}	0.00	2.72×10^{-4}	2.10×10^{1}	4.22	8.44×10^{-4}	1.62×10^{-9}	8.44×10^{-4}
T Barrier	5.27×10^{1}	5.75	1.51×10^{-3}	0.00	1.51×10^{-3}	1.17×10^{2}	5.98	4.67×10^{-3}	2.07×10^{-9}	4.67×10^{-3}
U Barrier	9.90×10^{-1}	1.40×10^{-1}	1.12×10^{-5}	0.00	1.12×10^{-5}	1.03	1.43×10^{-1}	2.97×10^{-5}	5.31×10^{-11}	2.97×10^{-5}
Core Zone Boundary	1.10×10^{1}	4.03	3.21×10^{-4}	0.00	3.21×10^{-4}	2.48×10^{1}	4.10	9.99×10^{-4}	1.58×10^{-9}	9.99×10^{-4}
Columbia River nearshore	2.83×10^{-1}	4.21×10^{-2}	8.87×10^{-6}	0.00	8.87×10^{-6}	6.74×10^{-1}	4.34×10^{-2}	2.83×10^{-5}	1.57×10^{-11}	2.83×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	3.15×10^{-5}	2.07×10^{-6}	1.28×10^{-9}	7.23×10^{-16}	1.28×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–25. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.17×10^{2}	1.04	5.16×10^{-3}	1.09×10^{-5}	5.16×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	8.35×10^{1}	2.14	3.72×10^{-3}	1.72×10^{-5}	3.72×10^{-3}	N/A	N/A	N/A	N/A	N/A
S Barrier	4.08×10^{1}	6.31	1.82×10^{-3}	7.44×10^{-5}	1.82×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	2.26×10^{2}	9.21	1.00×10^{-2}	9.52×10^{-5}	1.00×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	1.44	2.16×10^{-1}	6.38×10^{-5}	2.44×10^{-6}	6.38×10^{-5}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	4.82×10^{1}	6.12	2.15×10^{-3}	7.26×10^{-5}	2.15×10^{-3}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.34	6.61×10^{-2}	6.13×10^{-5}	7.21×10^{-7}	6.13×10^{-5}	6.74×10^{-3}	1.89×10^{-2}	9.01×10^{-8}	3.61×10^{-7}	4.20×10^{-7}
Off Site										
Columbia River	1.25×10^{-4}	1.02×10^{-3}	4.48×10^{-9}	3.32×10^{-11}	4.51×10^{-9}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–26. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Drinking-Water Well User and Resident Farmer Long-Term Human Health Impact Summary

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	3.27	1.84×10^{-1}	9.56×10^{-5}	8.57×10^{-14}	7.79×10^{-4}	7.37	2.16×10^{-1}	2.97×10^{-4}	3.43×10^{-11}	2.40×10^{-3}
B Barrier	6.31×10^{1}	5.79×10^{1}	1.93×10^{-3}	0.00	1.24×10^{-2}	1.47×10^{2}	6.67×10^{1}	6.08×10^{-3}	1.27×10^{-8}	3.48×10^{-2}
S Barrier	6.09	2.74	1.77×10^{-4}	0.00	2.72×10^{-4}	1.36×10^{1}	2.80	5.48×10^{-4}	1.07×10^{-9}	8.44×10^{-4}
T Barrier	3.55×10^{1}	9.63	1.02×10^{-3}	0.00	1.39×10^{-2}	7.89×10^{1}	1.04×10^{1}	3.14×10^{-3}	3.02×10^{-9}	2.43×10^{-2}
U Barrier	1.04	1.18×10^{-1}	1.79×10^{-5}	0.00	1.79×10^{-5}	1.36	1.19×10^{-1}	5.72×10^{-5}	3.91×10^{-11}	5.72×10^{-5}
Core Zone Boundary	5.42×10^{1}	3.39×10^{1}	1.66×10^{-3}	3.26×10^{-14}	1.24×10^{-2}	1.27×10^{2}	3.96×10^{1}	5.25×10^{-3}	6.55×10^{-9}	3.48×10^{-2}
Columbia River nearshore	4.28×10^{-1}	4.35×10^{-1}	1.30×10^{-5}	1.07×10^{-15}	1.30×10^{-5}	9.93×10^{-1}	4.70×10^{-1}	4.14×10^{-5}	1.35×10^{-10}	4.14×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	3.89×10^{-5}	1.91×10^{-5}	1.57×10^{-9}	3.96×10^{-15}	5.83×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–27. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impact Summary

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.43×10^{1}	3.82×10^{-1}	6.40×10^{-4}	1.57×10^{-6}	5.16×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	2.90×10^{2}	1.16×10^{2}	1.31×10^{-2}	5.82×10^{-4}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
S Barrier	2.64×10^{1}	4.19	1.18×10^{-3}	4.89×10^{-5}	1.82×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	1.53×10^{2}	1.67×10^{1}	6.76×10^{-3}	1.38×10^{-4}	4.85×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	2.71	1.84×10^{-1}	1.24×10^{-4}	1.79×10^{-6}	1.24×10^{-4}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	2.50×10^{2}	6.98×10^{1}	1.14×10^{-2}	3.00×10^{-4}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.96	7.58×10^{-1}	8.95×10^{-5}	6.17×10^{-6}	8.95×10^{-5}	5.69×10^{-2}	3.84×10^{-1}	7.24×10^{-7}	3.09×10^{-6}	6.40×10^{-6}
Off Site										
Columbia River	1.54×10^{-4}	2.77×10^{-2}	5.55×10^{-9}	1.82×10^{-10}	1.88×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

5.1.2.4 Tank Closure Alternative 3A: Existing WTP Vitrification with Thermal Supplemental Treatment (Bulk Vitrification); Landfill Closure

Activities under Tank Closure Alternative 3A would be similar to those under Tank Closure Alternative 2B. Likewise, impacts exceeding dose and risk standards, the estimated population dose for the year of maximum impact, and corresponding percent of the annual population dose due to background exposure would be the same as those under Tank Closure Alternative 2B for cribs and trenches (ditches), past leaks, and other tank farm sources.

5.1.2.5 Tank Closure Alternative 3B: Existing WTP Vitrification with Nonthermal Supplemental Treatment (Cast Stone); Landfill Closure

Activities under Tank Closure Alternative 3B would be similar to those under Tank Closure Alternative 2B. Likewise, impacts exceeding dose and risk standards, the estimated population dose for the year of maximum impact, and corresponding percent of the annual population dose due to background exposure would be the same as those under Tank Closure Alternative 2B for cribs and trenches (ditches), past leaks, and other tank farm sources.

5.1.2.6 Tank Closure Alternative 3C: Existing WTP Vitrification with Thermal Supplemental Treatment (Steam Reforming); Landfill Closure

Activities under Tank Closure Alternative 3C would be similar to those under Tank Closure Alternative 2B. Likewise, impacts exceeding dose and risk standards, the estimated population dose for the year of maximum impact, and corresponding percent of the annual population dose due to background exposure would be the same as those under Tank Closure Alternative 2B for cribs and trenches (ditches), past leaks, and other tank farm sources.

5.1.2.7 Tank Closure Alternative 4: Existing WTP Vitrification with Supplemental Treatment Technologies; Selective Clean Closure/Landfill Closure

Under Tank Closure Alternative 4, tank waste would be retrieved to a volume corresponding to 99.9 percent retrieval. Except for the BX and SX tank farms, residual material in tanks would be stabilized in place and the tank farms and adjacent cribs and trenches (ditches) would be covered with an engineered modified RCRA Subtitle C barrier. The BX and SX tank farms would be clean-closed by removing the tanks, ancillary equipment, and soils to a depth of 3 meters (10 feet) below the tank base. Where necessary, deep soil excavation would also be conducted to remove contamination plumes within the soil column. Potential human health impacts under Tank Closure Alternative 4 are detailed in Appendix Q and summarized in Tables 5–28 through 5–33; those related to cribs and trenches (ditches) after CY 1940 are in Tables 5–28 and 5–29; to past leaks after CY 1940 in Tables 5–30 and 5–31; and to the combination of cribs and trenches (ditches), past leaks, and other tank farm sources after CY 2050 in Tables 5–32 and 5–33.

Table 5–28. Tank Closure Alternative 4 Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	6.36×10^{2}	7.95×10^{2}	1.24×10^{-2}	0.00	1.24×10^{-2}	1.24×10^{3}	8.94×10^{2}	3.48×10^{-2}	2.00×10^{-7}	3.48×10^{-2}
T Barrier	1.46×10^{3}	1.27×10^{2}	1.39×10^{-2}	0.00	1.39×10^{-2}	2.32×10^{3}	1.39×10^{2}	2.43×10^{-2}	3.66×10^{-8}	2.43×10^{-2}
Core Zone Boundary	6.36×10^{2}	4.97×10^{2}	1.24×10^{-2}	0.00	1.24×10^{-2}	1.24×10^{3}	5.70×10^{2}	3.48×10^{-2}	1.10×10^{-7}	3.48×10^{-2}
Columbia River nearshore	2.08×10^{-1}	4.02×10^{-1}	5.89×10^{-6}	0.00	5.89×10^{-6}	4.79×10^{-1}	4.35×10^{-1}	1.85×10^{-5}	1.23×10^{-10}	1.85×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	1.91×10^{-4}	1.63×10^{-4}	5.83×10^{-9}	3.52×10^{-14}	5.83×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–29. Tank Closure Alternative 4 American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	2.36×10^{3}	1.51×10^{3}	7.43×10^{-2}	9.16×10^{-3}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
T Barrier	4.27×10^{3}	2.27×10^{2}	4.85×10^{-2}	1.68×10^{-3}	4.85×10^{-2}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	2.36×10^{3}	9.85×10^{2}	7.43×10^{-2}	5.05×10^{-3}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	9.53×10^{-1}	7.03×10^{-1}	4.01×10^{-5}	5.66×10^{-6}	4.01×10^{-5}	4.04×10^{-1}	7.14×10^{-1}	4.97×10^{-6}	2.83×10^{-6}	6.40×10^{-6}
Off Site										
Columbia River	5.59×10^{-4}	2.11×10^{-1}	1.80×10^{-8}	1.61×10^{-9}	1.88×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–30. Tank Closure Alternative 4 Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	2.75×10^{1}	6.52×10^{-1}	7.79×10^{-4}	0.00	7.79×10^{-4}	6.07×10^{1}	6.76×10^{-1}	2.40×10^{-3}	2.38×10^{-10}	2.40×10^{-3}
B Barrier	1.74×10^{1}	1.09	5.07×10^{-4}	0.00	5.07×10^{-4}	3.91×10^{1}	1.18	1.57×10^{-3}	3.39×10^{-10}	1.57×10^{-3}
S Barrier	8.92	3.99	2.55×10^{-4}	0.00	2.55×10^{-4}	1.98×10^{1}	4.06	7.90×10^{-4}	1.56×10^{-9}	7.90×10^{-4}
T Barrier	5.27×10^{1}	5.75	1.51×10^{-3}	0.00	1.51×10^{-3}	1.17×10^{2}	5.98	4.67×10^{-3}	2.07×10^{-9}	4.67×10^{-3}
U Barrier	9.90×10^{-1}	1.40×10^{-1}	1.12×10^{-5}	0.00	1.12×10^{-5}	1.03	1.43×10^{-1}	2.97×10^{-5}	5.31×10^{-11}	2.97×10^{-5}
Core Zone Boundary	1.12×10^{1}	2.56	3.26×10^{-4}	0.00	3.26×10^{-4}	2.52×10^{1}	2.61	1.02×10^{-3}	1.00×10^{-9}	1.02×10^{-3}
Columbia River nearshore	2.79×10^{-1}	3.45×10^{-2}	8.42×10^{-6}	0.00	8.42×10^{-6}	6.45×10^{-1}	3.55×10^{-2}	2.68×10^{-5}	1.30×10^{-11}	2.68×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	3.08×10^{-5}	1.85×10^{-6}	1.25×10^{-9}	6.26×10^{-16}	1.25×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–31. Tank Closure Alternative 4 American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.17×10^{2}	1.04	5.16×10^{-3}	1.09×10^{-5}	5.16×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	7.60×10^{1}	1.92	3.39×10^{-3}	1.55×10^{-5}	3.39×10^{-3}	N/A	N/A	N/A	N/A	N/A
S Barrier	3.83×10^{1}	6.08	1.70×10^{-3}	7.15×10^{-5}	1.70×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	2.26×10^{2}	9.21	1.00×10^{-2}	9.52×10^{-5}	1.00×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	1.44	2.16×10^{-1}	6.38×10^{-5}	2.44×10^{-6}	6.38×10^{-5}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	4.90×10^{1}	3.90	2.19×10^{-3}	4.59×10^{-5}	2.19×10^{-3}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.27	5.38×10^{-2}	5.81×10^{-5}	5.97×10^{-7}	5.81×10^{-5}	6.17×10^{-3}	1.56×10^{-2}	8.89×10^{-8}	2.99×10^{-7}	3.54×10^{-7}
Off Site										
Columbia River	1.23×10^{-4}	9.79×10^{-4}	4.41×10^{-9}	2.87×10^{-11}	4.43×10^{-9}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–32. Tank Closure Alternative 4 Drinking-Water Well User and Resident Farmer Long-Term Human Health Impact Summary

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	3.28	1.79×10^{-1}	9.61×10^{-5}	0.00	7.79×10^{-4}	7.40	2.09×10^{-1}	2.99×10^{-4}	3.47×10^{-11}	2.40×10^{-3}
B Barrier	5.92×10^{1}	5.77×10^{1}	1.81×10^{-3}	0.00	1.24×10^{-2}	1.38×10^{2}	6.64×10^{1}	5.71×10^{-3}	1.26×10^{-8}	3.48×10^{-2}
S Barrier	4.77×10^{-1}	3.61×10^{-1}	1.40×10^{-5}	0.00	2.55×10^{-4}	1.08	3.68×10^{-1}	4.38×10^{-5}	1.40×10^{-10}	7.90×10^{-4}
T Barrier	3.55×10^{1}	9.63	1.02×10^{-3}	0.00	1.39×10^{-2}	7.90×10^{1}	1.04×10^{1}	3.15×10^{-3}	3.02×10^{-9}	2.43×10^{-2}
U Barrier	1.02	1.15×10^{-1}	1.18×10^{-5}	0.00	1.18×10^{-5}	1.06	1.18×10^{-1}	3.68×10^{-5}	3.87×10^{-11}	3.68×10^{-5}
Core Zone Boundary	5.02×10^{1}	3.36×10^{1}	1.54×10^{-3}	0.00	1.24×10^{-2}	1.18×10^{2}	3.93×10^{1}	4.88×10^{-3}	6.47×10^{-9}	3.48×10^{-2}
Columbia River nearshore	3.91×10^{-1}	4.31×10^{-1}	1.21×10^{-5}	0.00	1.21×10^{-5}	9.24×10^{-1}	4.65×10^{-1}	3.85×10^{-5}	1.33×10^{-10}	3.85×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	3.85×10^{-5}	1.91×10^{-5}	1.55×10^{-9}	3.96×10^{-15}	5.83×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–33. Tank Closure Alternative 4 American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impact Summary

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.44×10^{1}	3.70×10^{-1}	6.44×10^{-4}	1.59×10^{-6}	5.16×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	2.72×10^{2}	1.15×10^{2}	1.24×10^{-2}	5.80×10^{-4}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
S Barrier	2.10	5.52×10^{-1}	9.43×10^{-5}	6.41×10^{-6}	1.70×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	1.53×10^{2}	1.67×10^{1}	6.77×10^{-3}	1.38×10^{-4}	4.85×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	1.77	1.85×10^{-1}	7.93×10^{-5}	1.78×10^{-6}	7.93×10^{-5}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	2.32×10^{2}	6.93×10^{1}	1.05×10^{-2}	2.97×10^{-4}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.83	7.51×10^{-1}	8.34×10^{-5}	6.10×10^{-6}	8.34×10^{-5}	5.69×10^{-2}	3.79×10^{-1}	7.24×10^{-7}	3.05×10^{-6}	6.40×10^{-6}
Off Site										
Columbia River	1.52×10^{-4}	2.77×10^{-2}	5.49×10^{-9}	1.81×10^{-10}	1.88×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Similar to Alternatives 2A, 2B, 3A, 3B, and 3C, the risk and hazard drivers are tritium, technetium-99, iodine-129, uranium-238, chromium, nitrate, and total uranium. The dose standard and Hazard Index guideline would be exceeded at the same locations and for the same receptors as under Alternatives 2A, 2B, 3A, 3B, and 3C for releases from cribs and trenches (ditches). The dose standard would be exceeded at the same locations and for the same receptors as under Alternatives 2A, 2B, 3A, 3B, and 3C for releases from past leaks, with slightly less impacts at the B Barrier, S Barrier, and Core Zone Boundary as a result of clean closure at the two tank farms located within the B and S Barriers. Impacts would be slightly less than those under Alternatives 2B, 3A, 3B, 3C, and 6C as a result of the combination of cribs and trenches (ditches), past leaks, and other tank farm sources, with the exception of the S Barrier, where no exceedances were identified. Overall, the population dose was estimated as 1.92×10^{-1} person-rem per year for the year of maximum impact. This corresponds to 1.05×10^{-5} percent of the annual population dose due to background exposure.

For releases from cribs and trenches (ditches) and past leaks, estimates of the magnitude and time series of impacts are substantially the same as those reported for Tank Closure Alternative 2B. The time series of radiological risk at the Core Zone Boundary for Tank Closure Alternative 4 is presented in Figure 5–328. Comparison of the time series of risk for other tank farm sources under Tank Closure Alternative 4 with the time series of risk under Tank Closure Alternative 2B (see Figure 5–327) identifies three points of interest. First, for the time period prior to CY 2500, the estimated risks under the two alternatives, presumably due to retrieval leaks, are nearly identical. Second, for the intermediate time between CYs 3000 and 4000, the broad peak is reduced by a factor of approximately 5 under Tank Closure Alternative 4 relative to that under Tank Closure Alternative 2B. Third, for the long-term period extending out to CY 11,940, risk is reduced by a factor of 10 under Tank Closure Alternative 4 relative to that under Tank Closure Alternative 2B. The reduction in risk estimate is due to clean closure of the BX and SX tank farms and greater retrieval of tank waste under Tank Closure Alternative 4 relative to that under Tank Closure Alternative 2B.

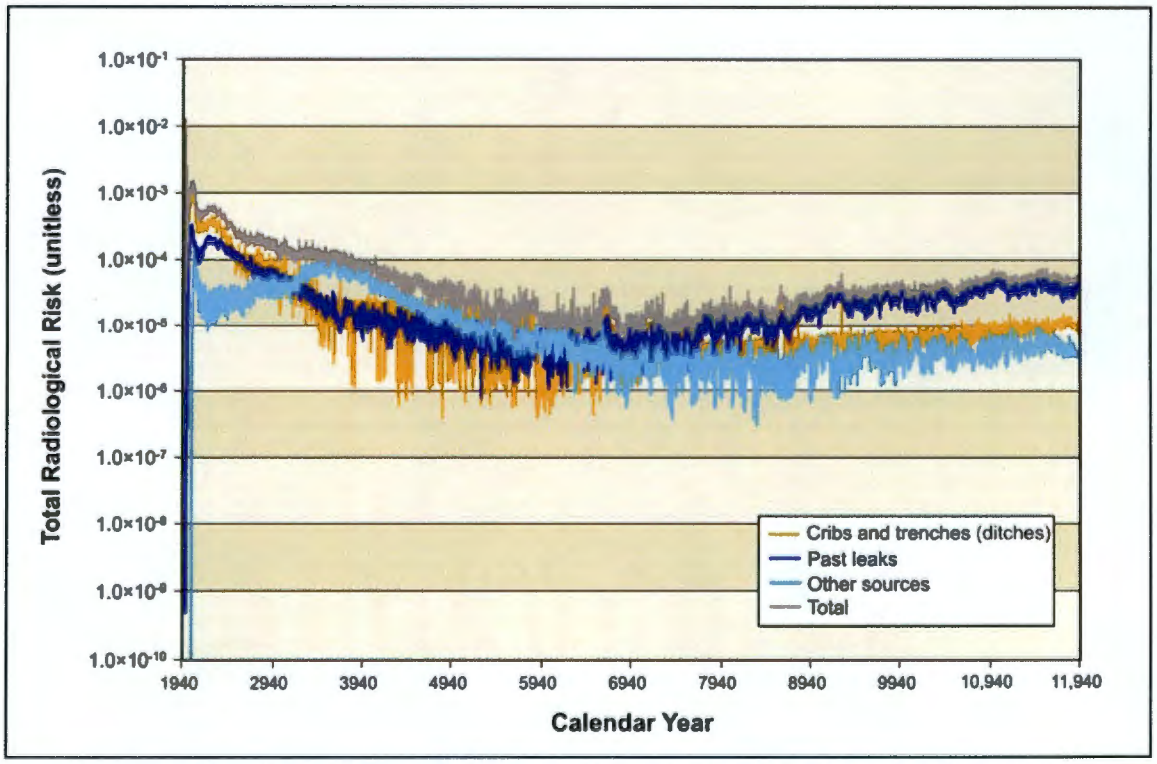


Figure 5–328. Tank Closure Alternative 4 Time Series of Radiological Risk for the Drinking-Water Well User at the Core Zone Boundary

5.1.2.8 Tank Closure Alternative 5: Expanded WTP Vitrification with Supplemental Treatment Technologies; Landfill Closure

Under Tank Closure Alternative 5, tank waste would be retrieved to a volume corresponding to 90 percent retrieval, residual material in tanks would be stabilized in place, and the tank farms and adjacent cribs and trenches (ditches) would be covered with a Hanford barrier. Potential human health impacts under Tank Closure Alternative 5 are detailed in Appendix Q and summarized in Tables 5–34 through 5–39; those related to cribs and trenches (ditches) after CY 1940 are in Tables 5–34 and 5–35; to past leaks after CY 1940 in Tables 5–36 and 5–37; and to the combination of cribs and trenches (ditches), past leaks, and other tank farm sources after CY 2050 in Tables 5–38 and 5–39.

The dose standard and Hazard Index guideline would be exceeded at the same locations and for the same receptors as under Tank Closure Alternatives 2A, 2B, 3A, 3B, 3C, and 4 for releases from cribs and trenches (ditches). The dose standard and Hazard Index guideline would be exceeded at the same locations and for the same receptors as under Tank Closure Alternatives 2A, 2B, 3A, 3B, and 3C for releases from past leaks, but would be slightly higher than under these alternatives. Impacts would occur at a later date than under Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C for onsite locations as a result of the combination of cribs and trenches (ditches), past leaks, and other tank farm sources. This may be due to the Hanford barrier. However, exceedances at the offsite locations are would be higher. The population dose was estimated as 3.39×10^{-1} person-rem per year for the year of maximum impact. This corresponds to 1.86×10^{-5} percent of the annual population dose due to background exposure.

For releases from cribs and trenches (ditches) and past leaks, estimates of the magnitude and time series of impacts are substantially the same as those reported for Tank Closure Alternative 2B. The time series of radiological risk at the Core Zone Boundary under Tank Closure Alternative 5 is presented in Figure 5–329. Comparison of the time series of risk for other tank farm sources under Tank Closure Alternative 5 with the time series of risk under Tank Closure Alternative 2B (see Figure 5–327) identifies three points of interest. First, for the time period prior to CY 2500, the estimated risks under the two alternatives, presumably due to retrieval leaks, are nearly identical. Second, for the intermediate time between CYs 3000 and 4000, the broad peak is increased by a factor of approximately five under Tank Closure Alternative 5 relative to that under Tank Closure Alternative 2B. Third, for the long-term period extending out to CY 11,940, risk is increased by a factor of three under Tank Closure Alternative 5 relative to that under Tank Closure Alternative 2B. The increase in risk estimate is due to less retrieval of tank waste under Tank Closure Alternative 5 relative to that under Tank Closure Alternative 2B.

Table 5–34. Tank Closure Alternative 5 Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	6.36×10^{2}	7.95×10^{2}	1.24×10^{-2}	0.00	1.24×10^{-2}	1.24×10^{3}	8.94×10^{2}	3.48×10^{-2}	2.00×10^{-7}	3.48×10^{-2}
T Barrier	1.46×10^{3}	1.27×10^{2}	1.39×10^{-2}	0.00	1.39×10^{-2}	2.32×10^{3}	1.39×10^{2}	2.43×10^{-2}	3.66×10^{-8}	2.43×10^{-2}
Core Zone Boundary	6.36×10^{2}	4.97×10^{2}	1.24×10^{-2}	0.00	1.24×10^{-2}	1.24×10^{3}	5.70×10^{2}	3.48×10^{-2}	1.10×10^{-7}	3.48×10^{-2}
Columbia River nearshore	2.08×10^{-1}	4.02×10^{-1}	5.89×10^{-6}	0.00	5.89×10^{-6}	4.79×10^{-1}	4.35×10^{-1}	1.85×10^{-5}	1.23×10^{-10}	1.85×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	1.91×10^{-4}	1.63×10^{-4}	5.83×10^{-9}	3.52×10^{-14}	5.83×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–35. Tank Closure Alternative 5 American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	2.36×10^{3}	1.51×10^{3}	7.43×10^{-2}	9.16×10^{-3}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
T Barrier	4.27×10^{3}	2.27×10^{2}	4.85×10^{-2}	1.68×10^{-3}	4.85×10^{-2}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	2.36×10^{3}	9.85×10^{2}	7.43×10^{-2}	5.05×10^{-3}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	9.53×10^{-1}	7.03×10^{-1}	4.01×10^{-5}	5.66×10^{-6}	4.01×10^{-5}	4.04×10^{-1}	7.14×10^{-1}	4.97×10^{-6}	2.83×10^{-6}	6.40×10^{-6}
Off Site										
Columbia River	5.59×10^{-4}	2.11×10^{-1}	1.80×10^{-8}	1.61×10^{-9}	1.88×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–36. Tank Closure Alternative 5 Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	2.87×10^{1}	6.67×10^{-1}	8.23×10^{-4}	0.00	8.23×10^{-4}	6.39×10^{1}	6.92×10^{-1}	2.55×10^{-3}	2.45×10^{-10}	2.55×10^{-3}
B Barrier	7.95	1.23	1.73×10^{-4}	0.00	1.73×10^{-4}	1.43×10^{1}	1.34	4.71×10^{-4}	3.81×10^{-10}	4.71×10^{-4}
S Barrier	9.29	4.20	2.69×10^{-4}	0.00	2.69×10^{-4}	2.08×10^{1}	4.26	8.34×10^{-4}	1.65×10^{-9}	8.34×10^{-4}
T Barrier	4.76×10^{1}	5.74	1.49×10^{-3}	0.00	1.49×10^{-3}	1.14×10^{2}	5.97	4.76×10^{-3}	2.07×10^{-9}	4.76×10^{-3}
U Barrier	9.89×10^{-1}	1.42×10^{-1}	1.12×10^{-5}	0.00	1.12×10^{-5}	1.03	1.45×10^{-1}	3.00×10^{-5}	5.40×10^{-11}	3.00×10^{-5}
Core Zone Boundary	1.11×10^{1}	4.49	3.28×10^{-4}	0.00	3.28×10^{-4}	2.51×10^{1}	4.56	1.03×10^{-3}	1.77×10^{-9}	1.03×10^{-3}
Columbia River nearshore	2.57×10^{-1}	4.62×10^{-2}	7.81×10^{-6}	0.00	7.81×10^{-6}	5.97×10^{-1}	4.73×10^{-2}	2.46×10^{-5}	1.77×10^{-11}	2.46×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	3.25×10^{-5}	2.04×10^{-6}	1.32×10^{-9}	7.17×10^{-16}	1.32×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–37. Tank Closure Alternative 5 American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.24×10^{2}	1.06	5.48×10^{-3}	1.12×10^{-5}	5.48×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	2.50×10^{1}	2.18	9.78×10^{-4}	1.75×10^{-5}	9.78×10^{-4}	N/A	N/A	N/A	N/A	N/A
S Barrier	4.03×10^{1}	6.36	1.80×10^{-3}	7.59×10^{-5}	1.80×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	2.26×10^{2}	9.20	1.03×10^{-2}	9.49×10^{-5}	1.03×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	1.45	2.19×10^{-1}	6.47×10^{-5}	2.48×10^{-6}	6.47×10^{-5}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	4.93×10^{1}	6.79	2.23×10^{-3}	8.14×10^{-5}	2.23×10^{-3}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.18	7.12×10^{-2}	5.33×10^{-5}	8.13×10^{-7}	5.33×10^{-5}	6.35×10^{-3}	1.89×10^{-2}	8.75×10^{-8}	4.06×10^{-7}	4.62×10^{-7}
Off Site										
Columbia River	1.28×10^{-4}	1.02×10^{-3}	4.62×10^{-9}	3.29×10^{-11}	4.65×10^{-9}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–38. Tank Closure Alternative 5 Drinking-Water Well User and Resident Farmer Long-Term Human Health Impact Summary

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	5.46	4.06×10^{-1}	1.84×10^{-4}	4.90×10^{-13}	8.23×10^{-4}	1.38×10^{1}	4.45×10^{-1}	6.02×10^{-4}	1.14×10^{-10}	2.55×10^{-3}
B Barrier	4.96×10^{1}	5.79×10^{1}	1.47×10^{-3}	0.00	1.24×10^{-2}	1.13×10^{2}	6.66×10^{1}	4.61×10^{-3}	1.26×10^{-8}	3.48×10^{-2}
S Barrier	6.04	2.91	2.03×10^{-4}	3.37×10^{-13}	2.69×10^{-4}	1.52×10^{1}	2.96	6.62×10^{-4}	1.14×10^{-9}	8.34×10^{-4}
T Barrier	3.26×10^{1}	9.77	9.86×10^{-4}	0.00	1.39×10^{-2}	7.56×10^{1}	1.05×10^{1}	3.11×10^{-3}	3.07×10^{-9}	2.43×10^{-2}
U Barrier	3.24	4.01×10^{-1}	1.08×10^{-4}	0.00	1.08×10^{-4}	8.13	4.23×10^{-1}	3.53×10^{-4}	1.41×10^{-10}	3.53×10^{-4}
Core Zone Boundary	6.50×10^{1}	3.38×10^{1}	2.18×10^{-3}	4.72×10^{-13}	1.24×10^{-2}	1.64×10^{2}	3.95×10^{1}	7.10×10^{-3}	6.79×10^{-9}	3.48×10^{-2}
Columbia River nearshore	1.37	4.43×10^{-1}	4.47×10^{-5}	7.09×10^{-15}	4.47×10^{-5}	3.37	4.79×10^{-1}	1.45×10^{-4}	1.37×10^{-10}	1.45×10^{-4}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	6.78×10^{-5}	1.92×10^{-5}	2.94×10^{-9}	3.97×10^{-15}	5.83×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–39. Tank Closure Alternative 5 American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impact Summary

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	2.80×10^{1}	7.28×10^{-1}	1.31×10^{-3}	5.23×10^{-6}	5.48×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	2.21×10^{2}	1.16×10^{2}	9.93×10^{-3}	5.77×10^{-4}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
S Barrier	3.09×10^{1}	4.43	1.44×10^{-3}	5.21×10^{-5}	1.80×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	1.49×10^{2}	1.69×10^{1}	6.73×10^{-3}	1.41×10^{-4}	4.85×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	1.65×10^{1}	6.64×10^{-1}	7.68×10^{-4}	6.45×10^{-6}	7.68×10^{-4}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	3.31×10^{2}	6.96×10^{1}	1.55×10^{-2}	3.11×10^{-4}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	6.78	7.74×10^{-1}	3.14×10^{-4}	6.26×10^{-6}	3.14×10^{-4}	5.68×10^{-2}	3.94×10^{-1}	7.20×10^{-7}	3.13×10^{-6}	6.40×10^{-6}
Off Site										
Columbia River	1.72×10^{-4}	2.77×10^{-2}	7.73×10^{-9}	1.82×10^{-10}	1.88×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

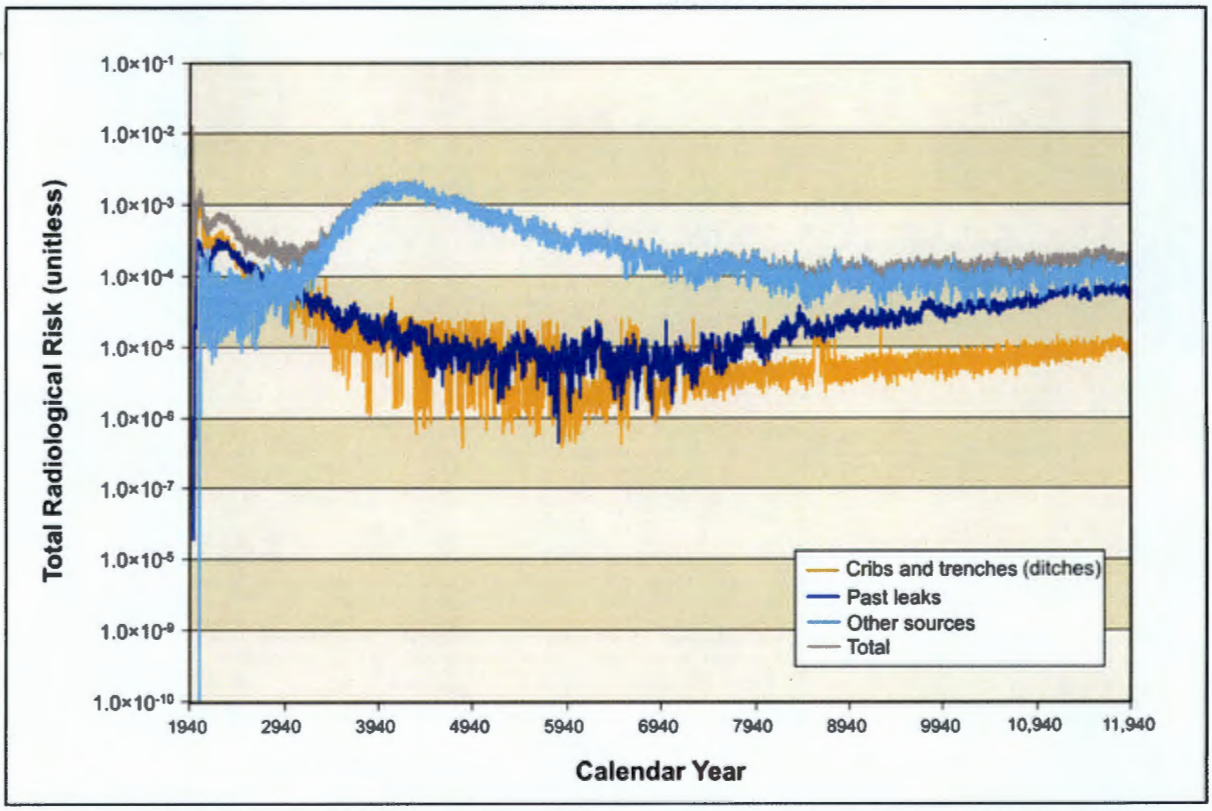


Figure 5–329. Tank Closure Alternative 5 Time Series of Radiological Risk for the Drinking-Water Well User at the Core Zone Boundary

5.1.2.9 Tank Closure Alternative 6A: All Vitrification/No Separations; Clean Closure

5.1.2.9.1 Base Case

Under Tank Closure Alternative 6A, Base Case, tank waste would be retrieved to a volume corresponding to 99.9 percent retrieval and all tank farms would be clean-closed by removing the tanks, ancillary equipment, and soils to a depth of 3 meters (10 feet) below the tank base. Where necessary, deep soil excavation would also be conducted to remove contamination plumes within the soil column. The adjacent cribs and trenches (ditches) would be covered with an engineered modified RCRA Subtitle C barrier. Potential human health impacts under Tank Closure Alternative 6A, Base Case, are detailed in Appendix Q and summarized in Tables 5–40 through 5–45; those related to cribs and trenches (ditches) after CY 1940 are in Tables 5–40 and 5–41; to past leaks after CY 1940 in Tables 5–42 and 5–43; and to the combination of cribs and trenches (ditches), past leaks, and other tank farm sources after CY 2050 in Tables 5–44 and 5–45.

Table 5–40. Tank Closure Alternative 6A, Base Case, Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	6.36×10^{2}	7.95×10^{2}	1.24×10^{-2}	0.00	1.24×10^{-2}	1.24×10^{3}	8.94×10^{2}	3.48×10^{-2}	2.00×10^{-7}	3.48×10^{-2}
T Barrier	1.46×10^{3}	1.27×10^{2}	1.39×10^{-2}	0.00	1.39×10^{-2}	2.32×10^{3}	1.39×10^{2}	2.43×10^{-2}	3.66×10^{-8}	2.43×10^{-2}
Core Zone Boundary	6.36×10^{2}	4.97×10^{2}	1.24×10^{-2}	0.00	1.24×10^{-2}	1.24×10^{3}	5.70×10^{2}	3.48×10^{-2}	1.10×10^{-7}	3.48×10^{-2}
Columbia River nearshore	2.08×10^{-1}	4.02×10^{-1}	5.89×10^{-6}	0.00	5.89×10^{-6}	4.79×10^{-1}	4.35×10^{-1}	1.85×10^{-5}	1.23×10^{-10}	1.85×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	1.91×10^{-4}	1.63×10^{-4}	5.83×10^{-9}	3.52×10^{-14}	5.83×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–41. Tank Closure Alternative 6A, Base Case, American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	2.36×10^{3}	1.51×10^{3}	7.43×10^{-2}	9.16×10^{-3}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
T Barrier	4.27×10^{3}	2.27×10^{2}	4.85×10^{-2}	1.68×10^{-3}	4.85×10^{-2}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	2.36×10^{3}	9.85×10^{2}	7.43×10^{-2}	5.05×10^{-3}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	9.53×10^{-1}	7.03×10^{-1}	4.01×10^{-5}	5.66×10^{-6}	4.01×10^{-5}	4.04×10^{-1}	7.14×10^{-1}	4.97×10^{-6}	2.83×10^{-6}	6.40×10^{-6}
Off Site										
Columbia River	5.59×10^{-4}	2.11×10^{-1}	1.80×10^{-8}	1.61×10^{-9}	1.88×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–42. Tank Closure Alternative 6A, Base Case, Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	2.80×10^{1}	6.57×10^{-1}	7.99×10^{-4}	0.00	7.99×10^{-4}	6.21×10^{1}	6.82×10^{-1}	2.47×10^{-3}	2.39×10^{-10}	2.47×10^{-3}
B Barrier	1.94×10^{1}	1.18	5.56×10^{-4}	0.00	5.56×10^{-4}	4.30×10^{1}	1.28	1.72×10^{-3}	3.64×10^{-10}	1.72×10^{-3}
S Barrier	9.24	3.99	2.65×10^{-4}	0.00	2.65×10^{-4}	2.05×10^{1}	4.05	8.18×10^{-4}	1.56×10^{-9}	8.18×10^{-4}
T Barrier	5.25×10^{1}	5.78	1.51×10^{-3}	0.00	1.51×10^{-3}	1.17×10^{2}	6.00	4.69×10^{-3}	2.09×10^{-9}	4.69×10^{-3}
U Barrier	3.39×10^{-1}	1.36×10^{-1}	9.91×10^{-6}	0.00	9.91×10^{-6}	7.64×10^{-1}	1.40×10^{-1}	3.09×10^{-5}	5.15×10^{-11}	3.09×10^{-5}
Core Zone Boundary	1.10×10^{1}	4.04	3.21×10^{-4}	0.00	3.21×10^{-4}	2.46×10^{1}	4.11	1.00×10^{-3}	1.58×10^{-9}	1.00×10^{-3}
Columbia River nearshore	3.04×10^{-1}	4.17×10^{-2}	9.37×10^{-6}	0.00	9.37×10^{-6}	7.15×10^{-1}	4.28×10^{-2}	2.97×10^{-5}	1.59×10^{-11}	2.97×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	3.39×10^{-5}	2.22×10^{-6}	1.37×10^{-9}	7.68×10^{-16}	1.37×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–43. Tank Closure Alternative 6A, Base Case, American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.20×10^{2}	1.05	5.31×10^{-3}	1.10×10^{-5}	5.31×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	8.32×10^{1}	2.08	3.69×10^{-3}	1.67×10^{-5}	3.69×10^{-3}	N/A	N/A	N/A	N/A	N/A
S Barrier	3.97×10^{1}	6.05	1.76×10^{-3}	7.16×10^{-5}	1.76×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	2.27×10^{2}	9.24	1.01×10^{-2}	9.59×10^{-5}	1.01×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	1.49	2.13×10^{-1}	6.64×10^{-5}	2.36×10^{-6}	6.64×10^{-5}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	4.82×10^{1}	6.15	2.17×10^{-3}	7.23×10^{-5}	2.17×10^{-3}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.41	6.47×10^{-2}	6.43×10^{-5}	7.27×10^{-7}	6.43×10^{-5}	1.89×10^{-3}	1.62×10^{-2}	9.48×10^{-8}	3.64×10^{-7}	4.11×10^{-7}
Off Site										
Columbia River	1.33×10^{-4}	1.06×10^{-3}	4.83×10^{-9}	3.52×10^{-11}	4.85×10^{-9}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–44. Tank Closure Alternative 6A, Base Case, Drinking-Water Well User and Resident Farmer Long-Term Human Health Impact Summary

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	3.03	8.36×10^{-2}	8.88×10^{-5}	0.00	7.99×10^{-4}	6.85	8.63×10^{-2}	2.77×10^{-4}	3.11×10^{-11}	2.47×10^{-3}
B Barrier	6.15×10^{1}	5.77×10^{1}	1.87×10^{-3}	0.00	1.24×10^{-2}	1.43×10^{2}	6.65×10^{1}	5.90×10^{-3}	1.25×10^{-8}	3.48×10^{-2}
S Barrier	6.14	2.91	1.78×10^{-4}	0.00	2.65×10^{-4}	1.37×10^{1}	2.96	5.52×10^{-4}	1.14×10^{-9}	8.18×10^{-4}
T Barrier	3.53×10^{1}	9.56	1.01×10^{-3}	0.00	1.39×10^{-2}	7.87×10^{1}	1.03×10^{1}	3.14×10^{-3}	2.99×10^{-9}	2.43×10^{-2}
U Barrier	3.39×10^{-1}	1.03×10^{-1}	9.91×10^{-6}	0.00	9.91×10^{-6}	7.64×10^{-1}	1.07×10^{-1}	3.09×10^{-5}	3.78×10^{-11}	3.09×10^{-5}
Core Zone Boundary	5.14×10^{1}	3.38×10^{1}	1.58×10^{-3}	0.00	1.24×10^{-2}	1.21×10^{2}	3.95×10^{1}	5.00×10^{-3}	6.52×10^{-9}	3.48×10^{-2}
Columbia River nearshore	3.55×10^{-1}	4.20×10^{-1}	1.07×10^{-5}	0.00	1.07×10^{-5}	8.16×10^{-1}	4.54×10^{-1}	3.41×10^{-5}	1.30×10^{-10}	3.41×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	4.14×10^{-5}	1.92×10^{-5}	1.67×10^{-9}	3.96×10^{-15}	5.83×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–45. Tank Closure Alternative 6A, Base Case, American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impact Summary

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.33×10^{1}	1.32×10^{-1}	5.97×10^{-4}	1.43×10^{-6}	5.31×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	2.81×10^{2}	1.15×10^{2}	1.28×10^{-2}	5.72×10^{-4}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
S Barrier	2.66×10^{1}	4.42	1.19×10^{-3}	5.21×10^{-5}	1.76×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	1.53×10^{2}	1.66×10^{1}	6.75×10^{-3}	1.37×10^{-4}	4.85×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	1.49	1.63×10^{-1}	6.64×10^{-5}	1.73×10^{-6}	6.64×10^{-5}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	2.38×10^{2}	6.97×10^{1}	1.08×10^{-2}	2.99×10^{-4}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.62	7.33×10^{-1}	7.39×10^{-5}	5.97×10^{-6}	7.39×10^{-5}	5.68×10^{-2}	3.76×10^{-1}	7.22×10^{-7}	2.98×10^{-6}	6.40×10^{-6}
Off Site										
Columbia River	1.60×10^{-4}	2.77×10^{-2}	5.82×10^{-9}	1.82×10^{-10}	1.88×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

The dose standard and Hazard Index guideline would be exceeded at the same locations and for the same receptors as under Tank Closure Alternatives 2A, 2B, 3A, 3B, 3C, 4, and 5 for releases from cribs and trenches (ditches). The dose standard and Hazard Index guideline would be exceeded at the same locations and for the same receptors as under Tank Closure Alternatives 2B, 3A, 3B, 3C, and 4 for releases from past leaks. Impacts would be slightly higher than those under Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C for onsite locations as a result of the combination of cribs and trenches (ditches), past leaks, and other tank farm sources. However, after the year 2940, the impacts drop significantly as a result of tank farm removal and clean closure activities. The population dose was estimated as 2.07×10^{-1} person-rem per year for the year of maximum impact. This corresponds to 1.13×10^{-5} percent of the annual population dose due to background exposure.

The time series of radiological risk under Tank Closure Alternative 6A, Base Case, is presented in Figure 5–330. Because of removal operations, impacts due to retrieval leaks and leaching from other tank farm sources do not occur. For cribs and trenches (ditches), estimated risk is similar to that estimated for Tank Closure Alternative 2B. For past leaks, risk estimated for the period prior to CY 3000 is similar to that estimated for Tank Closure Alternative 2B, while risk estimated for the long-term period is reduced by a factor of 10 relative to that estimated for Tank Closure Alternative 2B.

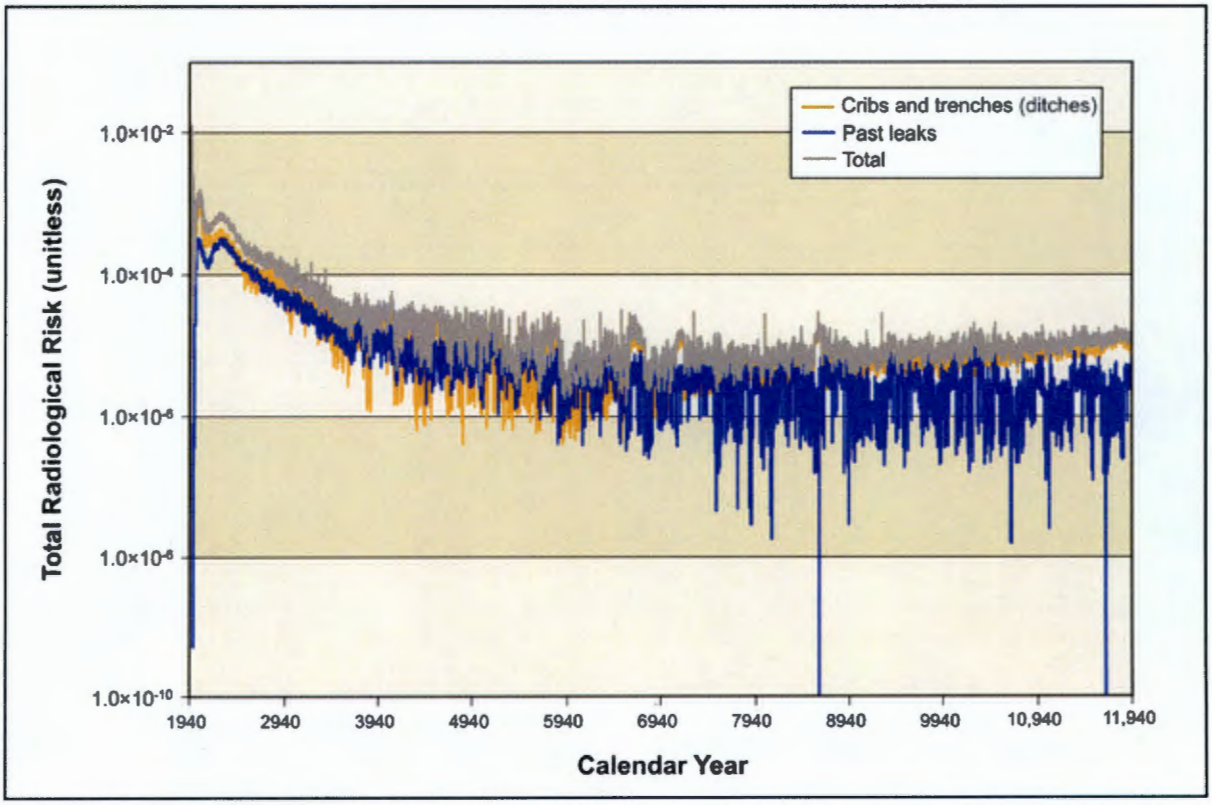


Figure 5–330. Tank Closure Alternative 6A, Base Case, Time Series of Radiological Risk for the Drinking-Water Well User at the Core Zone Boundary

5.1.2.9.2 Option Case

Under Tank Closure Alternative 6A, Option Case, tank waste would be retrieved to a volume corresponding to 99.9 percent retrieval, and all tanks farms would be clean-closed by removing the tanks, ancillary equipment, and soils to a depth of 3 meters (10 feet) below the tank base. Where necessary, deep soil excavation would also be conducted to remove contamination plumes within the soil column. In addition, the adjacent cribs and trenches (ditches) would be clean-closed. Potential human health impacts

under Tank Closure Alternative 6A, Option Case, are detailed in Appendix Q and summarized in Tables 5–46 and 5–51; those related to cribs and trenches (ditches) after CY 1940 are in Tables 5–46 and 5–47; to past leaks after CY 1940 in Tables 5–48 and 5–49; and to the combination of cribs and trenches (ditches), past leaks, and other tank farm sources after CY 2050 in Tables 5–50 and 5–51.

The dose standard and Hazard Index guideline would be exceeded at the same locations and for the same receptors as under Tank Closure Alternatives 2A, 2B, 3A, 3B, 3C, 4, 5, and 6A, Base Case, for releases from cribs and trenches (ditches). Similar to Tank Closure Alternative 6A, Base Case, the dose standard and Hazard Index guideline would be exceeded at the same locations and for the same receptors as under Tank Closure Alternatives 2A, 2B, 3A, 3B, and 3C, but would be slightly higher than under these alternatives. Impacts would be slightly higher than under Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C for onsite locations as a result of the combination of cribs and trenches (ditches), past leaks, and other tank farm sources. However, after the year 2940, the impacts drop significantly as a result of tank farm removal. The population dose was estimated as 2.05×10^{-1} person-rem per year for the year of maximum impact. This corresponds to 1.12×10^{-5} percent of the annual population dose due to background exposure.

The time series of radiological risk under Tank Closure Alternative 6A, Option Case, is presented in Figure 5–331. Because of removal operations, impacts due to retrieval leaks and leaching from other tank farm sources do not occur. For cribs and trenches (ditches), estimated risk is similar to that estimated for Tank Closure Alternative 6A, Base Case, prior to CY 5000, but is reduced by a factor of 1,000 for the long-term period. For past leaks, estimates of risk are similar to those estimated for Tank Closure Alternative 6A, Base Case.

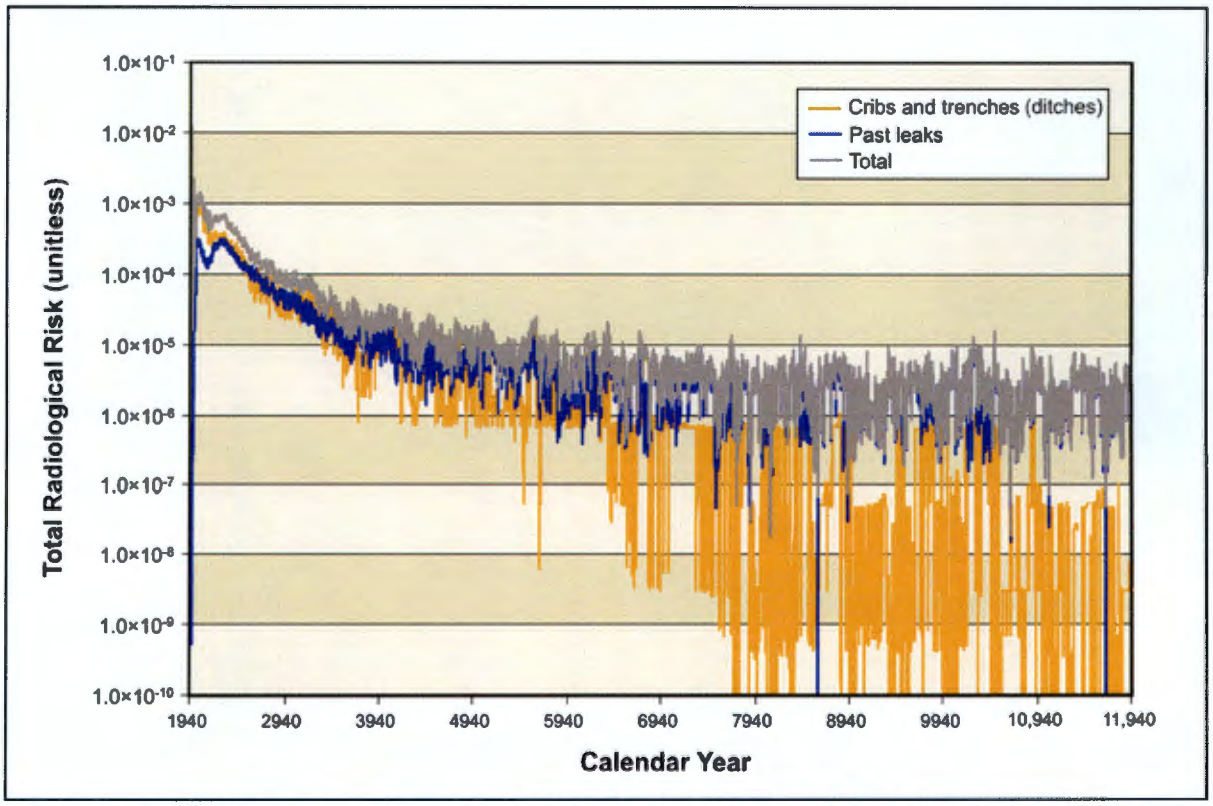


Figure 5–331. Tank Closure Alternative 6A, Option Case, Time Series of Radiological Risk for the Drinking-Water Well User at the Core Zone Boundary

Table 5–46. Tank Closure Alternative 6A, Option Case, Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	6.38×10^{2}	7.95×10^{2}	1.25×10^{-2}	0.00	1.25×10^{-2}	1.24×10^{3}	8.93×10^{2}	3.49×10^{-2}	2.00×10^{-7}	3.49×10^{-2}
T Barrier	1.44×10^{3}	1.22×10^{2}	1.37×10^{-2}	0.00	1.37×10^{-2}	2.30×10^{3}	1.34×10^{2}	2.40×10^{-2}	3.48×10^{-8}	2.40×10^{-2}
Core Zone Boundary	6.38×10^{2}	5.09×10^{2}	1.25×10^{-2}	0.00	1.25×10^{-2}	1.24×10^{3}	5.85×10^{2}	3.49×10^{-2}	1.11×10^{-7}	3.49×10^{-2}
Columbia River nearshore	1.99×10^{-1}	3.66×10^{-1}	4.76×10^{-6}	0.00	4.76×10^{-6}	4.20×10^{-1}	4.08×10^{-1}	1.44×10^{-5}	1.02×10^{-10}	1.44×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	1.89×10^{-4}	1.59×10^{-4}	5.75×10^{-9}	3.41×10^{-14}	5.75×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–47. Tank Closure Alternative 6A, Option Case, American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	2.37×10^{3}	1.51×10^{3}	7.45×10^{-2}	9.18×10^{-3}	7.45×10^{-2}	N/A	N/A	N/A	N/A	N/A
T Barrier	4.22×10^{3}	2.20×10^{2}	4.79×10^{-2}	1.60×10^{-3}	4.79×10^{-2}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	2.37×10^{3}	1.01×10^{3}	7.45×10^{-2}	5.11×10^{-3}	7.45×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	8.26×10^{-1}	6.84×10^{-1}	3.10×10^{-5}	4.69×10^{-6}	3.10×10^{-5}	4.00×10^{-1}	6.69×10^{-1}	4.92×10^{-6}	2.34×10^{-6}	5.77×10^{-6}
Off Site										
Columbia River	5.54×10^{-4}	2.13×10^{-1}	1.78×10^{-8}	1.56×10^{-9}	1.86×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–48. Tank Closure Alternative 6A, Option Case, Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	2.80×10^{1}	6.57×10^{-1}	7.99×10^{-4}	0.00	7.99×10^{-4}	6.21×10^{1}	6.82×10^{-1}	2.47×10^{-3}	2.39×10^{-10}	2.47×10^{-3}
B Barrier	1.94×10^{1}	1.18	5.56×10^{-4}	0.00	5.56×10^{-4}	4.30×10^{1}	1.28	1.72×10^{-3}	3.64×10^{-10}	1.72×10^{-3}
S Barrier	9.24	3.99	2.65×10^{-4}	0.00	2.65×10^{-4}	2.05×10^{1}	4.05	8.18×10^{-4}	1.56×10^{-9}	8.18×10^{-4}
T Barrier	5.25×10^{1}	5.78	1.51×10^{-3}	0.00	1.51×10^{-3}	1.17×10^{2}	6.00	4.69×10^{-3}	2.09×10^{-9}	4.69×10^{-3}
U Barrier	3.39×10^{-1}	1.36×10^{-1}	9.91×10^{-6}	0.00	9.91×10^{-6}	7.64×10^{-1}	1.40×10^{-1}	3.09×10^{-5}	5.15×10^{-11}	3.09×10^{-5}
Core Zone Boundary	1.10×10^{1}	4.04	3.21×10^{-4}	0.00	3.21×10^{-4}	2.46×10^{1}	4.11×10	1.00×10^{-3}	1.58×10^{-9}	1.00×10^{-3}
Columbia River nearshore	3.04×10^{-1}	4.17×10^{-2}	9.37×10^{-6}	0.00	9.37×10^{-6}	7.15×10^{-1}	4.28×10^{-2}	2.97×10^{-5}	1.59×10^{-11}	2.97×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	3.39×10^{-5}	2.22×10^{-6}	1.37×10^{-9}	7.68×10^{-16}	1.37×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–49. Tank Closure Alternative 6A, Option Case, American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.20×10^{2}	1.05	5.31×10^{-3}	1.10×10^{-5}	5.31×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	8.32×10^{1}	2.08	3.69×10^{-3}	1.67×10^{-5}	3.69×10^{-3}	N/A	N/A	N/A	N/A	N/A
S Barrier	3.97×10^{1}	6.05	1.76×10^{-3}	7.16×10^{-5}	1.76×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	2.27×10^{2}	9.24	1.01×10^{-2}	9.59×10^{-5}	1.01×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	1.49	2.13×10^{-1}	6.64×10^{-5}	2.36×10^{-6}	6.64×10^{-5}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	4.82×10^{1}	6.15	2.17×10^{-3}	7.23×10^{-5}	2.17×10^{-3}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.41	6.47×10^{-2}	6.43×10^{-5}	7.27×10^{-7}	6.43×10^{-5}	1.89×10^{-3}	1.62×10^{-2}	9.48×10^{-8}	3.64×10^{-7}	4.11×10^{-7}
Off Site										
Columbia River	1.33×10^{-4}	1.06×10^{-3}	4.83×10^{-9}	3.52×10^{-11}	4.85×10^{-9}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–50. Tank Closure Alternative 6A, Option Case, Drinking-Water Well User and Resident Farmer Long-Term Human Health Impact Summary

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	3.03	8.36×10^{-2}	8.88×10^{-5}	0.00	7.99×10^{-4}	6.85	8.63×10^{-2}	2.77×10^{-4}	3.11×10^{-11}	2.47×10^{-3}
B Barrier	5.61×10^{1}	6.46×10^{1}	1.64×10^{-3}	0.00	1.25×10^{-2}	1.26×10^{2}	7.38×10^{1}	5.09×10^{-3}	1.49×10^{-8}	3.49×10^{-2}
S Barrier	6.14	2.91	1.78×10^{-4}	0.00	2.65×10^{-4}	1.37×10^{1}	2.96	5.52×10^{-4}	1.14×10^{-9}	8.18×10^{-4}
T Barrier	3.54×10^{1}	9.64	1.01×10^{-3}	0.00	1.37×10^{-2}	7.79×10^{1}	1.04×10^{1}	3.13×10^{-3}	3.03×10^{-9}	2.40×10^{-2}
U Barrier	3.39×10^{-1}	1.03×10^{-1}	9.91×10^{-6}	0.00	9.91×10^{-6}	7.64×10^{-1}	1.07×10^{-1}	3.09×10^{-5}	3.78×10^{-11}	3.09×10^{-5}
Core Zone Boundary	4.51×10^{1}	3.67×10^{1}	1.35×10^{-3}	0.00	1.25×10^{-2}	1.04×10^{2}	4.34×10^{1}	4.27×10^{-3}	6.53×10^{-9}	3.49×10^{-2}
Columbia River nearshore	3.73×10^{-1}	3.91×10^{-1}	1.15×10^{-5}	0.00	1.15×10^{-5}	8.80×10^{-1}	4.34×10^{-1}	3.67×10^{-5}	1.13×10^{-10}	3.67×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	4.09×10^{-5}	2.00×10^{-5}	1.66×10^{-9}	4.17×10^{-15}	5.75×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–51. Tank Closure Alternative 6A, Option Case, American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impact Summary

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.33×10^{1}	1.32×10^{-1}	5.97×10^{-4}	1.43×10^{-6}	5.31×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	2.45×10^{2}	1.27×10^{2}	1.10×10^{-2}	6.82×10^{-4}	7.45×10^{-2}	N/A	N/A	N/A	N/A	N/A
S Barrier	2.66×10^{1}	4.42	1.19×10^{-3}	5.21×10^{-5}	1.76×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	1.51×10^{2}	1.67×10^{1}	6.73×10^{-3}	1.39×10^{-4}	4.79×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	1.49	1.63×10^{-1}	6.64×10^{-5}	1.73×10^{-6}	6.64×10^{-5}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	2.04×10^{2}	7.74×10^{1}	9.21×10^{-3}	3.00×10^{-4}	7.45×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.74	7.23×10^{-1}	7.94×10^{-5}	5.19×10^{-6}	7.94×10^{-5}	5.42×10^{-2}	3.52×10^{-1}	6.89×10^{-7}	2.60×10^{-6}	5.77×10^{-6}
Off Site										
Columbia River	1.59×10^{-4}	2.70×10^{-2}	5.78×10^{-9}	1.91×10^{-10}	1.86×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

5.1.2.10 Tank Closure Alternative 6B: All Vitrification with Separations; Clean Closure

5.1.2.10.1 Base Case

Tank Closure Alternative 6B, Base Case, resembles Tank Closure Alternative 6A, Base Case, except that waste retrieval and processing would proceed at a faster rate and closure would occur at an earlier date. All tank farms would be clean-closed, and the adjacent crib and trenches (ditches) would be covered with an engineered modified RCRA Subtitle C barrier. Potential human health impacts under Tank Closure Alternative 6B, Base Case, are detailed in Appendix Q and summarized in Tables 5–52 through 5–57; those related to cribs and trenches (ditches) after CY 1940 are in Tables 5–52 and 5–53; to past leaks after CY 1940 in Tables 5–54 and 5–55; and to the combination of cribs and trenches (ditches), past leaks, and other tank farm sources after CY 2050 in Tables 5–56 and 5–57.

Impacts would be similar to those under Tank Closure Alternative 6A, Base Case, and standards would be exceeded, as under Tank Closure Alternative 6A, Base Case. The population dose was estimated as 2.04×10^{-1} person-rem per year for the year of maximum impact. This corresponds to 1.12×10^{-5} percent of the annual population dose due to background exposure.

Table 5–52. Tank Closure Alternative 6B, Base Case, Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	6.36×10^{2}	7.95×10^{2}	1.24×10^{-2}	0.00	1.24×10^{-2}	1.24×10^{3}	8.94×10^{2}	3.48×10^{-2}	2.00×10^{-7}	3.48×10^{-2}
T Barrier	1.46×10^{3}	1.27×10^{2}	1.39×10^{-2}	0.00	1.39×10^{-2}	2.32×10^{3}	1.39×10^{2}	2.43×10^{-2}	3.66×10^{-8}	2.43×10^{-2}
Core Zone Boundary	6.36×10^{2}	4.97×10^{2}	1.24×10^{-2}	0.00	1.24×10^{-2}	1.24×10^{3}	5.70×10^{2}	3.48×10^{-2}	1.10×10^{-7}	3.48×10^{-2}
Columbia River nearshore	2.08×10^{-1}	4.02×10^{-1}	5.89×10^{-6}	0.00	5.89×10^{-6}	4.79×10^{-1}	4.35×10^{-1}	1.85×10^{-5}	1.23×10^{-10}	1.85×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	1.91×10^{-4}	1.63×10^{-4}	5.83×10^{-9}	3.52×10^{-14}	5.83×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–53. Tank Closure Alternative 6B, Base Case, American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	2.36×10^{3}	1.51×10^{3}	7.43×10^{-2}	9.16×10^{-3}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
T Barrier	4.27×10^{3}	2.27×10^{2}	4.85×10^{-2}	1.68×10^{-3}	4.85×10^{-2}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	2.36×10^{3}	9.85×10^{2}	7.43×10^{-2}	5.05×10^{-3}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	9.53×10^{-1}	7.03×10^{-1}	4.01×10^{-5}	5.66×10^{-6}	4.01×10^{-5}	4.04×10^{-1}	7.14×10^{-1}	4.97×10^{-6}	2.83×10^{-6}	6.40×10^{-6}
Off Site										
Columbia River	5.59×10^{-4}	2.11×10^{-1}	1.80×10^{-8}	1.61×10^{-9}	1.88×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–54. Tank Closure Alternative 6B, Base Case, Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	2.89×10^{1}	6.75×10^{-1}	8.27×10^{-4}	0.00	8.27×10^{-4}	6.42×10^{1}	7.00×10^{-1}	2.56×10^{-3}	2.48×10^{-10}	2.56×10^{-3}
B Barrier	1.96×10^{1}	1.18	5.68×10^{-4}	0.00	5.68×10^{-4}	4.38×10^{1}	1.28	1.76×10^{-3}	3.57×10^{-10}	1.76×10^{-3}
S Barrier	9.02	4.08	2.60×10^{-4}	0.00	2.60×10^{-4}	2.01×10^{1}	4.14	8.04×10^{-4}	1.60×10^{-9}	8.04×10^{-4}
T Barrier	5.40×10^{1}	5.75	1.56×10^{-3}	0.00	1.56×10^{-3}	1.21×10^{2}	5.97	4.83×10^{-3}	2.09×10^{-9}	4.83×10^{-3}
U Barrier	3.24×10^{-1}	1.40×10^{-1}	9.40×10^{-6}	0.00	9.40×10^{-6}	7.25×10^{-1}	1.44×10^{-1}	2.92×10^{-5}	5.31×10^{-11}	2.92×10^{-5}
Core Zone Boundary	1.03×10^{1}	4.14	3.02×10^{-4}	0.00	3.02×10^{-4}	2.32×10^{1}	4.20	9.41×10^{-4}	1.64×10^{-9}	9.41×10^{-4}
Columbia River nearshore	2.79×10^{-1}	3.64×10^{-2}	8.88×10^{-6}	0.00	8.88×10^{-6}	6.73×10^{-1}	3.73×10^{-2}	2.84×10^{-5}	1.38×10^{-11}	2.84×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	3.33×10^{-5}	2.07×10^{-6}	1.34×10^{-9}	7.12×10^{-16}	1.34×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–55. Tank Closure Alternative 6B, Base Case, American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.24×10^{2}	1.07	5.50×10^{-3}	1.14×10^{-5}	5.50×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	8.50×10^{1}	2.08	3.79×10^{-3}	1.64×10^{-5}	3.79×10^{-3}	N/A	N/A	N/A	N/A	N/A
S Barrier	3.89×10^{1}	6.19	1.73×10^{-3}	7.33×10^{-5}	1.73×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	2.34×10^{2}	9.19	1.04×10^{-2}	9.59×10^{-5}	1.04×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	1.41	2.17×10^{-1}	6.29×10^{-5}	2.44×10^{-6}	6.29×10^{-5}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	4.53×10^{1}	6.25	2.03×10^{-3}	7.51×10^{-5}	2.03×10^{-3}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.34	5.64×10^{-2}	6.17×10^{-5}	6.35×10^{-7}	6.17×10^{-5}	1.90×10^{-3}	1.57×10^{-2}	9.41×10^{-8}	3.18×10^{-7}	3.72×10^{-7}
Off Site										
Columbia River	1.31×10^{-4}	1.00×10^{-3}	4.75×10^{-9}	3.26×10^{-11}	4.77×10^{-9}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–56. Tank Closure Alternative 6B, Base Case, Drinking-Water Well User and Resident Farmer Long-Term Human Health Impact Summary

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	3.21	7.68×10^{-2}	9.24×10^{-5}	0.00	8.27×10^{-4}	7.15	7.94×10^{-2}	2.86×10^{-4}	2.84×10^{-11}	2.56×10^{-3}
B Barrier	6.17×10^{1}	5.78×10^{1}	1.88×10^{-3}	0.00	1.24×10^{-2}	1.44×10^{2}	6.65×10^{1}	5.94×10^{-3}	1.25×10^{-8}	3.48×10^{-2}
S Barrier	5.86	2.85	1.70×10^{-4}	0.00	2.60×10^{-4}	1.31×10^{1}	2.90	5.27×10^{-4}	1.11×10^{-9}	8.04×10^{-4}
T Barrier	3.61×10^{1}	9.65	1.03×10^{-3}	0.00	1.39×10^{-2}	8.04×10^{1}	1.04×10^{1}	3.20×10^{-3}	3.03×10^{-9}	2.43×10^{-2}
U Barrier	3.23×10^{-1}	9.89×10^{-2}	9.33×10^{-6}	0.00	9.40×10^{-6}	7.22×10^{-1}	1.02×10^{-1}	2.89×10^{-5}	3.63×10^{-11}	2.92×10^{-5}
Core Zone Boundary	5.16×10^{1}	3.38×10^{1}	1.59×10^{-3}	0.00	1.24×10^{-2}	1.21×10^{2}	3.95×10^{1}	5.02×10^{-3}	6.50×10^{-9}	3.48×10^{-2}
Columbia River nearshore	3.38×10^{-1}	4.22×10^{-1}	1.06×10^{-5}	0.00	1.06×10^{-5}	8.07×10^{-1}	4.56×10^{-1}	3.39×10^{-5}	1.31×10^{-10}	3.39×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	4.09×10^{-5}	1.91×10^{-5}	1.66×10^{-9}	3.98×10^{-15}	5.83×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–57. Tank Closure Alternative 6B, Base Case, American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impact Summary

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.38×10^{1}	1.21×10^{-1}	6.15×10^{-4}	1.30×10^{-6}	5.50×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	2.83×10^{2}	1.15×10^{2}	1.28×10^{-2}	5.72×10^{-4}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
S Barrier	2.55×10^{1}	4.35	1.13×10^{-3}	5.10×10^{-5}	1.73×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	1.56×10^{2}	1.67×10^{1}	6.89×10^{-3}	1.39×10^{-4}	4.85×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	1.40	1.57×10^{-1}	6.22×10^{-5}	1.67×10^{-6}	6.29×10^{-5}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	2.39×10^{2}	6.96×10^{1}	1.09×10^{-2}	2.98×10^{-4}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.60	7.35×10^{-1}	7.34×10^{-5}	6.00×10^{-6}	7.34×10^{-5}	5.68×10^{-2}	3.77×10^{-1}	7.22×10^{-7}	3.00×10^{-6}	6.40×10^{-6}
Off Site										
Columbia River	1.57×10^{-4}	2.76×10^{-2}	5.73×10^{-9}	1.82×10^{-10}	1.88×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

5.1.2.10.2 Option Case

Tank Closure Alternative 6B, Option Case, resembles Tank Closure Alternative 6A, Option Case, except that waste retrieval and processing would proceed at a faster rate and closure would occur at an earlier date. All tank farms would be clean-closed, and the adjacent crib and trenches (ditches) would be clean-closed. Potential human health impacts under Tank Closure Alternative 6B, Option Case, are detailed in Appendix Q and summarized in Tables 5–58 through 5–63; those related to cribs and trenches (ditches) after CY 1940 are in Tables 5–58 and 5–59; to past leaks after CY 1940 in Tables 5–60 and 5–61; and to the combination of cribs and trenches (ditches), past leaks, and other tank farm sources after CY 2050 in Tables 5–62 and 5–63.

Impacts would be slightly less than those under Tank Closure Alternative 6B, Base Case, and standards would be exceeded, as under Tank Closure Alternative 6B, Base Case. The population dose was estimated as 2.00×10^{-1} person-rem per year for the year of maximum impact. This corresponds to 1.09×10^{-5} percent of the annual population dose due to background exposure.

Table 5–58. Tank Closure Alternative 6B, Option Case, Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	6.37×10^{2}	8.06×10^{2}	1.24×10^{-2}	0.00	1.24×10^{-2}	1.24×10^{3}	9.07×10^{2}	3.48×10^{-2}	2.01×10^{-7}	3.48×10^{-2}
T Barrier	1.45×10^{3}	1.25×10^{2}	1.38×10^{-2}	0.00	1.38×10^{-2}	2.31×10^{3}	1.37×10^{2}	2.42×10^{-2}	3.59×10^{-8}	2.42×10^{-2}
Core Zone Boundary	6.37×10^{2}	5.15×10^{2}	1.24×10^{-2}	0.00	1.24×10^{-2}	1.24×10^{3}	5.92×10^{2}	3.48×10^{-2}	1.11×10^{-7}	3.48×10^{-2}
Columbia River nearshore	2.13×10^{-1}	3.56×10^{-1}	4.14×10^{-6}	0.00	4.14×10^{-6}	3.54×10^{-1}	3.92×10^{-1}	1.26×10^{-5}	1.01×10^{-10}	1.26×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	1.92×10^{-4}	1.60×10^{-4}	5.86×10^{-9}	3.50×10^{-14}	5.86×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–59. Tank Closure Alternative 6B, Option Case, American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	2.37×10^{3}	1.54×10^{3}	7.42×10^{-2}	9.23×10^{-3}	7.42×10^{-2}	N/A	N/A	N/A	N/A	N/A
T Barrier	4.25×10^{3}	2.26×10^{2}	4.83×10^{-2}	1.65×10^{-3}	4.83×10^{-2}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	2.37×10^{3}	1.03×10^{3}	7.42×10^{-2}	5.10×10^{-3}	7.42×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	6.85×10^{-1}	6.46×10^{-1}	2.71×10^{-5}	4.63×10^{-6}	2.71×10^{-5}	5.07×10^{-1}	6.93×10^{-1}	6.23×10^{-6}	2.31×10^{-6}	7.31×10^{-6}
Off Site										
Columbia River	5.59×10^{-4}	2.06×10^{-1}	1.80×10^{-8}	1.60×10^{-9}	1.88×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–60. Tank Closure Alternative 6B, Option Case, Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	2.89×10^{1}	6.75×10^{-1}	8.27×10^{-4}	0.00	8.27×10^{-4}	6.42×10^{1}	7.00×10^{-1}	2.56×10^{-3}	2.48×10^{-10}	2.56×10^{-3}
B Barrier	1.96×10^{1}	1.18	5.68×10^{-4}	0.00	5.68×10^{-4}	4.38×10^{1}	1.28	1.76×10^{-3}	3.57×10^{-10}	1.76×10^{-3}
S Barrier	9.02	4.08	2.60×10^{-4}	0.00	2.60×10^{-4}	2.01×10^{1}	4.14	8.04×10^{-4}	1.60×10^{-9}	8.04×10^{-4}
T Barrier	5.40×10^{1}	5.75	1.56×10^{-3}	0.00	1.56×10^{-3}	1.21×10^{2}	5.97	4.83×10^{-3}	2.09×10^{-9}	4.83×10^{-3}
U Barrier	3.24×10^{-1}	1.40×10^{-1}	9.40×10^{-6}	0.00	9.40×10^{-6}	7.25×10^{-1}	1.44×10^{-1}	2.92×10^{-5}	5.31×10^{-11}	2.92×10^{-5}
Core Zone Boundary	1.03×10^{1}	4.14	3.02×10^{-4}	0.00	3.02×10^{-4}	2.32×10^{1}	4.20	9.41×10^{-4}	1.64×10^{-9}	9.41×10^{-4}
Columbia River nearshore	2.79×10^{-1}	3.64×10^{-2}	8.88×10^{-6}	0.00	8.88×10^{-6}	6.73×10^{-1}	3.73×10^{-2}	2.84×10^{-5}	1.38×10^{-11}	2.84×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	3.33×10^{-5}	2.07×10^{-6}	1.34×10^{-9}	7.12×10^{-16}	1.34×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–61. Tank Closure Alternative 6B, Option Case, American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.24×10^{2}	1.07	5.50×10^{-3}	1.14×10^{-5}	5.50×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	8.50×10^{1}	2.08	3.79×10^{-3}	1.64×10^{-5}	3.79×10^{-3}	N/A	N/A	N/A	N/A	N/A
S Barrier	3.89×10^{1}	6.19	1.73×10^{-3}	7.33×10^{-5}	1.73×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	2.34×10^{2}	9.19	1.04×10^{-2}	9.59×10^{-5}	1.04×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	1.41	2.17×10^{-1}	6.29×10^{-5}	2.44×10^{-6}	6.29×10^{-5}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	4.53×10^{1}	6.25	2.03×10^{-3}	7.51×10^{-5}	2.03×10^{-3}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.34	5.64×10^{-2}	6.17×10^{-5}	6.35×10^{-7}	6.17×10^{-5}	1.90×10^{-3}	1.57×10^{-2}	9.41×10^{-8}	3.18×10^{-7}	3.72×10^{-7}
Off Site										
Columbia River	1.31×10^{-4}	1.00×10^{-3}	4.75×10^{-9}	3.26×10^{-11}	4.77×10^{-9}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–62. Tank Closure Alternative 6B, Option Case, Drinking-Water Well User and Resident Farmer Long-Term Human Health Impact Summary

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	3.21	7.68×10^{-2}	9.24×10^{-5}	0.00	8.27×10^{-4}	7.15	7.94×10^{-2}	2.86×10^{-4}	2.84×10^{-11}	2.56×10^{-3}
B Barrier	5.79×10^{1}	6.37×10^{1}	1.75×10^{-3}	0.00	1.24×10^{-2}	1.34×10^{2}	7.25×10^{1}	5.50×10^{-3}	1.48×10^{-8}	3.48×10^{-2}
S Barrier	5.86	2.85	1.70×10^{-4}	0.00	2.60×10^{-4}	1.31×10^{1}	2.90	5.27×10^{-4}	1.11×10^{-9}	8.04×10^{-4}
T Barrier	3.61×10^{1}	9.58	1.04×10^{-3}	0.00	1.38×10^{-2}	8.05×10^{1}	1.03×10^{1}	3.20×10^{-3}	3.05×10^{-9}	2.42×10^{-2}
U Barrier	3.23×10^{-1}	9.89×10^{-2}	9.33×10^{-6}	0.00	9.40×10^{-6}	7.22×10^{-1}	1.02×10^{-1}	2.89×10^{-5}	3.63×10^{-11}	2.92×10^{-5}
Core Zone Boundary	4.79×10^{1}	3.52×10^{1}	1.46×10^{-3}	0.00	1.24×10^{-2}	1.12×10^{2}	4.21×10^{1}	4.61×10^{-3}	6.92×10^{-9}	3.48×10^{-2}
Columbia River nearshore	3.38×10^{-1}	3.79×10^{-1}	1.04×10^{-5}	0.00	1.04×10^{-5}	7.91×10^{-1}	4.16×10^{-1}	3.28×10^{-5}	1.09×10^{-10}	3.28×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	3.99×10^{-5}	1.93×10^{-5}	1.62×10^{-9}	4.02×10^{-15}	5.86×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–63. Tank Closure Alternative 6B, Option Case, American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impact Summary

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.38×10^{1}	1.21×10^{-1}	6.15×10^{-4}	1.30×10^{-6}	5.50×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	2.63×10^{2}	1.24×10^{2}	1.19×10^{-2}	6.79×10^{-4}	7.42×10^{-2}	N/A	N/A	N/A	N/A	N/A
S Barrier	2.55×10^{1}	4.35	1.13×10^{-3}	5.10×10^{-5}	1.73×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	1.56×10^{2}	1.65×10^{1}	6.89×10^{-3}	1.40×10^{-4}	4.83×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	1.40	1.57×10^{-1}	6.22×10^{-5}	1.67×10^{-6}	6.29×10^{-5}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	2.20×10^{2}	7.60×10^{1}	9.96×10^{-3}	3.17×10^{-4}	7.42×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.56	6.83×10^{-1}	7.09×10^{-5}	5.01×10^{-6}	7.09×10^{-5}	5.53×10^{-2}	3.45×10^{-1}	7.10×10^{-7}	2.51×10^{-6}	7.32×10^{-6}
Off Site										
Columbia River	1.54×10^{-4}	2.69×10^{-2}	5.62×10^{-9}	1.84×10^{-10}	1.88×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

5.1.2.11 Tank Closure Alternative 6C: All Vitrification with Separations; Landfill Closure

Activities under Tank Closure Alternative 6C would be similar to those under Tank Closure Alternative 2B. Likewise, impacts exceeding dose and risk standards, the estimated population dose for the year of maximum impact, and corresponding percent of the annual population dose due to background exposure would be the same as those under Tank Closure Alternative 2B for cribs and trenches (ditches), past leaks, and other tank farm sources.

5.1.3 Ecological Risk

This section presents the results of the evaluation of long-term impacts on ecological resources of releases to air and groundwater under Tank Closure alternatives. Risk indices—Hazard Quotient or Hazard Index—were calculated by comparing predicted dose to benchmark dose (see Appendix P of this EIS). Risk indices could not be calculated for some chemical COPCs and some receptors. For each receptor, calculated risk indices are presented for the COPC with the highest Hazard Quotients or Hazard Indices.

Releases to air and groundwater are expected under all Tank Closure alternatives. The long-term impacts on terrestrial ecological resources of releases to air at Hanford were evaluated at the onsite maximum-exposure location (Core Zone Boundary) and on terrestrial, riparian, and aquatic resources at the offsite maximum-exposure location (Columbia River). Impacts on ecological resources of releases to groundwater were evaluated at the Columbia River.

5.1.3.1 Tank Closure Alternative 1: No Action

Predicted emissions of COPCs in air under Tank Closure Alternative 1, No Action, are unlikely to pose a hazard to ecological receptors. Under Tank Closure Alternative 1, the largest Hazard Quotient (1.16) for any COPC was calculated for the mouse exposed to xylene deposited to soil at the onsite maximum-exposure location (see Table 5–64). Hazard Quotients and Hazard Indices less than or equal to 1 indicate no risk, but there is uncertainty in the calculated value. The mouse Hazard Quotient for xylene is within the margin of error of the uncertainties in the estimated exposure and toxicity of chemical COPCs and does not indicate that small omnivorous mammals are likely to be adversely impacted (see Appendix P). The largest Hazard Index (0.0098) for radiological COPCs released to air under Tank Closure Alternative 1 (see Appendix P, Table P–3) is predicted for the mourning dove at the onsite maximum-exposure location. This indicates no risk from radiological COPCs released to air under Tank Closure Alternative 1.

Long-term impacts on ecological resources as a result of releases to groundwater from past leaks, residuals, ancillary equipment, and cribs and trenches (ditches) were evaluated at the Columbia River (see Appendix P). The largest risk index (Hazard Quotient is 21) for groundwater releases under Tank Closure Alternative 1 (see Table 5–65) is that calculated for exposure to chromium for aquatic biota, including salmonids, at the Columbia River. The uncertainty about the risk it poses to aquatic biota from chromium in groundwater releases under *TC & WM EIS* alternatives is discussed in Appendix P (see Section P.3.2). The next-largest Hazard Quotient (0.82) for any chemical COPC was calculated for the spotted sandpiper exposed to chromium deposited to sediment and taken up by its benthic invertebrate prey. Hazard Quotients and Hazard Indices less than or equal to 1 indicate no risk. The largest Hazard Index (0.02) for radiological COPCs released to groundwater under Tank Closure Alternative 1 (see Appendix P, Table P–12) is predicted for benthic invertebrates. This indicates no risk from radiological COPCs under Tank Closure Alternative 1.

Table 5–64. Tank Closure Alternatives – Long-Term Impacts of Chemical COPC Releases to Air on Terrestrial Resources at the Onsite Maximum-Exposure Location

Tank Closure Alternative	Hazard Quotient of Worst-Case Chemical COPC by Receptor								
	Plants	Soil-Dwelling Invertebrate	Side-Blotched Lizard	Great Basin Pocket Mouse	Coyote	Mule Deer	Meadow Lark	Mourning Dove	Burrowing Owl
	Mercury	Mercury	Mercury	Xylene	Xylene	Formaldehyde	Mercury	Mercury	Mercury
1	0.00	0.00	0.00	**1.16**	1.48×10^{-1}	1.63×10^{-1}	0.00	0.00	0.00
2A	6.46	9.02×10^{-1}	**1.52×10^{2}**	1.21×10^{2}	1.54×10^{1}	1.29×10^{1}	9.12×10^{1}	7.53	6.35
2B	7.05	9.85×10^{-1}	**1.66×10^{2}**	9.79×10^{1}	1.24×10^{1}	1.24×10^{1}	9.95×10^{1}	8.22	6.92
3A	1.67×10^{1}	2.33	**3.92×10^{2}**	1.02×10^{2}	1.30×10^{1}	1.24×10^{1}	2.35×10^{2}	1.94×10^{1}	1.64×10^{1}
3B	4.80	6.70×10^{-1}	1.13×10^{2}	**1.23×10^{2}**	1.57×10^{1}	1.39×10^{1}	6.77×10^{1}	5.59	4.71
3C	1.67×10^{1}	2.33	**3.92×10^{2}**	1.07×10^{2}	1.35×10^{1}	1.26×10^{1}	2.35×10^{2}	1.94×10^{1}	1.64×10^{1}
4	6.67	9.31×10^{-1}	**1.57×10^{2}**	9.06×10^{1}	1.15×10^{1}	1.35×10^{1}	9.41×10^{1}	7.77	6.54
5	6.34	8.85×10^{-1}	**1.49×10^{2}**	**1.49×10^{2}**	1.90×10^{1}	1.79×10^{1}	8.94×10^{1}	7.38	6.22
6A, Base	6.56	9.16×10^{-1}	1.54×10^{2}	**2.70×10^{2}**	3.43×10^{1}	3.49×10^{1}	9.25×10^{1}	7.64	6.44
6A, Option	6.51	9.09×10^{-1}	1.53×10^{2}	**2.74×10^{2}**	3.48×10^{1}	4.26×10^{1}	9.18×10^{1}	7.58	6.39
6B, Base	7.33	1.02	**1.72×10^{2}**	1.51×10^{2}	1.92×10^{1}	2.32×10^{1}	1.03×10^{2}	8.54	7.20
6B, Option	7.30	1.02	**1.71×10^{2}**	1.56×10^{2}	1.98×10^{1}	3.09×10^{1}	1.03×10^{2}	8.50	7.16
6C	7.30	1.02	**1.71×10^{2}**	9.70×10^{1}	1.23×10^{1}	1.04×10^{1}	1.03×10^{2}	8.50	7.16

Note: The maximum Hazard Quotient under each alternative is indicated by **bold** text.

Key: Base=Base Case; COPC=constituent of potential concern; Option=Option Case.

Table 5–65. Tank Closure Alternatives – Long-Term Impacts of Contaminant Releases to Groundwater on Aquatic and Riparian Resources at the Columbia River

Tank Closure Alternative	Hazard Quotient or Hazard Index of Worst-Case Chemical or Radiological COPC by Receptor						
	Benthic Invertebrate	Muskrat	Spotted Sandpiper	Raccoon	Least Weasel	Bald Eagle	Aquatic Biota/Salmonids
	Chromium	Chromium	Chromium	Uranium	Nitrate	Chromium	Chromium
1	1.20×10^{-1}	4.71×10^{-3}	8.16×10^{-1}	2.95×10^{-1}	6.31×10^{-1}	2.08×10^{-2}	**2.14×10^{1}**
2A	2.35×10^{-2}	9.17×10^{-4}	1.59×10^{-1}	4.11×10^{-2}	6.25×10^{-1}	1.49×10^{-2}	**2.20×10^{1}**
2B, 3A, 3B, 3C, 6C	2.50×10^{-2}	9.79×10^{-4}	1.70×10^{-1}	2.88×10^{-2}	6.30×10^{-1}	1.51×10^{-2}	**2.22×10^{1}**
4	2.47×10^{-2}	9.67×10^{-4}	1.68×10^{-1}	2.32×10^{-2}	6.30×10^{-1}	1.51×10^{-2}	**2.22×10^{1}**
5	2.54×10^{-2}	9.93×10^{-4}	1.72×10^{-1}	4.12×10^{-2}	6.30×10^{-1}	1.51×10^{-2}	**2.22×10^{1}**
6A, Base	2.42×10^{-2}	9.46×10^{-4}	1.64×10^{-1}	2.72×10^{-3}	6.30×10^{-1}	1.50×10^{-2}	**2.22×10^{1}**
6A, Option	2.11×10^{-2}	8.24×10^{-4}	1.43×10^{-1}	1.01×10^{-4}	6.36×10^{-1}	1.44×10^{-2}	**2.15×10^{1}**
6B, Base	2.43×10^{-2}	9.52×10^{-4}	1.65×10^{-1}	2.72×10^{-3}	6.30×10^{-1}	1.50×10^{-2}	**2.22×10^{1}**
6B, Option	2.03×10^{-2}	7.95×10^{-4}	1.38×10^{-1}	7.41×10^{-5}	6.16×10^{-1}	1.47×10^{-2}	**2.21×10^{1}**

Note: The maximum Hazard Quotient under each alternative is indicated by **bold** text.
Key: Base=Base Case; COPC=constituent of potential concern; Option=Option Case.

5.1.3.2 Tank Closure Alternative 2A: Existing WTP Vitrification; No Closure

Predicted emissions of COPCs in air under Tank Closure Alternative 2A pose a small probability of adverse impact on ecological receptors at the onsite maximum-exposure location. Hazard Quotients calculated for plants are between 1 and 10 for toluene and mercury under Tank Closure Alternative 2A. The chemical COPCs with the largest calculated Hazard Quotients for air releases are xylene for the mammals (mouse Hazard Quotient is 121) and mercury for the soil-dwelling invertebrates, lizards, and birds (side-blotched lizard Hazard Quotient is 152) at the onsite maximum-exposure location (see Table 5–64). There would be no risk from radiological COPCs under Tank Closure Alternative 2A. The largest Hazard Index (0.0167) for radiological COPCs released to air under Tank Closure Alternative 2A (see Appendix P, Table P–3) is predicted for the mouse at the onsite maximum-exposure location. There also would be no risk to terrestrial, riparian, or aquatic ecological receptors from COPC releases to air under Tank Closure Alternative 2A at the offsite maximum-exposure location (Columbia River).

The largest risk index (Hazard Quotient is 22) for groundwater releases under Tank Closure Alternative 2A is that calculated for exposure to hexavalent chromium for aquatic biota, including salmonids, at the Columbia River, only slightly greater than the Hazard Quotient under Tank Closure Alternative 1 (see Table 5–65). No other Hazard Quotients exceed 1.0. Hazard Quotients and Hazard Indices less than or equal to 1 indicate no risk. The largest Hazard Index (0.0049) for radiological COPCs released to groundwater under Tank Closure Alternative 2A (see Appendix P, Table P–12) is predicted for benthic invertebrates, a factor of 4 smaller than that under Tank Closure Alternative 1. This indicates no risk from radiological COPCs released to groundwater under Tank Closure Alternative 2A.

5.1.3.3 Tank Closure Alternative 2B: Expanded WTP Vitrification; Landfill Closure

Predicted emissions of COPCs in air under Tank Closure Alternative 2B pose a small probability of adverse impact on ecological receptors at the onsite maximum-exposure location, only slightly larger than under Tank Closure Alternative 2A (see Table 5–64). Hazard Quotients calculated for plants are between 1 and 10 for toluene and mercury under Tank Closure Alternative 2B. The chemical COPCs with the largest calculated Hazard Quotients for air releases are xylene for the mammals (mouse Hazard Quotient is 98) and mercury for the soil-dwelling invertebrates, lizards, and birds (side-blotched lizard Hazard Quotient is 166) at the onsite maximum-exposure location. There would be no risk from radiological COPCs under Tank Closure Alternative 2B. The largest Hazard Index (0.0091) for radiological COPCs released to air under Tank Closure Alternative 2B (see Appendix P, Table P–3) is predicted for the mouse at the onsite maximum-exposure location. There also would be no risk to terrestrial, riparian, or aquatic ecological receptors from releases of COPCs to air under Tank Closure Alternative 2B at the offsite maximum-exposure location (Columbia River).

The largest risk index (Hazard Quotient is 22) for groundwater releases under Tank Closure Alternative 2B is that calculated for exposure to chromium for aquatic biota, including salmonids, at the Columbia River, only slightly greater than the Hazard Quotient under Tank Closure Alternative 1 (see Table 5–65). No other Hazard Quotients exceed 1.0. Hazard Quotients and Hazard Indices less than or equal to 1 indicate no risk. The largest Hazard Index (0.003) for radiological COPCs released to groundwater under Tank Closure Alternative 2B (see Appendix P, Table P–12) is predicted for benthic invertebrates, a factor of 7 smaller than that under Tank Closure Alternative 1. This indicates no risk from radiological COPCs released to groundwater under Tank Closure Alternative 2B.

5.1.3.4 Tank Closure Alternative 3A: Existing WTP Vitrification with Thermal Supplemental Treatment (Bulk Vitrification); Landfill Closure

Predicted emissions of COPCs in air under Tank Closure Alternative 3A pose a small probability of adverse impact on ecological receptors at the onsite maximum-exposure location. Tank Closure

Alternative 3A (and Tank Closure Alternative 3C) poses the highest risk of all alternatives for soil-dwelling invertebrates and the side-blotched lizard, meadow lark, mourning dove, and owl at the onsite maximum-exposure location (see Table 5–64). Hazard Quotients calculated for plants are between 1 and 20 for toluene and mercury under Tank Closure Alternative 3A. The chemical COPCs with the largest calculated Hazard Quotients for air releases are xylene for the mammals (mouse Hazard Quotient is 102) and mercury for the soil-dwelling invertebrates, lizards, and birds (side-blotched lizard Hazard Quotient is 392) at the onsite maximum-exposure location. There would be no risk from radiological COPCs under Tank Closure Alternative 3A. The largest Hazard Index (0.0137) for radiological COPCs released to air under Tank Closure Alternative 3A (see Appendix P, Table P–3) is predicted for the mouse at the onsite maximum-exposure location. There also would be no risk to terrestrial, riparian, or aquatic ecological receptors from releases to air under Tank Closure Alternative 3A at the offsite maximum-exposure location (Columbia River).

The largest risk index (Hazard Quotient is 22) for groundwater releases under Tank Closure Alternative 3A is that calculated for exposure to chromium for aquatic biota, including salmonids, at the Columbia River, only slightly greater than the Hazard Quotient under Tank Closure Alternative 1 (see Table 5–65). No other Hazard Quotients exceed 1.0. Hazard Quotients and Hazard Indices less than or equal to 1 indicate no risk. The largest Hazard Index (0.003) for radiological COPCs released to groundwater under Tank Closure Alternative 3A (see Appendix P, Table P–12) is predicted for benthic invertebrates, a factor of 7 smaller than that under Tank Closure Alternative 1. This indicates no risk from radiological COPCs released to groundwater under Tank Closure Alternative 3A.

5.1.3.5 Tank Closure Alternative 3B: Existing WTP Vitrification with Nonthermal Supplemental Treatment (Cast Stone); Landfill Closure

Predicted emissions of COPCs in air under Tank Closure Alternative 3B pose a small probability of adverse impact on ecological receptors at the onsite maximum-exposure location (see Table 5–64). Hazard Quotients calculated for plants are between 1 and 10 for toluene and mercury under Tank Closure Alternative 3B. The chemical COPCs with the largest calculated Hazard Quotients for air releases are xylene for the mammals (mouse Hazard Quotient is 123) and mercury for the soil-dwelling invertebrates, lizards, and birds (side-blotched lizard Hazard Quotient is 113) at the onsite maximum-exposure location. There would be no risk from radiological COPCs under Tank Closure Alternative 3B. The largest Hazard Index (0.0086) for radiological COPCs released to air under Tank Closure Alternative 3B (see Appendix P, Table P–3) is predicted for the mouse at the onsite maximum-exposure location. There also would be no risk to terrestrial, riparian, or aquatic ecological receptors from releases to air under Tank Closure Alternative 3B at the offsite maximum-exposure location (Columbia River).

The largest risk index (Hazard Quotient is 22) for groundwater releases under Tank Closure Alternative 3B is that calculated for exposure to chromium for aquatic biota, including salmonids, at the Columbia River, only slightly greater than the Hazard Quotient under Tank Closure Alternative 1 (see Table 5–65). No other Hazard Quotients exceed 1.0. Hazard Quotients and Hazard Indices less than or equal to 1 indicate no risk. The largest Hazard Index (0.003) for radiological COPCs released to groundwater under Tank Closure Alternative 3B (see Appendix P, Table P–12) is predicted for benthic invertebrates, a factor of 7 smaller than that under Tank Closure Alternative 1. This indicates no risk from radiological COPCs released to groundwater under Tank Closure Alternative 3B.

5.1.3.6 Tank Closure Alternative 3C: Existing WTP Vitrification with Thermal Supplemental Treatment (Steam Reforming); Landfill Closure

Predicted emissions of COPCs in air under Tank Closure Alternative 3C pose a small probability of adverse impact on ecological receptors at the onsite maximum-exposure location. Tank Closure Alternative 3C risk indices are similar to those under Tank Closure Alternative 3A, posing the highest

risk of all alternatives for soil-dwelling invertebrates and the side-blotched lizard, meadow lark, mourning dove, and owl at the onsite maximum-exposure location (see Table 5–64). Hazard Quotients calculated for plants are between 1 and 20 for toluene and mercury under Tank Closure Alternative 3C. The chemical COPCs with the largest calculated Hazard Quotients for air releases are xylene for the mammals (mouse Hazard Quotient is 107) and mercury for the soil-dwelling invertebrates, lizards, and birds (side-blotched lizard Hazard Quotient is 392) at the onsite maximum-exposure location. There would be no risk from radiological COPCs under Tank Closure Alternative 3C. The largest Hazard Index (0.0137) for radiological COPCs released to air under Tank Closure Alternative 3C (see Appendix P, Table P–3) is predicted for the mouse at the onsite maximum-exposure location. There also would be no risk to terrestrial, riparian, or aquatic ecological receptors from releases to air under Tank Closure Alternative 3C at the offsite maximum-exposure location (Columbia River).

The largest risk index (Hazard Quotient is 22) for groundwater releases under Tank Closure Alternative 3C is that calculated for exposure to chromium for aquatic biota, including salmonids, at the Columbia River, only slightly greater than the Hazard Quotient under Tank Closure Alternative 1 (see Table 5–65). No other Hazard Quotients exceed 1.0. Hazard Quotients and Hazard Indices less than or equal to 1 indicate no risk. The largest Hazard Index (0.003) for radiological COPCs released to groundwater under Tank Closure Alternative 3C (see Appendix P, Table P–12) is predicted for benthic invertebrates, a factor of 7 smaller than that under Tank Closure Alternative 1. This indicates no risk from radiological COPCs released to groundwater under Tank Closure Alternative 3C.

5.1.3.7 Tank Closure Alternative 4: Existing WTP Vitrification with Supplemental Treatment Technologies; Selective Clean Closure/Landfill Closure

Predicted emissions of COPCs in air under Tank Closure Alternative 4 pose a small probability of adverse impact on ecological receptors at the onsite maximum-exposure location. Hazard Quotients calculated for plants are between 1 and 10 for toluene and mercury under Tank Closure Alternative 4. The chemical COPCs with the largest calculated Hazard Quotients for air releases are xylene for the mammals (mouse Hazard Quotient is 91) and mercury for the soil-dwelling invertebrates, lizards, and birds (side-blotched lizard Hazard Quotient is 157) at the onsite maximum-exposure location (see Table 5–64). There would be no risk from radiological COPCs under Tank Closure Alternative 4. The largest Hazard Index (0.01) for radiological COPCs released to air under Tank Closure Alternative 4 (see Appendix P, Table P–3) is predicted for the mouse at the onsite maximum-exposure location. There also would be no risk to terrestrial, riparian, or aquatic ecological receptors from releases of COPCs to air under Tank Closure Alternative 4 at the offsite maximum-exposure location (Columbia River).

The largest risk index (Hazard Quotient is 22) for groundwater releases under Tank Closure Alternative 4 is that calculated for exposure to chromium for aquatic biota, including salmonids, at the Columbia River, only slightly greater than the Hazard Quotient under Tank Closure Alternative 1 (see Table 5–65). No other Hazard Quotients exceed 1.0. Hazard Quotients and Hazard Indices less than or equal to 1 indicate no risk. The largest Hazard Index (0.0027) for radiological COPCs released to groundwater under Tank Closure Alternative 4 (see Appendix P, Table P–12) is predicted for benthic invertebrates, a factor of 7.5 smaller than that under Tank Closure Alternative 1. This indicates no risk from radiological COPCs released to groundwater under Tank Closure Alternative 4.

5.1.3.8 Tank Closure Alternative 5: Expanded WTP Vitrification with Supplemental Treatment Technologies; Landfill Closure

Predicted emissions of COPCs in air under Tank Closure Alternative 5 pose a small probability of adverse impact on ecological receptors at the onsite maximum-exposure location. Hazard Quotients calculated for plants are between 1 and 10 for toluene and mercury under Tank Closure Alternative 5. The chemical COPCs with the largest calculated Hazard Quotients for air releases are xylene for the

mammals (mouse Hazard Quotient is 149) and mercury for the soil-dwelling invertebrates, lizards, and birds (side-blotched lizard Hazard Quotient is 149) at the onsite maximum-exposure location (see Table 5–64). There would be no risk from radiological COPCs under Tank Closure Alternative 5. The largest Hazard Index (0.0098) for radiological COPCs released to air under Tank Closure Alternative 5 (see Appendix P, Table P–3) is predicted for the mouse at the onsite maximum-exposure location. There also would be no risk to terrestrial, riparian, or aquatic ecological receptors from releases of COPCs to air under Tank Closure Alternative 5 at the offsite maximum-exposure location (Columbia River).

The largest risk index (Hazard Quotient is 22) for groundwater releases under Tank Closure Alternative 5 is that calculated for exposure to chromium for aquatic biota, including salmonids, at the Columbia River, only slightly greater than the Hazard Quotient under Tank Closure Alternative 1 (see Table 5–65). No other Hazard Quotients exceed 1.0. Hazard Quotients and Hazard Indices less than or equal to 1 indicate no risk. The largest Hazard Index (0.003) for radiological COPCs released to groundwater under Tank Closure Alternative 5 (see Appendix P, Table P–12) is predicted for benthic invertebrates, a factor of 7 smaller than that under Tank Closure Alternative 1. This indicates no risk from radiological COPCs released to groundwater under Tank Closure Alternative 5.

5.1.3.9 Tank Closure Alternative 6A: All Vitrification/No Separations; Clean Closure

5.1.3.9.1 Base Case

Predicted emissions of COPCs in air under Tank Closure Alternative 6A, Base Case, pose a small probability of adverse impact on ecological receptors at the onsite maximum-exposure location. Hazard Quotients calculated for plants are between 1 and 10 for toluene and mercury under Tank Closure Alternative 6A, Base Case. The chemical COPCs with the largest calculated Hazard Quotients for air releases are xylene for the mammals (mouse Hazard Quotient is 270) and mercury for the soil-dwelling invertebrates, lizards, and birds (side-blotched lizard Hazard Quotient is 154) at the onsite maximum-exposure location (see Table 5–64). There would be no risk from radiological COPCs under Tank Closure Alternative 6A, Base Case. The largest Hazard Index (0.022) for radiological COPCs released to air under Tank Closure Alternative 6A, Base Case (see Appendix P, Table P–3), is predicted for the mouse at the onsite maximum-exposure location. There also would be no risk to terrestrial, riparian, or aquatic ecological receptors from releases of COPCs to air under Tank Closure Alternative 6A, Base Case, at the offsite maximum-exposure location (Columbia River).

The largest risk index (Hazard Quotient is 22) for groundwater releases under Tank Closure Alternative 6A, Base Case, is that calculated for exposure to chromium for aquatic biota, including salmonids, at the Columbia River, only slightly greater than the Hazard Quotient under Tank Closure Alternative 1 (see Table 5–65). No other Hazard Quotients exceed 1.0. Hazard Quotients and Hazard Indices less than or equal to 1 indicate no risk. The largest Hazard Index (0.0014) for radiological COPCs released to groundwater under Tank Closure Alternative 6A, Base Case (see Appendix P, Table P–12) is predicted for benthic invertebrates, a factor of 15 less than that under Tank Closure Alternative 1. This indicates no risk from radiological COPCs released to groundwater under Tank Closure Alternative 6A, Base Case.

5.1.3.9.2 Option Case

Predicted emissions of COPCs in air under Tank Closure Alternative 6A, Option Case, pose a small probability of adverse impact on ecological receptors at the onsite maximum-exposure location. Hazard Quotients calculated for plants are between 1 and 10 for toluene and mercury under Tank Closure Alternative 6A, Option Case. The chemical COPCs with the largest calculated Hazard Quotients for air releases are xylene for the mammals (mouse Hazard Quotient is 274) and mercury for the soil-dwelling invertebrates, lizards, and birds (side-blotched lizard Hazard Quotient is 153) at the onsite maximum-exposure location (see Table 5–64). There would be no risk from radiological COPCs under

Tank Closure Alternative 6A, Option Case. The largest Hazard Index (0.024) for radiological COPCs released to air under Tank Closure Alternative 6A, Option Case (see Appendix P, Table P–3), is predicted for the mouse at the onsite maximum-exposure location. There also would be no risk to terrestrial, riparian, or aquatic ecological receptors from releases of COPCs to air under Tank Closure Alternative 6A, Option Case, at the offsite maximum-exposure location (Columbia River).

The largest risk index (Hazard Quotient is 21.5) for groundwater releases under Tank Closure Alternative 6A, Option Case, is that calculated for exposure to chromium for aquatic biota, including salmonids, at the Columbia River, only slightly greater than the Hazard Quotient under Tank Closure Alternative 1 (see Table 5–65). No other Hazard Quotients exceed 1.0. Hazard Quotients and Hazard Indices less than or equal to 1 indicate no risk. The largest Hazard Index (0.0003) for radiological COPCs released to groundwater under Tank Closure Alternative 6A, Option Case (see Appendix P, Table P–12) is predicted for the least weasel, a factor of almost 6 less than that under Tank Closure Alternative 1 (Hazard Index is 0.002) and a factor of 65 less than the maximum Hazard Index under Tank Closure Alternative 1. This indicates no risk from radiological COPCs released to groundwater under Tank Closure Alternative 6A, Option Case.

5.1.3.10 Tank Closure Alternative 6B: All Vitrification with Separations; Clean Closure

5.1.3.10.1 Base Case

Predicted emissions of COPCs in air under Tank Closure Alternative 6B, Base Case, pose a small probability of adverse impact on ecological receptors at the onsite maximum-exposure location. Hazard Quotients calculated for plants are between 1 and 10 for toluene and mercury under Tank Closure Alternative 6B, Base Case. The chemical COPCs with the largest calculated Hazard Quotients for air releases are xylene for the mammals (mouse Hazard Quotient is 151) and mercury for the soil-dwelling invertebrates, lizards, and birds (side-blotched lizard Hazard Quotient is 172) at the onsite maximum-exposure location (see Table 5–64). There would be no risk from radiological COPCs under Tank Closure Alternative 6B, Base Case. The largest Hazard Index (0.022) for radiological COPCs released to air under Tank Closure Alternative 6B, Base Case (see Appendix P, Table P–3), is predicted for the mouse at the onsite maximum-exposure location. There also would be no risk to terrestrial, riparian, or aquatic ecological receptors from releases of COPCs to air under Tank Closure Alternative 6B, Base Case, at the offsite maximum-exposure location (Columbia River).

The largest risk index (Hazard Quotient is 22) for groundwater releases under Tank Closure Alternative 6B, Base Case, is that calculated for exposure to chromium for aquatic biota, including salmonids, at the Columbia River, only slightly greater than the Hazard Quotient under Tank Closure Alternative 1 (see Table 5–65). No other Hazard Quotients exceed 1.0. Hazard Quotients and Hazard Indices less than or equal to 1 indicate no risk. The largest Hazard Index (0.0014) for radiological COPCs released to groundwater under Tank Closure Alternative 6B, Base Case (see Appendix P, Table P–12) is predicted for benthic invertebrates, a factor of 15 less than that under Tank Closure Alternative 1. This indicates no risk from radiological COPCs released to groundwater under Tank Closure Alternative 6B, Base Case.

5.1.3.10.2 Option Case

Predicted emissions of COPCs in air under Tank Closure Alternative 6B, Option Case, pose a small probability of adverse impact on ecological receptors at the onsite maximum-exposure location. Hazard Quotients calculated for plants are between 1 and 10 for toluene and mercury under Tank Closure Alternative 6B, Option Case. The chemical COPCs with the largest calculated Hazard Quotients for air releases are xylene for the mammals (mouse Hazard Quotient is 156) and mercury for the soil-dwelling invertebrates, lizards, and birds (side-blotched lizard Hazard Quotient is 171) at the onsite maximum-exposure location (see Table 5–64). There would be no risk from radiological COPCs under

Tank Closure Alternative 6B, Option Case. The largest Hazard Index (0.023) for radiological COPCs released to air under Tank Closure Alternative 6B, Option Case (see Appendix P, Table P–3), is predicted for the mouse at the onsite maximum-exposure location. There also would be no risk to terrestrial, riparian, or aquatic ecological receptors from releases of COPCs to air under Tank Closure Alternative 6B, Option Case, at the offsite maximum-exposure location (Columbia River).

The largest risk index (Hazard Quotient is 22) for groundwater releases under Tank Closure Alternative 6B, Option Case, is that calculated for exposure to chromium for aquatic biota, including salmonids, at the Columbia River, only slightly greater than the Hazard Quotient under Tank Closure Alternative 1 (see Table 5–65). No other Hazard Quotients exceed 1.0. Hazard Quotients and Hazard Indices less than or equal to 1 indicate no risk. The largest Hazard Index (0.0003) for radiological COPCs released to groundwater under Tank Closure Alternative 6B, Option Case (see Appendix P, Table P–12) is predicted for the least weasel, a factor of almost 6 less than under Tank Closure Alternative 1 (Hazard Index is 0.002) and a factor of 65 less than the maximum Hazard Index under Tank Closure Alternative 1. This indicates no risk from radiological COPCs released to groundwater under Tank Closure Alternative 6B, Option Case.

5.1.3.11 Tank Closure Alternative 6C: All Vitrification with Separations; Landfill Closure

Predicted emissions of COPCs in air under Tank Closure Alternative 6C pose a small probability of adverse impact on ecological receptors at the onsite maximum-exposure location. Hazard Quotients calculated for plants are between 1 and 10 for toluene and mercury under Tank Closure Alternative 6C. The chemical COPCs with the largest calculated Hazard Quotients for air releases are xylene for the mammals (mouse Hazard Quotient is 97) and mercury for the soil-dwelling invertebrates, lizards, and birds (side-blotched lizard Hazard Quotient is 171) at the onsite maximum-exposure location (see Table 5–64). There would be no risk from radiological COPCs under Tank Closure Alternative 6C. The largest Hazard Index (0.0091) for radiological COPCs released to air under Tank Closure Alternative 6C (see Appendix P, Table P–3) is predicted for the mouse at the onsite maximum-exposure location. There also would be no risk to terrestrial, riparian, or aquatic ecological receptors from releases of COPCs to air under Tank Closure Alternative 6C at the offsite maximum-exposure location (Columbia River).

The largest risk index (Hazard Quotient is 22) for groundwater releases under Tank Closure Alternative 6C is that calculated for exposure to chromium for aquatic biota, including salmonids, at the Columbia River, only slightly greater than the Hazard Quotient under Tank Closure Alternative 1 (see Table 5–65). No other Hazard Quotients exceed 1.0. Hazard Quotients and Hazard Indices less than or equal to 1 indicate no risk. The largest Hazard Index (0.003) for radiological COPCs released to groundwater under Tank Closure Alternative 6C (see Appendix P, Table P–12) is predicted for benthic invertebrates, a factor of 7 smaller than that under Tank Closure Alternative 1. This indicates no risk from radiological COPCs released to groundwater under Tank Closure Alternative 6C.

5.1.4 Environmental Justice

Sections 5.1.1 and 5.1.2 evaluate groundwater impacts and associated potential long-term human health effects under the Tank Closure alternatives. Receptors analyzed with a potential for environmental justice concerns include a resident farmer, an American Indian resident farmer, and an American Indian hunter-gatherer. The hypothetical resident farmer, which could represent a low-income population, and American Indian resident farmer were both assumed to use only groundwater for drinking water ingestion and crop irrigation. While only a portion of the food consumed by the resident farmer was assumed to come from crops and animal products exposed to contaminated groundwater, all of the food consumed by the American Indian resident farmer was assumed to be exposed to contaminated groundwater. The American Indian hunter-gatherer was assumed to have a subsistence consumption pattern that differs

from that of the American Indian resident farmer. The American Indian hunter-gatherer does not cultivate crops but gathers food from indigenous plants, harvests fish from the Columbia River, and is exposed to a combination of surface water and groundwater. Given these assumptions, the two American Indian receptors would be most at risk from contaminated groundwater. These receptors were used to develop exposure scenarios at several on- and offsite locations identified in Appendix Q, Section Q.2.1. Long-term human health impacts of tank closure actions would be greatest under Tank Closure Alternative 1. Radiological releases under this alternative would result in the doses at the A and B Barriers and the Core Zone Boundary exceeding regulatory limits for the resident farmer, American Indian resident farmer, and American Indian hunter-gatherer; the dose at the S Barrier would exceed regulatory limits for the American Indian resident farmer and American Indian hunter-gatherer; at the T Barrier, for the American Indian hunter-gatherer. None of the hypothetical receptors at the Columbia River nearshore or surface-water locations would be exposed to a dose in excess of regulatory limits. Nonradiological releases under this alternative would result in exceedance of the Hazard Index for chromium and nitrate at all onsite locations analyzed for the resident farmer, American Indian resident farmer, and American Indian hunter-gatherer. The analysis determined that the greatest impact of any alternative on long-term human health could result in radiological doses in excess of regulatory limits and chemical exposures with a Hazard Index greater than 1 for receptors located on site at the A, B, S, T, or U Barriers, Core Zone Boundary, or Columbia River nearshore. There are no such onsite receptors currently at Hanford. The onsite exposure scenarios do not currently exist and have never existed during Hanford operations. Therefore, the estimated high health risks for past years are hypothetical risks only; no persons were ever exposed at these levels. While it is possible for these receptor scenarios to develop in the future, none are expected for the foreseeable future because the Core Zone is designated for Industrial-Exclusive land use, the Columbia River nearshore is designated for Preservation (Hanford Reach National Monument), and the area between them is designated for Conservation (Mining) (DOE 1999). It is unlikely, therefore, that any of the Tank Closure alternatives would pose a disproportionately high and adverse long-term human health risk to the offsite American Indian population. The greatest risk would be to the American Indian resident farmer at the Core Zone Boundary. During the year of peak dose, this receptor would receive a radiological dose of 3.4 rem. During the year of peak Hazard Index, this receptor would be exposed to chemicals resulting in a Hazard Index greater than 1. The adverse impacts would also be applicable to non–American Indian receptors at the same locations, but to a lesser extent.

5.2 FFTF DECOMMISSIONING ALTERNATIVES

This section describes the potential long-term environmental and human health impacts associated with the implementation of alternatives considered to decommission the Fast Flux Test Facility (FFTF) and auxiliary facilities at Hanford; manage waste from the decommissioning process, including waste designated as remote-handled special components (RH-SCs); and disposition the Hanford inventory of radioactively contaminated bulk sodium from FFTF, as well as other facilities on site. Three FFTF Decommissioning alternatives are considered and analyzed: (1) FFTF Decommissioning Alternative 1, No Action, in which only certain deactivation activities at FFTF would be conducted, consistent with previous DOE National Environmental Policy Act actions and two action alternatives; (2) FFTF Decommissioning Alternative 2, Entombment; and (3) FFTF Decommissioning Alternative 3, Removal. FFTF Decommissioning Alternative 2 would involve removing all aboveground structures within the 400 Area Property Protected Area (PPA), with minimal removal of below-grade structures, equipment, and materials as necessary to comply with regulatory standards. The FFTF reactor vessel and other equipment below grade would remain. FFTF Decommissioning Alternative 3 would consist of removing all above-grade structures within the 400 Area PPA and the additional removal of contaminated below-grade structures, including the FFTF reactor vessel, equipment, and materials. Associated construction, operations, deactivation, closure, and decommissioning activities are assessed, as applicable, for each alternative.

For each action alternative (i.e., FFTF Decommissioning Alternatives 2 and 3), two options (Hanford and Idaho Options) are evaluated for disposition of RH-SCs and two (Hanford Reuse and Idaho Reuse Options) for disposition of bulk sodium. For RH-SCs, the Hanford Option would involve treating the waste in a new, onsite treatment facility, followed by disposal of the treated components and residuals along with other Hanford waste in the 200 Areas. Under the Idaho Option, RH-SCs would be shipped to the proposed Remote Treatment Project (RTP) at the Idaho National Laboratory (INL) Materials and Fuels Complex (MFC). Following treatment at the RTP, the FFTF components and residuals would be disposed of with other INL waste at an offsite facility or returned to Hanford for disposal. For disposition of bulk sodium under the Hanford Reuse Option, the bulk sodium would be stored in its current locations until it is shipped to a new onsite facility for processing. The caustic would then be transferred to the WTP for reuse. Under the Idaho Reuse Option, the bulk sodium would be stored in its current locations until it is shipped to the INL MFC for processing in the existing Sodium Processing Facility (SPF). Following processing, the caustic would be returned to Hanford for use in the WTP. These alternatives and options are described further in Chapter 2, Section 2.5.

5.2.1 Groundwater

The focus is on the impacts of FFTF disposition (sodium processing and remote-handled treatment should not have a groundwater impact); the waste removed from FFTF or resulting from removal will be discussed under the Waste Management alternatives.

5.2.1.1 FFTF Decommissioning Alternative 1: No Action

This section describes the groundwater analysis results for FFTF Decommissioning Alternative 1: No Action, including long-term groundwater impacts of contaminant sources within the FFTF Barrier (for analysis purposes, the FFTF Barrier is represented by a rectangle surrounding FFTF). Impacts of sources removed from within the FFTF Barrier and disposed of in an IDF are presented in Section 5.3, which discusses waste management impacts.

5.2.1.1.1 Actions and Timeframes Influencing Groundwater Impacts

Under FFTF Decommissioning Alternative 1, after a period of administrative control, no further actions would be taken to remove radionuclides or chemicals from within the FFTF Barrier. Summaries of the proposed actions and timelines for this alternative are provided in Chapter 2, Section 2.5. For the long-term groundwater impact analysis, two major periods were identified for FFTF Decommissioning Alternative 1, as follows:

- The administrative control period was assumed to start in 2008 and end in CY 2107 (100-year duration). It was assumed that during this administrative control period, corrective action or emergency response measures would preclude releases of contaminants from FFTF to the environment.

- The post–administrative control period was assumed to start in CY 2108 and continue through the 10,000-year period of analysis until CY 11,940. During this post–administrative control period, all remaining constituents at FFTF would be available for release to the environment.

5.2.1.1.2 COPC Drivers

A total of 40 COPCs were analyzed for FFTF Decommissioning Alternative 1. Complete results for all 40 COPCs are provided in Appendices M, N, and O. The discussion in this section of long-term impacts associated with FFTF Decommissioning Alternative 1 is focused on the following COPC drivers:

- Radiological risk drivers: tritium and technetium-99
- Chemical risk drivers: none
- Chemical hazard drivers: none

The COPC drivers for FFTF Decommissioning Alternative 1 were selected by evaluating the risk or hazard associated with all 40 COPCs during the year of peak risk or hazard at the FFTF Barrier during the 10,000-year period of analysis and selecting the major contributors. This process is described in Appendix Q. The radiological risk drivers account for essentially all of the radiological risk. The peak chemical hazard to a drinking-water well user at the FFTF Barrier is essentially negligible.

The COPC drivers that are discussed in detail in this section fall into two categories. Technetium-99 is mobile (i.e., moves with groundwater) and long-lived (relative to the 10,000-year period of analysis). It is essentially a conservative tracer. Tritium is also mobile, but short-lived. The half-life of tritium is about 13 years, and tritium concentrations are strongly attenuated by radioactive decay during travel through the vadose zone and groundwater systems. The other COPCs that were analyzed do not significantly contribute to drinking water risk or hazard at the FFTF Barrier during the period of analysis because of low inventories, low release rates, high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of these factors.

5.2.1.1.3 Analysis of Release and Mass Balance

This section presents the impacts of FFTF Decommissioning Alternative 1 in terms of total amount of radiological COPCs released to the vadose zone, groundwater, and the Columbia River during the 10,000-year period of analysis. Releases of radionuclides are totaled in curies (see Figures 5–332 through 5–334). Note that the release amounts are plotted on a logarithmic scale to facilitate visual comparison of releases that vary over four orders of magnitude.

Figure 5–332 shows the estimated release to the vadose zone for the radiological risk drivers. The total release to the vadose zone is controlled only by the inventory (i.e., 100 percent of the inventory was released during the period of analysis). About 2 curies of tritium and about 27 curies of technetium-99 were released to the vadose zone in the analysis. Figure 5–333 shows the release to groundwater for the radiological risk drivers. In addition to the inventory considerations, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. For technetium-99, the amount released to groundwater is essentially equal to the amount released to the vadose zone. For tritium, the amount released to groundwater is strongly attenuated by radioactive decay. Less than 1 percent of the tritium that was released in the analysis into the vadose zone reached the groundwater. Figure 5–334 shows the release to the Columbia River for the radiological risk drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers. For technetium-99, the amount released to the Columbia River is essentially equal to the amount released to groundwater. For tritium, the amount released to the Columbia River is strongly attenuated by radioactive decay. Overall, only about 6 percent of the tritium released to groundwater reaches the Columbia River in the analysis.

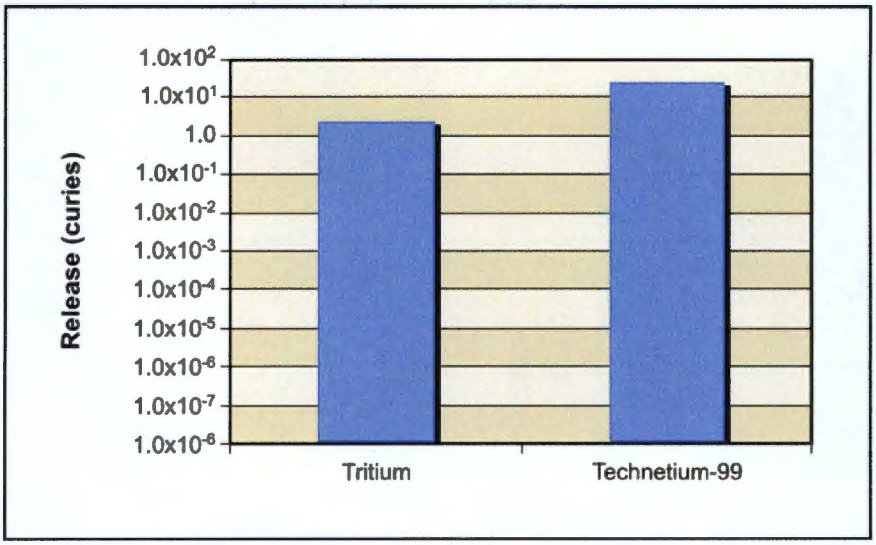


Figure 5–332. FFTF Decommissioning Alternative 1 Releases of Radiological Constituent of Potential Concern to Vadose Zone from Sources Inside the Fast Flux Test Facility Barrier

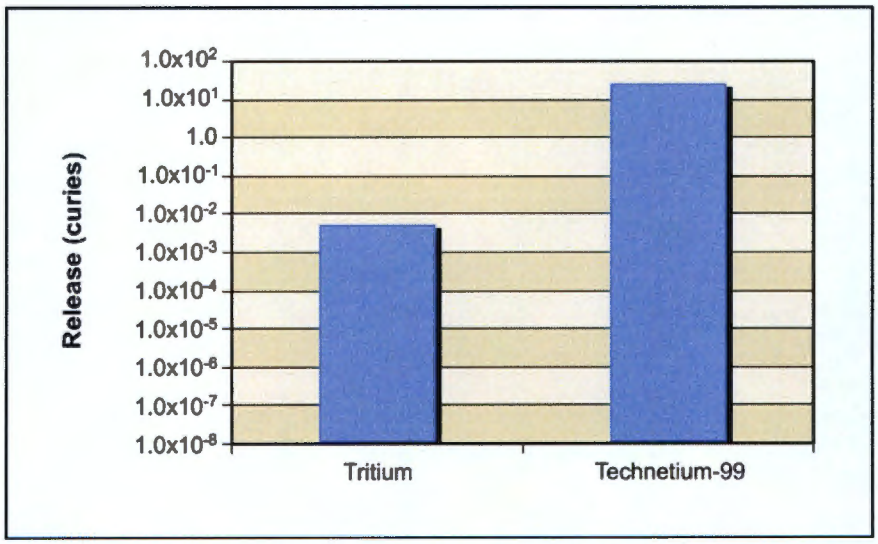


Figure 5–333. FFTF Decommissioning Alternative 1 Releases of Radiological Constituent of Potential Concern to Groundwater from Sources Inside the Fast Flux Test Facility Barrier

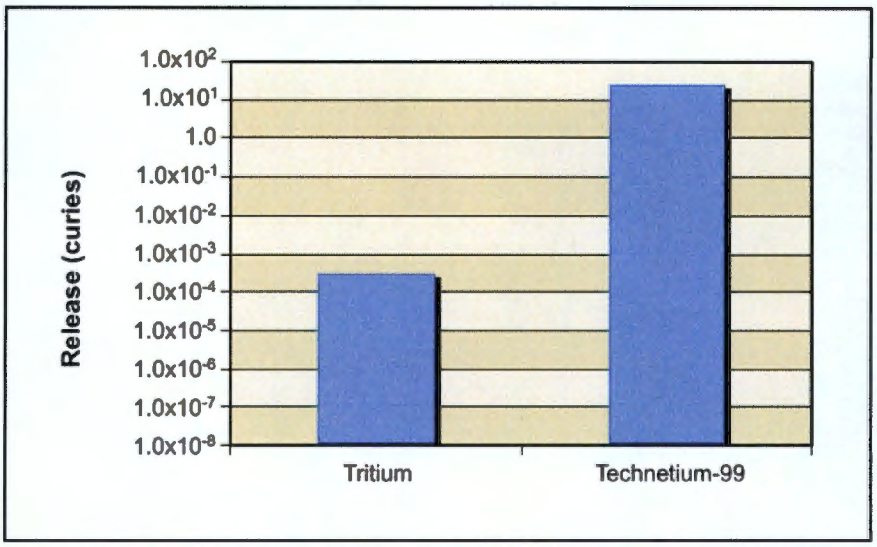


Figure 5–334. FFTF Decommissioning Alternative 1 Releases of Radiological Constituent of Potential Concern to Columbia River from Sources Inside the Fast Flux Test Facility Barrier

5.2.1.1.4 Analysis of Concentration Versus Time

This section presents the analysis of FFTF Decommissioning Alternative 1 impacts in terms of groundwater concentration versus time at the FFTF Barrier and the Columbia River nearshore. Concentrations of radionuclides are in picocuries per liter (see Figures 5–335 and 5–336). The benchmark concentration for each radionuclide is also shown (900 and 20,000 picocuries per liter for technetium-99 and tritium, respectively). Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over two orders of magnitude.

Figure 5–335 shows concentration versus time for technetium-99. The concentration of technetium-99 at the FFTF Barrier peaks at about 40 percent of the benchmark around CY 2550. During this time, groundwater concentrations at the Columbia River nearshore peak at about two orders of magnitude below the benchmark concentration. Technetium-99 is essentially not a factor at times later than CY 5800.

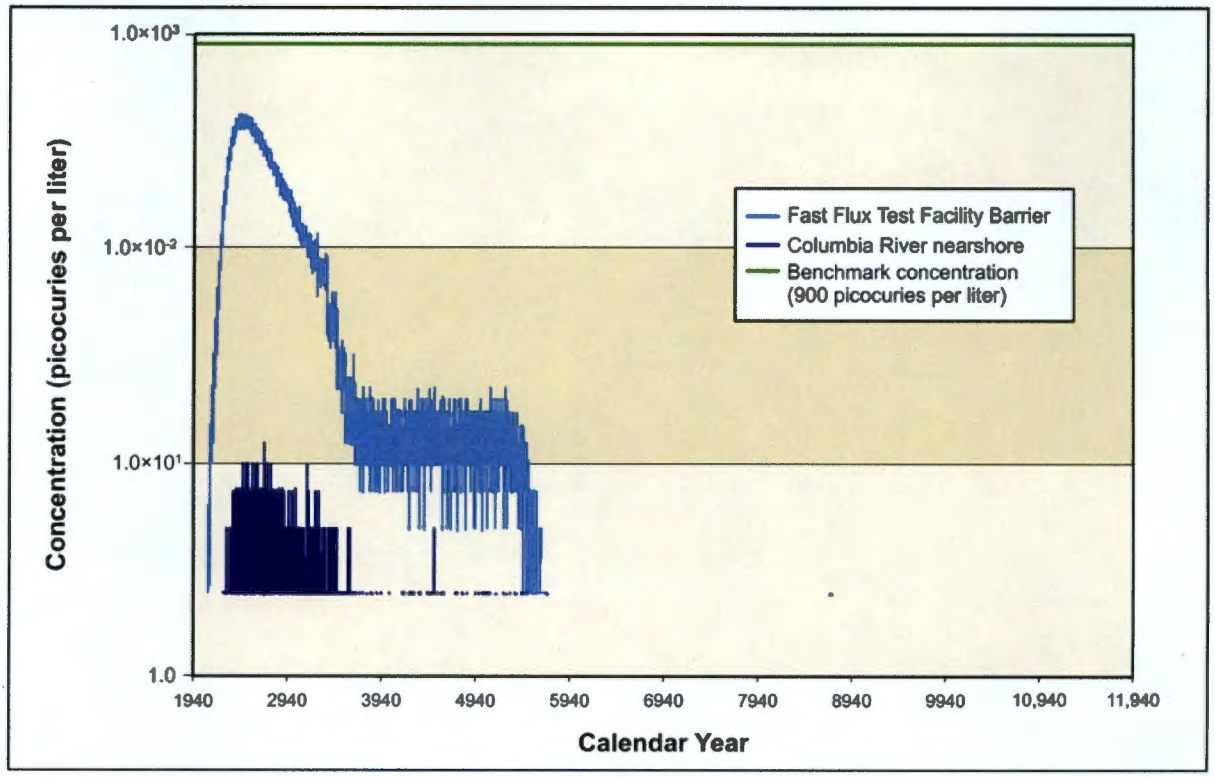


Figure 5–335. FFTF Decommissioning Alternative 1 Technetium-99 Concentration Versus Time

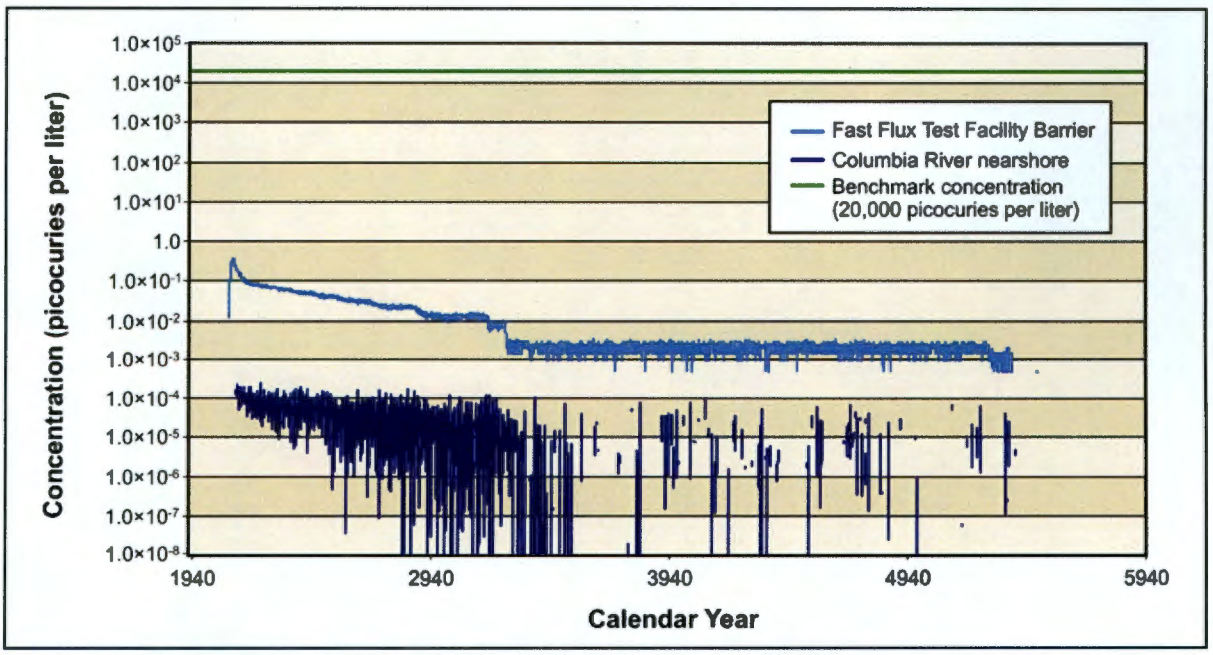


Figure 5–336. FFTF Decommissioning Alternative 1 Hydrogen-3 (Tritium) Concentration Versus Time

Figure 5–336 shows concentration versus time for tritium. Because the half-life of tritium is less than 13 years, radioactive decay rapidly attenuates groundwater concentration. Releases from FFTF did not cause groundwater concentrations to exceed the benchmark throughout the period of analysis. The concentrations at the FFTF Barrier peak at about five orders of magnitude below the benchmark. During this time, groundwater concentrations at the Columbia River nearshore peak at about eight orders of magnitude below the benchmark. Table 5–66 lists the estimated maximum concentrations of tritium and technetium-99 in the peak year at the FFTF Barrier and the Columbia River nearshore.

Table 5–66. FFTF Decommissioning Alternative 1 Maximum COPC Concentrations in the Peak Year at the FFTF Barrier and Columbia River Nearshore

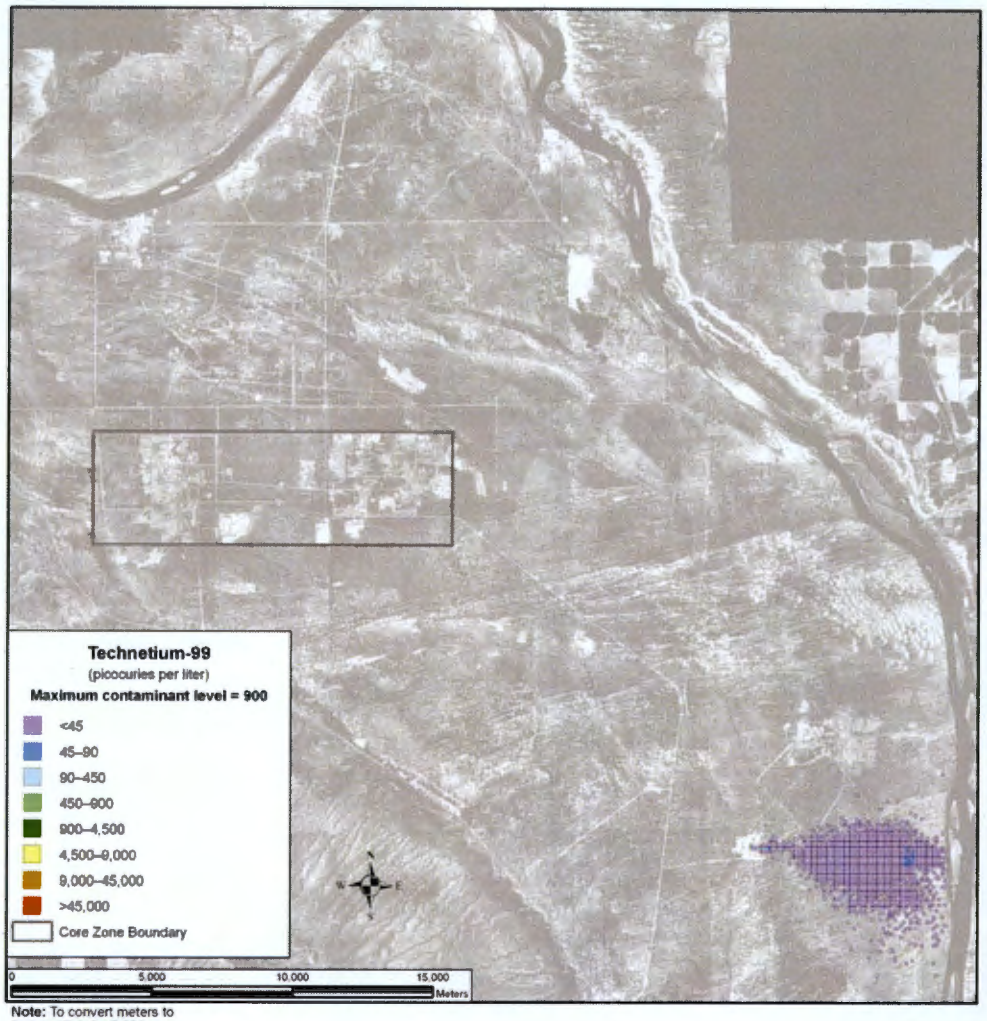
Contaminant	FFTF Barrier	Columbia River Nearshore	Benchmark Concentration
Radionuclide in picocuries per liter			
Hydrogen-3 (tritium)	0.36	0.00024	20,000
	(2122)	(2243)	
Technetium-99	416	12	900
	(2425)	(2702)	

Note: Corresponding calendar years shown in parentheses.
Key: COPC=constituent of potential concern; FFTF=Fast Flux Test Facility.

5.2.1.1.5 Analysis of Spatial Distribution of Concentration

This section presents the impacts of FFTF Decommissioning Alternative 1 in terms of the spatial distribution of groundwater concentration at selected times. Concentrations of radionuclides are in picocuries per liter (see Figures 5–337 and 5–338). Concentrations for each radionuclide are indicated by a color scale that is relative to the benchmark concentration (900 and 20,000 picocuries per liter for technetium-99 and tritium, respectively). Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations less than the benchmark concentration are indicated by the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude.

Figure 5–337 shows the spatial distribution of groundwater concentration for technetium-99 during CY 2590, roughly the time of greatest development of the groundwater plume. Analysis releases from FFTF result in a groundwater concentration plume that extends easterly from the facility to the Columbia River nearshore. Peak concentrations in this plume are less than a tenth of the benchmark during CY 2590.



Note: To convert meters to feet, multiply by 3.281

Figure 5–337. FFTF Decommissioning Alternatives 1 and 2 Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2590

Figure 5–338 shows the spatial distribution of groundwater concentration for tritium during CY 2135. Analysis releases from FFTF result in a groundwater concentration plume that extends from the facility easterly to the Columbia River nearshore. Peak concentrations in this plume are about 20 times less than the benchmark.

Note: To convert meters to feet, multiply by 3.281

Figure 5–338. FFTF Decommissioning Alternative 1 Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2135

5.2.1.1.6 Summary of Impacts

Under FFTF Decommissioning Alternative 1, technetium-99 and tritium are the COPC drivers in the analysis. Neither COPC exceeds benchmark standards at the FFTF Barrier or the Columbia River nearshore during the 10,000-year period of analysis. Tritium concentrations are strongly attenuated by radioactive decay, and the impacts are dominated by technetium-99. The impacts are greatest around CY 2500.

5.2.1.2 FFTF Decommissioning Alternative 2: Entombment

This section describes the groundwater analysis results for FFTF Decommissioning Alternative 2, Entombment, including long-term groundwater impacts of contaminant sources within the FFTF Barrier. Impacts of sources removed from within the FFTF Barrier and disposed of in an IDF are presented in Section 5.3, which discusses waste management impacts.

5.2.1.2.1 Actions and Timeframes Influencing Groundwater Impacts

Under FFTF Decommissioning Alternative 2, all aboveground structures and minimal below-grade structures, equipment, and materials would be removed. An RCRA-compliant barrier would be constructed over the Reactor Containment Building and any other remaining below-grade structures (including the reactor vessel). Summaries of the proposed actions and timelines for this alternative are provided in Chapter 2, Section 2.5. For the long-term groundwater impact analysis, two major periods were identified for FFTF Decommissioning Alternative 2, as follows:

- The entombment period was assumed to start in CY 2013 when decommissioning activities begin and to end in CY 2121, following the completion of decommissioning and entombment activities and a 100-year postclosure period. It was assumed that during this entombment period, there would be no releases from FFTF.

- The post-entombment period was assumed to start in CY 2122 and continue through the 10,000-year period of analysis until CY 11,940. During this post-entombment period, all remaining constituents at FFTF would be available for release to the environment.

5.2.1.2.2 COPC Drivers

A total of 40 COPCs were analyzed for FFTF Decommissioning Alternative 2. Complete results for all 40 COPCs are provided in Appendices M, N, and O. The discussion in this section of long-term impacts associated with FFTF Decommissioning Alternative 2 is focused on the following COPC drivers:

- Radiological risk drivers: technetium-99
- Chemical risk drivers: none
- Chemical hazard drivers: none

The COPC drivers for FFTF Decommissioning Alternative 2 were selected by evaluating the risk or hazard associated with all 40 COPCs during the year of peak risk or hazard at the FFTF Barrier during the 10,000-year period of analysis and selecting the major contributors. This process is described in Appendix Q. The radiological risk drivers account for essentially all of the radiological risk. The peak chemical hazard to a drinking-water well user at the FFTF Barrier is essentially negligible.

The COPC driver that is discussed in detail in this section is technetium-99. Technetium-99 is mobile (i.e., moves with groundwater) and long-lived (relative to the 10,000-year period of analysis). It is essentially a conservative tracer. The other COPCs that were analyzed do not significantly contribute to drinking water risk or hazard at the FFTF Barrier during the period of analysis because of low inventories, low release rates, high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of these factors.

5.2.1.2.3 Analysis of Release and Mass Balance

This section presents the impacts of FFTF Decommissioning Alternative 2 in terms of total amount of radiological COPCs released to the vadose zone, groundwater, and the Columbia River during the 10,000-year period of analysis. Releases of radionuclides are totaled in curies (see Figures 5–339 through 5–341). Note that the release amounts are plotted on a logarithmic scale to facilitate visual comparison of releases that vary over seven orders of magnitude.

Figure 5–339 shows the estimated release to the vadose zone for technetium-99, about 27 curies. Figure 5–340 shows the release to groundwater, which is essentially the same as that released to the vadose zone. This is due to technetium-99's lack of retardation and long half-life. Figure 5–341 shows the release to the Columbia River for technetium-99, which also is about 27 curies.

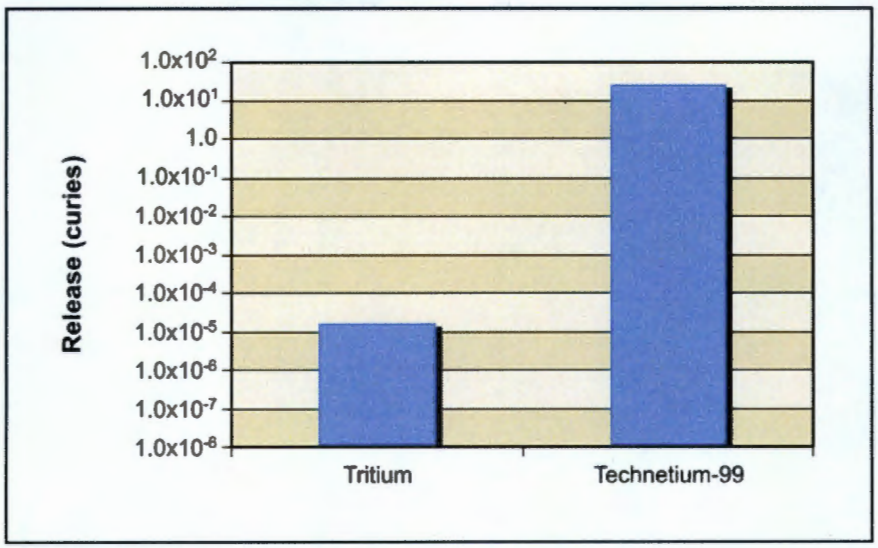


Figure 5–339. FFTF Decommissioning Alternative 2 Releases of Radiological Constituent of Potential Concern to Vadose Zone from Sources Inside the Fast Flux Test Facility Barrier

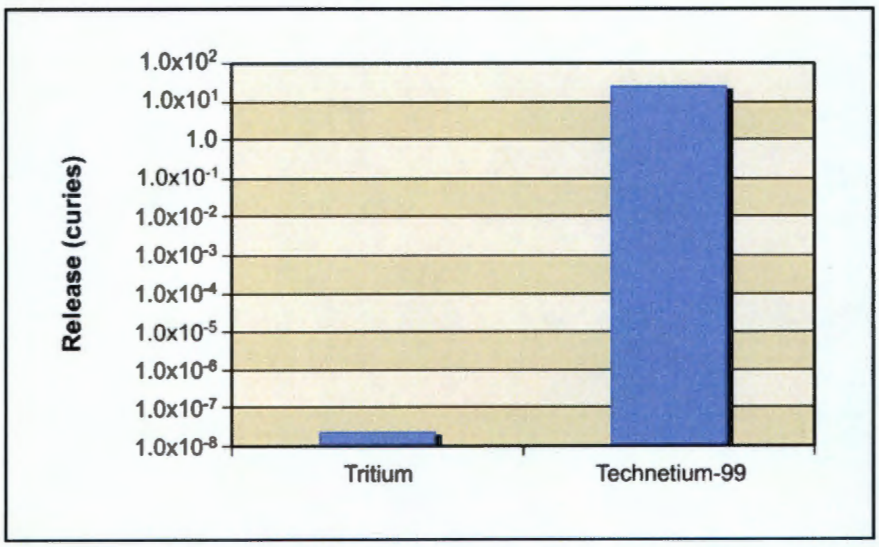


Figure 5–340. FFTF Decommissioning Alternative 2 Releases of Radiological Constituent of Potential Concern to Groundwater from Sources Inside the Fast Flux Test Facility Barrier

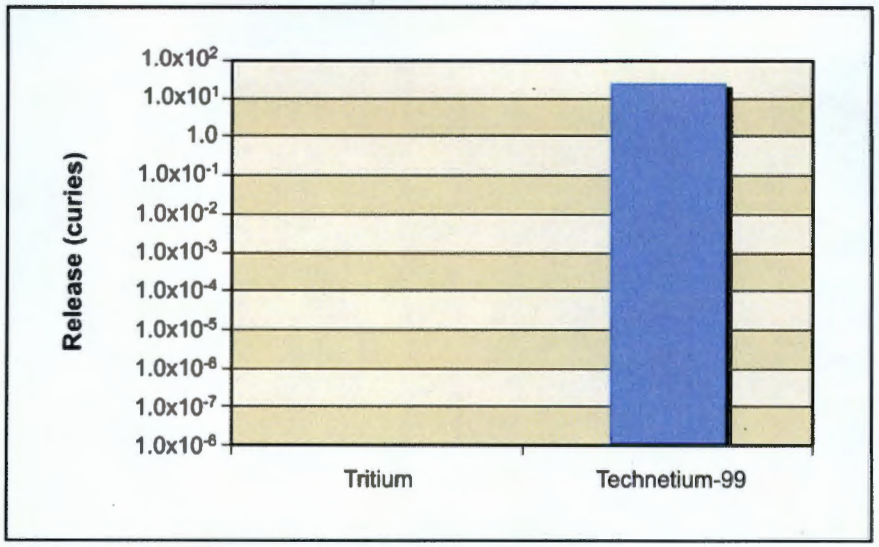


Figure 5–341. FFTF Decommissioning Alternative 2 Releases of Radiological Constituent of Potential Concern to Columbia River from Sources Inside the Fast Flux Test Facility Barrier

5.2.1.2.4 Analysis of Concentration Versus Time

This section presents the impacts of FFTF Decommissioning Alternative 2 in terms of groundwater concentration versus time at the FFTF Barrier and the Columbia River nearshore. Concentrations of radionuclides are in picocuries per liter (see Figure 5–342). The benchmark concentration for technetium-99 is also shown (900 picocuries per liter). Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over two to three orders of magnitude.

Figure 5–342 shows concentration versus time for technetium-99. The concentration of technetium-99 at the FFTF Barrier peaks at about 40 percent of the benchmark around CY 2550. During this time, groundwater concentrations at the Columbia River nearshore peak at about two orders of magnitude below the benchmark concentration. Technetium-99 is essentially not a factor at times later than CY 5800. Table 5–67 lists the estimated maximum concentrations of technetium-99 in the peak year at the FFTF Barrier and the Columbia River nearshore.

Table 5–67. FFTF Decommissioning Alternative 2 Maximum COPC Concentrations in the Peak Year at the FFTF Barrier and Columbia River Nearshore

Contaminant	FFTF Barrier	Columbia River Nearshore	Benchmark Concentration
Radionuclide in picocuries per liter			
Hydrogen-3 (tritium)	0	0	20,000
	N/A	N/A	
Technetium-99	407	12	900
	(2819)	(2965)	

Note: Corresponding calendar years shown in parentheses.
Key: COPC=constituent of potential concern; FFTF=Fast Flux Test Facility; N/A=not applicable.

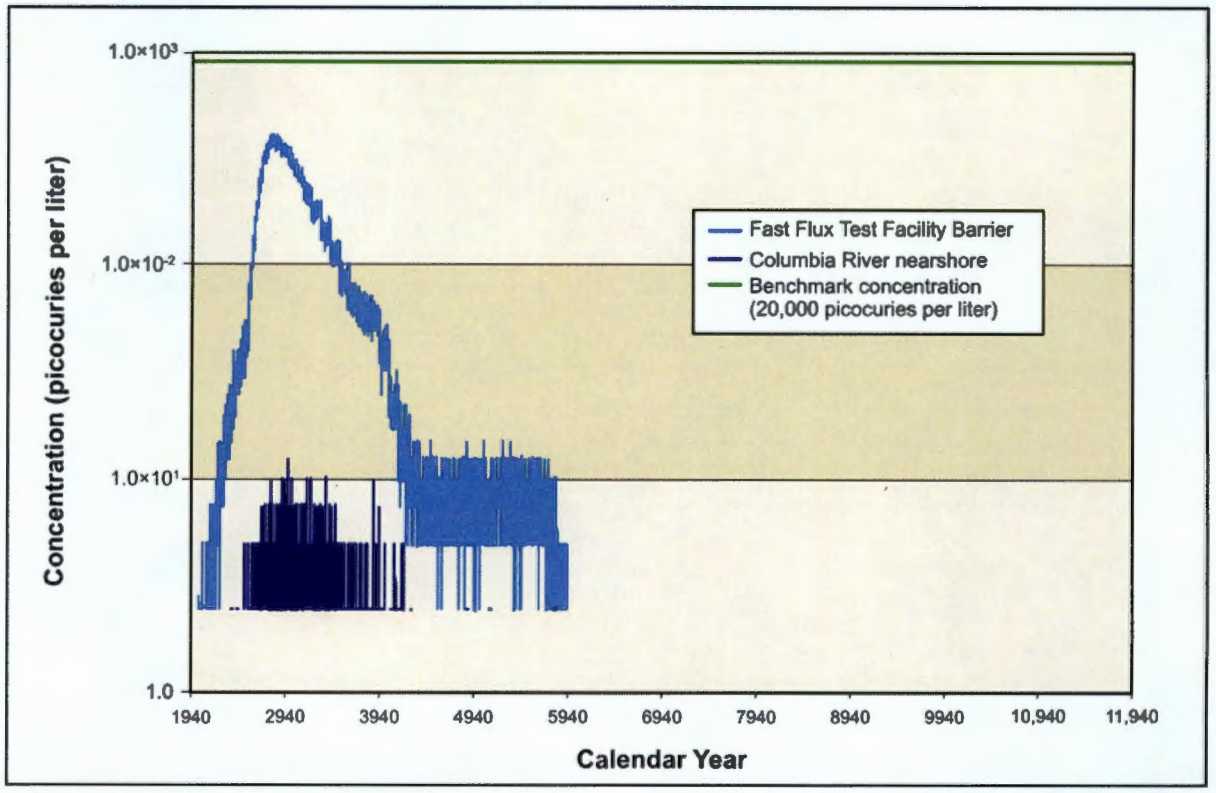


Figure 5–342. FFTF Decommissioning Alternative 2 Technetium-99 Concentration Versus Time

5.2.1.2.5 Analysis of Spatial Distribution of Concentration

This section presents the impacts of FFTF Decommissioning Alternative 2 in terms of the spatial distribution of groundwater concentration at selected times. Concentrations of radionuclides are in picocuries per liter (see Figure 5–337). Concentrations of technetium-99 are indicated by a color scale that is relative to the benchmark concentration (900 picocuries per liter). Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations less than the benchmark concentration are indicated by the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude.

The results of the analyses of release and mass balance and of concentration versus time show that the plume development for technetium-99 is identical under FFTF Decommissioning Alternatives 1 and 2. Figure 5–337 shows the spatial distribution of the technetium plume during CY 2590, roughly the time of greatest development of the groundwater plume. Analysis releases from FFTF result in a groundwater concentration plume that extends easterly from the facility to the Columbia River nearshore. Peak concentrations in this plume are less than a tenth of the benchmark during CY 2590.

5.2.1.2.6 Summary of Impacts

Under FFTF Decommissioning Alternative 2, technetium-99 is the COPC driver in the analysis. Groundwater impacts of technetium-99 are similar to those under FFTF Decommissioning Alternative 1. Technetium-99 concentrations do not exceed benchmark standards at the FFTF Barrier or the Columbia River nearshore during the 10,000-year period of analysis. The impacts are greatest around CY 2500.

5.2.1.3 FFTF Decommissioning Alternative 3: Removal

This section describes the groundwater analysis results for FFTF Decommissioning Alternative 3, Removal, including long-term groundwater impacts of contaminant sources within the FFTF Barrier. Impacts of sources removed from within the FFTF Barrier and disposed of in an IDF are presented in Section 5.3, which discusses waste management impacts.

5.2.1.3.1 Actions and Timeframes Influencing Groundwater Impacts

Under FFTF Decommissioning Alternative 3, all above-grade structures within the 400 Area PPA would be removed; additionally, contaminated below-grade structures, equipment, and materials would be removed. Summaries of the proposed actions and timelines for this alternative are provided in Chapter 2, Section 2.5. For the long-term groundwater impact analysis, two major periods were identified for FFTF Decommissioning Alternative 3, as follows:

- The removal period was assumed to start in CY 2013 when decommissioning activities begin and to end in CY 2121, following the completion of decommissioning and removal activities and a 100-year postclosure period. It was assumed that during this removal period, there would be no releases from FFTF.

- The post-removal period was assumed to start in CY 2122 and continue through the 10,000-year period of analysis until CY 11,940. During this post-removal period, all remaining constituents at FFTF would be available for release to the environment.

5.2.1.3.2 COPC Drivers

A total of 40 COPCs were analyzed for FFTF Decommissioning Alternative 3. These COPCs become available for release to the environment at the end of the post-removal period in 2121. The total amount of each COPC released to the aquifer is limited first by the inventory remaining after removal. The removal activities limit the residual inventories to a much greater extent under FFTF Decommissioning Alternative 3 than under FFTF Decommissioning Alternatives 1 and 2. The maximum residual inventory calculated under FFTF Decommissioning Alternative 3 is for carbon-14, which is approximately 4×10^{-4} curies. The second factor that limits release to the aquifer is attenuation by retardation and/or radioactive decay. Accounting for both factors, the calculated maximum total release to the aquifer of all COPCs is for technetium-99, which is 4×10^{-6} curies. For all COPCs, the calculated peak rate of release to the aquifer is less than 10^{-8} curies per year, the threshold for evaluating long-term groundwater impacts (see Appendix O). Thus, the analysis predicts no long-term groundwater impacts associated with FFTF Decommissioning Alternative 3 above *de minimis* values.

5.2.2 Human Health Impacts

Potential human health impacts due to release of radionuclides are estimated as dose and as lifetime risk of incidence of cancer. For long-term performance assessment, radiological dose and risk are estimated consistent with the recommendations of *Cancer Risk Coefficients for Environmental Exposure to Radionuclides*, Federal Guidance Report No. 13 (Eckerman et al. 1999), including use of radionuclide-specific dose factors and risk coefficients. Potential human health effects due to release of chemical constituents include both carcinogenic effects and other forms of toxicity. Impacts of carcinogenic chemicals are estimated as lifetime risk of incidence of cancer. Noncarcinogenic effects were estimated as a Hazard Quotient, the ratio of the long-term intake of a single chemical to intake that produces no observable effect, and as a Hazard Index, the sum of the Hazard Quotients of a group of chemicals. Further information on the nature of human health effects in response to exposure to radiological and chemical constituents is provided in Appendix K. Screening analysis identified 14 radionuclide and 26 chemical constituents as contributing the greatest risk of adverse impacts. Appendix Q provides more

information on the screening analysis, including time of occurrence of peak impacts and constituent- and location-specific impacts under each Tank Closure, FFTF Decommissioning, and Waste Management alternative.

Four measures of human health impacts were considered in this analysis: lifetime risks of developing cancer from both radiological and chemical constituents, dose from radiological constituents, and Hazard Index from chemical constituents. These measures were calculated for each year for 10,000 years for each receptor at three locations: the FFTF Barrier, Columbia River nearshore, and surface water of the Columbia River. This large amount of information must be summarized to allow an interpretation of results. The method chosen was to present the dose for the year of maximum dose, the risk for the year of maximum risk, and the Hazard Index for the year of maximum Hazard Index. This choice was based on regulation of radiological impacts as dose and observations from the analysis results that (1) risk due to exposure to chemical constituents would be small relative to risk due to exposure to radiological constituents and (2) peak noncarcinogenic impacts expressed as a Hazard Index may occur at times other than that of peak dose.

Impacts on human health over the long period following decommissioning of the FFTF would be due primarily to the materials left in place following no action, entombment, or removal. Onsite analysis locations included the FFTF boundary and the Columbia River nearshore. Offsite analysis locations included access points to Columbia River surface water near the site and at population centers downstream of the site. Estimates of constituent concentrations in Columbia River surface water were used to calculate the impacts for both offsite location points of analysis. The total offsite population is 5 million people. Four types of receptor were considered. The first type, a drinking-water well user, uses groundwater as a source of drinking water. The second type, a resident farmer, uses groundwater for drinking-water consumption and irrigation of crops. Garden size and crop yield were assumed to be adequate to produce approximately 25 percent of average requirements for crops and animal products. The third type, an American Indian resident farmer, also uses groundwater for drinking-water consumption and irrigation of crops. Garden size and crop yield were assumed to be adequate to produce the entirety of average requirements for crops and animal products. The fourth type, an American Indian hunter-gatherer, uses both groundwater and surface water because surface water is used for drinking-water consumption and both wild plant materials, which use groundwater, and game, which use surface water, are consumed.

The significance of the dose impacts was evaluated by comparison with the 100-millirem-per-year all-exposure modes standard specified for protection of the public and the environment in DOE Order 5400.5, *Radiation Protection of the Public and the Environment.* The level of protection provided for the drinking-water pathway was evaluated by comparison with the applicable drinking-water standards presented in Section 5.2.1. The population doses were compared with the total effective dose equivalent from background sources of 365 millirem per year for a member of the population of the United States (NCRP 1987). The significance of noncarcinogenic chemical impacts was evaluated by comparison with a guideline value of unity for Hazard Index.

5.2.2.1 FFTF Decommissioning Alternative 1: No Action

This section contains the results for FFTF Decommissioning Alternative 1, No Action. The section includes analysis of long-term human health impacts from sources within the FFTF Barrier. Impacts from sources removed from the FFTF Barrier and disposed of in an IDF are discussed in Section 5.3, which deals with waste management issues.

Under FFTF Decommissioning Alternative 1, only those actions consistent with previous DOE National Environmental Policy Act actions would be completed. Final decommissioning of FFTF would not occur. For analysis purposes, the remaining waste would be available for release to the environment after an institutional control period of 100 years.

The potential human health impacts of this alternative are summarized in Tables 5–68 and 5–69 and are detailed in Appendix Q. The key constituent contributors to human health risk would be tritium and technetium-99 for radionuclides. The chemical risk and hazard drivers were essentially negligible. Neither the dose standards nor the Hazard Index guideline would be exceeded at any location. The population dose was estimated as 9.80×10^{-3} person-rem per year for the year of peak dose. This corresponds to 5.27×10^{-7} percent of the annual population dose due to background exposure. The time series of radiological risk for the drinking-water well user at the FFTF Barrier is presented in Figure 5–343.

Table 5–68. FFTF Decommissioning Alternative 1 Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts Summary

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
Fast Flux Test Facility	7.29×10^{-1}	3.19×10^{-6}	2.51×10^{-5}	0.00	2.51×10^{-5}	1.87	3.22×10^{-6}	8.23×10^{-5}	3.48×10^{-16}	8.23×10^{-5}
Columbia River nearshore	2.16×10^{-2}	1.01×10^{-7}	7.42×10^{-7}	0.00	7.42×10^{-7}	5.54×10^{-2}	1.02×10^{-7}	2.43×10^{-6}	1.02×10^{-17}	2.43×10^{-6}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	1.96×10^{-6}	8.56×10^{-13}	8.60×10^{-11}	3.49×10^{-22}	8.60×10^{-11}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–69. FFTF Decommissioning Alternative 1 American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts Summary

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
Fast Flux Test Facility	3.82	3.33×10^{-6}	1.79×10^{-4}	1.60×10^{-11}	1.79×10^{-4}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.13×10^{-1}	1.06×10^{-7}	5.31×10^{-6}	4.67×10^{-13}	5.31×10^{-6}	1.36×10^{-4}	5.74×10^{-9}	7.43×10^{-9}	2.34×10^{-13}	7.43×10^{-9}
Off Site										
Columbia River	4.53×10^{-6}	1.37×10^{-12}	2.14×10^{-10}	1.60×10^{-17}	2.14×10^{-10}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

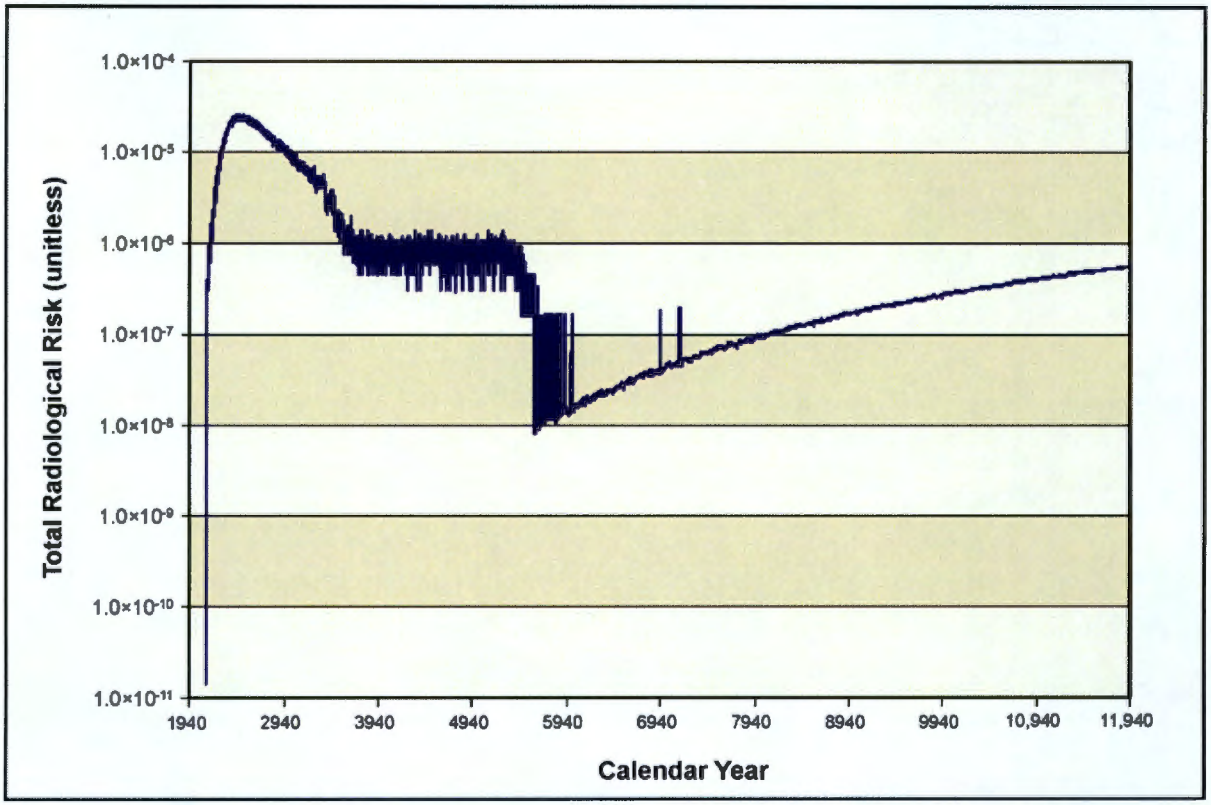


Figure 5–343. FFTF Decommissioning Alternative 1 Total Radiological Risk for Fast Flux Test Facility Barrier Drinking-Water Well User Versus Time

5.2.2.2 FFTF Decommissioning Alternative 2: Entombment

Under FFTF Decommissioning Alternative 2, Entombment, all aboveground structures and minimal below-grade structures, equipment, and materials would be removed. An RCRA-compliant barrier would be constructed over the Reactor Containment Building and any other remaining below-grade structures, including the reactor vessel. Impacts from sources removed from the FFTF Barrier and disposed of in an IDF are discussed in Section 5.3, which discusses waste management issues.

The potential human health impacts of this alternative are summarized in Tables 5–70 and 5–71 and are detailed in Appendix Q. The key constituent contributor to human health risk would be technetium-99 for radionuclides. The chemical risk and hazard drivers would be essentially negligible. Neither dose standards nor the Hazard Index guideline would be exceeded at any location. The population dose was estimated as 8.90×10^{-3} person-rem per year for the year of peak dose. This corresponds to 4.87×10^{-7} percent of the annual population dose due to background exposure. The time series of radiological risk for the drinking-water well user at the FFTF Barrier is presented in Figure 5–344.

Table 5–70. FFTF Decommissioning Alternative 2 Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts Summary

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
Fast Flux Test Facility	7.13×10^{-1}	0.00	2.45×10^{-5}	0.00	2.45×10^{-5}	1.83	0.00	8.04×10^{-5}	0.00	8.04×10^{-5}
Columbia River nearshore	2.16×10^{-2}	0.00	7.42×10^{-7}	0.00	7.42×10^{-7}	5.55×10^{-2}	0.00	2.44×10^{-6}	0.00	2.44×10^{-6}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	1.78×10^{-6}	0.00	7.81×10^{-11}	0.00	7.81×10^{-11}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–71. FFTF Decommissioning Alternative 2 American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts Summary

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
Fast Flux Test Facility	3.73	0.00	1.75×10^{-4}	0.00	1.75×10^{-4}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.13×10^{-1}	0.00	5.31×10^{-6}	0.00	5.31×10^{-6}	1.36×10^{-4}	0.00	7.46×10^{-9}	0.00	7.46×10^{-9}
Off Site										
Columbia River	4.11×10^{-6}	0.00	1.95×10^{-10}	0.00	1.95×10^{-10}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

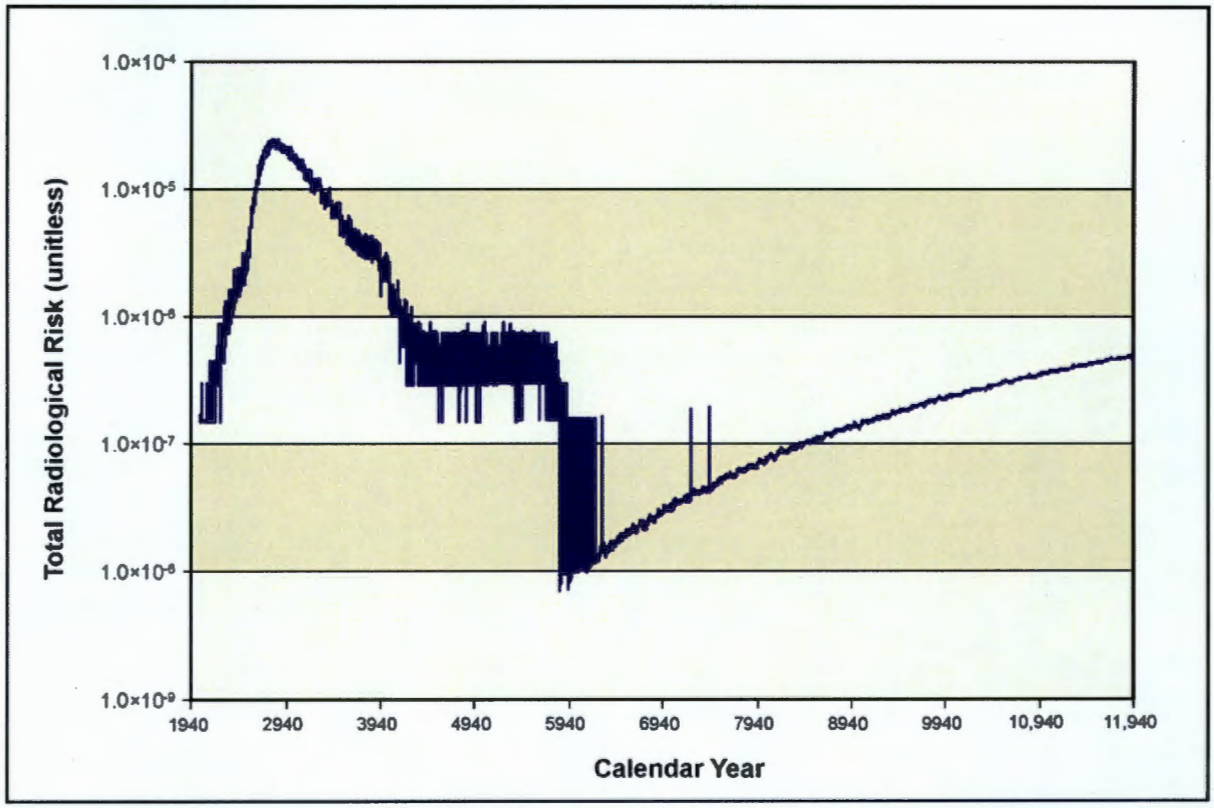


Figure 5–344. FFTF Decommissioning Alternative 2 Total Radiological Risk for Fast Flux Test Facility Barrier Drinking-Water Well User Versus Time

5.2.2.3 FFTF Decommissioning Alternative 3: Removal

Under FFTF Decommissioning Alternative 3, all aboveground structures, as well as contaminated below-grade structures, equipment, and materials would be removed. As a result of the removal of all contaminated material, there would be no impacts on groundwater, surface water, or human health.

5.2.3 Ecological Risk

This section presents the results of the evaluation of long-term impacts on ecological resources of releases to air and groundwater under the FFTF Decommissioning alternatives. Risk indices—Hazard Quotient or Hazard Index—were calculated by comparing predicted dose to benchmark dose (see Appendix P). Risk indices could not be calculated for lizards, toads, or birds for COPCs (organic compounds only) released under the FFTF Decommissioning alternatives because there are no toxicity reference values for such receptors for these COPCs. Risk indices for air emissions were calculated for the three FFTF Decommissioning alternatives and the Hanford and Idaho Options and Reuse Options for FFTF Decommissioning Alternatives 2 and 3. Separate risk indices for air releases were not calculated for the three components of each alternative: disposition of facilities, RH-SCs, and bulk sodium. Calculated risk indices for the COPC with the highest Hazard Quotient or Hazard Index are presented for each receptor.

Releases to air are expected for Environmental Assessment-associated activities under the No Action Alternative (FFTF Decommissioning Alternative 1) and facility disposition under FFTF Decommissioning Alternatives 2 and 3. Releases to air associated with the disposition of RH-SCs and bulk sodium are expected under all FFTF Decommissioning alternatives at Hanford under the Hanford Option and Hanford Reuse Option and, under FFTF Decommissioning Alternatives 2 and 3, at both Hanford and INL under the Idaho Option and Idaho Reuse Option. The impacts on ecological resources

of releases to air were evaluated together for the disposition of RH-SCs and bulk sodium. The estimated impacts are identical under FFTF Decommissioning Alternatives 2 and 3 because the options for RH-SC disposition and bulk sodium disposition are identical under the two alternatives. There would be impacts of releases to groundwater associated with the FFTF Decommissioning Alternatives—No Action, Entombment, and Removal.

The long-term impacts on terrestrial ecological resources of releases to air at Hanford were evaluated at the onsite maximum-exposure location (Core Zone Boundary) and on terrestrial, riparian, and aquatic resources at the offsite maximum-exposure location (Columbia River). Impacts on ecological resources of releases to groundwater were evaluated at the Columbia River.

5.2.3.1 FFTF Decommissioning Alternative 1: No Action

The FFTF Decommissioning No Action Alternative is not expected to result in releases of radionuclides to air. Releases of chemicals to air are expected due to activities associated with the Environmental Assessment (see Section 5.2 and Chapter 2, Section 2.3). The calculated risks to plants, the Great Basin pocket mouse, and the coyote from air releases under FFTF Decommissioning Alternative 1 are the highest of all Tank Closure, FFTF Decommissioning, and Waste Management alternatives. Predicted emissions of COPCs in air under FFTF Decommissioning Alternative 1 pose a small risk to plants (Hazard Quotient is 47) and a moderate risk to mammals at the onsite maximum-exposure location (see Table 5–72). The chemical COPCs released to air with the largest calculated Hazard Quotients for the Great Basin pocket mouse are xylene (2120), toluene (338), formaldehyde (79), and benzene (17) at the onsite maximum-exposure location. The coyote has the next-largest calculated chemical COPC with the Hazard Quotient for xylene (269).

Table 5–72. FFTF Decommissioning Alternatives – Long-Term Impacts of Chemical COPC Releases to Air on Terrestrial Resources at the Onsite Maximum-Exposure Location

FFTF Decommissioning Alternative	Hazard Quotient of Worst-Case Chemical COPC by Receptor			
	Plants	Great Basin Pocket Mouse	Coyote	Mule Deer
	Toluene	Xylene	Xylene	Formaldehyde
1	4.68×10^{1}	**2.12×10^{3}**	2.69×10^{2}	4.79×10^{1}
2	1.63×10^{-1}	**7.60**	9.65×10^{-1}	6.09×10^{-1}
3	1.64×10^{-1}	**7.65**	9.71×10^{-1}	5.79×10^{-1}

Note: The maximum Hazard Quotient under each alternative is indicated by **bold** text. Results are not available for other terrestrial receptors: side-blotched lizard, mourning dove, western meadowlark, and burrowing owl.
Key: COPC=constituent of potential concern; FFTF=Fast Flux Test Facility.

There would be no risk to terrestrial, riparian, or aquatic ecological receptors from releases to air under FFTF Decommissioning Alternative 1 at the offsite maximum-exposure location (Columbia River). The only estimated Hazard Quotient exceeding 1 is xylene for the mouse (2.4). This value is well within the margin of error of the uncertainties in the estimated exposure and toxicity.

Predicted emissions of chemical and radiological COPCs in groundwater discharging at the Columbia River do not pose a risk to ecological receptors. The largest risk index (Hazard Index is 0.00001) for groundwater releases under FFTF Decommissioning Alternative 1 (see Table 5–73) is that calculated for total internal and external exposure to all radiological COPCs for birds eating benthic invertebrates (the spotted sandpiper) at the Columbia River. This indicates no risk to ecological receptors from chemical or radiological COPCs released to groundwater at Hanford under FTFF Decommissioning Alternative 1.

Table 5–73. FFTF Decommissioning Alternatives – Long-Term Impacts of Contaminant Releases to Groundwater on Aquatic and Riparian Resources at the Columbia River

FFTF Decommissioning Alternative	Hazard Quotient or Hazard Index of Worst-Case Chemical or Radiological COPC by Receptor						
	Benthic Invertebrate	Muskrat	Spotted Sandpiper	Raccoon	Least Weasel	Bald Eagle	Aquatic Biota/Salmonids
	All Rad. COPCs	All Rad. COPCs	All Rad. COPCs	All Rad. COPCs	All Rad. COPCs	All Rad. COPCs	All Rad. COPCs
1	1.05×10^{-6}	9.76×10^{-6}	1.07×10^{-5}	1.01×10^{-5}	5.60×10^{-6}	1.98×10^{-6}	9.42×10^{-7}
2	7.43×10^{-7}	6.69×10^{-6}	7.65×10^{-6}	7.06×10^{-6}	5.10×10^{-6}	1.80×10^{-6}	8.56×10^{-7}
3	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Key: COPC=constituent of potential concern; FFTF=Fast Flux Test Facility; N/A=not applicable; Rad.=radiological.

5.2.3.2 FFTF Decommissioning Alternative 2: Entombment

Under FFTF Decommissioning Alternative 2, long-term impacts on ecological resources were evaluated for releases to air and groundwater at Hanford (Hanford and Hanford Reuse Options) and releases to air at Idaho (Idaho and Idaho Reuse Options) associated with the disposition of FFTF and associated facilities, RH-SCs, and bulk sodium.

Predicted emissions of COPCs in the air at Hanford under FFTF Decommissioning Alternative 2 (Hanford and Idaho Options) do not pose a risk to ecological receptors. The chemical COPC with the largest calculated Hazard Quotient for air releases is xylene for the mouse (7.6) at the onsite maximum-exposure location under the Hanford Option (see Table 5–72). This is within the margin of error of the uncertainties in the estimated exposure and toxicity of COPCs. Hazard Quotients calculated for chemical COPCs released to air under FFTF Decommissioning Alternative 2, Idaho Option, are about half as large as those under the Hanford Option. The largest Hazard Index (6.6×10^{-6}) for radiological COPCs released to air under FFTF Decommissioning Alternative 2, Hanford Option (see Appendix P, Table P–3), is predicted for the mouse at the onsite maximum-exposure location, with tritium as the primary contributor. This Hazard Index, much smaller than 1, indicates no risk from radiological COPCs released to air at Hanford under FFTF Decommissioning Alternative 2, either Hanford or Idaho Option. Also, there would be no risk to terrestrial, riparian, or aquatic ecological receptors from releases to air under FFTF Decommissioning Alternative 2 at the offsite maximum-exposure location (Columbia River) under both Hanford and Idaho Options.

Although risk indices were not calculated for ecological receptors at INL, the relative magnitude of emissions there suggests little to no risk. For the disposition of RH-SCs and bulk sodium under FFTF Decommissioning Alternative 2, Idaho and Idaho Reuse Options, the predicted peak annual emissions of tritium (5.72 curies per year) and cesium-137 (3.3×10^{-4} curies per year) at INL are orders of magnitude smaller than the maximum emissions at Hanford under any *TC & WM EIS* alternative (1.22×10^{3} curies per year for tritium, 2.5×10^{2} curies per year for cesium-137). The emissions of COPCs at INL would be smaller than emissions at Hanford under at least one of the Tank Closure, FFTF Decommissioning, or Waste Management alternatives (see Table 5–74). There would be no releases of mercury at INL. Because predicted emissions of COPCs do not pose a risk to ecological receptors at Hanford, the smaller rates at INL are unlikely to pose a risk to similar ecological receptors with similar exposure pathways.

Predicted emissions of chemical and radiological COPCs in groundwater discharging at the Columbia River do not pose a risk to ecological receptors. The largest risk index (Hazard Index is 0.000008) for groundwater releases under FFTF Decommissioning Alternative 2 (Table 5–73) is that calculated for total internal and external exposure to all radiological COPCs for birds eating benthic invertebrates (the spotted sandpiper) at the Columbia River. This indicates no risk to ecological receptors from chemical or radiological COPCs released to groundwater at Hanford under FTFF Decommissioning Alternative 2.

5.2.3.3 FFTF Decommissioning Alternative 3: Removal

Under FFTF Decommissioning Alternative 3, long-term impacts on ecological resources were evaluated for releases to air and groundwater at Hanford (Hanford Option) and releases to air at Idaho (Idaho Option).

Predicted emissions of COPCs in air at Hanford under FFTF Decommissioning Alternative 3 (Hanford and Idaho Options) are similar to those under FFTF Decommissioning Alternative 2 and do not pose a risk to ecological receptors. The chemical COPC with the largest calculated Hazard Quotient (xylene, 7.65) is for the mouse at the onsite maximum-exposure location (see Table 5–72). Hazard Quotients calculated for chemical COPCs released to air under FFTF Decommissioning Alternative 3, Idaho Option, are about half as large as those under the Hanford Option. The largest Hazard Index (6.6×10^{-6}) for radiological COPCs released to air under FFTF Decommissioning Alternative 3, Hanford Option

(see Appendix P, Table P–3), is predicted for the mouse at the onsite maximum-exposure location, primarily from tritium. This indicates no risk from radiological COPCs released to air at Hanford under FFTF Decommissioning Alternative 3, either Hanford or Idaho Option. There also would be no risk to terrestrial, riparian, or aquatic ecological receptors from releases of COPCs to air under FFTF Decommissioning Alternative 3 at the offsite maximum-exposure location (Columbia River).

Although risk indices were not calculated for ecological receptors at INL, the relative magnitude of emissions there suggests little to no risk. For the disposition of RH-SCs and bulk sodium under FFTF Decommissioning Alternative 3, Idaho and Idaho Reuse Options, the predicted peak annual emissions of tritium (5.72 curies per year) and cesium-137 (3.30×10^{-4} curies per year) at INL are orders of magnitude smaller than the maximum emissions at Hanford under any *TC & WM EIS* alternative (1.22×10^{3} curies per year for tritium, 2.50×10^{2} curies per year for cesium-137). The emissions of COPCs at INL would be smaller than emissions at Hanford under at least one of the Tank Closure, FFTF Decommissioning, or Waste Management alternatives (see Table 5–74). There would be no releases of mercury at INL. Because predicted emissions of COPCs under FFTF Decommissioning Alternative 3 do not pose a risk to ecological receptors at Hanford, the smaller rates at INL are unlikely to pose a risk to similar ecological receptors with similar exposure pathways.

Table 5–74. Comparison of Peak Annual Emission Rates at INL Under FFTF Decommissioning Alternatives 2 and 3 and at the Hanford Site Under Tank Closure Alternatives

Constituent of Potential Concern	INL	Hanford	Alternative
Radionuclide (curies per year)			
Hydrogen-3 (tritium)	5.72	1.22×10^{3}	Tank Closure 2A
Carbon-14	0	N/A	N/A
Cobalt-60	0	N/A	N/A
Strontium-90	0	N/A	N/A
Technetium-99	0	N/A	N/A
Iodine-129	0	N/A	N/A
Cesium-137	3.30×10^{-4}	2.50×10^{2}	Tank Closure 6B
Uranium (all isotopes)	0	N/A	N/A
Plutonium-238	0	N/A	N/A
Plutonium-239, -240	0	N/A	N/A
Plutonium-241	0	N/A	N/A
Americium-241	0	N/A	N/A
Chemical (grams per year)			
Nitrogen dioxide	0	N/A	N/A
Sulfur dioxide	2.26×10^{3}	5.60×10^{7}	Tank Closure 2B
Ammonia	0	N/A	N/A
Benzene	0	N/A	N/A
Toluene	1.71×10^{4}	5.50×10^{6}	Tank Closure 5
Xylene	4.87×10^{3}	1.60×10^{6}	Tank Closure 5
1,3-Butadiene	1.55×10^{1}	2.58×10^{4}	Waste Management 3 (Disposal Group 2)
Mercury	0	N/A	N/A
Formaldehyde	0	N/A	N/A

Note: To convert grams to ounces, multiply by 0.03527.

Key: FFTF=Fast Flux Test Facility; INL=Idaho National Laboratory; N/A=not applicable because constituent not released at INL.

Under FFTF Decommissioning Alternative 3, all aboveground structures, as well as contaminated below grade structures, equipment, and materials would be removed. As a result of the removal of all contaminated material, there would be no impacts on ecological receptors resulting from releases to groundwater.

5.2.4 Environmental Justice

Sections 5.2.1 and 5.2.2 evaluate groundwater impacts and associated potential long-term human health effects under the FFTF Decommissioning alternatives. Receptors analyzed with a potential for environmental justice concerns include a resident farmer, an American Indian resident farmer, and an American Indian hunter-gatherer. The hypothetical resident farmer, which could represent a low-income population, and American Indian resident farmer were both assumed to use only groundwater for drinking water ingestion and crop irrigation. While only a portion of the food consumed by the resident farmer was assumed to come from crops and animal products exposed to contaminated groundwater, all of the food consumed by the American Indian resident farmer was assumed to be exposed to contaminated groundwater. The American Indian hunter-gatherer was assumed to have a subsistence consumption pattern that differing from that of the American Indian resident farmer. The American Indian hunter gatherer does not cultivate crops but gathers food from indigenous plants, harvests fish from the Columbia River, and is exposed to a combination of surface water and groundwater. Given these assumptions, the two American Indian receptors would be most at risk from contaminated groundwater. These receptors were used to develop exposure scenarios at several on- and offsite locations identified in Appendix Q, Section Q.2.1. Long-term human health impacts of FFTF decommissioning actions would be greatest under FFTF Decommissioning Alternative 1. Under this alternative, none of the hypothetical receptors at any of the assessment boundaries would be exposed to radiological doses in excess of regulatory limits or to chemicals with a Hazard Index greater than 1. The greatest risk would be to the American Indian resident farmer at the FFTF boundary. During the year of peak dose, this receptor would receive a radiological dose of 3.8 millirem, compared to the regulatory limit of 100 millirem from all sources. During the year of peak Hazard Index, this receptor would be exposed to chemicals resulting in a Hazard Index less than 1. Therefore, none of the FFTF Decommissioning alternatives would pose a disproportionately high and adverse long-term human health risk to the American Indian population at offsite locations.

5.3 WASTE MANAGEMENT ALTERNATIVES

This section describes the potential long-term environmental impacts associated with the implementation of alternatives for administering ongoing solid waste management operations and proposed disposal of low-level radioactive waste (LLW) and mixed low-level radioactive waste (MLLW) from Hanford and a limited volume of offsite LLW and MLLW in an IDF located at Hanford. Specifically, this includes the management and disposal of LLW and MLLW from tank closure activities as described in Chapter 4, Section 4.1.14, as well as other non–Comprehensive Environmental Response, Compensation, and Liability Act (non-CERCLA) LLW and MLLW from Hanford, including the waste from FFTF decommissioning described in Chapter 4, Section 4.2.14, and waste from other DOE sites (i.e., offsite waste). This section analyzes the impacts of expanding Hanford's waste disposal capacity to provide space for on- and offsite waste; this section also includes an analysis of associated storage, disposal, and closure activities, as well as facility-specific construction, operations, deactivation, and closure activities.

Three Waste Management alternatives are considered and analyzed, including (1) Waste Management Alternative 1: No Action; (2) Waste Management Alternative 2: Disposal in IDF, 200-East Area Only; and (3) Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas.

Waste Management Alternative 1 would include storing and disposing of LLW and MLLW in trenches 31 and 34 of existing low-level radioactive waste burial ground (LLBG) 218-W-5 and storing and disposing of transuranic (TRU) waste in the Waste Isolation Project Plant (WIPP) near Carlsbad, New Mexico. No offsite waste would be received; construction/use of the IDF located in the 200-East Area (IDF-East) would be discontinued; and IDF-East would be deactivated.

Waste Management Alternative 2 would include storing LLW, MLLW, and TRU waste in the Central Waste Complex (CWC) prior to disposal and processing waste prior to disposal at new facilities or existing-facility expansions at the CWC, Waste Receiving and Processing Facility, and the T Plant. A total volume of 62,000 cubic meters (2.2 million cubic feet) of LLW and 20,000 cubic meters (706,300 cubic feet) of MLLW from other DOE sites would be received for disposal under this alternative. Waste from tank closure and treatment operations, onsite non-CERCLA sources, FFTF decommissioning, and waste management, as well as offsite waste from other DOE sites would be disposed of in IDF-East. A new RPPDF would be constructed for disposal of lightly contaminated equipment and soils as a result of tank farm clean closure activities.

Waste Management Alternative 3 would involve the same waste storage and processing provisions as Waste Management Alternative 2 and the same volume of offsite waste accepted for disposal; a new RPPDF would also be constructed. However, an additional IDF would be constructed in the 200-West Area (IDF-West). Waste from tank closure and treatment operations would be disposed of in IDF-East, while onsite non-CERCLA waste, FFTF decommissioning waste, waste management, and offsite waste from other DOE sites would be disposed of in IDF-West.

In addition, under each Waste Management action alternative (i.e., Alternatives 2 and 3), three disposal groupings are analyzed: Disposal Groups 1, 2, and 3. These disposal groupings encompass the sizing requirements and associated construction, operations, and closure requirements for the IDF(s) and RPPDF necessary to accommodate the varying waste volumes considered under each disposal configuration. These alternatives and options are described further in Chapter 2, Section 2.5, of this EIS.

These disposal groupings are further divided into subgroupings for the consideration of the different types and volumes of waste generated from the 10 Tank Closure action alternatives and the 2 FFTF Decommissioning action alternatives to analyze the long-term impacts associated with disposal of the various waste types and volumes. These subgroupings are described in Table 5–75.

Table 5–75. Waste Management Action Alternative Subgroupings

Waste Management Alternative	Disposal Group and Subgroup	Disposal Location	Tank Closure Alternative Waste	Other DOE Waste
1	N/A	LLBG, trenches 31 and 34	N/A	Non-CERCLA waste
2	Disposal Group 1, Subgroup 1-A	IDF-East	Tank Closure Alternative 2B • ILAW glass • LAW melters • Secondary waste (LLW and MLLW)	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	Tank Closure Alternative 2B • Closure waste (LLW and MLLW)	N/A
2	Disposal Group 1, Subgroup 1-B	IDF-East	Tank Closure Alternative 3A • ILAW glass • Bulk vitrification glass • LAW melters • Secondary waste (LLW and MLLW)	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	Tank Closure Alternative 3A • Closure waste (LLW and MLLW)	N/A
2	Disposal Group 1, Subgroup 1-C	IDF-East	Tank Closure Alternative 3B • ILAW glass • Cast stone waste • LAW melters • Secondary waste (LLW and MLLW)	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	Tank Closure Alternative 3B • Closure waste (LLW and MLLW)	N/A
2	Disposal Group 1, Subgroup 1-D	IDF-East	Tank Closure Alternative 3C • ILAW glass • Steam reforming waste • LAW melters • Secondary waste (LLW and MLLW)	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	Tank Closure Alternative 3C • Closure waste (LLW and MLLW)	N/A
2	Disposal Group 1, Subgroup 1-E	IDF-East	Tank Closure Alternative 4 • ILAW glass • Bulk vitrification glass • Cast stone waste • LAW melters • Secondary waste (LLW and MLLW)	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	Tank Closure Alternative 4 • Closure waste (LLW and MLLW)	N/A

Table 5-75. Waste Management Action Alternative Subgroupings *(continued)*

Waste Management Alternative	Disposal Group and Subgroup	Disposal Location	Tank Closure Alternative Waste	Other DOE Waste
2	Disposal Group 1, Subgroup 1-F	IDF-East	Tank Closure Alternative 5 • ILAW glass • Bulk vitrification glass • Cast stone waste • Sulfate grout • LAW melters • Secondary waste (LLW and MLLW)	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	N/A	N/A
2	Disposal Group 1, Subgroup 1-G	IDF-East	Tank Closure Alternative 6C • Secondary waste (LLW and MLLW)	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	Tank Closure Alternative 6C • Closure waste (LLW and MLLW)	N/A
2	Disposal Group 2, Subgroup 2-A	IDF-East	Tank Closure Alternative 2A • ILAW glass • LAW melters • Secondary waste (LLW and MLLW)	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	N/A	N/A
2	Disposal Group 2, Subgroup 2-B	IDF-East	Tank Closure Alternative 6B, Base and Option Cases • PPF melters • PPF glass • Secondary waste (LLW and MLLW)	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	Tank Closure Alternative 6B, Base and Option Cases • Closure waste (LLW and MLLW)	N/A
2	Disposal Group 3	IDF-East	Tank Closure Alternative 6A, Base and Option Cases • PPF melters • PPF glass • Secondary waste (LLW and MLLW)	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	Tank Closure Alternative 6A, Base and Option Cases • Closure waste (LLW and MLLW)	N/A

Table 5-75. Waste Management Action Alternative Subgroupings *(continued)*

Waste Management Alternative	Disposal Group and Subgroup	Disposal Location	Tank Closure Alternative Waste	Other DOE Waste
3	Disposal Group 1, Subgroup 1-A	IDF-East	Tank Closure Alternative 2B • ILAW glass • LAW melters • Secondary waste (LLW and MLLW)	N/A
		IDF-West	N/A	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	Tank Closure Alternative 2B • Closure waste (LLW and MLLW)	N/A
3	Disposal Group 1, Subgroup 1-B	IDF-East	Tank Closure Alternative 3A • ILAW glass • Bulk vitrification glass • LAW melters • Secondary waste (LLW and MLLW)	N/A
		IDF-West	N/A	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	Tank Closure Alternative 3A • Closure waste (LLW and MLLW)	N/A
3	Disposal Group 1, Subgroup 1-C	IDF-East	Tank Closure Alternative 3B • ILAW glass • Cast stone waste • LAW melters • Secondary waste (LLW and MLLW)	N/A
		IDF-West	N/A	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	Tank Closure Alternative 3B • Closure waste (LLW and MLLW)	N/A
3	Disposal Group 1, Subgroup 1-D	IDF-East	Tank Closure Alternative 3C • ILAW glass • Steam reforming waste • LAW melters • Secondary Waste (LLW and MLLW)	N/A
		IDF-West	N/A	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	Tank Closure Alternative 3C • Closure waste (LLW and MLLW)	N/A

Table 5-75. Waste Management Action Alternative Subgroupings *(continued)*

Waste Management Alternative	Disposal Group and Subgroup	Disposal Location	Tank Closure Alternative Waste	Other DOE Waste
3	Disposal Group 1, Subgroup 1-E	IDF-East	Tank Closure Alternative 4 • ILAW glass • Bulk vitrification glass • Cast stone waste • LAW melters • Secondary waste (LLW and MLLW)	N/A
		IDF-West	N/A	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	Tank Closure Alternative 4 • Closure waste (LLW and MLLW)	N/A
3	Disposal Group 1, Subgroup 1-F	IDF-East	Tank Closure Alternative 5 • ILAW glass • Bulk vitrification glass • Cast stone waste • Sulfate grout • LAW melters • Secondary waste (LLW and MLLW)	N/A
		IDF-West	N/A	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	N/A	N/A
3	Disposal Group 1, Subgroup 1-G	IDF-East	Tank Closure Alternative 6C • Secondary waste (LLW and MLLW)	N/A
		IDF-West	N/A	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	Tank Closure Alternative 6C • Closure waste (LLW and MLLW)	N/A
3	Disposal Group 2, Subgroup 2-A	IDF-East	Tank Closure Alternative 2A • ILAW glass • LAW melters • Secondary waste (LLW and MLLW)	N/A
		IDF-West	N/A	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	N/A	N/A

Table 5-75. Waste Management Action Alternative Subgroupings *(continued)*

Waste Management Alternative	Disposal Group and Subgroup	Disposal Location	Tank Closure Alternative Waste	Other DOE Waste
3	Disposal Group 2, Subgroup 2-B	IDF-East	Tank Closure Alternative 6B, Base and Option Cases • PPF melters • PPF glass • Secondary waste (LLW and MLLW)	N/A
		IDF-West	N/A	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	Tank Closure Alternative 6B, Base and Option Cases • Closure waste (LLW and MLLW)	N/A
3	Disposal Group 3	IDF-East	Tank Closure Alternative 6A, Base and Option Cases • PPF melters • PPF glass • Secondary waste (LLW and MLLW)	N/A
		IDF-West	N/A	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	Tank Closure Alternative 6A, Base and Option Cases • Closure waste (LLW and MLLW)	N/A

Key: CERCLA=Comprehensive Environmental Response, Compensation, and Liability Act; DOE= U.S. Department of Energy; FFTF=Fast Flux Test Facility; IDF-East=200-East Area Integrated Disposal Facility; IDF-West=200-West Area Integrated Disposal Facility; ILAW=immobilized low-activity waste; LAW=low-activity waste; LLBG=low-level radioactive waste burial ground; LLW=low-level radioactive waste; MLLW=mixed low-level radioactive waste; N/A=not applicable; PPF=Preprocessing Facility; RPPDF=River Protection Project Disposal Facility.

5.3.1 Groundwater

5.3.1.1 Waste Management Alternative 1: No Action

This section describes the groundwater analysis results for Waste Management Alternative 1, including long-term groundwater impacts of contaminant sources within the Trenches 31 and 34 Barrier. Impacts of sources remaining within the tank farm barriers are presented in Section 5.1, which discusses tank closure impacts. Impacts of sources remaining within the FFTF Barrier are presented in Section 5.2, which discusses FFTF decommissioning impacts.

5.3.1.1.1 Actions and Timeframes Influencing Groundwater Impacts

Summaries of the proposed actions and timelines for Waste Management Alternative 1 are provided in Chapter 2, Section 2.5. For the long-term groundwater impact analysis, two major periods were identified for Waste Management Alternative 1, as follows:

- The disposal period was assumed to start with the onset of disposal operations in LLBG 218-W-5, trenches 31 and 34, in CY 2008 and continue through CY 2035, when the trenches would be operationally closed. During this time, these trenches have accepted, and would continue to

accept, onsite non-CERCLA LLW and MLLW. During the disposal period, the materials in this permitted, operational facility would not be available for release to the environment.

- The post-disposal period was assumed to start in CY 2036 and continue through the 10,000-year period of analysis until CY 11,940. At the start of this period, materials in the trenches become available for release to the environment. Waste Management Alternative 1 does not include construction of barriers over trenches 31 and 34. However, the surrounding LLBG 218-W-5, which is included in the cumulative impact analysis, would have a barrier emplaced consistent with the cumulative impact analysis end-state methodology (see Appendix S). For the purpose of analyzing long-term groundwater impacts under Waste Management Alternative 1, trenches 31 and 34 are assumed to be covered by a barrier that limits infiltration for the first 500 years of the post-disposal period.

5.3.1.1.2 COPC Drivers

A total of 40 COPCs were analyzed for Waste Management Alternative 1. Complete results for all 40 COPCs are tabulated in Appendices M, N, and O. The discussion in this section of long-term impacts associated with Waste Management Alternative 1 is focused on the following COPC drivers:

- Radiological risk drivers: iodine-129 and technetium-99
- Chemical risk drivers: none
- Chemical hazard drivers: chromium, fluoride, and nitrate

The COPC drivers for Waste Management Alternative 1 were selected by evaluating the risk or hazard associated with all 40 COPCs in the year of peak risk or hazard at the Core Zone Boundary during the 10,000-year period of analysis and selecting the major contributors. This process is described in Appendix Q. The radiological risk drivers listed above account for essentially 100 percent of the radiological risk. No chemical risk is predicted. The chemical hazard drivers above account for over 99 percent of the chemical hazard associated with Waste Management Alternative 1.

The COPC drivers that are discussed in detail in this section (iodine-129, technetium-99, chromium, fluoride, and nitrate) are all mobile (i.e., move with groundwater) and long-lived (relative to the 10,000-year period of analysis), or stable. They are essentially conservative tracers. The other COPCs that were analyzed do not significantly contribute to drinking water risk at the Core Zone Boundary during the period of analysis because of high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of both factors.

5.3.1.1.3 Analysis of Release and Mass Balance

This section presents the impacts of Waste Management Alternative 1 in terms of the total amount of COPCs released to the vadose zone, groundwater, and the Columbia River during the 10,000-year period of analysis. Releases of radionuclides are totaled in curies; chemicals in kilograms (see Figures 5–345 through 5–350). Two subtotals are plotted representing releases from trenches 31 and 34. Note that the release amounts are plotted on a logarithmic scale to facilitate visual comparison of releases that vary over three orders of magnitude.

Figure 5–345 shows the estimated release to the vadose zone for the radiological risk drivers and Figure 5–346, the chemical hazard drivers. For both sources, the release to the vadose zone is controlled by the inventory (i.e., 100 percent of the inventory was released during the period of analysis). Trenches 31 and 34 are equal sources for all COPCs.

Figure 5–347 shows the estimated release to groundwater for the radiological risk drivers and Figure 5–348, the chemical hazard drivers. In addition to the inventory considerations discussed in the

previous paragraph, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. All COPCs act as conservative tracers, and essentially all of the release to the vadose zone reached groundwater in the analysis.

Figure 5–349 shows the estimated release at IDF-East to the Columbia River for the radiological risk drivers and Figure 5–350, the chemical hazard drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers. In all cases, nearly 100 percent of the amount released to groundwater reached the Columbia River in the analysis.

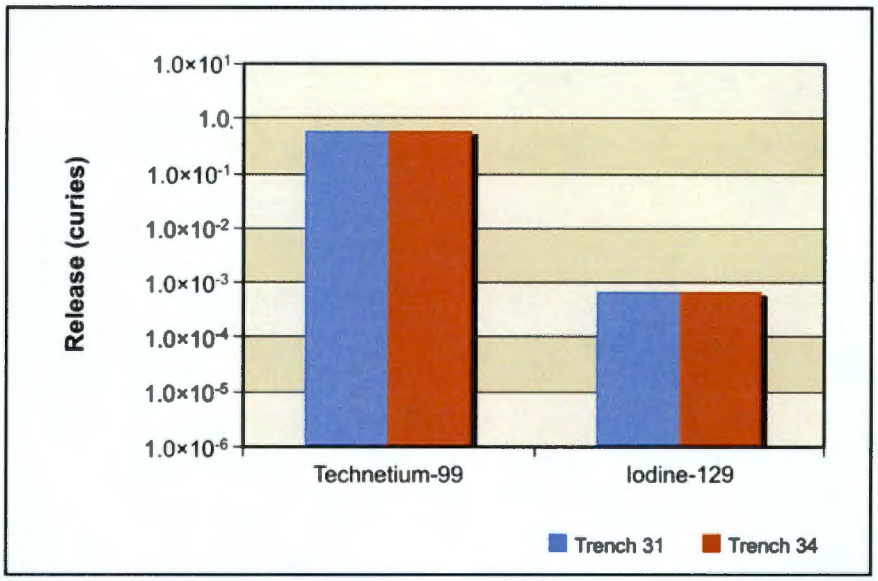


Figure 5–345. Waste Management Alternative 1, Radiological Releases at 200-East Area Integrated Disposal Facility to Vadose Zone

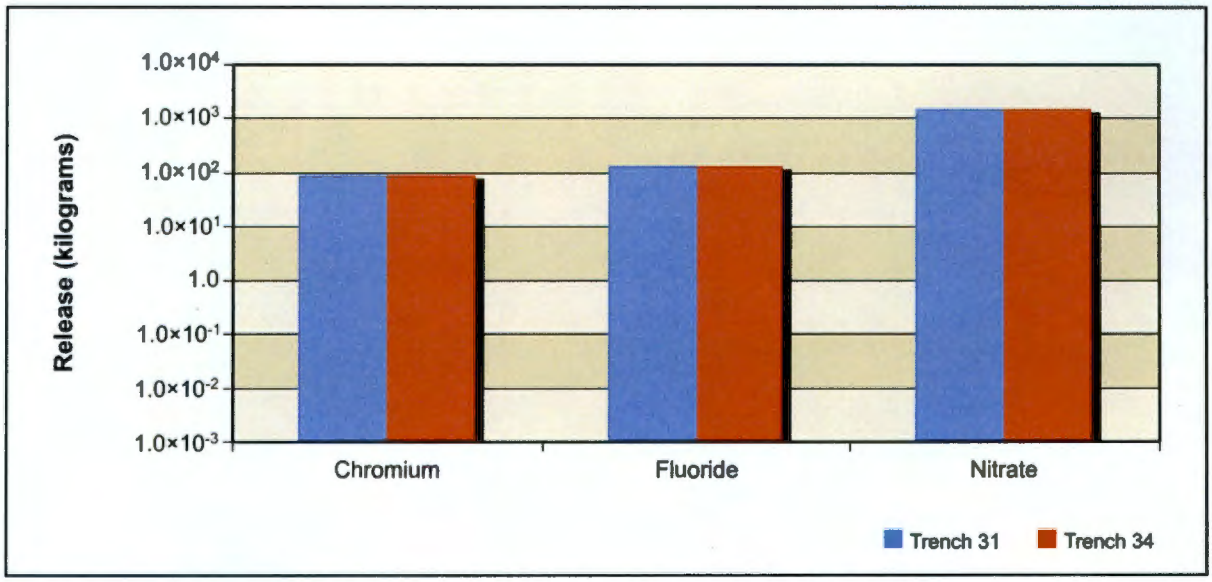


Figure 5–346. Waste Management Alternative 1, Chemical Releases at 200-East Area Integrated Disposal Facility to Vadose Zone

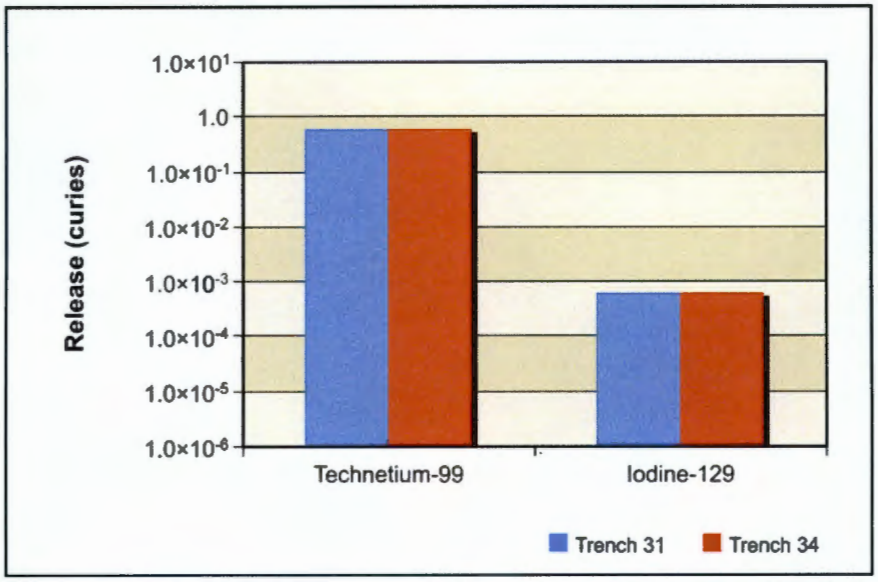


Figure 5–347. Waste Management Alternative 1, Radiological Releases at 200-East Area Integrated Disposal Facility to Groundwater

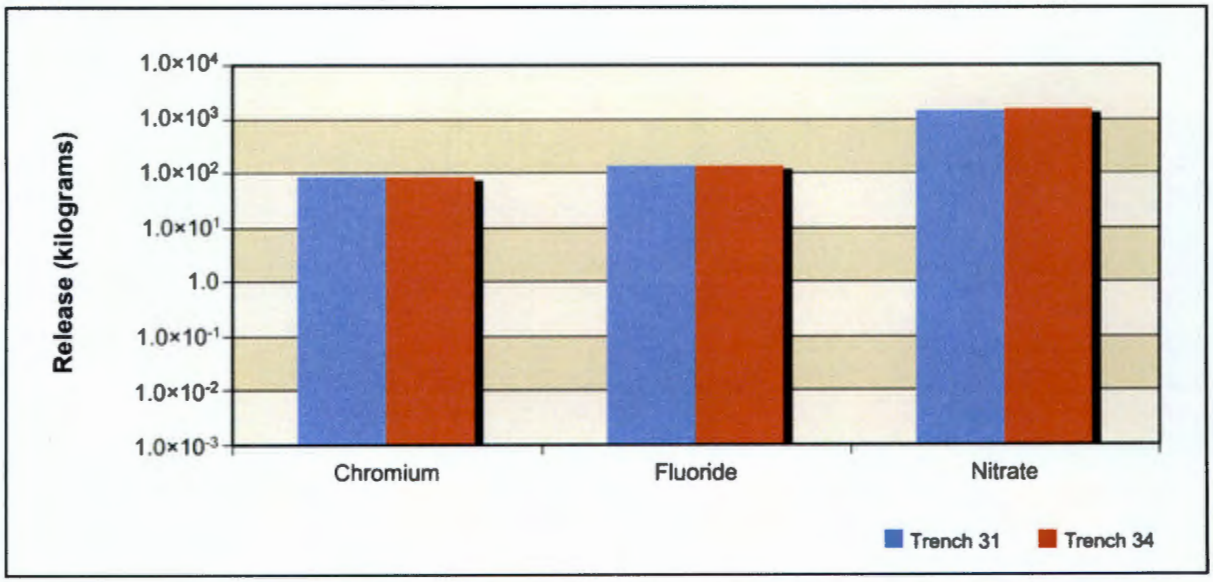


Figure 5–348. Waste Management Alternative 1, Chemical Releases at 200-East Area Integrated Disposal Facility Groundwater

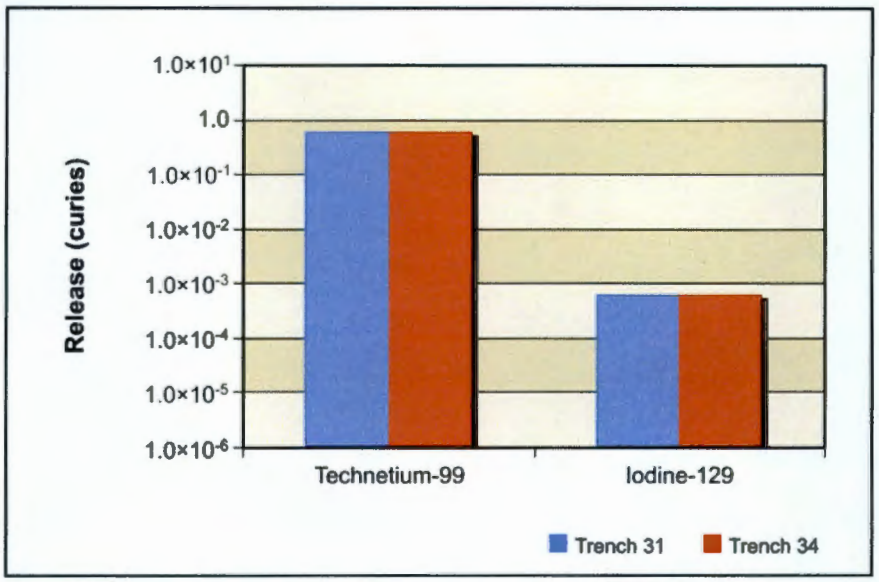


Figure 5–349. Waste Management Alternative 1, Radiological Releases at 200-East Area Integrated Disposal Facility to Columbia River

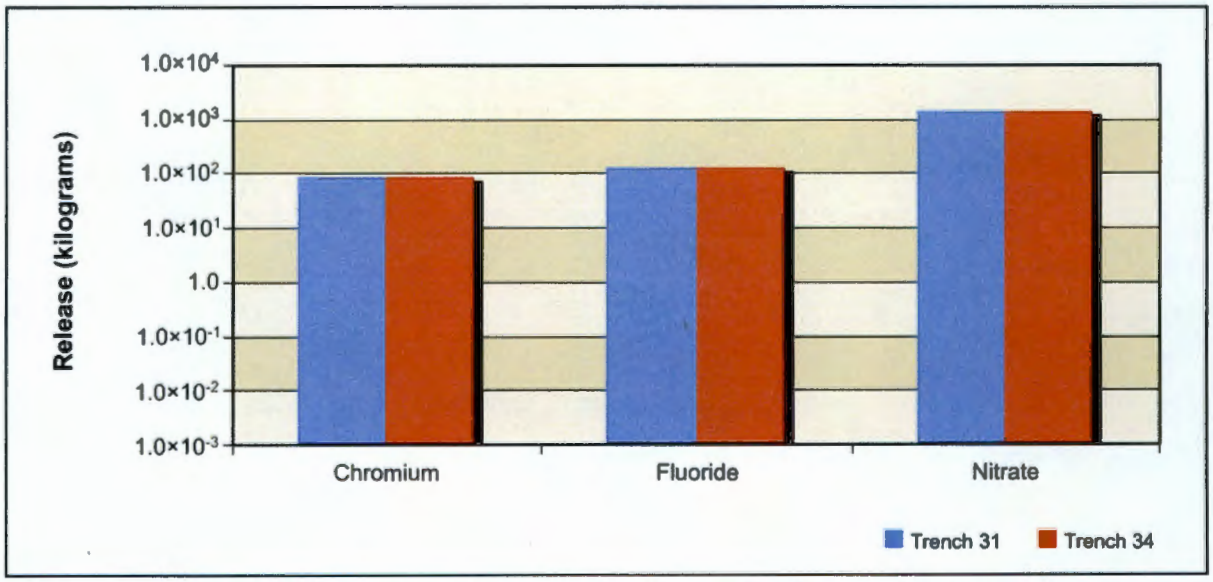


Figure 5–350. Waste Management Alternative 1, Chemical Releases at 200-East Area Integrated Disposal Facility to Columbia River

5.3.1.1.4 Analysis of Concentration Versus Time

This section presents the analysis of Waste Management Alternative 1 impacts in terms of groundwater concentration versus time at the Core Zone Boundary and the Columbia River. Concentrations of radionuclides are in picocuries per liter; chemicals in micrograms per liter (see Figures 5–351 through 5–356). The benchmark concentration for each radionuclide and chemical is also shown. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude. Table 5–76 lists the maximum concentrations of the COPCs in the peak year at trenches 31 and 34 and the RPPDF, Core Zone Boundary, and Columbia River nearshore.

Figures 5–351 through 5–354 show concentration versus time for iodine-129, technetium-99, chromium, and nitrate (the conservative tracers). For technetium-99, concentrations at the Core Zone Boundary rise early in the simulation, reaching a peak of about two orders of magnitude below the benchmark between CYs 2940 and 3940. After the peak, concentrations decline for the remainder of the simulation. Iodine-129, chromium, and nitrate all follow similar patterns, although the peak concentration for nitrate at the Core Zone Boundary is over three orders of magnitude below the benchmark.

Figures 5–355 and 5–356 show concentration versus time for uranium-238 and total uranium. Because of the high retardation of uranium, no contamination appears until CY 8940, when uranium-238 concentrations at the Core Zone Boundary first surpass 1.0×10^{-8} micrograms per liter. Uranium-238 remains over four orders of magnitude below the benchmark throughout the simulation. Total uranium remains over seven orders of magnitude below the benchmark concentration at the Core Zone Boundary throughout the simulation.

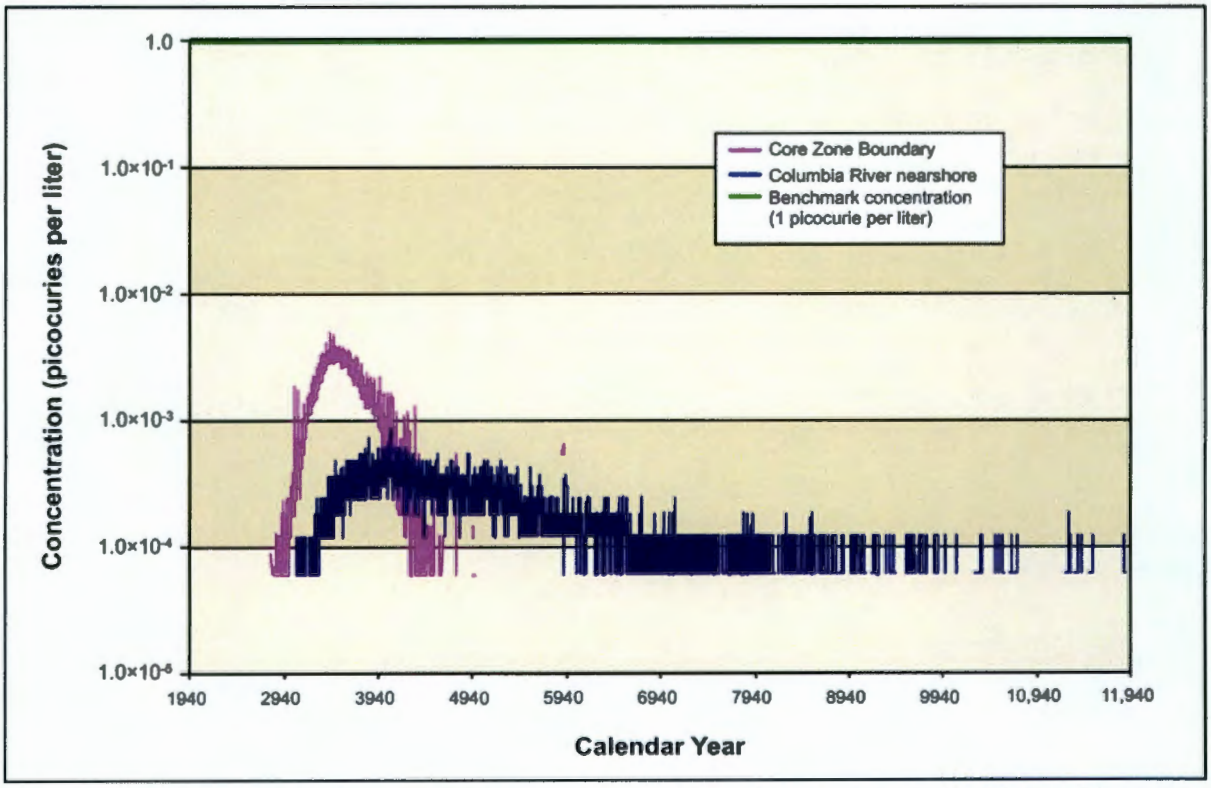


Figure 5–351. Waste Management Alternative 1, Iodine-129 Concentration Versus Time

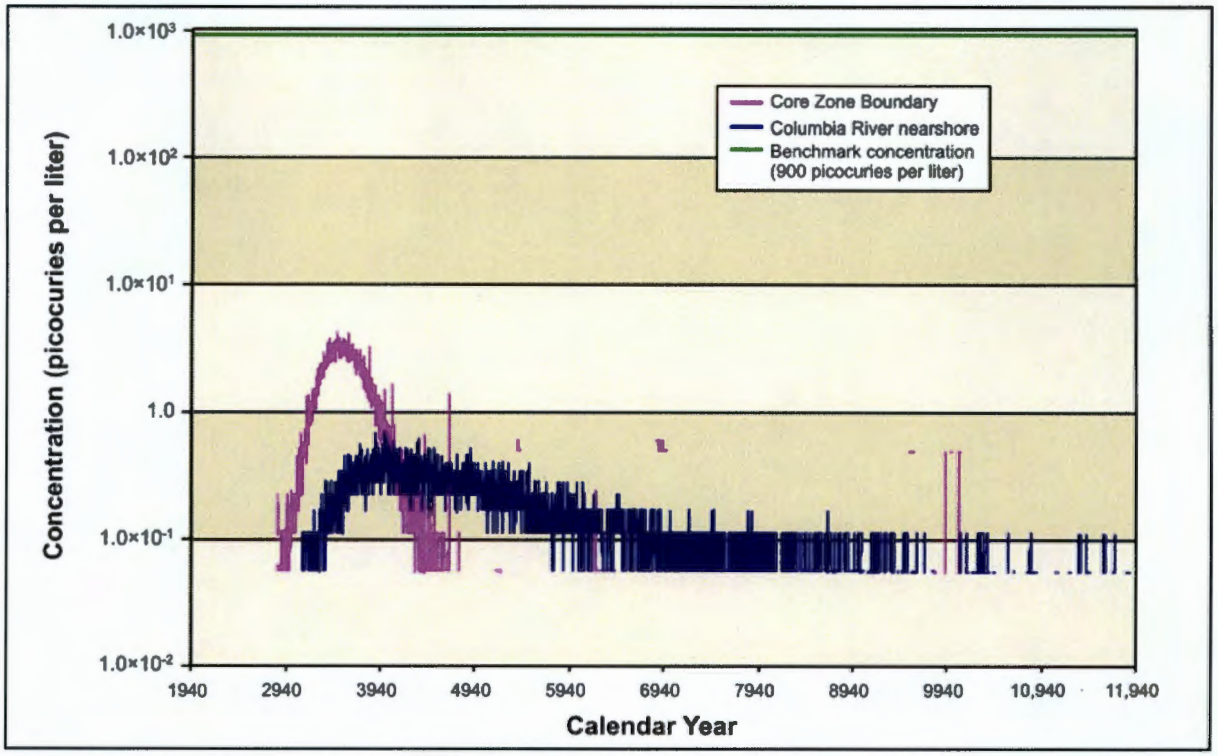


Figure 5–352. Waste Management Alternative 1, Technetium-99 Concentration Versus Time

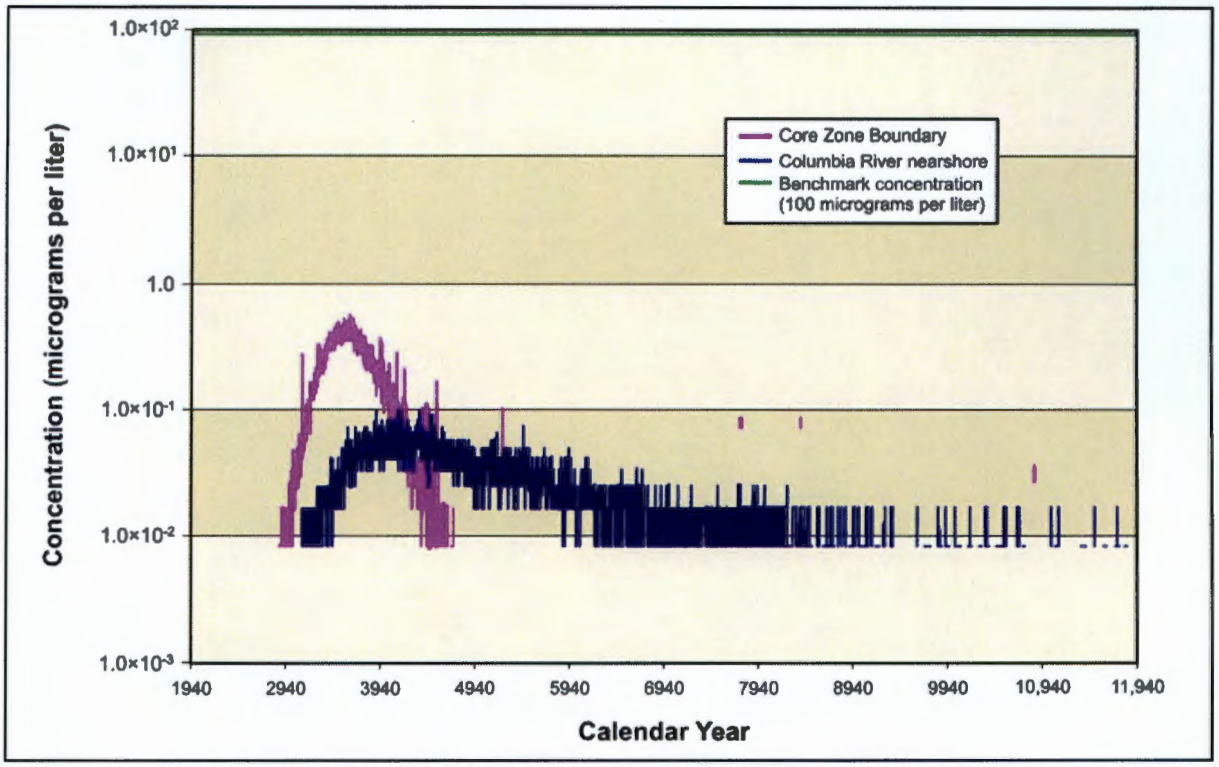


Figure 5–353. Waste Management Alternative 1, Chromium Concentration Versus Time

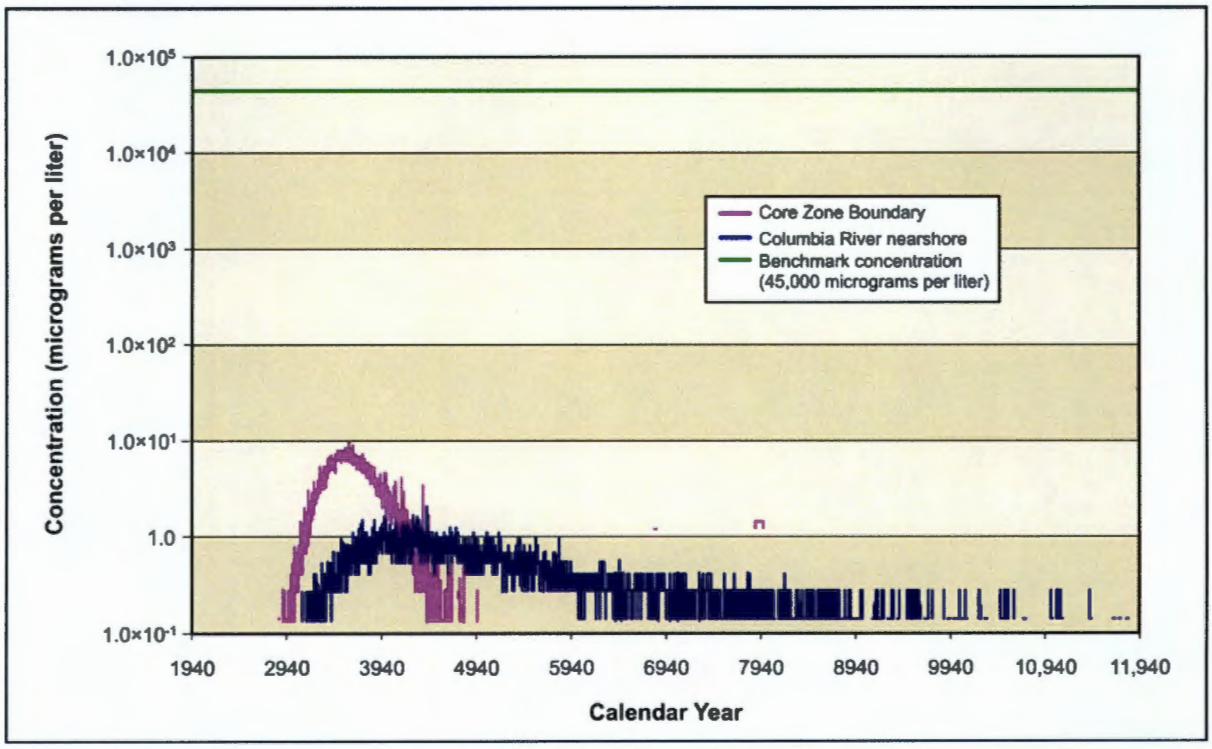


Figure 5–354. Waste Management Alternative 1, Nitrate Concentration Versus Time

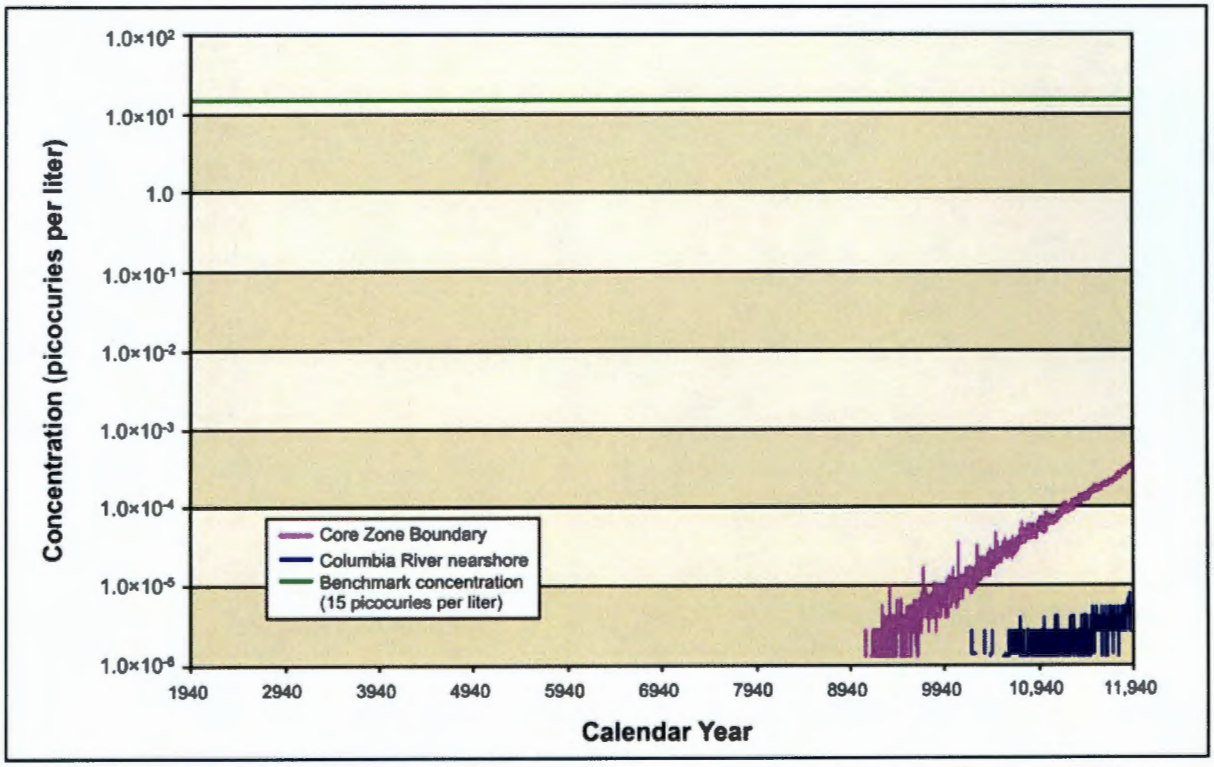


Figure 5–355. Waste Management Alternative 1, Uranium-238 Concentration Versus Time

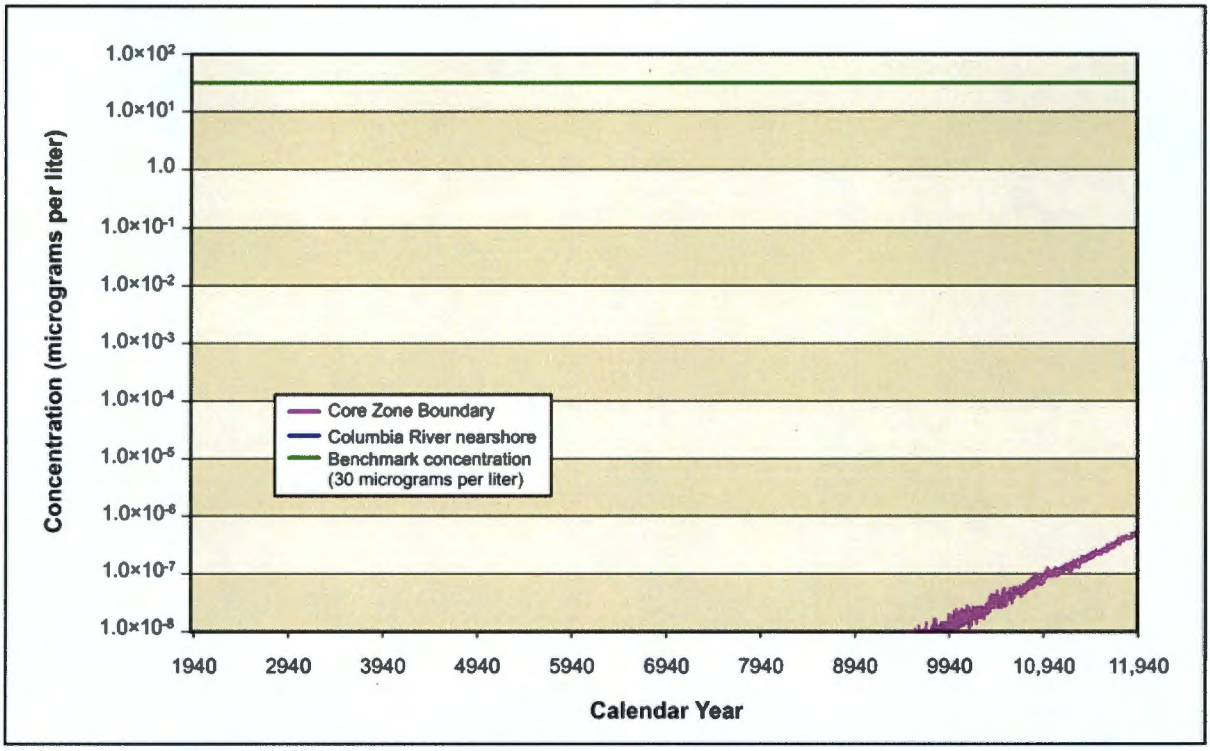


Figure 5–356. Waste Management Alternative 1, Total Uranium Concentration Versus Time

Table 5–76. Waste Management Alternative 1 Maximum COPC Concentrations in the Peak Year at Trenches 31 and 34, and the RPPDF, Core Zone Boundary, and Columbia River Nearshore

Contaminant	Trenches 31 and 34	RPPDF	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclide in picocuries per liter					
Technetium-99	22 (3499)	N/A	4 (3474)	1 (3974)	900
Chemical in micrograms per liter					
Chromium	3 (3526)	N/A	1 (3615)	0 (4353)	100
Fluoride	4 (3545)	N/A	1 (3661)	0 (4592)	4,000
Nitrate	47 (3534)	N/A	9 (3600)	2 (4417)	45,000

Note: Corresponding calendar year shown in parentheses.
Key: COPC=constituent of potential concern; N/A=not applicable; RPPDF=River Protection Project Disposal Facility.

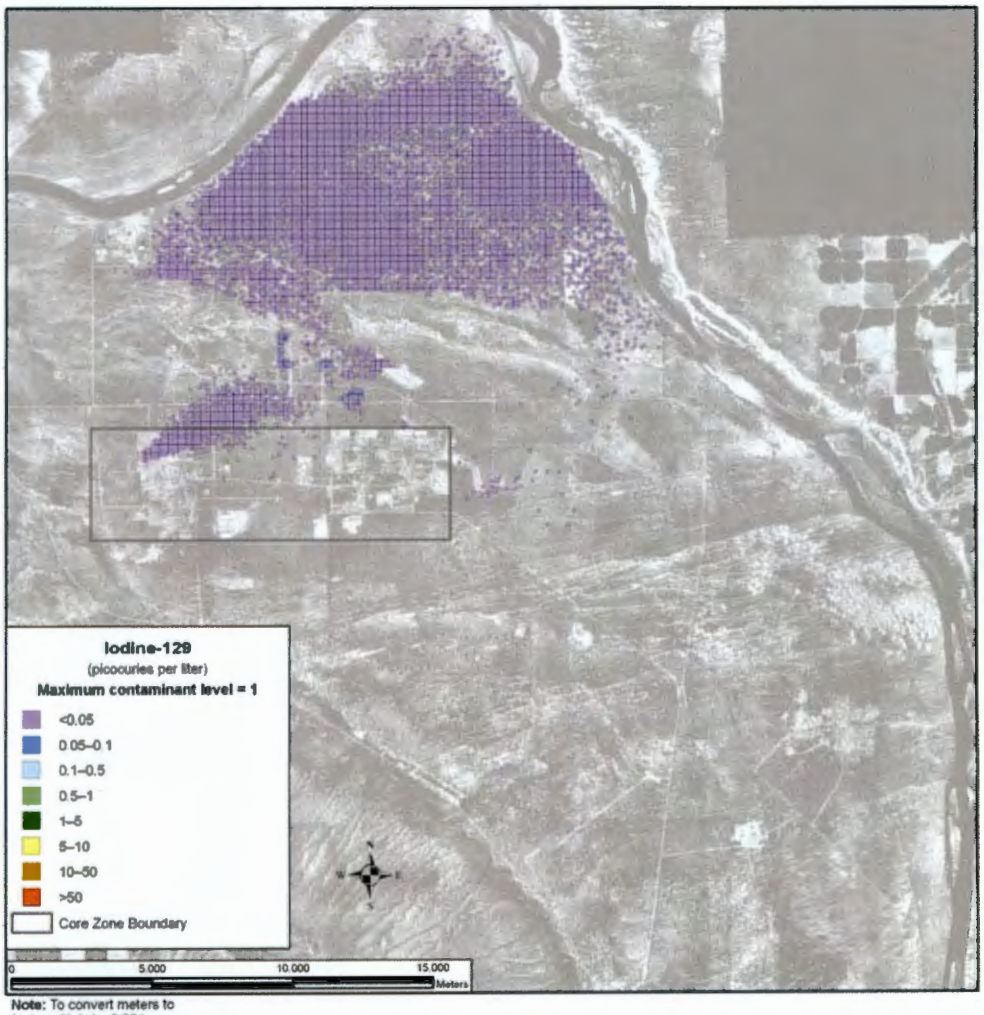
5.3.1.1.5 Analysis of Spatial Distribution of Concentration

This section presents the impacts of Waste Management Alternative 1 in terms of the spatial distribution of groundwater concentrations at selected times. Concentrations of radionuclides are in picocuries per liter, chemicals in micrograms per liter (see Figures 5–357 through 5–366). Concentrations for each radionuclide and chemical are indicated by a color scale that is relative to the benchmark concentration. Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations less than the benchmark concentration are indicated by the faded colors green, blue, indigo, and violet in order of decreasing

concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude.

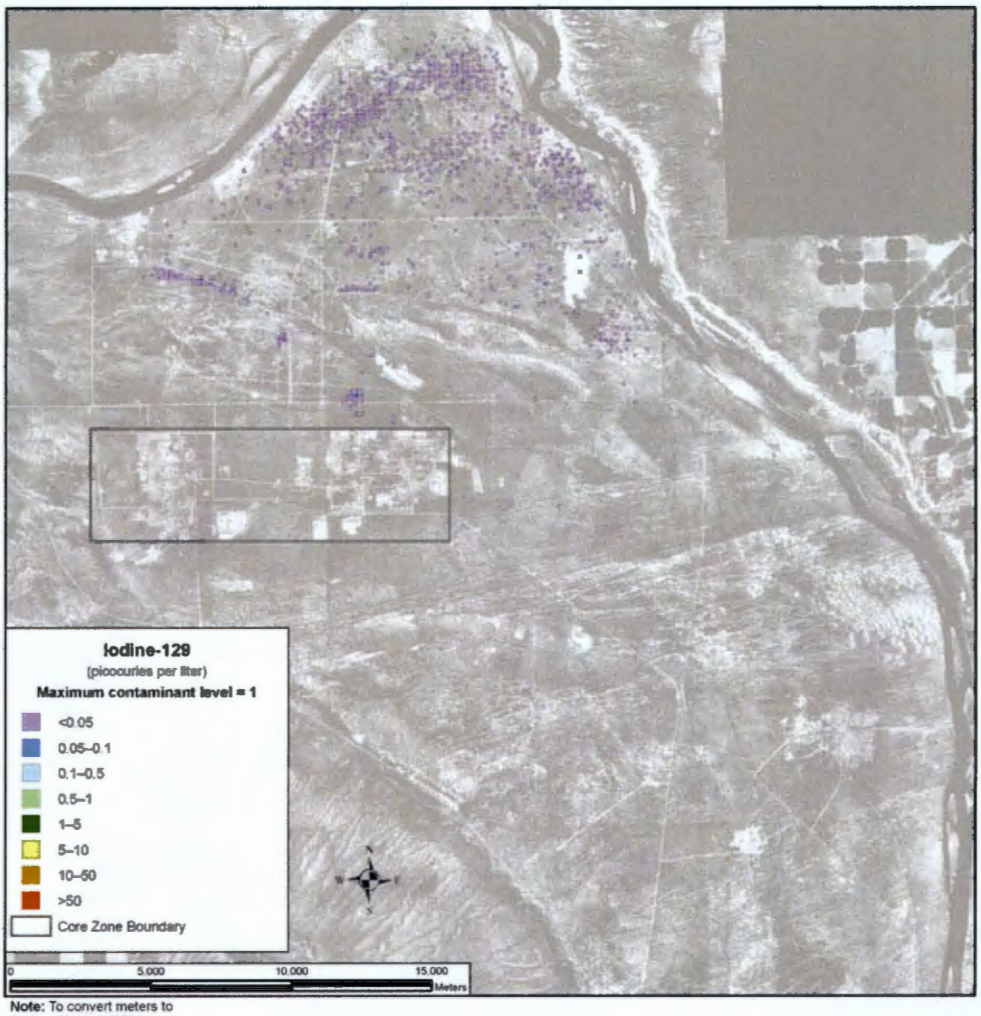
At CY 3890 (see Figure 5–357), there is a very low-concentration plume of iodine-129 stretching northeast of trenches 31 and 34 and through Gable Gap. By CY 7140 (Figure 5–358), the plume has almost completely dissipated. Technetium-99 (see Figures 5–359 and 5–360), nitrate (see Figures 5–361 and 5–362), and chromium (see Figures 5–363 and 5–364) show similar spatial distributions at selected times. Iodine-129, technetium-99, chromium, and nitrate are all conservative tracers (i.e., move at the rate of the pore water velocity).

Total uranium and uranium-238 show a different spatial distribution over time. They are not as mobile as the COPCs discussed above, moving about seven times slower than the pore water velocity. As a result, travel times through the vadose zone are longer, release to the aquifer is delayed, and travel times through the aquifer to the Columbia River are longer. By CY 11,885, there are total uranium and uranium-238 plumes (see Figures 5–365 and 5–366, respectively) extending through Gable Gap from trenches 31 and 34. Concentrations in all areas of the plumes remain below one-twentieth of the benchmark.



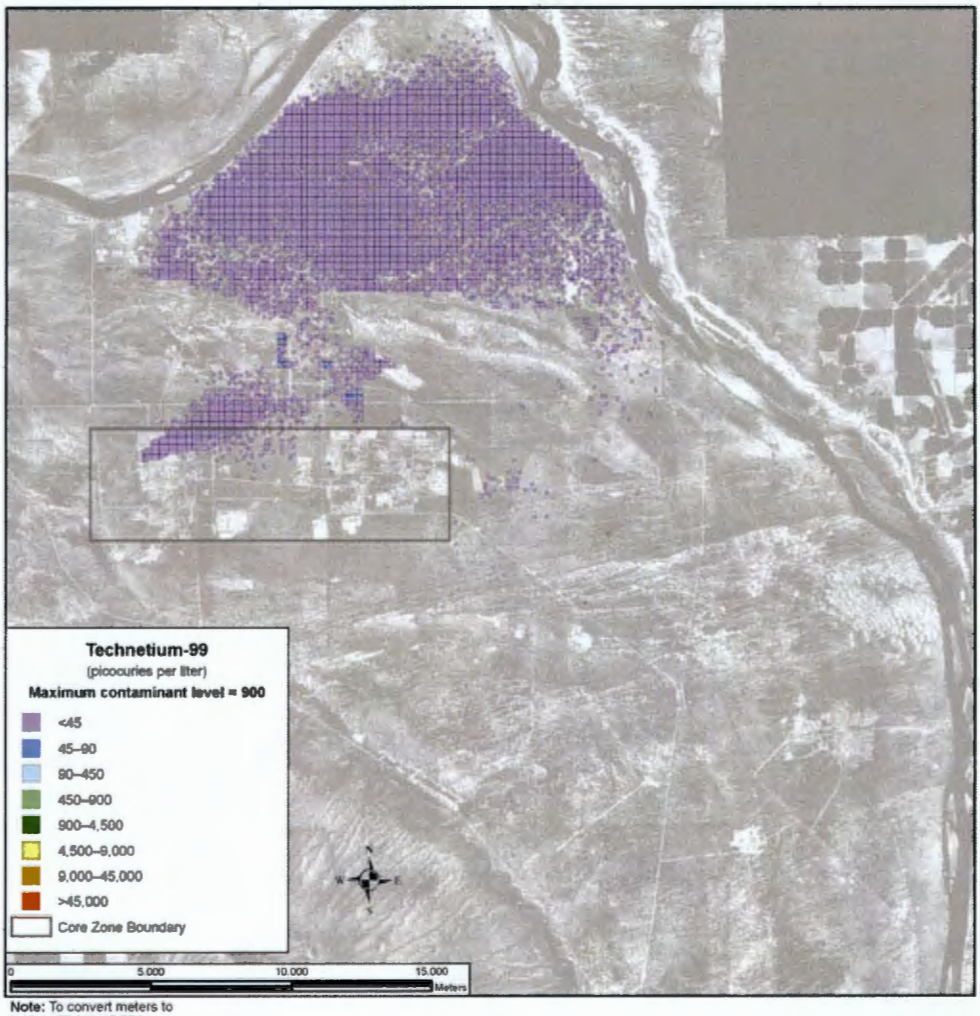
Note: To convert meters to feet, multiply by 3.281

Figure 5–357. Waste Management Alternative 1, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 3890



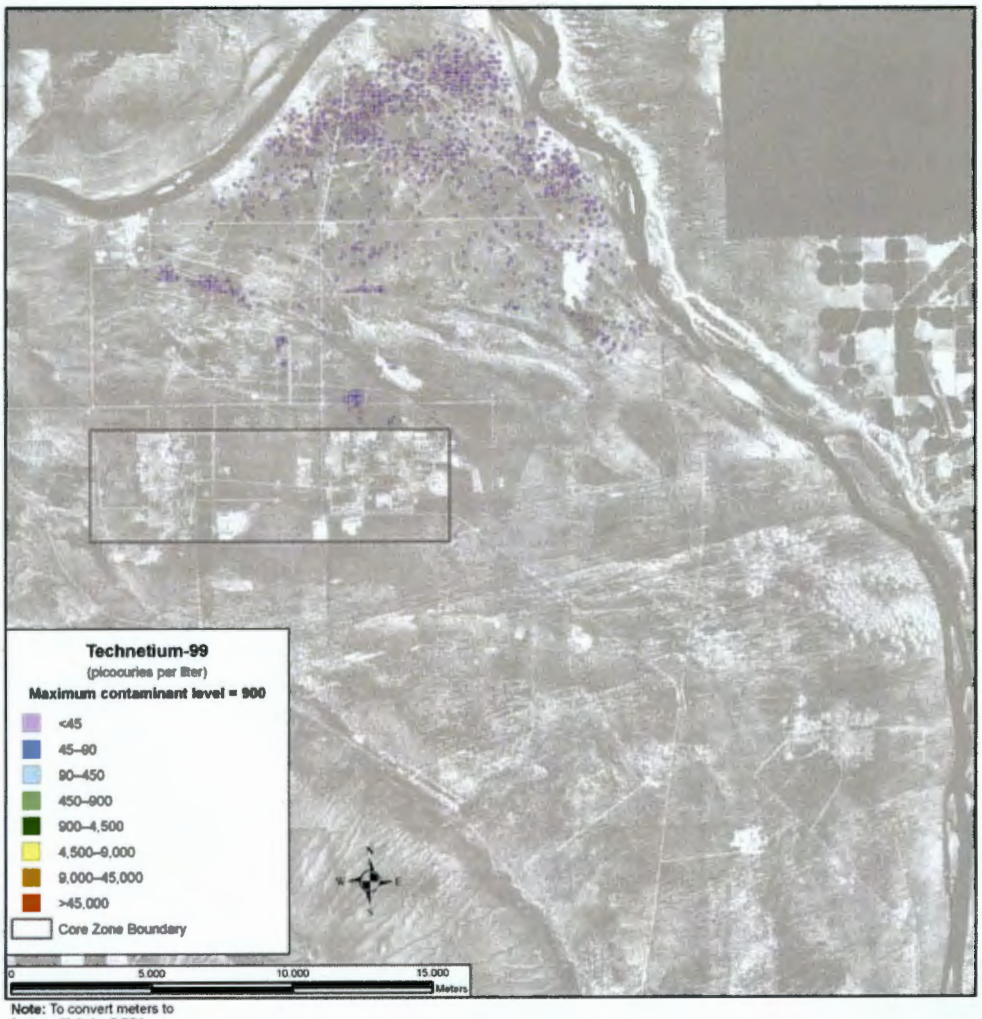
Note: To convert meters to feet, multiply by 3.281

Figure 5–358. Waste Management Alternative 1, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140



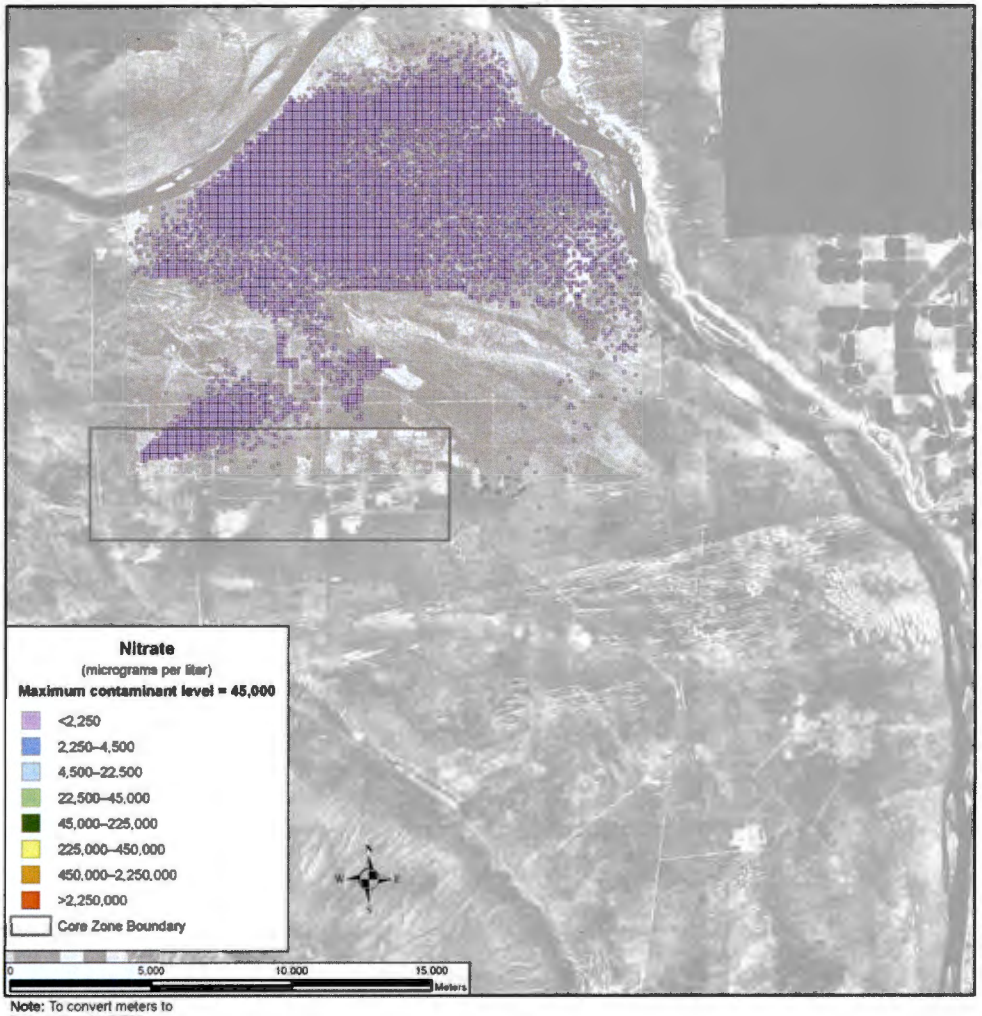
Note: To convert meters to feet, multiply by 3.281

Figure 5–359. Waste Management Alternative 1, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 3890



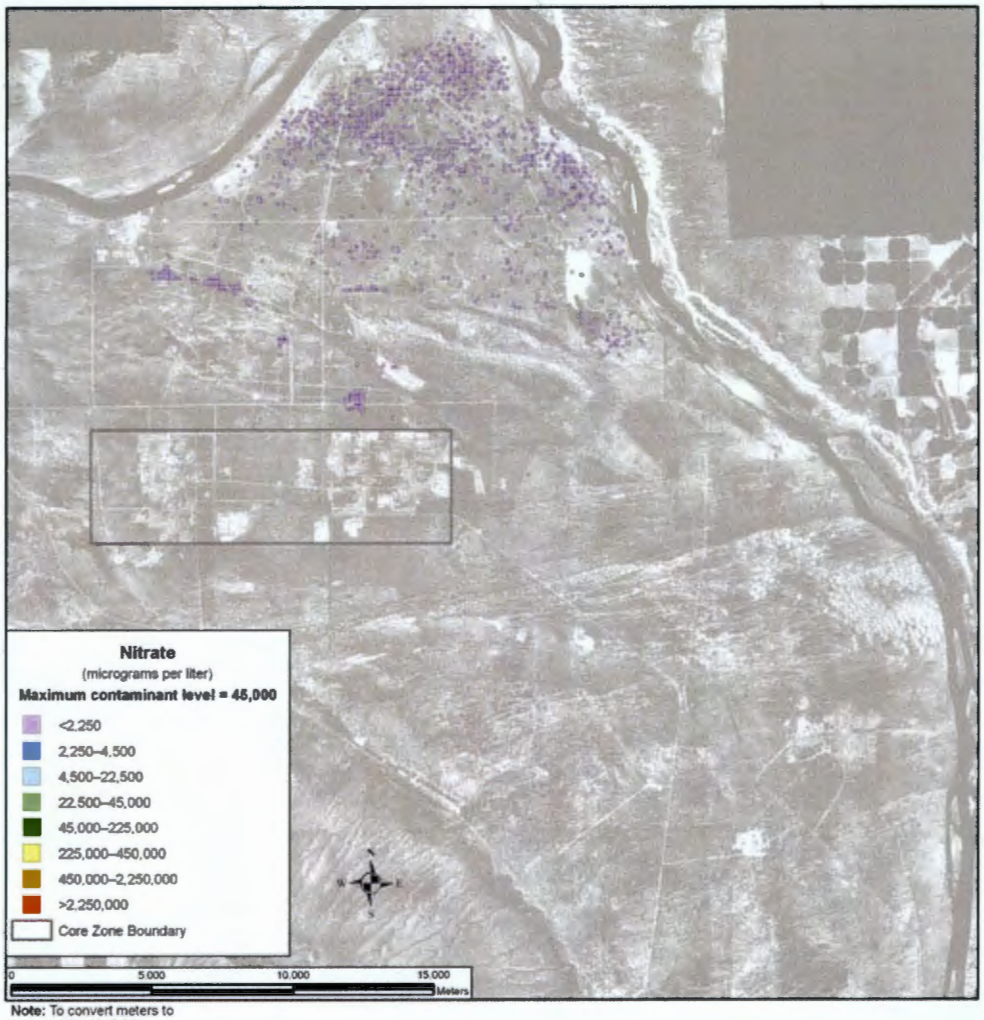
Note: To convert meters to feet, multiply by 3.281

Figure 5–360. Waste Management Alternative 1, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140



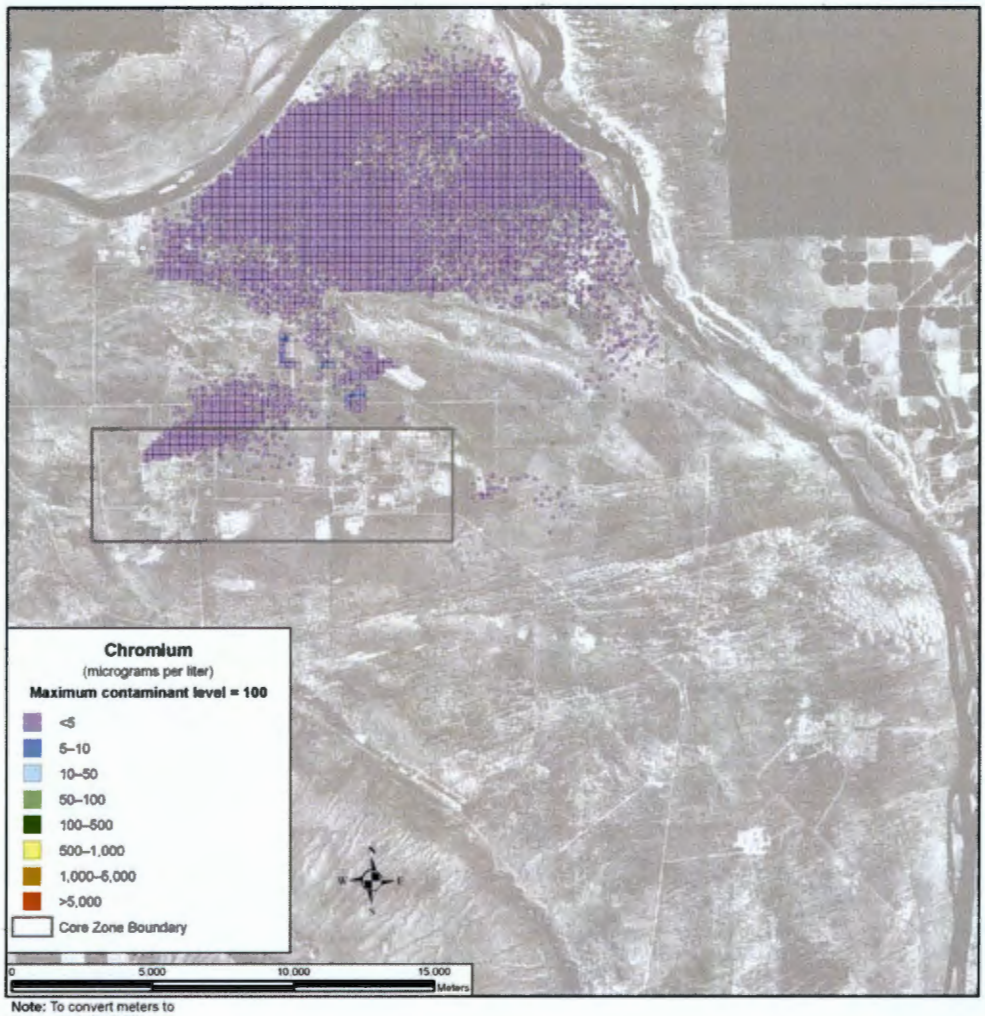
Note: To convert meters to feet, multiply by 3.281

Figure 5–361. Waste Management Alternative 1, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 3890



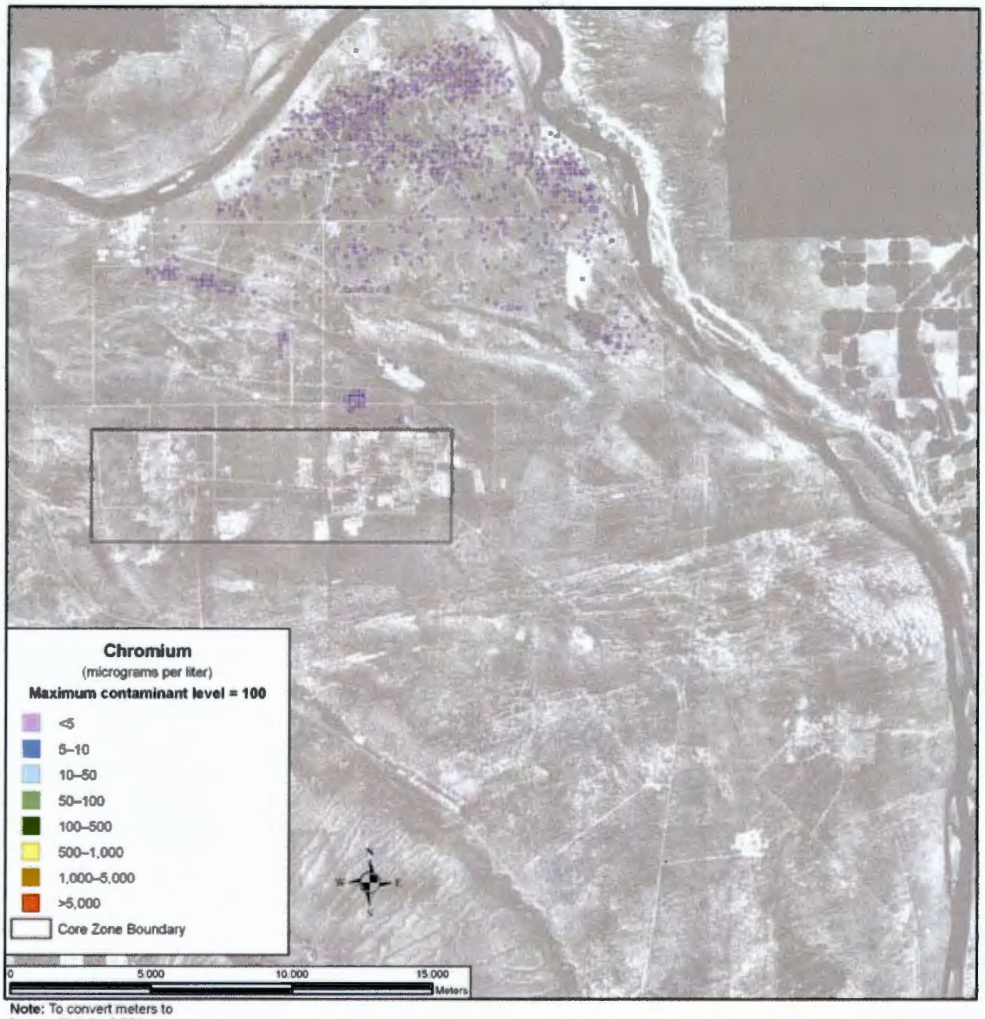
Note: To convert meters to feet, multiply by 3.281

Figure 5–362. Waste Management Alternative 1, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 7140



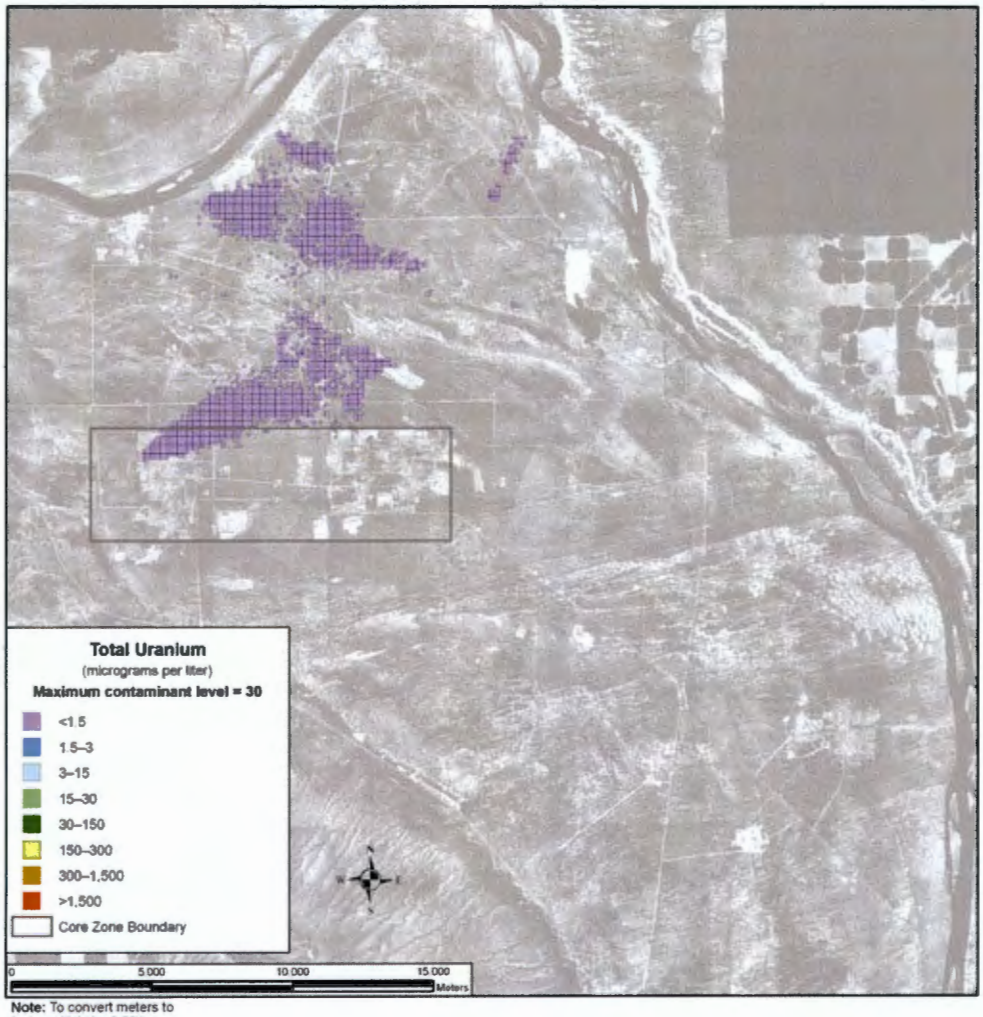
Note: To convert meters to feet, multiply by 3.281

Figure 5–363. Waste Management Alternative 1, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 3890



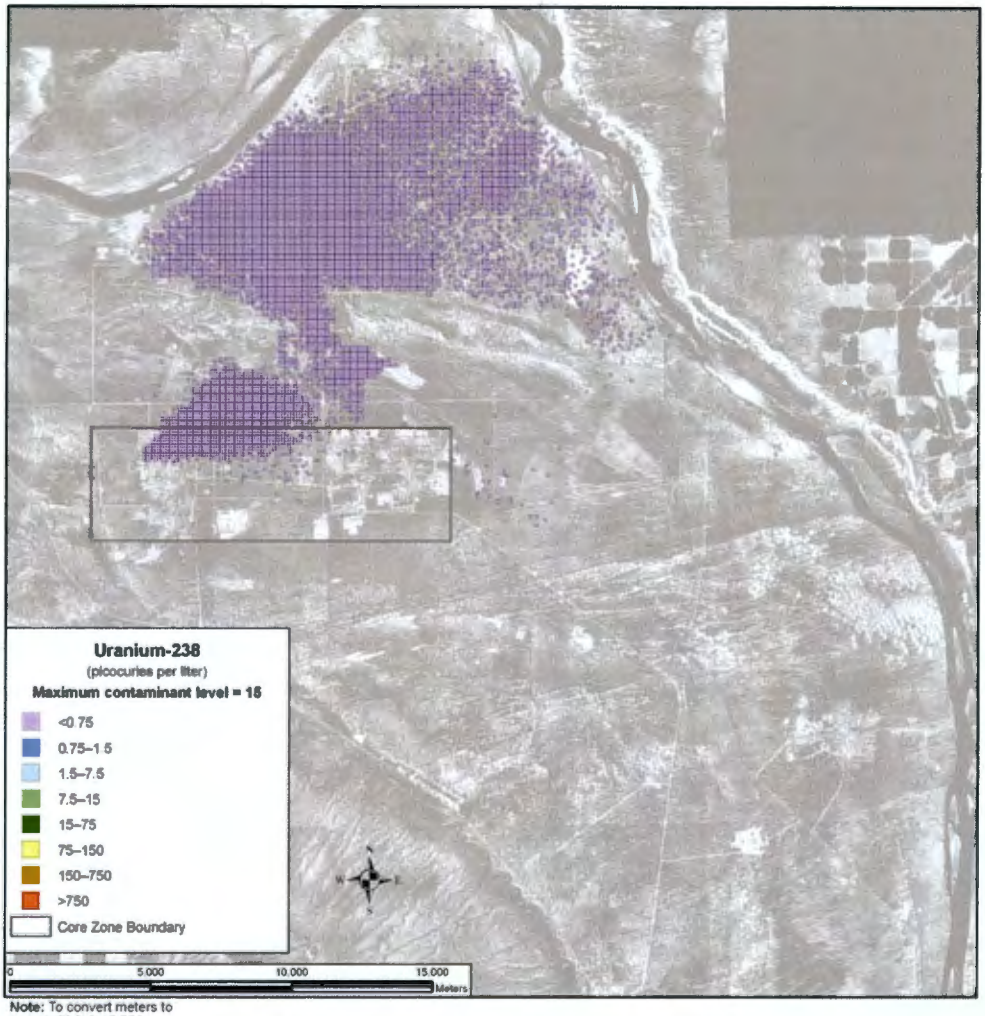
Note: To convert meters to feet, multiply by 3.281

Figure 5–364. Waste Management Alternative 1, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281

Figure 5–365. Waste Management Alternative 1, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 11,885



Note: To convert meters to feet, multiply by 3.281

Figure 5–366. Waste Management Alternative 1, Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 11,885

5.3.1.1.6 Summary of Impacts

Under Waste Management Alternative 1, all discharges originate in trenches 31 and 34.

No COPCs reached a concentration exceeding the benchmark concentration at the Core Zone Boundary or Columbia River during the course of the simulation.

5.3.1.2 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only

This section describes the groundwater analysis results for Waste Management Alternative 2, including long-term groundwater impacts of contaminant sources within the IDF-East and RPPDF Barriers. Impacts of sources remaining within the tank farm barriers are presented in Section 5.1, which discusses tank closure impacts. Impacts of sources remaining within the FFTF Barrier are presented in Section 5.2, which discusses FFTF decommissioning impacts.

Summaries of the proposed actions and timelines for Waste Management Alternative 2 are provided in Chapter 2, Section 2.5. There are three disposal facilities, as follows:

- LLBG 218-W-5 trenches 31 and 34, which receive LLW and MLLW. For the purposes of this analysis, the waste inventories associated with these trenches are included with the IDF-East inventory.

- IDF-East, located in the south-central part of the 200-East Area, which receives tank waste, FFTF decommissioning waste, onsite-generated non-CERCLA waste, and offsite-received LLW and MLLW. The LLW and MLLW inventories for trenches 31 and 34 are also included at IDF-East in this analysis.

- The RPPDF, located in the Core Zone between the 200-East and 200-West Areas, which receives lightly contaminated equipment and soils resulting from tank farm closure activities.

Three disposal groups were analyzed. Each has a different configuration and timeline for IDF-East and the RPPDF. The three disposal groups are discussed in detail in the following subsections.

5.3.1.2.1 Disposal Group 1

Disposal Group 1 is characterized by an operational completion date of CY 2050 for both IDF-East and the RPPDF. Under Disposal Group 1, IDF-East has a large capacity (1,200,000 cubic meters [1,570,000 cubic yards]) and the RPPDF has a smaller capacity (1,030,000 cubic meters [1,350,000 cubic yards]). These capacities were designed to meet the waste generation volumes associated with Tank Closure Alternatives 2B, 3A, 3B, 3C, 4, 5, and 6C; either FFTF Decommissioning Alternative 2 or 3; and waste management activities.

5.3.1.2.1.1 Disposal Group 1, Subgroup 1-A

ACTIONS AND TIMEFRAMES INFLUENCING GROUNDWATER IMPACTS

Subgroup 1-A covers disposal of waste generated under Tank Closure Alternative 2B and either FFTF Decommissioning Alternative 2 or 3, as well as onsite- and offsite-generated waste. Waste would be converted to IHLW and ILAW glass. IHLW would be stored on site, while ILAW glass would be disposed of at IDF-East.

For the long-term groundwater impact analysis, two major periods were identified for Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, as follows:

- The disposal period was assumed to start with the onset of disposal operations in IDF-East and the RPPDF in CY 2008 and continue through CY 2050, when these facilities would be operationally closed. During the disposal period, the materials in these permitted, operational facilities would not be available for release to the environment.

- The post-disposal period was assumed to start in CY 2051 and continue through the 10,000-year period of analysis until CY 11,940. At the start of this period, materials in the facilities become available for release to the environment, and modified RCRA Subtitle C barriers would be emplaced over IDF-East and the RPPDF to limit infiltration during the first 500 years of the post-disposal period.

COPC DRIVERS

A total of 40 COPCs were analyzed for Waste Management Alternative 2. Complete results are tabulated in Appendices M, N, and O. The discussion in this section of long-term impacts associated with Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A (Tank Closure Alternative 2B, FFTF Decommissioning Alternative 3, and onsite- and offsite-generated waste), is focused on the following COPC drivers:

- Radiological risk drivers: iodine-129 and technetium-99
- Chemical risk drivers: none
- Chemical hazard drivers: boron, chromium, fluoride, and nitrate

The COPC drivers for Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, were selected by evaluating the risk or hazard associated with all 40 COPCs during the year of peak risk or hazard at the Core Zone Boundary during the 10,000-year period of analysis and selecting the major contributors. This process is described in Appendix Q. The radiological risk drivers listed above account for essentially 100 percent of the radiological risk. No chemical risk is predicted. The chemical hazard drivers above account for over 99 percent of the chemical hazard associated with Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A.

The COPC drivers that are discussed in detail in this section (iodine-129, technetium-99, boron, chromium, fluoride, and nitrate) are all mobile (i.e., move with groundwater) and long-lived (relative to the 10,000-year period of analysis), or stable. They are essentially conservative tracers. The other COPCs that were analyzed do not significantly contribute to drinking water risk at the Core Zone Boundary during the period of analysis because of high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of both factors.

ANALYSIS OF RELEASE AND MASS BALANCE

This section presents the impacts of Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, in terms of the total amount of COPCs released to the vadose zone, groundwater, and the Columbia River during the 10,000-year period of analysis. Releases of radionuclides are totaled in curies; chemicals in kilograms (see Figures 5–367 through 5–378). Three subtotals are plotted, representing releases from the RPPDF and IDF-East, which include ILAW glass, Effluent Treatment Facility (ETF)-generated secondary waste, retired melters, tank closure secondary waste, FFTF Decommissioning Alternative 3 waste, waste management secondary waste, and onsite- and offsite-generated waste. Note that the release amounts are plotted on a logarithmic scale to facilitate visual comparison of releases that vary over more than 10 orders of magnitude.

Figure 5–367 shows the estimated release at IDF-East to the vadose zone for the radiological risk drivers representing the individual waste form release and Figure 5–368, the chemical hazard drivers. The release to the vadose zone is controlled by the inventory (i.e., 100 percent of the inventory was released during the post-disposal period in the analysis). For the radiological COPCs (technetium-99 and iodine-129), the releases range over seven orders of magnitude, depending on the source. The chemical COPCs (boron, chromium, fluoride, and nitrate) in IDF-East all have releases associated with waste management secondary waste and onsite-generated waste. Other sources include 99 percent of the nitrate release from ETF-generated secondary waste and 81 percent of the chromium release from tank closure secondary waste; the other chromium releases are dispersed in the other waste forms.

Figure 5–369 shows the estimated release at IDF-East to groundwater for the radiological risk drivers and Figure 5–370, the chemical hazard drivers. In addition to the inventory considerations discussed in the previous paragraph, release to groundwater is controlled by the transport properties of the COPC drivers

and by the rate of moisture movement through the vadose zone. For the conservative tracers (iodine-129, technetium-99, boron, chromium, fluoride, and nitrate), the amount released to groundwater is essentially equal to the amount released to the vadose zone. The exception to this is the release associated with retired melters, which decreases at groundwater for both technetium-99 and iodine-129 by more than 40 percent. These results suggest that melters as a source do not continue to release after the initial exposure.

Figure 5–371 shows the estimated release at IDF-East to the Columbia River for the radiological risk drivers and Figure 5–372, the chemical hazard drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers. For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), the amount released to the Columbia River is essentially equal to the amount released to groundwater. The exception to this is the *de minimis* release associated with the retired melters.

Figure 5–373 shows the estimated release at the RPPDF to the vadose zone for the radiological risk drivers and Figure 5–374, the chemical hazard drivers. The release of technetium-99 is more than two orders of magnitude greater than the release of iodine-129 at the RPPDF. The chemical constituents show nitrate as the predominant COPC, about two orders of magnitude greater than the release of chromium at the RPPDF.

Figure 5–375 shows the estimated release at the RPPDF to groundwater for the radiological risk drivers and Figure 5–376, the chemical hazard drivers. For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), the amount released to groundwater is essentially equal to the amount released to the vadose zone.

Figure 5–377 shows the estimated release at the RPPDF to the Columbia River for the radiological risk drivers and Figure 5–378, the chemical hazard drivers. Both figures show trends similar to those discussed in the previous paragraph for the release to the Columbia River for all COPC drivers at the RPPDF.

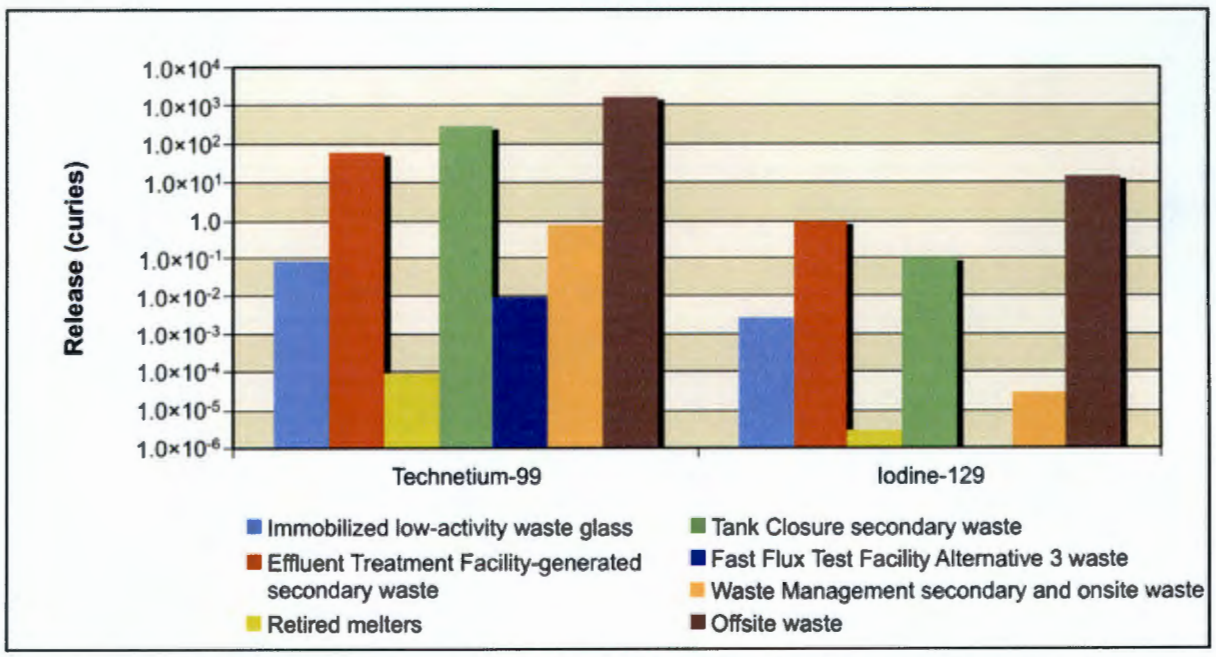


Figure 5–367. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Radiological Releases at 200-East Area Integrated Disposal Facility to Vadose Zone

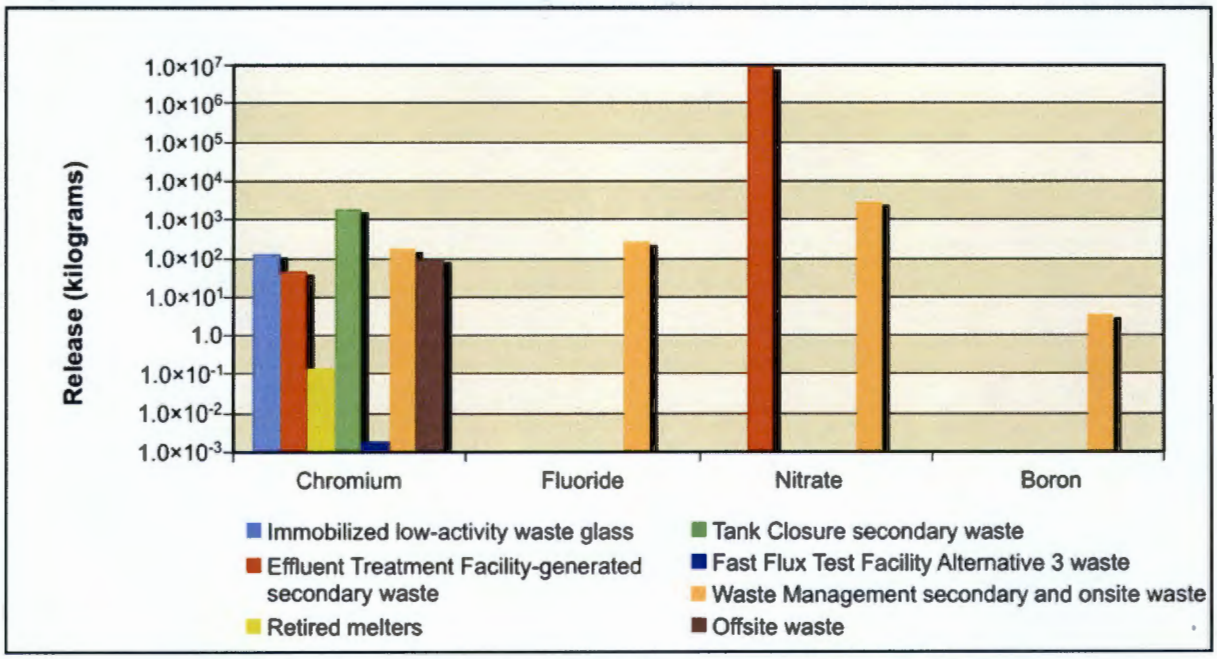


Figure 5–368. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Chemical Releases at 200-East Area Integrated Disposal Facility to Vadose Zone

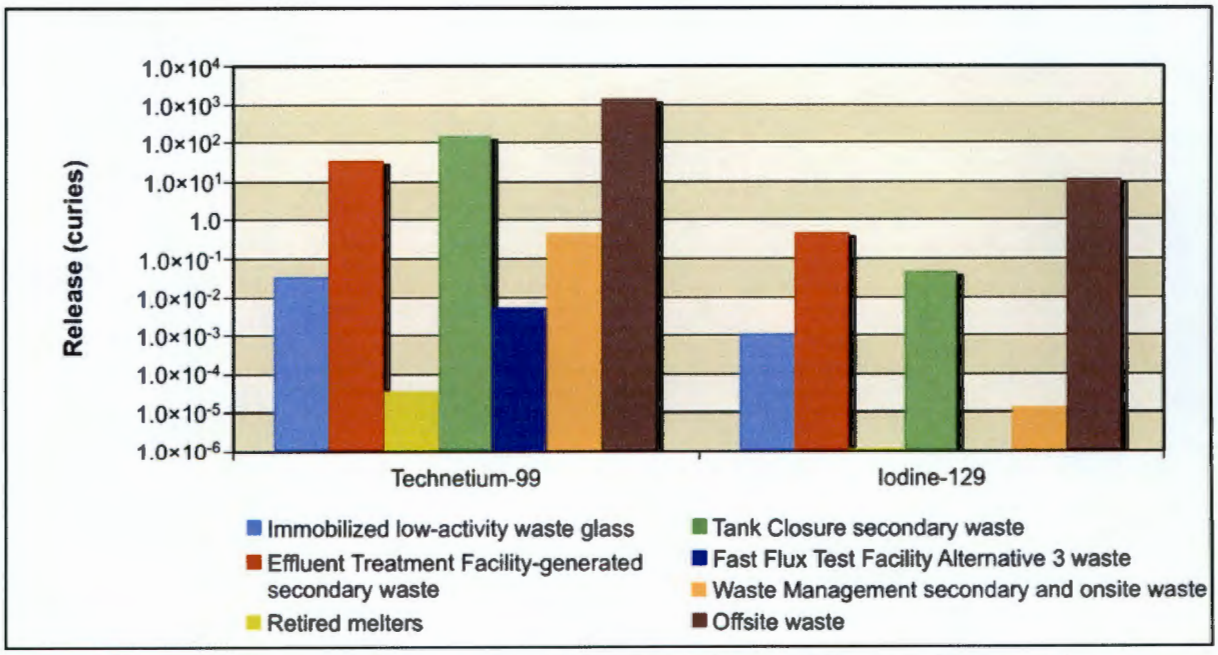


Figure 5–369. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Radiological Releases at 200-East Area Integrated Disposal Facility to Groundwater

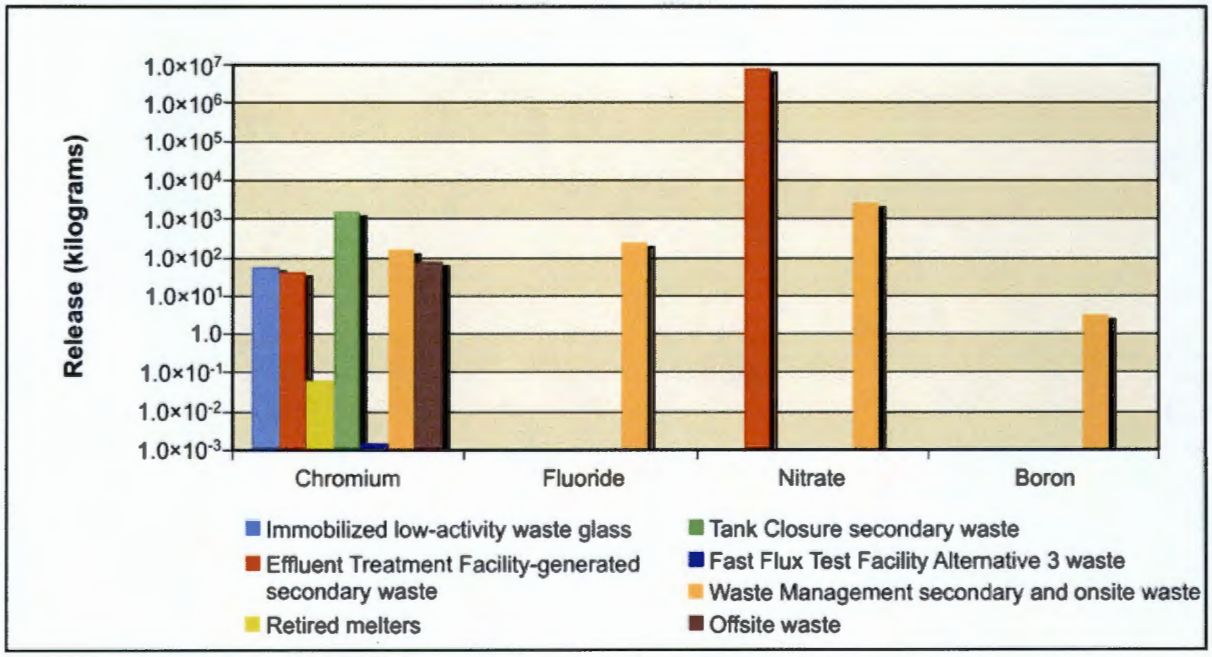


Figure 5–370. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Chemical Releases at 200-East Area Integrated Disposal Facility to Groundwater

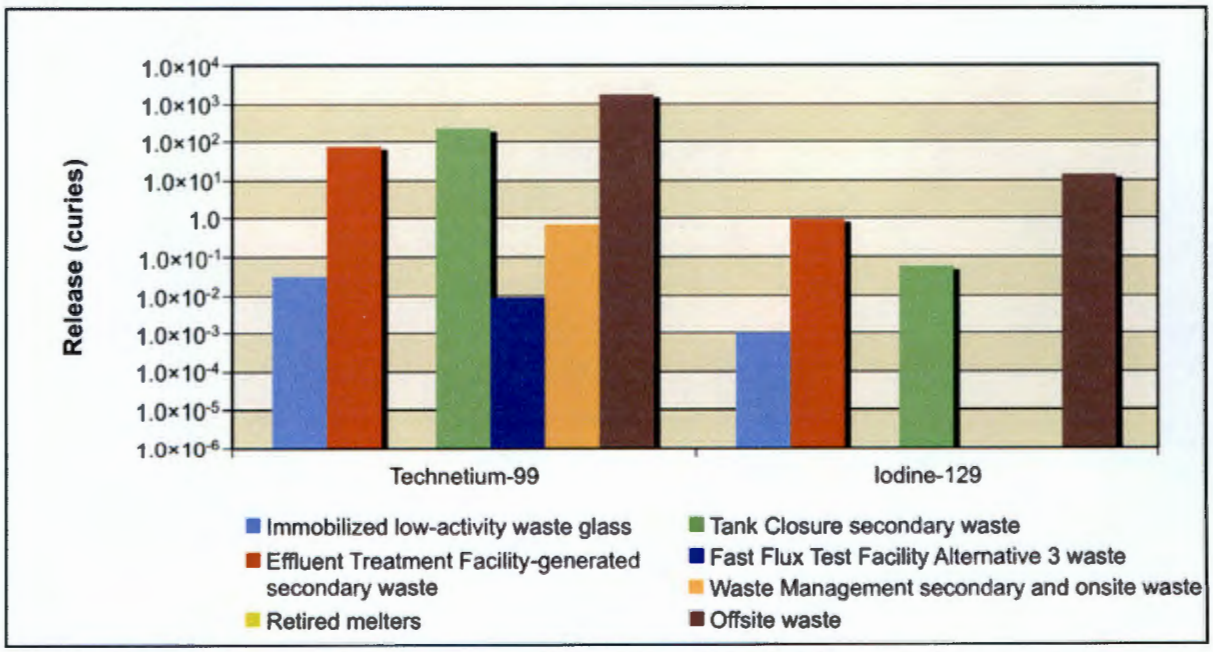


Figure 5–371. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Radiological Releases at 200-East Area Integrated Disposal Facility to Columbia River

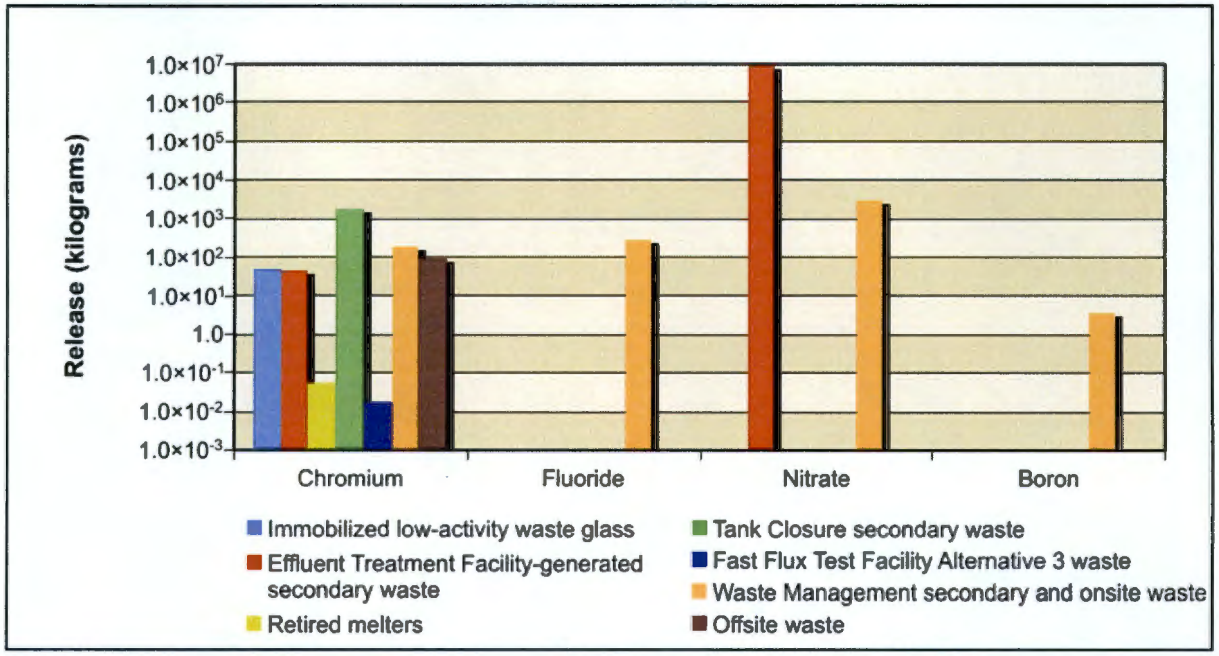


Figure 5–372. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Chemical Releases at 200-East Area Integrated Disposal Facility to Columbia River

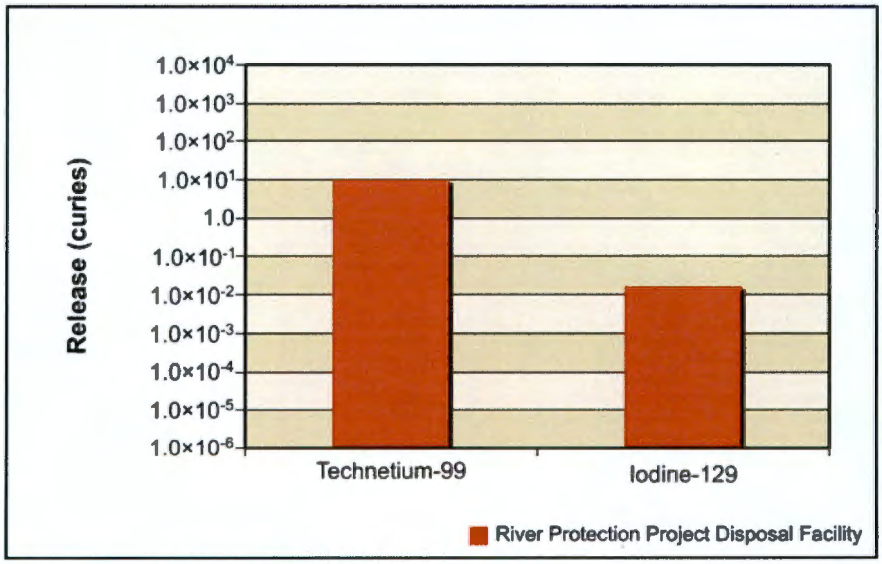


Figure 5–373. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Radiological Releases at River Protection Project Disposal Facility to Vadose Zone

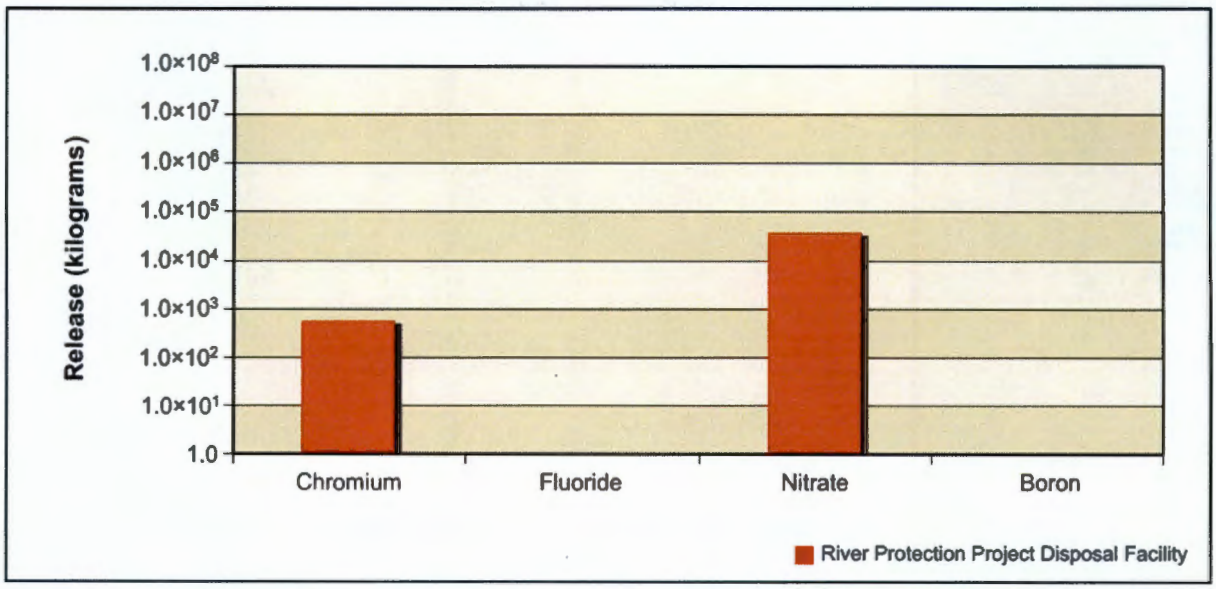


Figure 5–374. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Chemical Releases at River Protection Project Disposal Facility to Vadose Zone

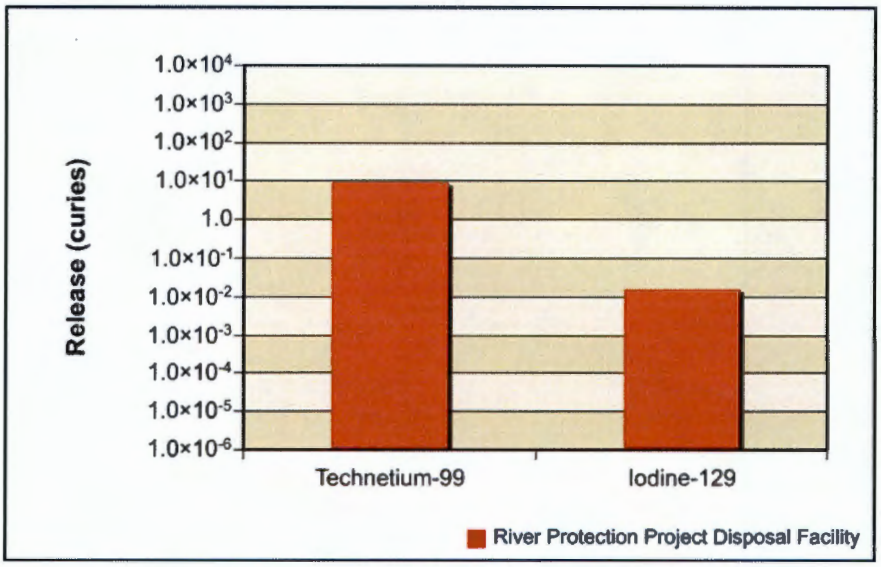


Figure 5–375. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Radiological Releases at River Protection Project Disposal Facility to Groundwater

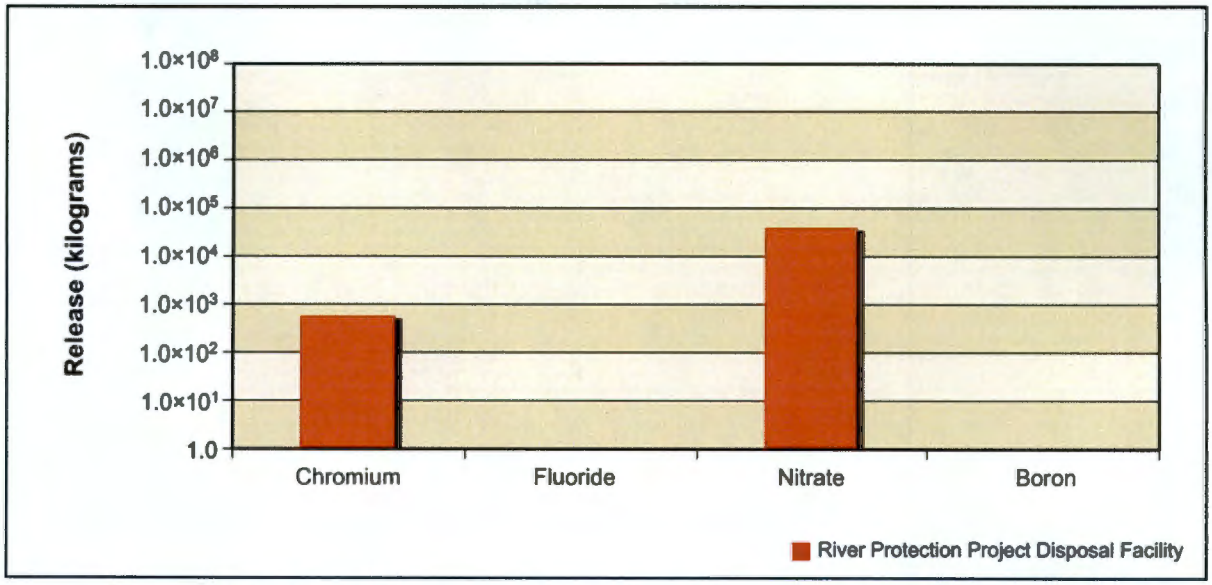


Figure 5–376. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Chemical Releases at River Protection Project Disposal Facility to Groundwater

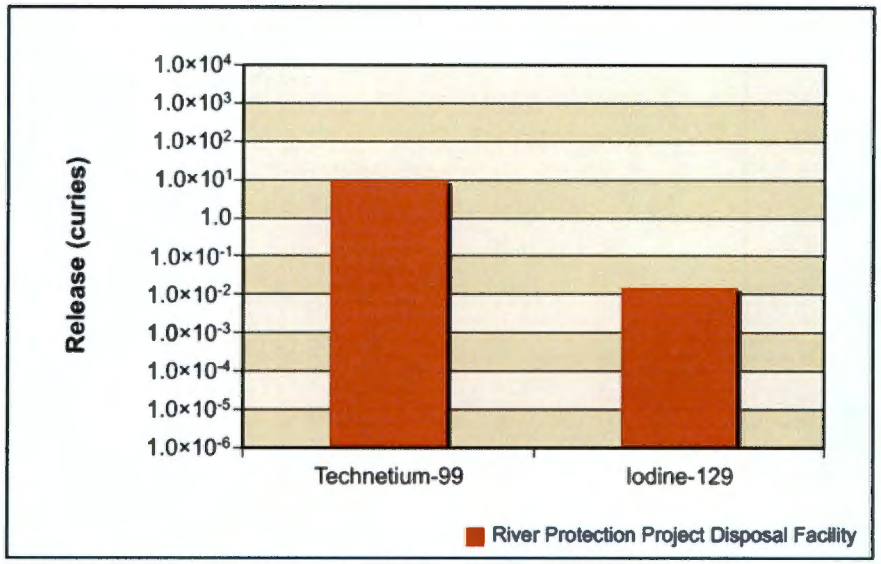


Figure 5–377. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Radiological Releases at River Protection Project Disposal Facility to Columbia River

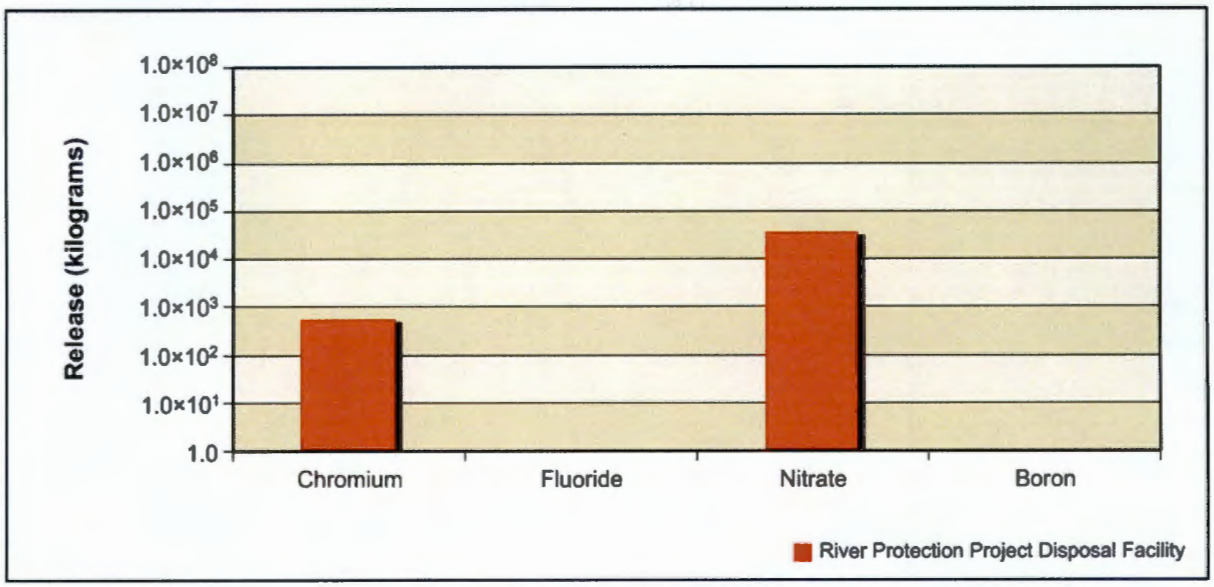


Figure 5–378. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Chemical Releases at River Protection Project Disposal Facility to Columbia River

ANALYSIS OF CONCENTRATION VERSUS TIME

This section presents the analysis of Disposal Group 1, Subgroup 1-A, impacts in terms of groundwater concentration versus time at the Core Zone Boundary and the Columbia River. Concentrations of radionuclides are in picocuries per liter; chemicals in micrograms per liter (see Figures 5–379 through 5–383). The benchmark concentration for each radionuclide and chemical is also shown. Because of the discrete nature of the concentration carried across a barrier or the river, a line denoting the 95th percentile upper confidence limit of the concentration is included on a few graphs. This confidence interval was calculated to show when the actual concentration over a certain time interval is likely (95 percent of the time) to be at or below this value. The confidence interval is basically a statistical aid to interpreting data with a significant amount of random fluctuation (noise). The confidence interval was calculated when the concentration had a reasonable degree of noise, the concentration's trend was level, and the concentrations were near the benchmark. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over five orders of magnitude. Table 5–77 lists the maximum concentrations of the COPCs in the peak year at IDF-East and the RPPDF, Core Zone Boundary, and Columbia River nearshore.

Figures 5–379 through 5–382 show concentration versus time for iodine-129, technetium-99, chromium, and nitrate (the conservative tracers). Releases from IDF-East and the RPPDF at the Core Zone Boundary cause groundwater concentrations to exceed the benchmark concentration for iodine-129 in CY 5500; using the confidence interval, the concentrations appear slightly below the benchmark for both the Core Zone Boundary and the Columbia River nearshore. The same trend is applicable to technetium-99 concentrations during the period of analysis. Chromium and nitrate measurements at the Core Zone Boundary and the Columbia River nearshore are below the benchmark concentrations by one to three orders of magnitude, showing a trend similar to iodine-129 and technetium-99.

Figure 5–383 shows concentration versus time for total uranium. Because of the high retardation of uranium, no contamination appears until CY 9800, when total uranium concentrations at the Core Zone Boundary first surpass 1.0×10^{-8} micrograms per liter. Uranium-238 does not surpass 1.0×10^{-8} picocuries per liter during the simulation, but total uranium continues to rise near the end of the

10,000-year period of analysis, still well below the benchmark for both the Core Zone Boundary and Columbia River nearshore by eight to nine orders of magnitude at the end of the period of analysis.

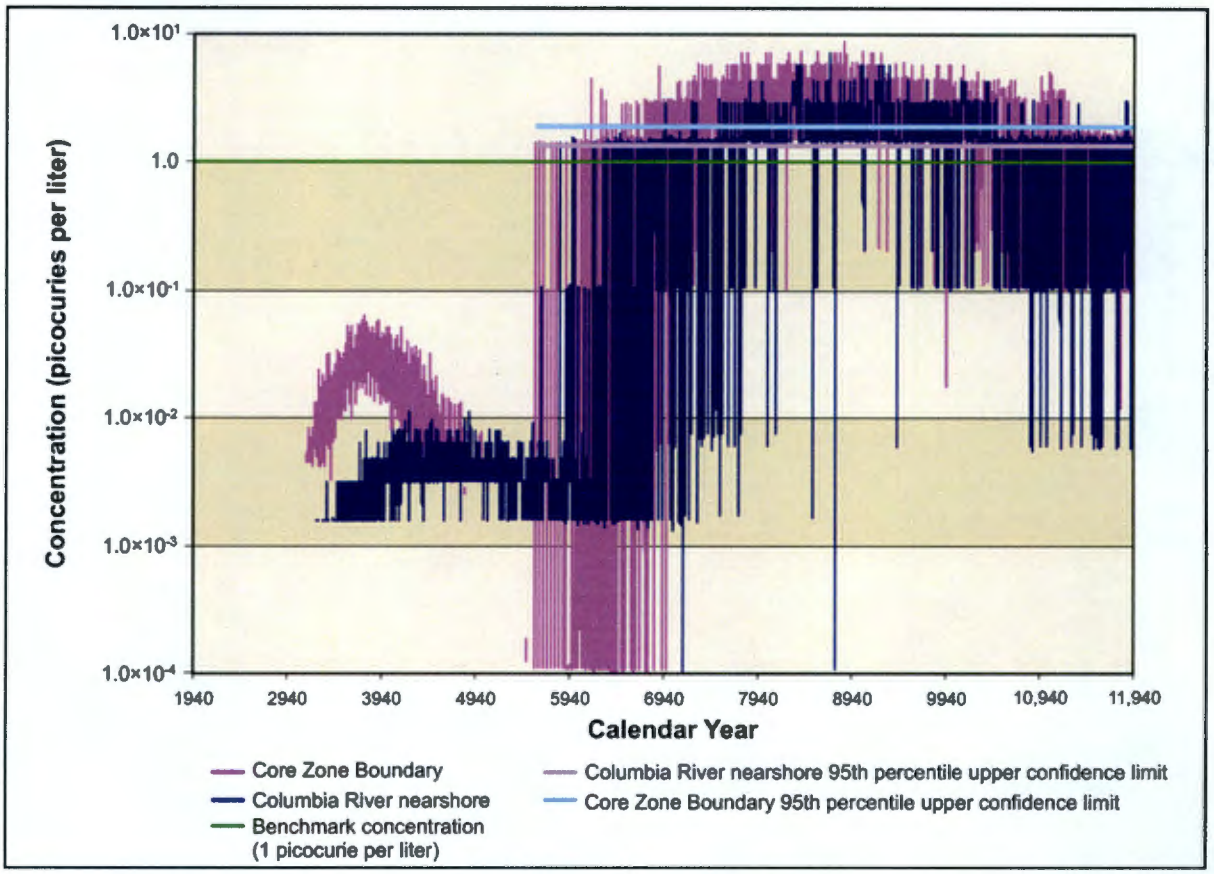


Figure 5–379. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Iodine-129 Concentration Versus Time

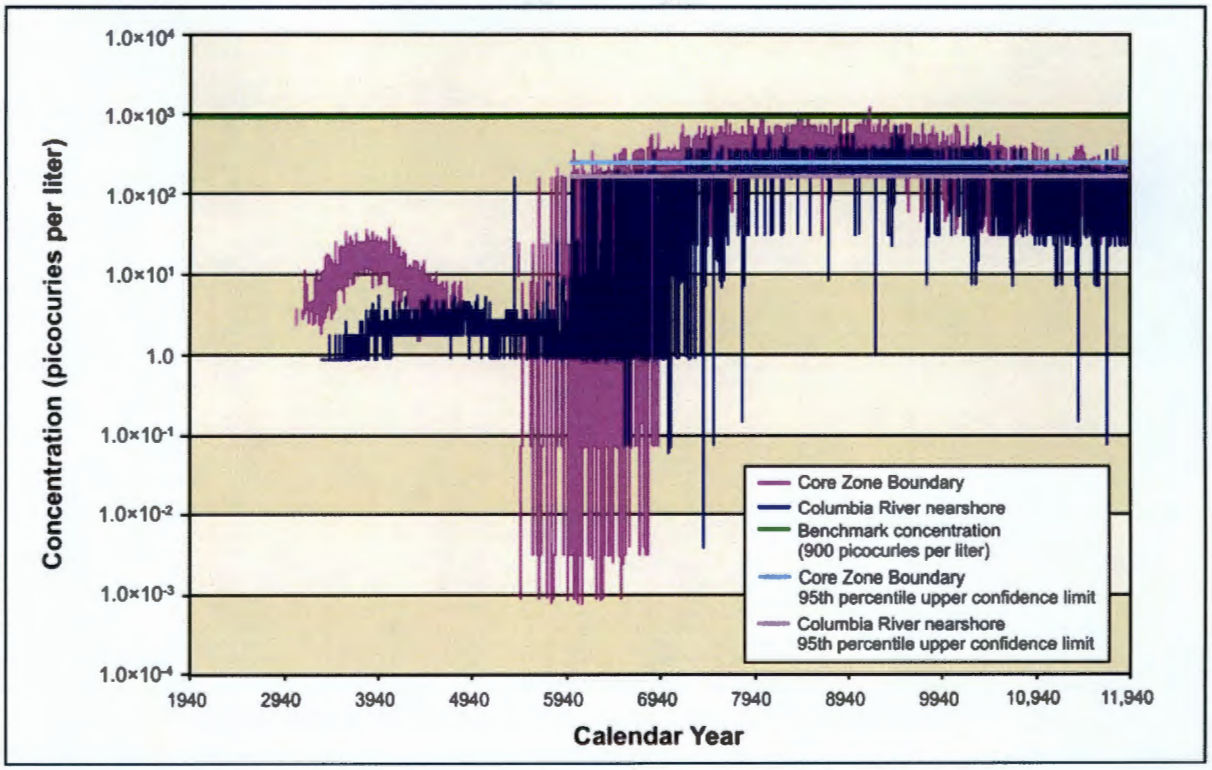


Figure 5–380. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Technetium-99 Concentration Versus Time

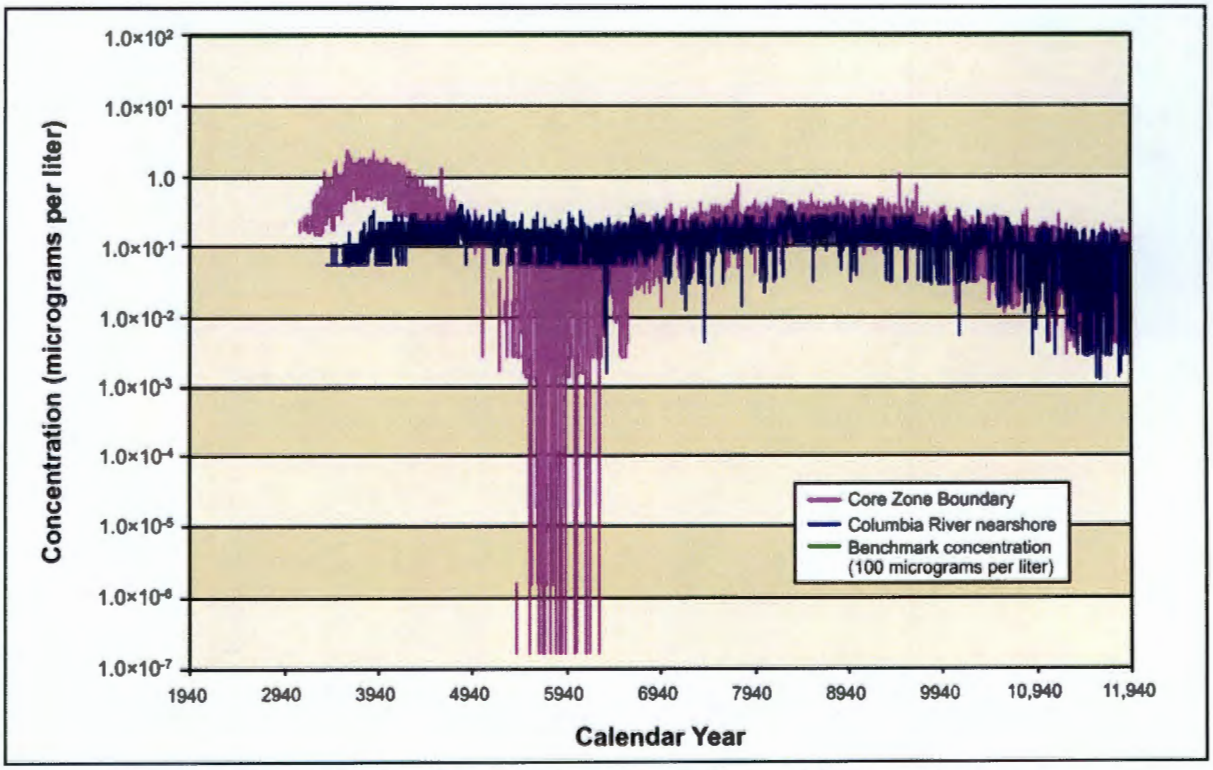


Figure 5–381. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Chromium Concentration Versus Time

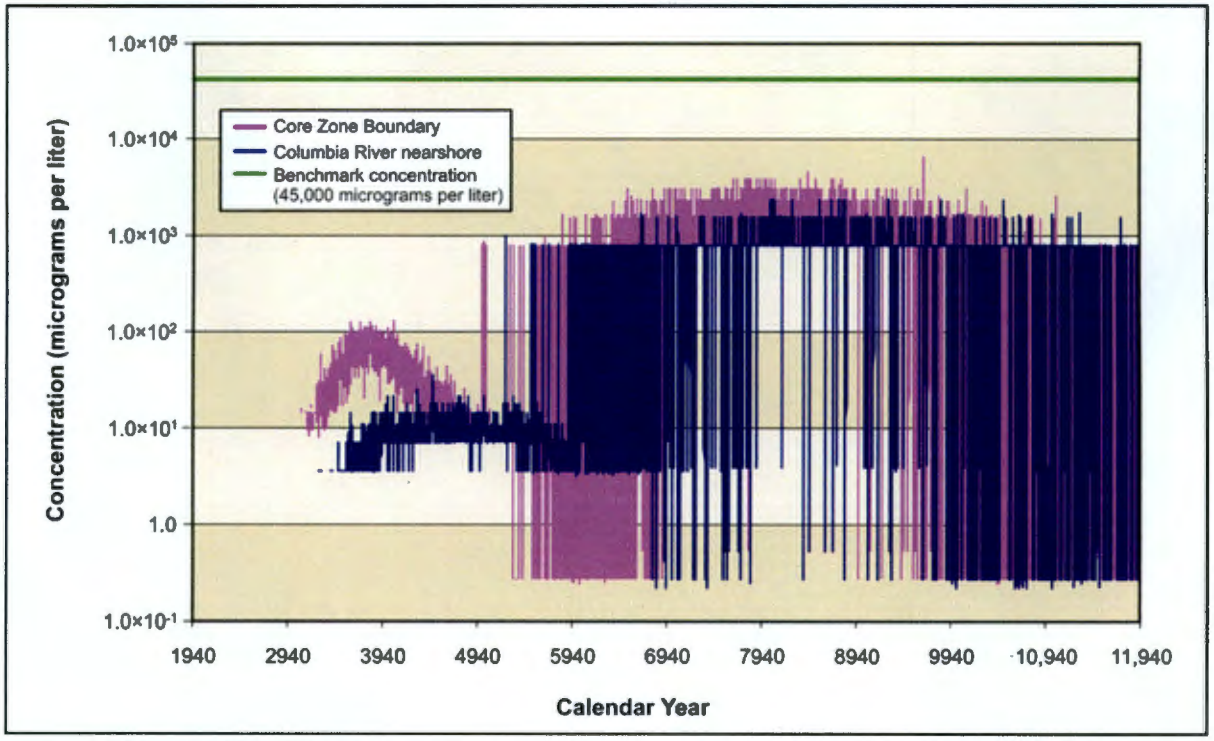


Figure 5–382. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Nitrate Concentration Versus Time

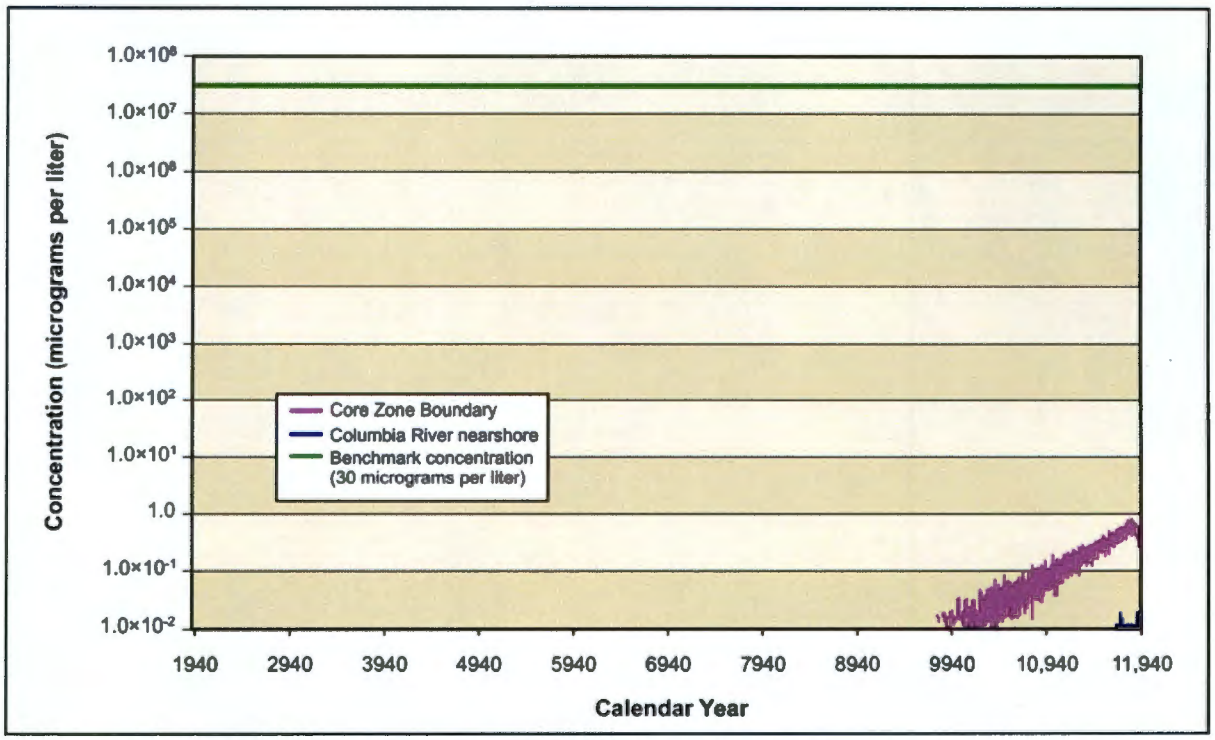


Figure 5–383. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Total Uranium Concentration Versus Time

Table 5–77. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Maximum COPC Concentrations in the Peak Year at IDF-East and the RPPDF, Core Zone Boundary, and Columbia River Nearshore

Contaminant	IDF-East	RPPDF	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclide in picocuries per liter					
Technetium-99	**2,040**	33	**1,180**	675	900
	(9004)	(3825)	(9155)	(9451)	
Iodine-129	**19**	0.1	**9**	**7**	1
	(8739)	(3772)	(8858)	(8700)	
Chemical in micrograms per liter					
Chromium	4	2	2	1	100
	(8511)	(3856)	(3889)	(8898)	
Fluoride	0	0	1	0	4,000
	(8035)	(1940)	(7258)	(8913)	
Nitrate	14,200	149	5,630	2,440	45,000
	(8522)	(3811)	(9653)	(8827)	

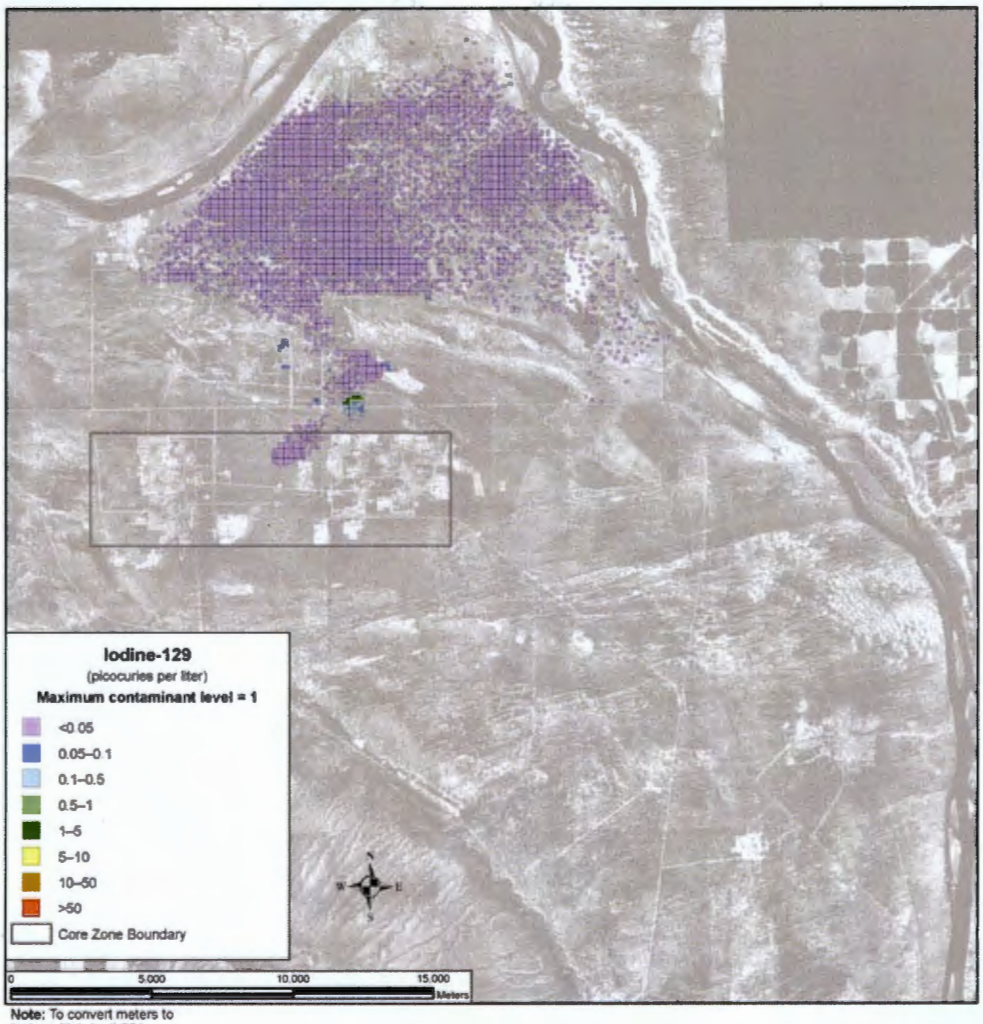
Note: Corresponding calendar years shown in parentheses. Concentrations that would exceed the benchmark value are indicated in **bold** text.

Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility; RPPDF=River Protection Project Disposal Facility.

ANALYSIS OF SPATIAL DISTRIBUTION OF CONCENTRATION

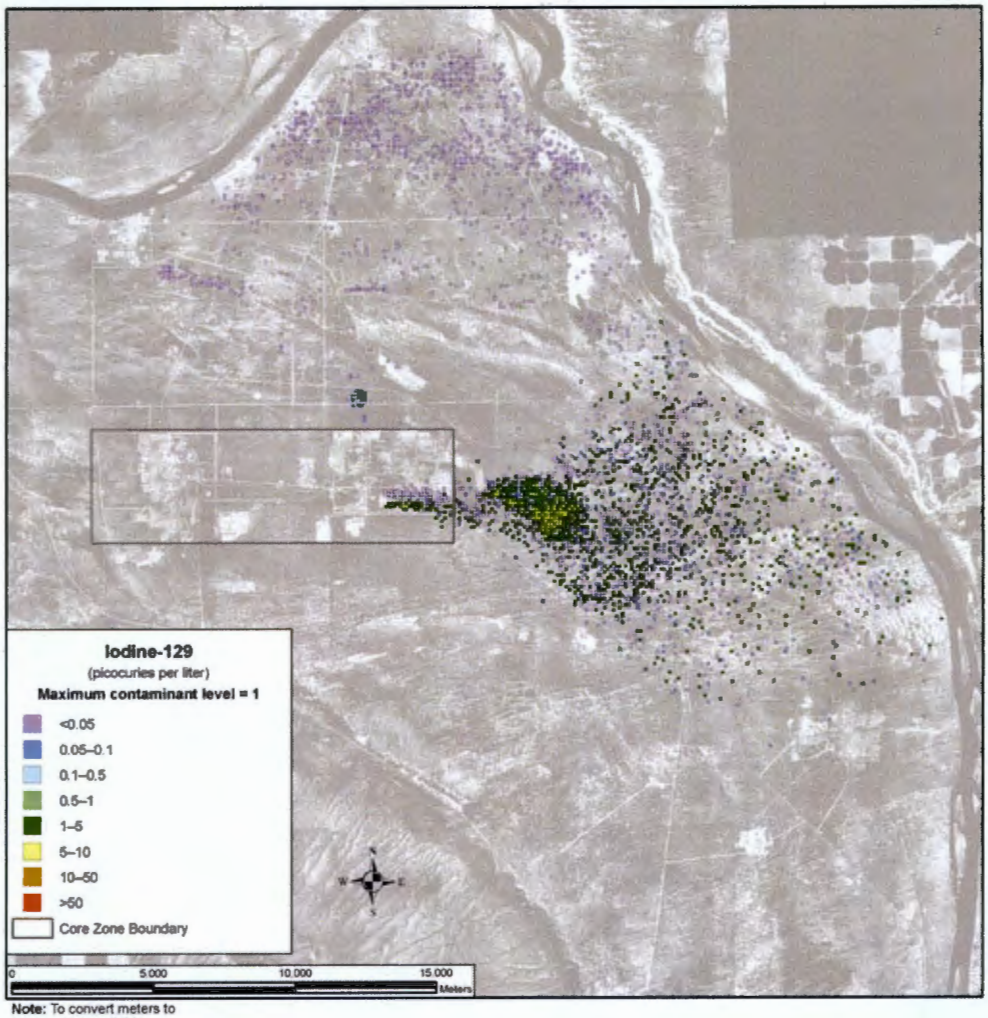
This section presents the impacts of Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, in terms of the spatial distribution of groundwater concentration at selected times. Concentrations of radionuclides are in picocuries per liter; chemicals in micrograms per liter (see Figures 5–384 through 5–396). Concentrations for each radionuclide and chemical are indicated by a color scale that is relative to the benchmark concentration. Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations less than the benchmark concentration are indicated by the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude.

Figures 5–384 through 5–386 show the spatial distribution of groundwater concentration for iodine-129. During CY 3890, there is a low-concentration plume that stretches north from the RPPDF and through Gable Gap. By CY 7140, the plume from the RPPDF is gone, but a new plume has formed, traveling east from IDF-East. The peak concentrations in this plume are greater than the benchmark. By CY 11,885, the plume continues to spread toward the river and the concentrations within remain relatively the same. Technetium-99 (see Figures 5–387 through 5–389), chromium (see Figures 5–390 through 5–392), and nitrate (see Figures 5–393 through 5–395) show similar spatial distributions at selected times. Iodine-129, technetium-99, chromium, and nitrate are all conservative tracers (i.e., move at the rate of the pore water velocity).



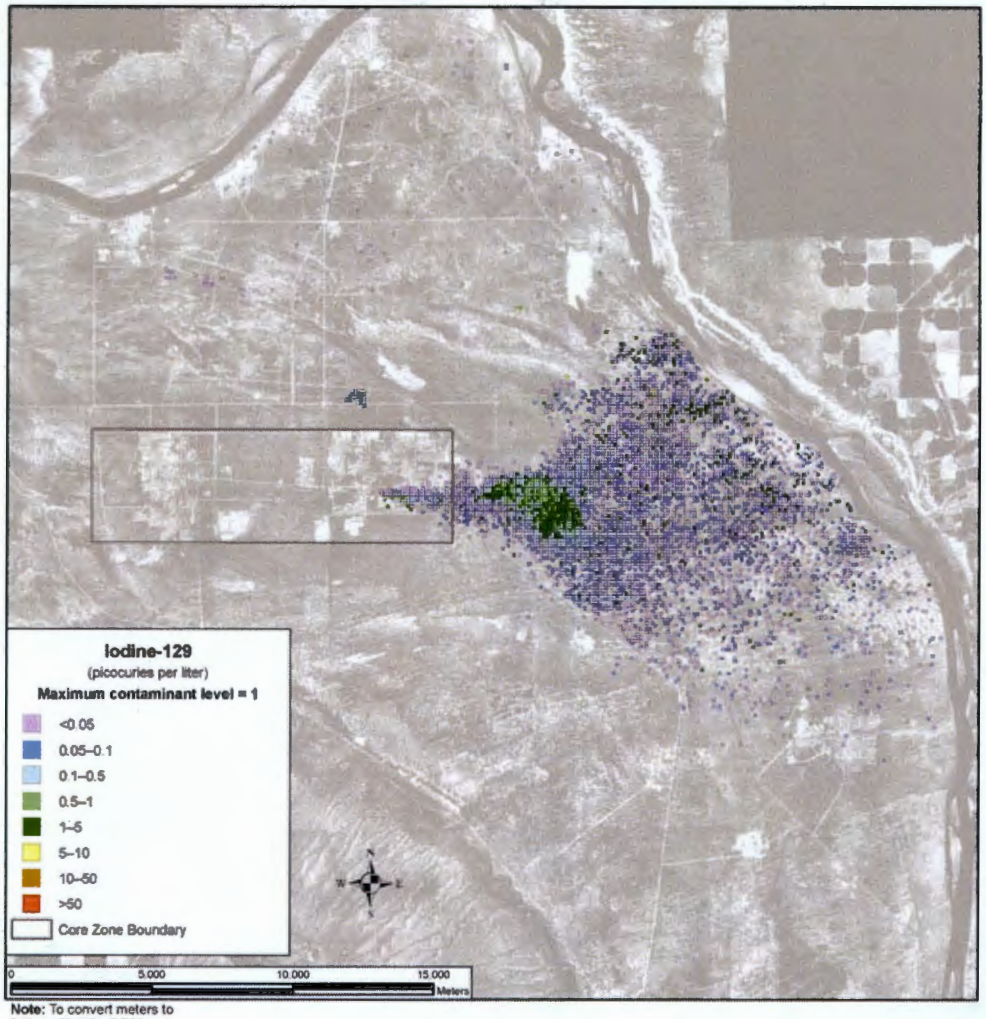
Note: To convert meters to feet, multiply by 3.281

Figure 5–384. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 3890



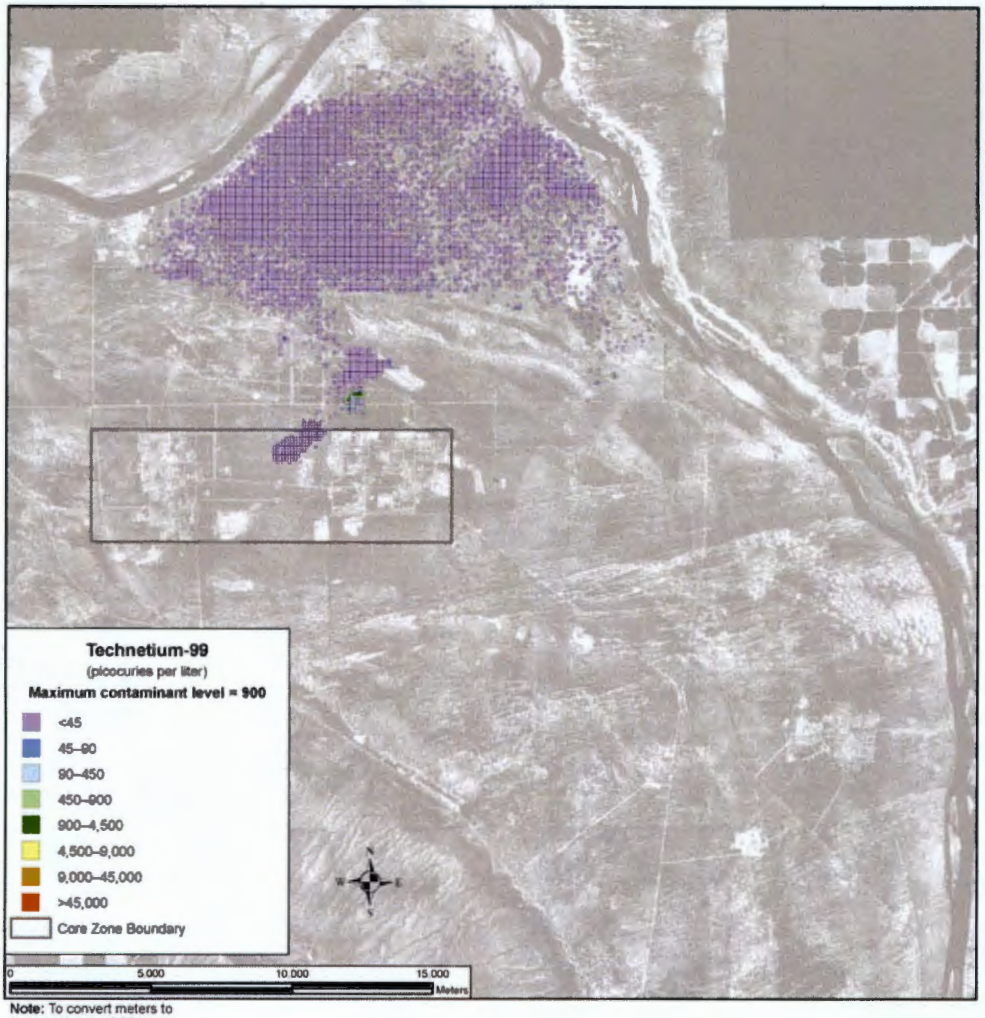
Note: To convert meters to feet, multiply by 3.281

Figure 5–385. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140



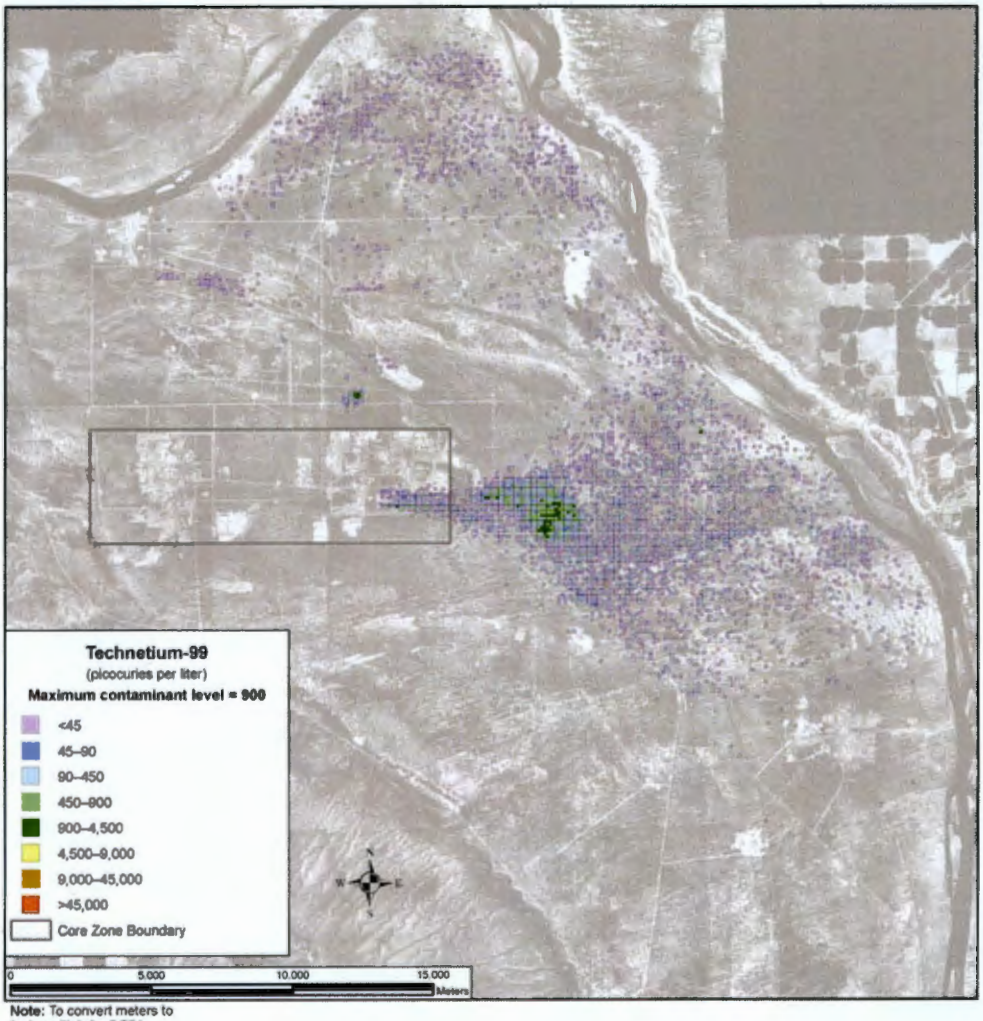
Note: To convert meters to feet, multiply by 3.281

Figure 5–386. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 11,885



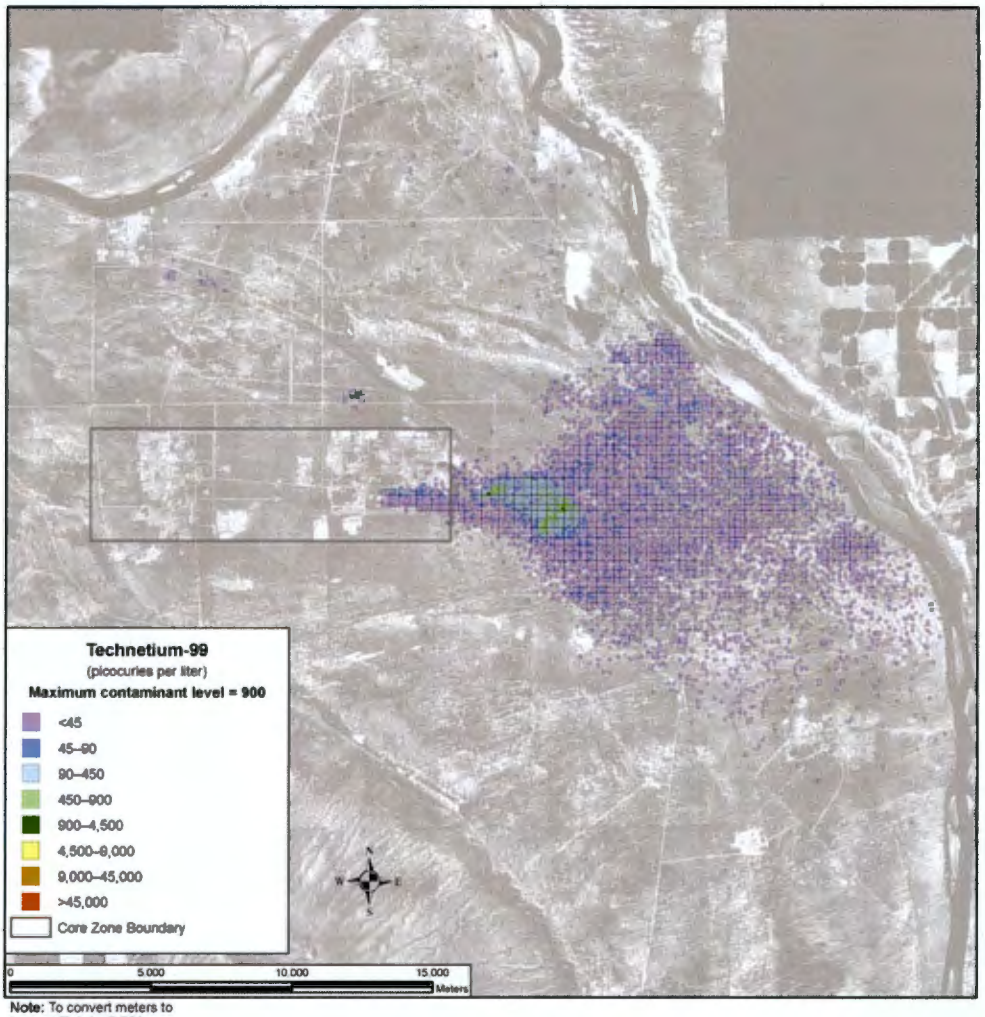
Note: To convert meters to feet, multiply by 3.281

Figure 5–387. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 3890



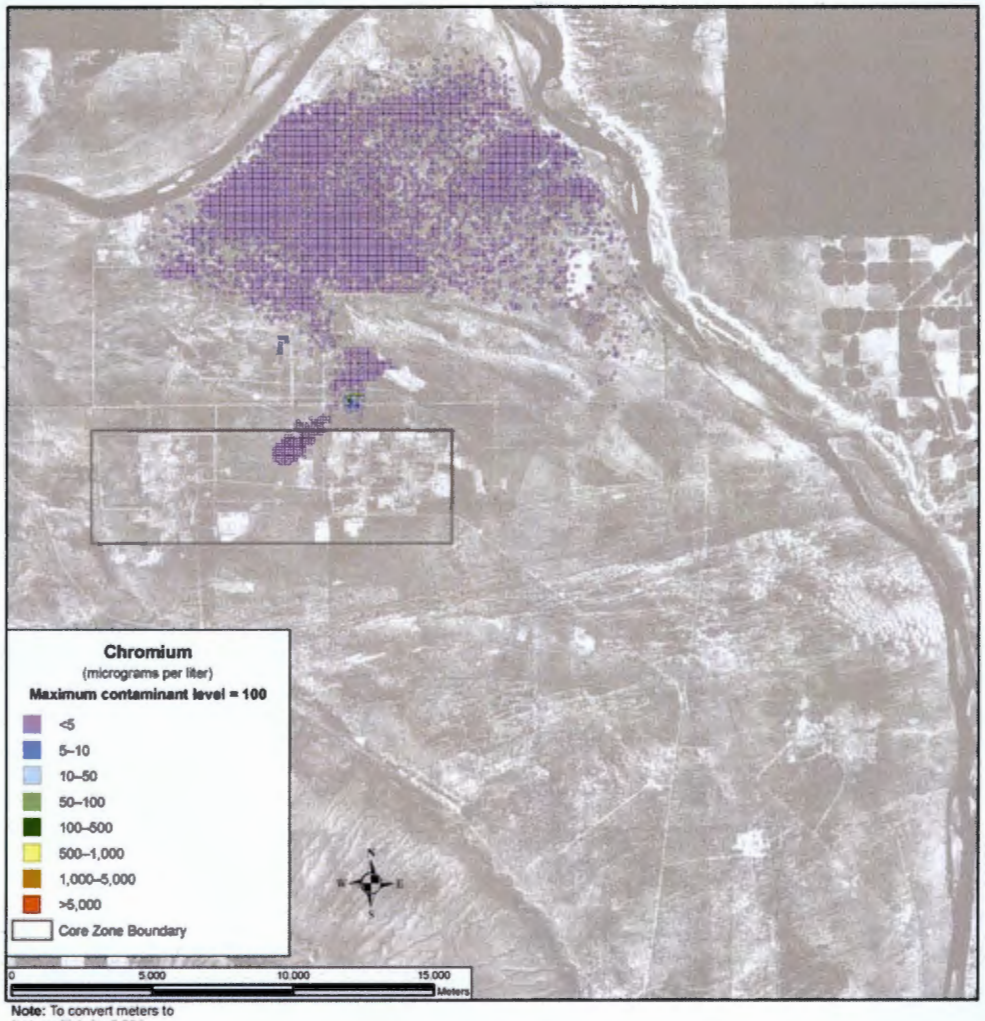
Note: To convert meters to feet, multiply by 3.281

Figure 5–388. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140



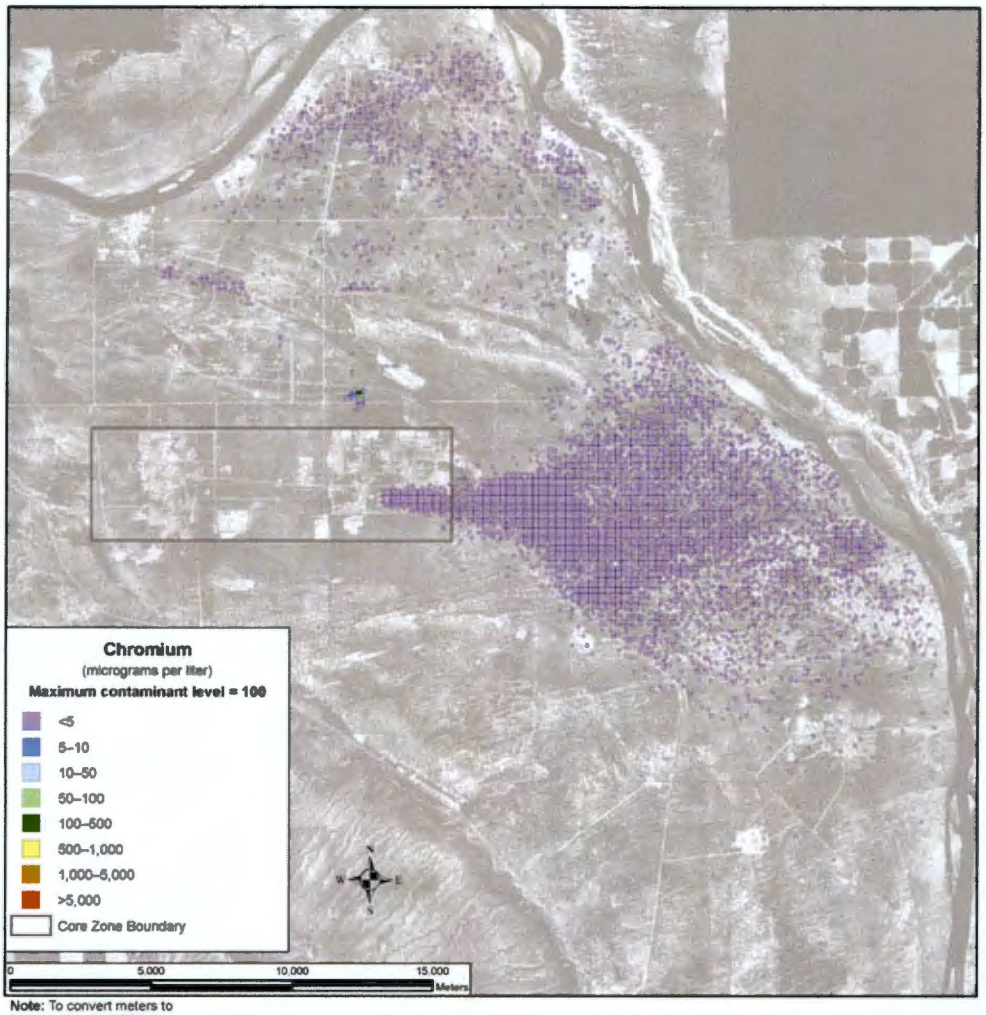
Note: To convert meters to feet, multiply by 3.281

Figure 5–389. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 11,885



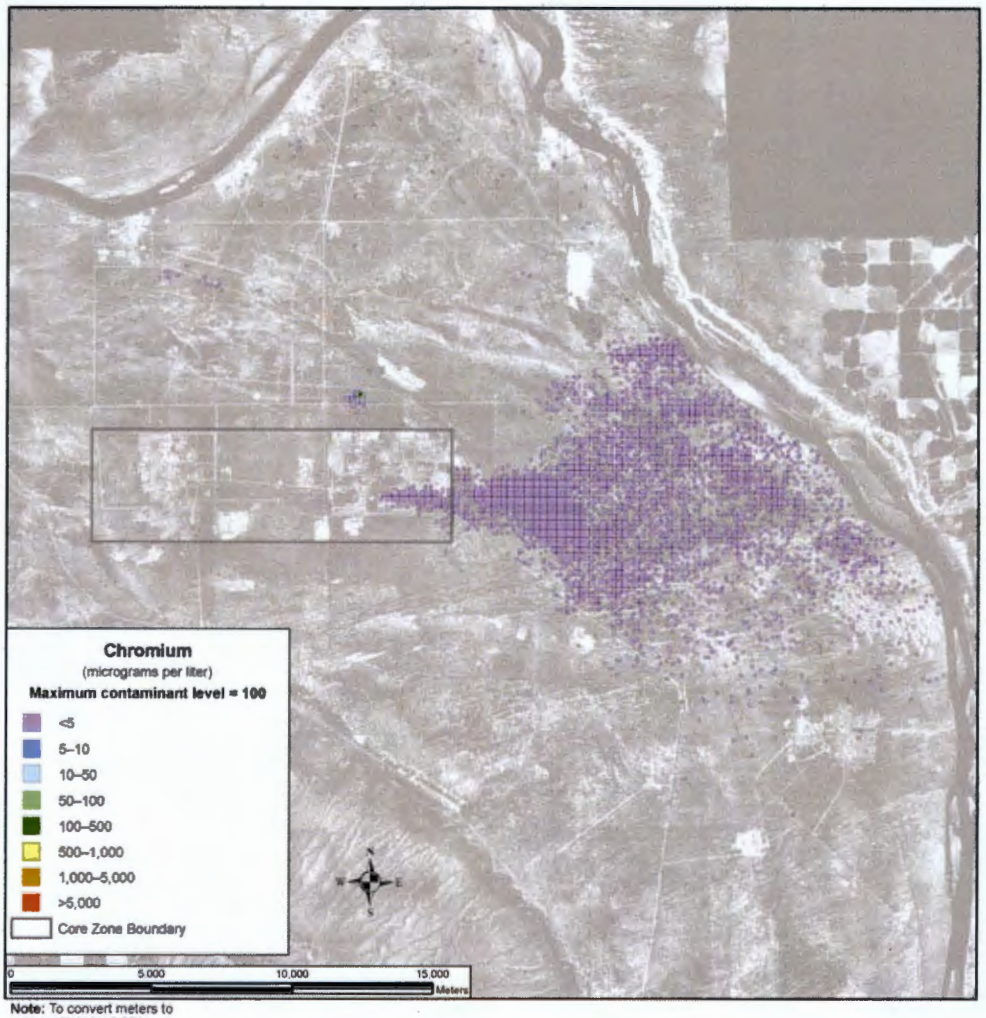
Note: To convert meters to feet, multiply by 3.281

Figure 5–390. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 3890



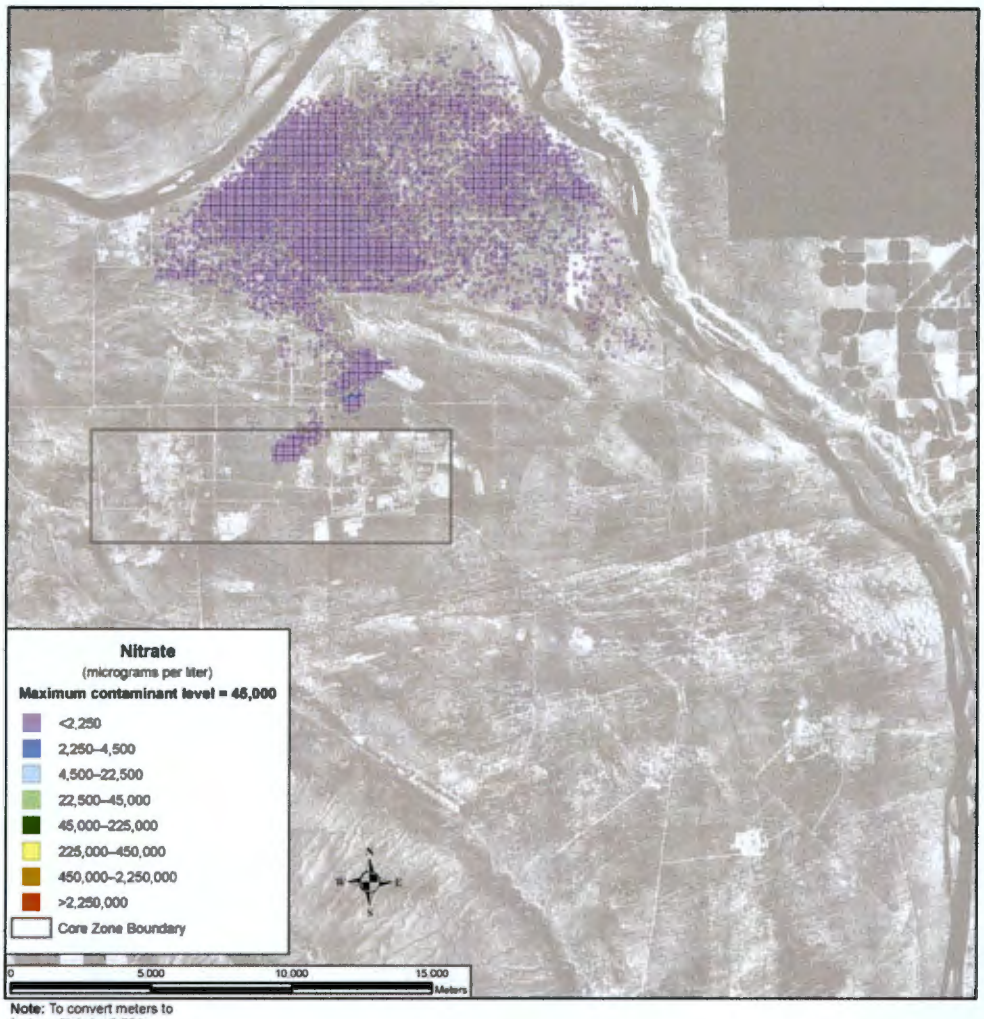
Note: To convert meters to feet, multiply by 3.281

Figure 5–391. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 7140



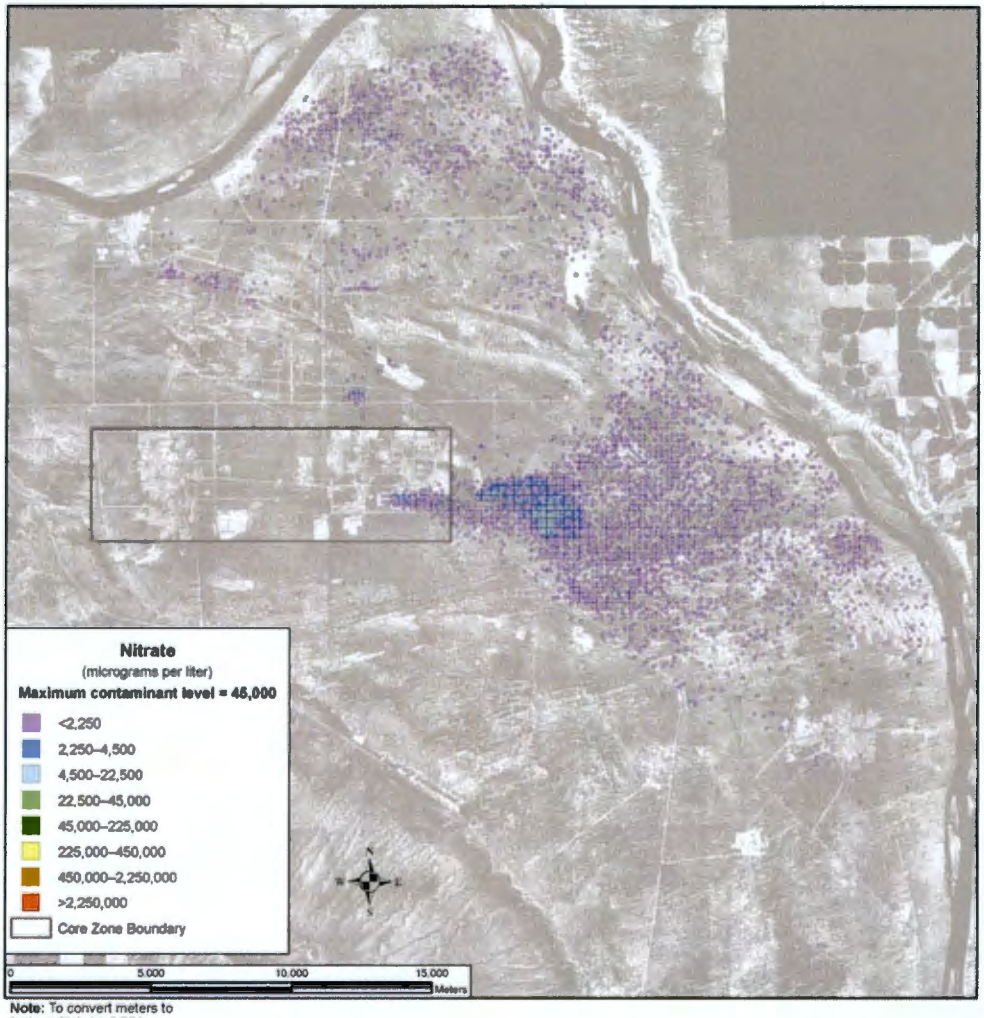
Note: To convert meters to feet, multiply by 3.281

Figure 5–392. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 11,885



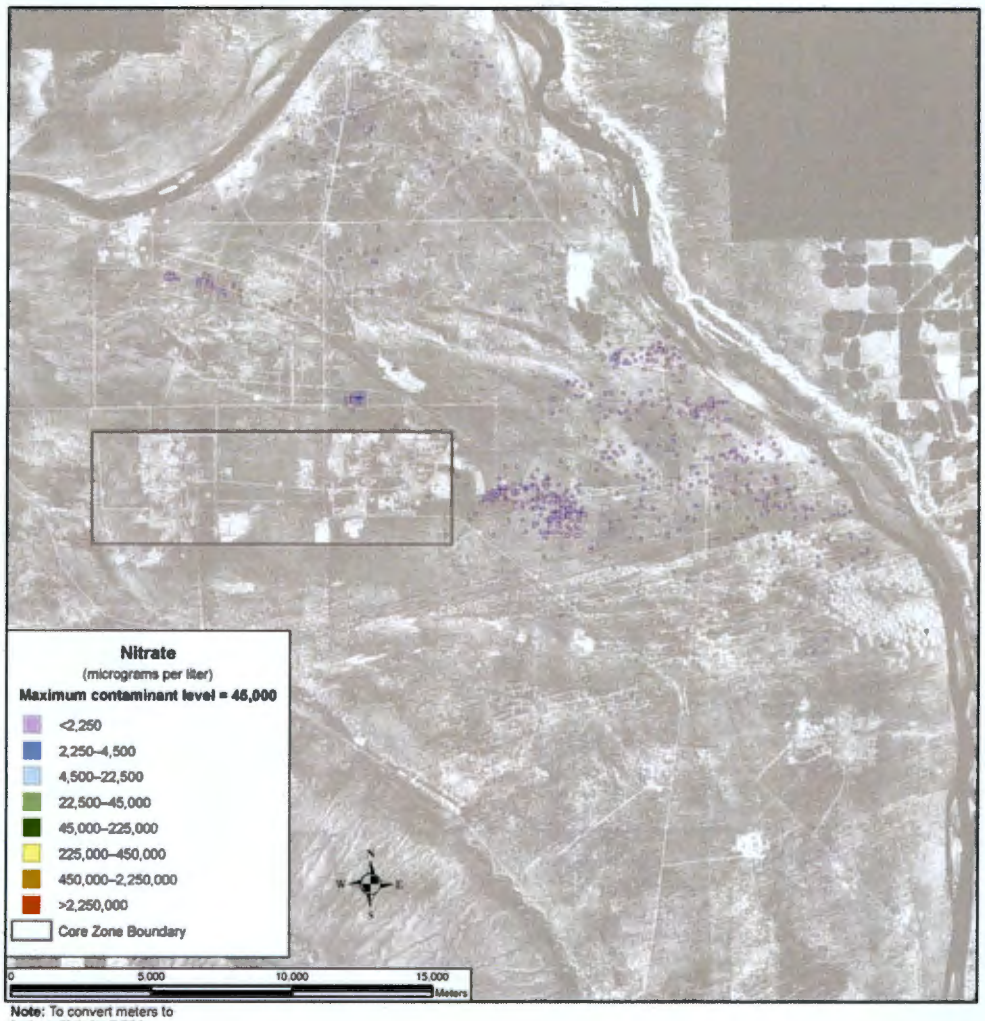
Note: To convert meters to feet, multiply by 3.281

Figure 5–393. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 3890



Note: To convert meters to feet, multiply by 3.281

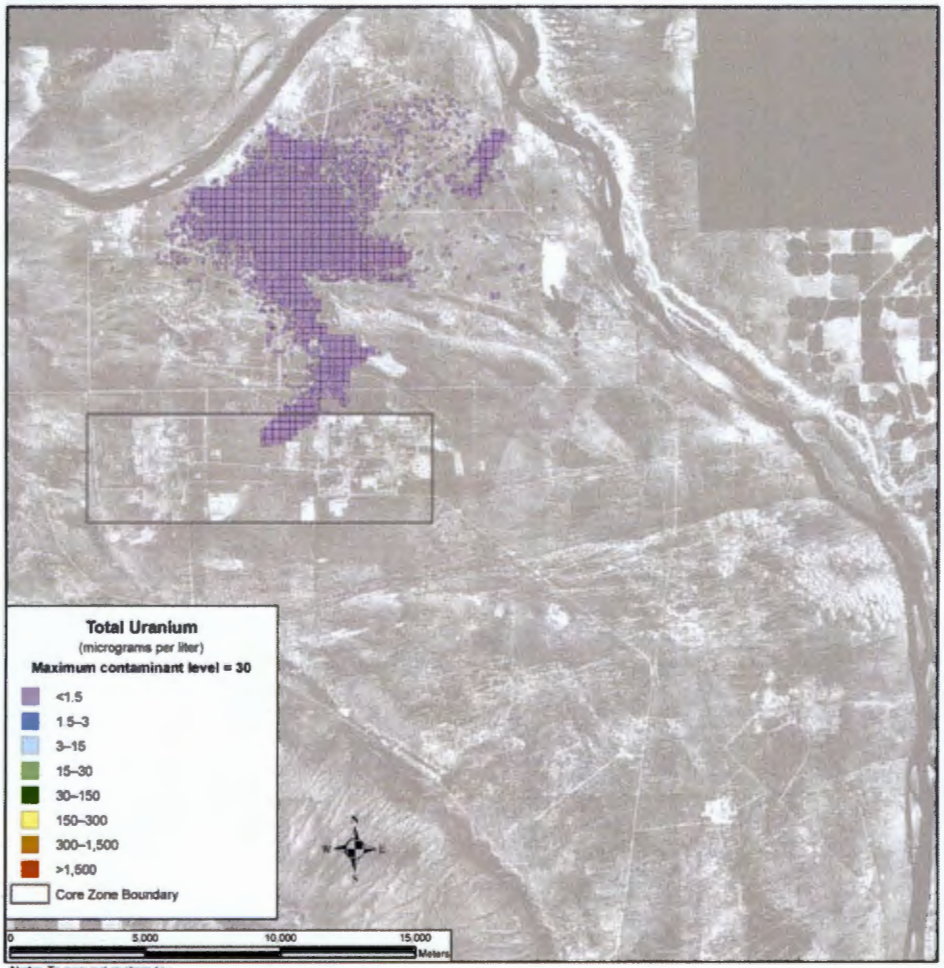
Figure 5–394. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281

Figure 5–395. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 11,885

Total uranium shows a different spatial distribution over time. This COPC is not as mobile as those discussed above, moving about seven times slower than the pore water velocity. As a result, travel times through the vadose zone are longer, release to the aquifer is delayed, and travel times through the aquifer to the Columbia River are longer. Figure 5–396 shows the distribution of total uranium at CY 11,885. There is a low-concentration plume that stretches north from the RPPDF and Gable Gap. Concentrations in all areas of the plume remain below one-tenth of the benchmark.



Note: To convert meters to feet, multiply by 3.281

Figure 5–396. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 11,885

SUMMARY OF IMPACTS

Under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, in general, the inventory remaining in IDF-East, available for release to the environment at the start of the post-disposal period, is the predominant contributor. The inventory available for release from the RPPDF during the post-disposal period is a secondary contributor.

For the conservative tracers, concentrations at the Core Zone Boundary approach or exceed benchmark standards by less than one order of magnitude during most of the period of analysis. Concentrations at the Columbia River nearshore are similar to or slightly lower than the concentrations at the Core Zone Boundary. The intensities and areas of these groundwater plumes peak between CYs 8000 and 9000.

For total uranium, limited mobility is an important factor governing the timeframes and scale of groundwater impacts. The concentrations of these retarded species are increasing, but are well below the benchmark at the Core Zone Boundary beyond CY 9940, and remain eight orders of magnitude below the benchmark at the Columbia River after CY 11,940. The peak intensity and area of the contamination plume are largest near the end of the period of analysis.

5.3.1.2.1.2 Disposal Group 1, Subgroup 1-B

ACTIONS AND TIMEFRAMES INFLUENCING GROUNDWATER IMPACTS

Subgroup 1-B covers disposal of waste generated under Tank Closure Alternative 3A and FFTF Decommissioning Alternative 2 or 3, as well as onsite- and offsite-generated waste. Waste would be converted to IHLW, ILAW glass, and bulk vitrification glass. IHLW would be stored on site, while ILAW glass and bulk vitrification glass would be disposed of at IDF-East.

For the long-term groundwater impact analysis, two major periods were identified for Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, as follows:

- The disposal period was assumed to start with the onset of disposal operations in IDF-East and the RPPDF in CY 2009 and continue through CY 2050, when these facilities would be operationally closed. During the disposal period, the materials in these permitted, operational facilities would not be available for release to the environment.
- The post-disposal period was assumed to start in CY 2051 and continue through the 10,000-year period of analysis until CY 11,940. At the start of this period, materials in the facilities become available for release to the environment, and modified RCRA Subtitle C barriers would be emplaced over IDF-East and the RPPDF to limit infiltration during the first 500 years of the post-disposal period.

COPC DRIVERS

A total of 40 COPCs were analyzed for Waste Management Alternative 2. Complete results for all 40 COPCs are tabulated in Appendices M, N, and O. The discussion in this section of long-term impacts associated with Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, is focused on the following COPC drivers:

- Radiological risk drivers: iodine-129 and technetium-99
- Chemical risk drivers: none
- Chemical hazard drivers: boron, chromium, fluoride, and nitrate

The COPC drivers for Waste Management Alternative 2 were selected by evaluating the risk or hazard associated with all 40 COPCs during the year of peak risk or hazard at the Core Zone Boundary during the 10,000-year period of analysis and selecting the major contributors. This process is described in Appendix Q. The radiological risk drivers listed above account for essentially 100 percent of the radiological risk. No chemical risk is predicted. The chemical hazard drivers above account for over 99 percent of the chemical hazard associated with Waste Management Alternative 2.

The COPC drivers that are discussed in detail in this section (iodine-129, technetium-99, boron, chromium, fluoride, and nitrate) are all mobile (i.e., move with groundwater) and long-lived (relative to the 10,000-year period of analysis), or stable. They are essentially conservative tracers. The other COPCs that were analyzed do not significantly contribute to drinking water risk at the Core Zone Boundary during the period of analysis because of high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of both factors.

ANALYSIS OF RELEASE AND MASS BALANCE

This section presents the impacts of Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, in terms of the total amount of COPCs released to the vadose zone, groundwater, and the Columbia River during the 10,000-year period of analysis. Releases of radionuclides are totaled in curies; chemicals in kilograms (see Figures 5–397 through 5–408). Three subtotals are plotted representing releases from ILAW glass, bulk vitrification glass, ETF-generated secondary waste, retired melters, tank closure secondary waste, FFTF Decommissioning Alternative 3 waste, waste management secondary waste, and onsite- and offsite-generated waste. Note that the release amounts are plotted on a logarithmic scale to facilitate visual comparison of releases that vary over eight orders of magnitude.

Figure 5–397 shows the estimated release at IDF-East to the vadose zone for the radiological risk drivers and Figure 5–398, the chemical hazard drivers. For all types of sources, the release to the vadose zone is controlled by the inventory (i.e., 100 percent of the inventory was released during the period of analysis). The predominant sources of technetium-99 are bulk vitrification glass and offsite-generated waste; of iodine-129 is offsite-generated waste; and of boron is waste management secondary waste. The predominant sources for chromium are tank closure secondary waste, waste management secondary waste, and onsite- and offsite-generated waste. The predominant sources for fluoride are waste management secondary waste and onsite-generated waste. The predominant source for nitrate is ETF-generated secondary waste.

Figure 5–399 shows the estimated release at IDF-East to groundwater for the radiological risk drivers and Figure 5–400, the chemical hazard drivers. In addition to the inventory considerations discussed in the previous paragraph, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. Nearly all of the technetium-99 and iodine-129 released to the vadose zone reached groundwater in the analysis, as well as nearly all of the chromium, fluoride, nitrate, and boron.

Figure 5–401 shows the estimated release at IDF-East to the Columbia River for the radiological risk drivers and Figure 5–402, the chemical hazard drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers. For technetium-99 and iodine-129, about 90 percent of the total amounts released from the vadose zone reached the Columbia River in the analysis; for chromium, about 93 percent; and for fluoride, nitrate, and boron, about 98 percent.

Figure 5–403 shows the estimated release at the RPPDF to the vadose zone for the radiological risk drivers and Figure 5–404, the chemical hazard drivers. For all types of sources, the release to the vadose zone is controlled by the inventory (i.e. 100 percent of the inventory was released during the period of analysis). Technetium-99, iodine-129, chromium, and nitrate are all present at the RPPDF in the analysis (fluoride and boron are not).

Figure 5–405 shows the estimated release at the RPPDF to groundwater for the radiological risk drivers and Figure 5–406, the chemical hazard drivers. In addition to the inventory considerations discussed in the previous paragraph, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. All of the COPC drivers present at the RPPDF behave as conservative tracers, with essentially all of the mass released to the vadose zone reaching groundwater.

Figure 5–407 shows the estimated release at the RPPDF to the Columbia River for the radiological risk drivers and Figure 5–408, the chemical hazard drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers. For technetium-99, iodine-129, chromium, and nitrate, approximately 100 percent of the total amounts released to the vadose zone at the RPPDF reached the Columbia River in the analysis.

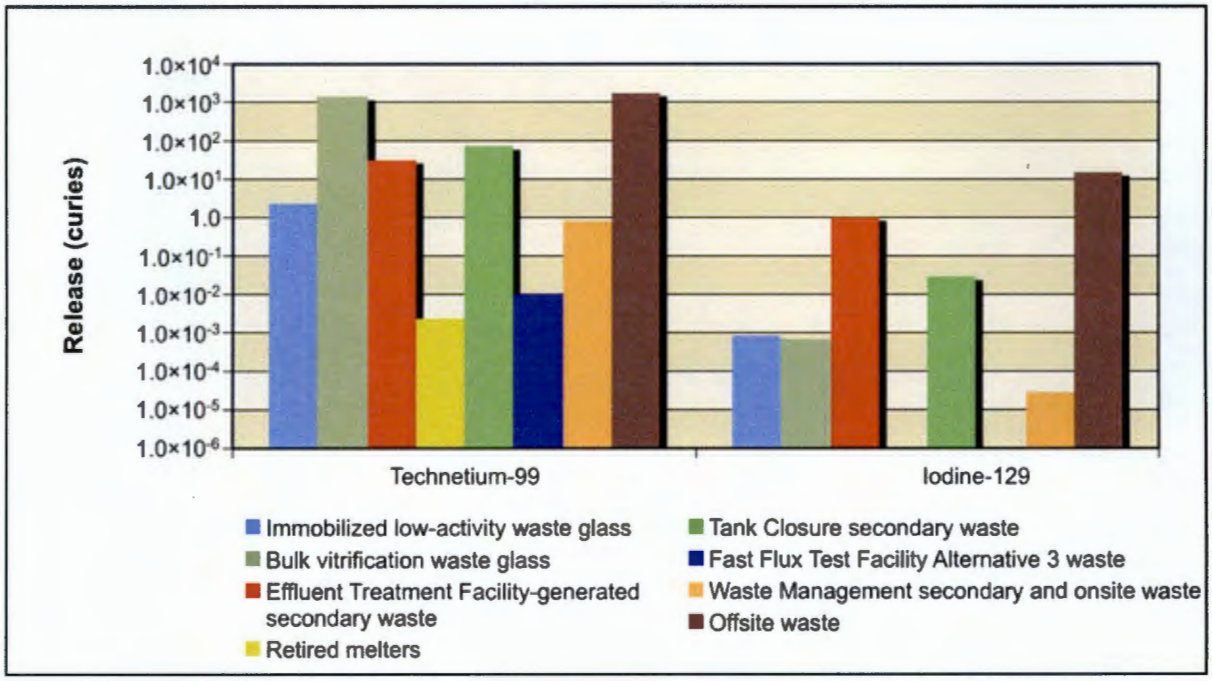


Figure 5–397. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Radiological Releases at 200-East Area Integrated Disposal Facility to Vadose Zone

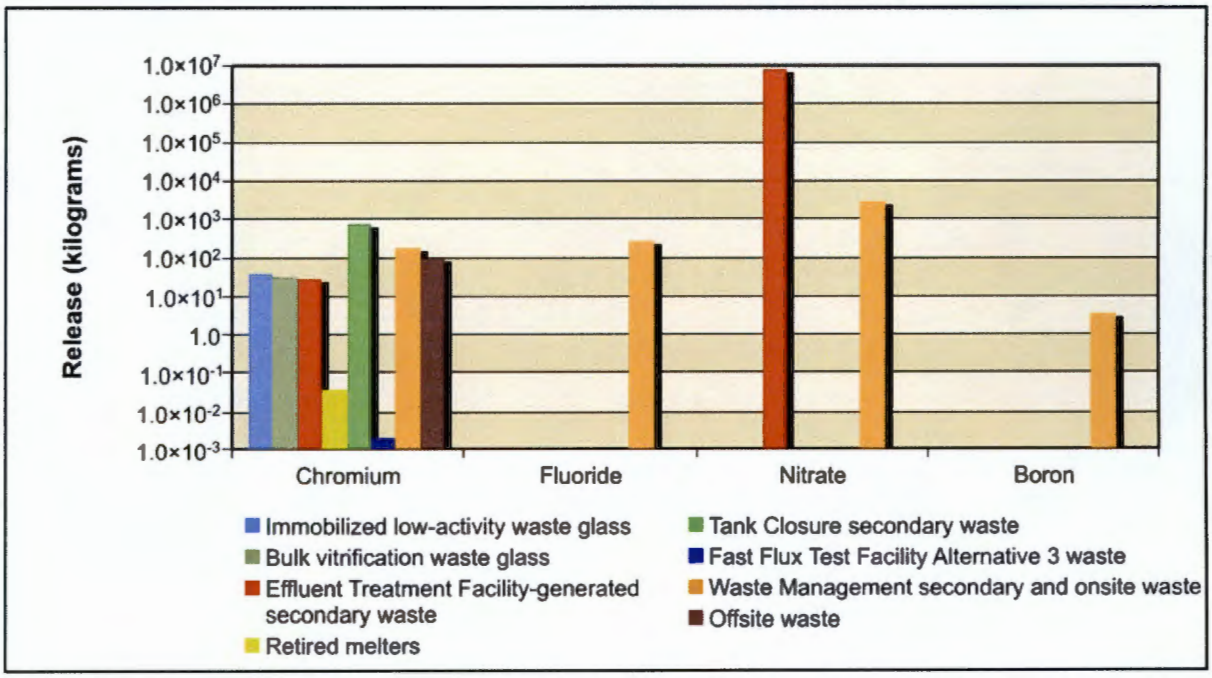


Figure 5–398. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Chemical Releases at 200-East Area Integrated Disposal Facility to Vadose Zone

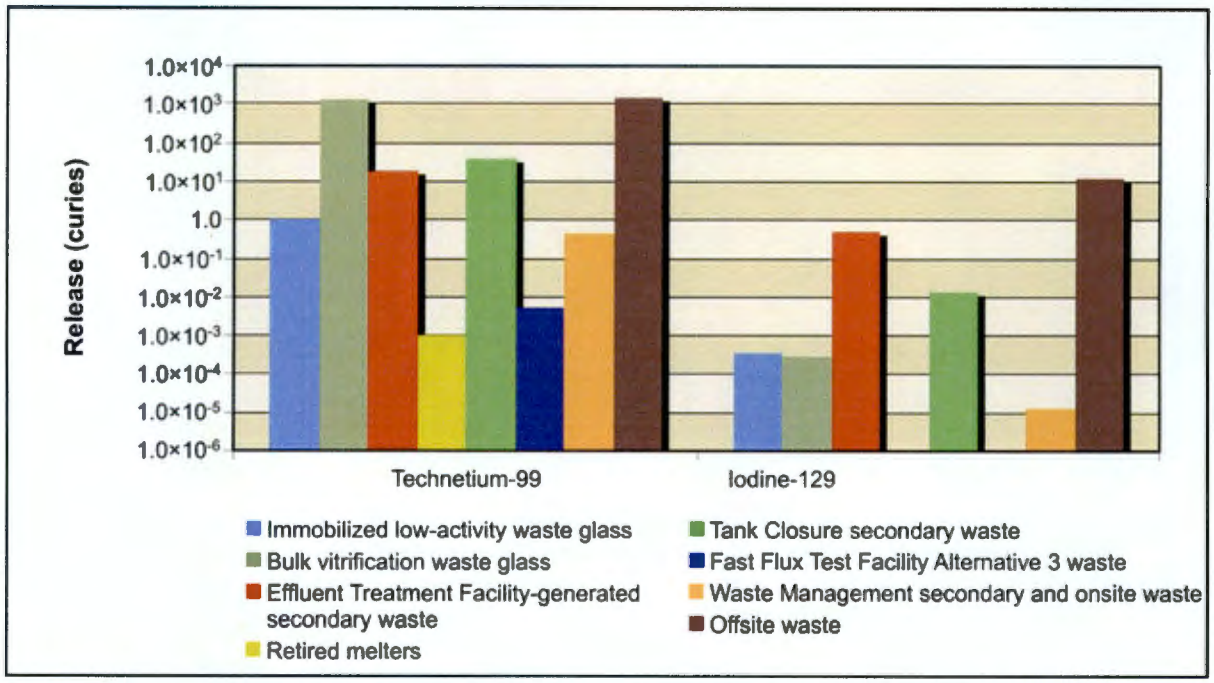


Figure 5–399. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Radiological Releases at 200-East Area Integrated Disposal Facility to Groundwater

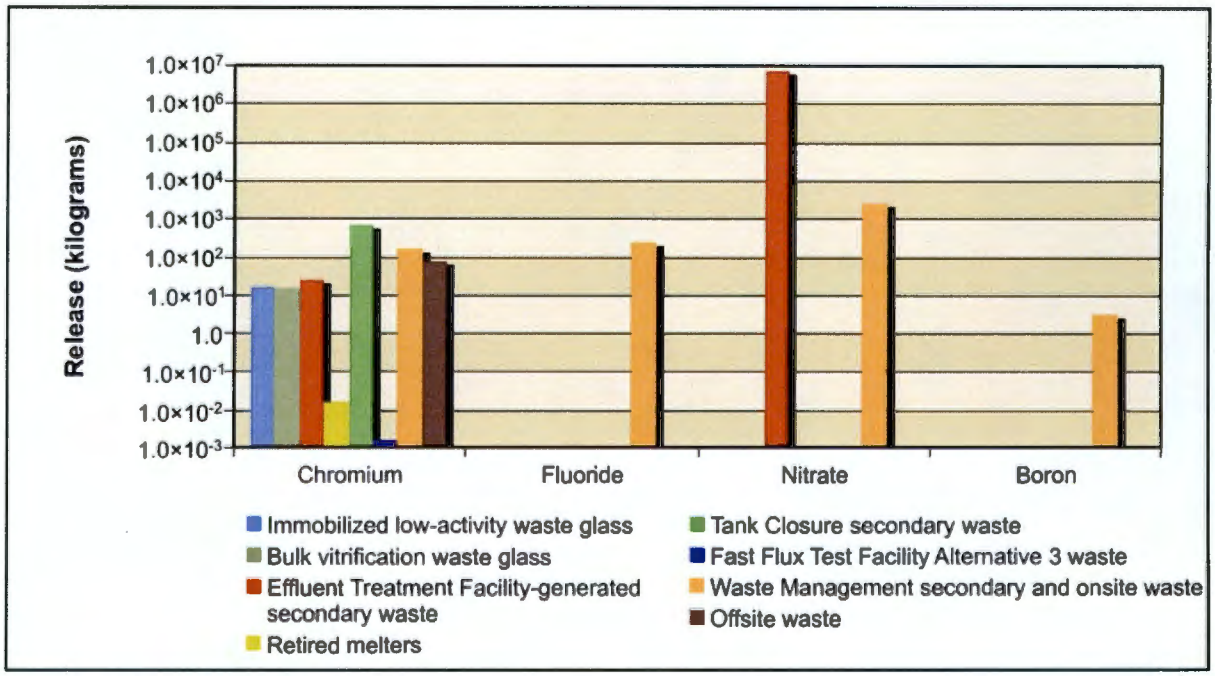


Figure 5–400. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Chemical Releases at 200-East Area Integrated Disposal Facility to Groundwater

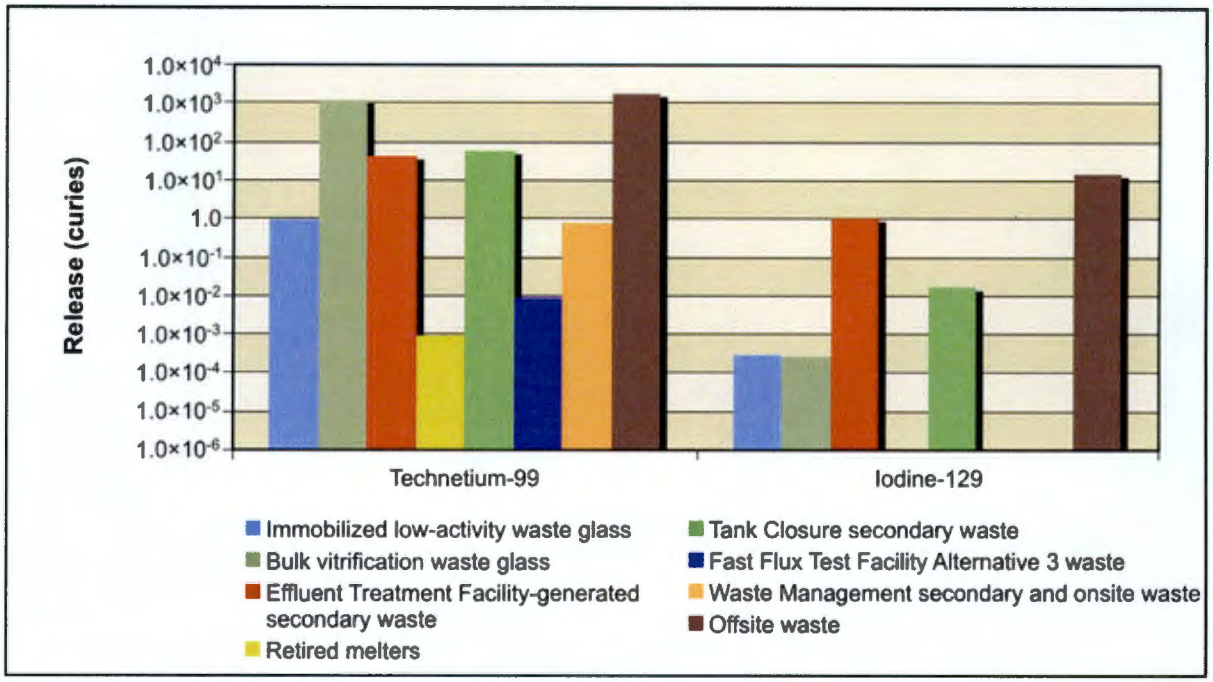


Figure 5–401. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Radiological Releases at 200-East Area Integrated Disposal Facility to Columbia River

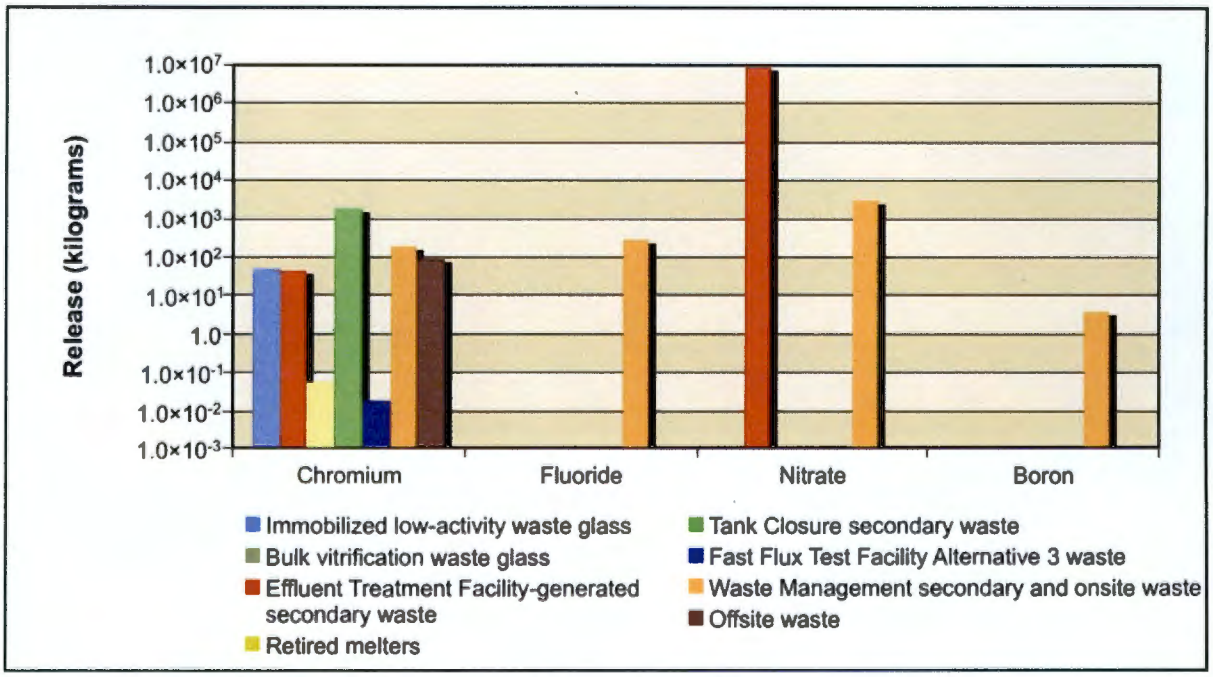


Figure 5–402. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Chemical Releases at 200-East Area Integrated Disposal Facility to Columbia River

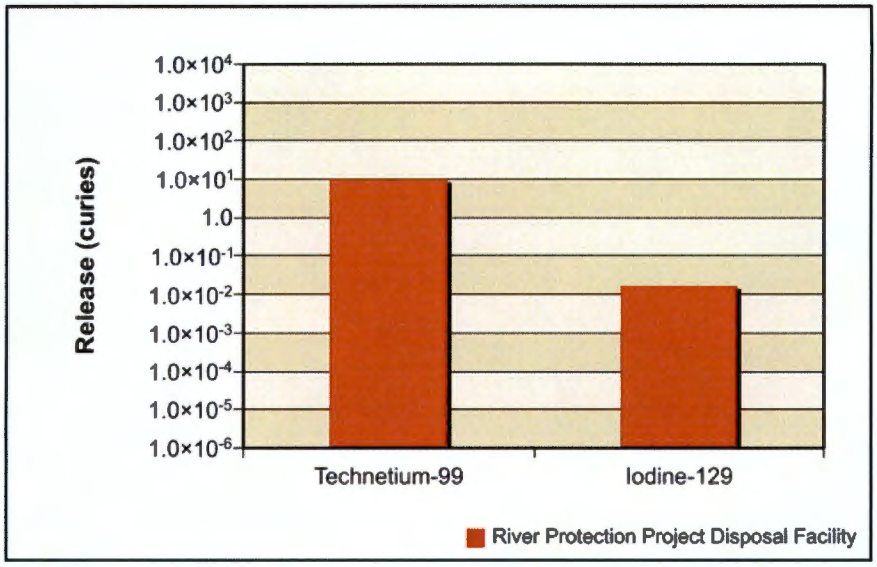


Figure 5–403. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Radiological Releases at River Protection Project Disposal Facility to Vadose Zone

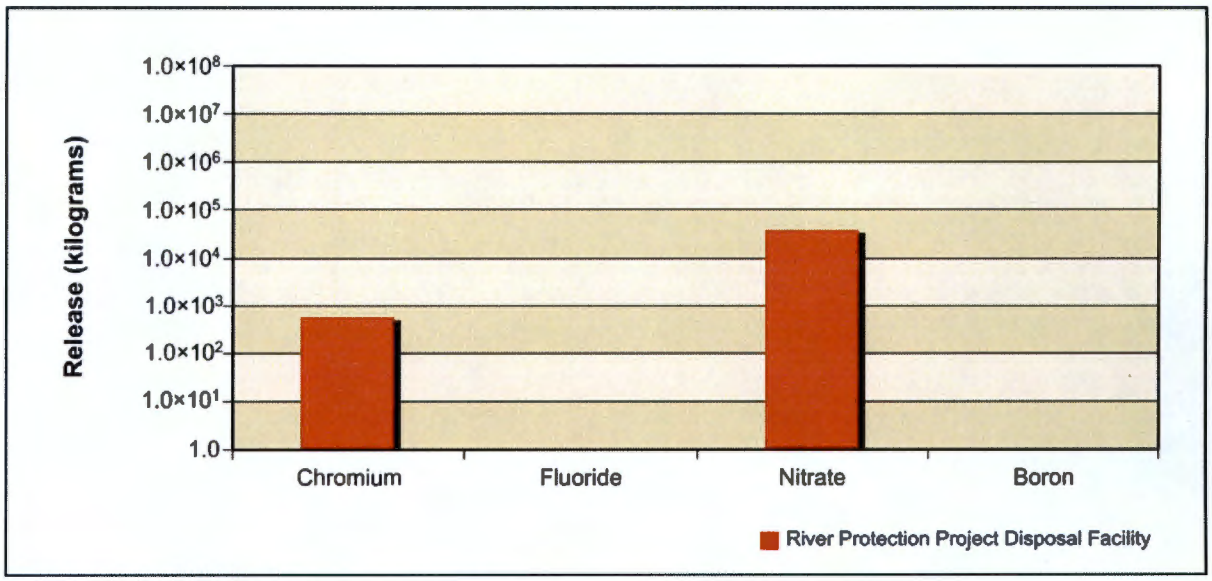


Figure 5–404. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Chemical Releases at River Protection Project Disposal Facility to Vadose Zone

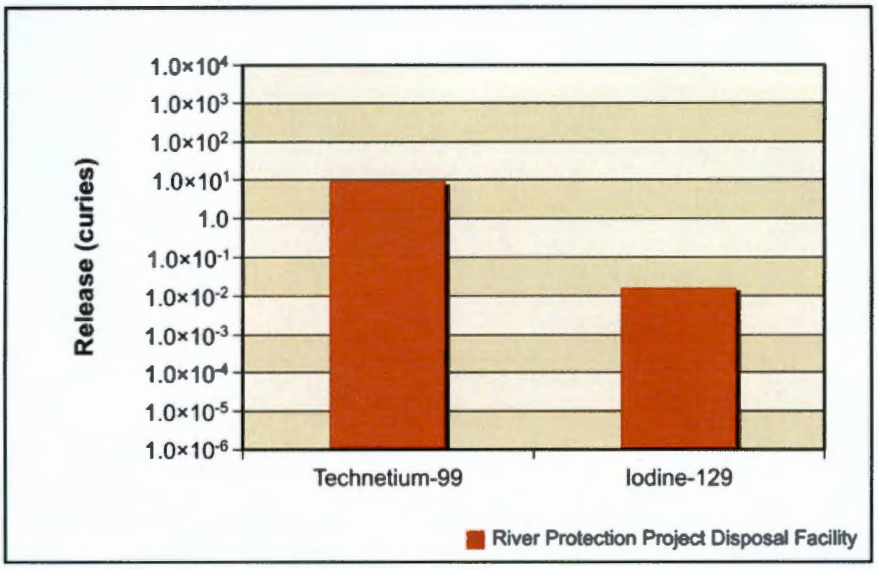


Figure 5–405. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Radiological Releases at River Protection Project Disposal Facility to Groundwater

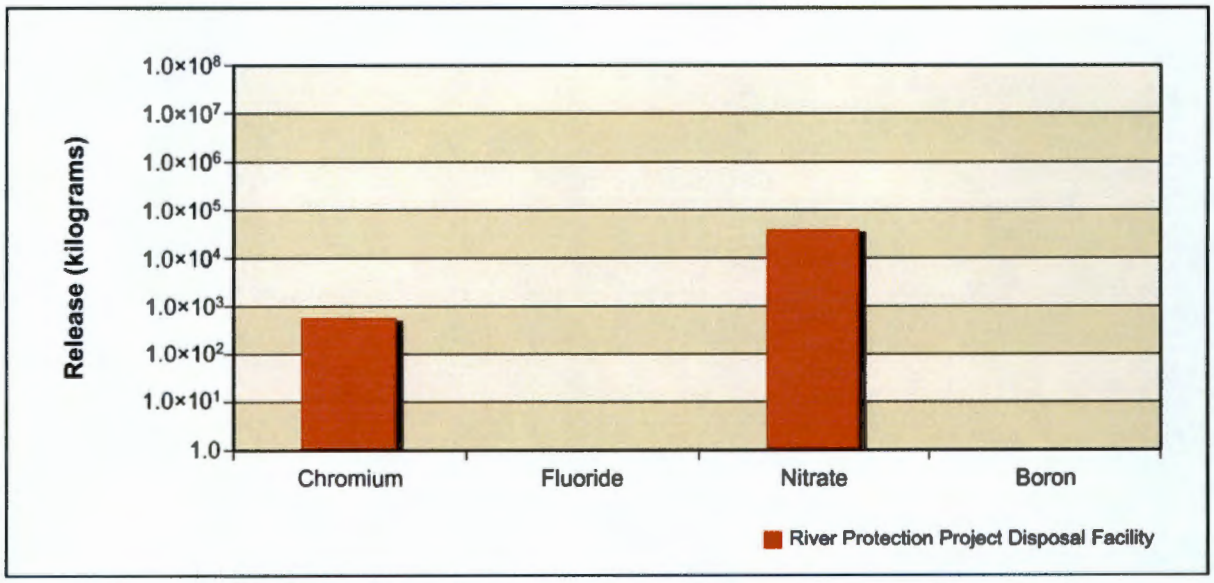


Figure 5–406. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Chemical Releases at River Protection Project Disposal Facility to Groundwater

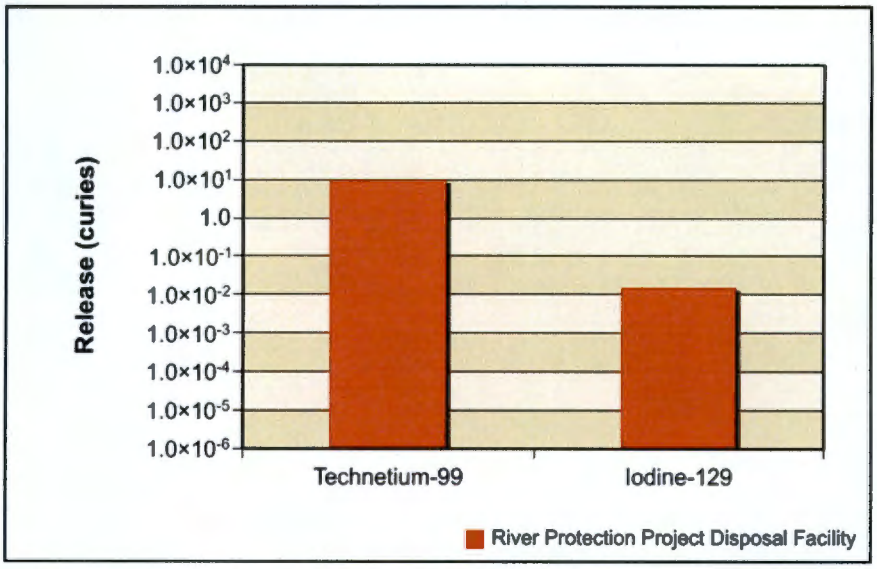


Figure 5–407. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Radiological Releases at River Protection Project Disposal Facility to Columbia River

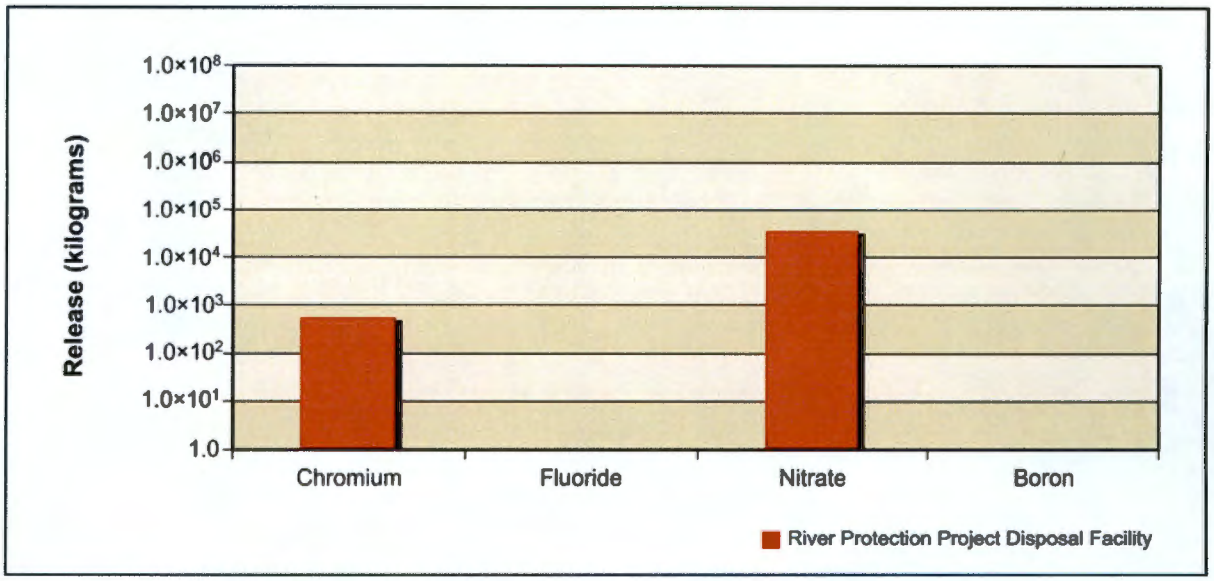


Figure 5–408. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Chemical Releases at River Protection Project Disposal Facility to Columbia River

ANALYSIS OF CONCENTRATION VERSUS TIME

This section presents the analysis of Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, impacts in terms of groundwater concentration versus time at the Core Zone Boundary and the Columbia River. Concentrations of radionuclides are in picocuries per liter chemicals in micrograms per liter (see Figures 5–409 through 5–413). The benchmark concentration for each radionuclide and chemical is also shown. Because of the discrete nature of the concentration carried across a barrier or the river, a line denoting the 95th percentile upper confidence limit of the concentration is included on several of these graphs. This confidence interval was calculated to show when the actual concentration over a certain time interval is likely (95 percent of the time) to be at or below this value. The confidence interval is basically a statistical aid to interpreting data with a significant amount of random fluctuation (noise). The confidence interval was calculated when the concentration had a reasonable degree of noise, the concentration's trend was level, and the concentrations were near the benchmark. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude. Table 5–78 lists the maximum concentrations of the COPCs in the peak year at IDF-East and the RPPDF, Core Zone Boundary, and Columbia River nearshore.

Figures 5–409 through 5–412 show concentration versus time for iodine-129, technetium-99, chromium, and nitrate (the conservative tracers). For technetium-99, a small rise in concentration is evident in the early years, peaking around CY 3940, but remaining over an order of magnitude below the benchmark concentration. Beginning in CY 5400, concentrations at the Core Zone Boundary begin climbing again, reaching a level just below the benchmark concentration at CY 7940. Iodine-129 follows a similar pattern, reaching a concentration slightly above the benchmark, while chromium and nitrate peak over an order of magnitude below the benchmark.

Figure 5–413 shows concentration versus time for total uranium. Because of the high retardation of uranium, no contamination appears until CY 9940, when total uranium concentrations at the Core Zone Boundary first surpass 1.0×10^{-8} micrograms per liter. Total uranium remains over seven orders of magnitude below the benchmark concentration at the Core Zone Boundary throughout the simulation. Uranium-238 does not surpass 1.0×10^{-8} picocuries per liter during the simulation.

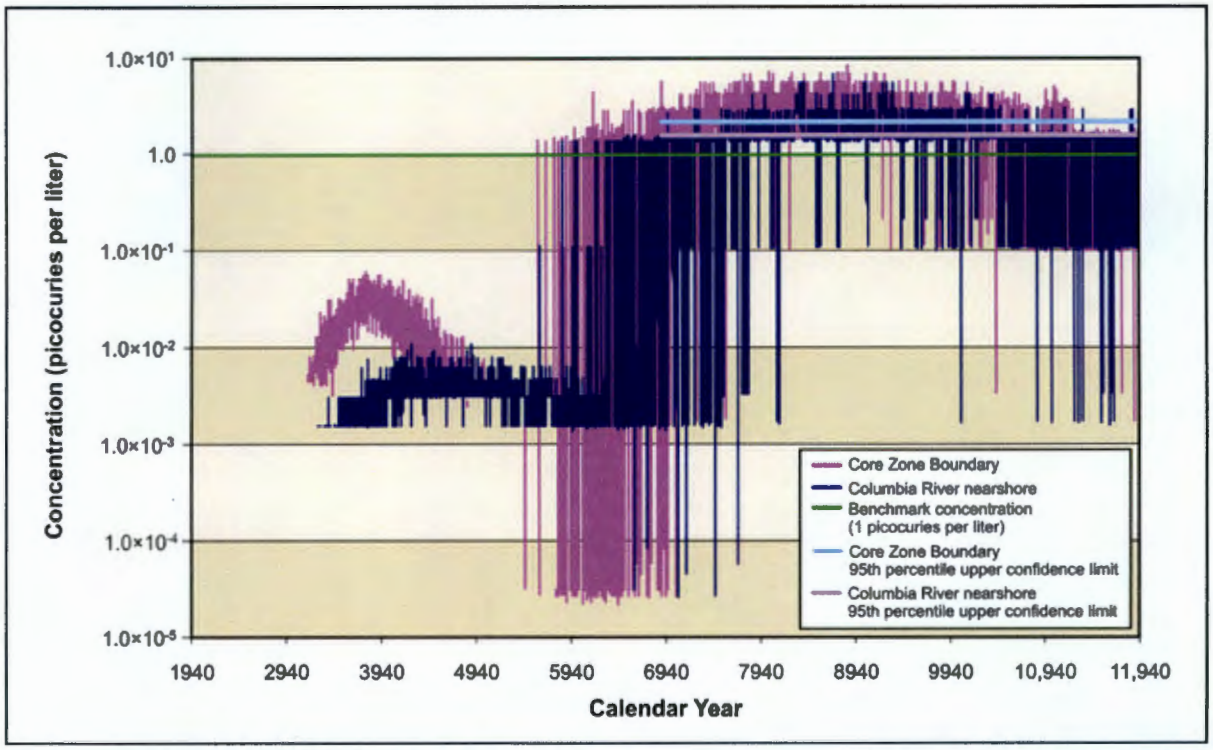


Figure 5–409. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Iodine-129 Concentration Versus Time

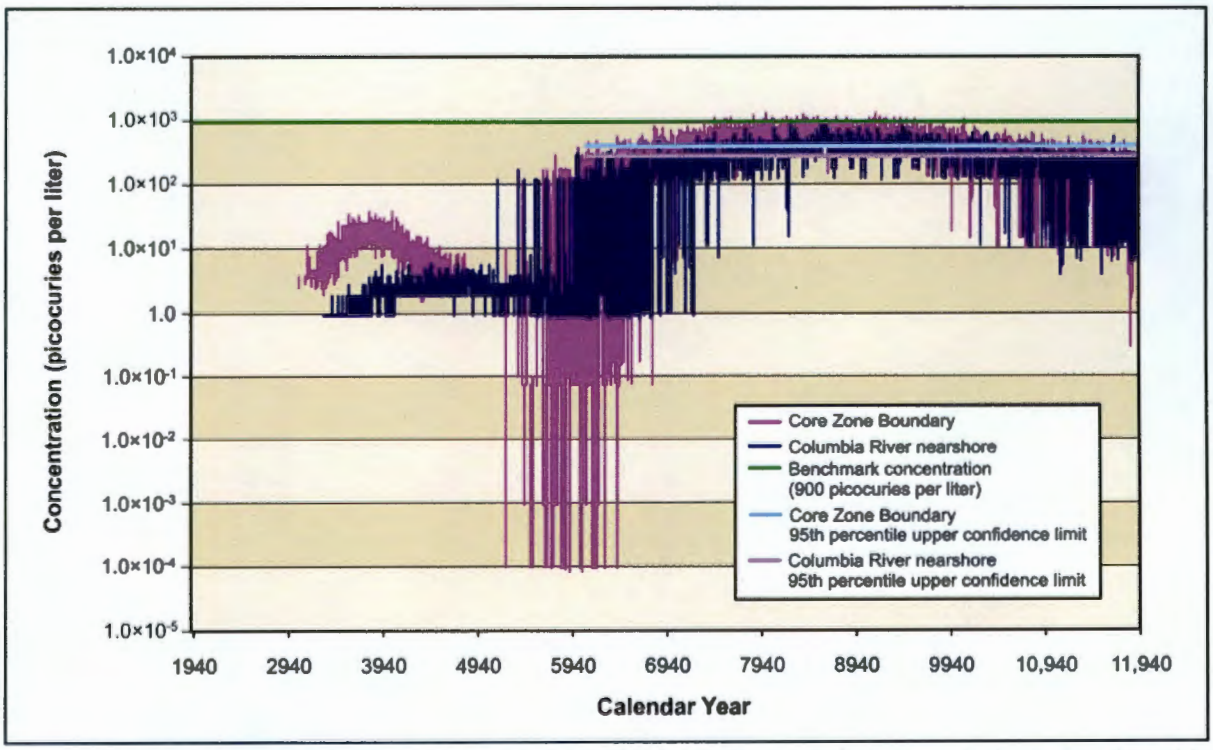


Figure 5–410. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Technetium-99 Concentration Versus Time

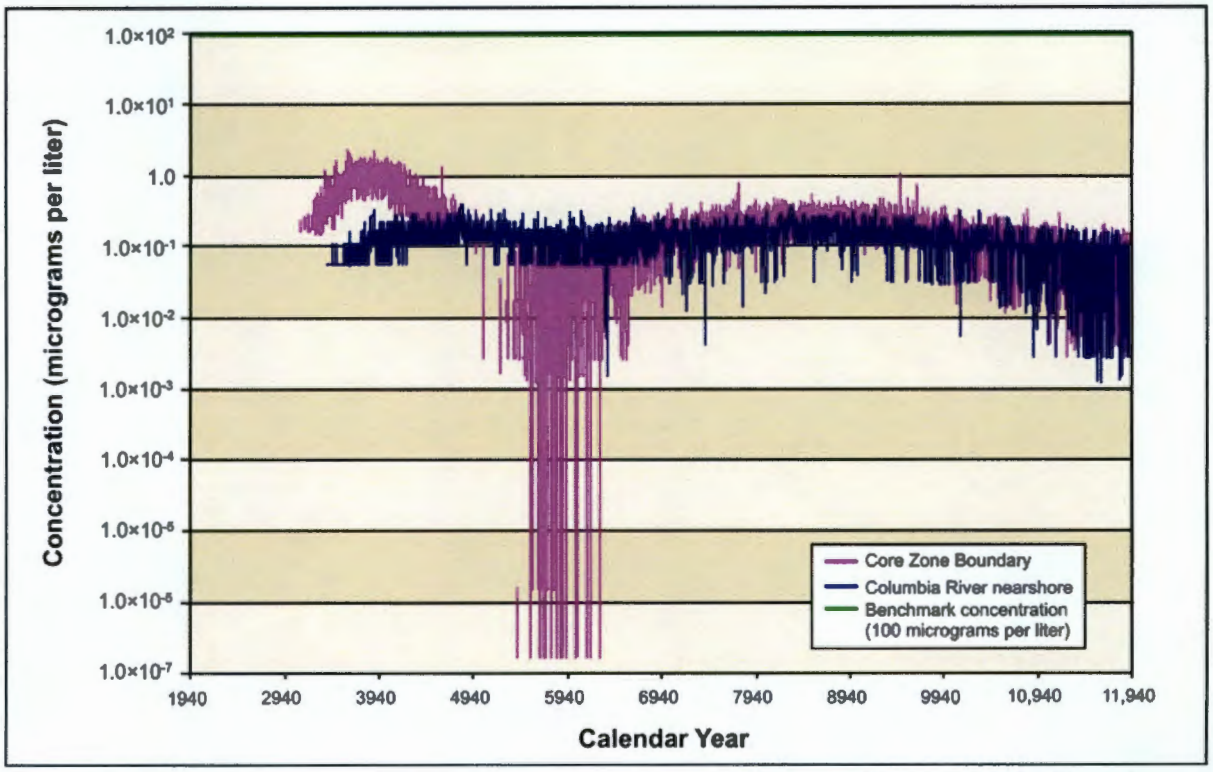


Figure 5–411. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Chromium Concentration Versus Time

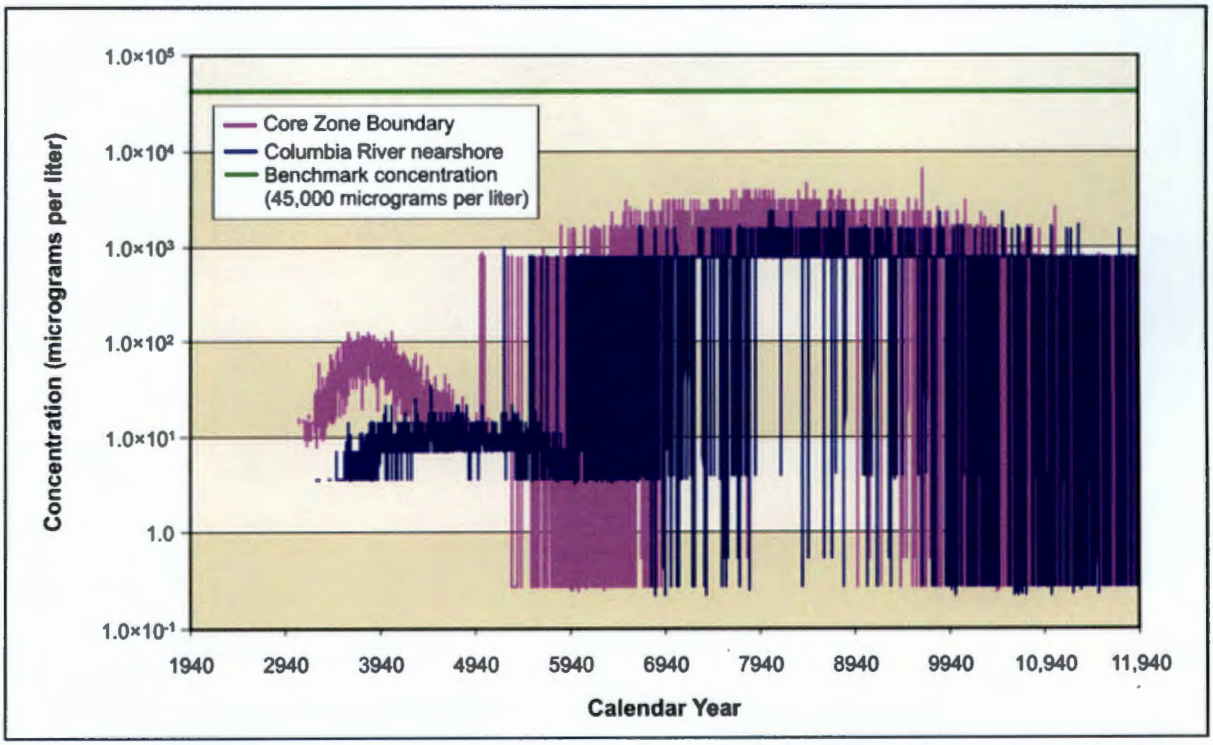


Figure 5–412. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Nitrate Concentration Versus Time

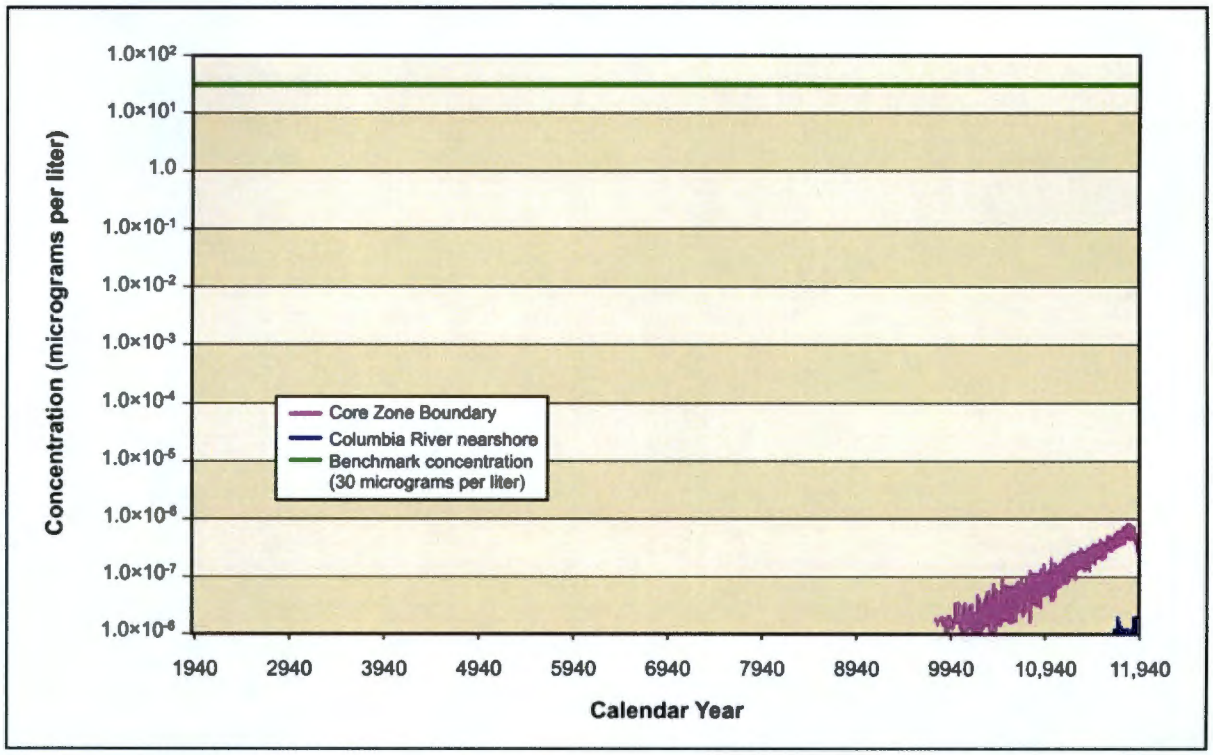


Figure 5–413. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Total Uranium Concentration Versus Time

Table 5–78. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Maximum COPC Concentrations in the Peak Year at IDF-East and the RPPDF, Core Zone Boundary, and Columbia River Nearshore

Contaminant	IDF-East	RPPDF	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclide in picocuries per liter					
Technetium-99	**2,880**	33	**1,250**	815	900
	(8486)	(3825)	(7998)	(8273)	
Iodine-129	**18**	0.1	**8**	**7**	1
	(8195)	(3772)	(8858)	(8700)	
Chemical in micrograms per liter					
Chromium	2	2	2	0	100
	(8278)	(3856)	(3889)	(4826)	
Fluoride	0	0	1	0	4,000
	(8035)	(1940)	(7258)	(8913)	
Nitrate	14,400	149	5,860	3,680	45,000
	(7821)	(3811)	(8905)	(8144)	

Note: Corresponding calendar years shown in parentheses. Concentrations that would exceed the benchmark value are indicated in **bold** text.

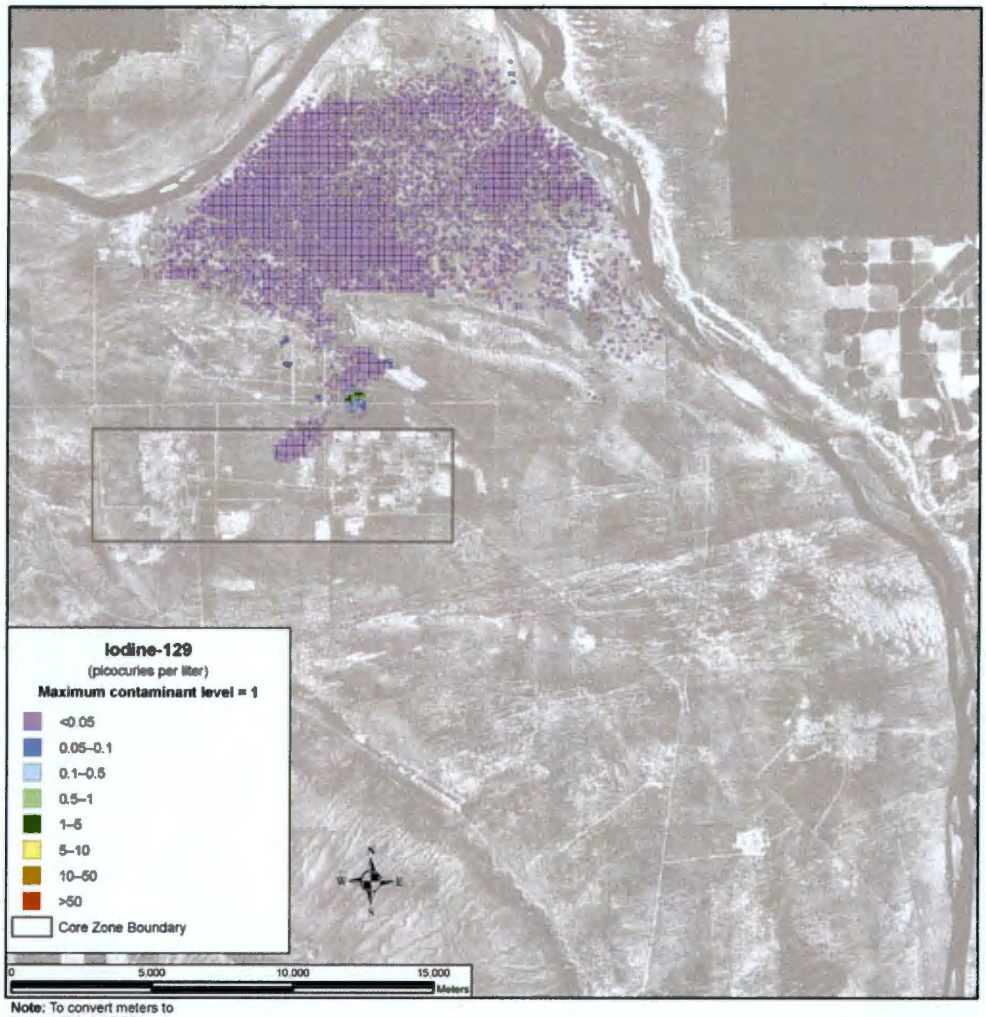
Key: COPC=constituent of potential concern; IDF-East=an Integrated Disposal Facility in the 200-East Area of Hanford; RPPDF=River Protection Project Disposal Facility.

ANALYSIS OF SPATIAL DISTRIBUTION OF CONCENTRATION

This section presents the impacts of Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, in terms of the spatial distribution of groundwater concentration at selected times. Concentrations of radionuclides are in picocuries per liter; chemicals in micrograms per liter (see Figures 5–414 through 5–426). Concentrations for each radionuclide and chemical are indicated by a color scale that is relative to the benchmark concentration. Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations less than the benchmark concentration are indicated by the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude.

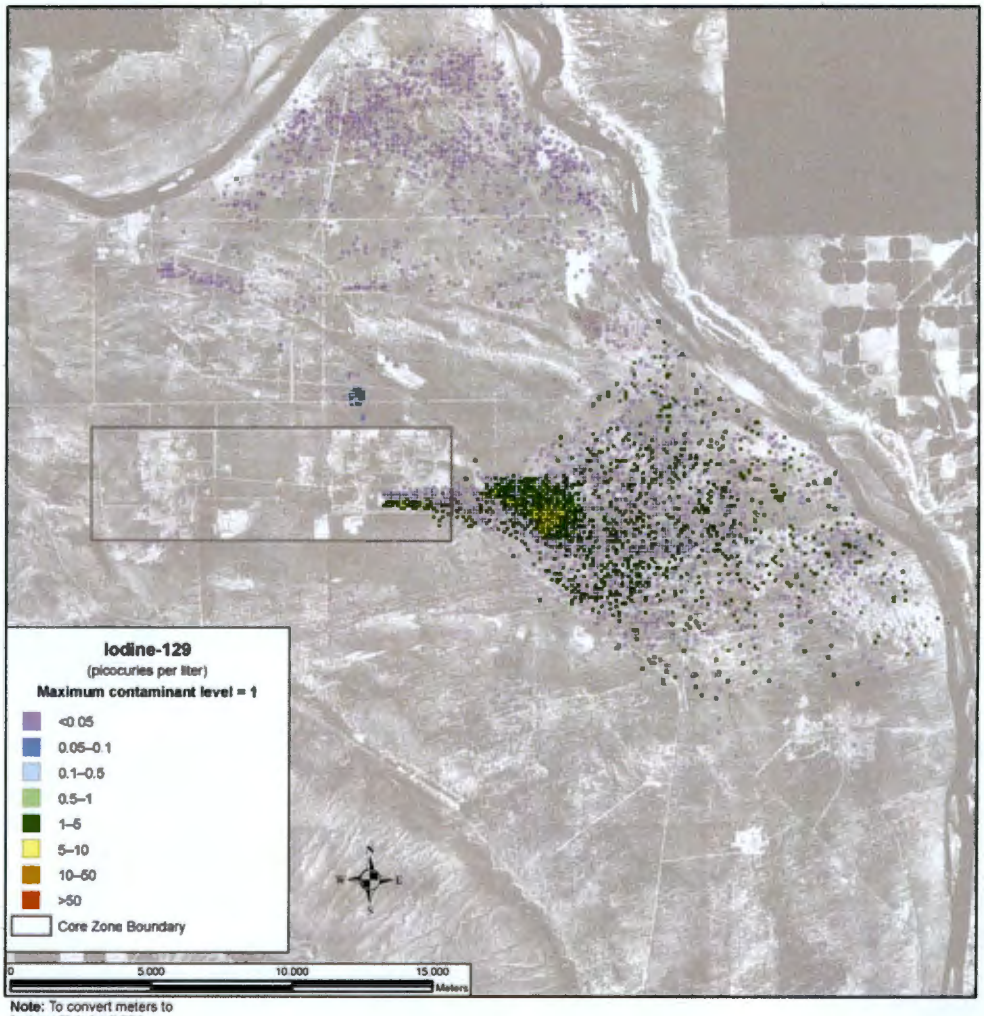
At CY 3890 (see Figure 5–414), there is a low-concentration plume of iodine-129 that stretches north from the RPPDF and through Gable Gap. By CY 7140 (see Figure 5–415), the plume from the RPPDF is gone, but a new plume has formed, traveling east from IDF-East. Concentrations in this plume reach a level over an order of magnitude above the benchmark. Figure 5–416 shows the iodine-129 concentration for CY 11,885. Technetium-99 (see Figures 5–417 through 5–419), chromium (see Figures 5–420 through 5–422), and nitrate (see Figures 5–423 through 5–425) show similar spatial distributions, with lower concentrations at selected times. Iodine-129, technetium-99, chromium, and nitrate are all conservative tracers (i.e., move at the rate of the pore water velocity).

Total uranium shows a different spatial distribution over time. It is not as mobile as the COPCs discussed above, moving about seven times slower than the pore water velocity. As a result, travel times through the vadose zone are longer, release to the aquifer is delayed, and travel times through the aquifer to the Columbia River are longer. By CY 11,885, there is a plume extending through Gable Gap from the RPPDF (see Figure 5–426). Concentrations in all areas of the plume remain below one-twentieth of the benchmark.



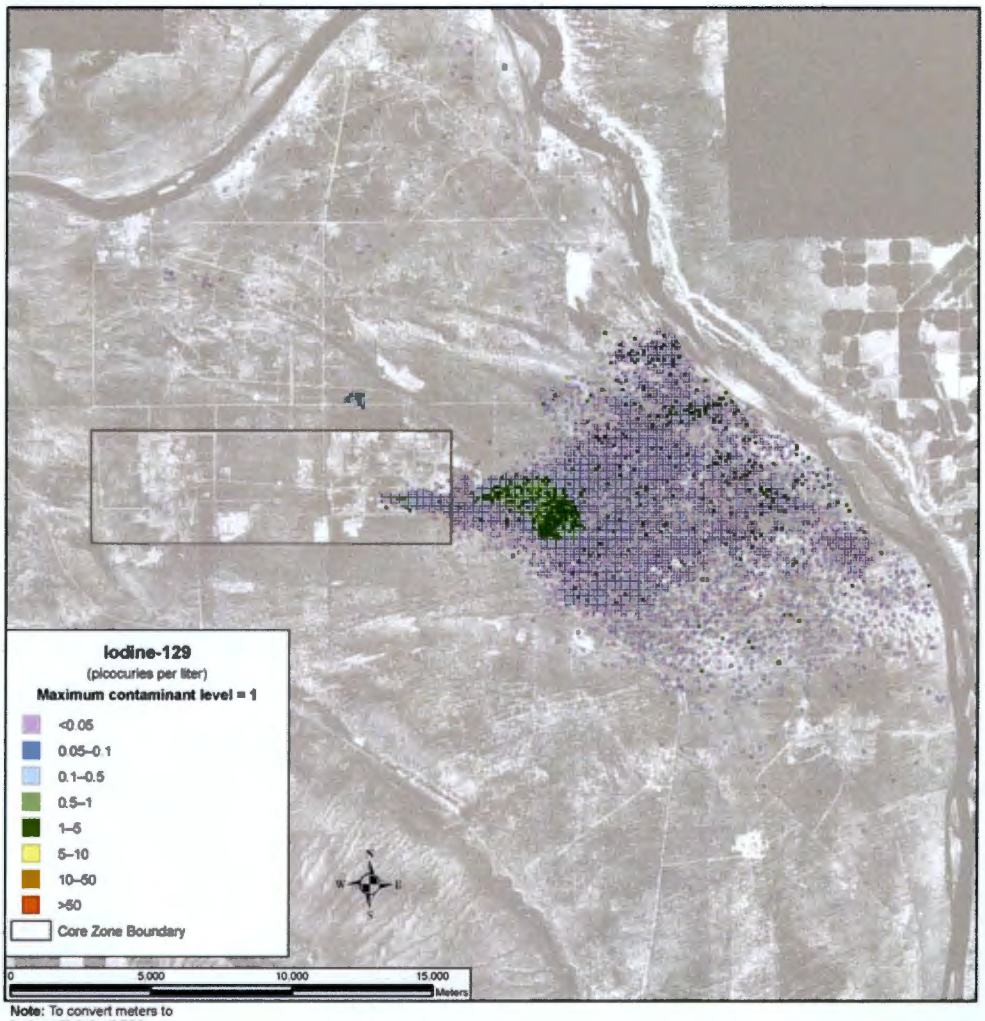
Note: To convert meters to feet, multiply by 3.281

Figure 5–414. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 3890



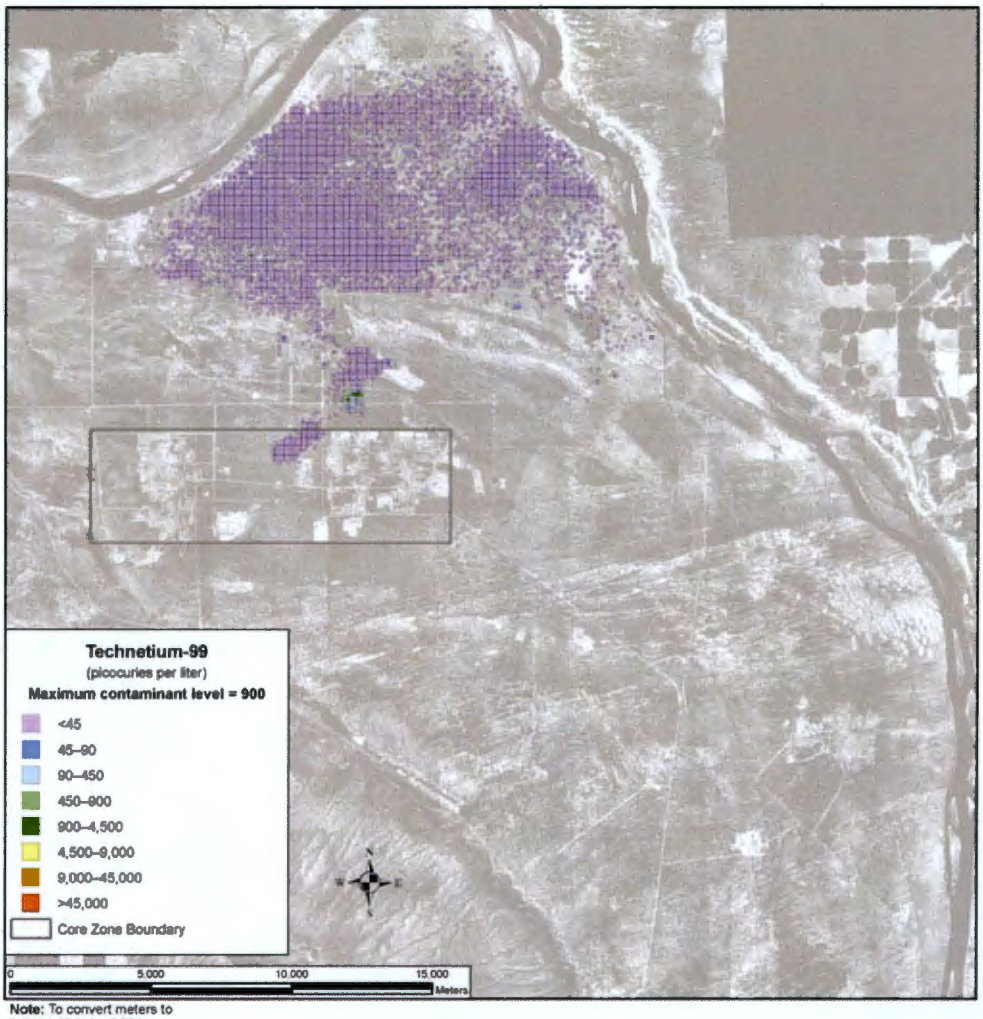
Note: To convert meters to feet, multiply by 3.281

Figure 5–415. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140



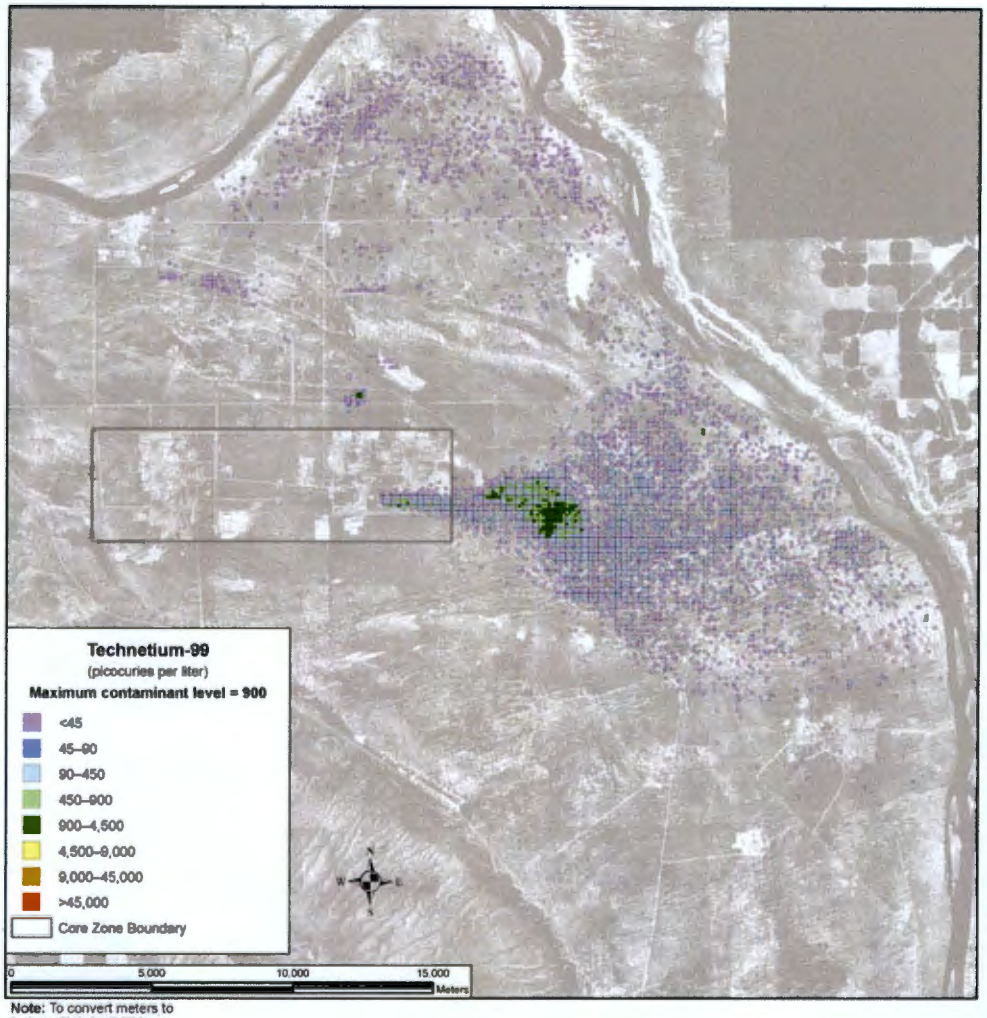
Note: To convert meters to feet, multiply by 3.281

Figure 5–416. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 11,885



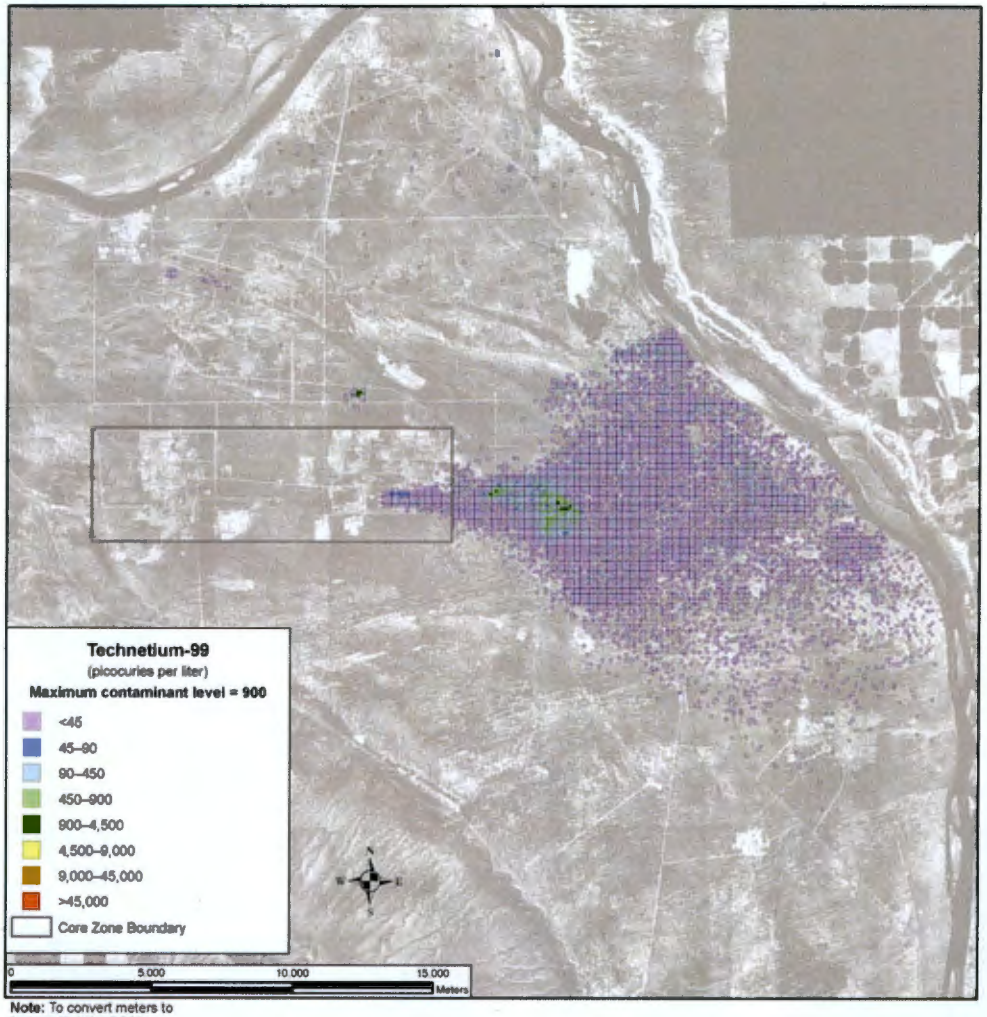
Note: To convert meters to feet, multiply by 3.281

Figure 5–417. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 3890



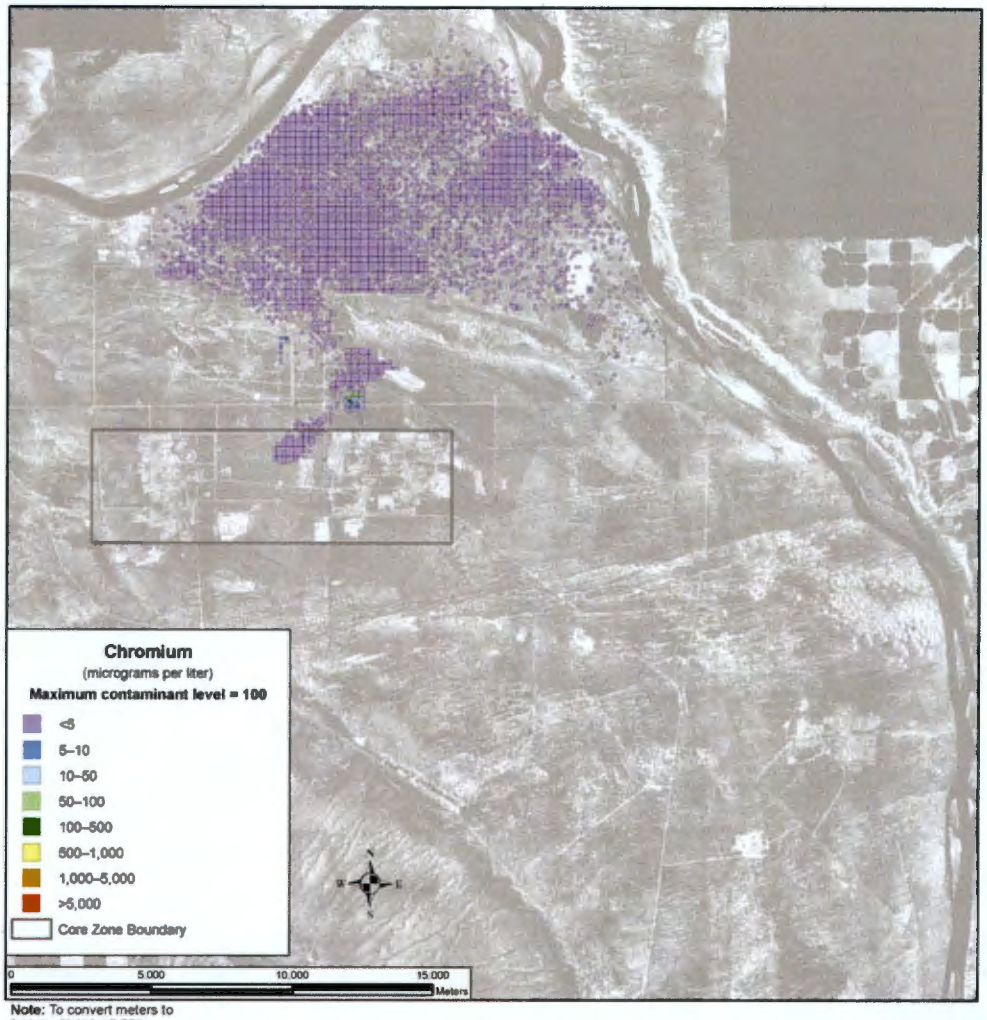
Note: To convert meters to feet, multiply by 3.281

Figure 5–418. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281

Figure 5–419. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 11,885



Note: To convert meters to feet, multiply by 3.281

Figure 5–420. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 3890