CHAPTER 5
LONG-TERM ENVIRONMENTAL CONSEQUENCES

Chapter 5 presents the potential long-term impacts on the existing natural and human environment and on human health of implementation of reasonable alternatives for each of the following: (1) tank waste retrieval and treatment and single-shell tank system closure at the Hanford Site (Hanford); (2) decommissioning of the Fast Flux Test Facility and auxiliary facilities and disposition of Hanford's inventory of radioactively contaminated bulk sodium; and (3) management of waste resulting from the above and other Hanford activities and limited volumes from other U.S. Department of Energy sites. Impact analyses for the alternatives and options considered for each of the three sets of proposed actions are presented separately in Sections 5.1, 5.2, and 5.3, respectively. Impact analyses are grouped first by resource area or discipline (i.e., groundwater, human health, and ecological risks) and then by alternative so that impacts of releases to air and groundwater can be meaningfully compared across alternatives. All disciplines are analyzed in a manner commensurate with their importance and the expected level of impact on them under a specific alternative—the sliding-scale assessment approach. The combined impacts of implementing selected alternatives from each of the three sets of proposed actions are presented in Section 5.4. Cumulative impacts associated with the alternative combinations are presented in Chapter 6. Mitigation measures to reduce the potential for environmental impacts are summarized in Chapter 7, Section 7.1. Analyses of comparative impacts across the alternatives are presented in Chapter 7, Sections 7.2 through 7.4. A detailed discussion of each alternative is provided in Chapter 2, Section 2.5.

The long-term impact analysis results for groundwater, human health, and ecological risk through the 10,000-year period of analysis presented in this *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington (TC & WM EIS)* are derived from modeling releases to air and groundwater, as appropriate. The air modeling process used for this *TC & WM EIS* is described in Appendix F and Appendix G. Figure 5–1 describes the groundwater modeling process used for this *TC & WM EIS*. The process begins with development of inventories of constituents of potential concern (COPCs) for the alternative and cumulative impact analyses described in Appendices D and S, respectively.

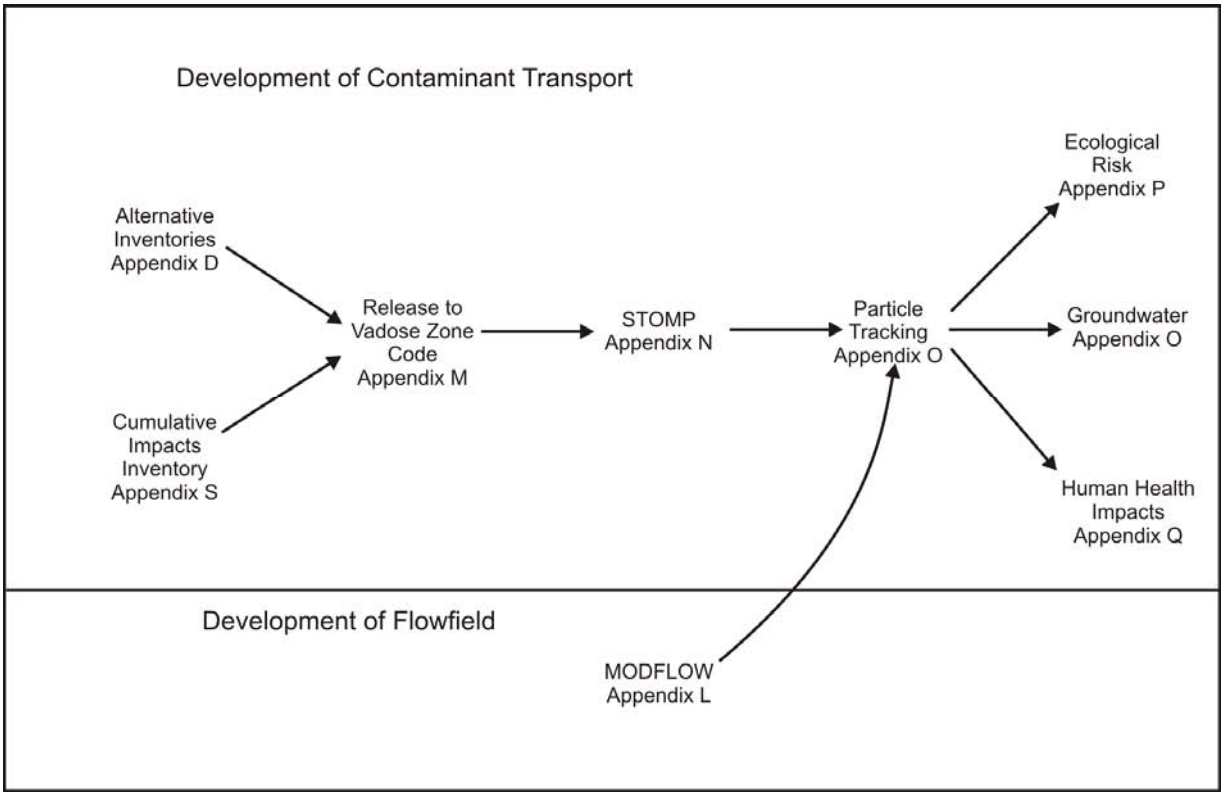


Figure 5–1. Groundwater Modeling Process

The Release to Vadose Zone code uses site-specific parameters to estimate release rates to the vadose zone for each source location analyzed in the alternative and cumulative impact analyses. Parameter examples include contaminant inventories, aqueous recharge, and subsurface geology. Appendix M includes further description of the Release to Vadose Zone code. The output of the Release to Vadose Zone code is an input file to the vadose zone model STOMP [Subsurface Transport Over Multiple Phases] computer code (White and Oostrom 2000, 2006). Appendix M also presents the releases from a number of assumed source forms, some of which are intact and leaching during the entire 10,000-year period of analysis.

The STOMP model uses an integrated-volume finite-difference approach to solve nonlinear water and solute transport balances for the vadose zone. The development and implementation of the vadose zone modeling are presented in Appendix N. The vadose zone modeling provides contaminant and aqueous releases to the aquifer over time, which are incorporated into the groundwater contaminant transport.

A groundwater flow field was developed to determine the direction and rate of water movement in the aquifer, that is, where contaminants entering the groundwater will go and how long it will take to move a given contaminant from the point where it enters the groundwater to any given point along its trajectory toward a location of interest. Groundwater flow through the unconfined aquifer is simulated using the U.S. Geological Survey MODFLOW [modular three-dimensional finite-difference groundwater flow model] 2000 Engine, Version 1.15.00 (USGS 2004). The commercial version used in this *TC & WM EIS* is Visual MODFLOW, Version 4.2 (WHI 2006). A description of the development of the groundwater flow field is provided in Appendix L.

The input for the groundwater contaminant transport runs was based on the output from the vadose zone flow and transport runs that were calculated using the STOMP code. The particle-tracking code (see Appendix O, Section O.2), in combination with the MODFLOW Base Case flow field (see Appendix L), was used to calculate a fully three-dimensional transient analysis of groundwater transport over a period of 10,000 years for each site. The particle-tracking model provides contaminant concentrations in the groundwater over time. A description of the particle-tracking model, along with the listing of benchmarks used to compare COPC concentrations, is provided in Appendix O. These concentrations were used to analyze ecological and human health risk. Detailed descriptions of these risk analyses are provided in Appendices P and Q, respectively. Appendix Q also provides the process to identify the COPCs used for long-term analysis. A map of the Core Zone and barrier boundaries used for the analysis is also provided in Chapter 2, Figure 2–80, and Appendix O, Figure O–1.

5.1 TANK CLOSURE ALTERNATIVES

This section describes the potential long-term environmental impacts associated with implementation of each of the 11 Tank Closure alternatives considered in this *TC & WM EIS* for retrieving and treating the tank waste inventory generated during the defense production years at the Hanford Site (Hanford). The impact analysis also considers different closure scenarios associated with the single-shell tank (SST) system.

Tank Closure Alternative 1, No Action, reflects the environmental baseline against which the impacts of the other action alternatives can be compared. Under Alternative 1, the U.S. Department of Energy (DOE) has assumed for purposes of analysis that construction of the River Protection Project Waste Treatment Plant (WTP) would be terminated in 2008. The tank waste in the SST and double-shell tank (DST) systems would remain in the tank farm indefinitely. DOE would maintain security and management of the site for a 100-year administrative control period (ending in calendar year [CY] 2107), after which the tank waste would be available for release to the environment.

In contrast, Tank Closure Alternatives 2 through 6 involve the construction, subsequent operations, and eventual deactivation of new facilities over varying timeframes (ranging from 34 to 161 years) in the 200-East and 200-West Areas of Hanford to support tank waste retrieval, treatment, and disposal. The waste in the SST and DST systems would be retrieved, treated, and disposed of. With the exception of Alternative 2A, each alternative also analyzes closure of the SST system by either landfill closure (i.e., construction of a surface barrier) or selective or full clean closure (i.e., removal) of the SST system and associated waste and contaminated soils. Each of the 11 Tank Closure alternatives (Alternatives 1 through 6C) are described in detail in Chapter 2, Section 2.5, of this environmental impact statement (EIS).

5.1.1 Groundwater

5.1.1.1 Tank Closure Alternative 1: No Action

This section describes the groundwater analysis results for Tank Closure Alternative 1, 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 Integrated Disposal Facility (IDF) and the River Protection Project Disposal Facility (RPPDF) are presented in Section 5.3, which discusses waste management impacts.

5.1.1.1.1 Actions and Timeframes Influencing Groundwater Impacts

Under Tank Closure Alternative 1, no sources would be removed from within the tank farm barriers. 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, three major periods were identified for Tank Closure Alternative 1, 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 1 that are presented in this section would be common to all of the Tank Closure alternatives.

- 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 further releases from the SST and DST systems, but that releases that occurred during the past-practice period would continue to migrate through the vadose zone and groundwater system.

- 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, releases that occurred during the past-practice period would continue to migrate through the vadose zone and groundwater system. In addition, all stored waste at the SST and DST farms (referred to as “other tank farm sources” in this chapter) would be released to the vadose zone at the start of the post–administrative control period.

5.1.1.1.2 COPC Drivers

A total of 19 COPCs were analyzed for Tank Closure Alternative 1. 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 1 is focused on the following COPC drivers:

- Radiological risk drivers: hydrogen-3 (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 1 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, they become major contributors toward the end of the period of analysis. 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 1.

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 are the radionuclides carbon-14, cesium-137, neptunium-237, plutonium-239, and strontium-90 and the chemicals acetonitrile, benzene, 1-butanol, lead, mercury, polychlorinated biphenyls, and 2,4,6-trichlorophenol. These constituents 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.

5.1.1.1.3 Analysis of Release and Mass Balance[1]

This section presents the impacts of Tank Closure Alternative 1 in terms of total amount of COPCs released to the vadose zone, groundwater, and the Columbia River during the 10,000-year period of

[1] A "mass balance" (also called a material balance) is an application of conservation of mass to the analysis of a physical system, i.e., the mass of a chemical or radionuclide that enters a system must, by conservation of mass, either leave the system, accumulate within the system, or decay/react to a different chemical or radionuclide (input = output + accumulation + decay/reaction). By accounting for material entering and leaving a system, mass flows can be identified that might have been unknown, or difficult to measure without this technique.

Applied to this EIS, mass balance refers to accounting for the total amount of COPCs released from key sources to the vadose zone, groundwater, and Columbia River during the 10,000-year period of analysis at various locations and points in time, taking into consideration retardation factors (retention in the vadose zone and aquifer) and radioactive decay. This accounting allows tracking of the mass flows, accumulations, and decays at each stage through transit from source to arrival at the Columbia River.

analysis. Releases of radionuclides are totaled in curies, chemicals in kilograms (see Figures 5–2 through 5–7). Three subtotals are plotted representing releases from cribs and trenches (ditches), past leaks, and other tank farm sources. 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 5–2 shows the estimated release to the vadose zone for the radiological risk drivers and Figure 5–3, the chemical hazard drivers. For all three 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 for tritium 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 other tank farm sources. This suggests that other tank farm sources, which are released in the analysis during the post–administrative control period, are an important impact driver under Tank Closure Alternative 1.

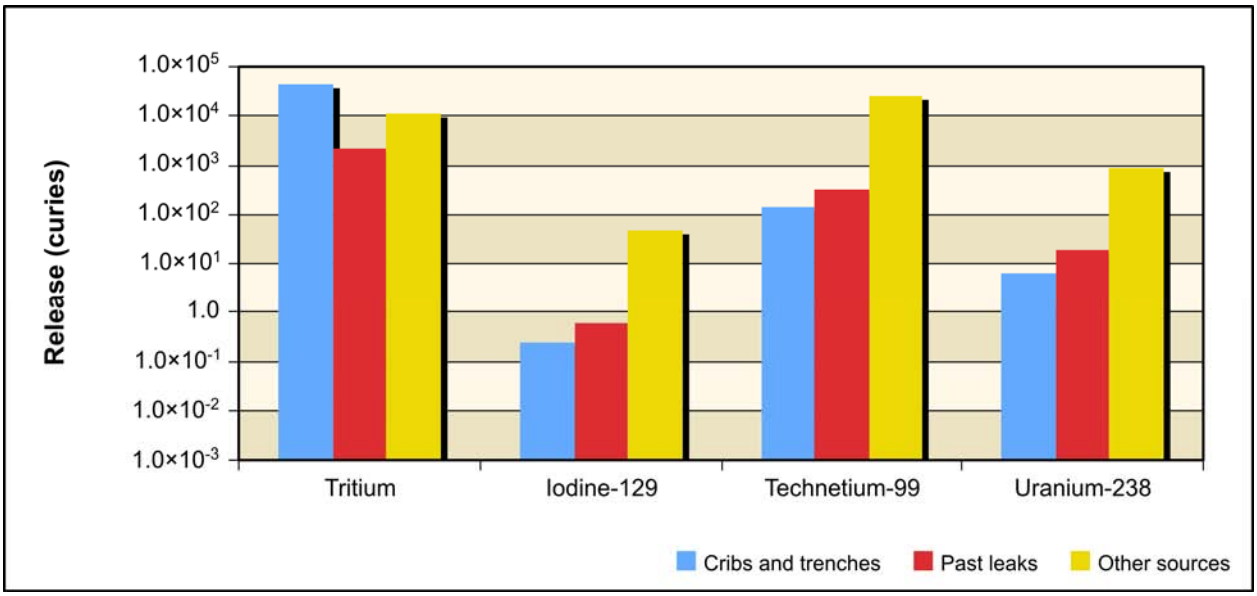


Figure 5–2. Tank Closure Alternative 1 Releases of Radiological Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

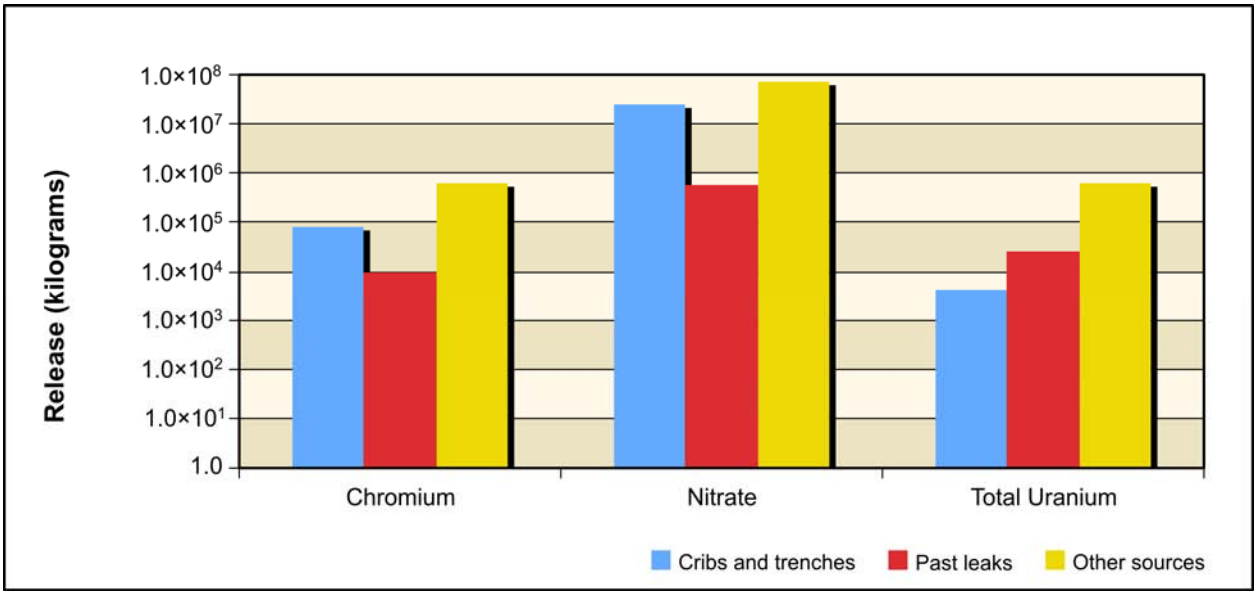


Figure 5–3. Tank Closure Alternative 1 Releases of Chemical Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

Figure 5–4 shows the estimated release to groundwater for the radiological risk drivers and Figure 5–5, 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, chromium, and nitrate), the amount released to groundwater is essentially equal to the amount released to the vadose zone.

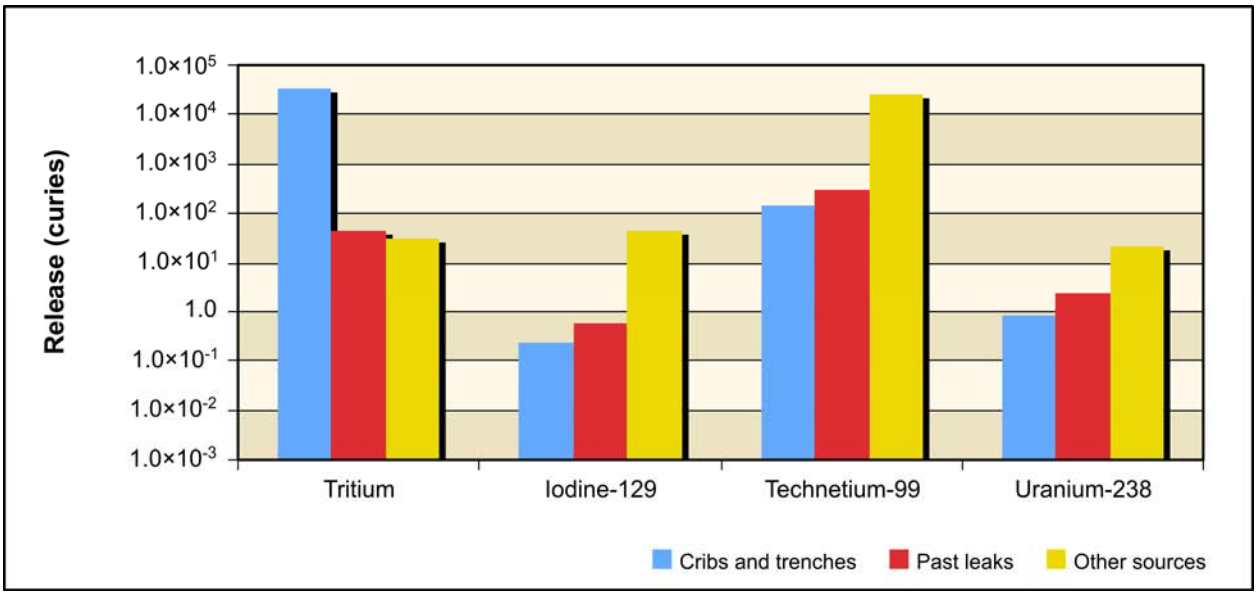


Figure 5–4. Tank Closure Alternative 1 Releases of Radiological Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

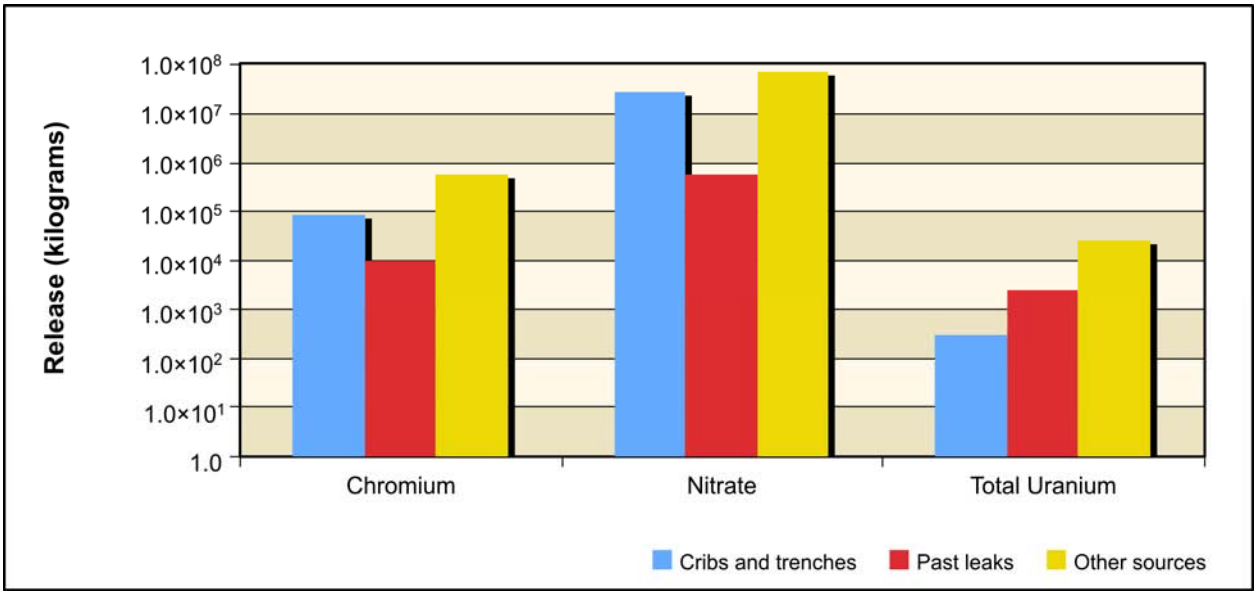


Figure 5–5. Tank Closure Alternative 1 Releases of Chemical Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

For tritium, the amount released to groundwater is attenuated by radioactive decay in the vadose zone. For cribs and trenches (ditches), about 70 percent of the total inventory of tritium reached groundwater in the analysis; for past leaks, only 2 percent; and for other tank farm sources, less than 1 percent reached the water table. 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.

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 addition and 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), about 14 percent of uranium-238 and 8 percent of total uranium inventory reached groundwater during the period of analysis. For past leaks, about 18 percent of uranium-238 and 14 percent of total uranium of the total inventory reached groundwater during the period of analysis. For other tank farm sources, about 4 percent of uranium-238 and 7 percent of total uranium of the total inventory reached groundwater during the period of analysis. These results also suggest that uranium-238 and total uranium impacts would occur later in the post–administrative control period because of the long travel times for these COPCs in the vadose zone.

Figure 5–6 shows the estimated release to the Columbia River for the radiological risk drivers and Figure 5–7, 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.

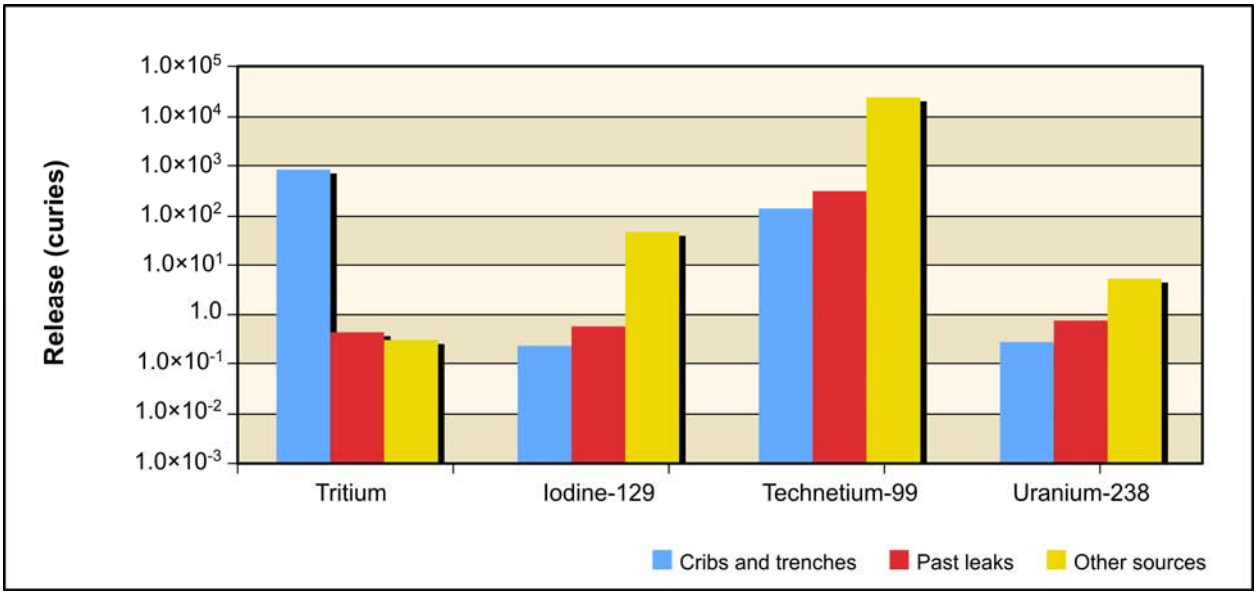


Figure 5–6. Tank Closure Alternative 1 Releases of Radiological Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

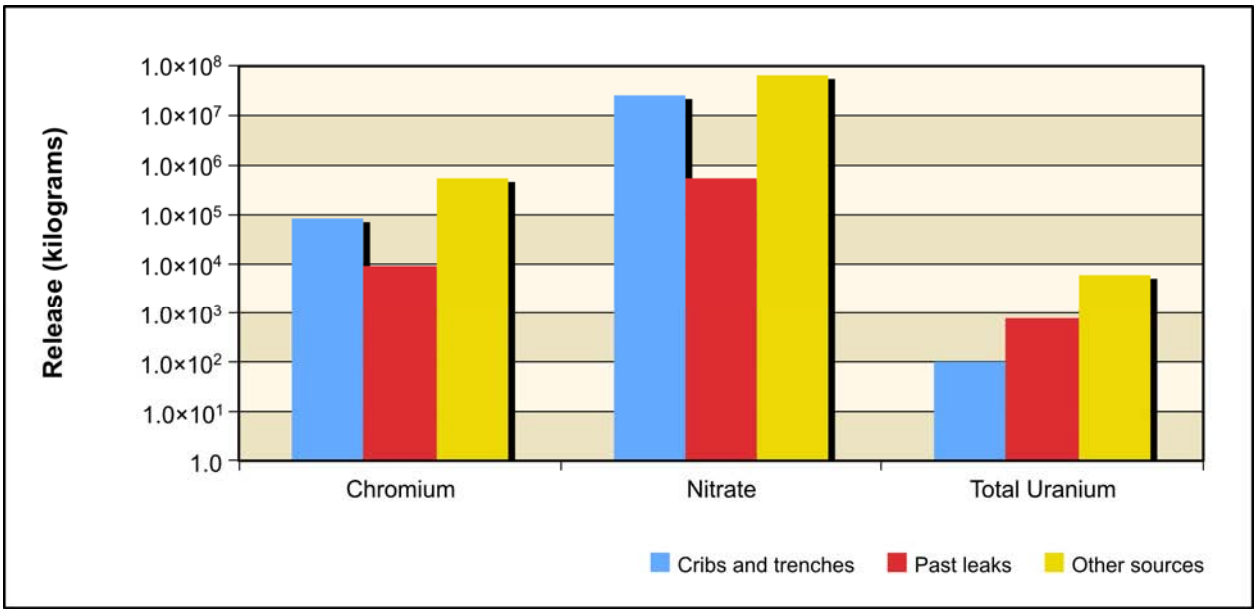


Figure 5–7. Tank Closure Alternative 1 Releases of Chemical Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

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. Overall, about 25 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. Overall, only about 3 percent of the tritium released to groundwater reached the Columbia River during the period of analysis. 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.

5.1.1.1.4 Analysis of Concentration Versus Time

This section presents the analysis of Tank Closure Alternative 1 impacts in terms of groundwater concentration versus time at the tank farm barriers, Core Zone Boundary, and the Columbia River. Concentrations of radionuclides are in picocuries per liter, chemicals in micrograms per liter (see Table 5–1 and Figures 5–8 through 5–14). 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 five orders of magnitude. Although the concentration-versus-time plots presented in this section (as well as in the following sections and throughout this *TC & WM EIS*) appear similar in structure to the classic advection-dispersion breakthrough curves, the reader is cautioned that the curves presented in these sections are not amenable to the classic analysis. The classic presentation is a time-series plot of concentration from a single source at a fixed location. In this *TC & WM EIS*, each concentration-versus-time plot is from a multiple number of sources (typically on the order of 30) at a variable location (the location of the highest peak concentration along the line of analysis). Therefore, attempts to apply classic transport theory to these results can, in general, result in misleading conclusions. Table 5–1 lists the maximum concentrations of the COPCs in the peak year after CY 2050 at the tank farm barriers, Core Zone Boundary, and Columbia River nearshore.

Table 5–1. Tank Closure Alternative 1 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)	4,190	2,690	2,460	5,570	12	3,790	180	20,000
	(2112)	(2052)	(2117)	(2052)	(2051)	(2102)	(2054)	
Technetium-99	**70,100**	**175,000**	**38,700**	**15,000**	**14,800**	**350,000**	**5,230**	900
	(2114)	(3837)	(3238)	(2051)	(3536)	(3837)	(4032)	
Iodine-129	**71**	**398**	**67**	**71**	**29**	**682**	**13**	1
	(2114)	(3801)	(3312)	(3756)	(3536)	(3801)	(4411)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	**23**	**490**	**259**	**102**	**40**	**1,070**	6	15
	(11,789)	(11,749)	(11,730)	(11,820)	(11,758)	(11,683)	(11,918)	
Chemical in micrograms per liter								
Chromium	**284**	**5,050**	**1,650**	**911**	**308**	**12,200**	**165**	100
	(2114)	(3628)	(3172)	(2050)	(3587)	(3524)	(4019)	
Nitrate	**69,600**	**1,740,000**	**107,000**	**201,000**	34,900	**1,130,000**	23,500	45,000
	(2119)	(2087)	(3138)	(2088)	(3654)	(2059)	(3911)	
Total uranium	5	**695**	**281**	**96**	**51**	**1,220**	8	30
	(11,769)	(11,762)	(11,762)	(11,836)	(11,739)	(11,648)	(11,591)	

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 5–8 shows concentration versus time for tritium. Note that for visual clarity, the time period shown in this figure is from CYs 1940 through 2440 (500 years), rather than the full 10,000-year period of analysis. Releases from cribs and trenches (ditches) cause groundwater concentrations to exceed benchmark concentrations by about three orders of magnitude for a short period of time during the early part of the period of analysis. During this time, groundwater concentrations at the Columbia River nearshore approach the benchmark concentration. Because the half-life of tritium is less than 13 years, radioactive decay rapidly attenuates groundwater concentration, and tritium is essentially not a factor at times later than CY 2100.

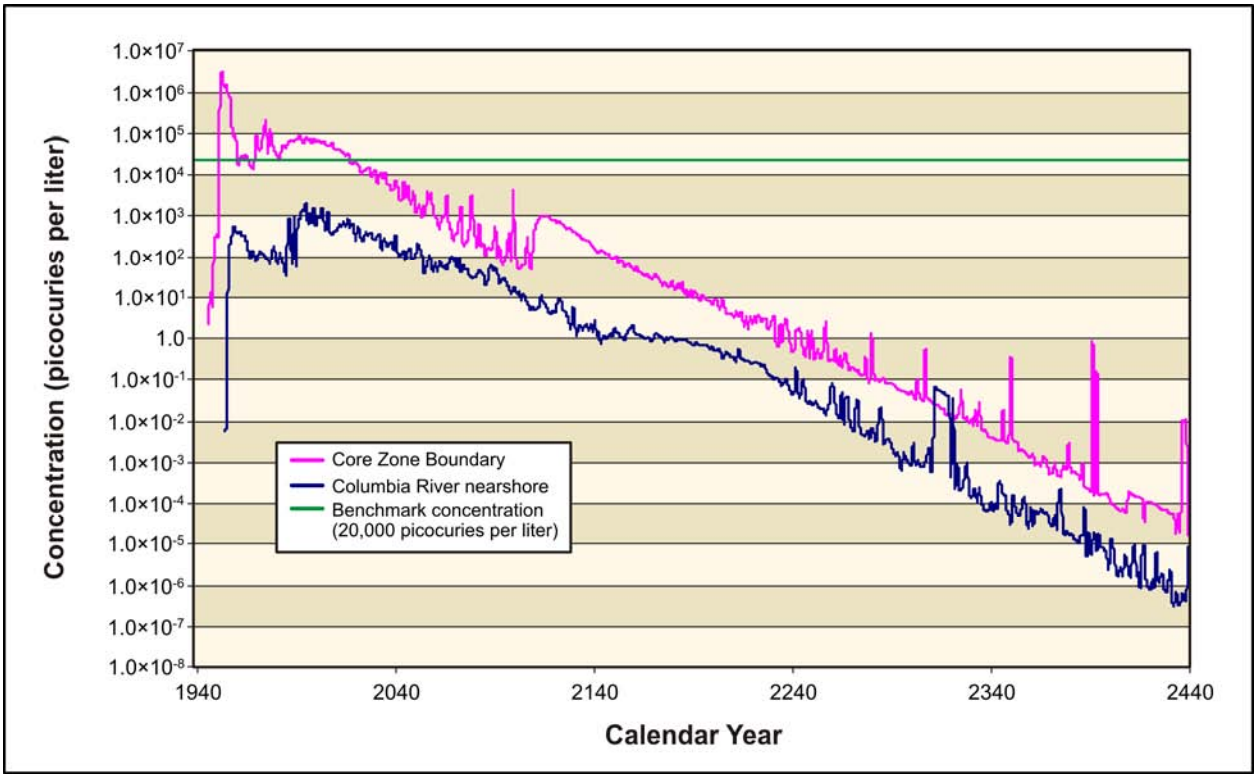


Figure 5–8. Tank Closure Alternative 1 Hydrogen-3 (Tritium) Concentration Versus Time

Figures 5–9 through 5–12 show concentration versus time for iodine-129, technetium-99, chromium, and nitrate (the conservative tracers). Releases from cribs and trenches (ditches) cause groundwater concentrations of iodine-129 to exceed benchmark concentrations by about two to three orders of magnitude during the early part of the period of analysis. During this time, groundwater concentrations at the Columbia River nearshore approach or exceed the benchmark concentration. Releases from other tank farm sources cause groundwater concentrations to exceed benchmark concentrations by about three orders of magnitude during the middle and latter parts of the period of analysis. During this time, groundwater concentrations at the Columbia River nearshore exceed the benchmark concentration by about an order of magnitude, tapering off to near the benchmark concentration at the end of the period of analysis. Technetium-99, chromium, and nitrate concentrations show a similar curve, with chromium and nitrate concentrations at the Columbia River nearshore dropping below the benchmark concentrations.

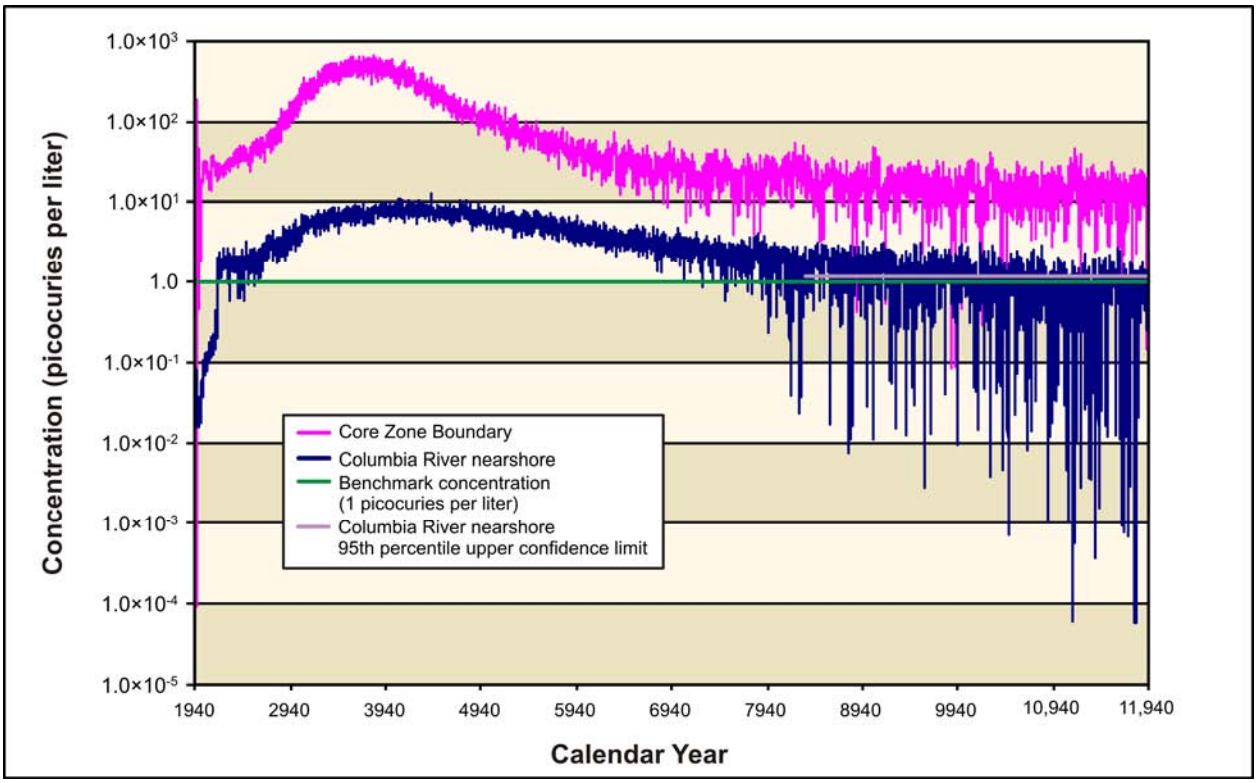


Figure 5–9. Tank Closure Alternative 1 Iodine-129 Concentration Versus Time

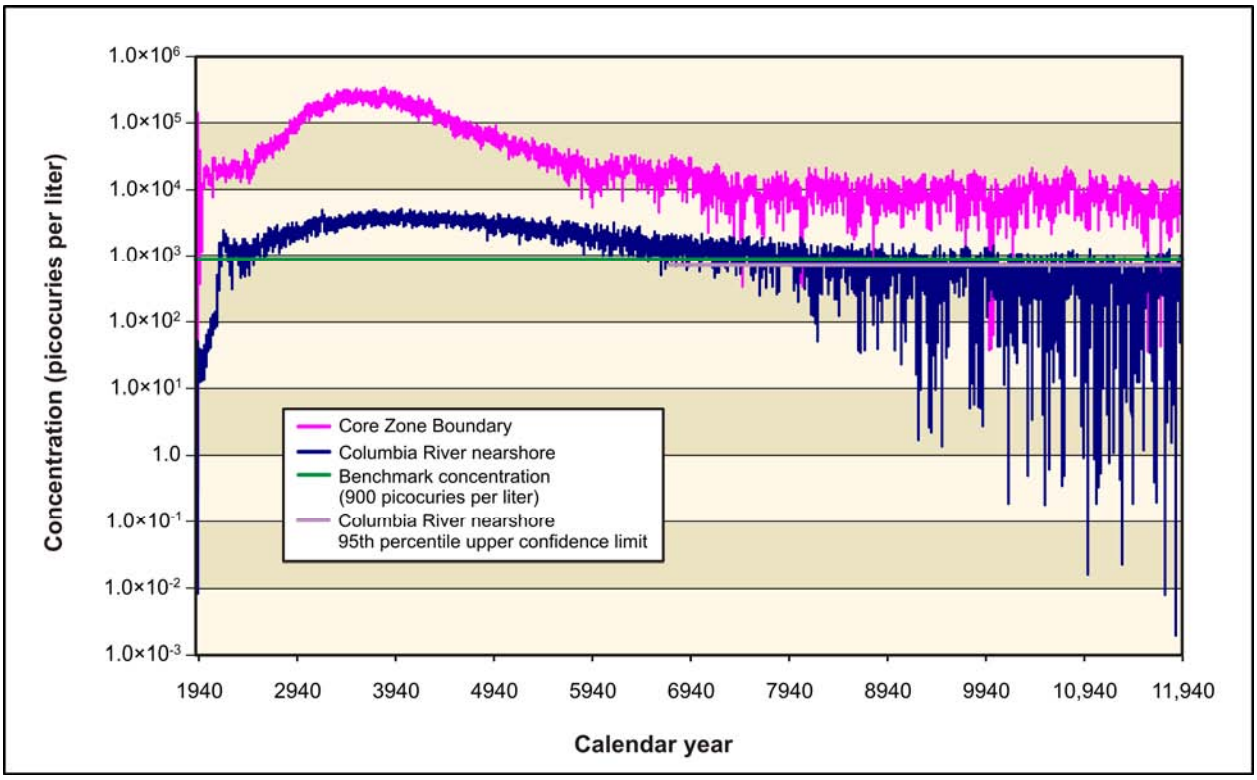


Figure 5–10. Tank Closure Alternative 1 Technetium-99 Concentration Versus Time

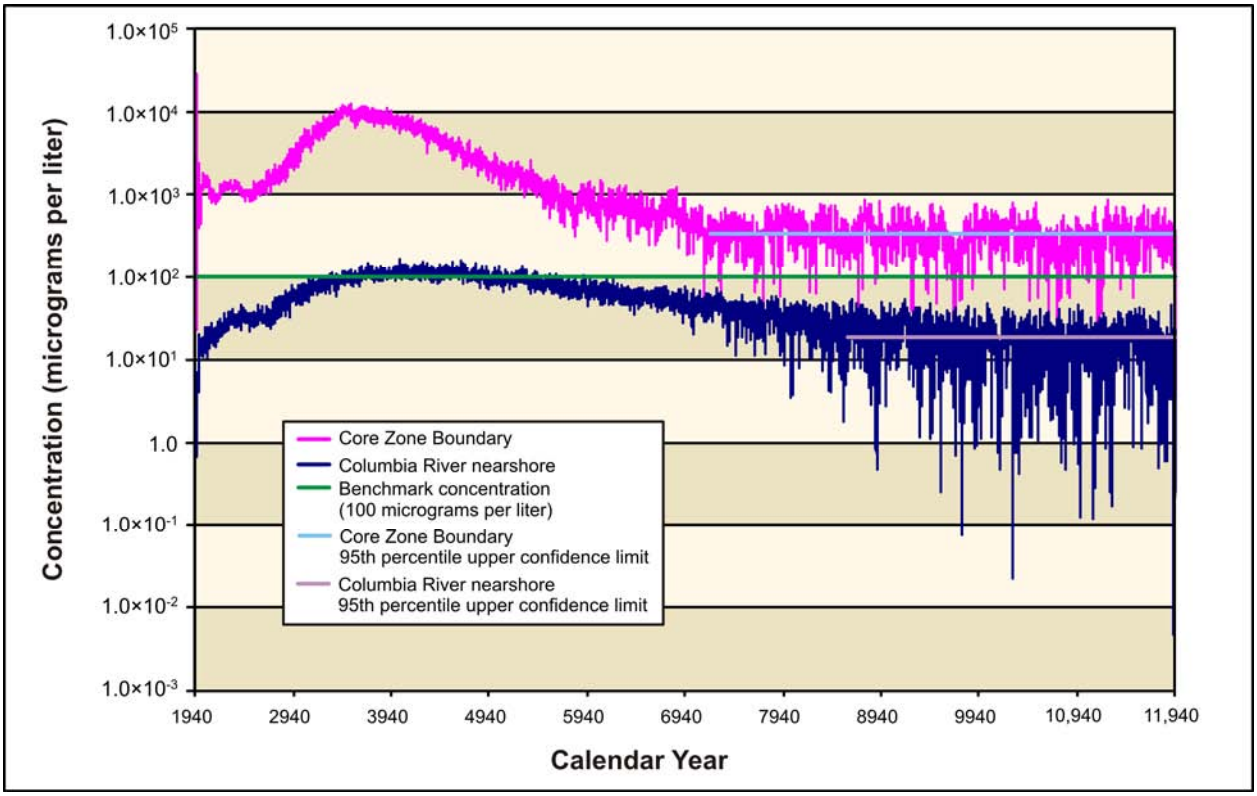


Figure 5–11. Tank Closure Alternative 1 Chromium Concentration Versus Time

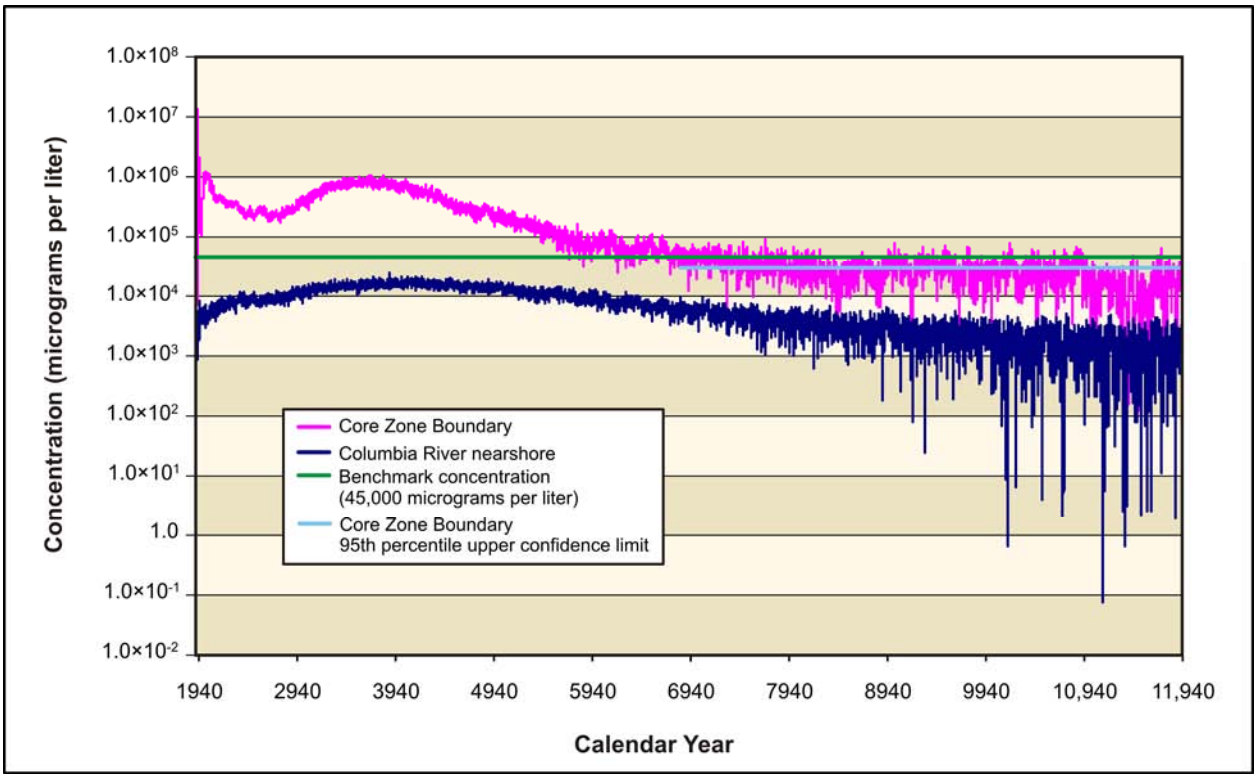


Figure 5–12. Tank Closure Alternative 1 Nitrate Concentration Versus Time

Figures 5–13 and 5–14 show concentration versus time for uranium-238 and total uranium. Early releases from cribs and trenches (ditches) result in groundwater concentrations that are one to two orders of magnitude lower than benchmark concentrations. Releases from other tank farm sources cause groundwater concentrations to rise, nearing benchmark concentrations by CY 6000. Concentrations continue to rise throughout the duration of the period of analysis, exceeding benchmark concentrations by about two orders of magnitude at the end of the period of analysis. Groundwater concentrations at the Columbia River nearshore rise throughout the period of analysis, nearing the benchmark concentration by CY 11,940.

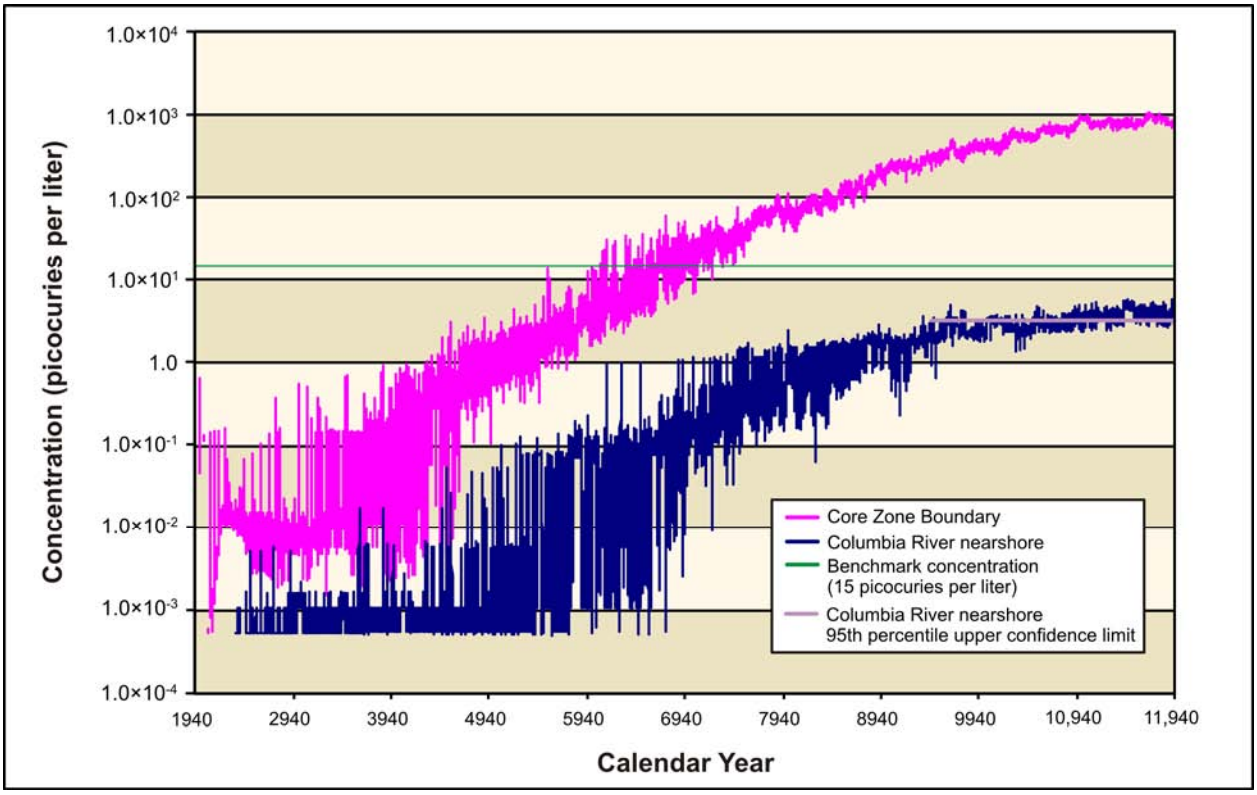


Figure 5–13. Tank Closure Alternative 1 Uranium-238 Concentration Versus Time

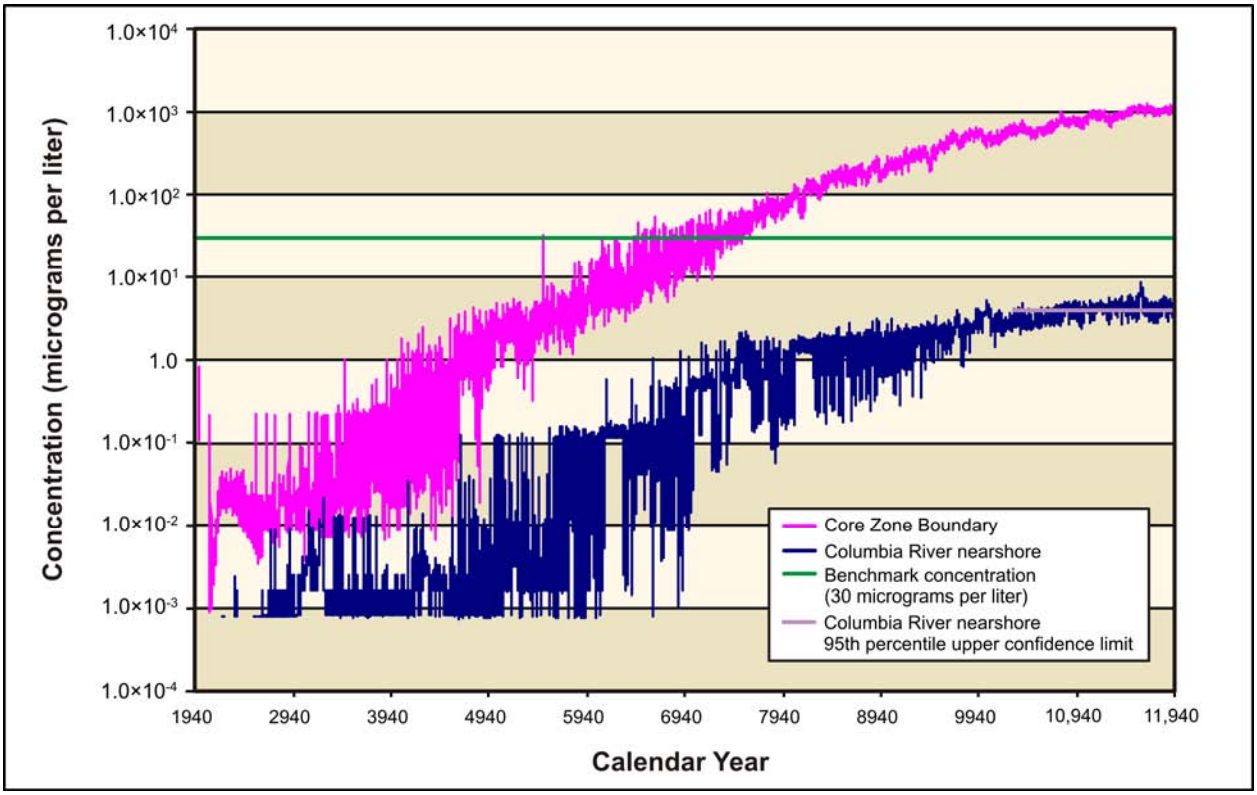
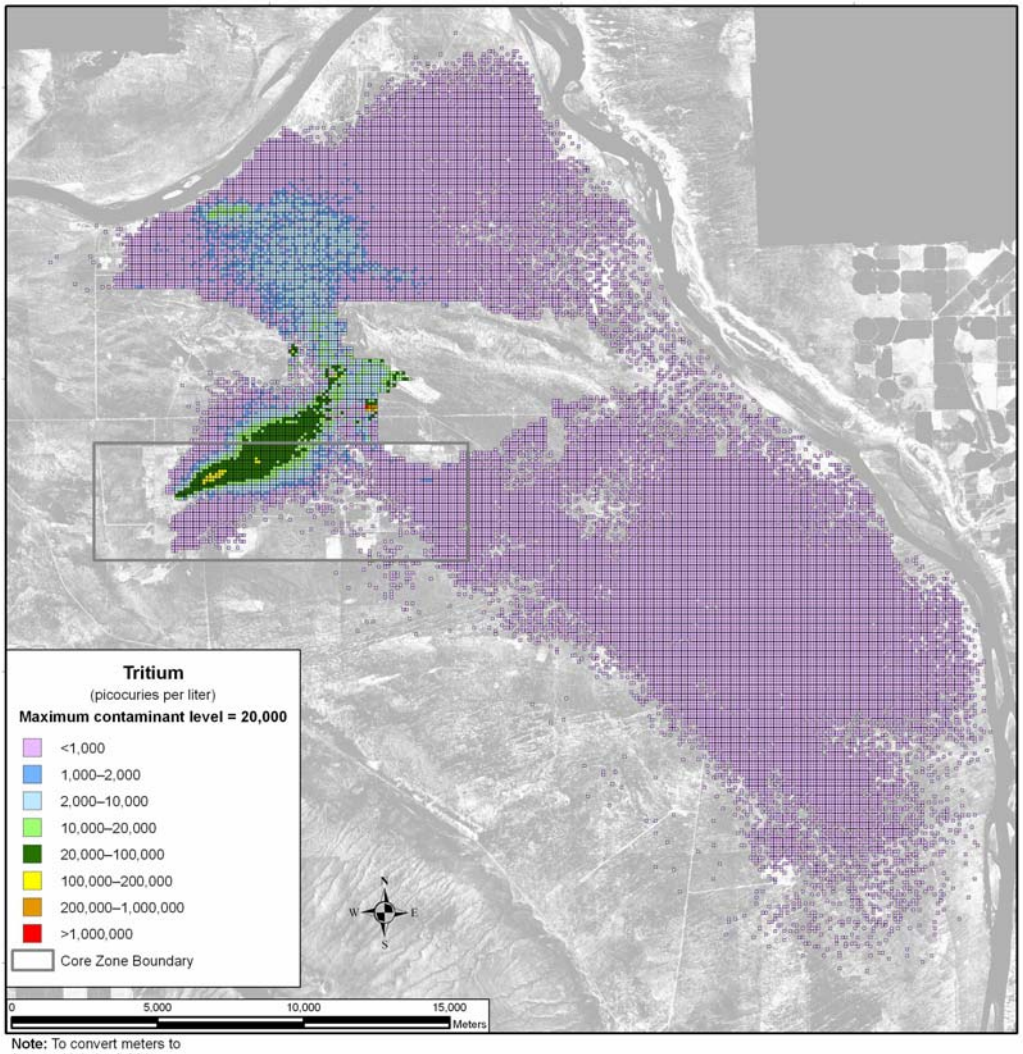


Figure 5–14. Tank Closure Alternative 1 Total Uranium Concentration Versus Time

5.1.1.1.5 Analysis of Spatial Distribution of Concentration

This section presents the impacts of Tank Closure Alternative 1 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 5–15 through 5–36). Concentrations for each radionuclide and chemical are indicated by a color scale that is relative to the benchmark concentration. Note that, in this section and in subsequent sections, the benchmark concentration is identified as "maximum contaminant level" in the legend of the spatial distribution figures. 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.

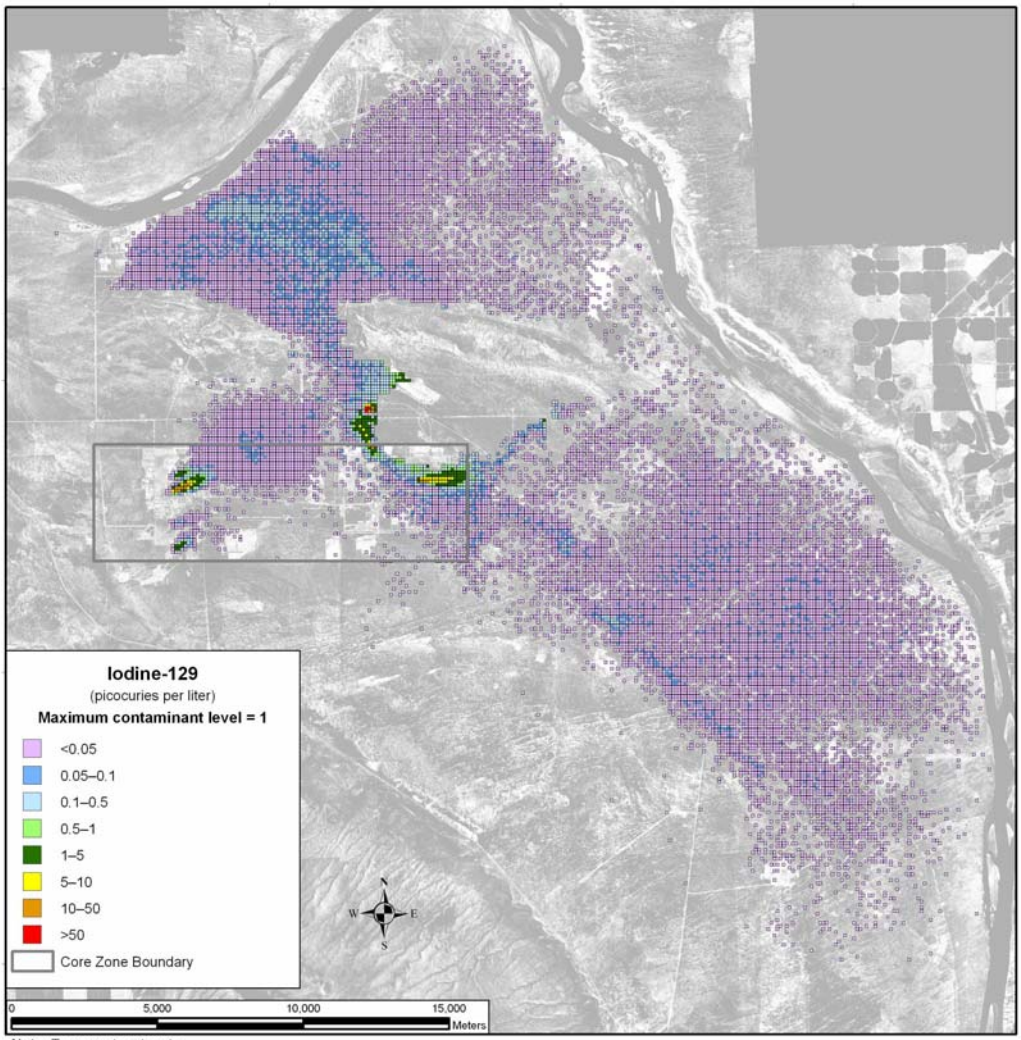
Figure 5–15 shows the spatial distribution of groundwater concentration for tritium during CY 2005. Analysis releases from cribs and trenches (ditches) and past leaks, associated primarily with the T, TX, and TY tank farms, result in a groundwater concentration plume (exceeding the benchmark concentration) that extends from the center part of the 200-West Area northeast, crossing the Core Zone Boundary, and extending toward the Gable Mountain–Gable Butte Gap (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. Tritium concentrations are attenuated by radioactive decay to levels less than one-twentieth of the benchmark concentration by CY 2135, as shown in Figure 5–8.



Note: To convert meters to feet, multiply by 3.281

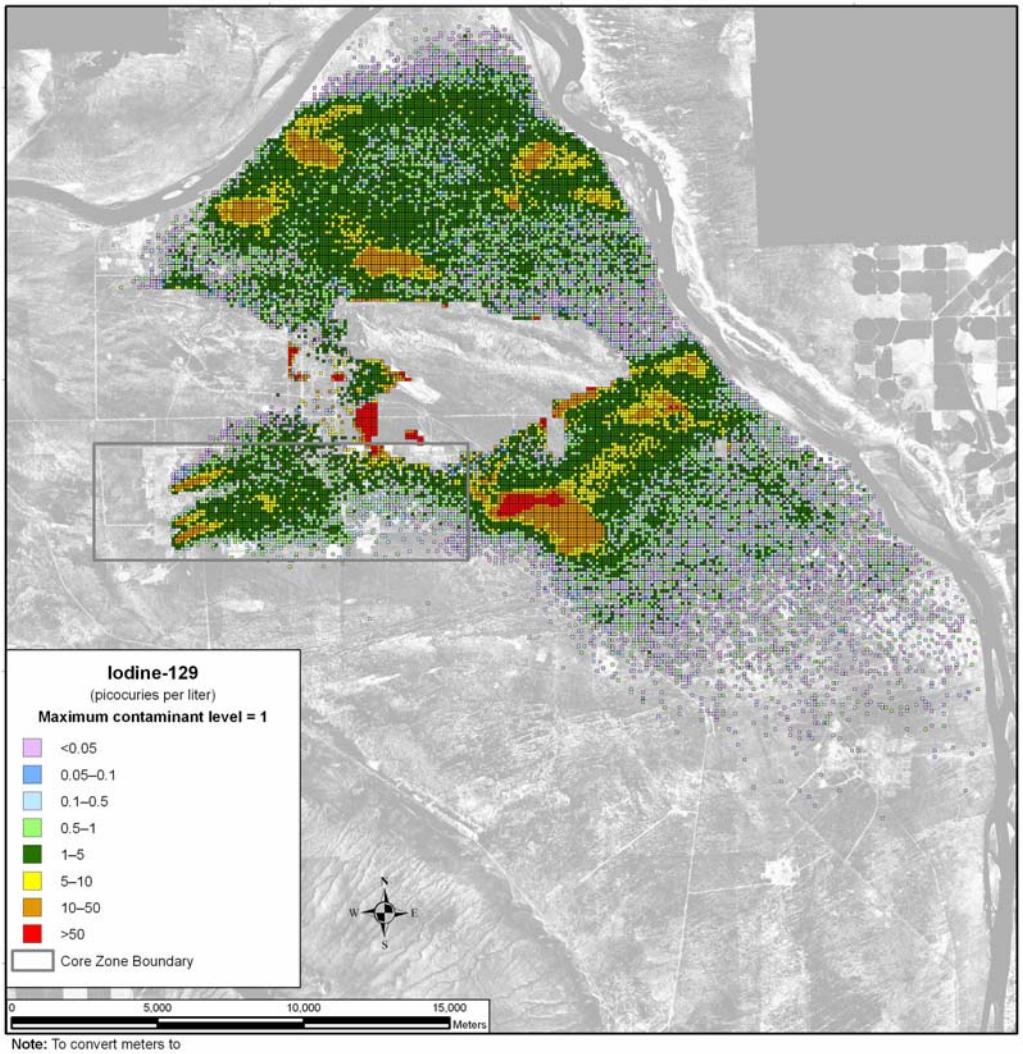
Figure 5–15. Tank Closure Alternative 1 Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2005

Figure 5–16 shows the spatial distribution of groundwater concentration for iodine-129 during CY 2005. 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 50 times greater than the benchmark, and mostly contained within the Core Zone Boundary. Around CY 3890, releases from other tank farm sources create a large plume exceeding the benchmark, extending from the A Barrier to the Columbia River (see Figure 5–17). By CY 7140, most of the mass in the plume has reached the Columbia River, with only isolated pockets of high-concentration areas where the groundwater flow velocities are extremely small (see Figure 5–18). Figure 5–19 shows the total area in which groundwater concentrations of iodine-129 exceed the benchmark concentration in the analysis as a function of time. The area of exceedance peaks between CY 3240 and CY 4540 as a result of releases from other tank farm sources. Figures 5–20 through 5–23 show the spatial distribution at the same three times and the total area of exceedance versus time for technetium-99. The spatial distribution of technetium-99 is similar to that of iodine-129. The other conservative tracers, chromium (see Figures 5–24 through 5–26) and nitrate (see Figures 5–27 through 5–29), show similar spatial distributions at selected times.



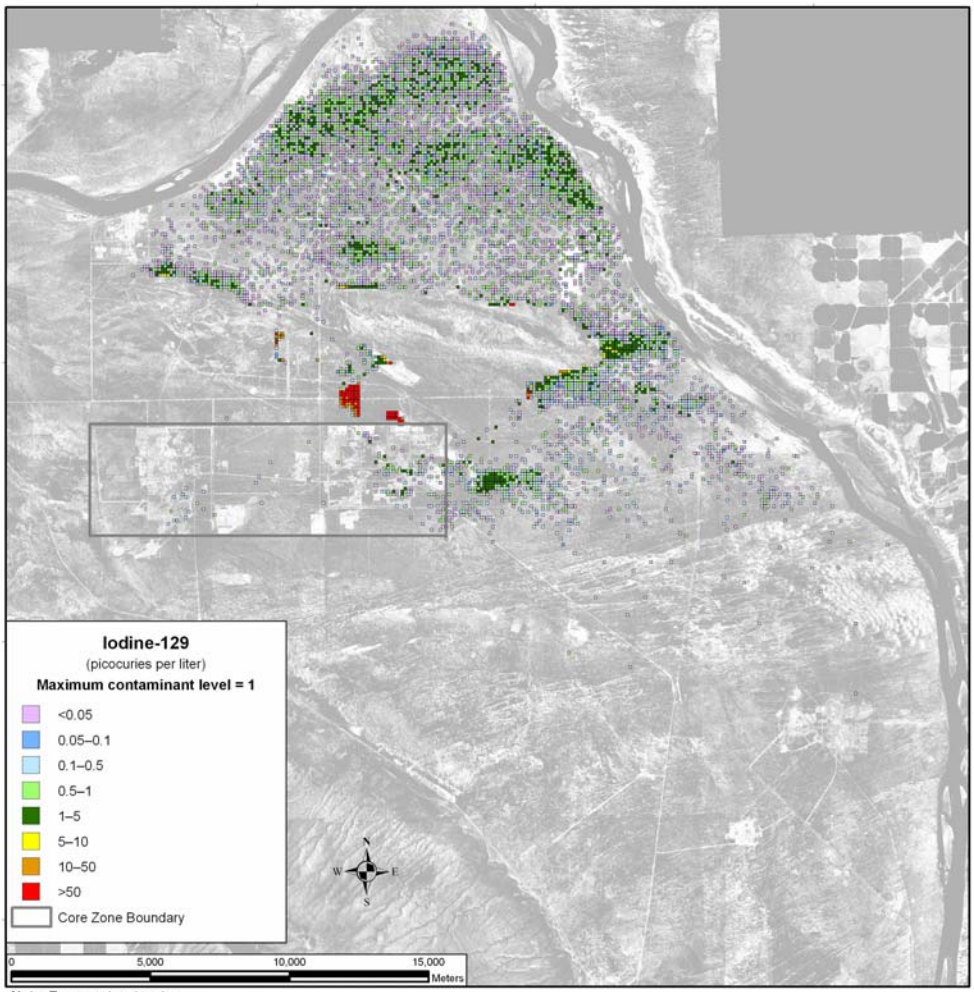
Note: To convert meters to feet, multiply by 3.281

Figure 5–16. Tank Closure Alternative 1 Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

Figure 5–17. Tank Closure Alternative 1 Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 3890



Note: To convert meters to feet, multiply by 3.281

Figure 5–18. Tank Closure Alternative 1 Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140

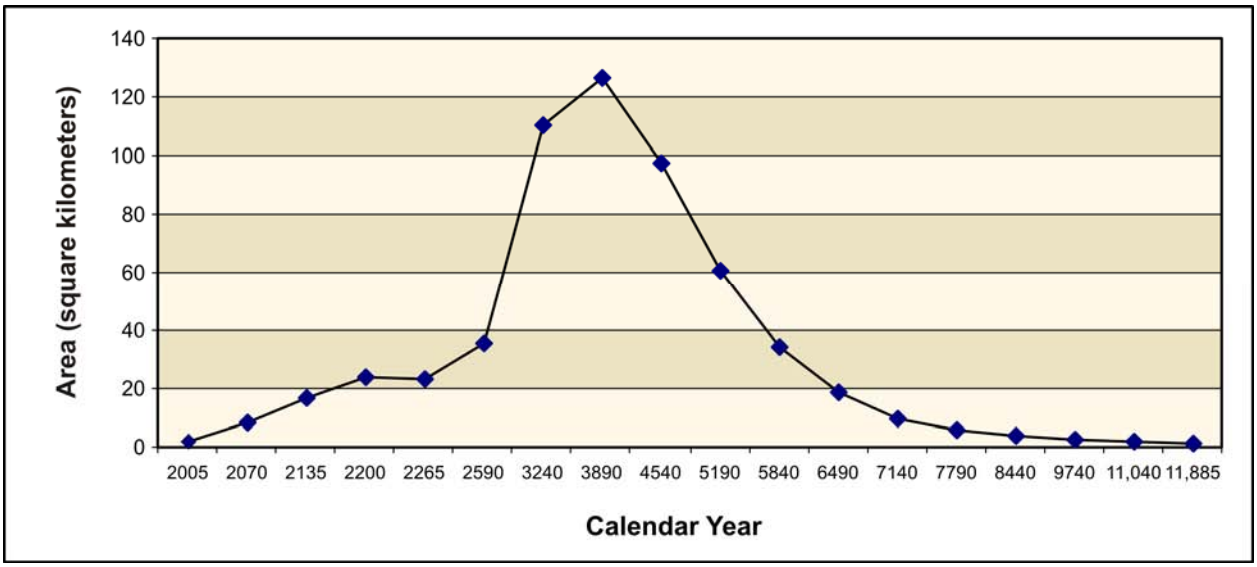
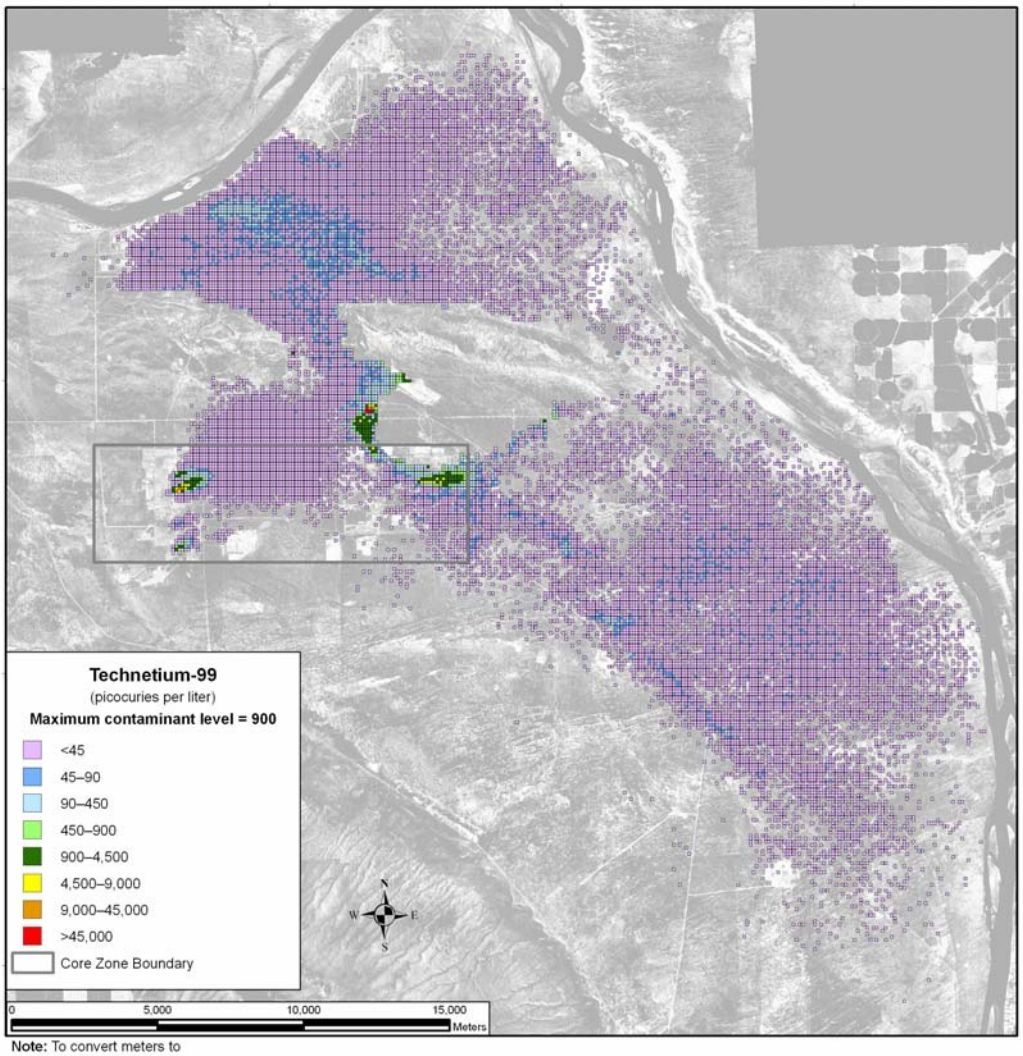
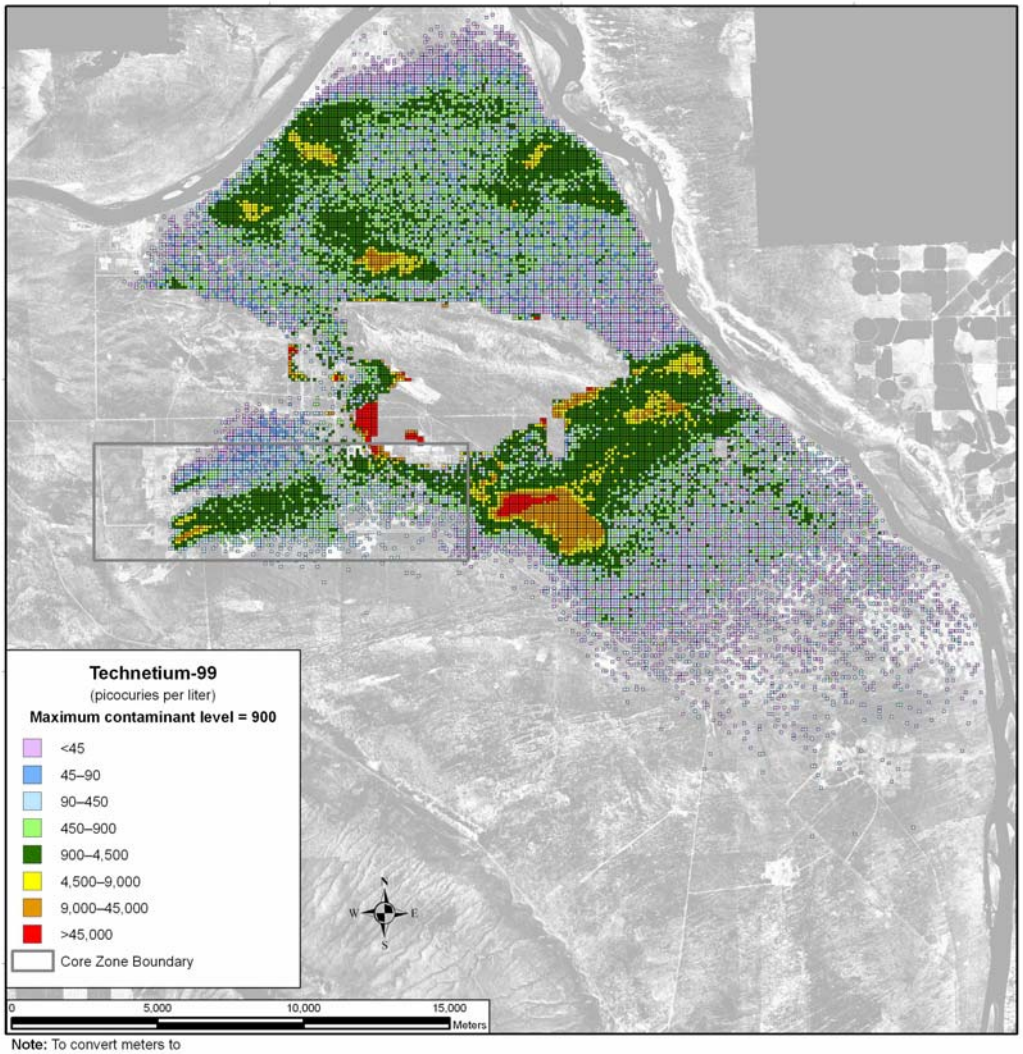


Figure 5–19. Tank Closure Alternative 1 Total Area of Groundwater Iodine-129 Concentration Exceeding the Benchmark Concentration as a Function of Time



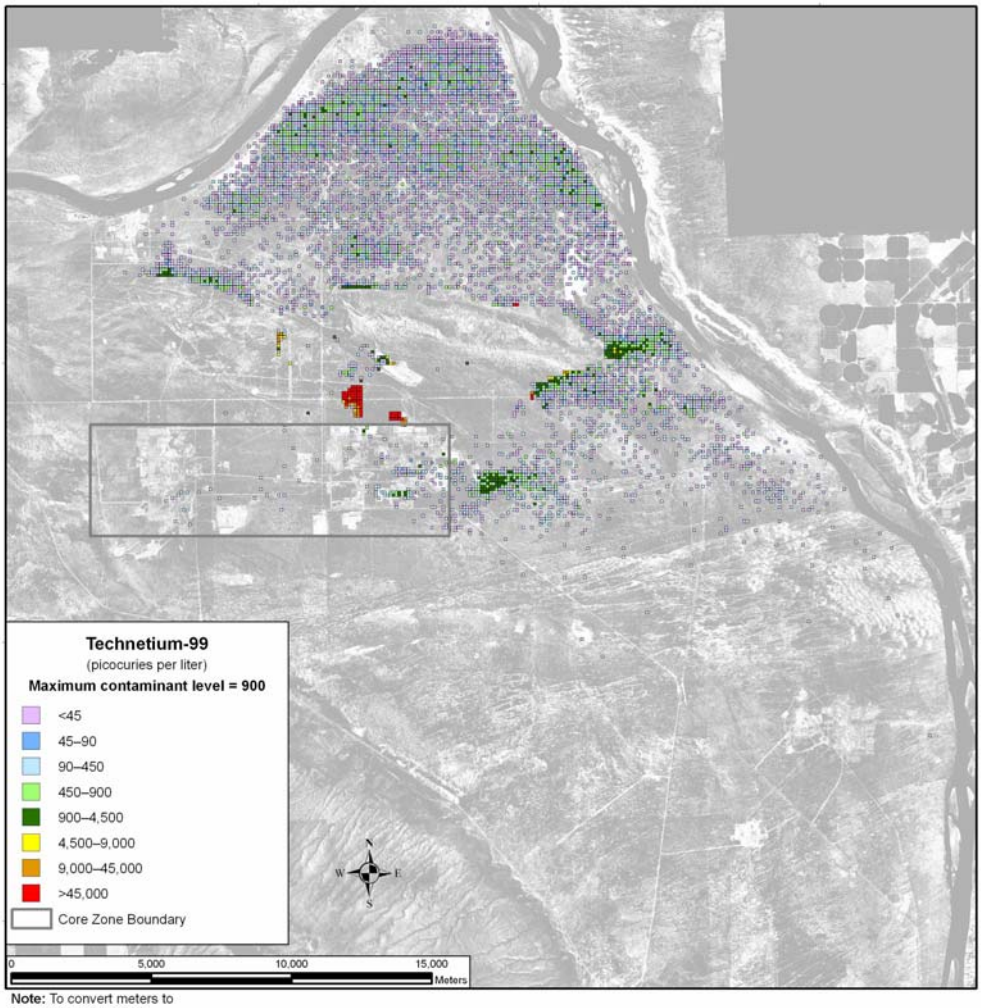
Note: To convert meters to feet, multiply by 3.281

Figure 5–20. Tank Closure Alternative 1 Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

Figure 5–21. Tank Closure Alternative 1 Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 3890



Note: To convert meters to feet, multiply by 3.281

Figure 5–22. Tank Closure Alternative 1 Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140

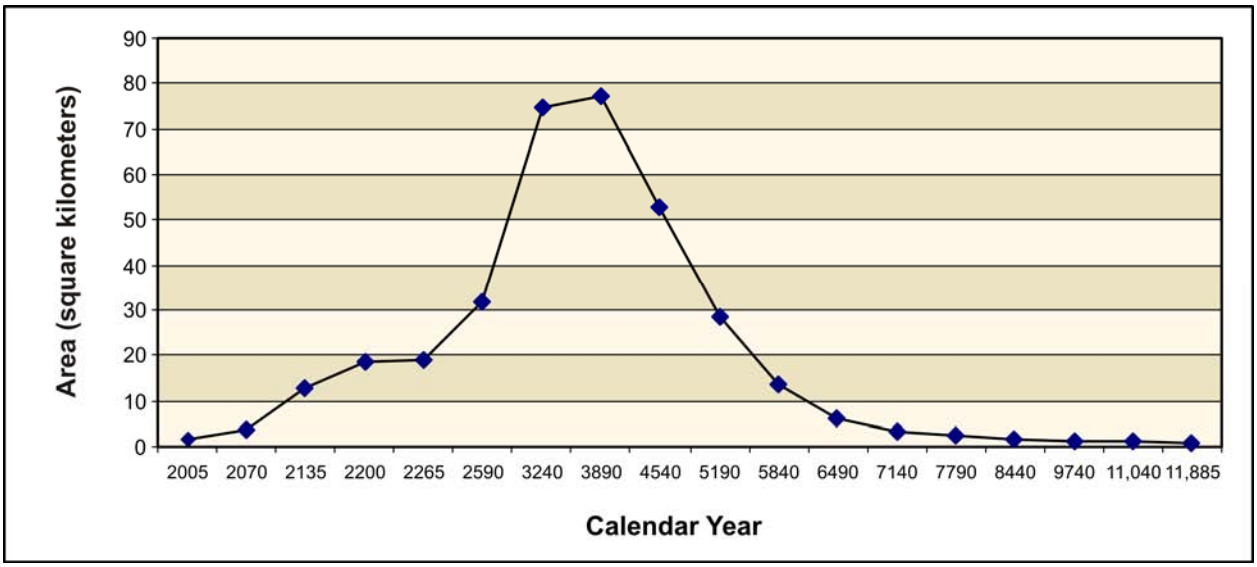
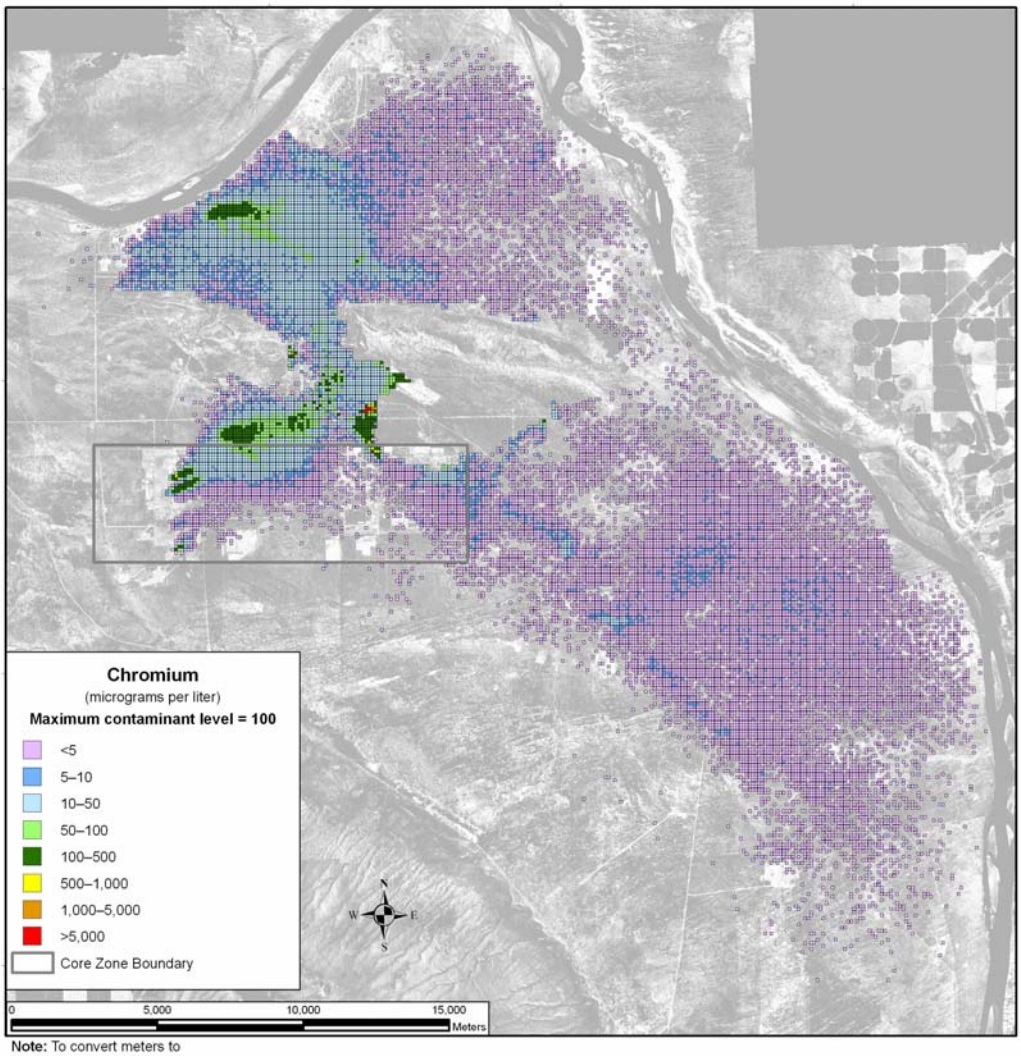
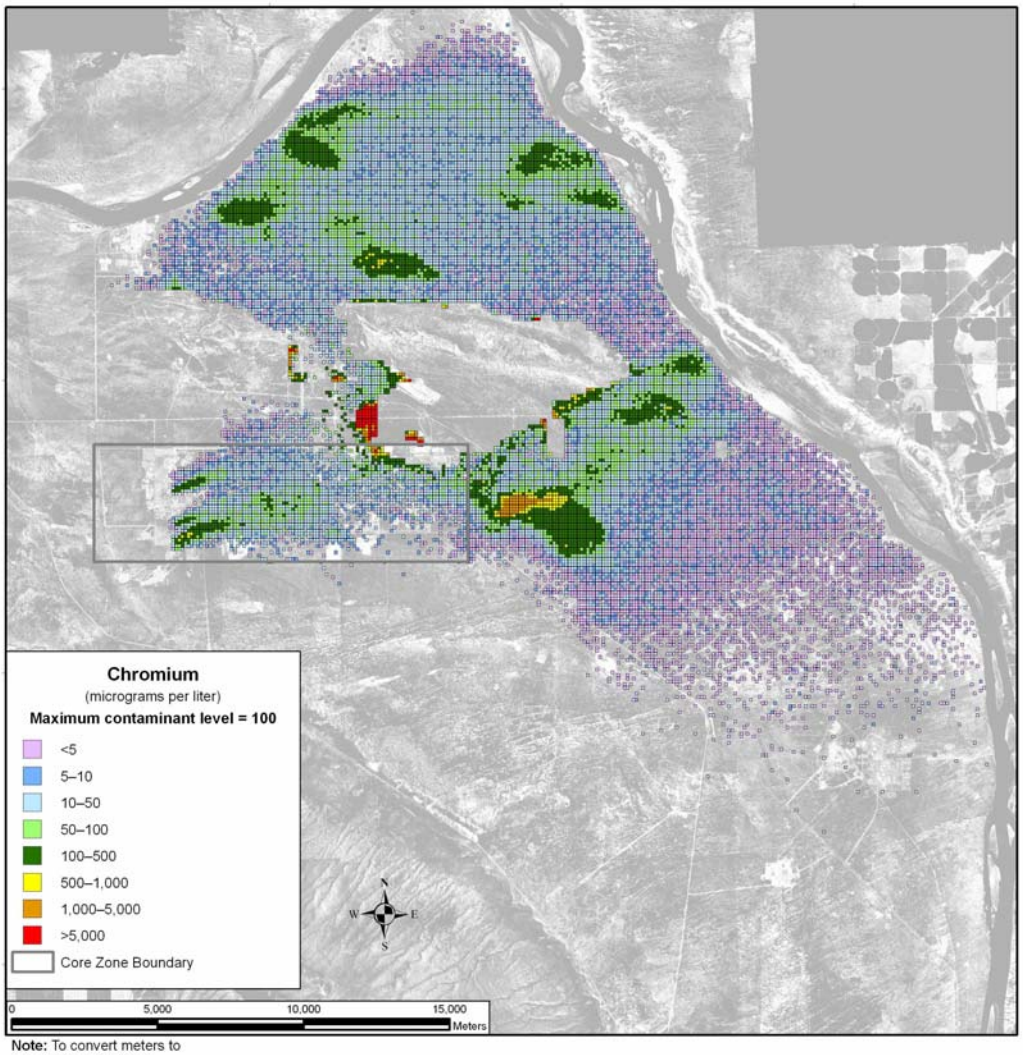


Figure 5–23. Tank Closure Alternative 1 Total Area of Groundwater Technetium-99 Concentration Exceeding the Benchmark Concentration as a Function of Time



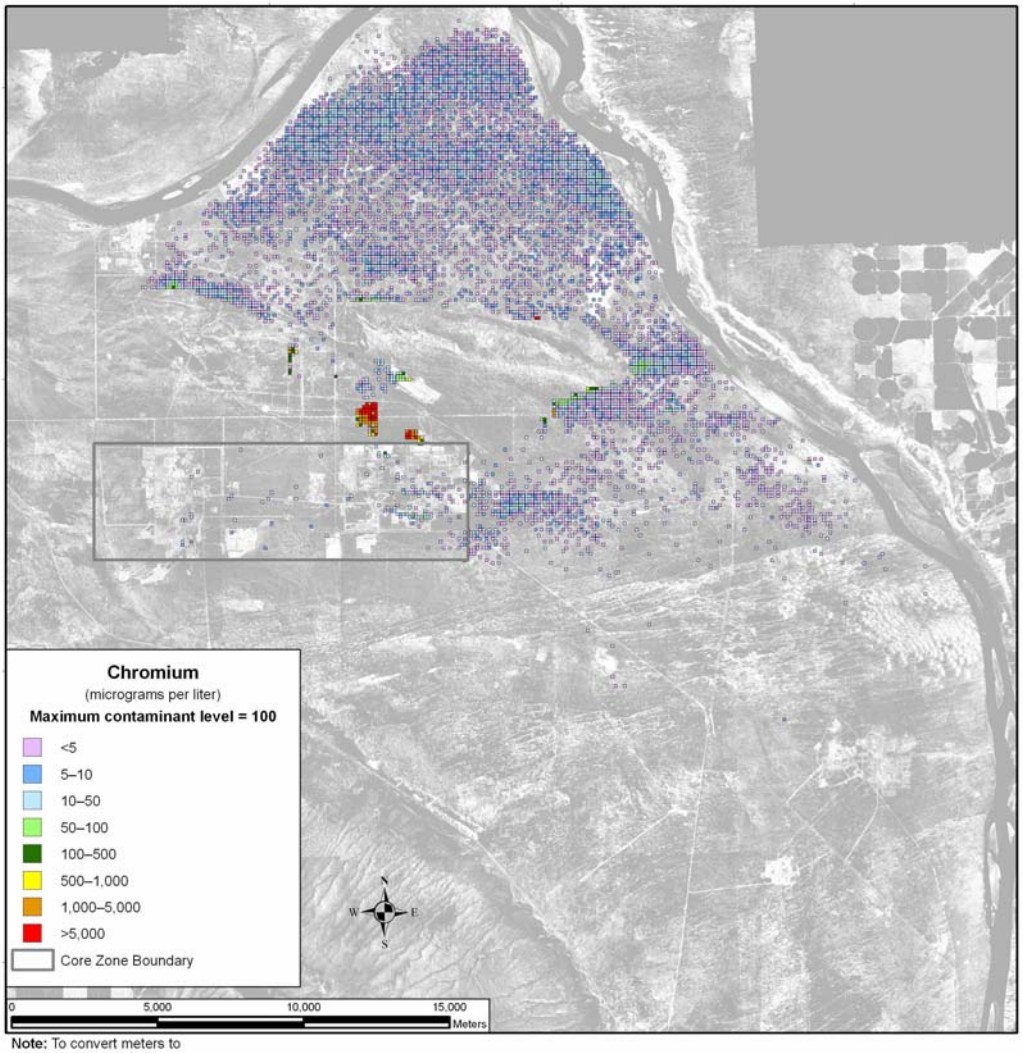
Note: To convert meters to feet, multiply by 3.281

Figure 5–24. Tank Closure Alternative 1 Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 2005



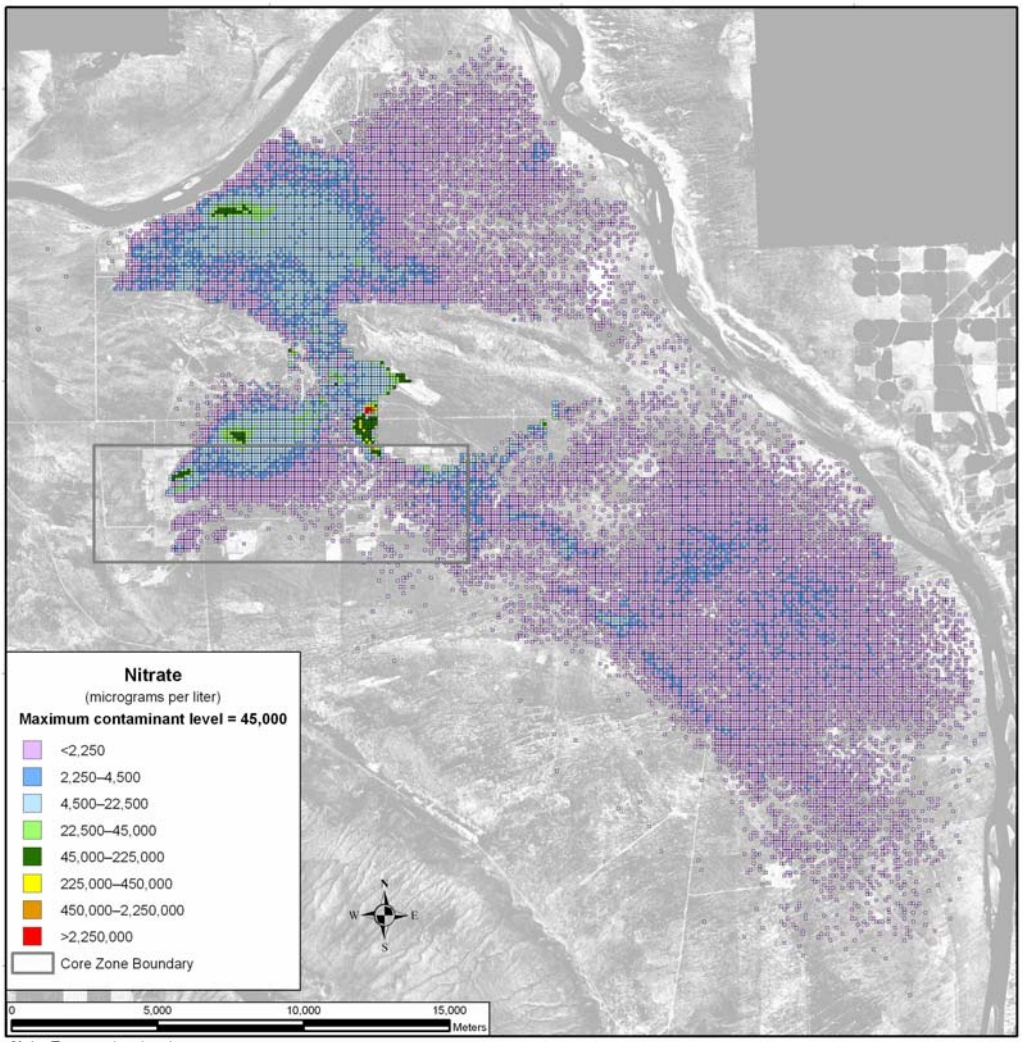
Note: To convert meters to feet, multiply by 3.281

Figure 5–25. Tank Closure Alternative 1 Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 3890



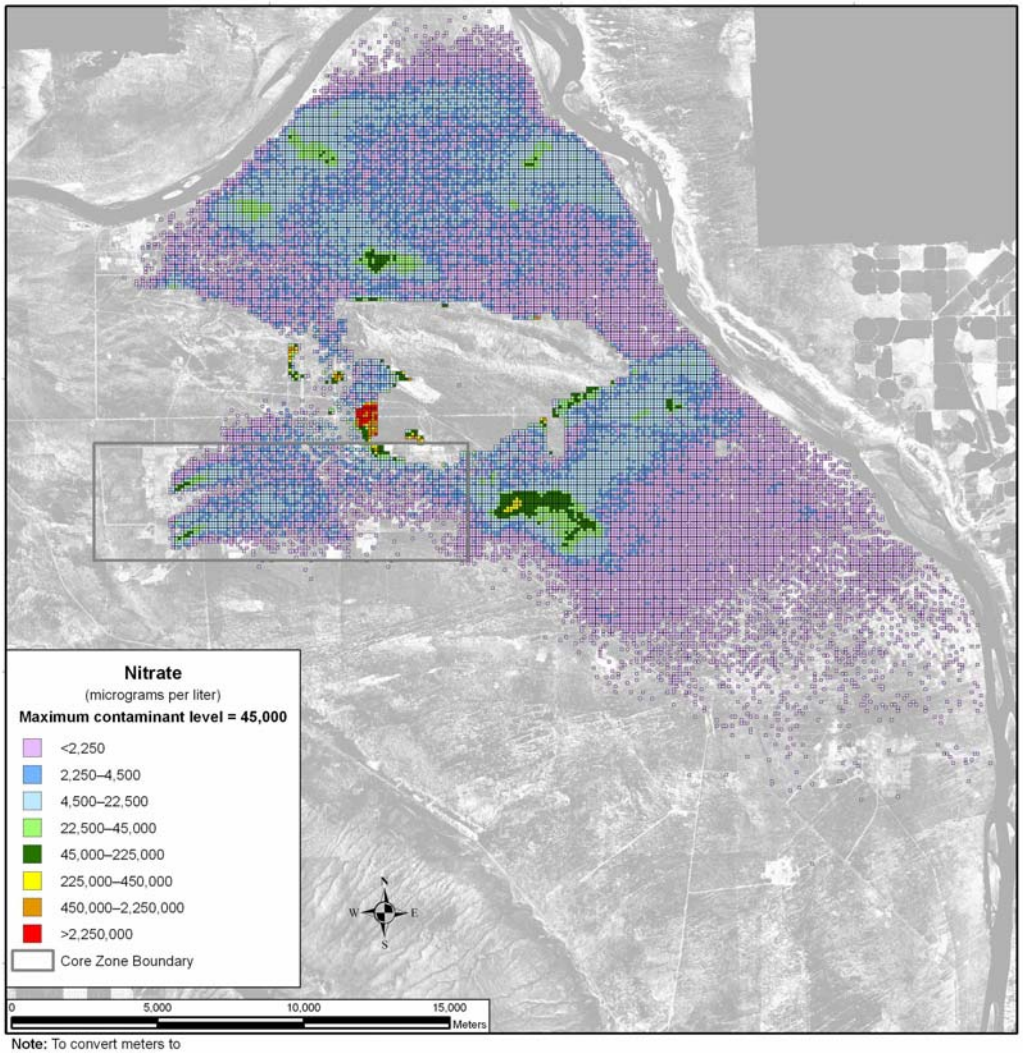
Note: To convert meters to feet, multiply by 3.281

Figure 5–26. Tank Closure Alternative 1 Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 7140



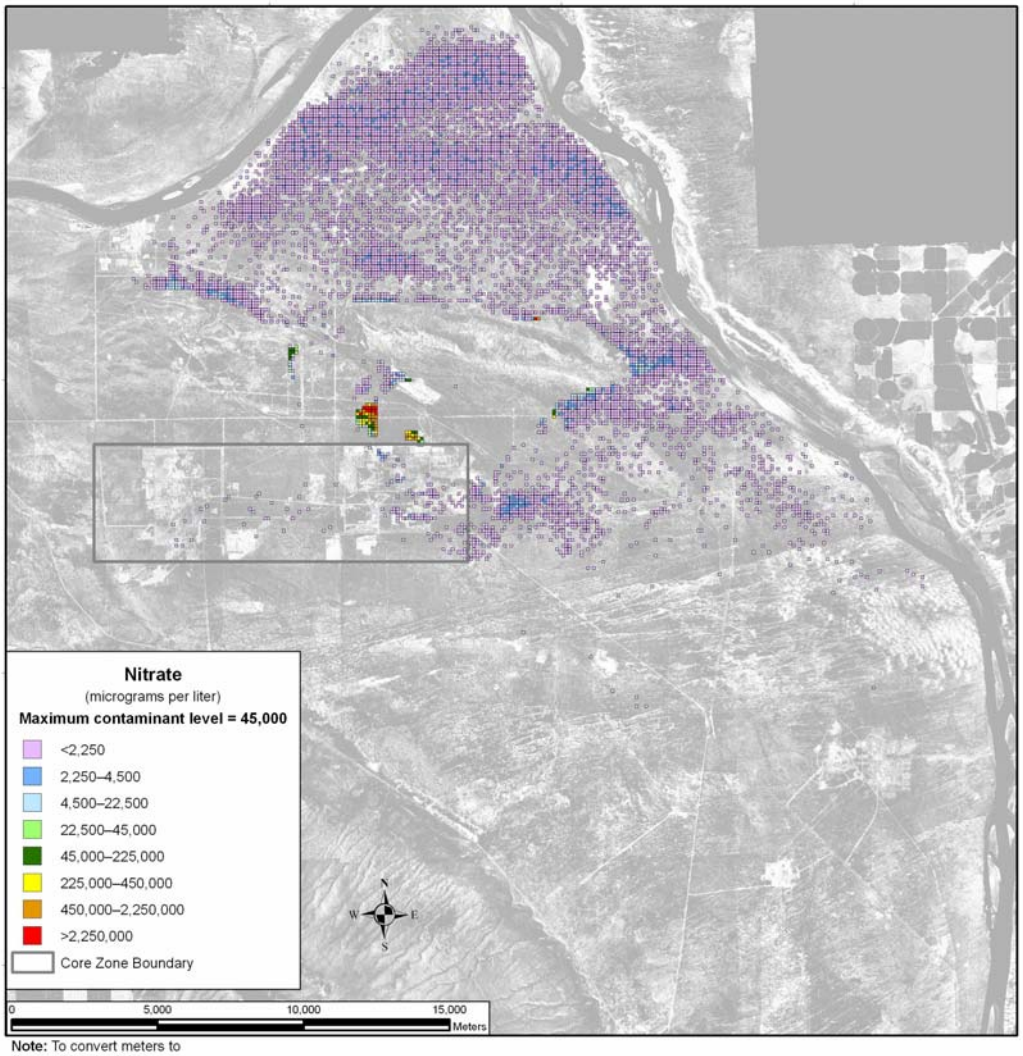
Note: To convert meters to feet, multiply by 3.281

Figure 5–27. Tank Closure Alternative 1 Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

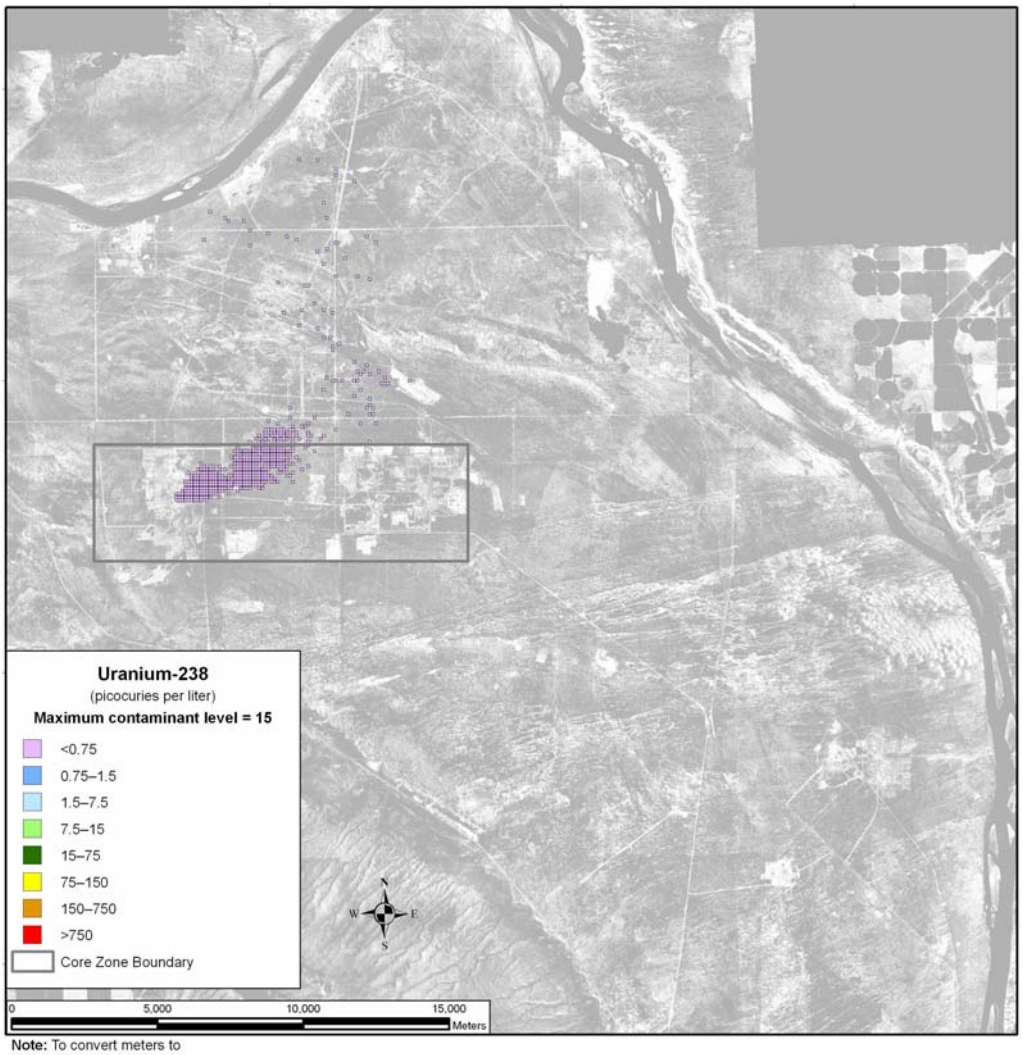
Figure 5–28. Tank Closure Alternative 1 Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 3890



Note: To convert meters to feet, multiply by 3.281

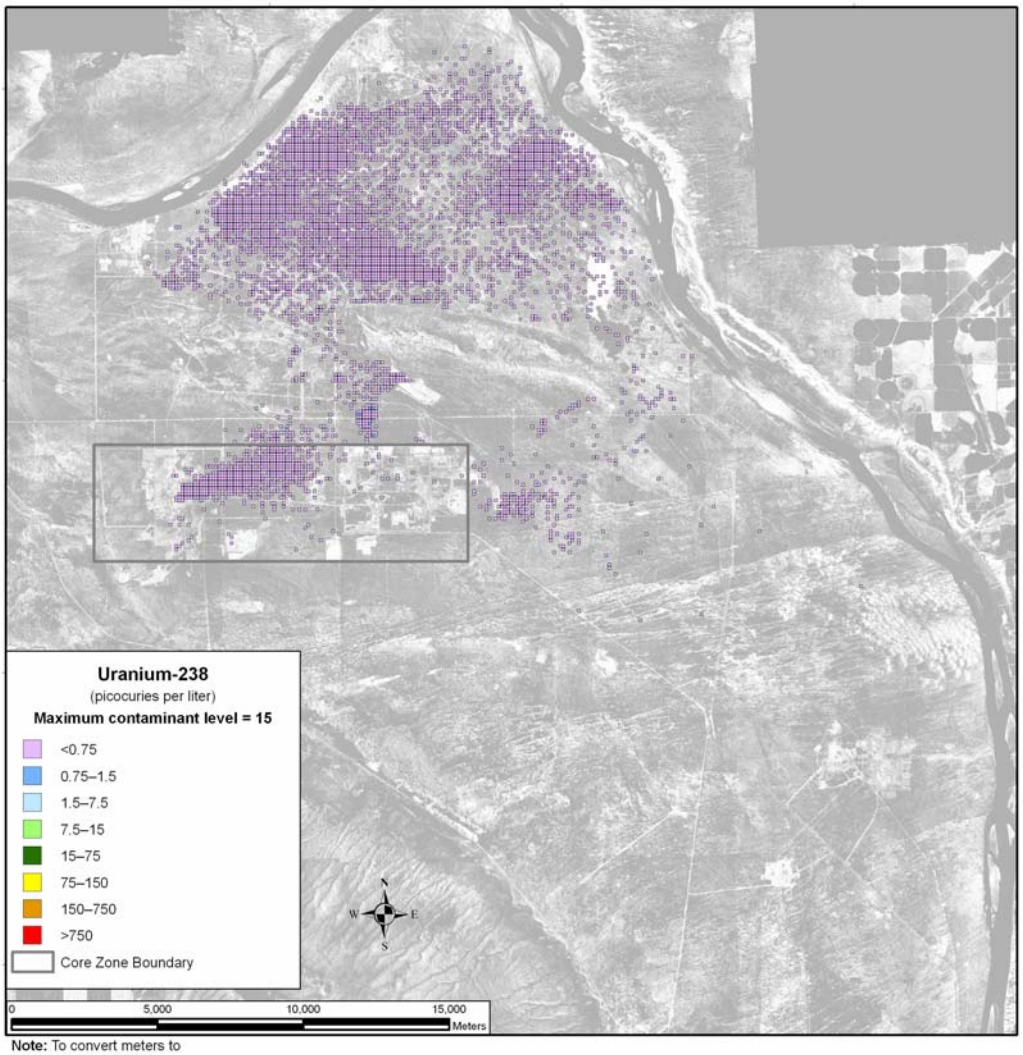
Figure 5–29. Tank Closure Alternative 1 Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 7140

Uranium-238 and total uranium show a different spatial distribution in the analysis over time. These COPCs are 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 5–30 shows the distribution of uranium-238 during CY 2135. 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 that is predominantly contained within the Core Zone Boundary. By CY 3890 (see Figure 5–31), the area of the plume has grown, but there are no significant increases in peak concentration. At CY 11,885 (see Figure 5–32), the greatest development of the plume during the analysis period is seen, resulting primarily from the release of other tank farm sources at the A and B Barriers. Figure 5–33 shows the total area in which groundwater concentrations of uranium-238 exceed the benchmark concentration as a function of time. The area of exceedance is largest near the end of the period of analysis. Figures 5–34 through 5–36 show the corresponding spatial distribution for total uranium.



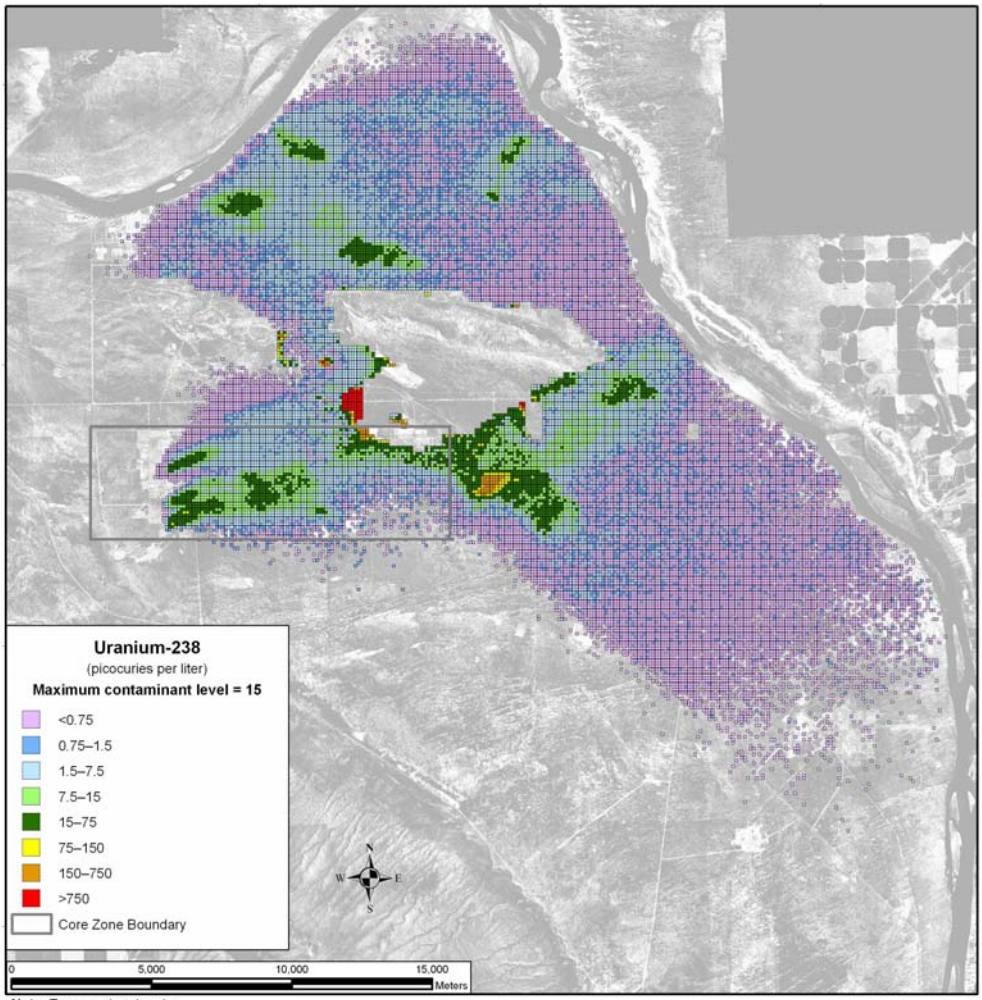
Note: To convert meters to feet, multiply by 3.281

Figure 5–30. Tank Closure Alternative 1 Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281

Figure 5–31. Tank Closure Alternative 1 Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 3890



Note: To convert meters to feet, multiply by 3.281

Figure 5–32. Tank Closure Alternative 1 Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 11,885

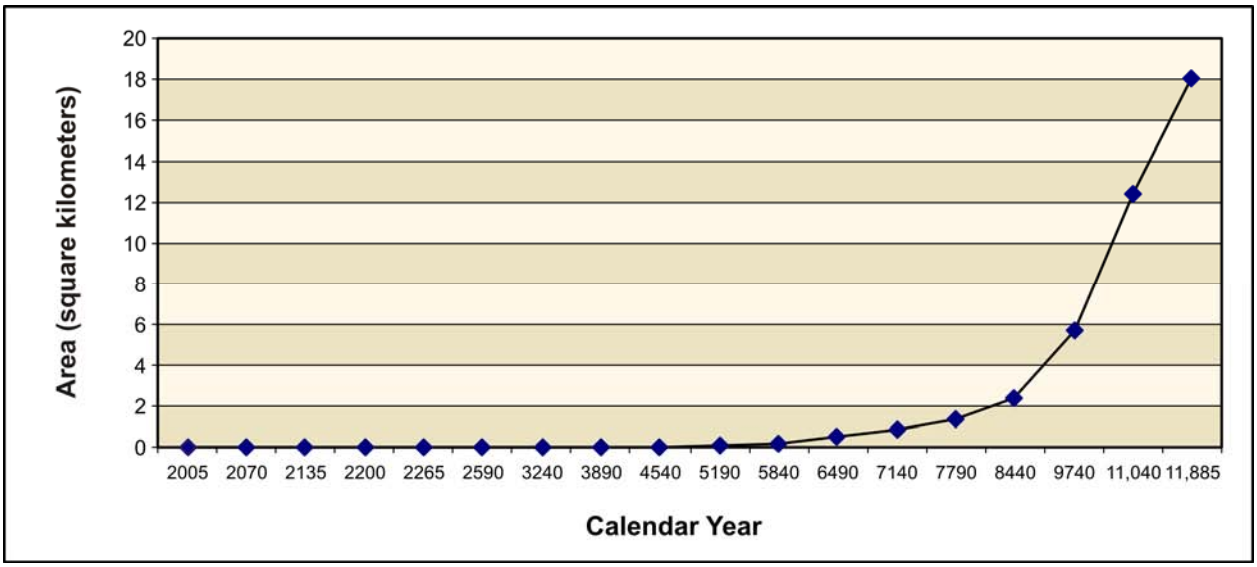
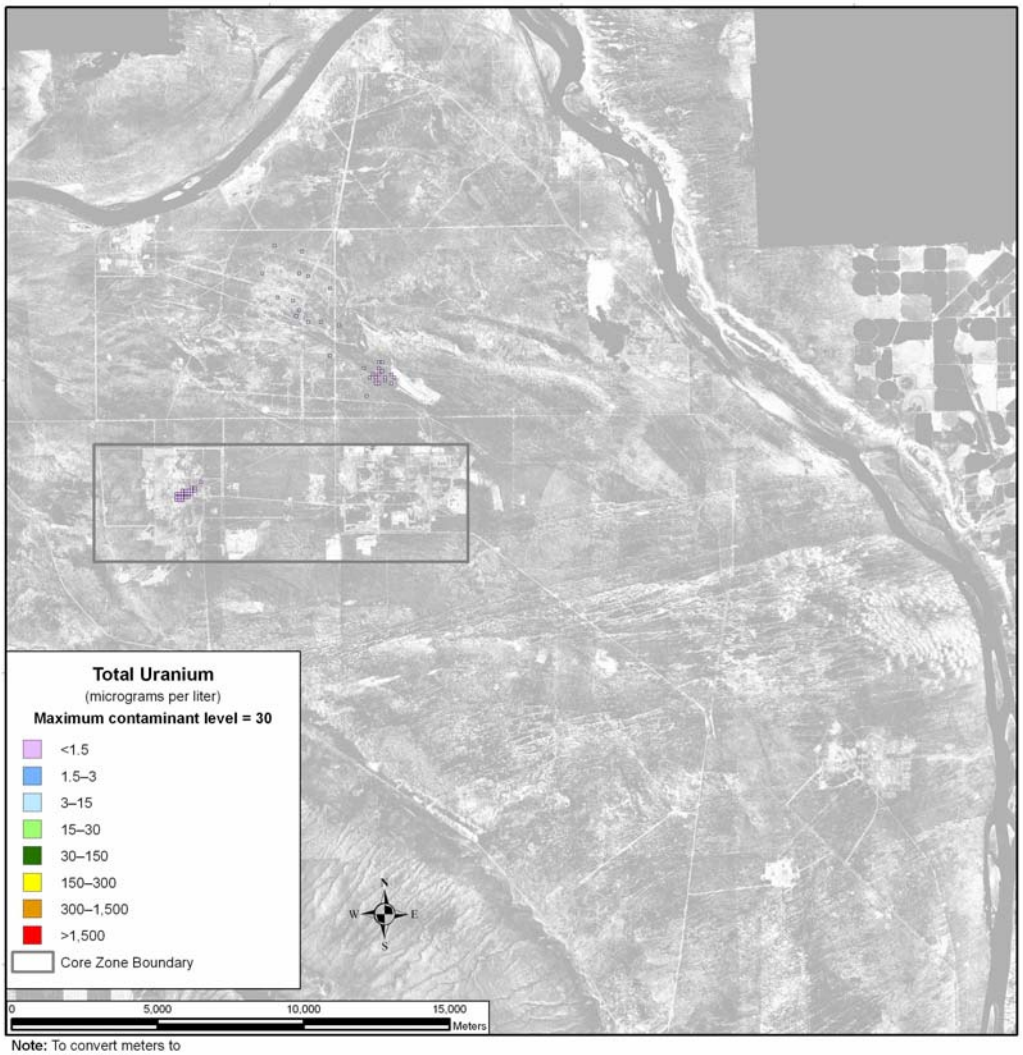
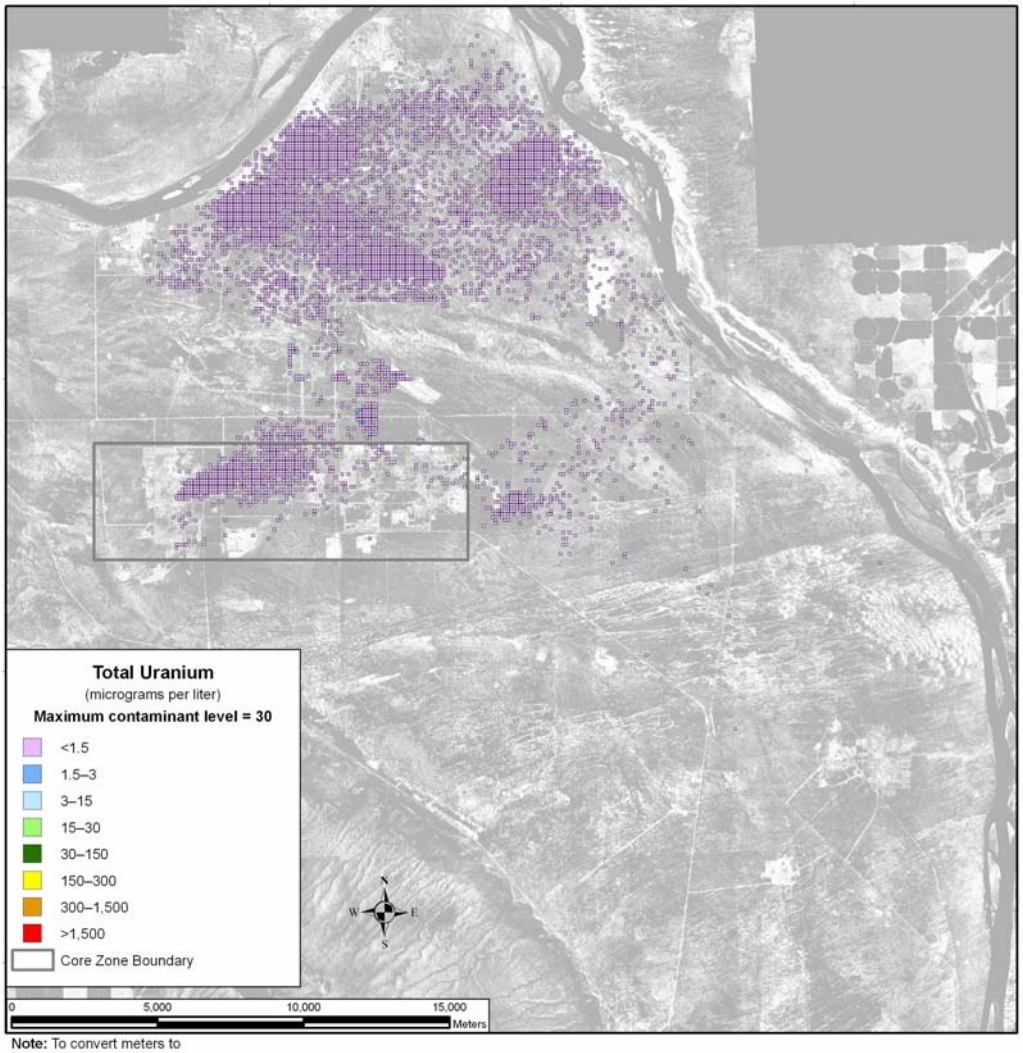


Figure 5–33. Tank Closure Alternative 1 Total Area of Groundwater Uranium-238 Concentration Exceeding the Benchmark Concentration as a Function of Time



Note: To convert meters to feet, multiply by 3.281

Figure 5–34. Tank Closure Alternative 1 Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

Figure 5–35. Tank Closure Alternative 1 Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 3890

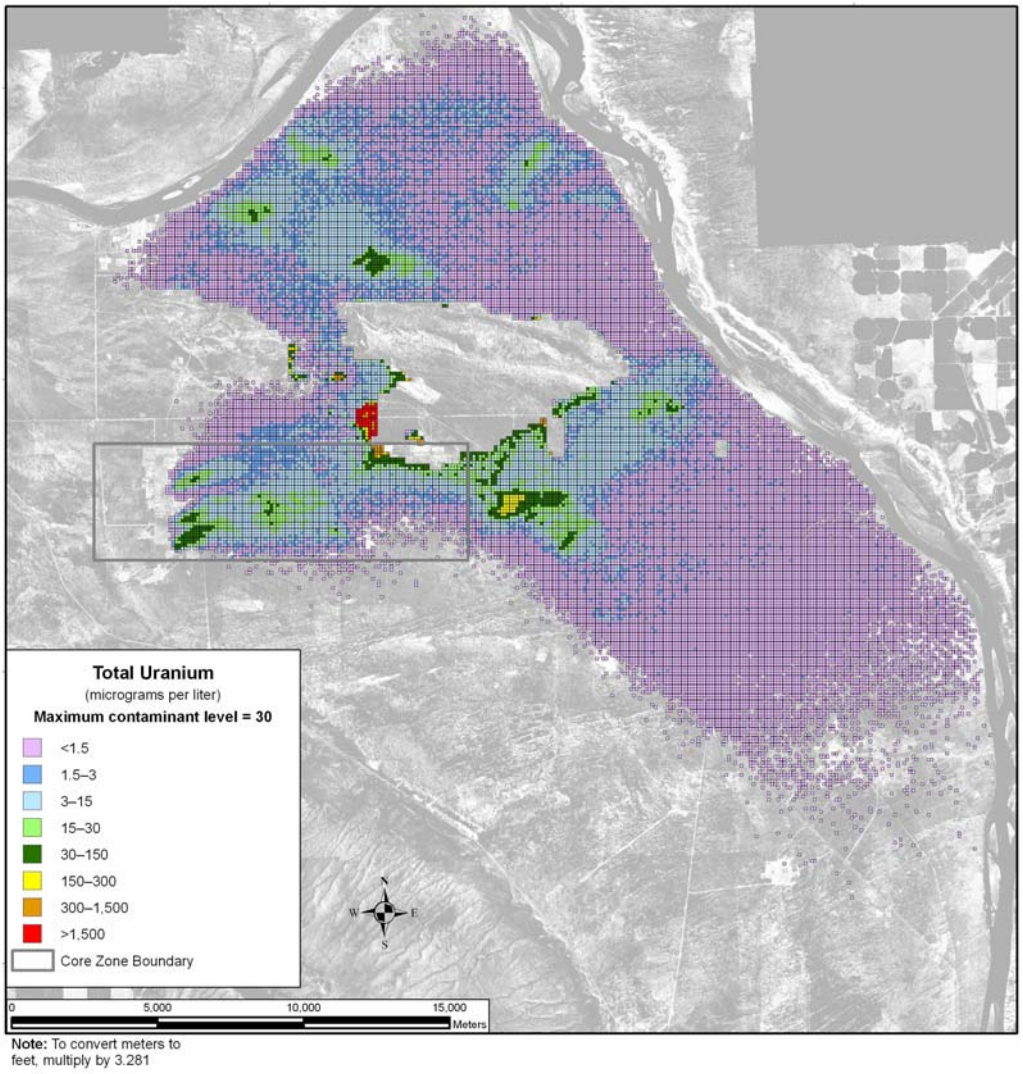


Figure 5–36. Tank Closure Alternative 1 Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 11,885

5.1.1.1.6 Summary of Impacts

In general, the inventory remaining in the tank farms, available for release to the environment at the start of the post–administrative control period, is the predominant contributor in the analysis. Discharges to cribs and trenches (ditches) and past leaks during the past-practice period are a secondary contributor.

For the conservative tracers, concentrations at the Core Zone Boundary exceed benchmark standards by two to three orders of magnitude during most of the period of analysis. Concentrations at the Columbia River are about two orders of magnitude smaller. The intensities and areas of these groundwater plumes peak between CY 3200 and CY 4000.

For tritium, concentrations at the Core Zone Boundary exceed the benchmark by about three orders of magnitude during the first 100 years of the period of analysis. Concentrations at the Columbia River approach the benchmark during this time. Attenuation by radioactive decay is a predominant mechanism that limits the intensity and duration of groundwater impacts of tritium. After CY 2100, tritium impacts are essentially negligible.

For uranium-238 and total uranium, limited mobility is an important factor governing the timeframes and scale of groundwater impacts. The concentrations of these retarded species exceed the benchmark at the Core Zone Boundary beyond CY 6000, and approach the benchmark at the Columbia River after CY 10,000. The peak intensity and area of the contamination plume are largest near the end of the period of analysis.

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

This section describes the groundwater analysis results for Tank Closure Alternative 2A, 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.

5.1.1.2.1 Actions and Timeframes Influencing Groundwater Impacts

Summaries of the proposed actions and timelines for Tank Closure Alternative 2A are provided in Chapter 2, Section 2.5. For the long-term groundwater impact analysis, three major periods were identified for Tank Closure Alternative 2A, 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 2A that are presented in this section would be common to all of the Tank Closure alternatives.

- The retrieval period was assumed to start in 2008 and end in CY 2193. Waste treatment operations were assumed to be complete for immobilized high-level radioactive waste (IHLW) and immobilized low-activity waste (ILAW) in 2093; starting in 2094, tanks and facilities would be maintained in operational standby condition for 100 years. It was assumed that 99 percent of waste volume would be retrieved from the tanks. The leakage rate for SSTs was assumed to be 15,140 liters (4,000 gallons) per SST. Releases that occurred during the past-practice period would continue to migrate through the vadose zone and groundwater system.

- The post–administrative control period was assumed to start in CY 2194 and continue through the 10,000-year period of analysis until CY 11,940. Releases that occurred during the past-practice period would continue to migrate through the vadose zone and groundwater system during the post–administrative control period. In addition, all remaining waste at the SST and DST farms (other tank farm sources) would be released to the vadose zone at the start of the post–administrative control period.

5.1.1.2.2 COPC Drivers

A total of 19 COPCs were analyzed for Tank Closure Alternative 2A. 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 2A 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 2A 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, they become major contributors toward the end 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^{-14}, 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 2A.

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.

5.1.1.2.3 Analysis of Release and Mass Balance

This section presents the impacts of Tank Closure Alternative 2A 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 5–37 through 5–42). Three subtotals are plotted representing releases from cribs and trenches (ditches), past leaks, and other tank farm sources. 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 5–37 shows the estimated release to the vadose zone for the radiological risk drivers and Figure 5–38, 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 both past leaks and other tank farm sources.

Figure 5–39 shows the estimated release to groundwater for the radiological risk drivers and Figure 5–40, 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, chromium, and nitrate), the amount released to groundwater is essentially equal to the amount released to the vadose zone from cribs and trenches (ditches) and past leaks.

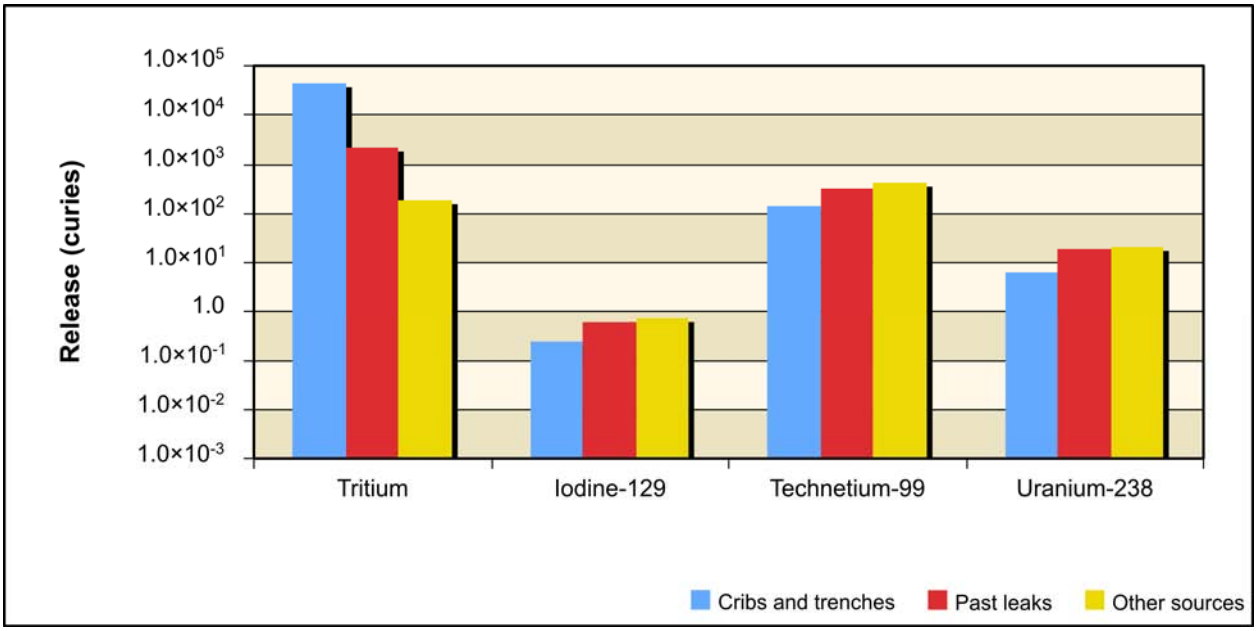


Figure 5–37. Tank Closure Alternative 2A Releases of Radiological Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

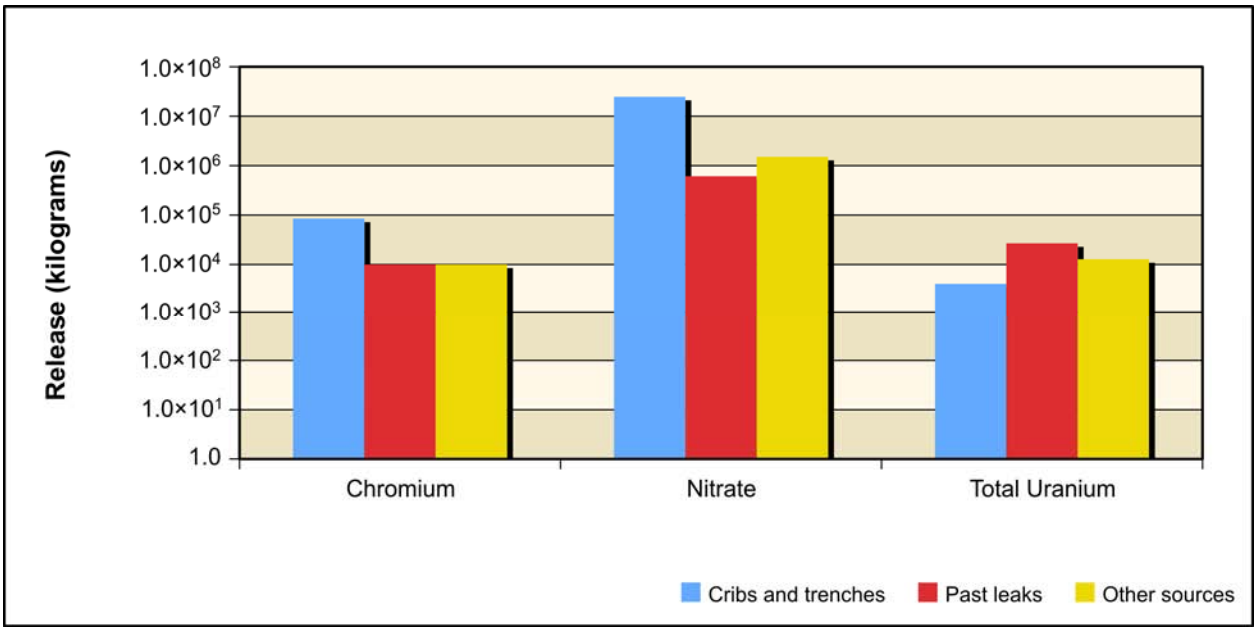


Figure 5–38. Tank Closure Alternative 2A Releases of Chemical Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

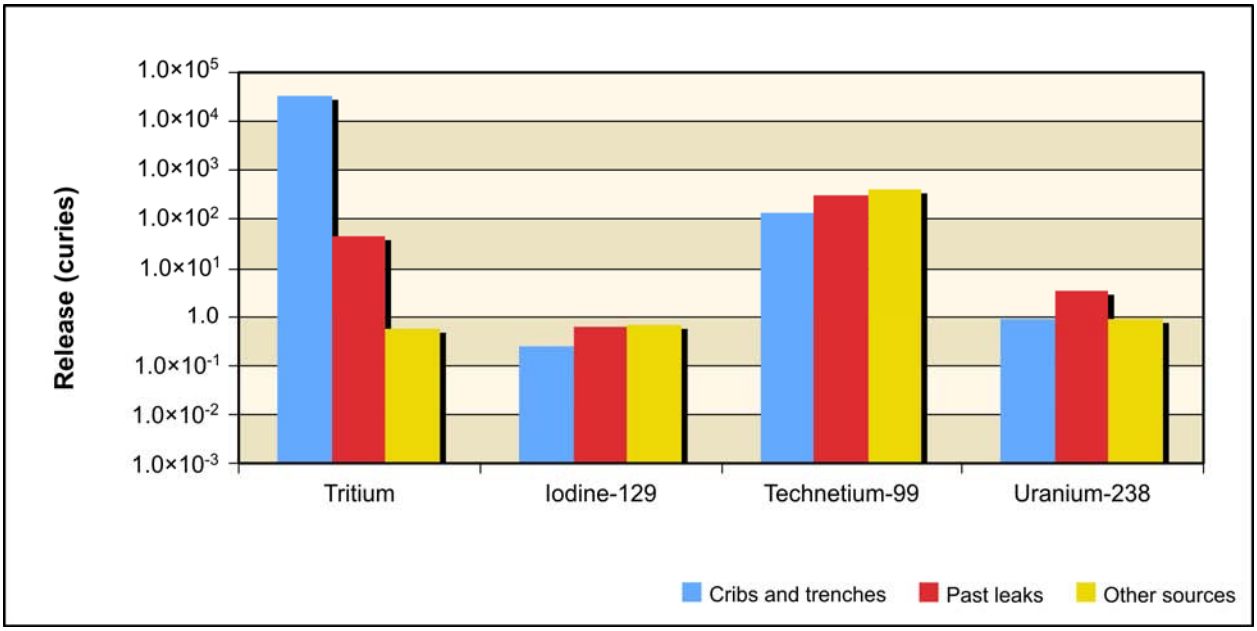


Figure 5–39. Tank Closure Alternative 2A Releases of Radiological Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

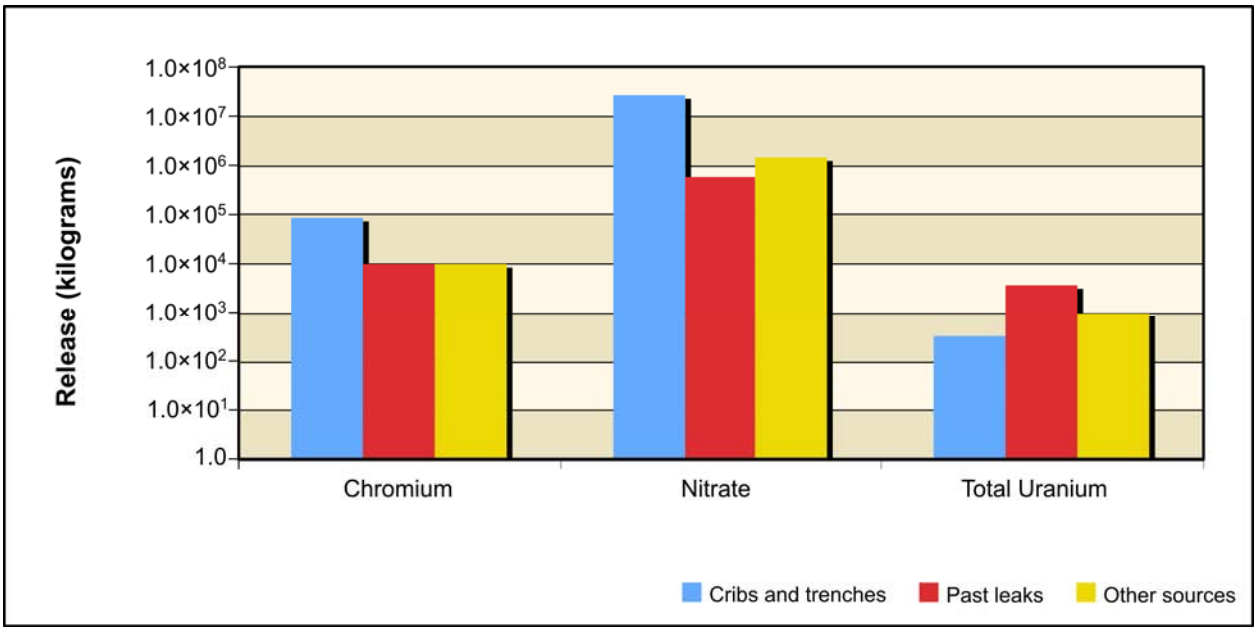


Figure 5–40. Tank Closure Alternative 2A Releases of Chemical Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

For tritium, the amount released to groundwater is attenuated by radioactive decay in the vadose zone. For cribs and trenches (ditches), about 74 percent of the total inventory of tritium reached groundwater in the analysis; for past leaks, only 2 percent; and for other tank farm sources, only one-third of 1 percent of the inventory reached the water table. 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.

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), about 14 percent of uranium-238 and 8 percent of total uranium inventory reached groundwater during the period of analysis. For past leaks, about 18 percent of uranium-238 and 14 percent of total uranium of the total inventory reached groundwater during the period of analysis. For other tank farm sources, about 4 percent of uranium-238 and 7 percent of total uranium of the total inventory reached groundwater during the period of analysis. These results 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 5–41 shows the estimated release to the Columbia River for the radiological risk drivers and Figure 5–42, 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. For tritium, the amount released to the Columbia River is attenuated by radioactive decay. Overall, only about 3 percent of the tritium released to groundwater reached the Columbia River during the period of analysis. These results suggest that tritium impacts on the Columbia River are strongly attenuated by radioactive decay. 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. Overall, about 38 percent of the amount of uranium-238 and about 40 percent of total uranium released to groundwater reached the Columbia River during the period of analysis. These results 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.

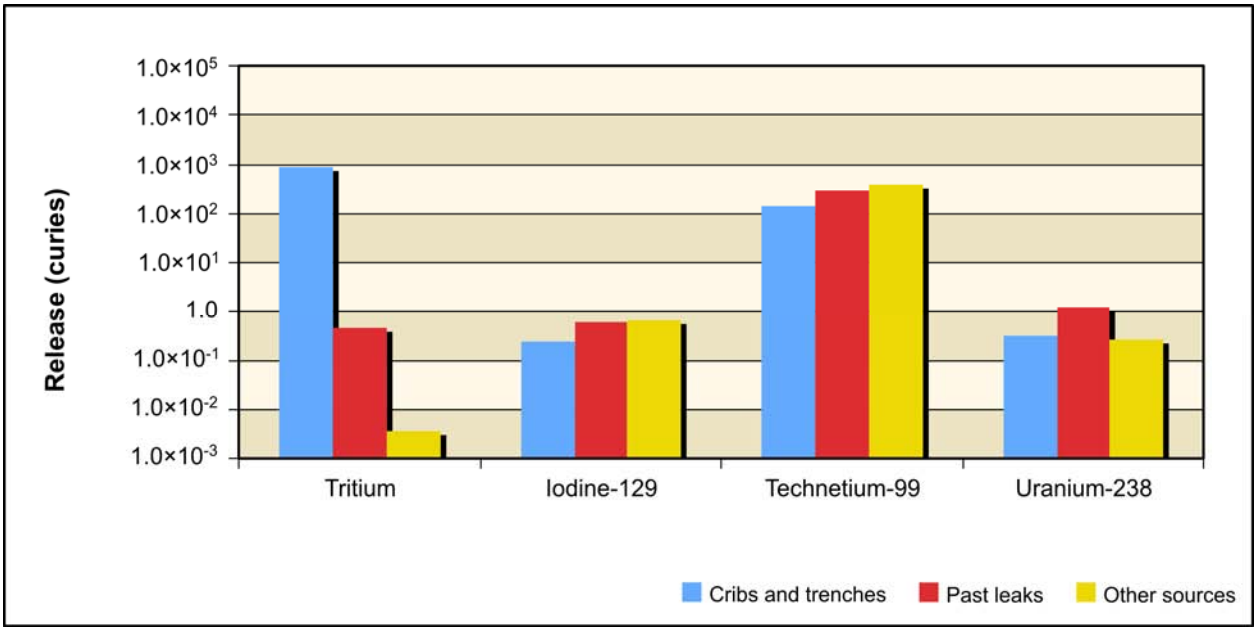


Figure 5–41. Tank Closure Alternative 2A Releases of Radiological Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

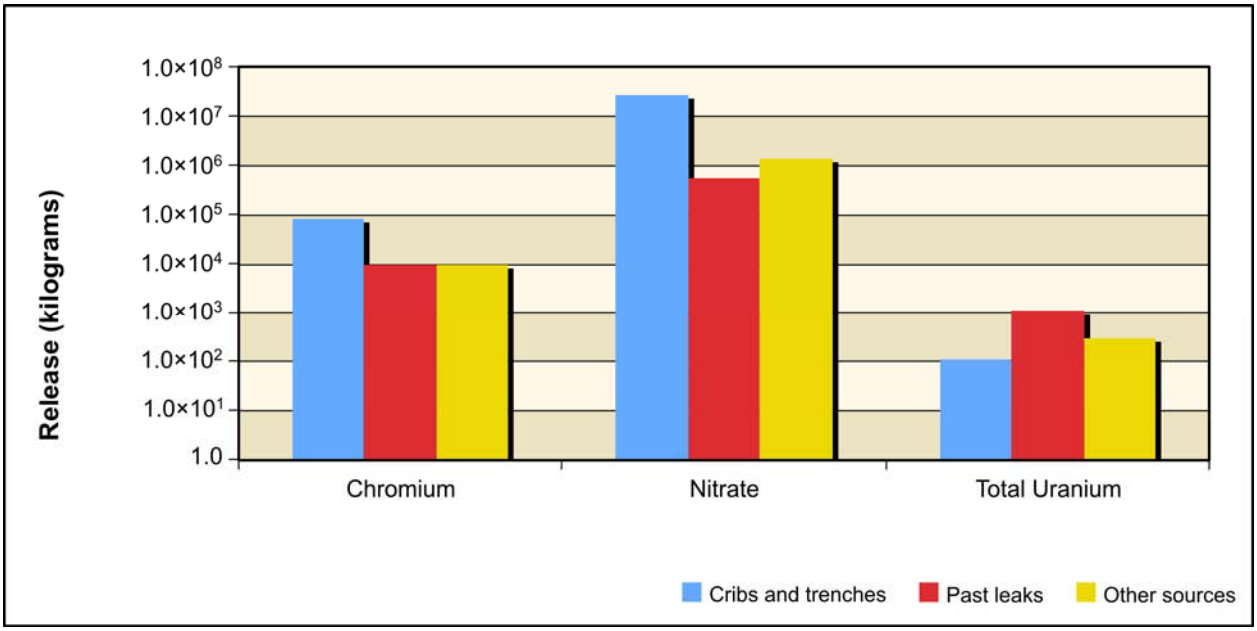


Figure 5–42. Tank Closure Alternative 2A Releases of Chemical Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

5.1.1.2.4 Analysis of Concentration Versus Time

This section presents the analysis of Tank Closure Alternative 2A 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 Table 5–2 and Figures 5–43 through 5–49). 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 five orders of magnitude. Table 5–2 lists the maximum concentrations of the COPCs in the peak year after CY 2050 at the tank farm barriers, Core Zone Boundary, and Columbia River nearshore.

Table 5–2. Tank Closure Alternative 2A 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)	35	5,030	51	5,220	13	5,630	135	20,000
	(2052)	(2051)	(2050)	(2061)	(2050)	(2051)	(2050)	
Technetium-99	**1,590**	**31,700**	**2,820**	**15,000**	546	**27,800**	204	900
	(2055)	(2076)	(2050)	(2051)	(2096)	(2076)	(3464)	
Iodine-129	**3**	**50**	**5**	**30**	**1**	**43**	0.4	1
	(2057)	(2072)	(2050)	(2051)	(2089)	(2072)	(3355)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	3	**142**	7	**42**	11	**148**	1	15
	(11,707)	(11,814)	(11,714)	(11,799)	(11,763)	(11,828)	(11,783)	
Chemical in micrograms per liter								
Acetonitrile	1	0	0	0	0	1	0	100
	(3341)	(1940)	(3417)	(1940)	(1940)	(3551)	(3617)	
Chromium	12	**4,260**	**290**	**800**	17	**1,960**	32	100
	(2070)	(2085)	(2050)	(2050)	(2086)	(2066)	(2603)	
Nitrate	11,600	**1,640,000**	10,000	**168,000**	5,800	**1,100,000**	9,100	45,000
	(2068)	(2081)	(2073)	(2086)	(2083)	(2059)	(2400)	
Total uranium	1	**190**	8	20	15	**196**	1	30
	(11,805)	(11,839)	(9863)	(11,709)	(10,978)	(11,624)	(11,809)	

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 5–43 shows concentration versus time for tritium. Releases from cribs and trenches (ditches) cause groundwater concentrations to exceed benchmark concentrations by about two orders of magnitude for a short period of time during the early part of the period of analysis. During this time, groundwater concentrations at the Columbia River nearshore are over an order of magnitude below the benchmark concentration. Because the half-life of tritium is less than 13 years, radioactive decay rapidly attenuates groundwater concentration, and tritium is essentially not a factor at times later than CY 2040.

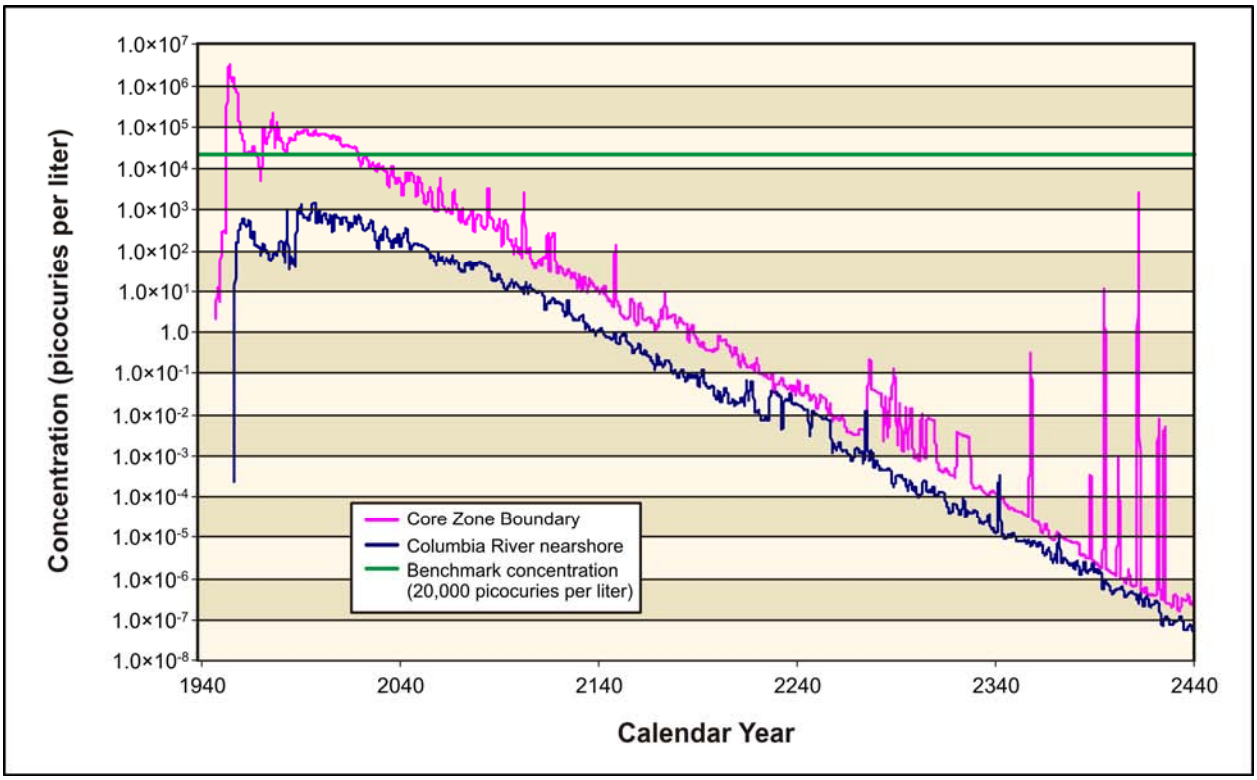


Figure 5–43. Tank Closure Alternative 2A Hydrogen-3 (Tritium) Concentration Versus Time

Figures 5–44 through 5–47 show concentration versus time for iodine-129, technetium-99, chromium, and nitrate (the conservative tracers). Releases from cribs and trenches (ditches) cause groundwater concentrations at the Core Zone Boundary to exceed benchmark concentrations by about two to three orders of magnitude during the early part of the period of analysis, but return to levels below the benchmark by CY 5000. During this time, groundwater concentrations at the Columbia River nearshore are about an order of magnitude less than the benchmark concentration and gradually decrease to around one to two orders of magnitude less than the benchmark concentration.

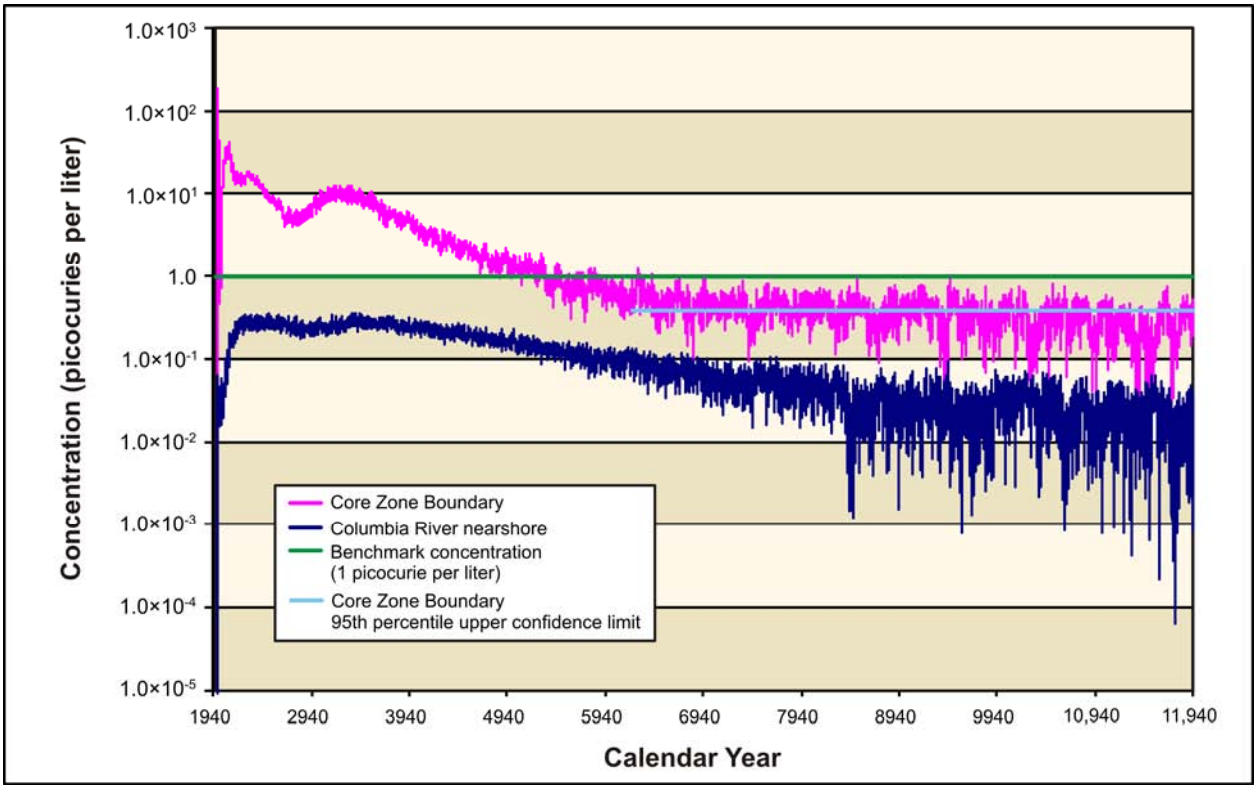


Figure 5–44. Tank Closure Alternative 2A Iodine-129 Concentration Versus Time

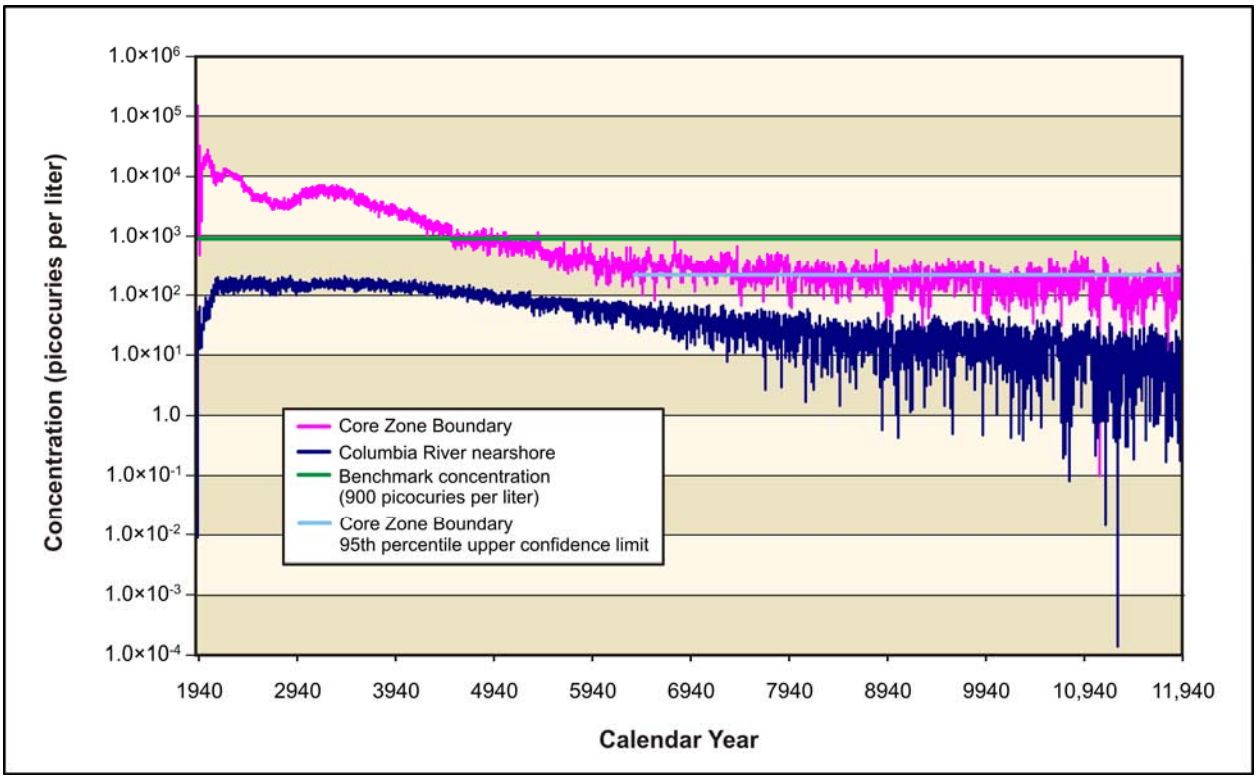


Figure 5–45. Tank Closure Alternative 2A Technetium-99 Concentration Versus Time

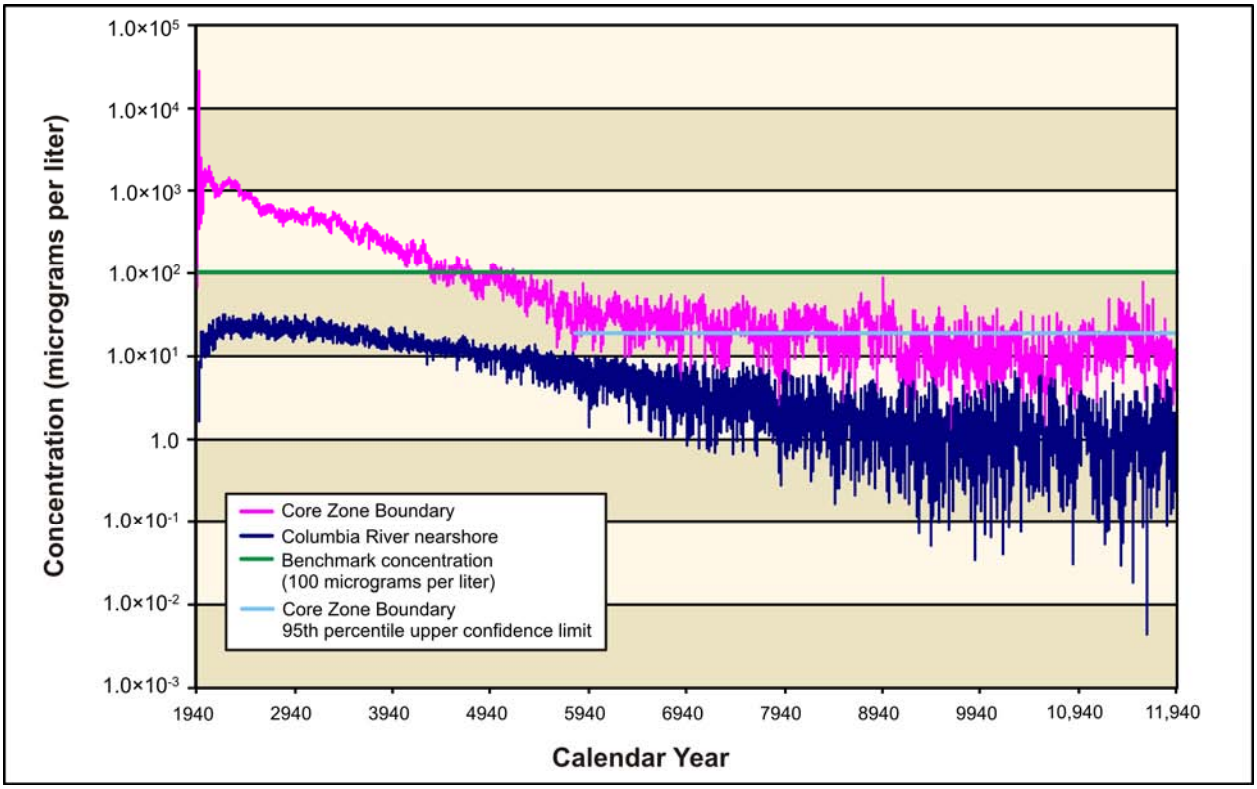


Figure 5–46. Tank Closure Alternative 2A Chromium Concentration Versus Time

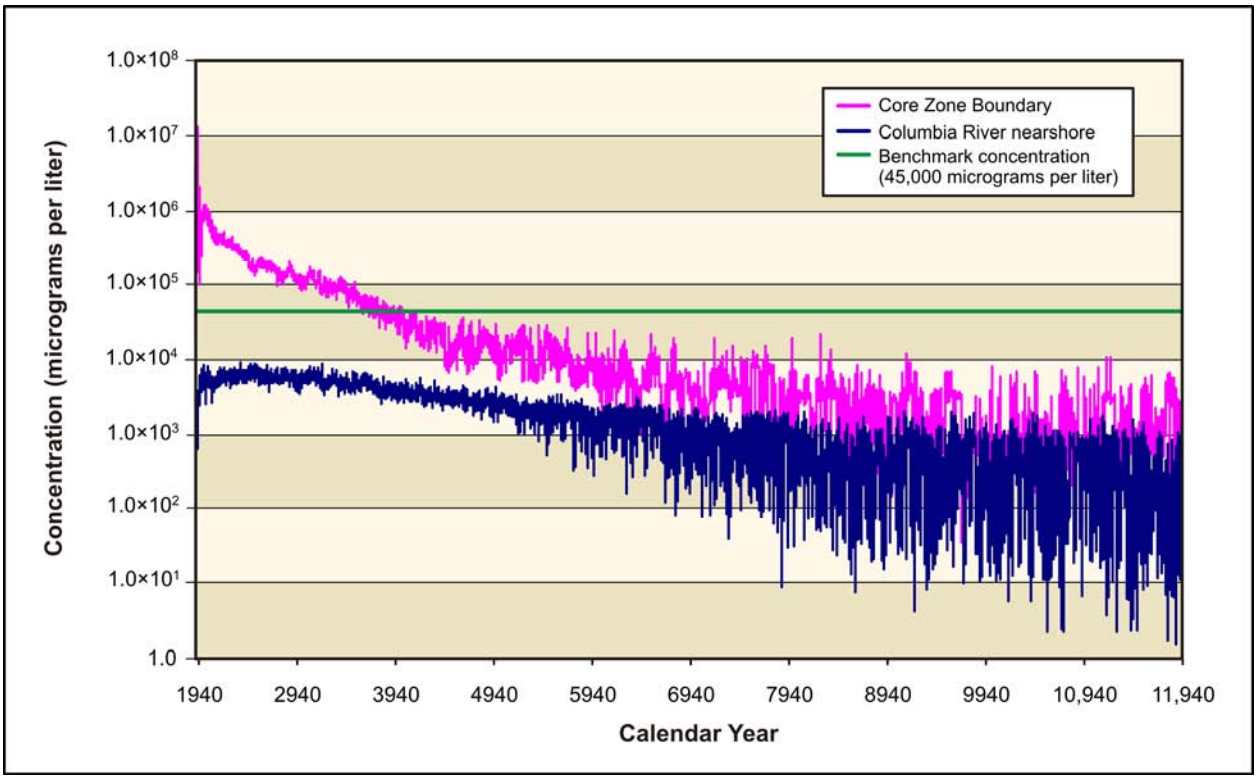


Figure 5–47. Tank Closure Alternative 2A Nitrate Concentration Versus Time

Figures 5–48 and 5–49 show concentration versus time for uranium-238 and total uranium. Early releases from cribs and trenches (ditches) result in groundwater concentrations that are one to two orders of magnitude lower than benchmark concentrations. Concentrations continue to rise throughout the duration of the period of analysis, first surpassing the benchmark concentration at the Core Zone Boundary near CY 5900 for uranium-238 and near CY 6900 for total uranium. Groundwater concentrations at the Columbia River nearshore rise throughout the period of analysis, but stay below an order of magnitude less than the benchmark concentration.

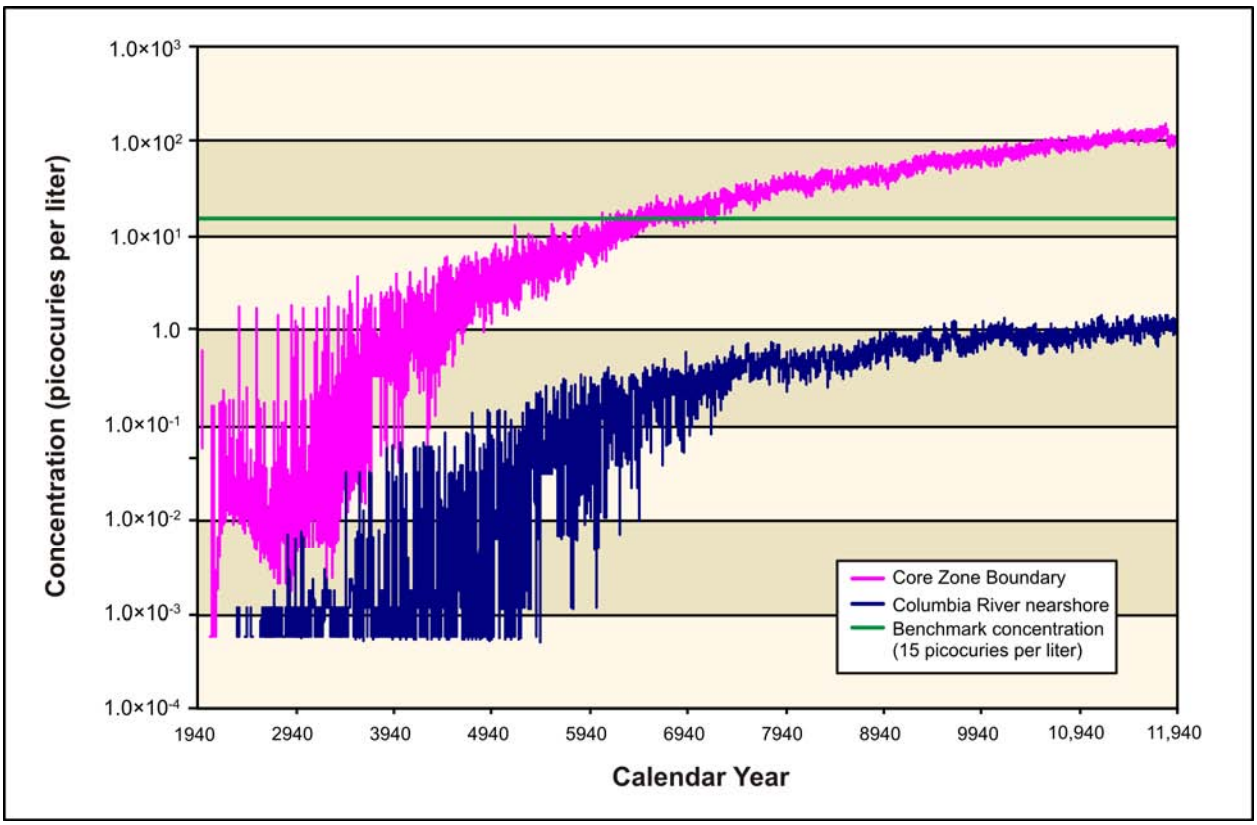


Figure 5–48. Tank Closure Alternative 2A Uranium-238 Concentration Versus Time

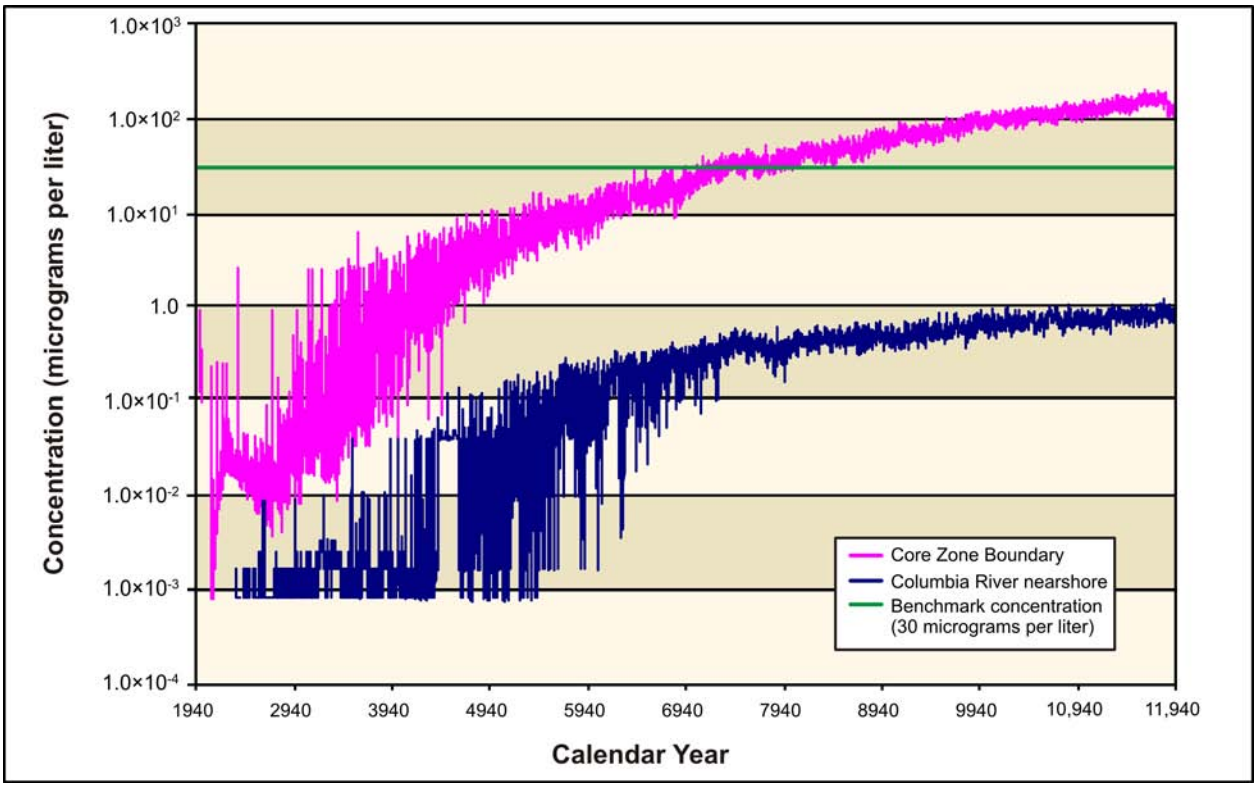
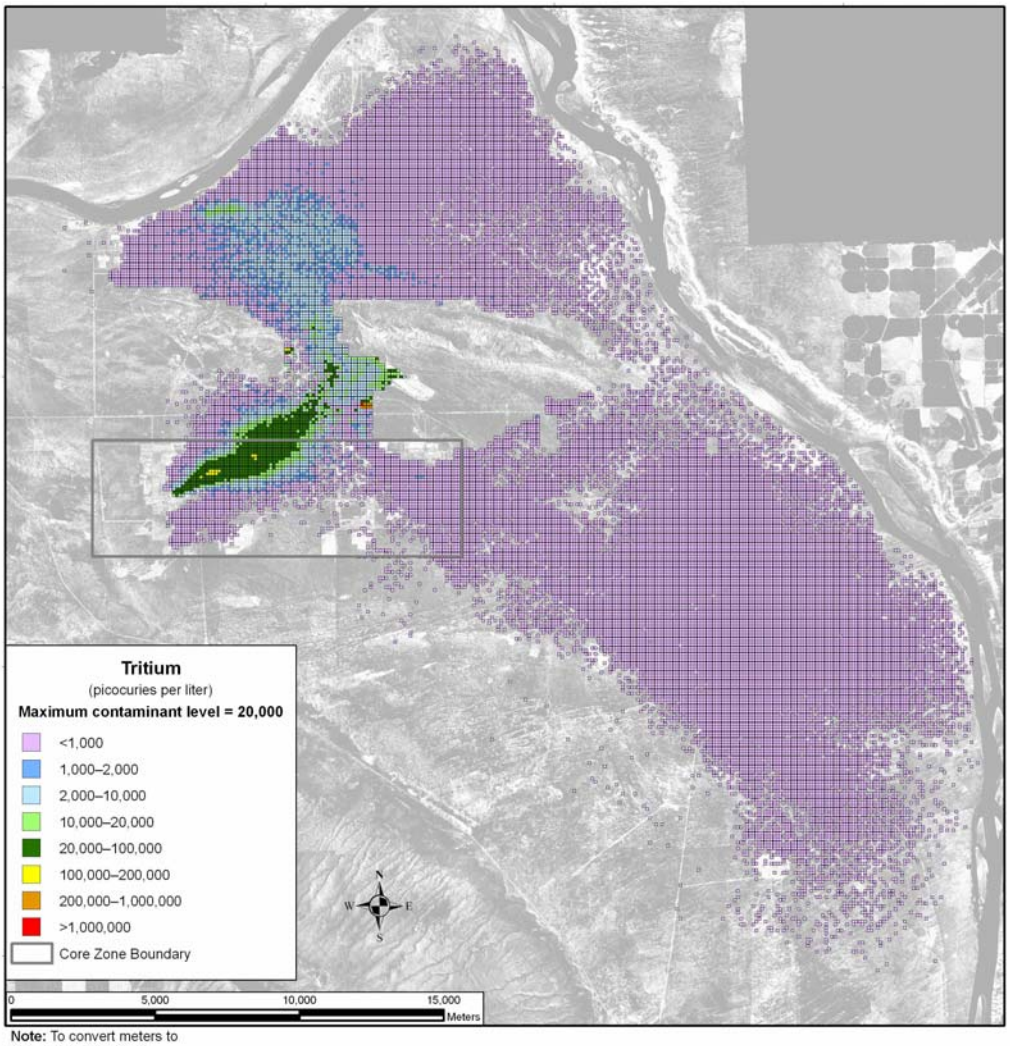


Figure 5–49. Tank Closure Alternative 2A Total Uranium Concentration Versus Time

5.1.1.2.5 Analysis of Spatial Distribution of Concentration

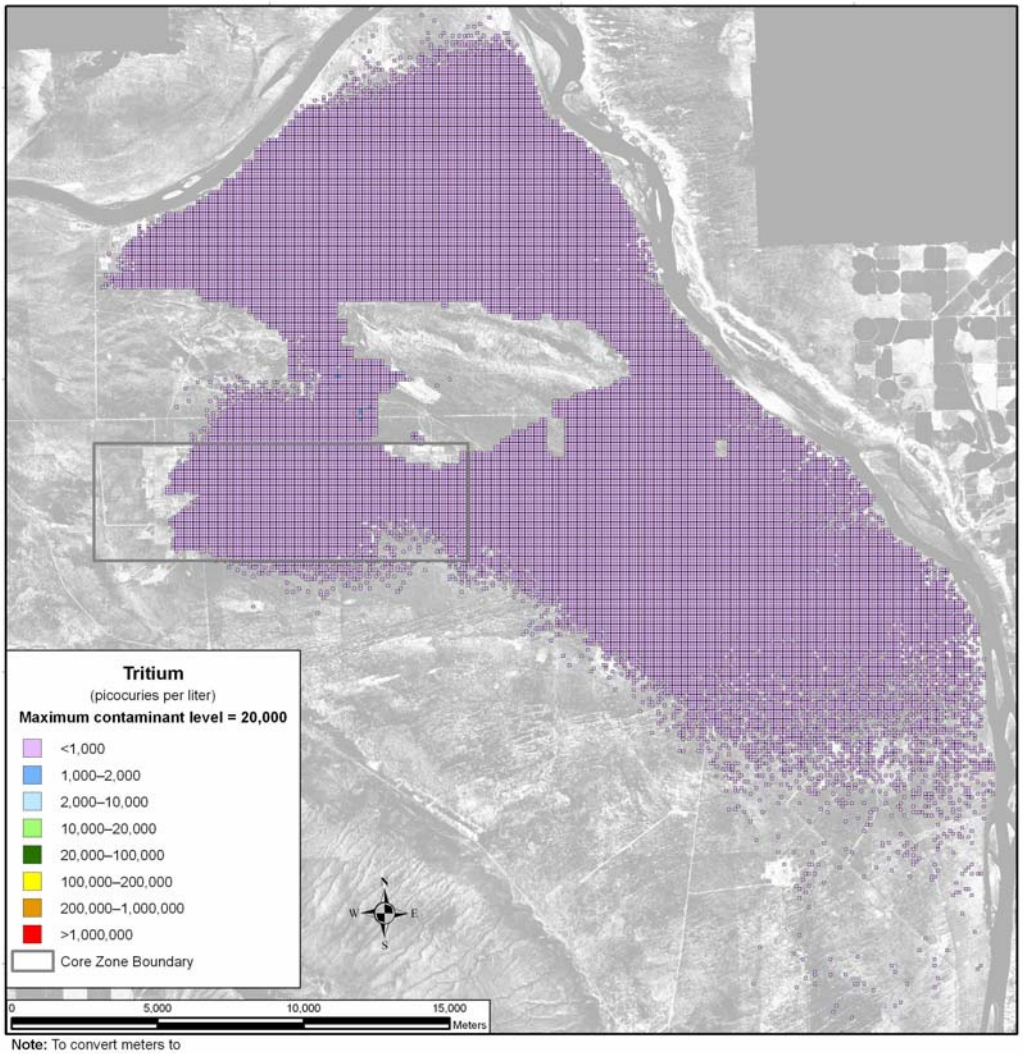
This section presents the impacts of Tank Closure Alternative 2A in terms of the spatial distribution of groundwater concentration at selected times. Concentrations of radionuclides are in picocuries per liter, chemicals in micrograms per liter. Concentrations for each radionuclide and chemical are indicated 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 5–50 shows the spatial distribution of groundwater concentration for tritium during CY 2005. Analysis 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 5 to 19 times greater than the benchmark, and mostly contained within the Core Zone Boundary. Tritium concentrations are attenuated by radioactive decay to levels less than one-twentieth of the benchmark concentration by CY 2135 (see Figure 5–51).



Note: To convert meters to feet, multiply by 3.281

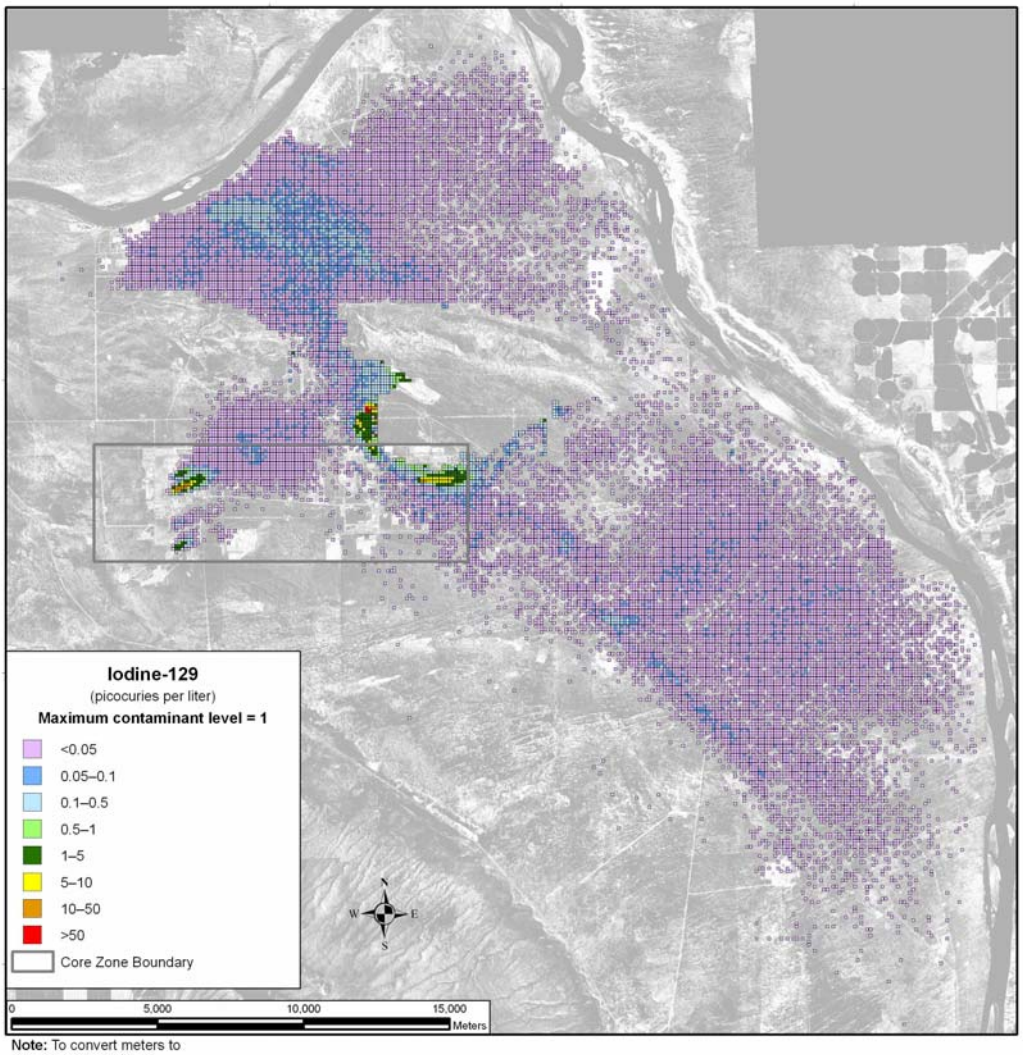
Figure 5–50. Tank Closure Alternative 2A Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

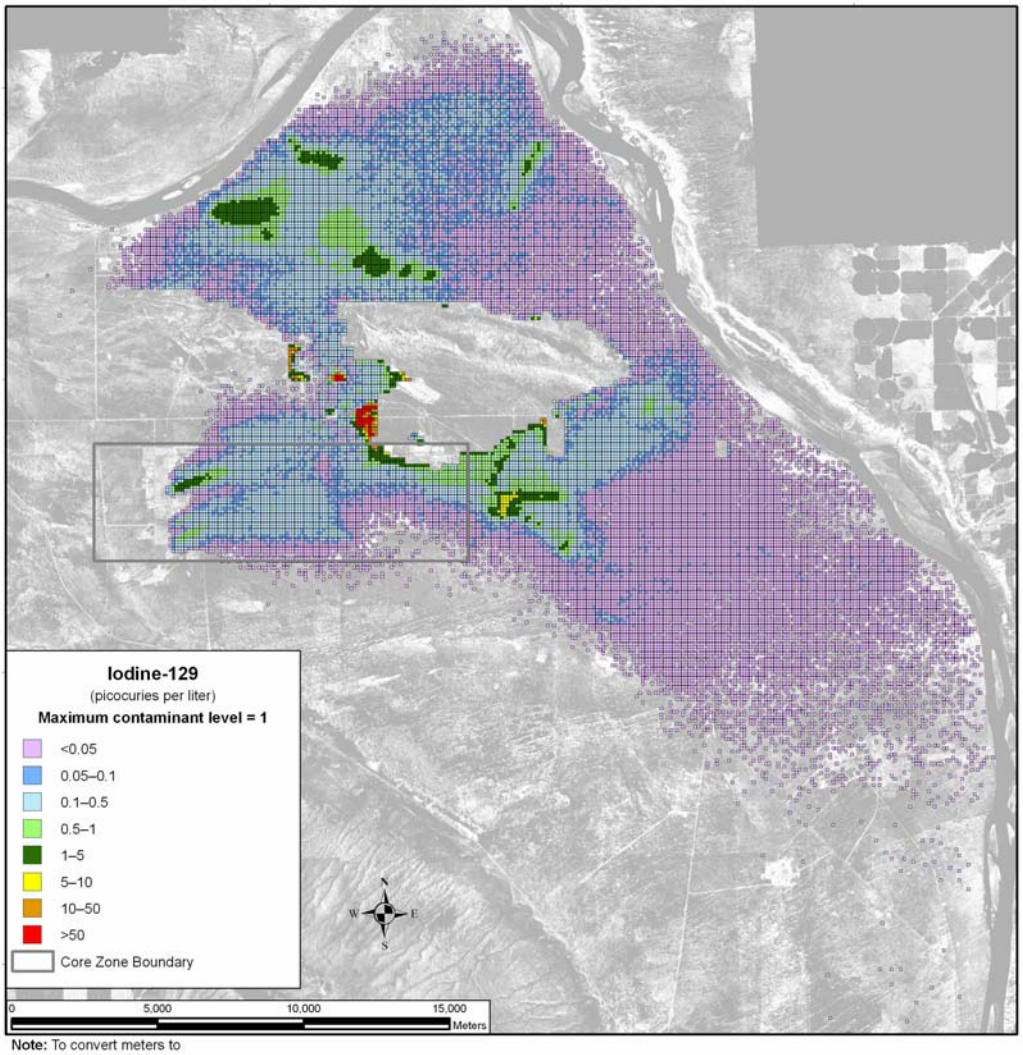
Figure 5–51. Tank Closure Alternative 2A Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2135

Figure 5–52 shows the spatial distribution of groundwater concentration for iodine-129 during CY 2005. Analysis releases from cribs and trenches (ditches) and past leaks result in a low-concentration plume that extends over most of the site but exceeds the benchmark concentration in only a few patches in and around the Core Zone Boundary. In CY 2135, the iodine-129 concentration continues to exceed the benchmark concentration in a few areas, just north of the Core Zone Boundary in Gable Gap (see Figure 5–53). At CY 3890, the majority of the plume has concentrations below the benchmark concentration, although there is a high-concentration patch north of the Core Zone Boundary and east of the 200-East Area that remains above the benchmark (see Figure 5–54). By CY 7140, most of the mass in the plume has reached the Columbia River, with only isolated pockets of high-concentration areas where the groundwater flow velocities are extremely small (see Figure 5–55). Technetium-99 (see Figures 5–56 through 5–58), chromium (see Figures 5–59 through 5–61), and nitrate (see Figures 5–62 and 5–63) show similar spatial distributions at similarly selected times. Iodine-129, technetium-99, chromium, and nitrate are all conservative tracers (i.e., move at the rate of the pore water velocity).



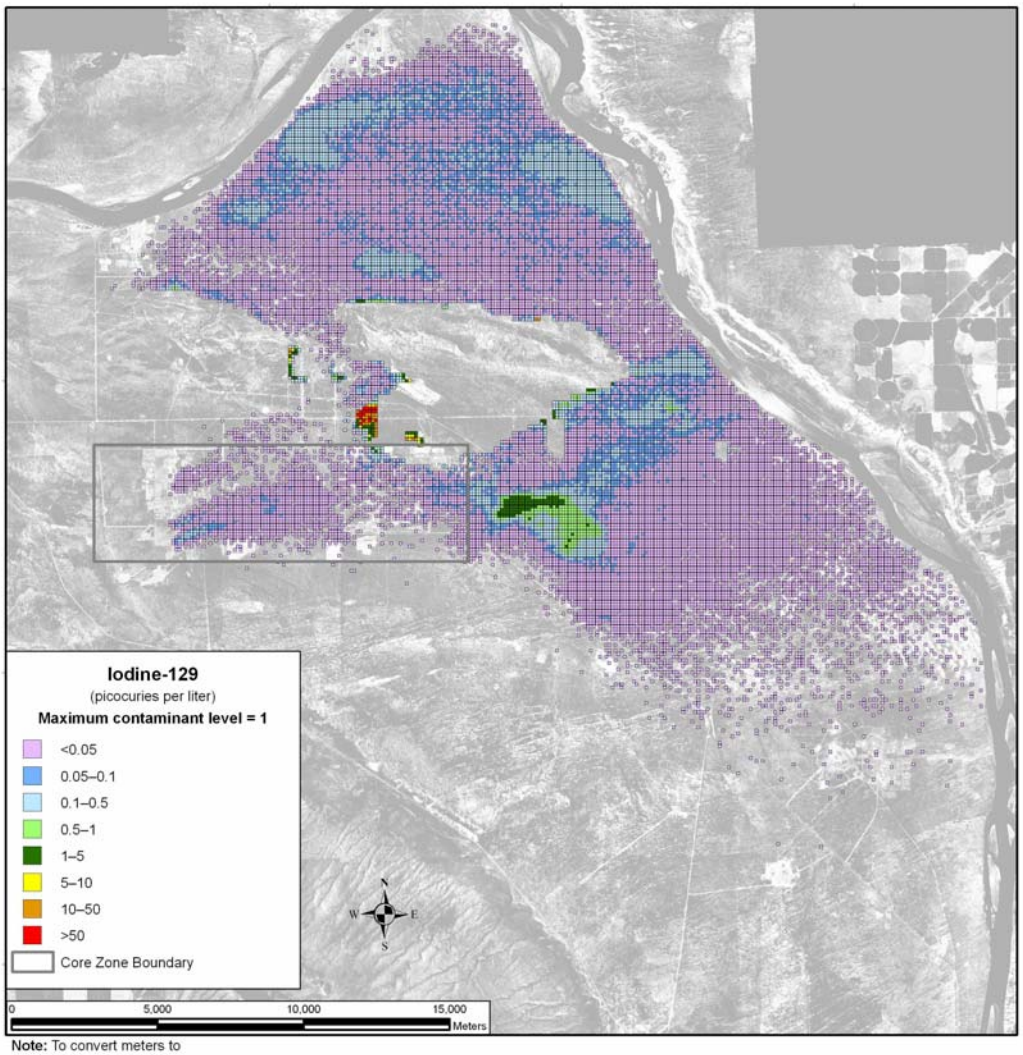
Note: To convert meters to feet, multiply by 3.281

Figure 5–52. Tank Closure Alternative 2A Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2005



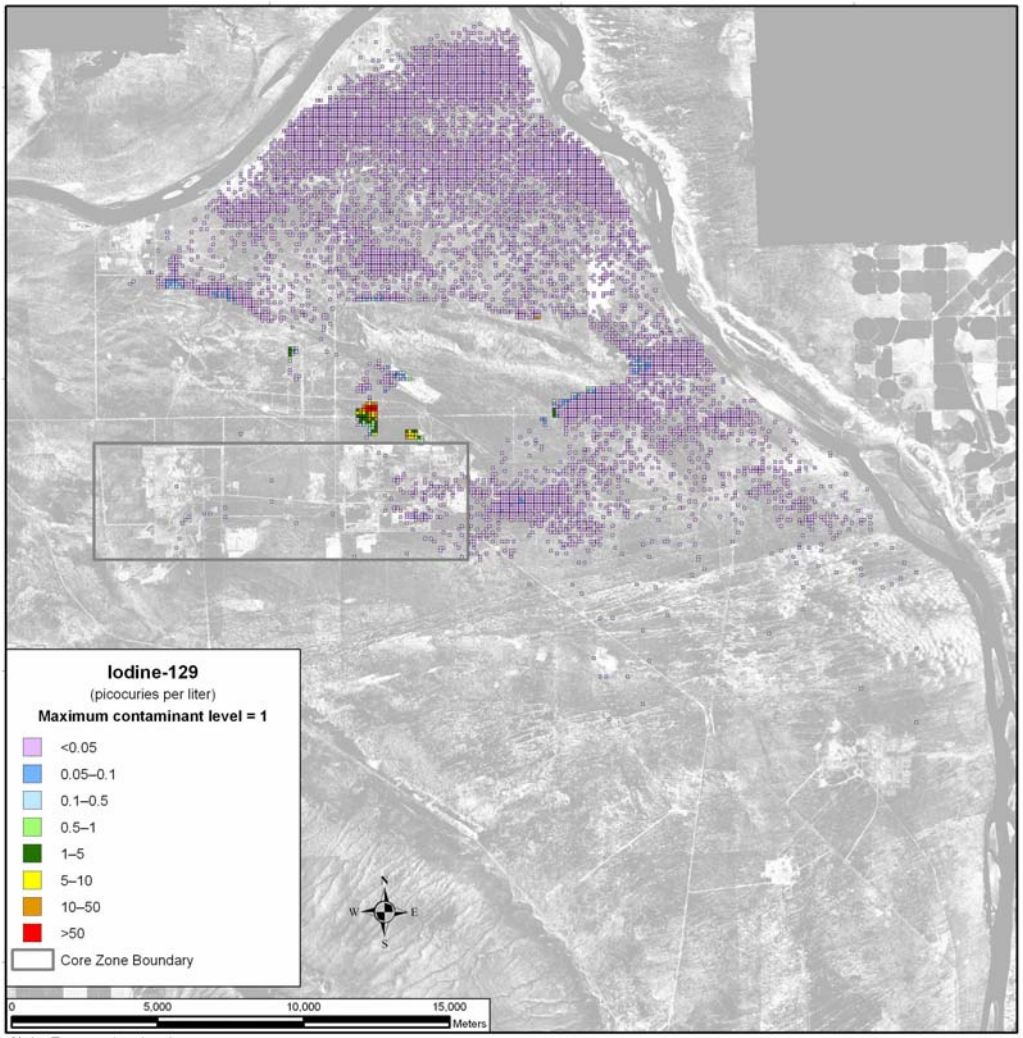
Note: To convert meters to feet, multiply by 3.281

Figure 5–53. Tank Closure Alternative 2A Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2135



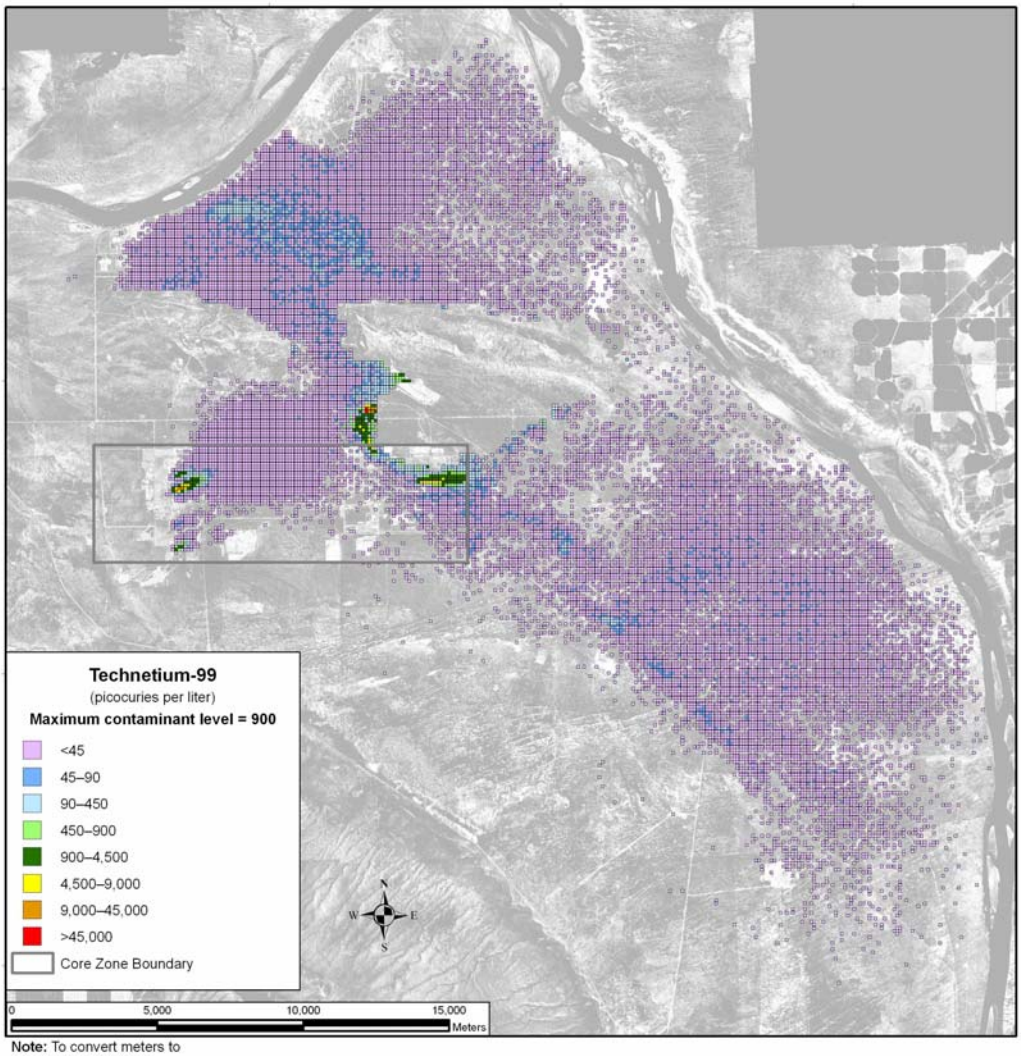
Note: To convert meters to feet, multiply by 3.281

Figure 5–54. Tank Closure Alternative 2A Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 3890



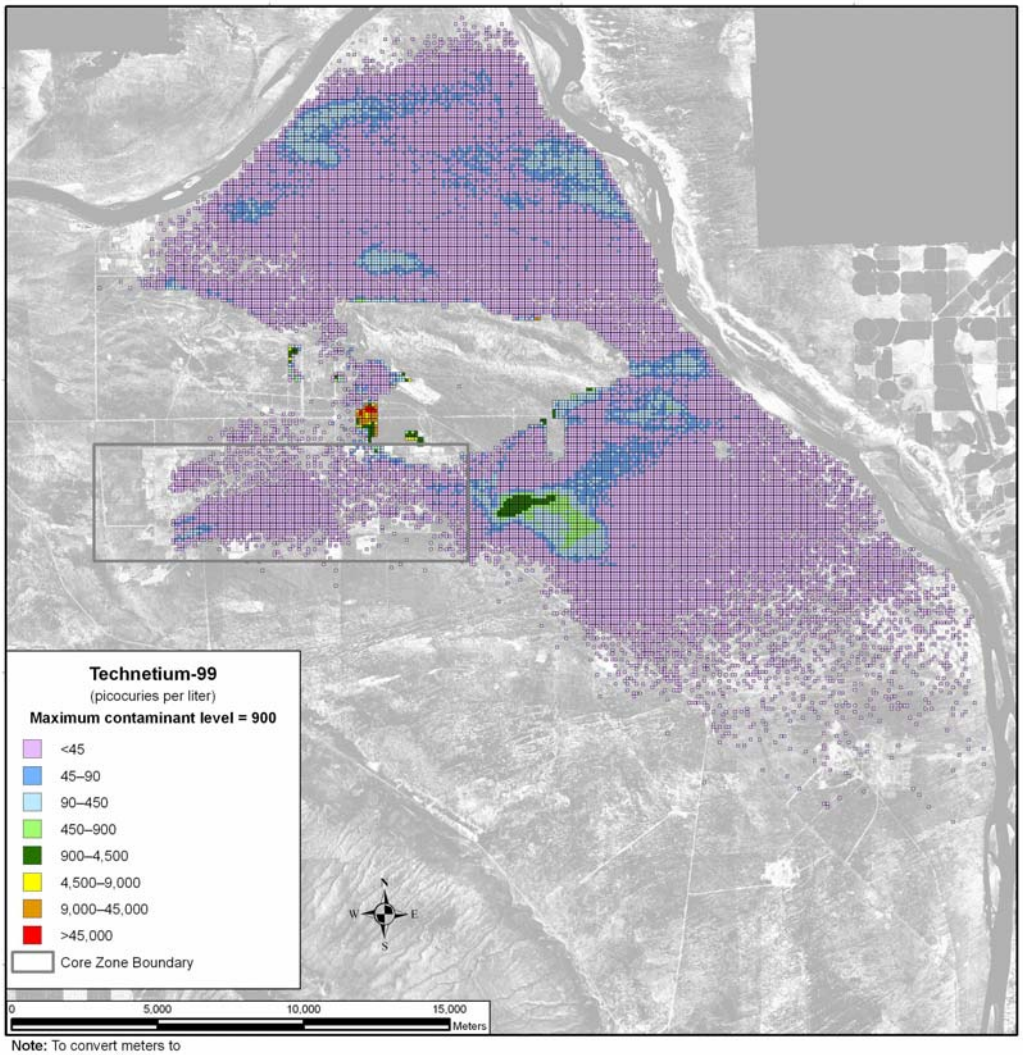
Note: To convert meters to feet, multiply by 3.281

Figure 5–55. Tank Closure Alternative 2A Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140



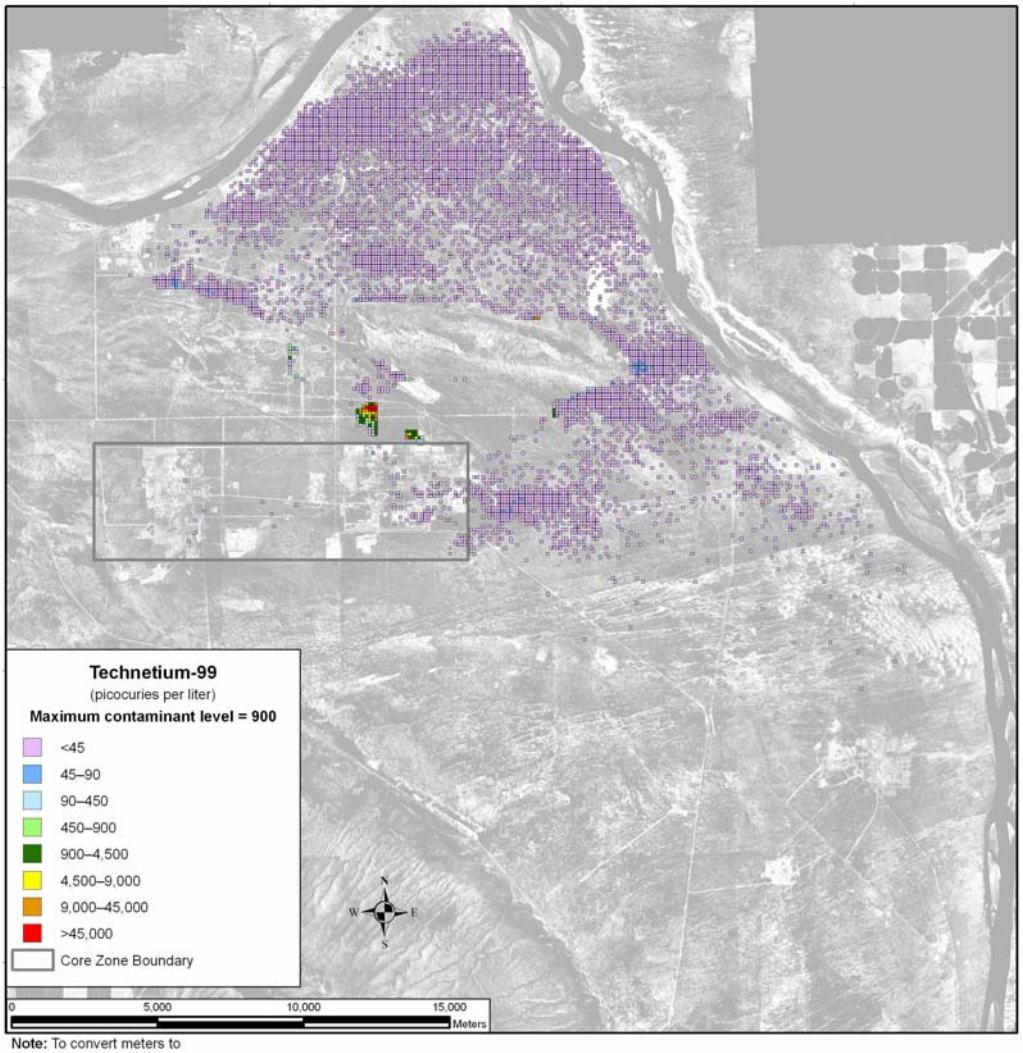
Note: To convert meters to feet, multiply by 3.281

Figure 5–56. Tank Closure Alternative 2A Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2005



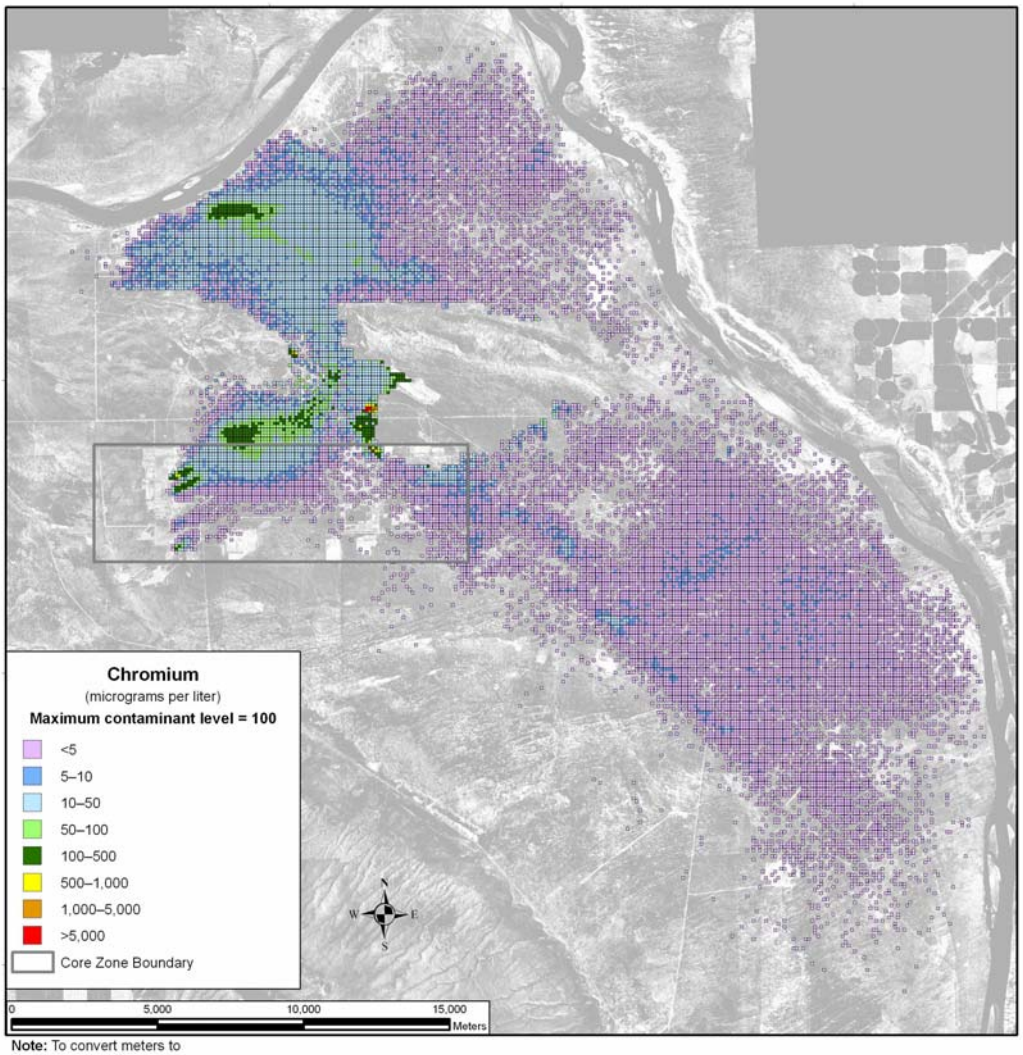
Note: To convert meters to feet, multiply by 3.281

Figure 5–57. Tank Closure Alternative 2A Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 3890



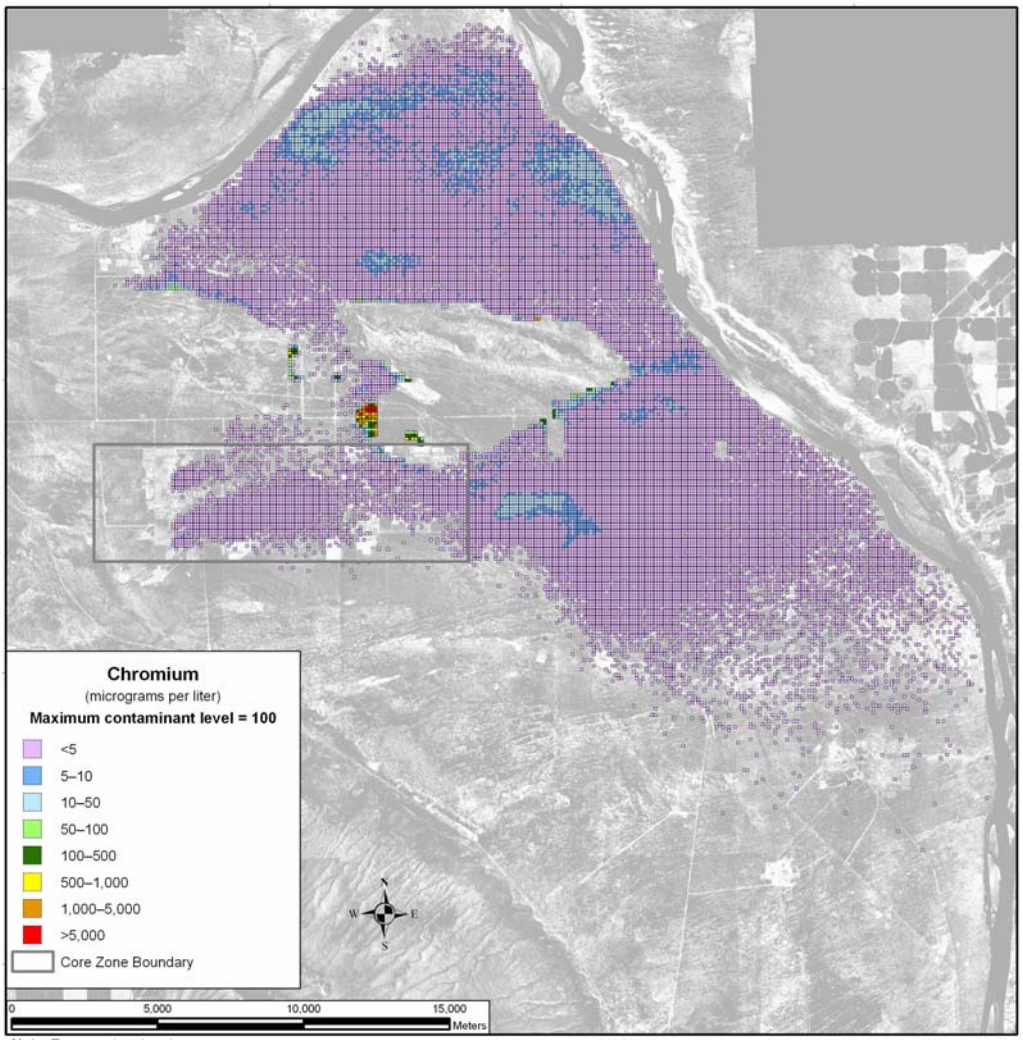
Note: To convert meters to feet, multiply by 3.281

Figure 5–58. Tank Closure Alternative 2A Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140



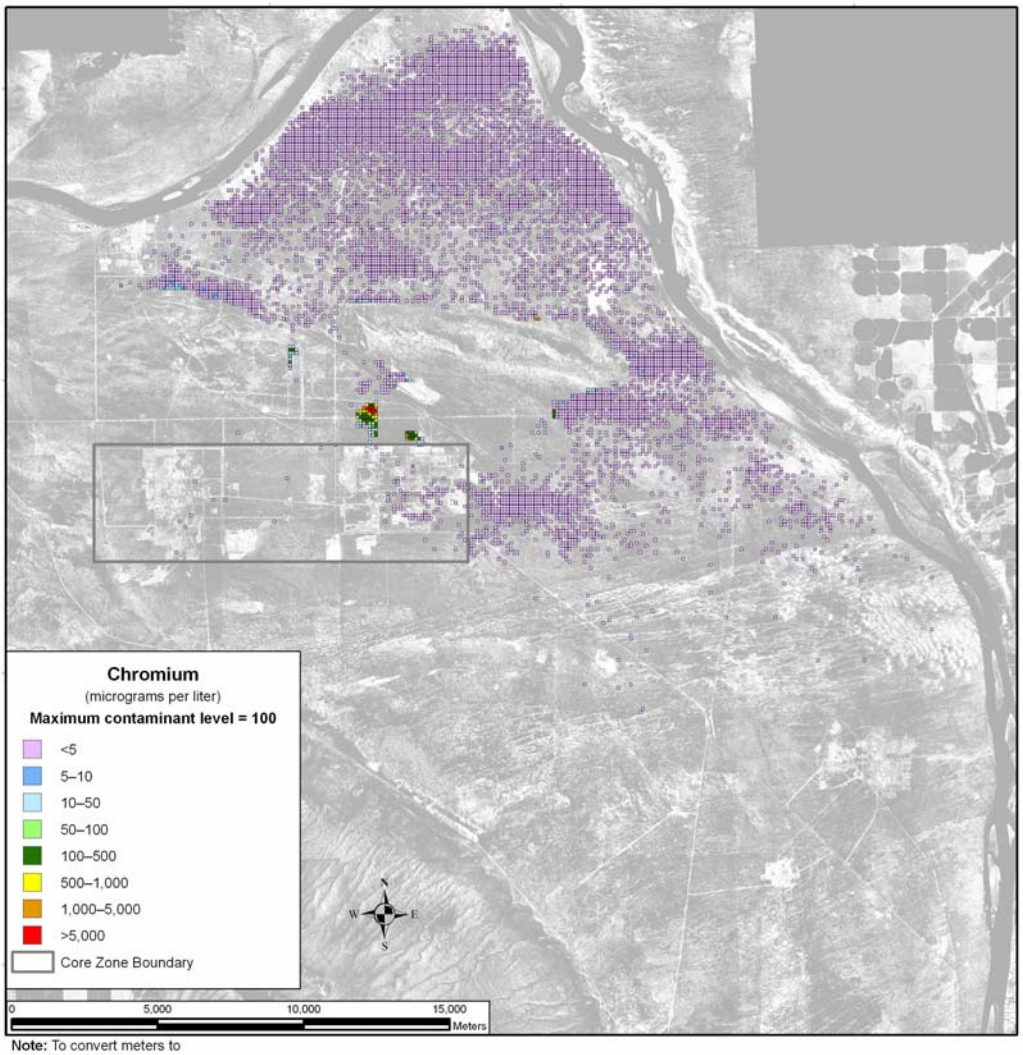
Note: To convert meters to feet, multiply by 3.281

Figure 5–59. Tank Closure Alternative 2A Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 2005



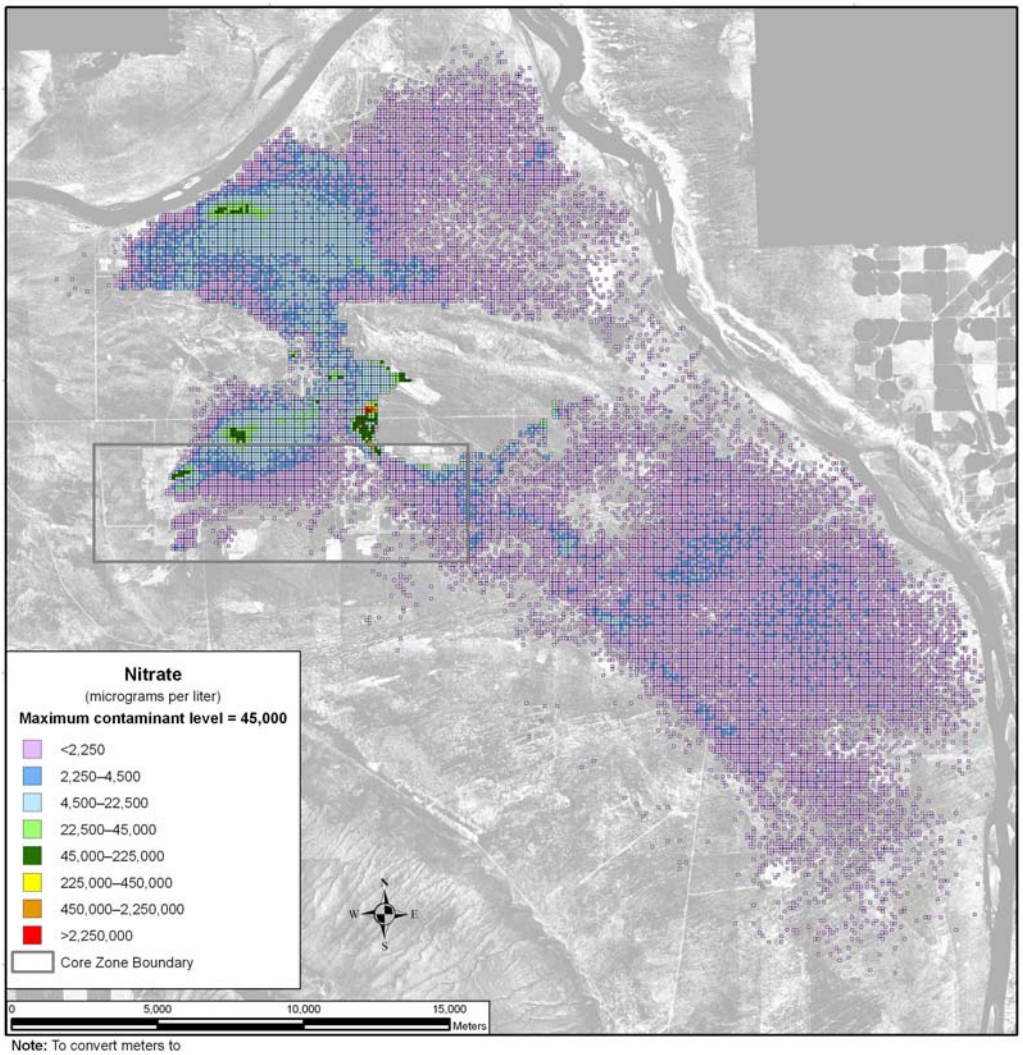
Note: To convert meters to feet, multiply by 3.281

Figure 5–60. Tank Closure Alternative 2A Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 3890



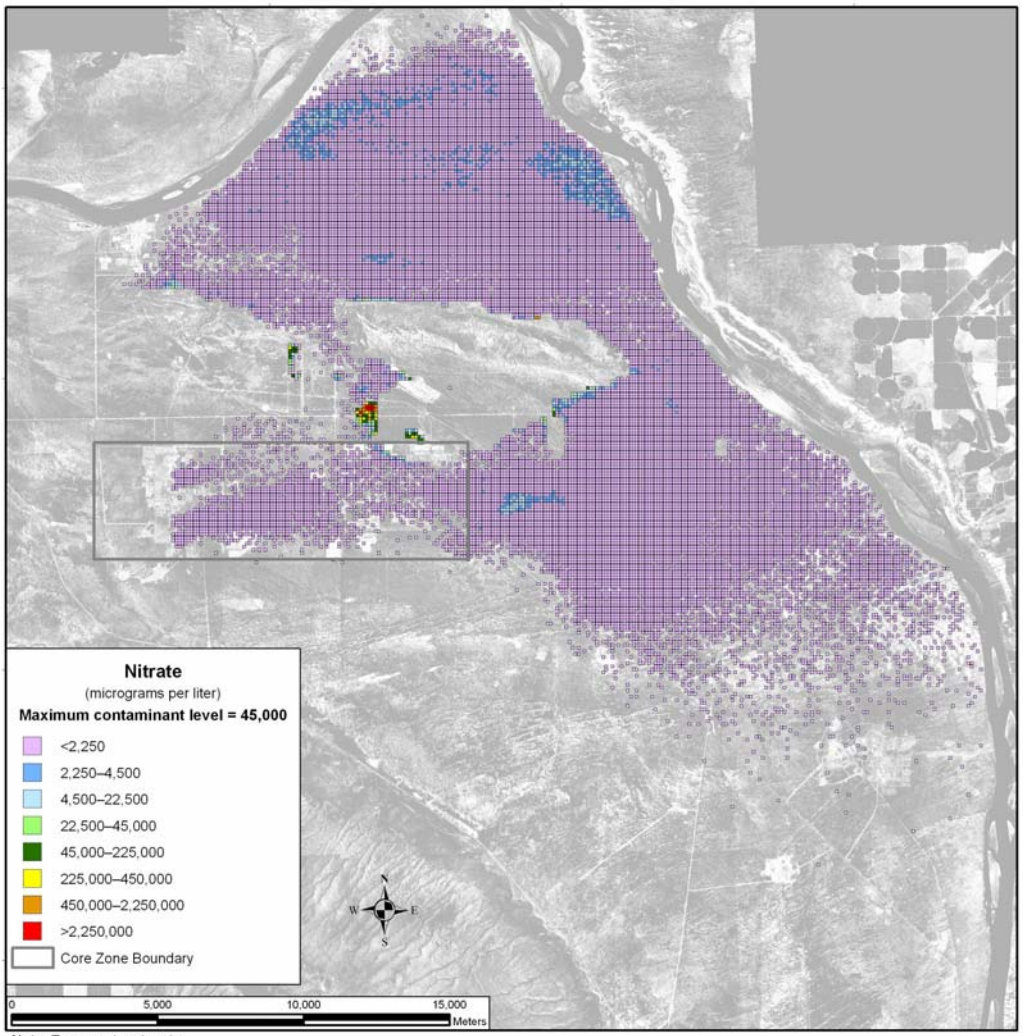
Note: To convert meters to feet, multiply by 3.281

Figure 5–61. Tank Closure Alternative 2A Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281

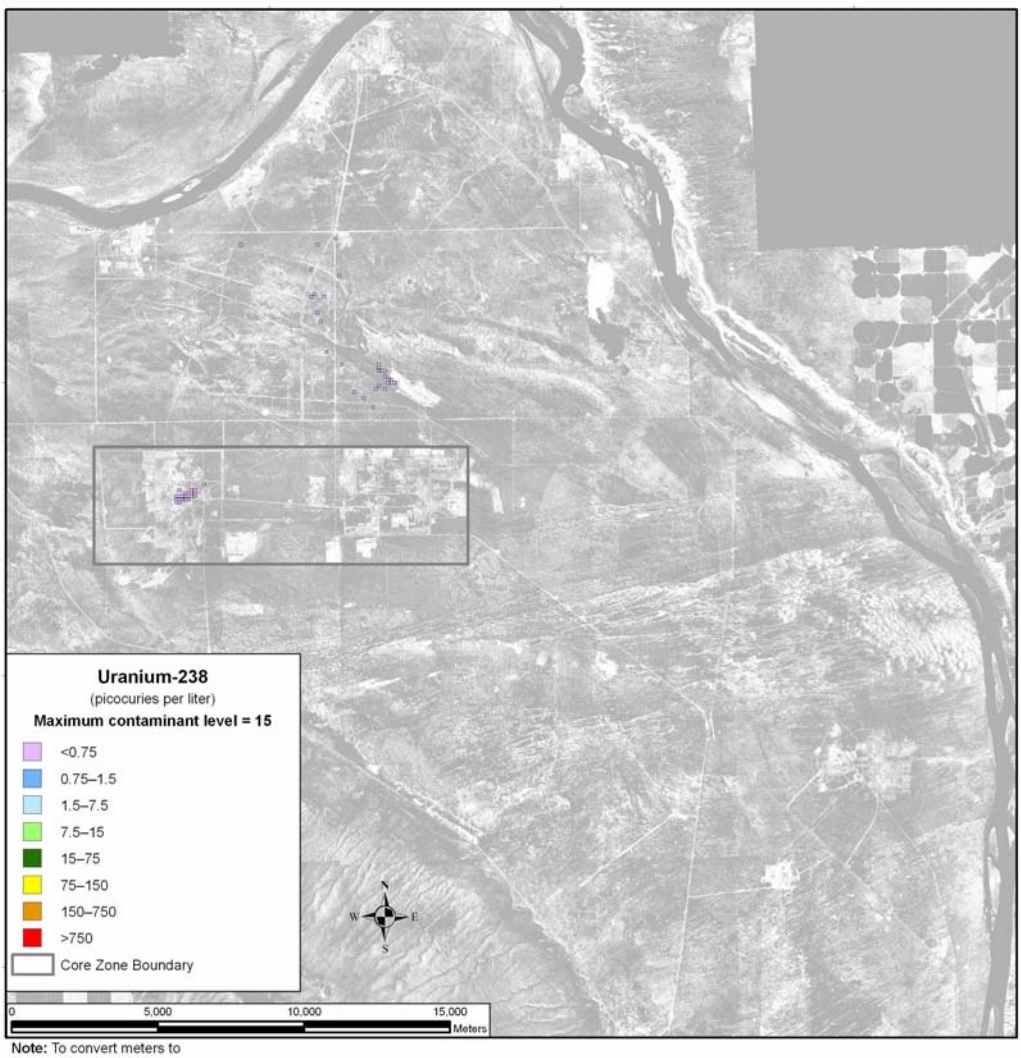
Figure 5–62. Tank Closure Alternative 2A Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

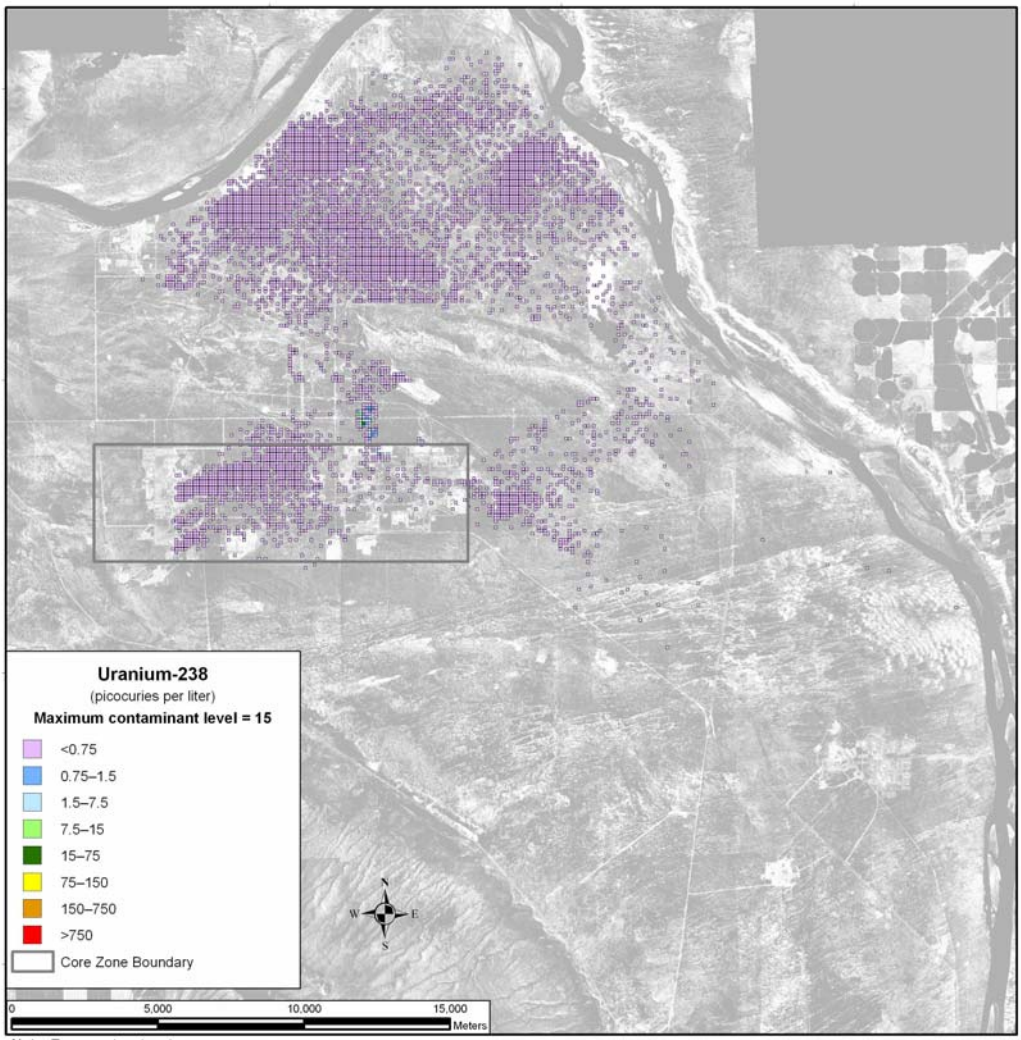
Figure 5–63. Tank Closure Alternative 2A Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 3890

Uranium-238 and total uranium show a different spatial distribution over time. These COPCs are 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 5–64 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 3890 (see Figure 5–65), the area of the plume has grown significantly, but there are no significant increases in peak concentration. By CY 7140, an area of high concentration has formed north of the Core Zone Boundary. At CY 11,885 (see Figure 5–66), the greatest development of the plume during the analysis period is seen, with areas north and east of the Core Zone Boundary reaching concentrations above the benchmark concentration. Figures 5–67 through 5–69 show the corresponding results for total uranium, which shows similar spatial distributions at similarly selected times. Concentrations east of the Core Zone Boundary do not exceed the benchmark concentration for total uranium, although the area north of the Core Zone Boundary does have concentrations above the benchmark concentration from CY 7140 to the end of the period of analysis.



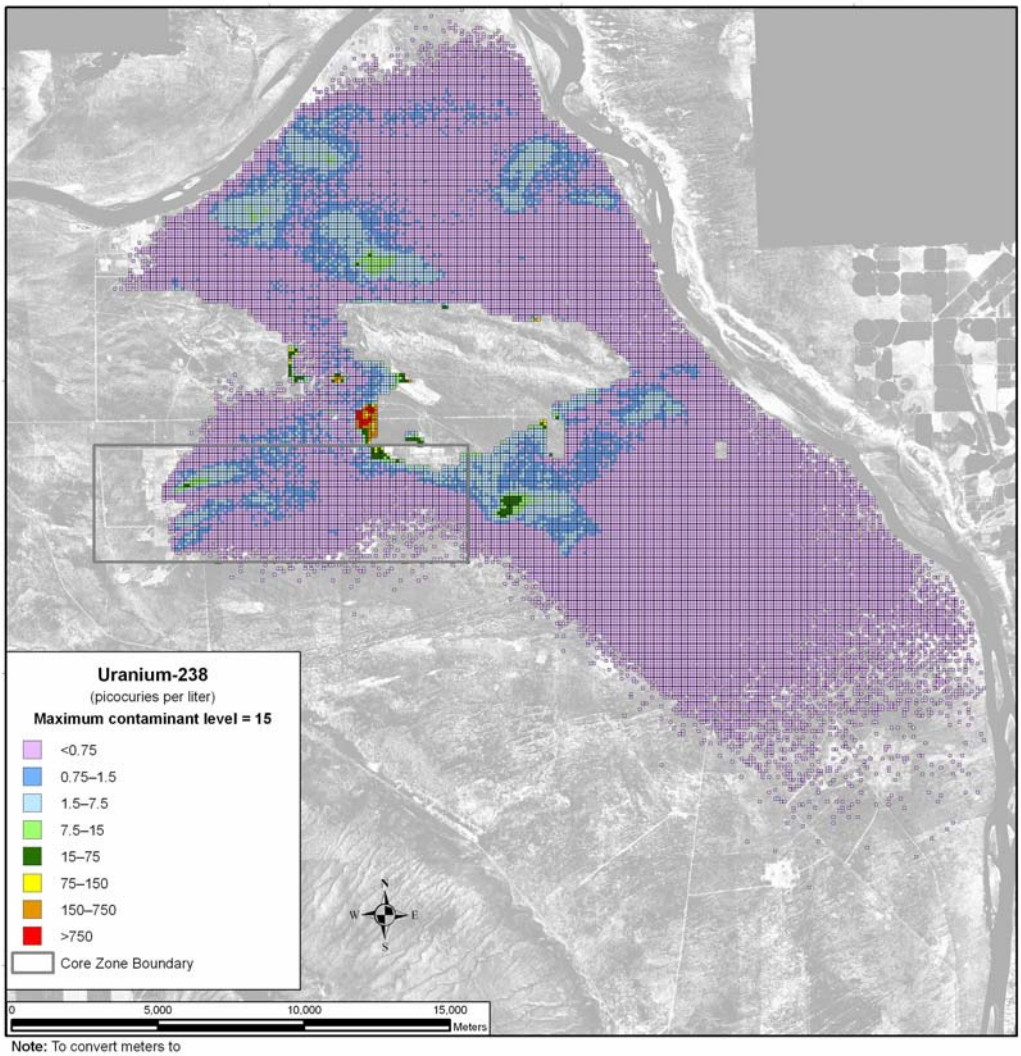
Note: To convert meters to feet, multiply by 3.281

Figure 5–64. Tank Closure Alternative 2A Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 2005



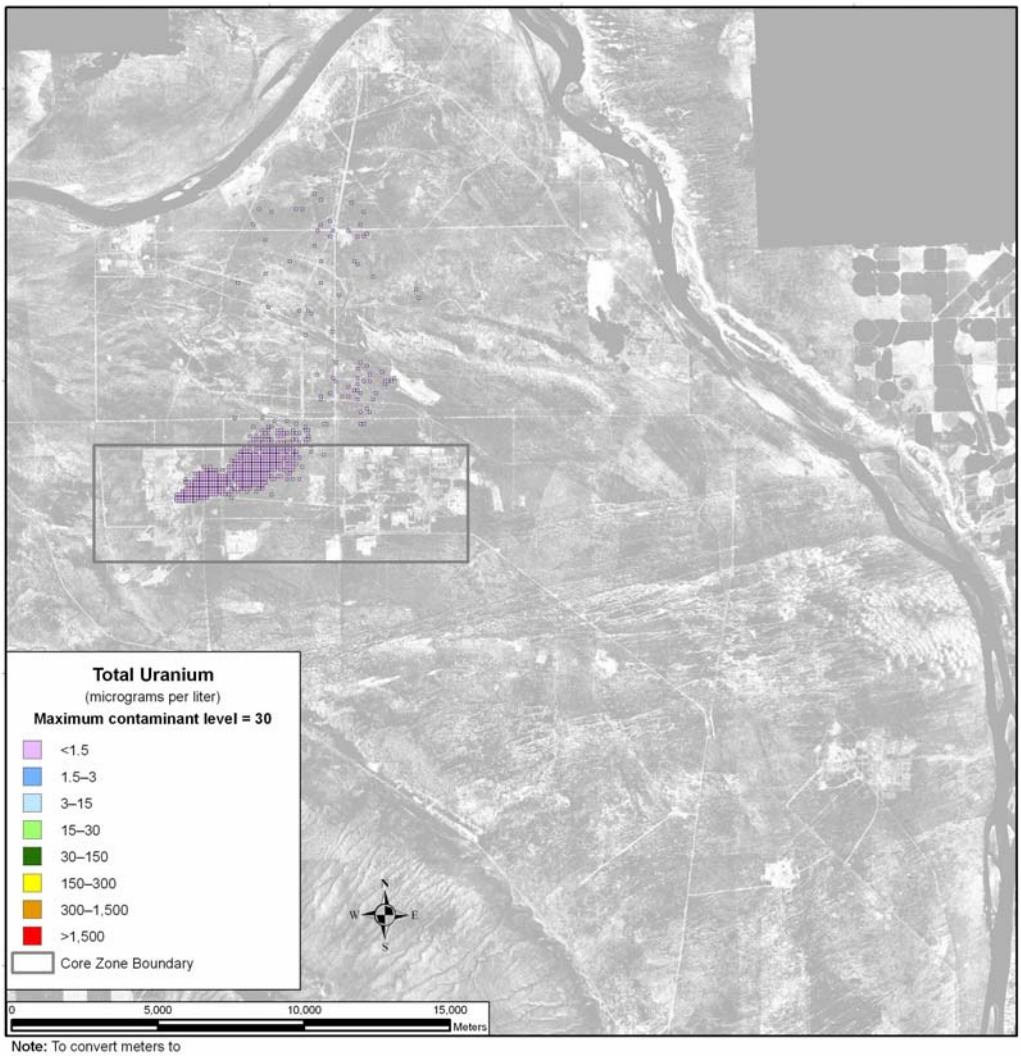
Note: To convert meters to feet, multiply by 3.281

Figure 5–65. Tank Closure Alternative 2A Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 3890



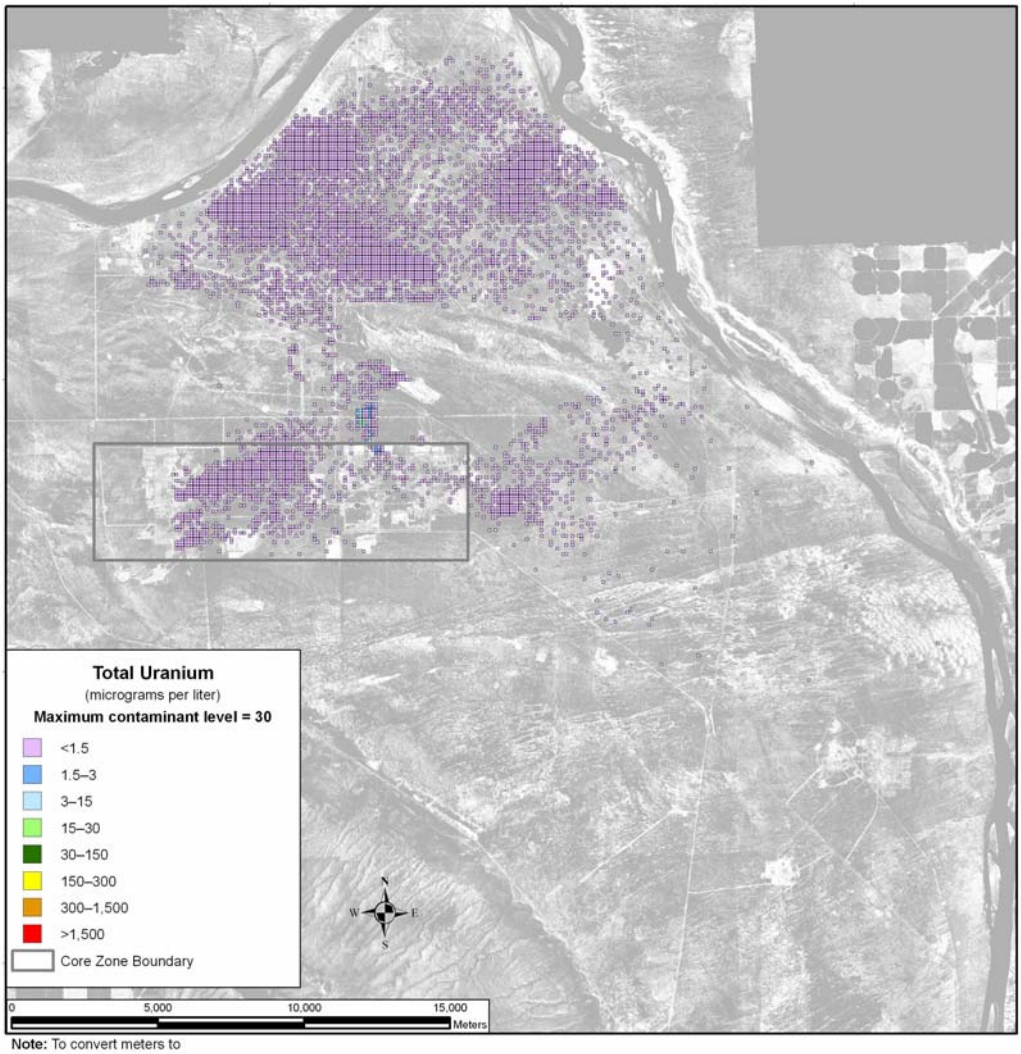
Note: To convert meters to feet, multiply by 3.281

Figure 5–66. Tank Closure Alternative 2A Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 11,885



Note: To convert meters to feet, multiply by 3.281

Figure 5–67. Tank Closure Alternative 2A Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281

Figure 5–68. Tank Closure Alternative 2A Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 3890

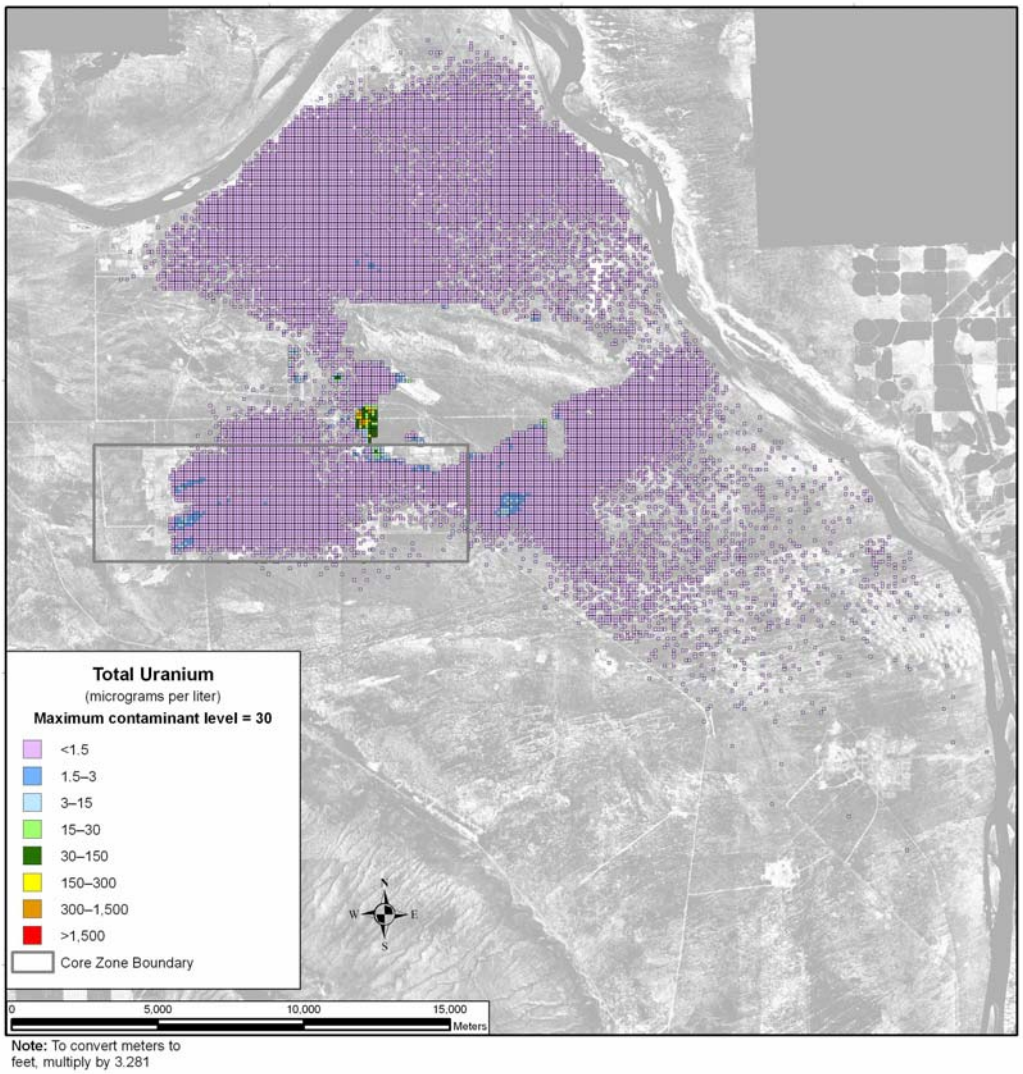


Figure 5–69. Tank Closure Alternative 2A Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 7140

Figures 5–70 through 5–72 show the area covered by concentrations above the benchmark concentration for iodine-129, technetium-99, and uranium-238. Iodine-129 spikes early in the simulation, covering a peak area of just over 9 square kilometers (3.5 square miles) around CY 2070. This area decreases rapidly until CY 2590, when it begins to rise again, peaking at 2.5 square kilometers (0.96 square miles) around CY 3240. The total area covered by the iodine-129 plume that is above the benchmark concentration drops below 1 square kilometer (0.38 square miles) around CY 5840, continuing its decline to approximately 0.8 square kilometers (0.3 square miles) by CY 9740 and remaining near that level for the remainder of the simulation. Technetium-99 shows a similar trend, peaking at approximately 5 square kilometers (1.9 square miles) in CY 2135 and reaching 0.5 square kilometers (0.19 square miles) in CY 9740. Uranium-238 shows a distinctly different pattern, without any area above the benchmark concentration until CY 4540. From CY 4540 until the end of the simulation, areas of uranium-238 concentrations above the benchmark slowly increase, never exceeding 2 square kilometers (0.77 square miles) during the simulation.

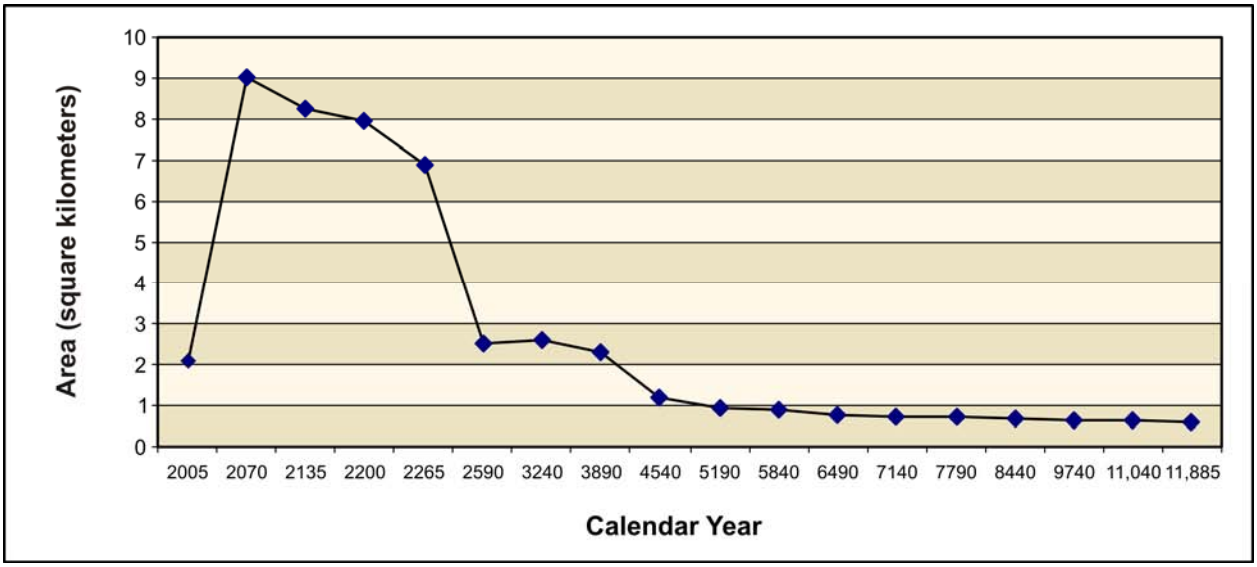


Figure 5–70. Tank Closure Alternative 2A Total Area of Groundwater Iodine-129 Concentration Exceeding the Benchmark Concentration as a Function of Time

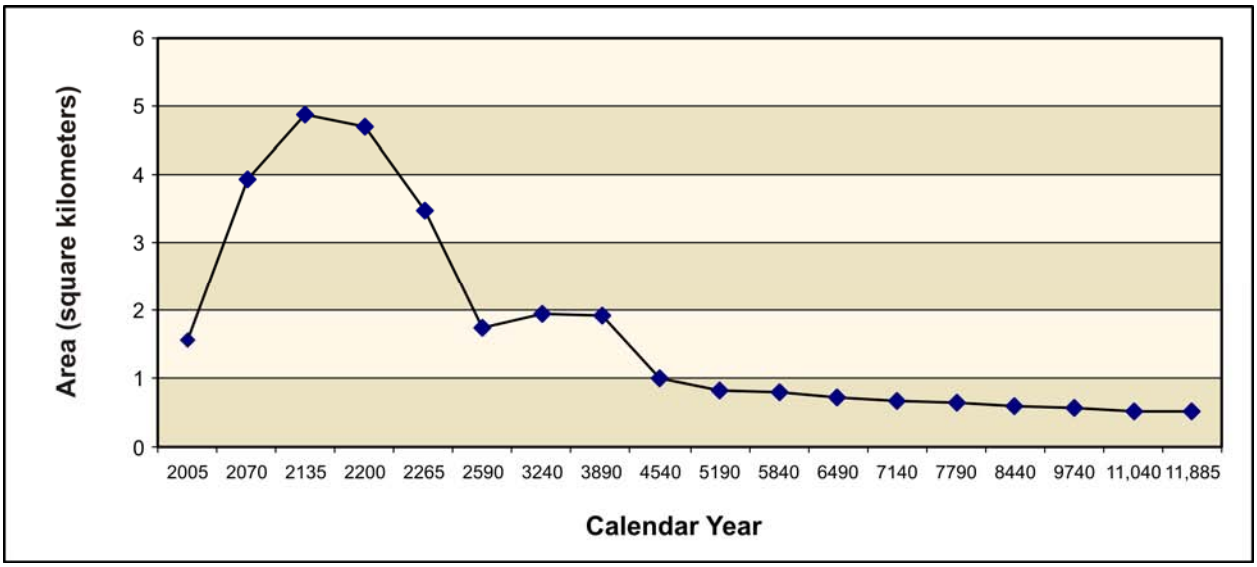


Figure 5–71. Tank Closure Alternative 2A Total Area of Groundwater Technetium-99 Concentration Exceeding the Benchmark Concentration as a Function of Time

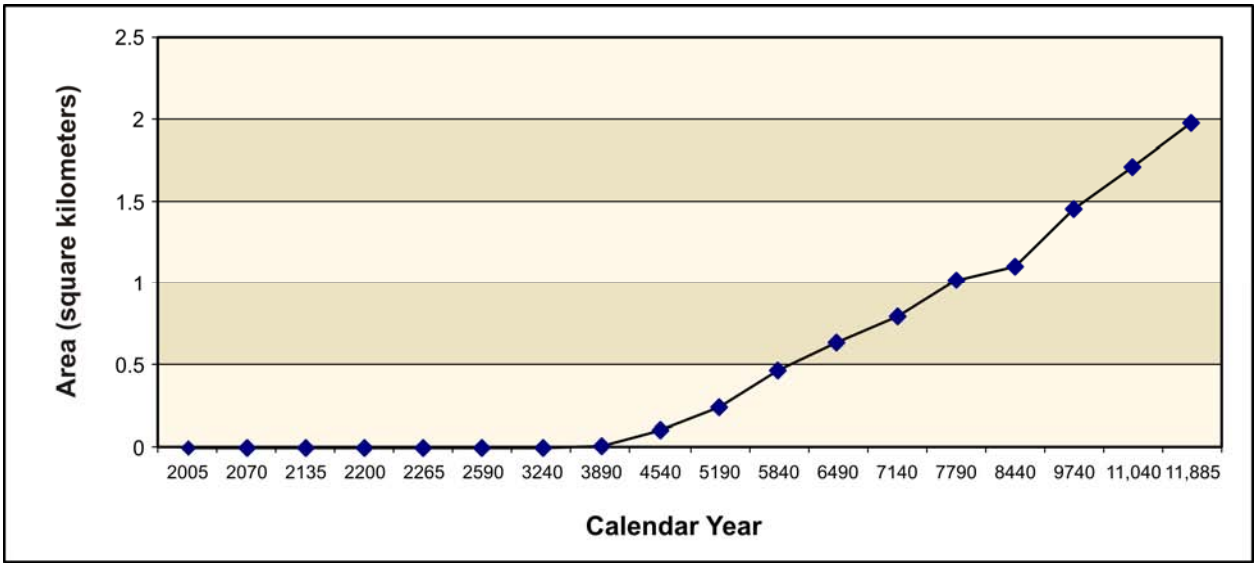


Figure 5–72. Tank Closure Alternative 2A Total Area of Groundwater Uranium-238 Concentration Exceeding the Benchmark Concentration as a Function of Time

5.1.1.2.6 Summary of Impacts

Under Tank Closure Alternative 2A, releases from cribs and trenches (ditches), past leaks, and other tank farm sources available after the retrieval period are all major contributors in the analysis. The retrieval of waste from the SSTs lowers the contribution of other tank farm sources relative to Tank Closure Alternative 1.

For the conservative tracers, concentrations at the Core Zone Boundary exceed benchmark standards by one to two orders of magnitude early in the analysis, between CY 2100 and 2200. These concentrations fall below the benchmark between 3,000 and 4,000 years into the analysis. Concentrations at the Columbia River remain below the benchmark concentration throughout the period of analysis.

For tritium, concentrations at the Core Zone Boundary exceed the benchmark by about two orders of magnitude during the first 100 years of the period of analysis. Concentrations at the Columbia River approach the benchmark during this time. Attenuation by radioactive decay is a predominant mechanism that limits the intensity and duration of groundwater impacts of tritium. After CY 2040, tritium impacts are essentially negligible.

For uranium-238 and total uranium, limited mobility is an important factor governing the timeframes and scale of groundwater impacts. Concentrations at the Core Zone Boundary exceed the benchmark concentration in CY 5900 for uranium-238 and in CY 6900 for total uranium. Groundwater concentrations at the Columbia River nearshore rise throughout the period of analysis, but stay below an order of magnitude less than the benchmark concentration.

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

This section describes the groundwater analysis results for Tank Closure Alternative 2B, including long-term groundwater impacts of contaminant sources from 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.

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 Resource Conservation and Recovery Act (RCRA) Subtitle C barrier. From the long-term groundwater impact perspective, the results from the analyses of these alternatives are identical.

5.1.1.3.1 Actions and Timeframes Influencing Groundwater Impacts

Summaries of the proposed actions and timelines for Tank Closure Alternative 2B are provided in Chapter 2, Section 2.5. For the long-term groundwater impact analysis, three major periods were identified for Tank Closure Alternative 2B, 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 2B that are presented in this section would be common to all of the Tank Closure alternatives.

- The retrieval period was assumed to start in 2008 and continue through CY 2145. This period includes retrieval, WTP pretreatment and treatment, landfill closure of the SST farm system, and 100 years of postclosure care. It was assumed that during the retrieval period, 99 percent of waste volume would be retrieved from the tanks. The SST farm system would be landfill-closed with a modified RCRA Subtitle C barrier. A retrieval leakage rate of 15,140 liters (4,000 gallons) per SST (other tank farm sources) was assumed to be released to the vadose zone during the first part of this period. Releases that occurred during the past-practice period would continue to migrate through the vadose zone and groundwater system.

- The post–administrative control period was assumed to start in CY 2146 and continue through the 10,000-year period of analysis until CY 11,940. Releases that occurred during the past-practice and retrieval periods would continue to migrate through the vadose zone and groundwater system during the post–administrative control period. In addition, the remaining other tank farm sources waste (e.g., residual waste, ancillary equipment) would be released to the vadose zone at the start of the post–administrative control period.

5.1.1.3.2 COPC Drivers

A total of 19 COPCs were analyzed for Tank Closure Alternative 2B. 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 2B 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 2B 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, they become

major contributors toward the end of the period of analysis. 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^{-14}, 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 2B.

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.

5.1.1.3.3 Analysis of Release and Mass Balance

This section presents the impacts of Tank Closure Alternative 2B 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 5–73 through 5–78). Three subtotals are plotted representing releases from cribs and trenches (ditches), past leaks, and other tank farm sources. For all three 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). 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 5–73 shows the estimated release to the vadose zone for the radiological risk drivers and Figure 5–74, 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. The predominant contributing sources for the remaining COPC drivers are a combination of past leaks and other tank farm sources. This suggests that all three sources are important impact drivers under Tank Closure Alternative 2B.

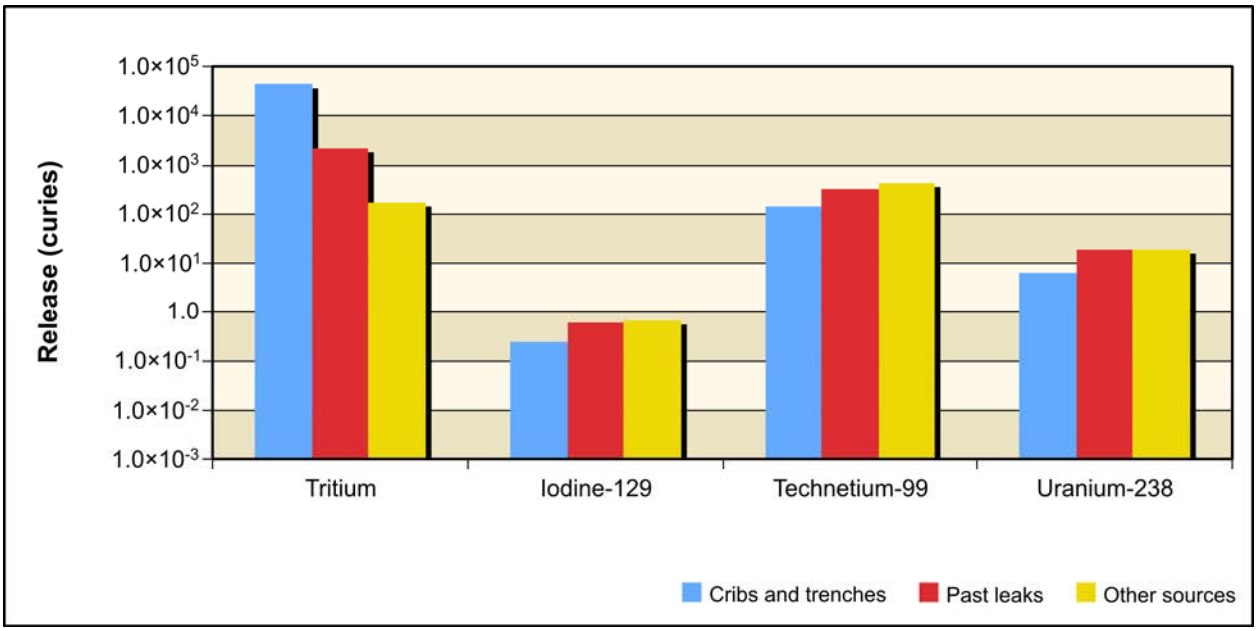


Figure 5–73. Tank Closure Alternative 2B Releases of Radiological Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

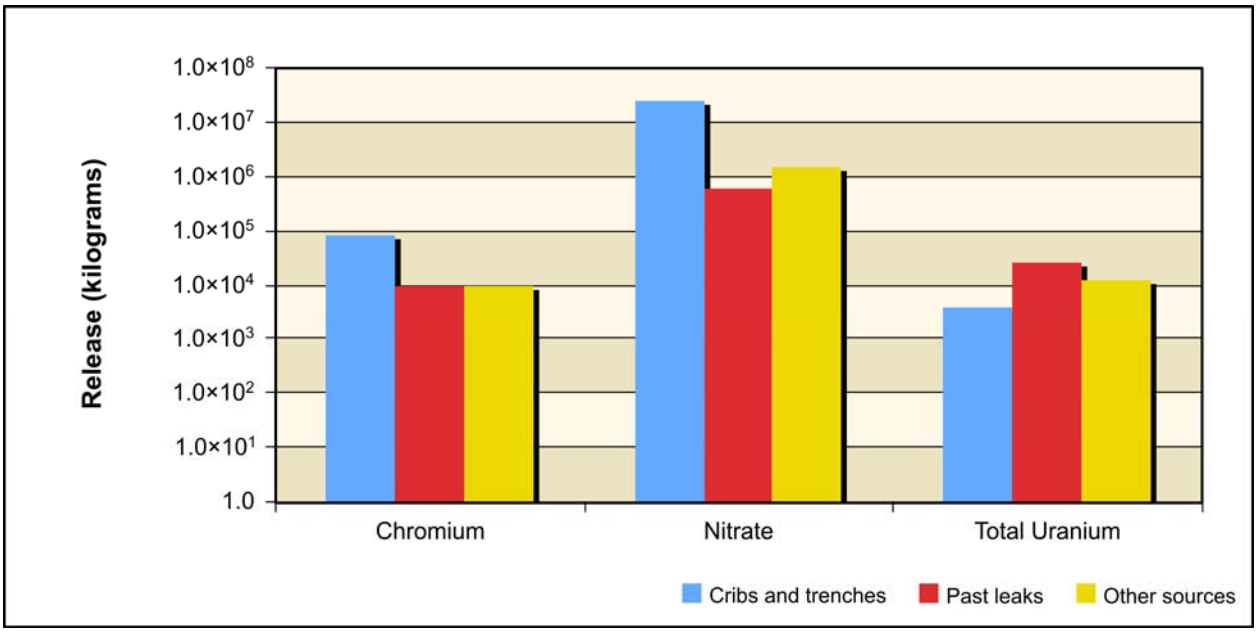


Figure 5–74. Tank Closure Alternative 2B Releases of Chemical Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

Figure 5–75 shows the estimated release to groundwater for the radiological risk drivers and Figure 5–76, 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, chromium, and nitrate), the amount released to groundwater is essentially equal to the amount released to the vadose zone.

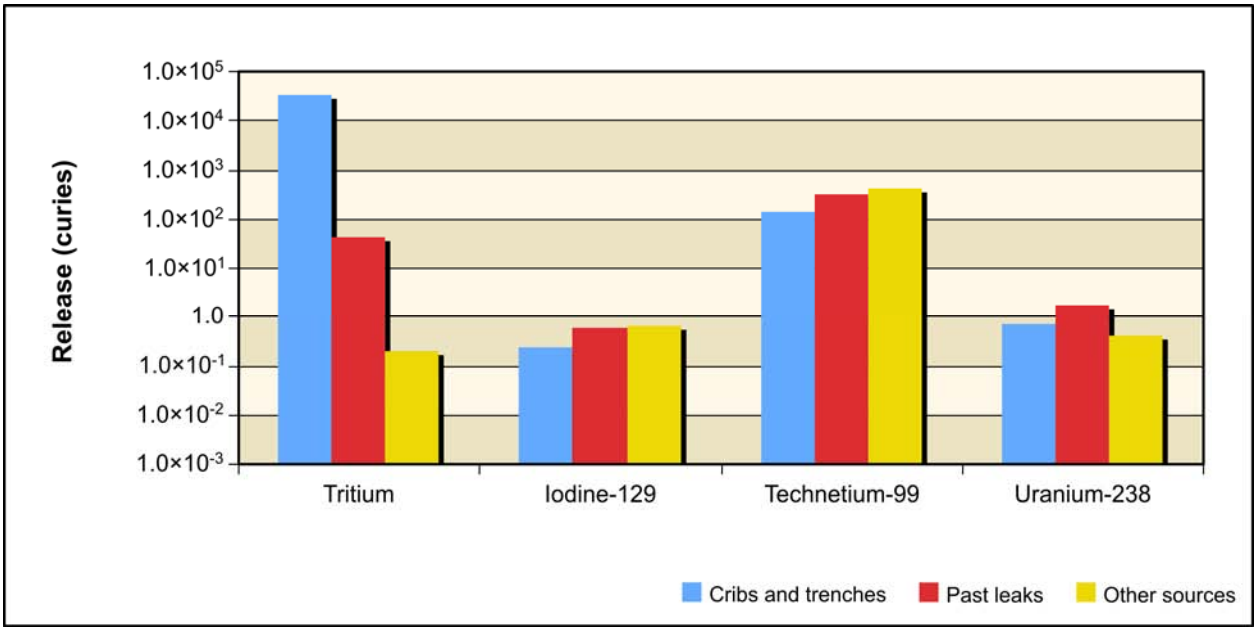


Figure 5–75. Tank Closure Alternative 2B Releases of Radiological Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

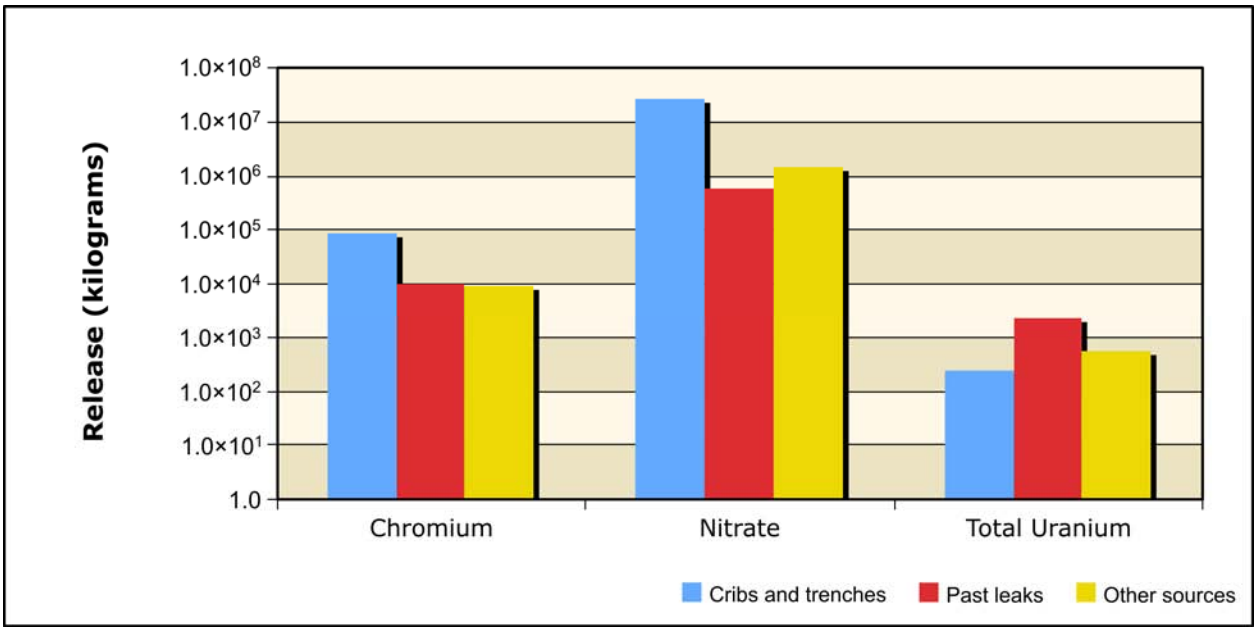


Figure 5–76. Tank Closure Alternative 2B Releases of Chemical Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

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) and past leaks, where moisture movement through the vadose zone is relatively rapid (because of the volume of water associated with the source), about 10 percent of the total inventory of uranium-238 and total uranium reached groundwater during the period of analysis; for other tank farm sources, only about 3 percent of the total inventory reached groundwater during the period of analysis.

For tritium, the amount released to groundwater is attenuated by radioactive decay. For cribs and trenches (ditches), about 70 percent of the total inventory reaches groundwater, for past leaks only about 3 percent, and for other tank farm sources, only about one-tenth of 1 percent of the inventory reached the water table. 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 5–77 shows the estimated release to the Columbia River for the radiological risk drivers and Figure 5–78, 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. 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. Overall, about 25 percent of the uranium-238 and total uranium 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. Overall, only about 2 percent of the tritium released to groundwater reached the Columbia River during the period of analysis. 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.

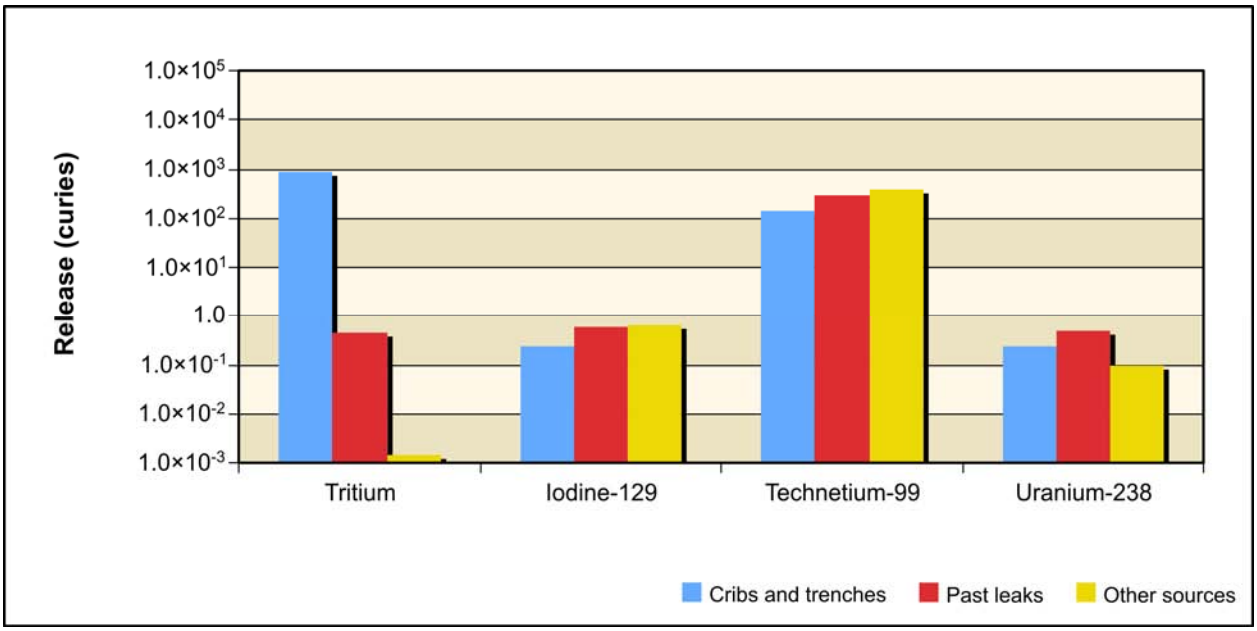


Figure 5–77. Tank Closure Alternative 2B Releases of Radiological Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

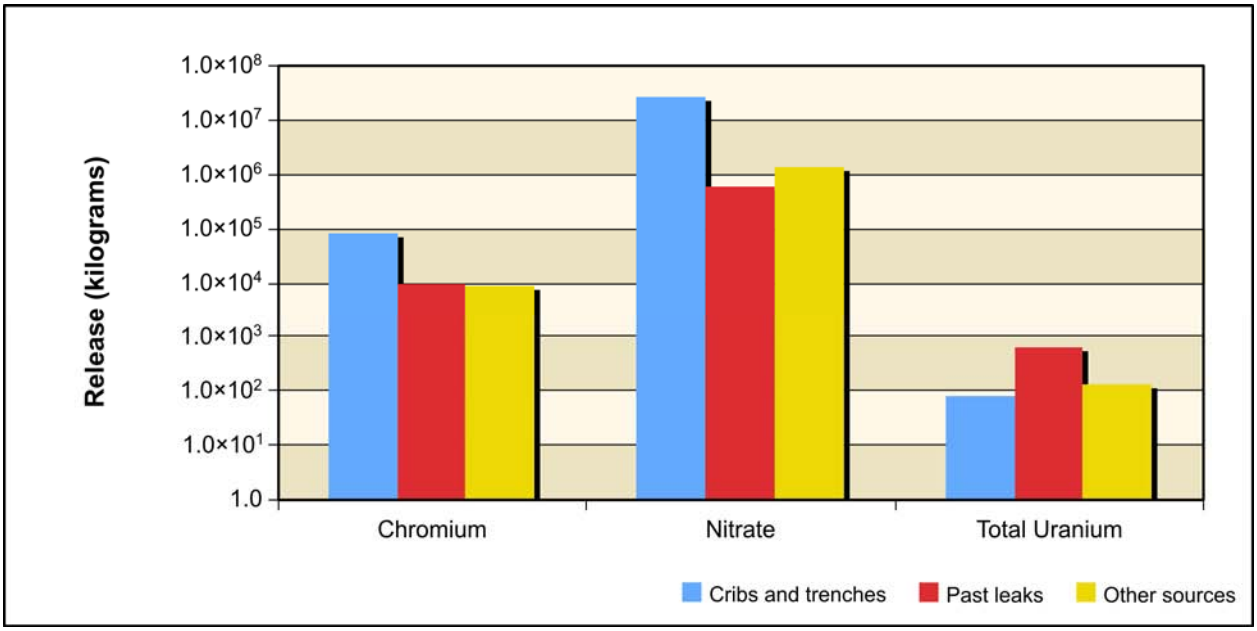


Figure 5–78. Tank Closure Alternative 2B Releases of Chemical Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

5.1.1.3.4 Analysis of Concentration Versus Time

This section presents the analysis of Tank Closure Alternative 2B 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 Table 5–3 and Figures 5–79 through 5–85). 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 five orders of magnitude. Table 5–3 lists the maximum concentrations of the COPCs in the peak year after CY 2050 at the tank farm barriers, Core Zone Boundary, and Columbia River nearshore.

Figure 5–79 shows concentration versus time for tritium. Releases from cribs and trenches (ditches) cause groundwater concentrations within the Core Zone Boundary to exceed benchmark concentrations by about two orders of magnitude for a short period of time during the early part of the period of analysis. During this time, groundwater concentrations at the Columbia River nearshore approach the benchmark concentration but stay about one order of magnitude below it. Because the half-life of tritium is less than 13 years, radioactive decay rapidly attenuates groundwater concentration, and tritium concentrations fall (and stay) below the benchmark concentration at the Core Zone Boundary after CY 2030.

Table 5–3. Tank Closure Alternative 2B 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)	28	5,080	52	7,270	13	6,080	178	20,000
	(2051)	(2054)	(2050)	(2055)	(2050)	(2054)	(2050)	
Technetium-99	**1,450**	**30,000**	**2,660**	**15,200**	284	**25,900**	205	900
	(2058)	(2050)	(2050)	(2050)	(3499)	(2050)	(2480)	
Iodine-129	**3**	**40**	**5**	**30**	0.4	**34**	0.4	1
	(2053)	(2057)	(2050)	(2050)	(3708)	(2057)	(2876)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	1	**55**	6	**27**	8	**73**	1	15
	(11,755)	(11,739)	(11,765)	(11,780)	(11,441)	(11,691)	(11,871)	
Chemical in micrograms per liter								
Acetonitrile	1	0	0	0	0	1	0	100
	(3701)	(1940)	(3566)	(1940)	(1940)	(3829)	(4021)	
Chromium	9	**3,230**	**271**	**768**	10	**1,670**	34	100
	(2057)	(2055)	(2050)	(2050)	(2050)	(2050)	(2695)	
Nitrate	5,650	**1,540,000**	8,950	**133,000**	1,380	**1,010,000**	8,580	45,000
	(2057)	(2050)	(2050)	(2054)	(2068)	(2050)	(2450)	
Total uranium	0	**46**	8	11	12	**103**	1	30
	(11,795)	(11,792)	(11,602)	(11,840)	(11,599)	(11,683)	(11,146)	

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.

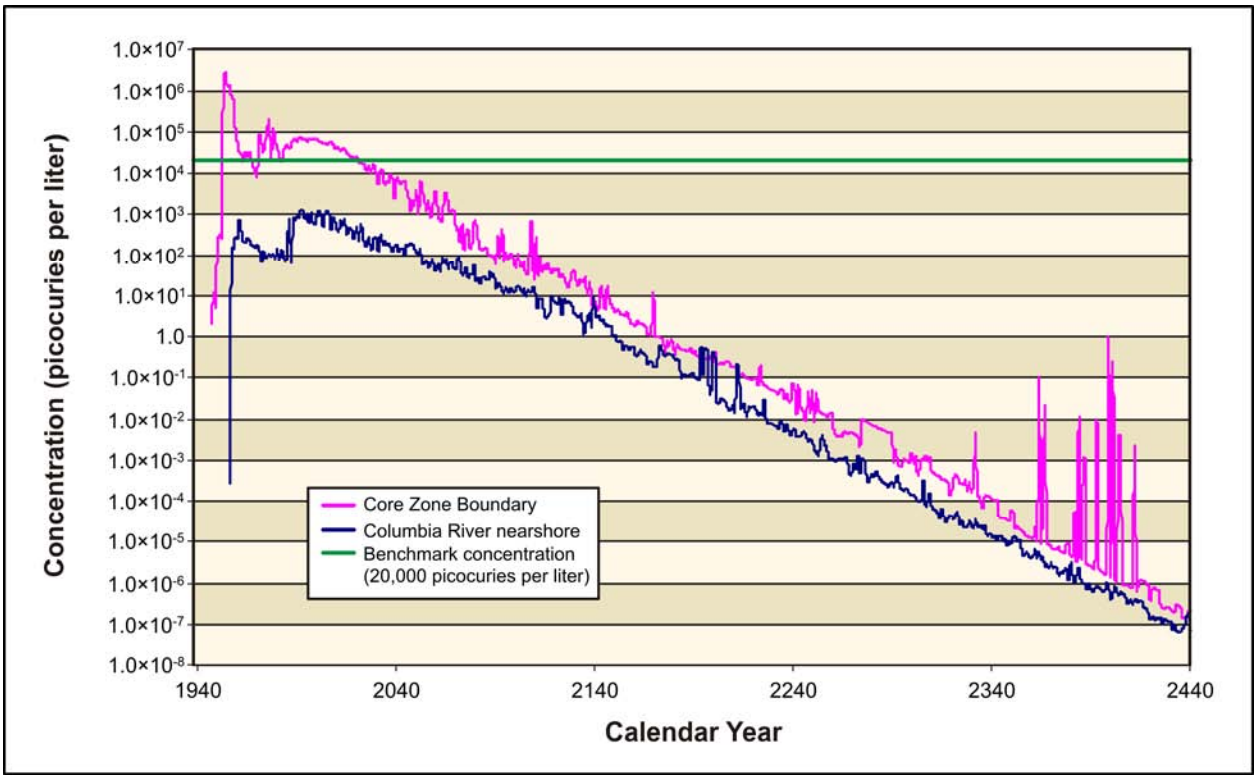


Figure 5–79. Tank Closure Alternative 2B Hydrogen-3 (Tritium) Concentration Versus Time

Figures 5–80 through 5–83 show concentration versus time for iodine-129, technetium-99, chromium, and nitrate (the conservative tracers). Releases from cribs and trenches (ditches) cause groundwater concentrations to exceed benchmark concentrations by about two to three orders of magnitude during the early part of the period of analysis. During this time, groundwater concentrations at the Columbia River nearshore approach the benchmark concentration but remain about one order of magnitude below the benchmark at peak-year conditions. Releases from past leaks and other tank farm sources cause groundwater concentrations to continue to exceed benchmark concentrations in the Core Zone Boundary by about one order of magnitude through about CY 8000 for iodine-129 and CY 5000 for the other conservative tracers. During this time, groundwater concentrations at the Columbia River nearshore are below the benchmark concentration and continue to decline through the end of the period of analysis.

Figures 5–84 and 5–85 show concentration versus time for uranium-238 and total uranium. Early releases from cribs and trenches (ditches) result in groundwater concentrations that are two to three orders of magnitude lower than benchmark concentrations. Releases from past leaks and other tank farm sources cause groundwater concentrations to rise in the Core Zone Boundary, nearing benchmark concentrations by about CY 8000. Concentrations continue to rise throughout the duration of the period of analysis, exceeding benchmark concentrations by approximately one-half of an order of magnitude at the end of the period of analysis (CY 11,940). Groundwater concentrations at the Columbia River nearshore rise throughout the period of analysis but remain below the benchmark concentration by over one order of magnitude at the end of the period of analysis (CY 11,940).

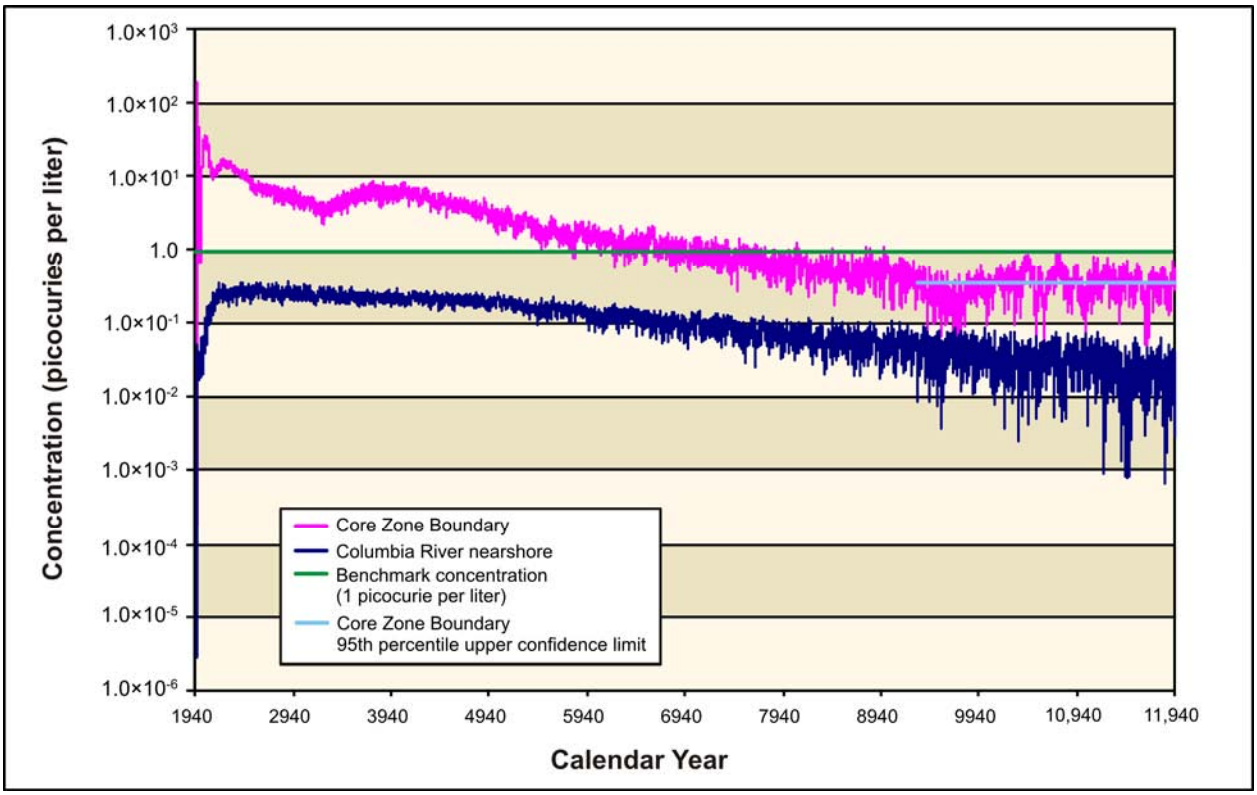


Figure 5–80. Tank Closure Alternative 2B Iodine-129 Concentration Versus Time

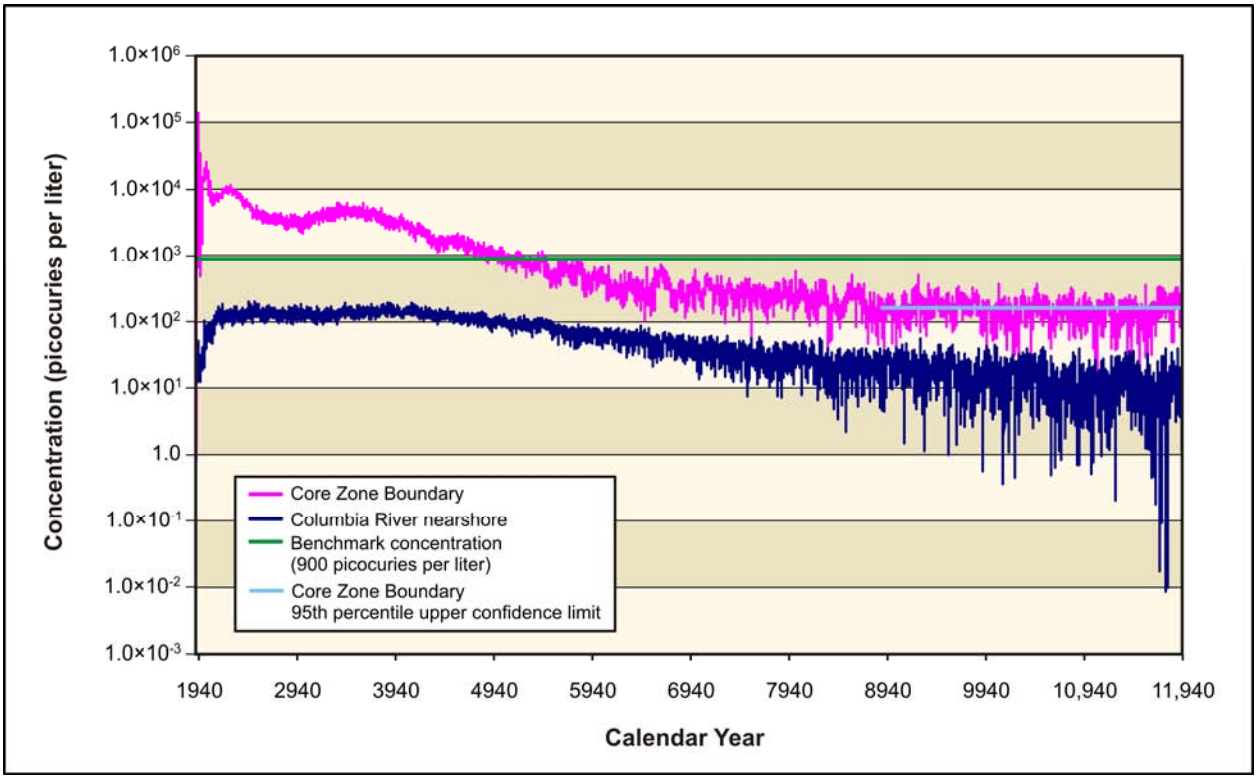


Figure 5–81. Tank Closure Alternative 2B Technetium-99 Concentration Versus Time

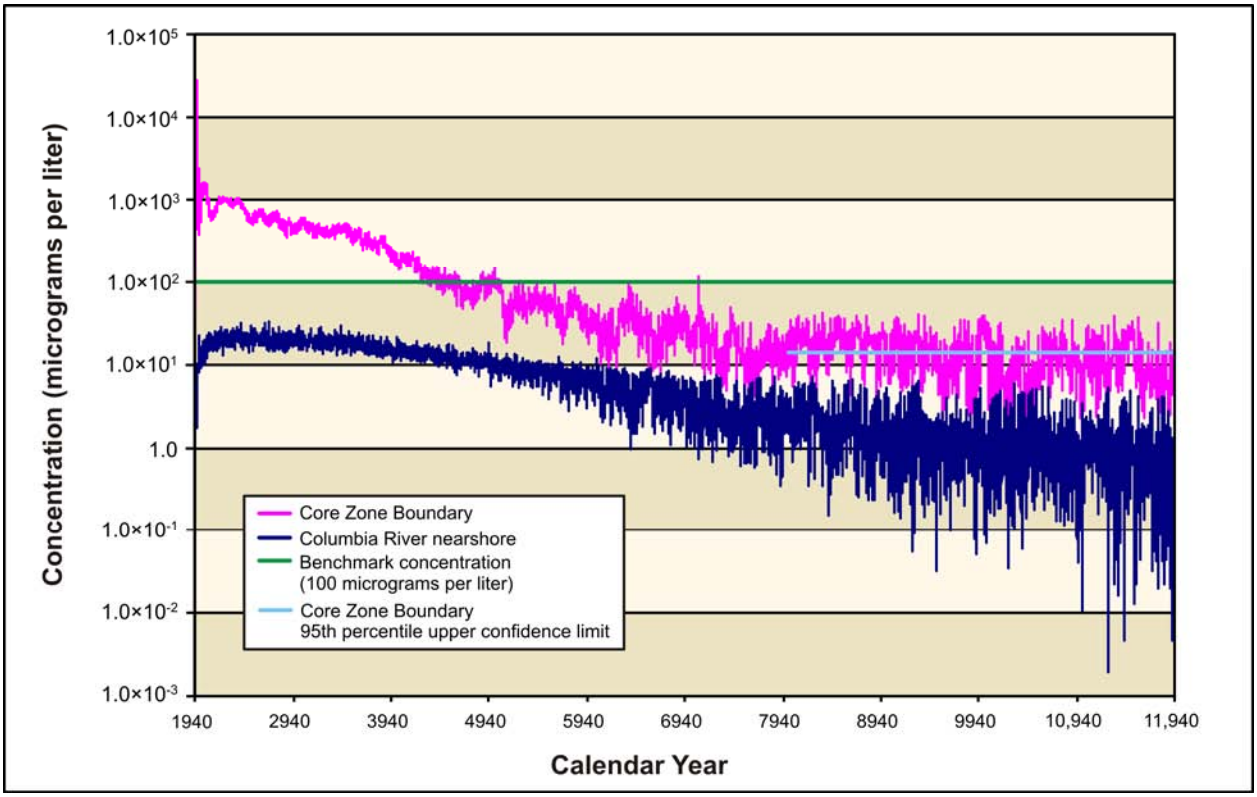


Figure 5–82. Tank Closure Alternative 2B Chromium Concentration Versus Time

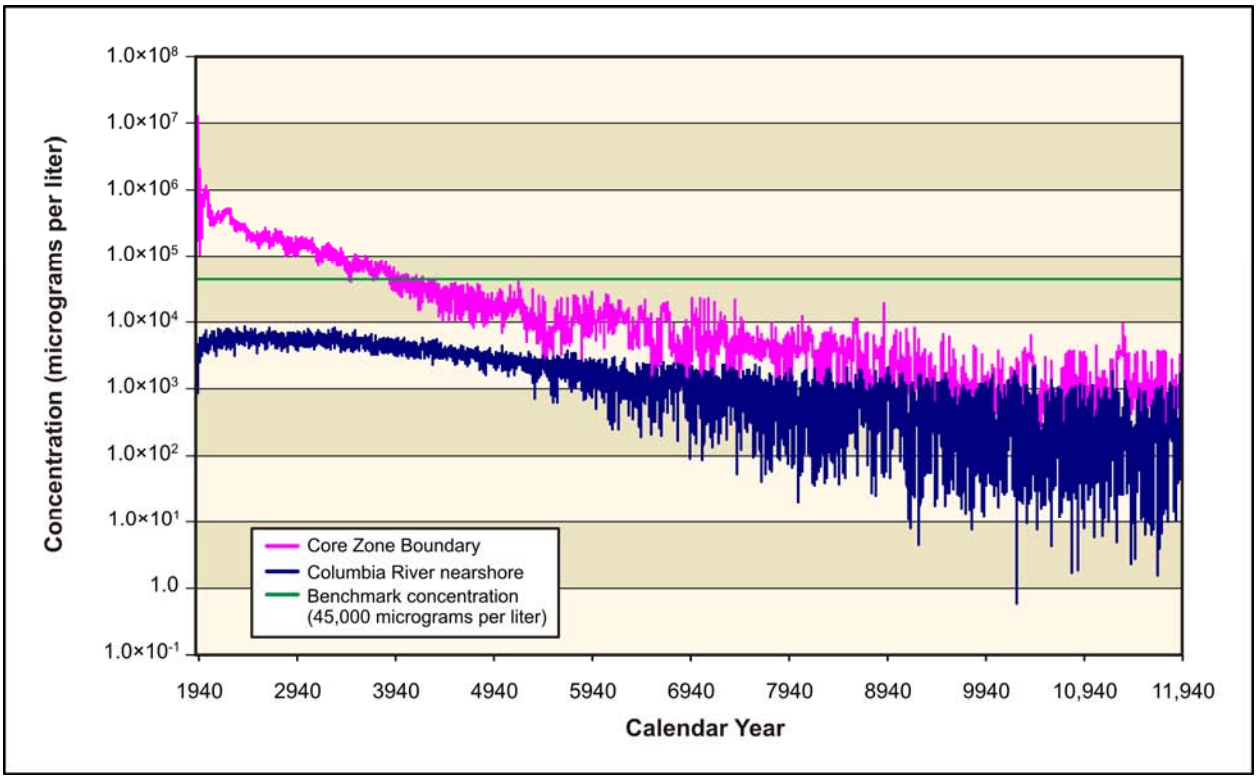


Figure 5–83. Tank Closure Alternative 2B Nitrate Concentration Versus Time

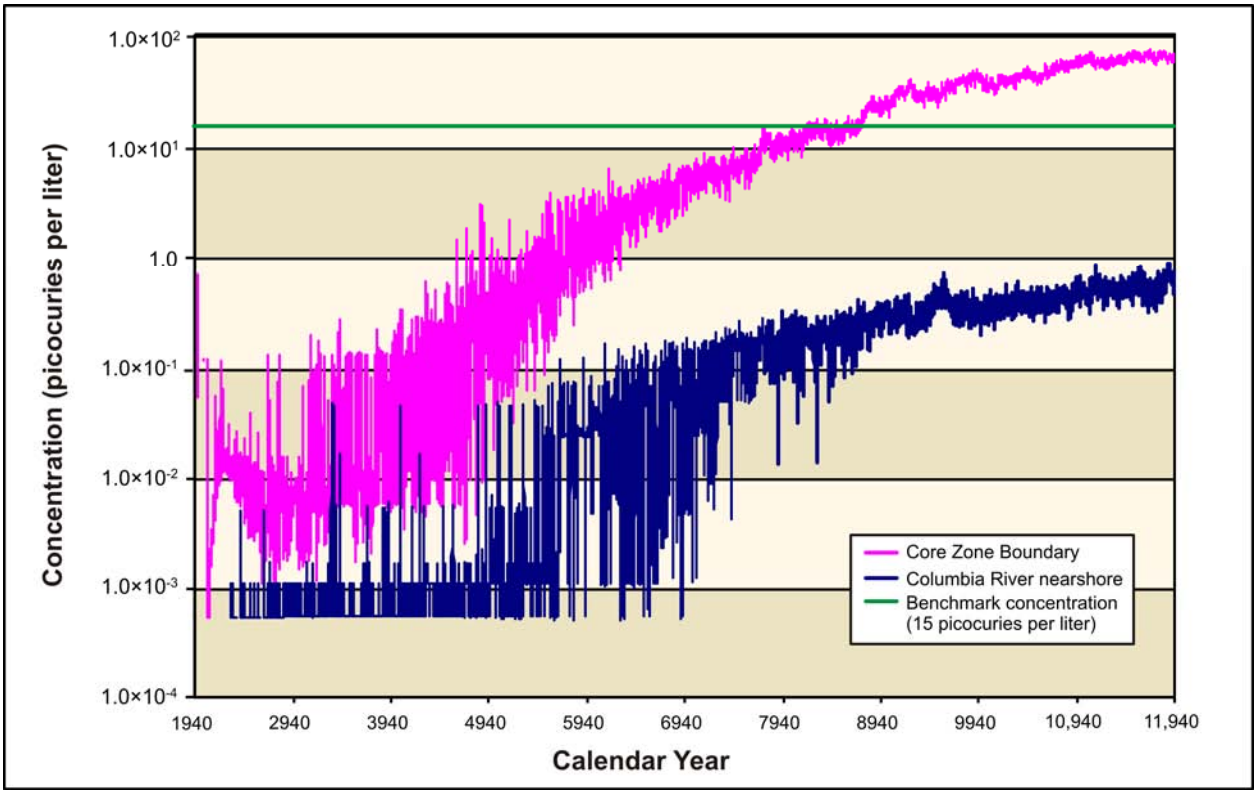


Figure 5–84. Tank Closure Alternative 2B Uranium-238 Concentration Versus Time

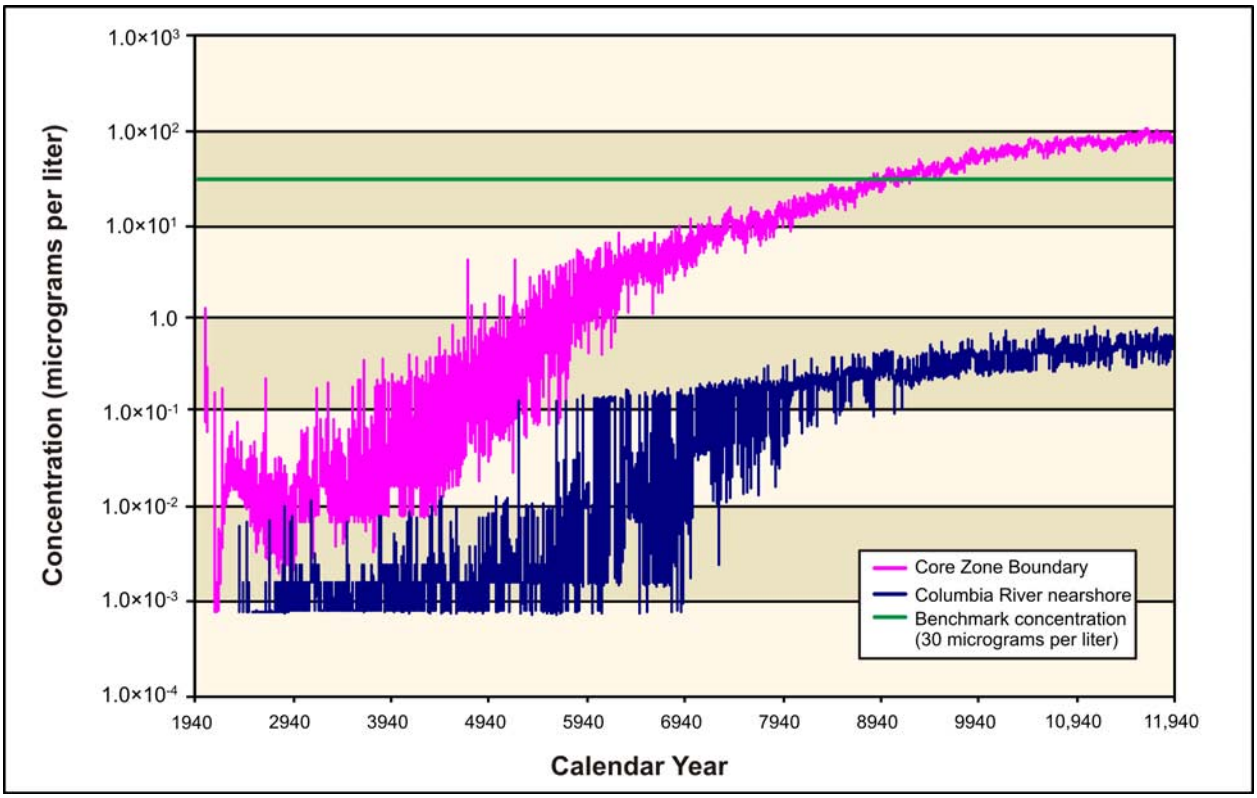
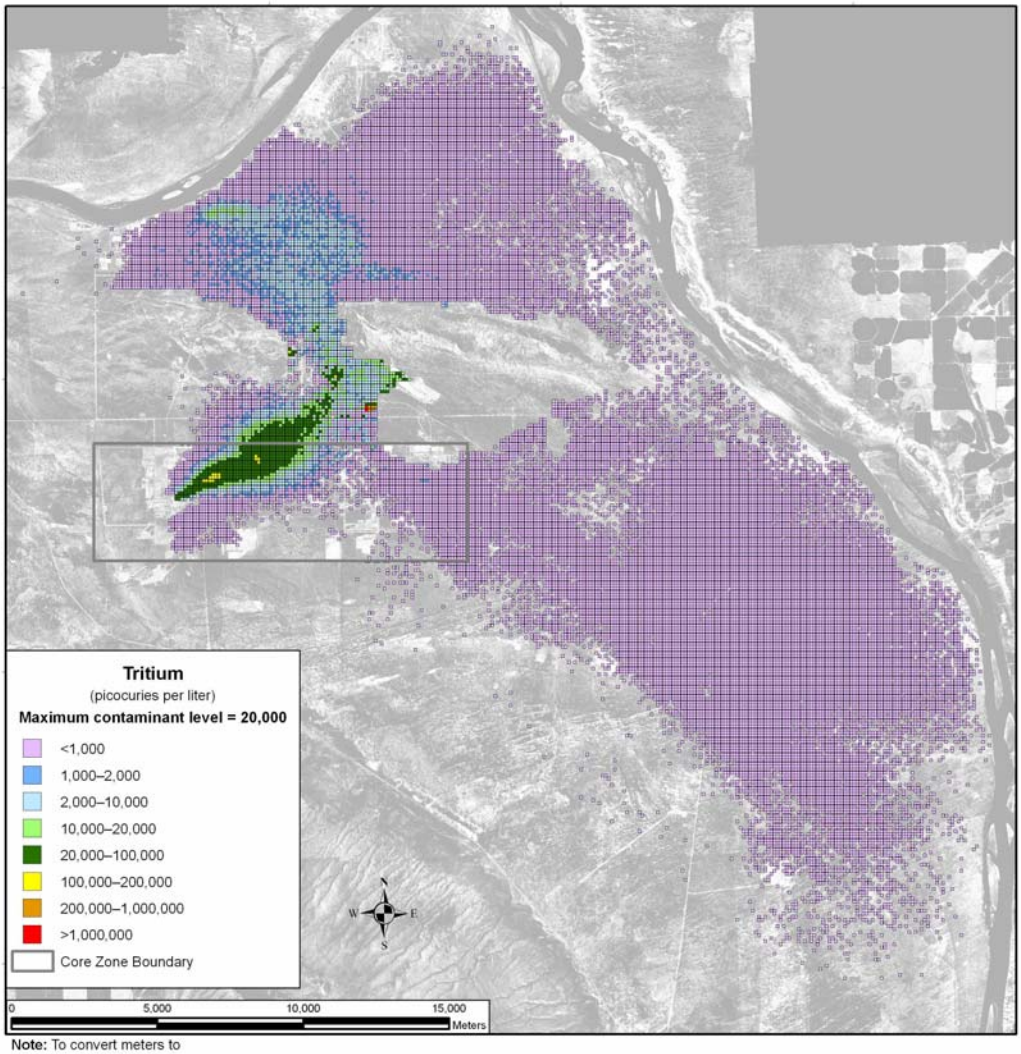


Figure 5–85. Tank Closure Alternative 2B Total Uranium Concentration Versus Time

5.1.1.3.5 Analysis of Spatial Distribution of Concentration

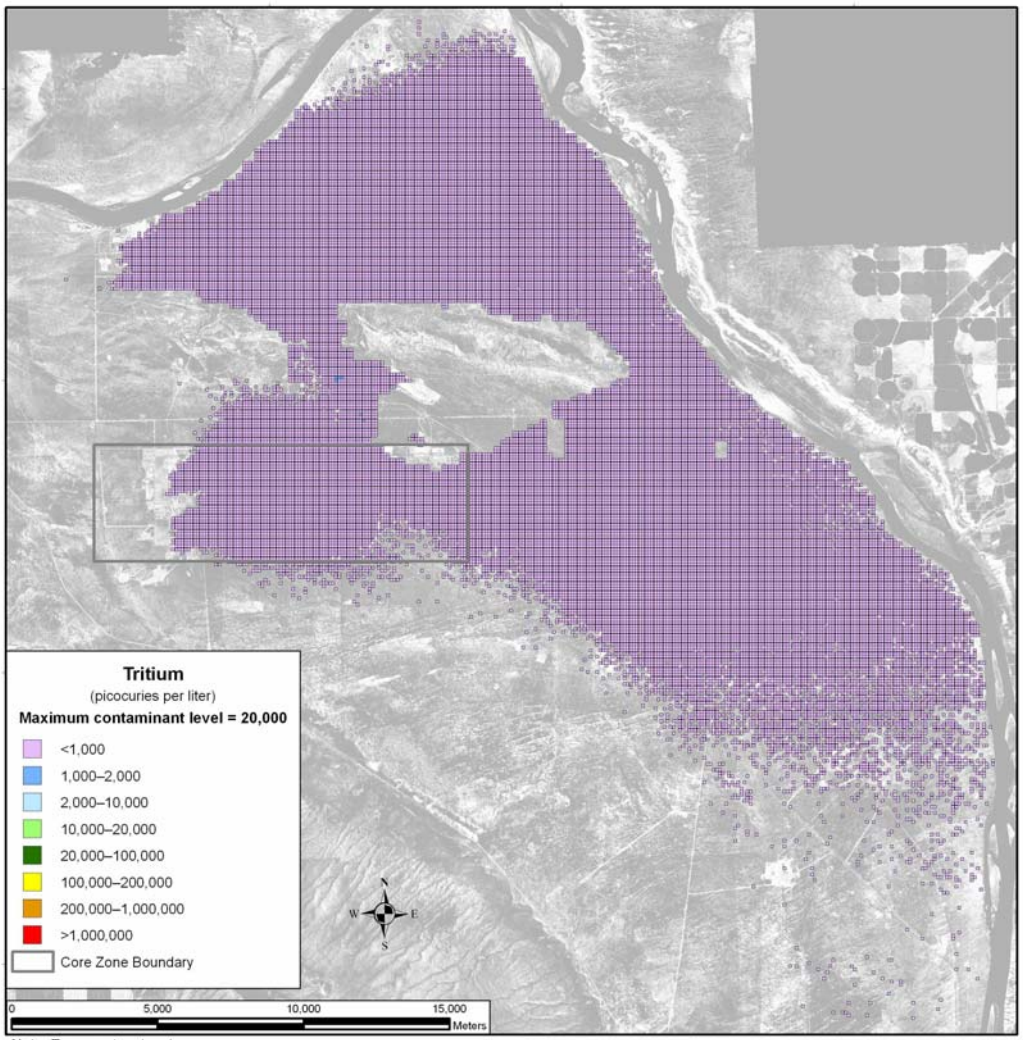
This section presents the impacts of Tank Closure Alternative 2B in terms of the spatial distribution of groundwater concentration at selected times. Concentrations of radionuclides are in picocuries per liter, chemicals in micrograms per liter. Concentrations for each radionuclide and chemical are indicated 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 5–86 shows the spatial distribution of groundwater concentration for tritium during CY 2005. Analysis 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 5 to 10 times greater than the benchmark, and mostly contained within the Core Zone Boundary. By CY 2135, the tritium plume has diminished to levels less than one-twentieth of the benchmark concentration (see Figure 5–87).



Note: To convert meters to feet, multiply by 3.281

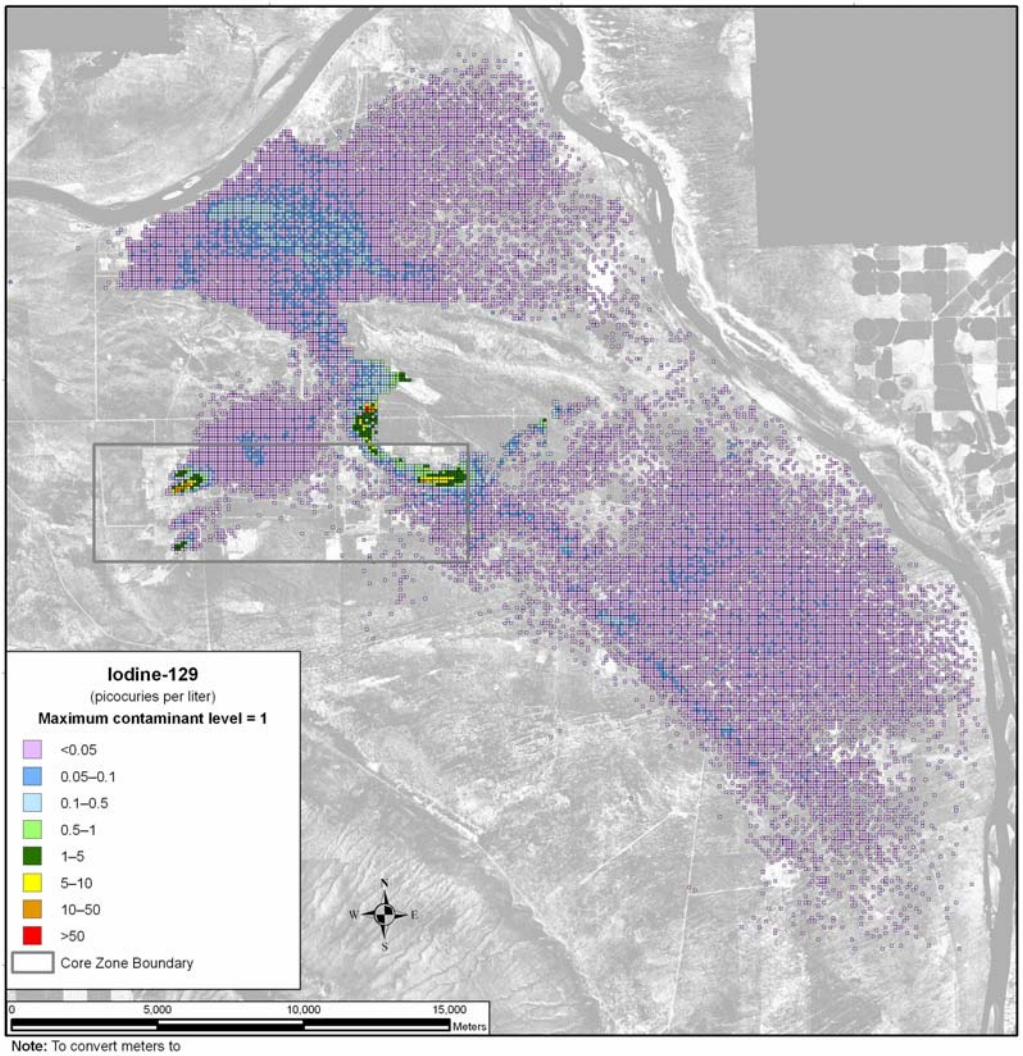
Figure 5–86. Tank Closure Alternative 2B Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

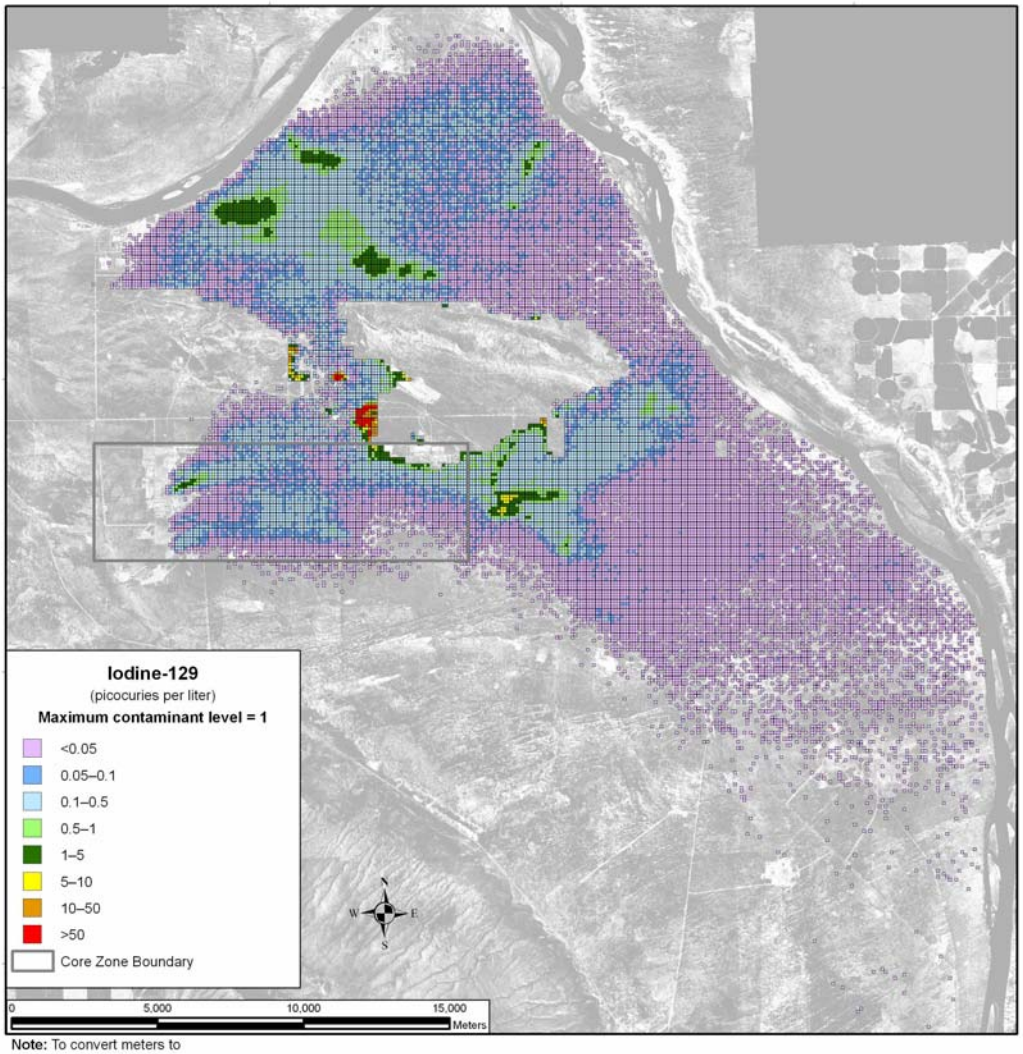
Figure 5–87. Tank Closure Alternative 2B Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2135

The conservative tracers (iodine-129, technetium-99, chromium, and nitrate) move at the rate of the pore water velocity and are discussed as a group, as they show similar spatial distributions. Figure 5–88 shows the spatial distribution of groundwater concentration of iodine-129 during CY 2005. 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 50 times greater than the benchmark, and mostly contained within the Core Zone Boundary. During CY 2135, releases from other tank farm sources create another, less-intense plume (up to 5 to 10 times greater than the benchmark) that extends from the A Barrier toward the Columbia River (see Figure 5–89). By CY 7140, most of the mass in the plumes has reached the Columbia River, with only isolated pockets of high concentrations in Gable Gap (see Figure 5–90). Technetium-99, chromium, and nitrate show a similar spatial distribution at selected times (see Figures 5–91 through 5–99).



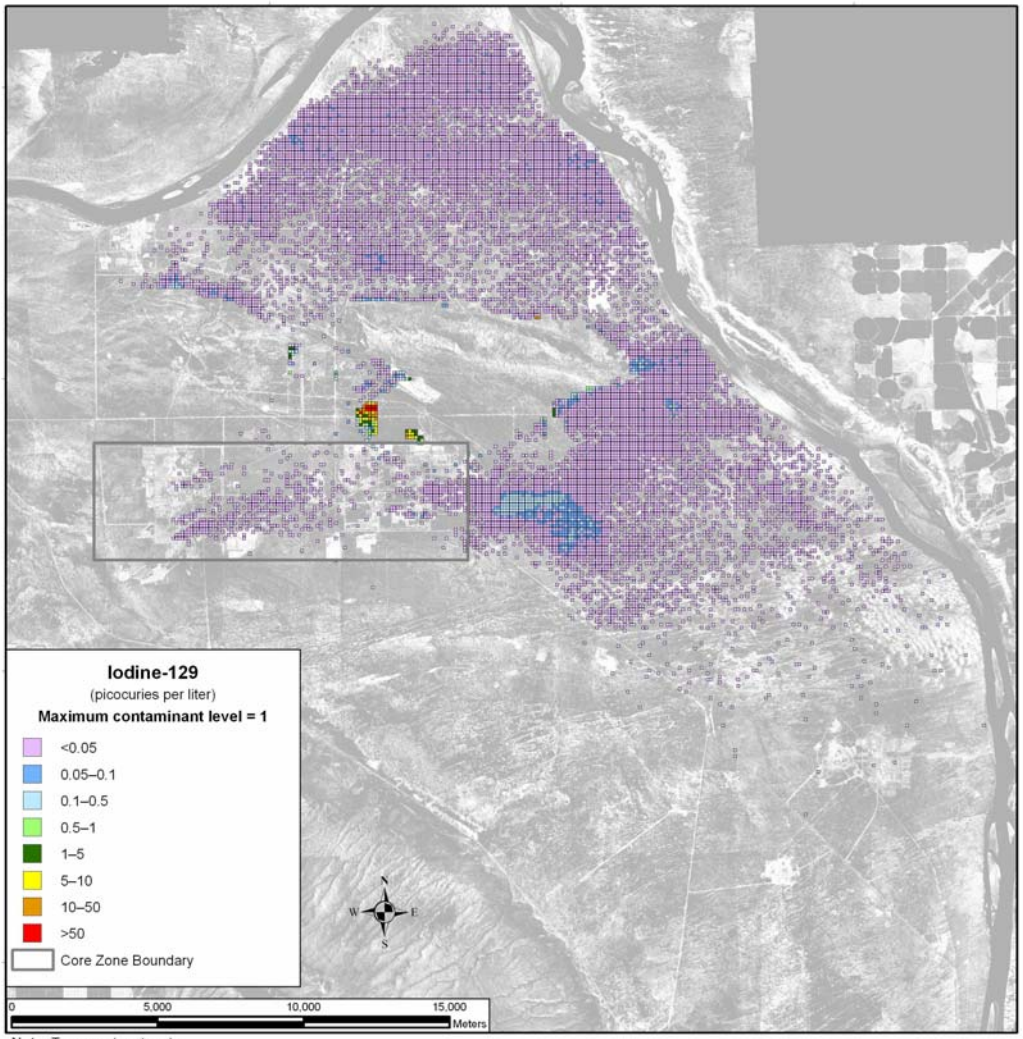
Note: To convert meters to feet, multiply by 3.281

Figure 5–88. Tank Closure Alternative 2B Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2005



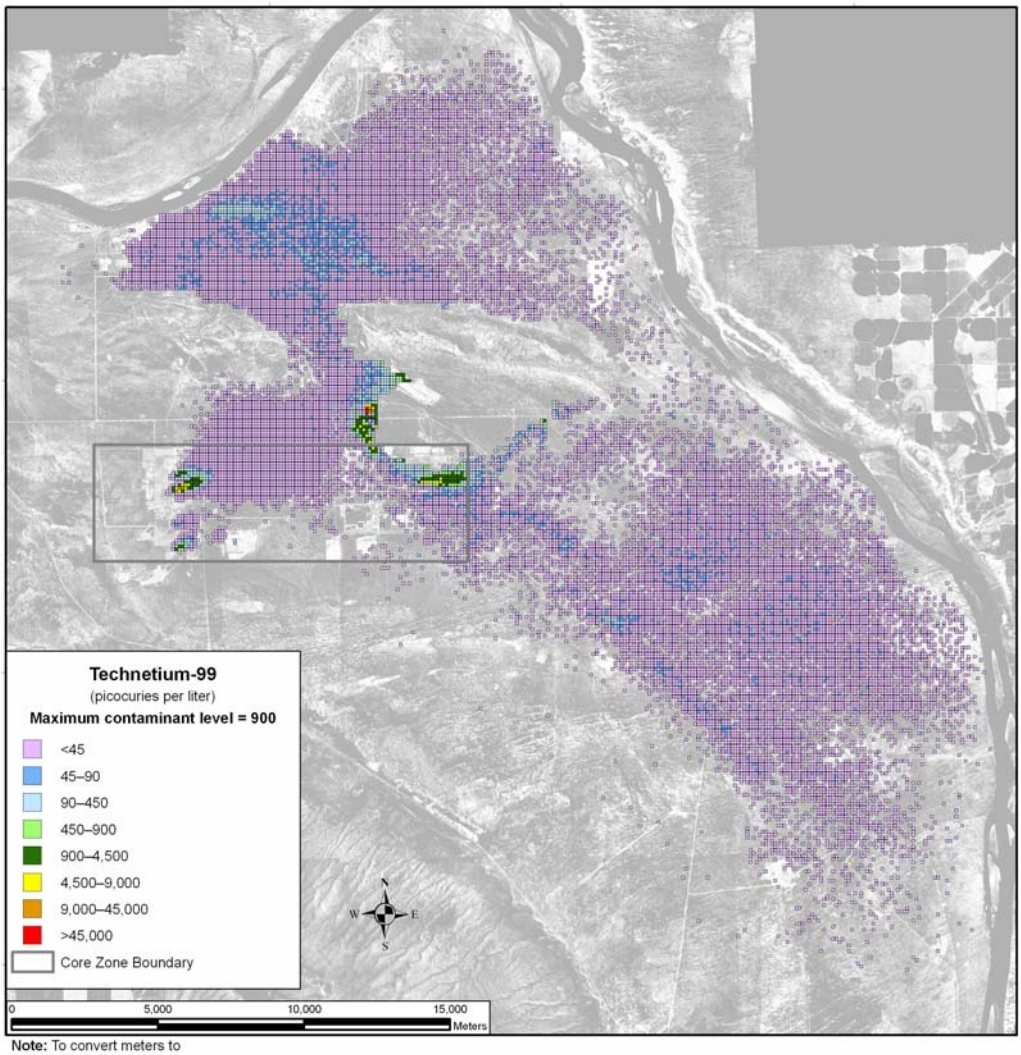
Note: To convert meters to feet, multiply by 3.281

Figure 5–89. Tank Closure Alternative 2B Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2135



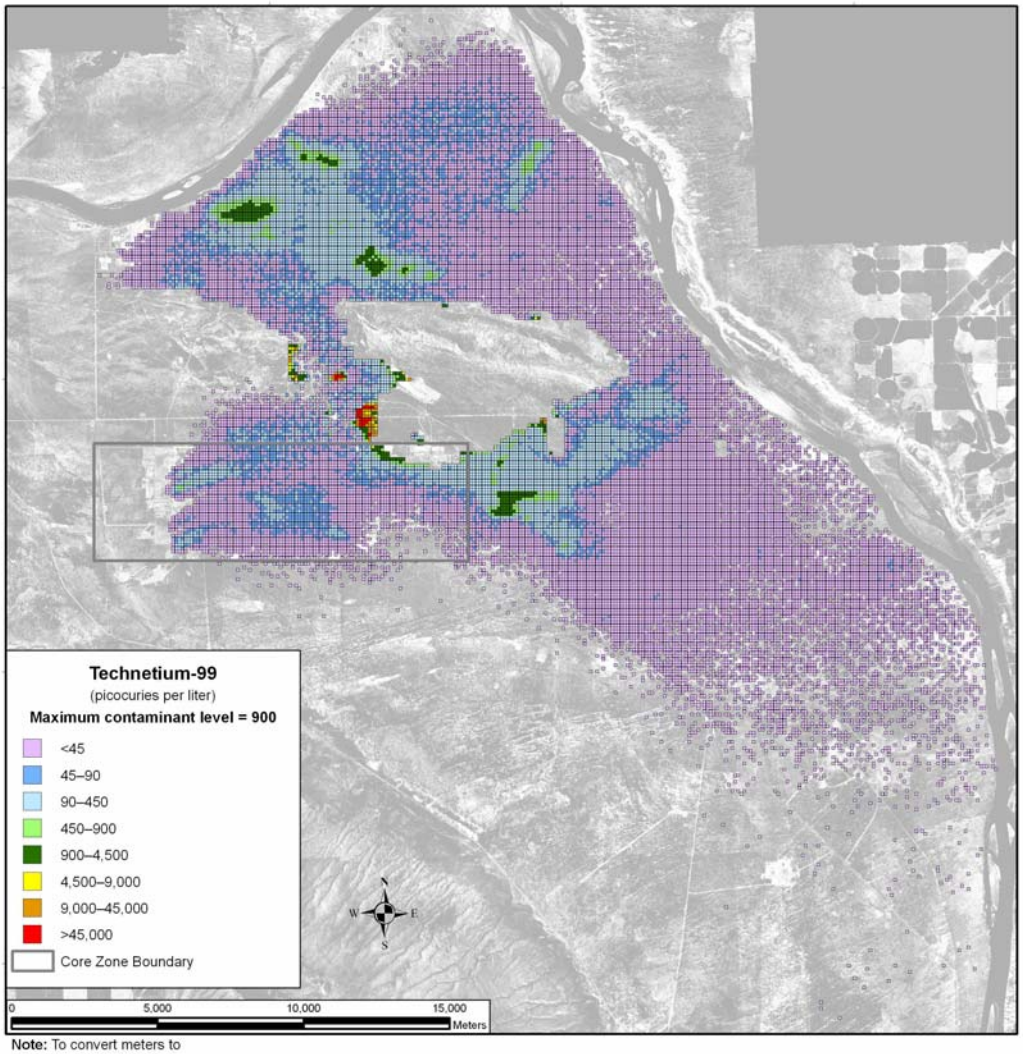
Note: To convert meters to feet, multiply by 3.281

Figure 5–90. Tank Closure Alternative 2B Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140



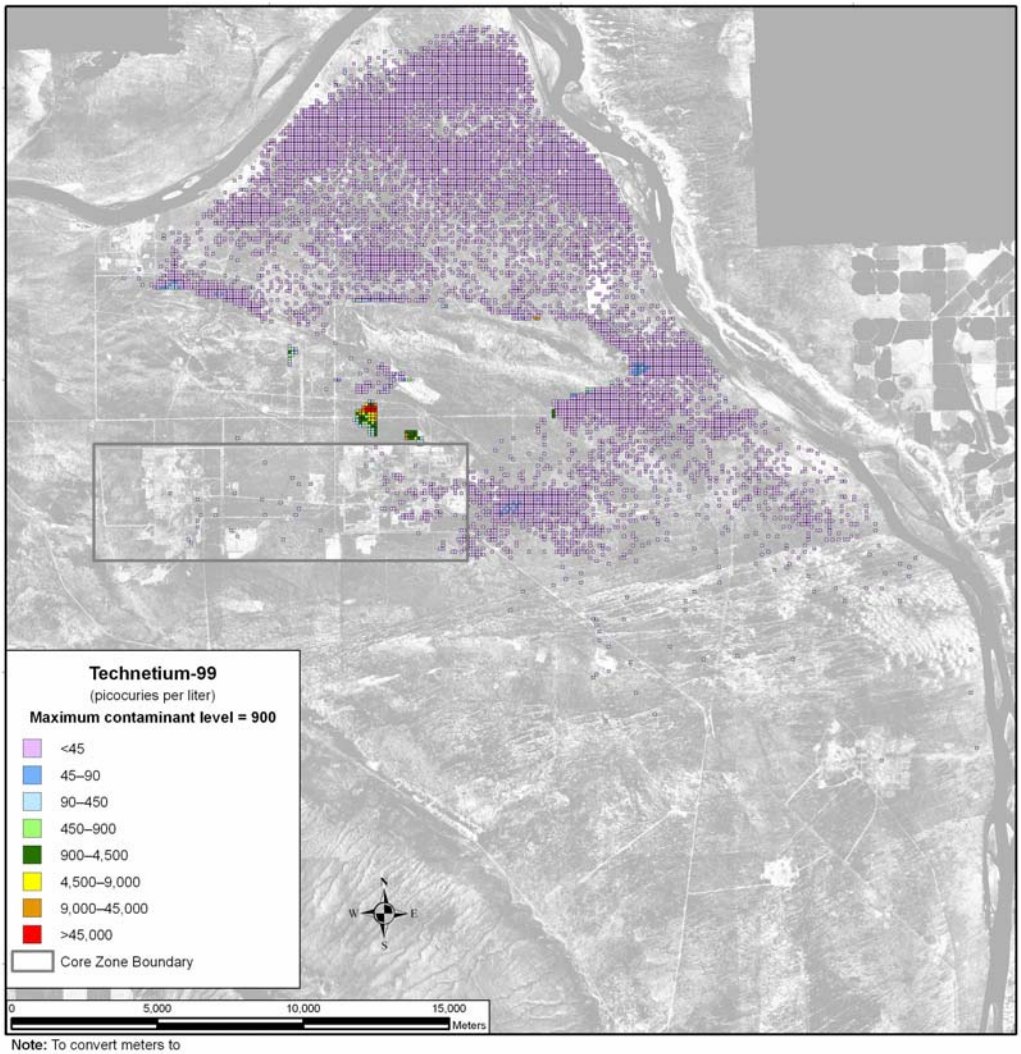
Note: To convert meters to feet, multiply by 3.281

Figure 5–91. Tank Closure Alternative 2B Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2005



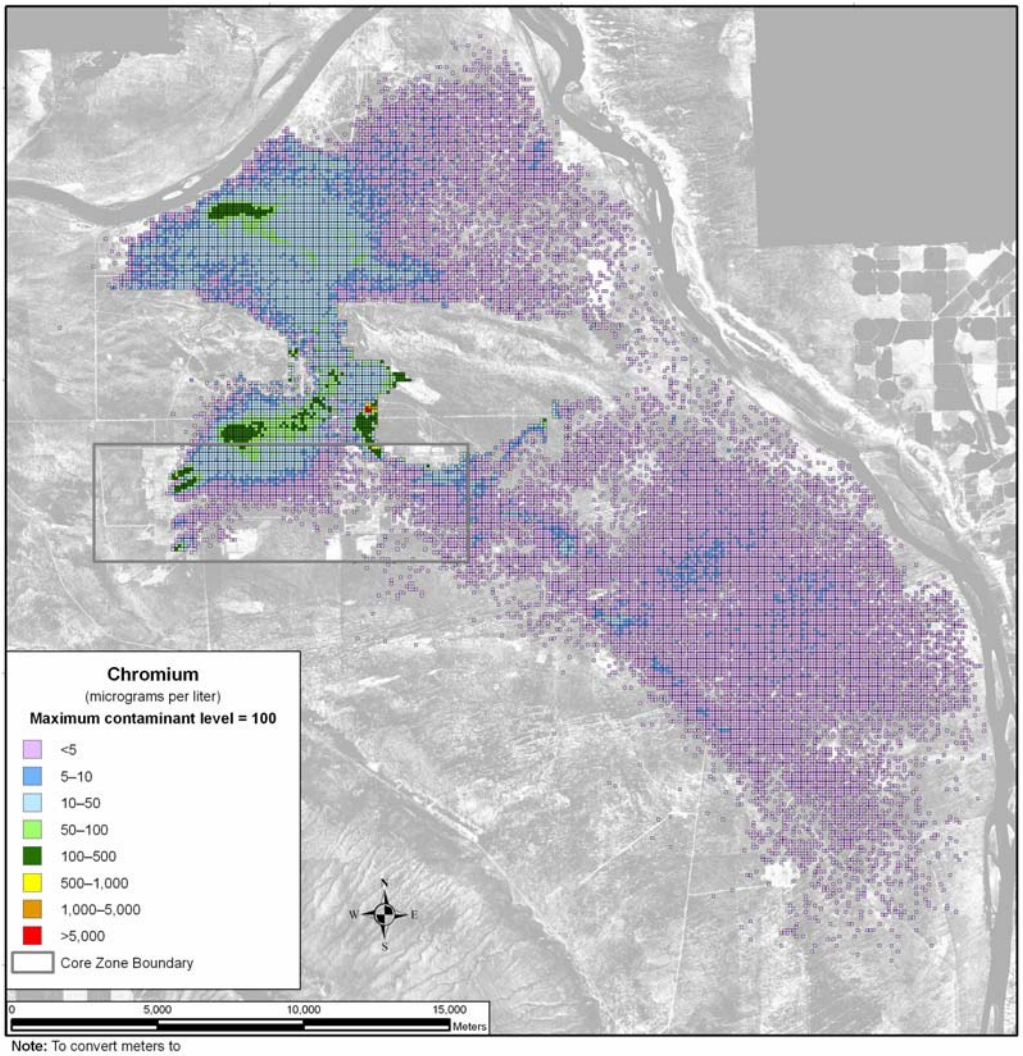
Note: To convert meters to feet, multiply by 3.281

Figure 5–92. Tank Closure Alternative 2B Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2135



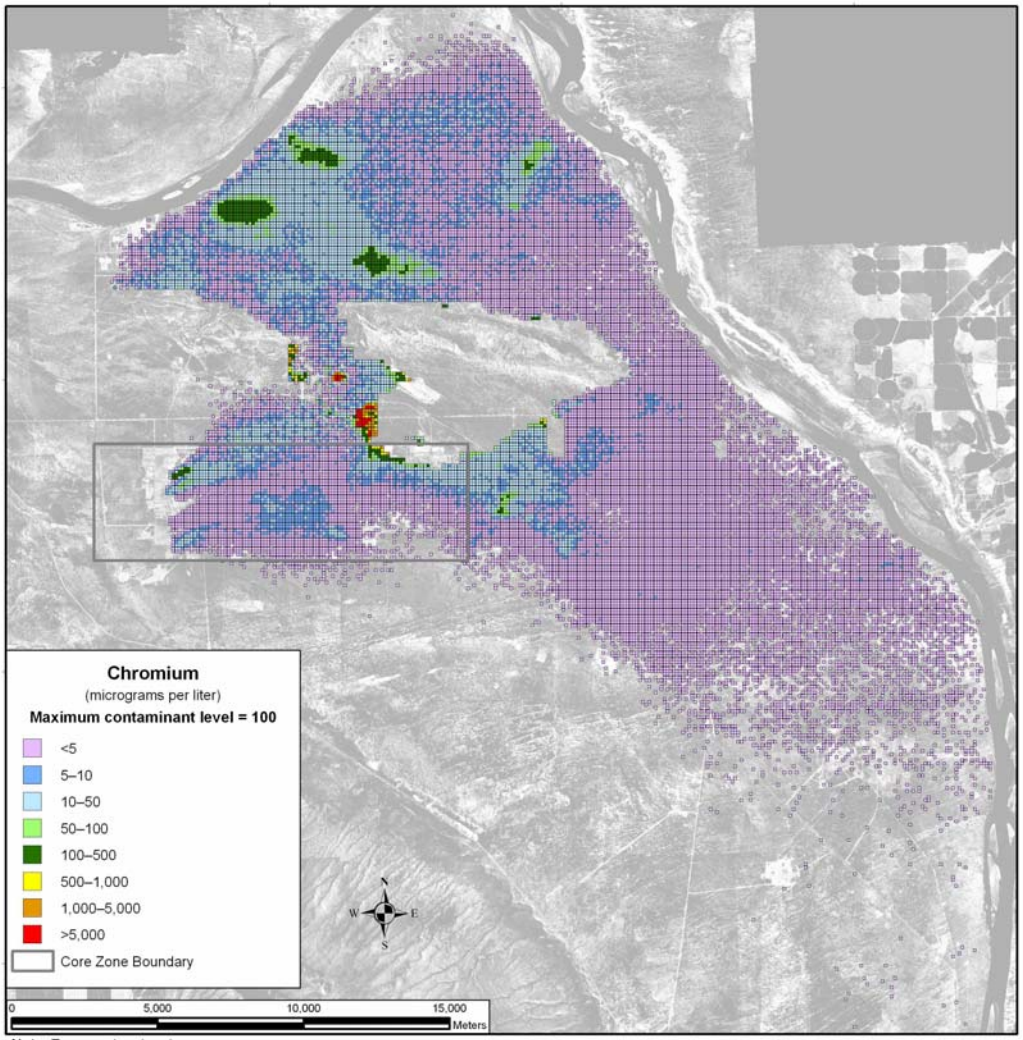
Note: To convert meters to feet, multiply by 3.281

Figure 5–93. Tank Closure Alternative 2B Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140



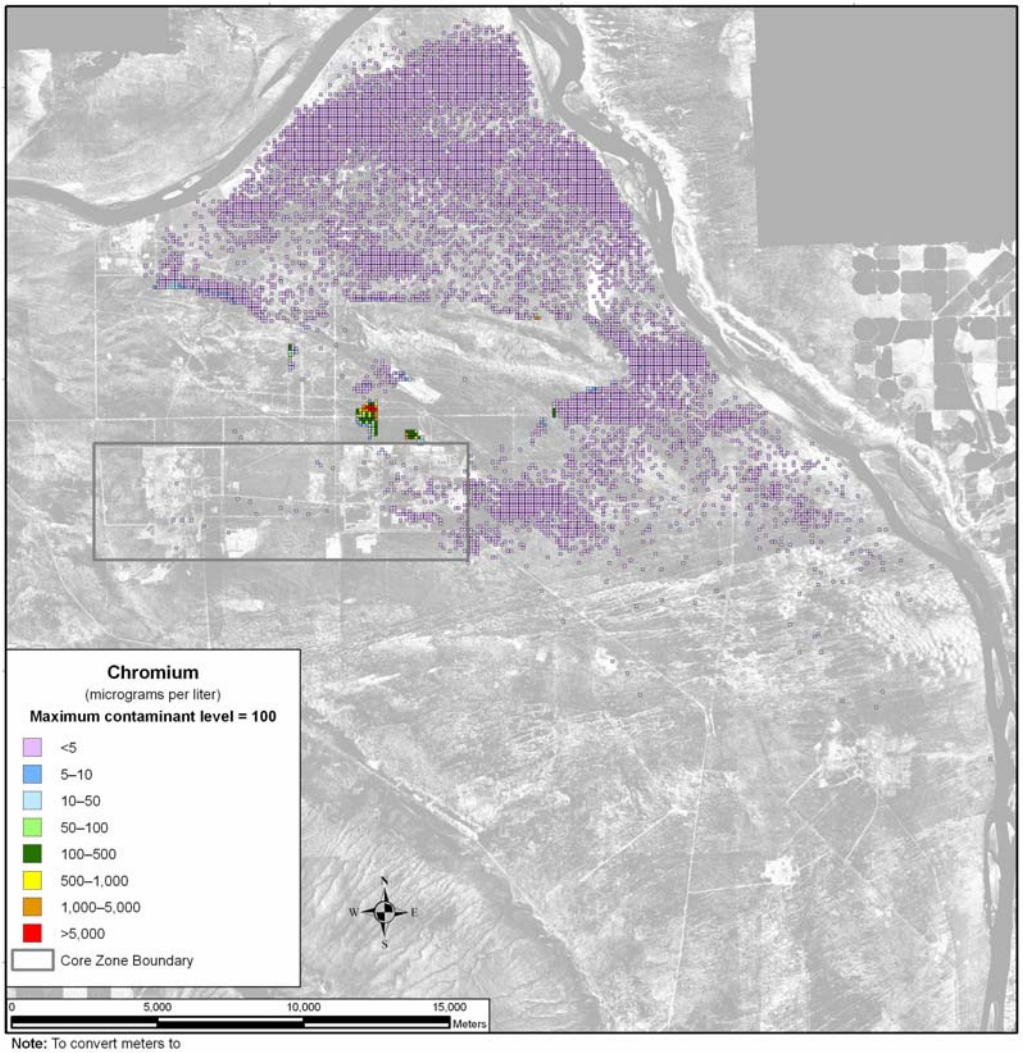
Note: To convert meters to feet, multiply by 3.281

Figure 5–94. Tank Closure Alternative 2B Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 2005



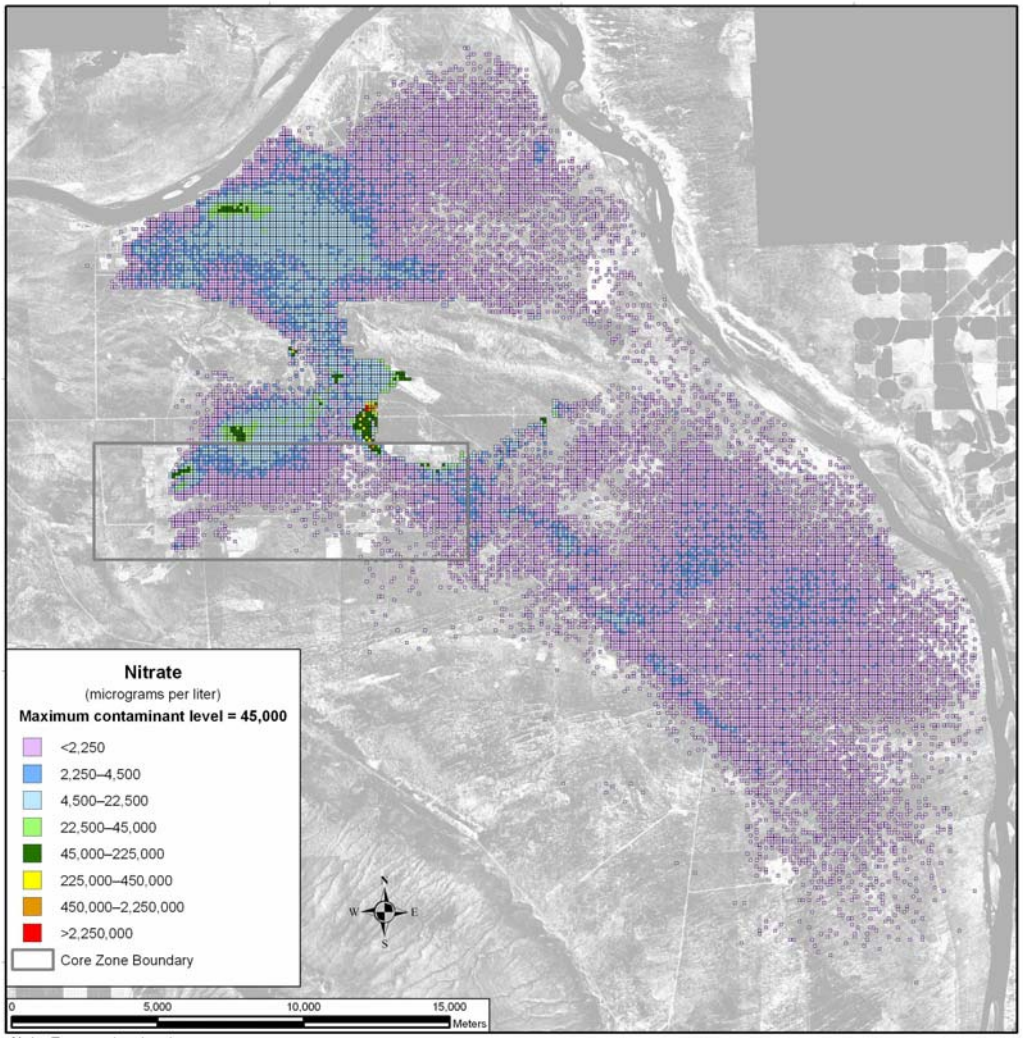
Note: To convert meters to feet, multiply by 3.281

Figure 5–95. Tank Closure Alternative 2B Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 2135



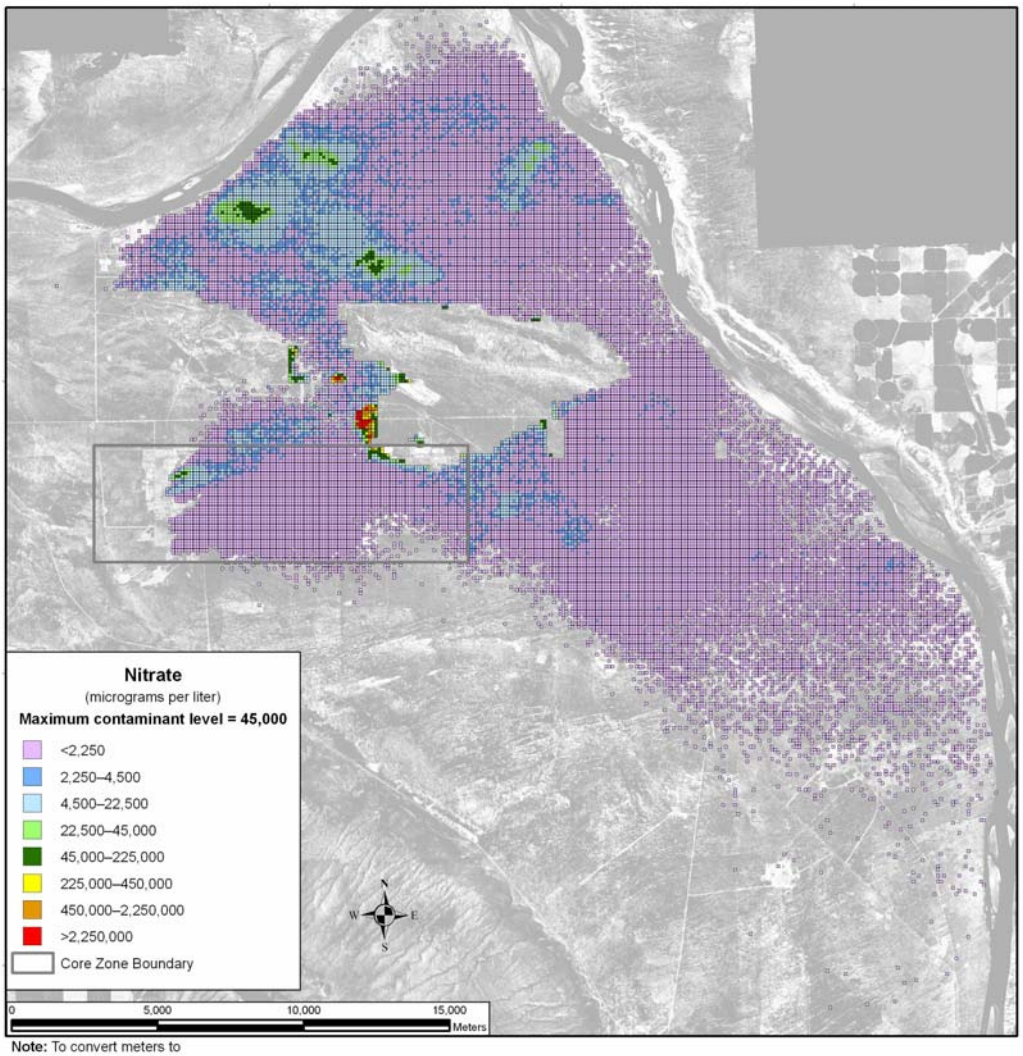
Note: To convert meters to feet, multiply by 3.281

Figure 5–96. Tank Closure Alternative 2B Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 7140



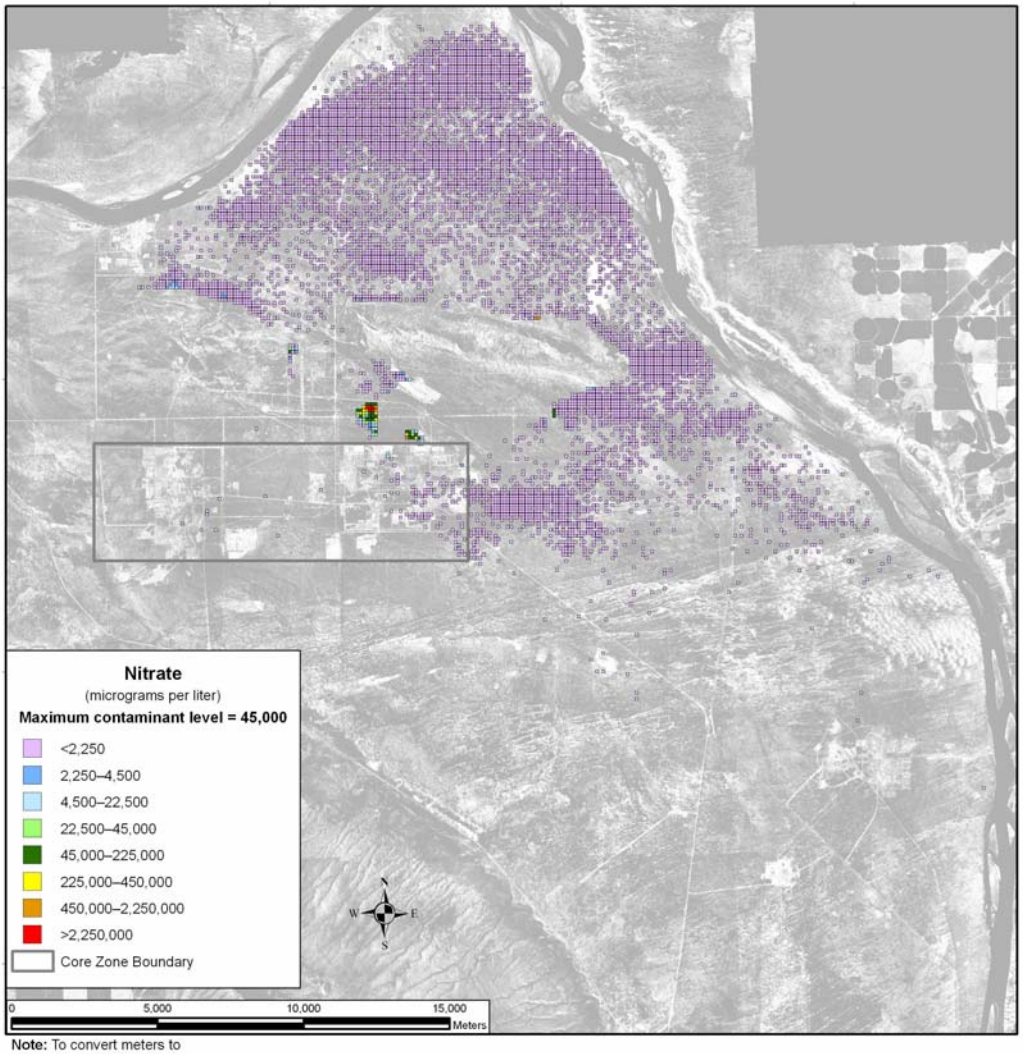
Note: To convert meters to feet, multiply by 3.281

Figure 5–97. Tank Closure Alternative 2B Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

Figure 5–98. Tank Closure Alternative 2B Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281

Figure 5–99. Tank Closure Alternative 2B Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 7140

Figure 5–100 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. A peak area of about 4 square kilometers (1.5 square miles) occurs around CY 2135, followed by a fairly sharp decrease. Another peak area of about 2 square kilometers (0.77 square miles) occurs around CY 3890, followed by another decrease. By about CY 6000, the area with a concentration above the benchmark concentration begins to level out to around 0.5 square kilometers (0.2 square miles). Iodine-129 shows a pattern similar to that of technetium-99, as both constituents are conservative tracers (see Figure 5–101).

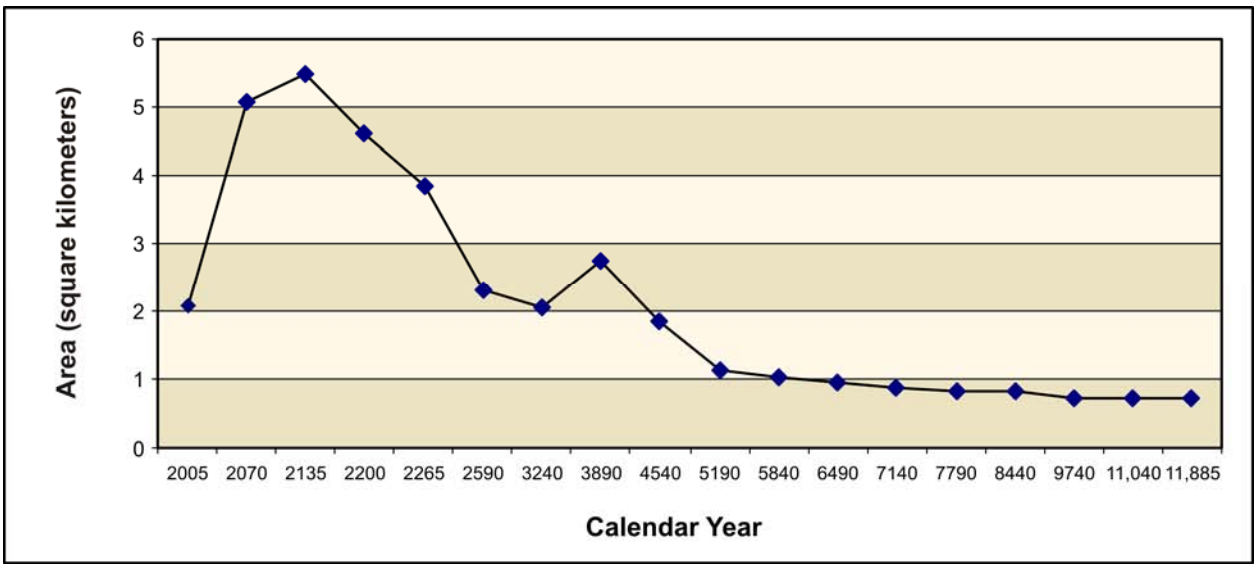


Figure 5–100. Tank Closure Alternative 2B Total Area of Groundwater Technetium-99 Concentration Exceeding the Benchmark Concentration as a Function of Time

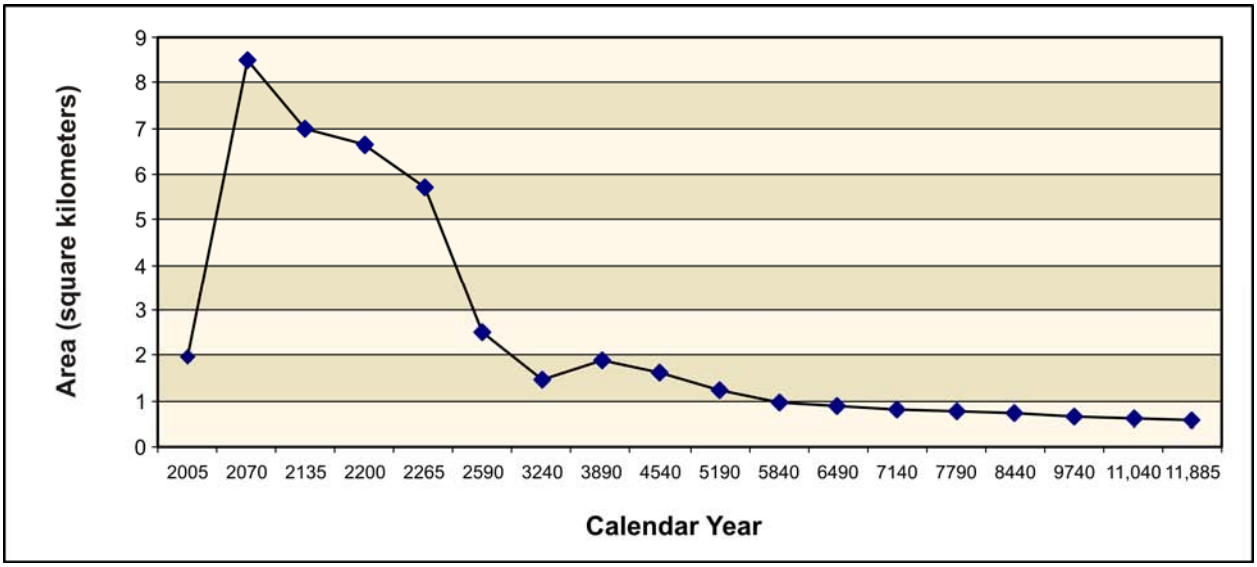
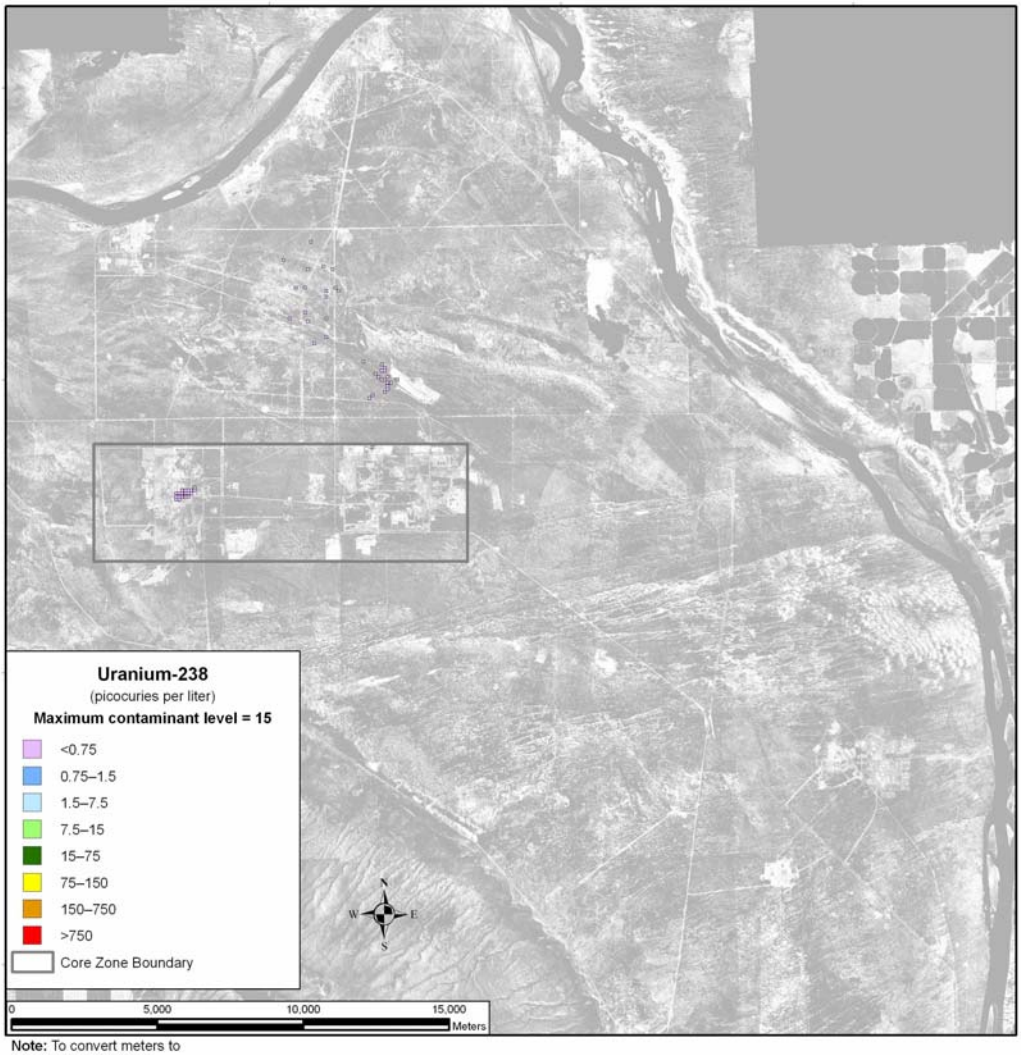


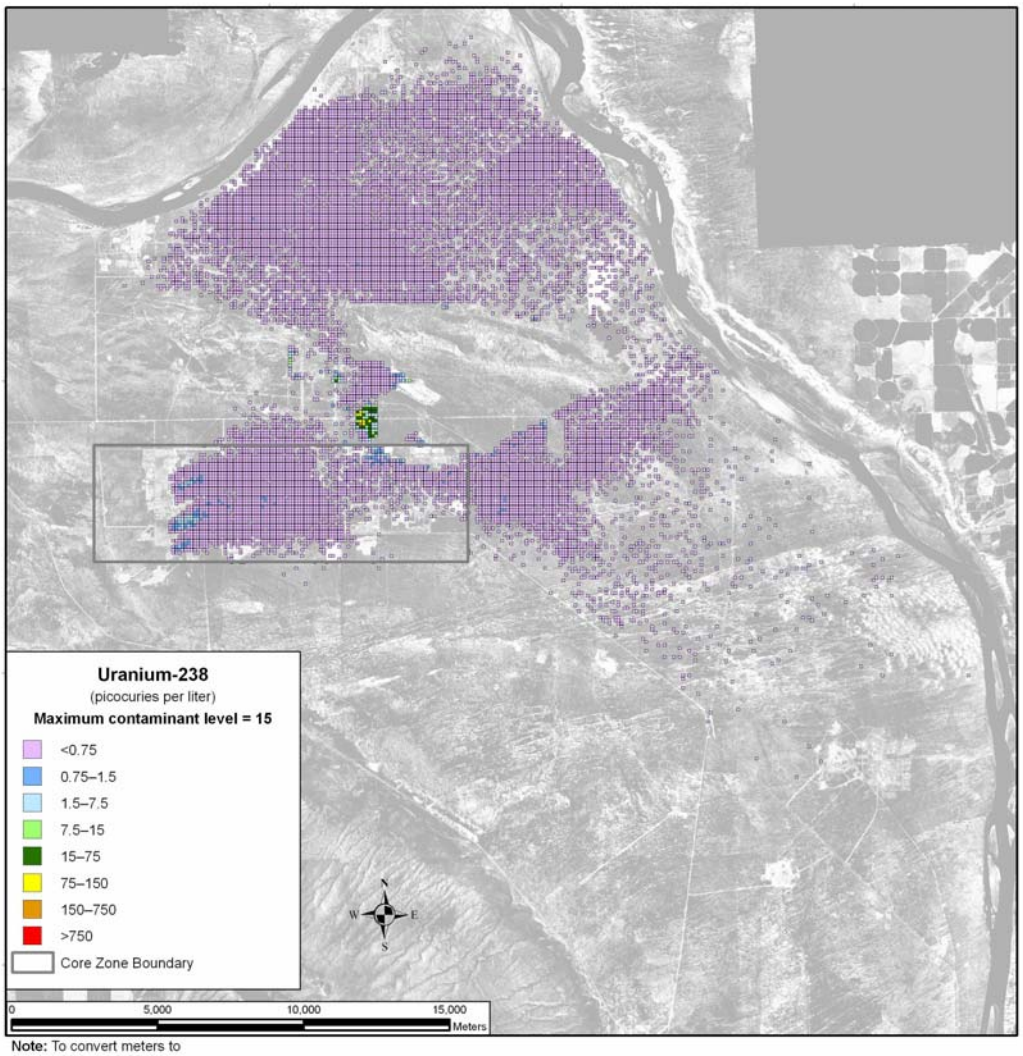
Figure 5–101. Tank Closure Alternative 2B Total Area of Groundwater Iodine-129 Concentration Exceeding the Benchmark Concentration as a Function of Time

Uranium-238 and total uranium show a different spatial distribution in the analysis over time. These COPCs are 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 5–102 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 5–103). There is only a small area in Gable Gap that is 5 to 10 times greater in uranium-238 concentration than the benchmark concentration. By CY 11,885, the greatest development of the plume during the analysis period is seen, resulting primarily from past leaks and the release of other tank farm sources at the A Barrier and B Barrier (see Figure 5–104). Figures 5–105 through 5–107 show the corresponding results for total uranium.



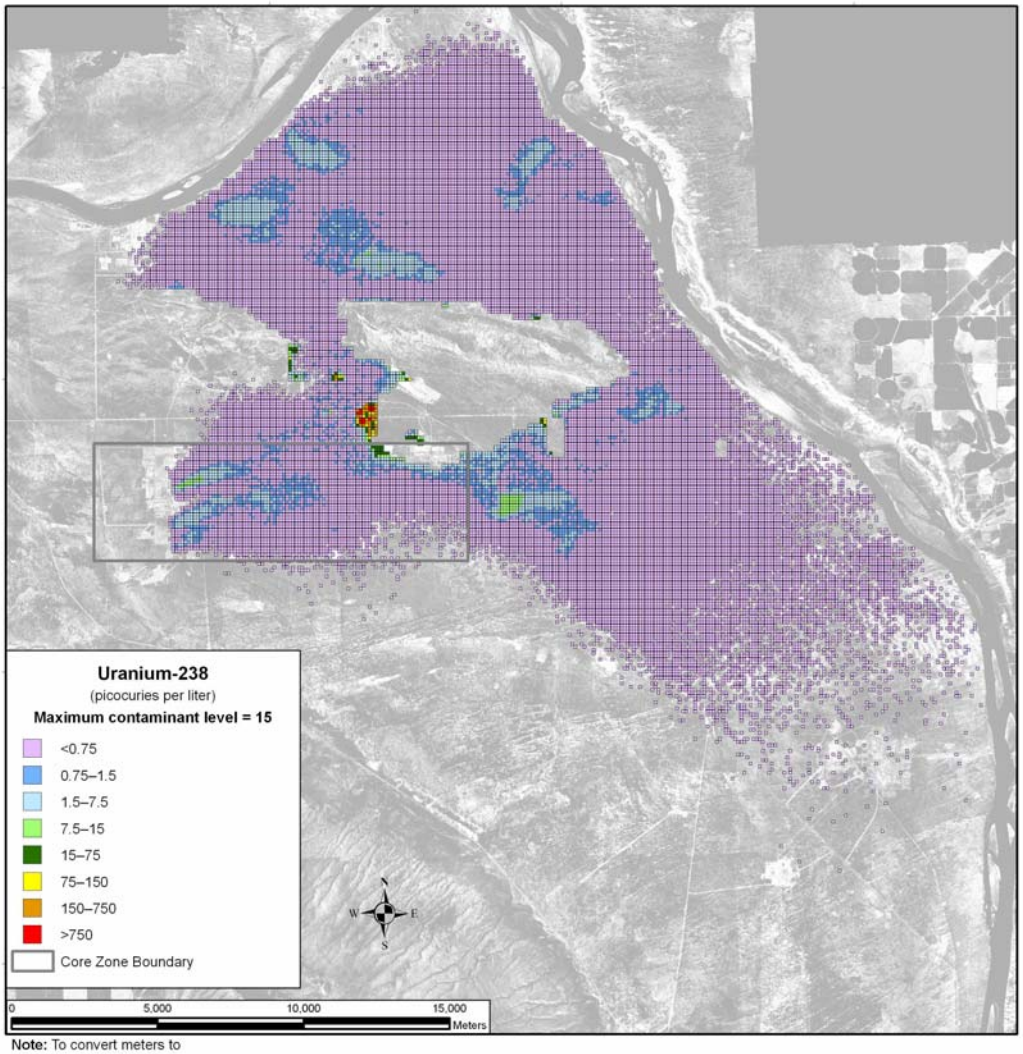
Note: To convert meters to feet, multiply by 3.281

Figure 5–102. Tank Closure Alternative 2B Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 2005



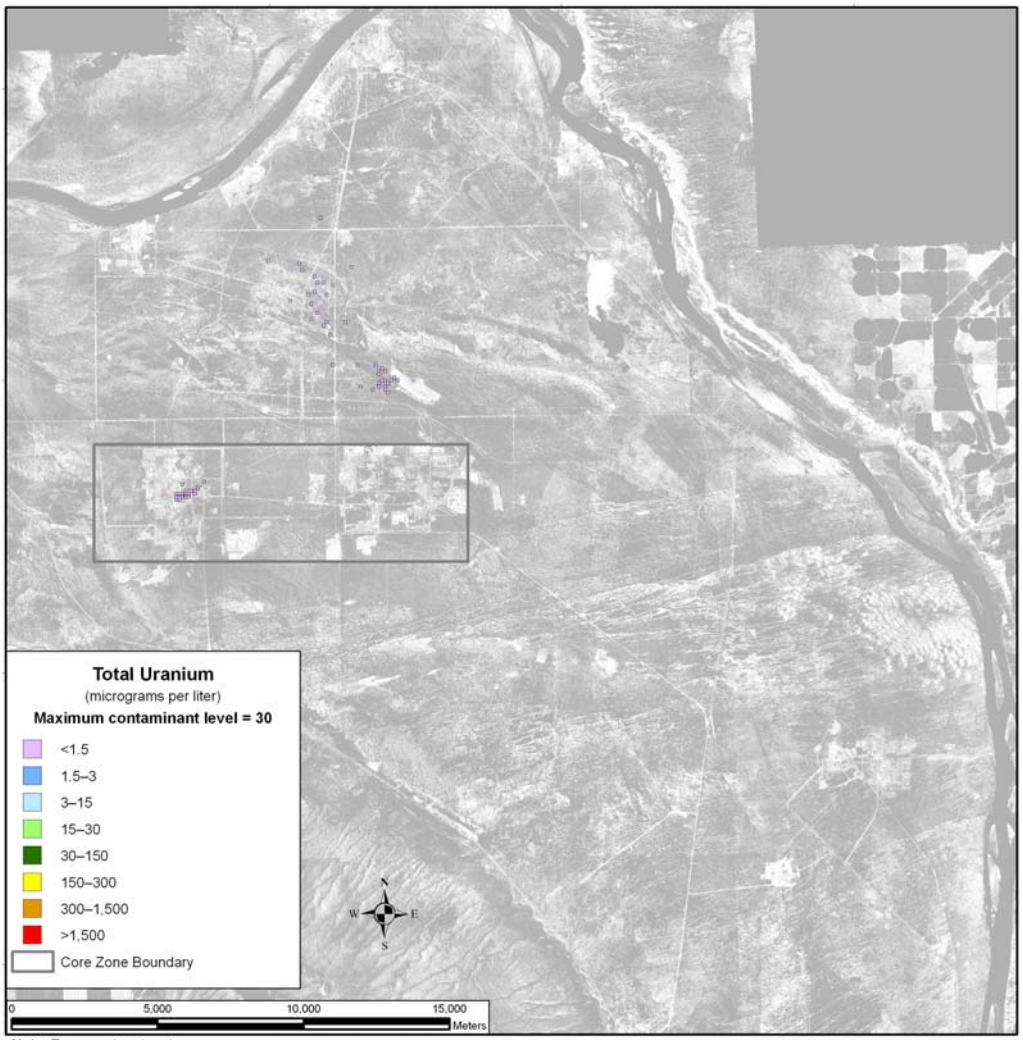
Note: To convert meters to feet, multiply by 3.281

Figure 5–103. Tank Closure Alternative 2B Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 7140



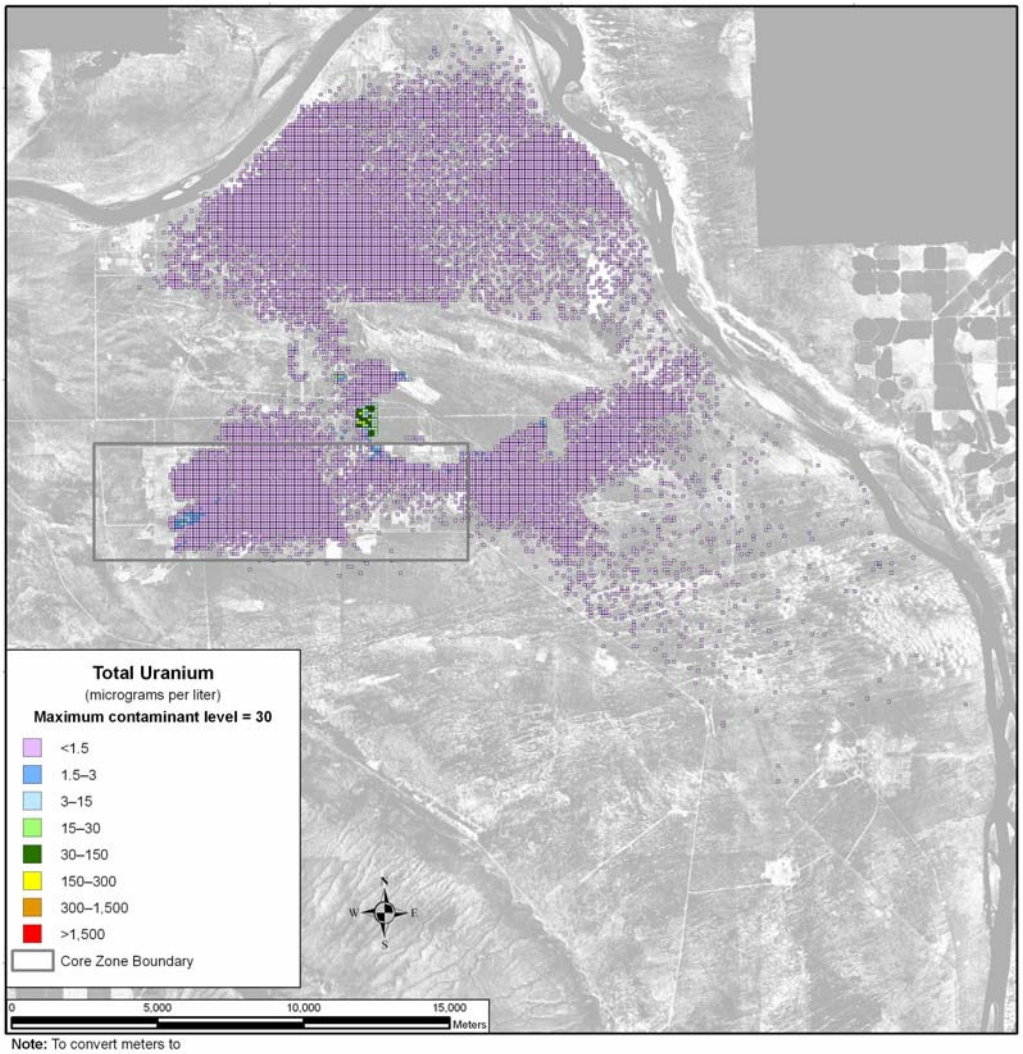
Note: To convert meters to feet, multiply by 3.281

Figure 5–104. Tank Closure Alternative 2B Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 11,885



Note: To convert meters to feet, multiply by 3.281

Figure 5–105. Tank Closure Alternative 2B Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

Figure 5–106. Tank Closure Alternative 2B Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 7140

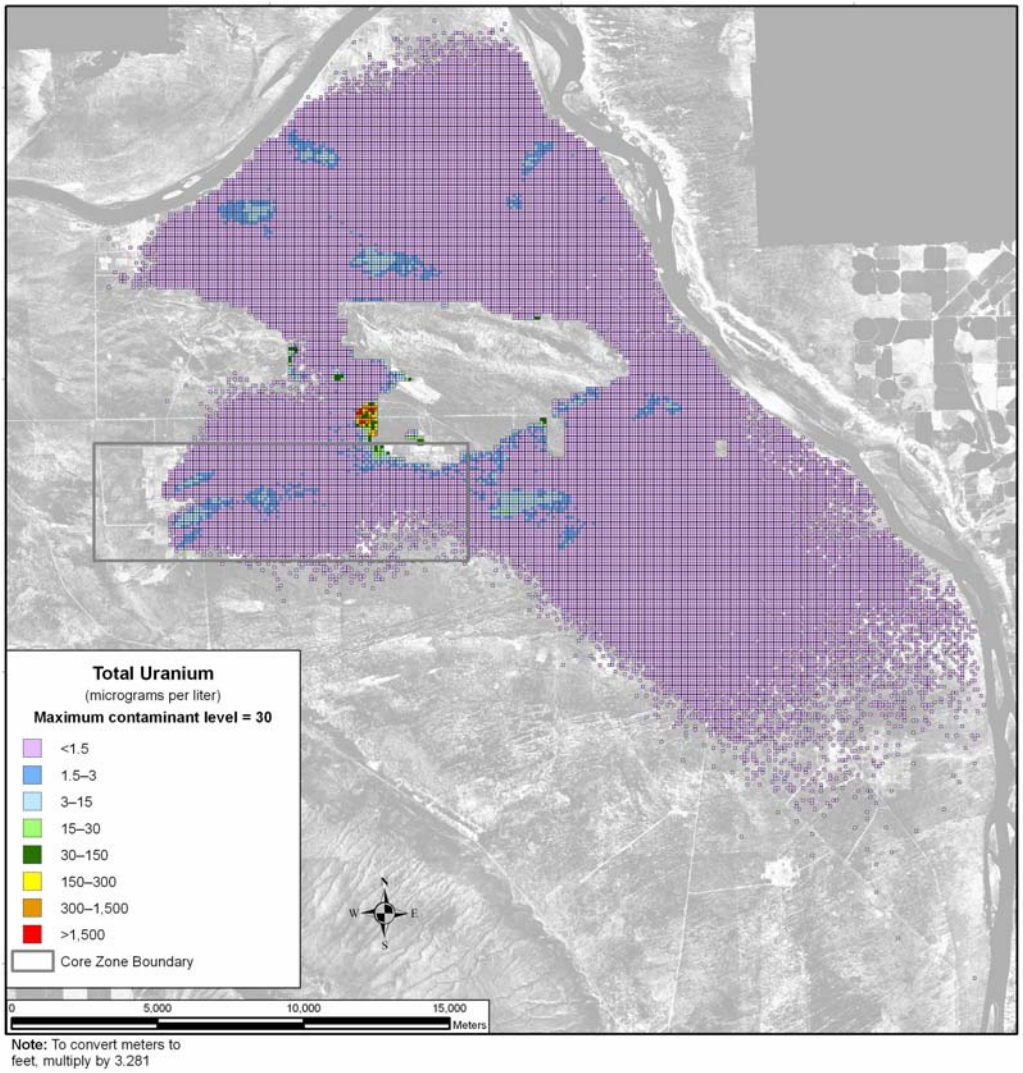


Figure 5–107. Tank Closure Alternative 2B Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 11,885

Uranium-238 does not exceed the benchmark concentration in any area until after CY 5190 (see Figure 5–108). A sharp increase in area with concentrations above the maximum contaminant level is seen after this time and continues to rise to over 1.25 square kilometers (0.48 square miles) 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.

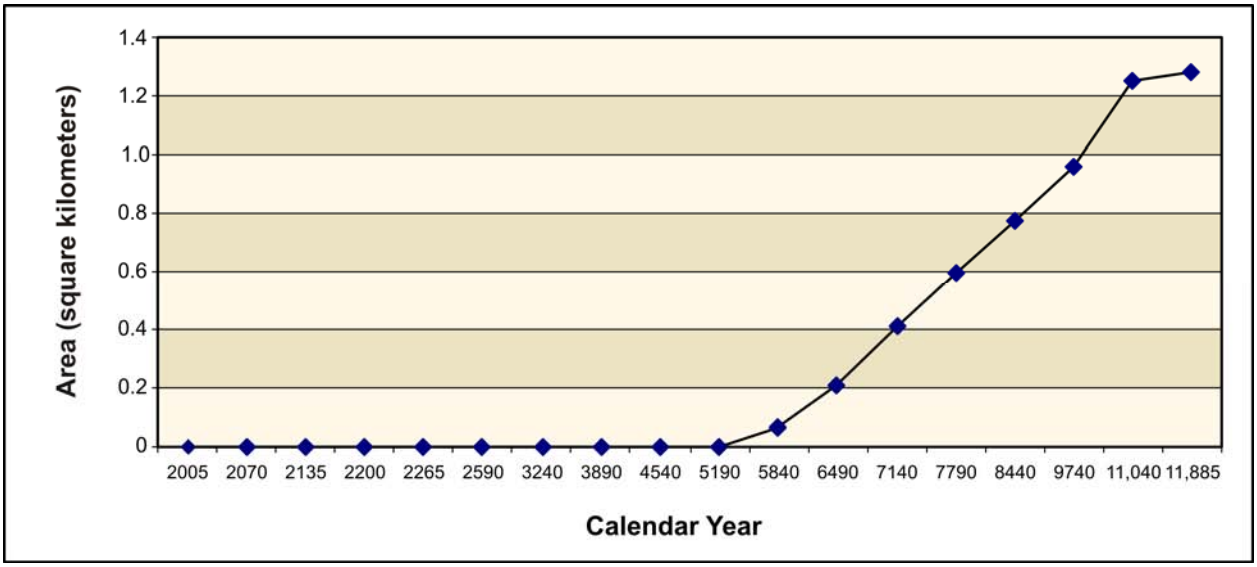


Figure 5–108. Tank Closure Alternative 2B Total Area of Groundwater Uranium-238 Concentration Exceeding the Benchmark Concentration as a Function of Time

5.1.1.3.6 Summary of Impacts

Under Tank Closure Alternative 2B, concentrations of tritium at the Core Zone Boundary exceed the benchmark concentration by about two orders of magnitude during the first 100 years of the period of analysis. Concentrations at the Columbia River nearshore approach but do not exceed the benchmark during this time. Attenuation by radioactive decay is a predominant mechanism that limits the intensity and duration of groundwater impacts of tritium.

For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), concentrations at the Core Zone Boundary exceed benchmark standards by two to three orders of magnitude during the early part of the period of analysis and then gradually decline to around one order of magnitude below the benchmark, where they remain throughout the period of analysis. Concentrations at the Columbia River nearshore remain below the benchmark throughout the period of analysis.

For uranium-238 and total uranium, limited mobility is an important factor governing the timeframes and scale of groundwater impacts. The concentrations of these retarded species exceed the benchmark at the Core Zone Boundary beyond about CY 8000. Concentrations at the Columbia River nearshore rise throughout the period of analysis but remain below the benchmark by around one order of magnitude. The peak intensity and area of the contamination plume is at the end of the period of analysis.

5.1.1.4 Tank Closure Alternative 3A: Existing WTP Vitrification with Thermal Supplemental Treatment (Bulk Vitrification); 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 5.1.1.3 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 3A.

5.1.1.4.1 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 3A.

5.1.1.4.2 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 3A.

5.1.1.4.3 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 3A.

5.1.1.4.4 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 3A.

5.1.1.4.5 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 3A.

5.1.1.4.6 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 3A.

5.1.1.5 Tank Closure Alternative 3B: Existing WTP Vitrification with Nonthermal Supplemental Treatment (Cast Stone); 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 5.1.1.3 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 3B.

5.1.1.5.1 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 3B.

5.1.1.5.2 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 3B.

5.1.1.5.3 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 3B.

5.1.1.5.4 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 3B.

5.1.1.5.5 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 3B.

5.1.1.5.6 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 3B.

5.1.1.6 Tank Closure Alternative 3C: Existing WTP Vitrification with Thermal Supplemental Treatment (Steam Reforming); 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 5.1.1.3 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 3C.

5.1.1.6.1 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 3C.

5.1.1.6.2 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 3C.

5.1.1.6.3 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 3C.

5.1.1.6.4 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 3C.

5.1.1.6.5 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 3C.

5.1.1.6.6 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 3C.

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

This section describes the groundwater analysis results for Tank Closure Alternative 4, including long-term groundwater impacts of contaminant sources from 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.

5.1.1.7.1 Actions and Timeframes Influencing Groundwater Impacts

Summaries of the proposed actions and timelines for Tank Closure Alternative 4 are provided in Chapter 2, Section 2.5. For the long-term groundwater impact analysis, three major periods were identified for Tank Closure Alternative 4, 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 4 presented in this section would be common to all the Tank Closure alternatives.

- The retrieval period was assumed to start in 2008 and end in CY 2144. During this period, 99.9 percent of the waste would be retrieved from the tanks. A retrieval loss of 15,140 liters (4,000 gallons) per tank was assumed for all SSTs. Most tank farms would be landfill-closed with a modified RCRA Subtitle C barrier. The exceptions are the BX and SX tank farms, which would undergo clean closure.

- The post–administrative control period was assumed to start in CY 2145 and continue through the 10,000-year period of analysis until CY 11,940. Releases that occurred during the past-practice period would continue to migrate through the vadose zone and groundwater system during the post–administrative control period. All remaining waste would be available for release into the vadose zone at the start of the post–administrative control period.

5.1.1.7.2 COPC Drivers

A total of 19 COPCs were analyzed for Tank Closure Alternative 4. 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 4 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 4 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, they become major contributors toward the end of the period of analysis. The radiological risk drivers account for essentially 100 percent of the radiological risk. There would be no chemical risk. The chemical hazard drivers account for 100 percent of the chemical hazard associated with Tank Closure Alternative 4.

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.

5.1.1.7.3 Analysis of Release and Mass Balance

This section presents the impacts of Tank Closure Alternative 4 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 5–109 through 5–114). Three subtotals are plotted representing releases from cribs and trenches (ditches), past leaks, and other tank farm sources. 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 5–109 shows the estimated release to the vadose zone for the radiological risk drivers and Figure 5–110, the chemical hazard drivers. For all three 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 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 past leaks. This suggests that activities during the past-practice period are an important impact driver under Tank Closure Alternative 4.

Figure 5–111 shows the estimated release to groundwater for the radiological risk drivers and Figure 5–112, 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, chromium, and nitrate), the amount released to groundwater is essentially equal to the amount released to the vadose zone.

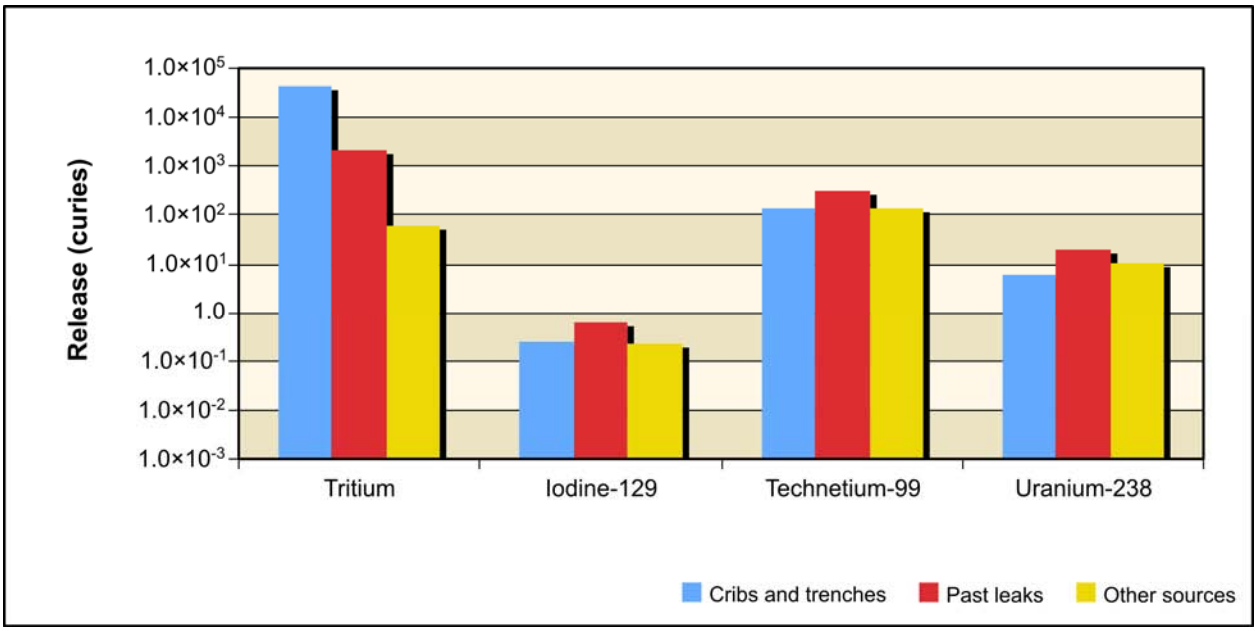


Figure 5–109. Tank Closure Alternative 4 Releases of Radiological Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

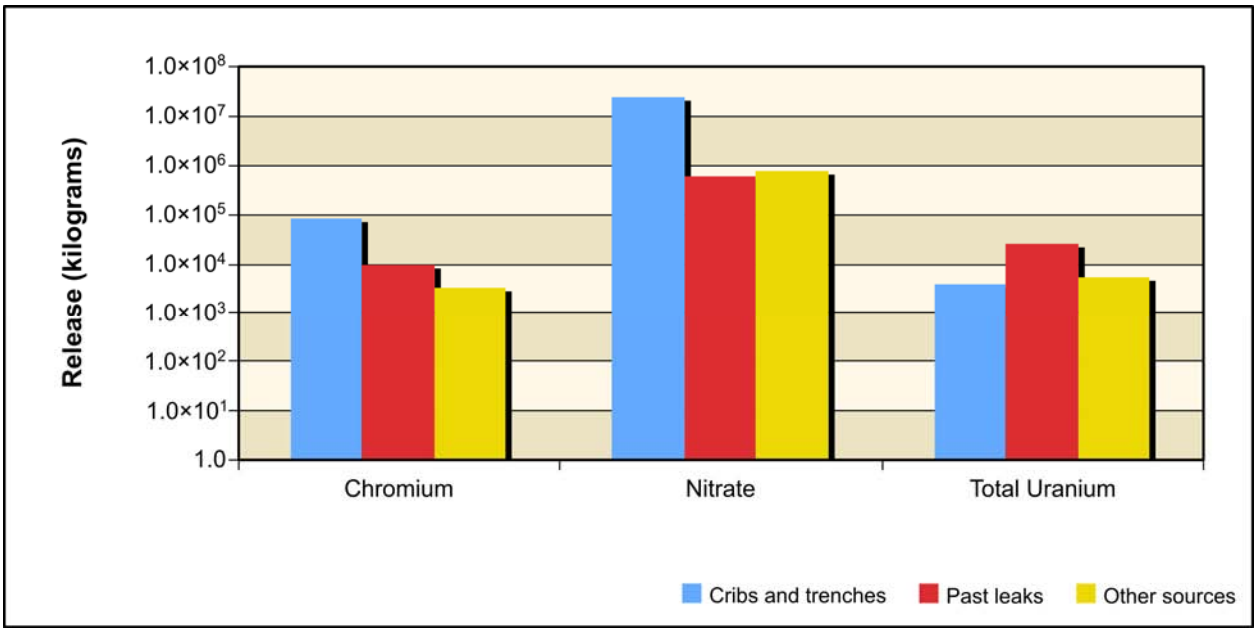


Figure 5–110. Tank Closure Alternative 4 Releases of Chemical Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

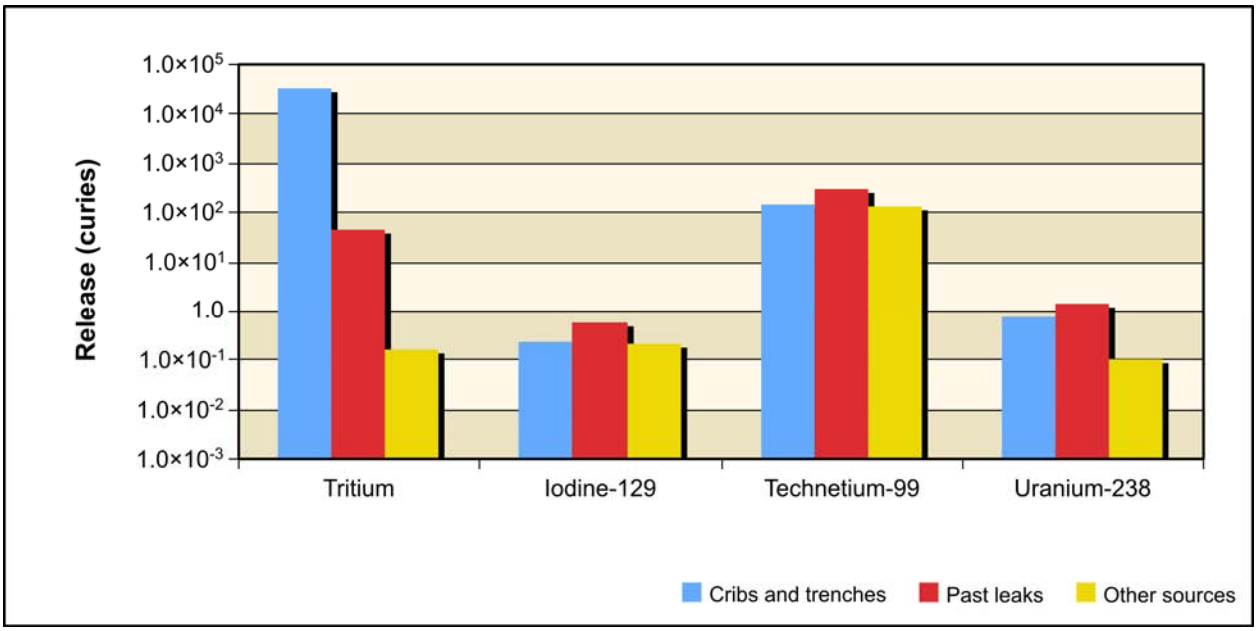


Figure 5–111. Tank Closure Alternative 4 Releases of Radiological Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

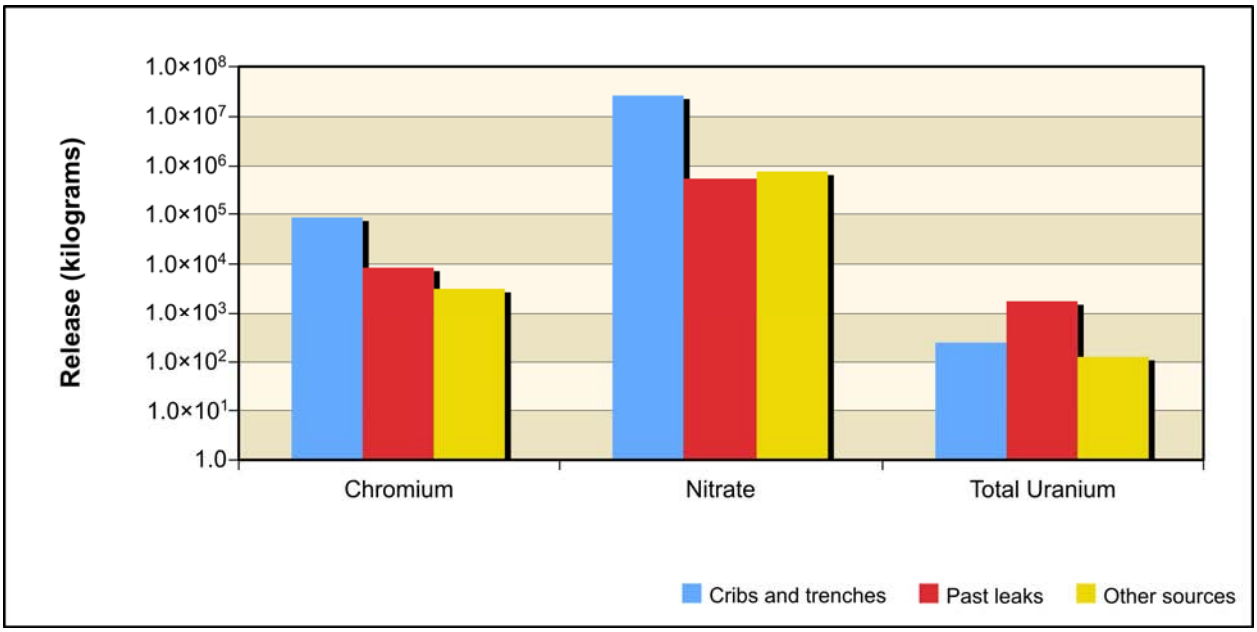


Figure 5–112. Tank Closure Alternative 4 Releases of Chemical Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

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) and past leaks, where moisture movement through the vadose zone is relatively rapid (because of the volume of water associated with the source), about 10 percent of the total inventory reached groundwater during the period of analysis; for other tank farm sources, only about 2 percent of the total inventory reached groundwater during the period of analysis.

For tritium, the amount released to groundwater is attenuated by radioactive decay. For cribs and trenches (ditches), about 70 percent of the total inventory reached groundwater in the analysis; for past leaks, only 2 percent; and for other tank farm sources, only one-third of 1 percent reached the water table. 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-remediation period because of the long travel times in the vadose zone for these COPCs.

Figure 5–113 shows the estimated release to the Columbia River for the radiological risk drivers and Figure 5–114, 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. 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. Overall, about 25 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. Overall, only about 3 percent of the tritium released to groundwater reached the Columbia River during the period of analysis. 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-remediation period because of the long travel times in the vadose zone and through the groundwater system for these COPCs.

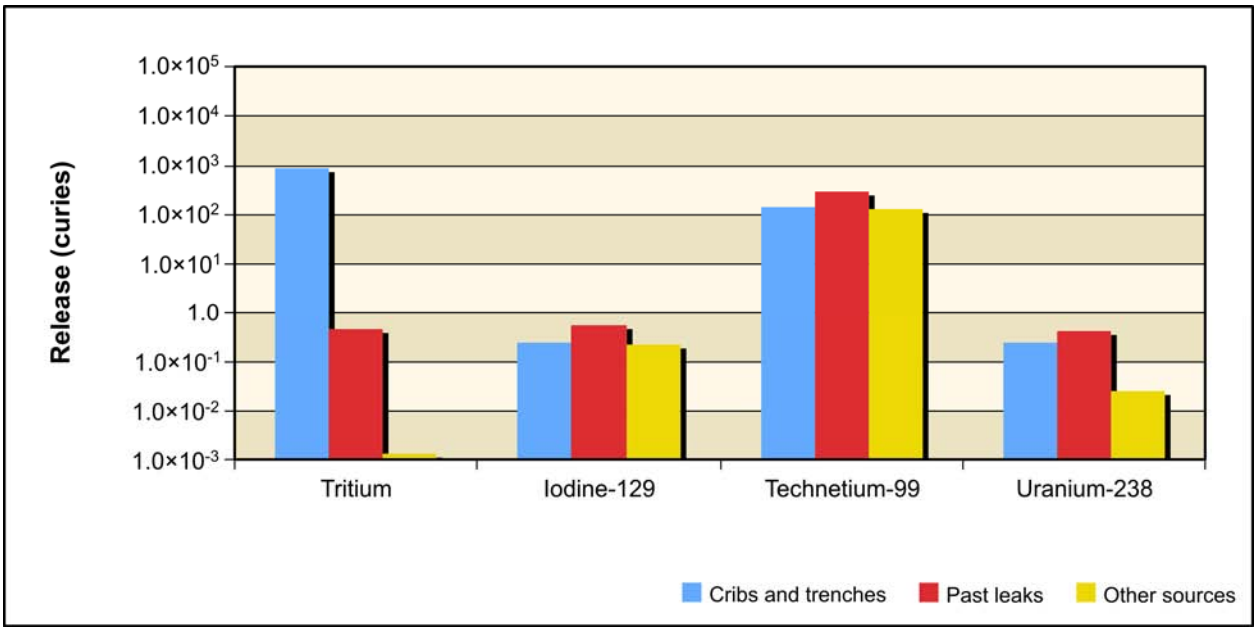


Figure 5–113. Tank Closure Alternative 4 Releases of Radiological Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

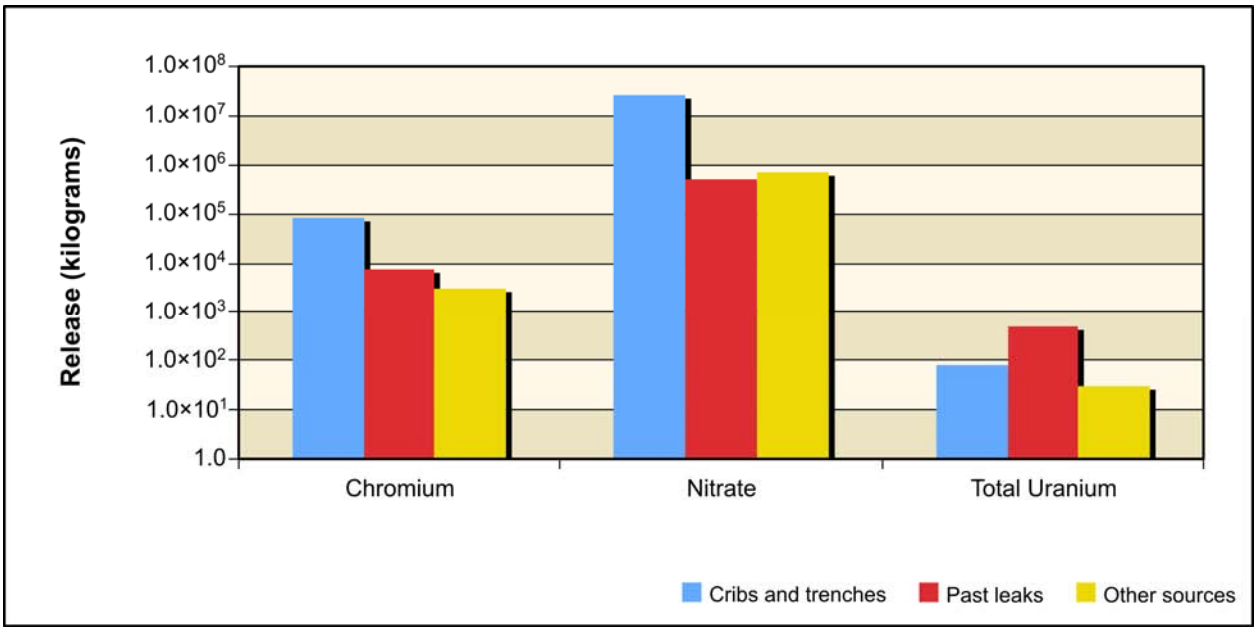


Figure 5–114. Tank Closure Alternative 4 Releases of Chemical Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

5.1.1.7.4 Analysis of Concentration Versus Time

This section presents the analysis of Tank Closure Alternative 4 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 Table 5–4 and Figures 5–115 through 5–121). 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 five orders of magnitude. Table 5–4 lists the maximum concentrations of the COPCs in the peak year after CY 2050 at the tank farm barriers, Core Zone Boundary, and Columbia River nearshore.

Figure 5–115 shows concentration versus time for tritium. Releases from cribs and trenches (ditches) cause groundwater concentrations to exceed benchmark concentrations by about two orders of magnitude for a short period of time during the early part of the period of analysis. During this time, groundwater concentrations at the Columbia River nearshore remain over an order of magnitude below the benchmark concentration. Because the half-life of tritium is less than 13 years, radioactive decay rapidly attenuates groundwater concentration, and tritium is essentially not a factor at times later than CY 2050.

Table 5–4. Tank Closure Alternative 4 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)	28	5,060	4	7,270	13	6,060	178	20,000
	(2051)	(2054)	(2062)	(2055)	(2050)	(2054)	(2050)	
Technetium-99	**1,460**	**28,200**	214	**15,200**	180	**24,100**	191	900
	(2058)	(2050)	(2060)	(2050)	(2060)	(2050)	(2480)	
Iodine-129	**3**	**38**	0.4	**30**	0.3	**31**	0.3	1
	(2053)	(2057)	(2052)	(2050)	(2052)	(2057)	(2181)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	0	**36**	1	**26**	8	**48**	1	15
	(11,814)	(11,742)	(11,795)	(11,780)	(11,441)	(11,529)	(11,891)	
Chemical in micrograms per liter								
Chromium	9	**3,220**	36	**768**	10	**1,650**	34	100
	(2057)	(2055)	(2057)	(2050)	(2050)	(2050)	(2695)	
Nitrate	5,530	**1,540,000**	1,400	**133,000**	1,230	**1,010,000**	8,490	45,000
	(2056)	(2050)	(2059)	(2054)	(2067)	(2050)	(2450)	
Total uranium	0	14	1	11	12	**63**	1	30
	(11,819)	(11,678)	(11,828)	(11,840)	(11,599)	(11,690)	(11,577)	

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.

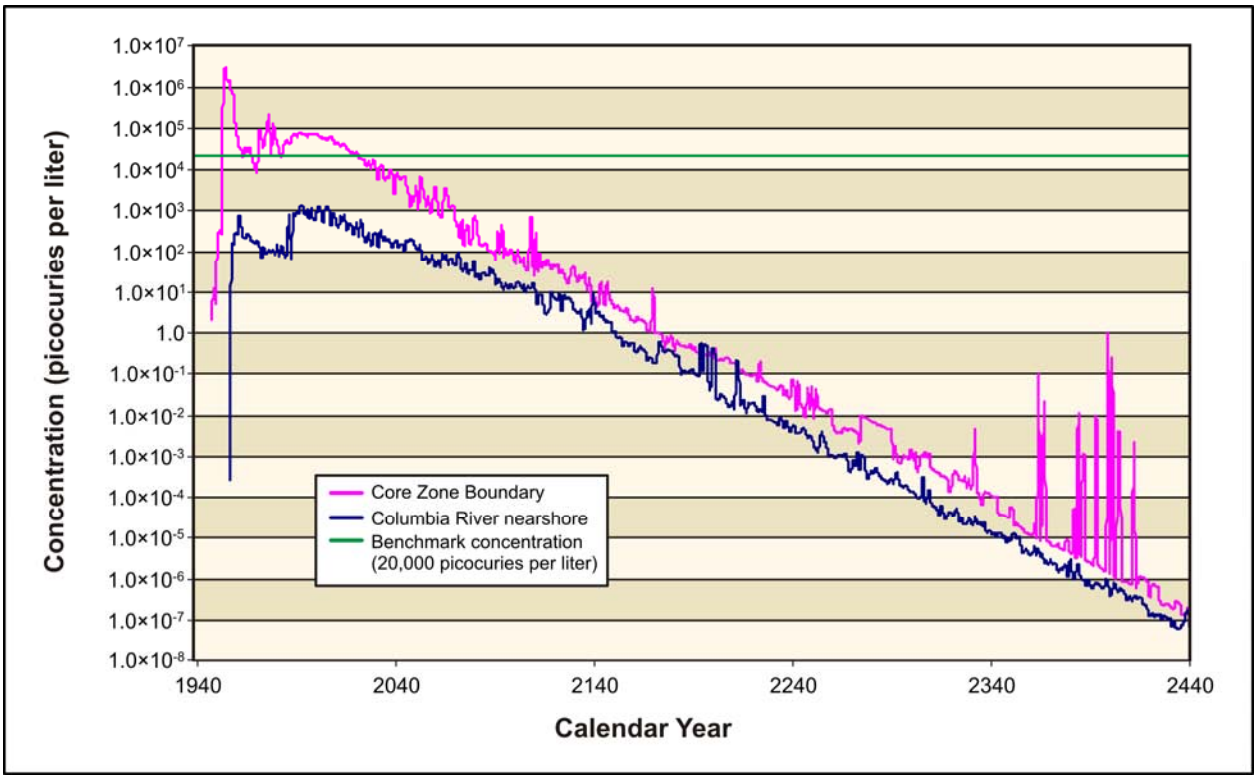


Figure 5–115. Tank Closure Alternative 4 Hydrogen-3 (Tritium) Concentration Versus Time

Figures 5–116 through 5–119 show concentration versus time for iodine-129, technetium-99, chromium, and nitrate (the conservative tracers). Releases from cribs and trenches (ditches) cause groundwater concentrations to exceed benchmark concentrations by about two to three orders of magnitude during the early part of the period of analysis at the Core Zone Boundary. During this time, groundwater concentrations at the Columbia River nearshore approach but do not exceed the benchmark concentration. Technetium-99 and nitrate concentrations fall below the benchmark concentration at the Core Zone Boundary around CY 4000, while iodine-129 and chromium fall below the benchmark around CY 5000. Concentrations for all four conservative tracers decline over the remainder of the period of analysis.

Figures 5–120 and 5–121 show concentration versus time for uranium-238 and total uranium. Early releases from cribs and trenches (ditches) result in groundwater concentrations that are one to two orders of magnitude lower than benchmark concentrations. These concentrations continue to rise throughout the duration of the period of analysis. Uranium-238 concentrations exceed the benchmark concentration around CY 8000, while total uranium concentrations exceed the benchmark around CY 9500. Groundwater concentrations at the Columbia River nearshore rise throughout the period of analysis but remain over an order of magnitude below the benchmark concentration for the duration of the simulation.

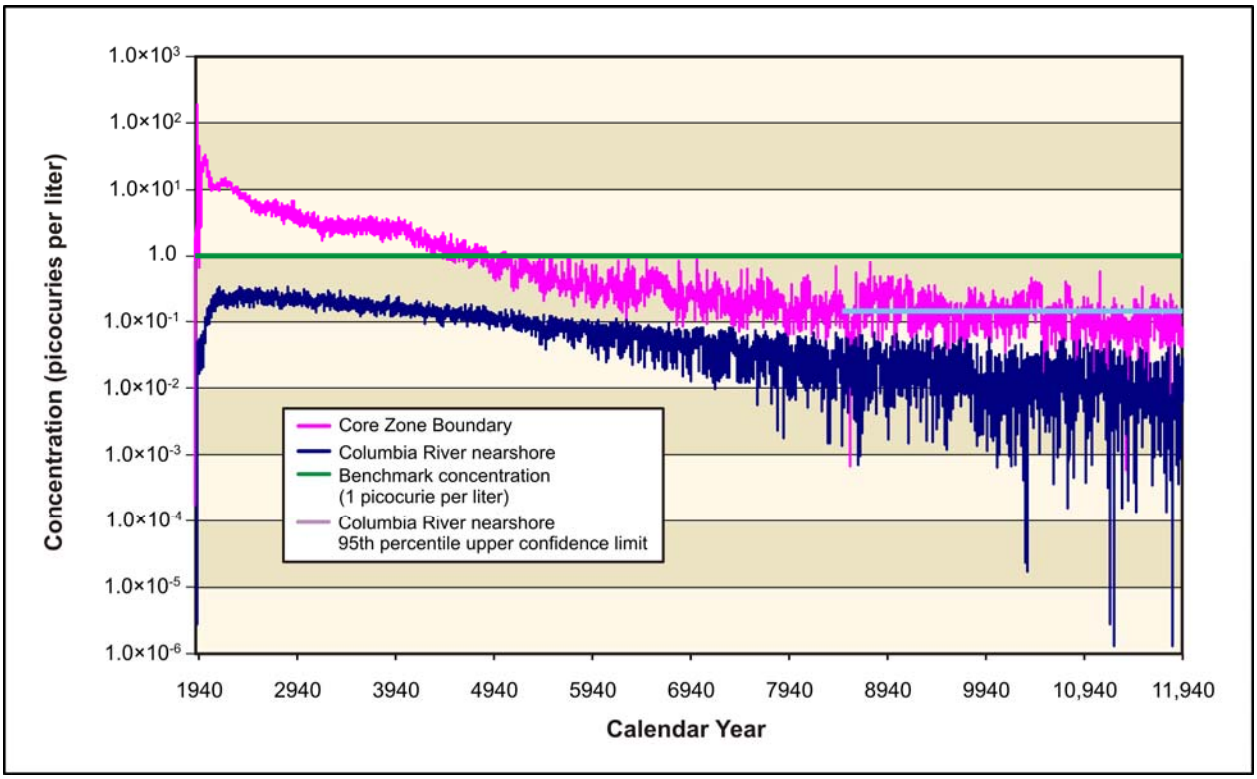


Figure 5–116. Tank Closure Alternative 4 Iodine-129 Concentration Versus Time

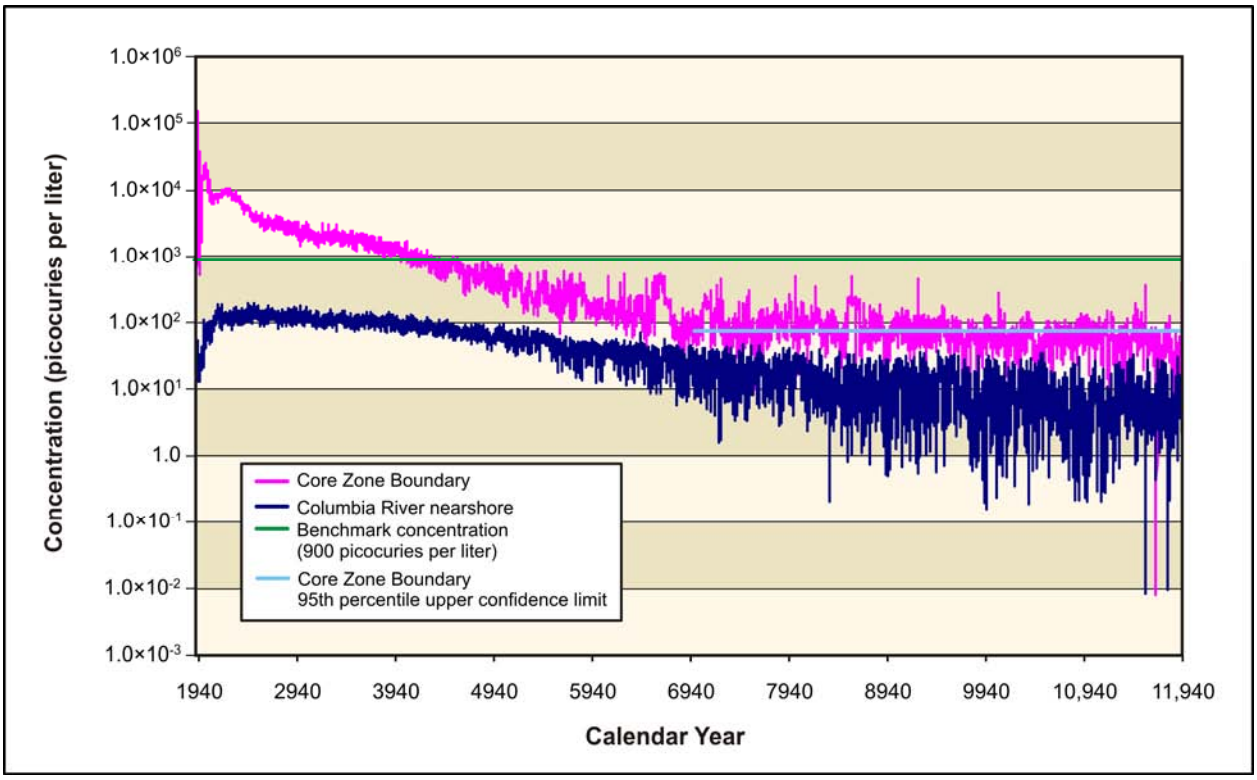


Figure 5–117. Tank Closure Alternative 4 Technetium-99 Concentration Versus Time

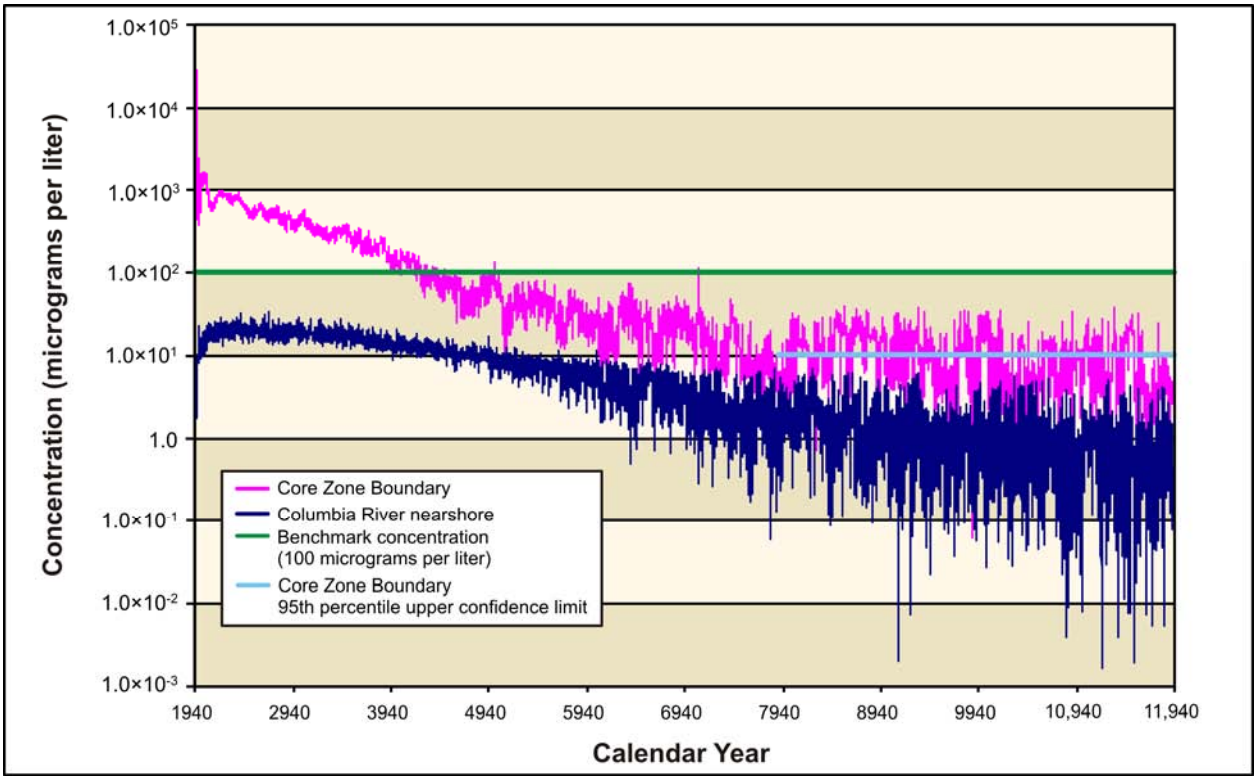


Figure 5–118. Tank Closure Alternative 4 Chromium Concentration Versus Time

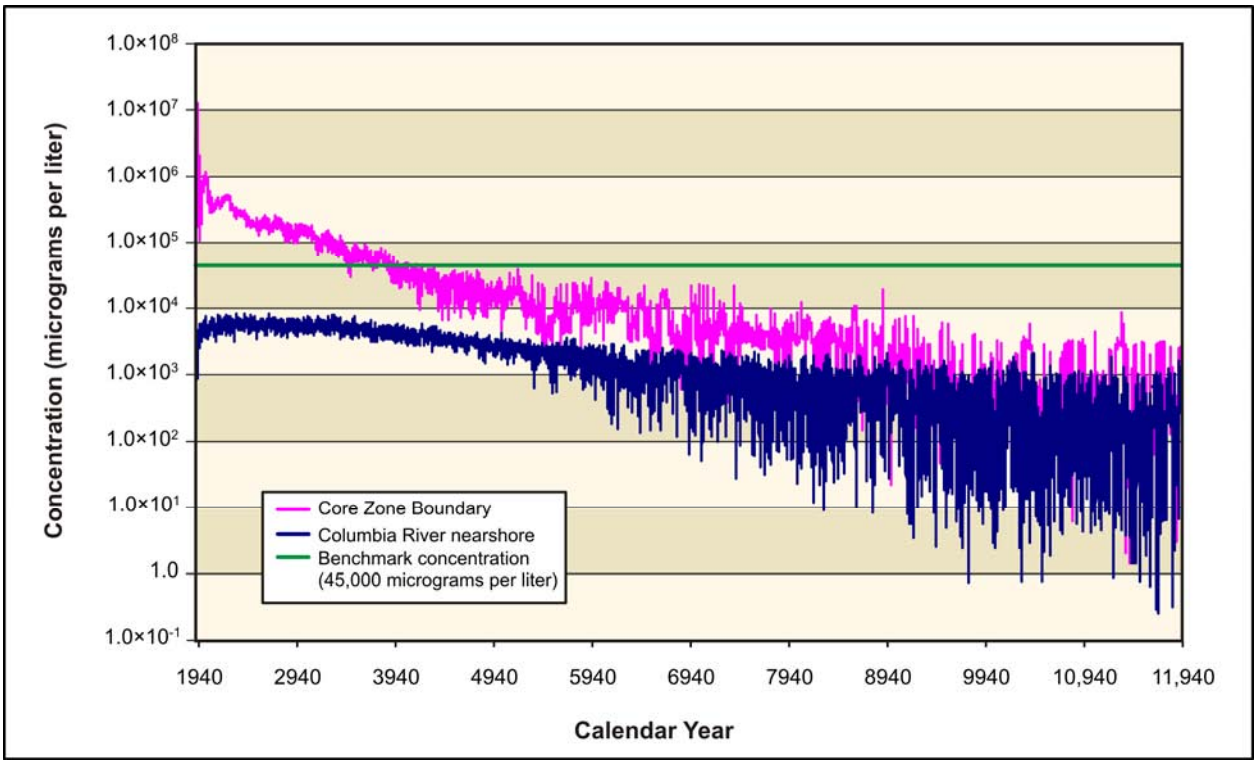


Figure 5–119. Tank Closure Alternative 4 Nitrate Concentration Versus Time

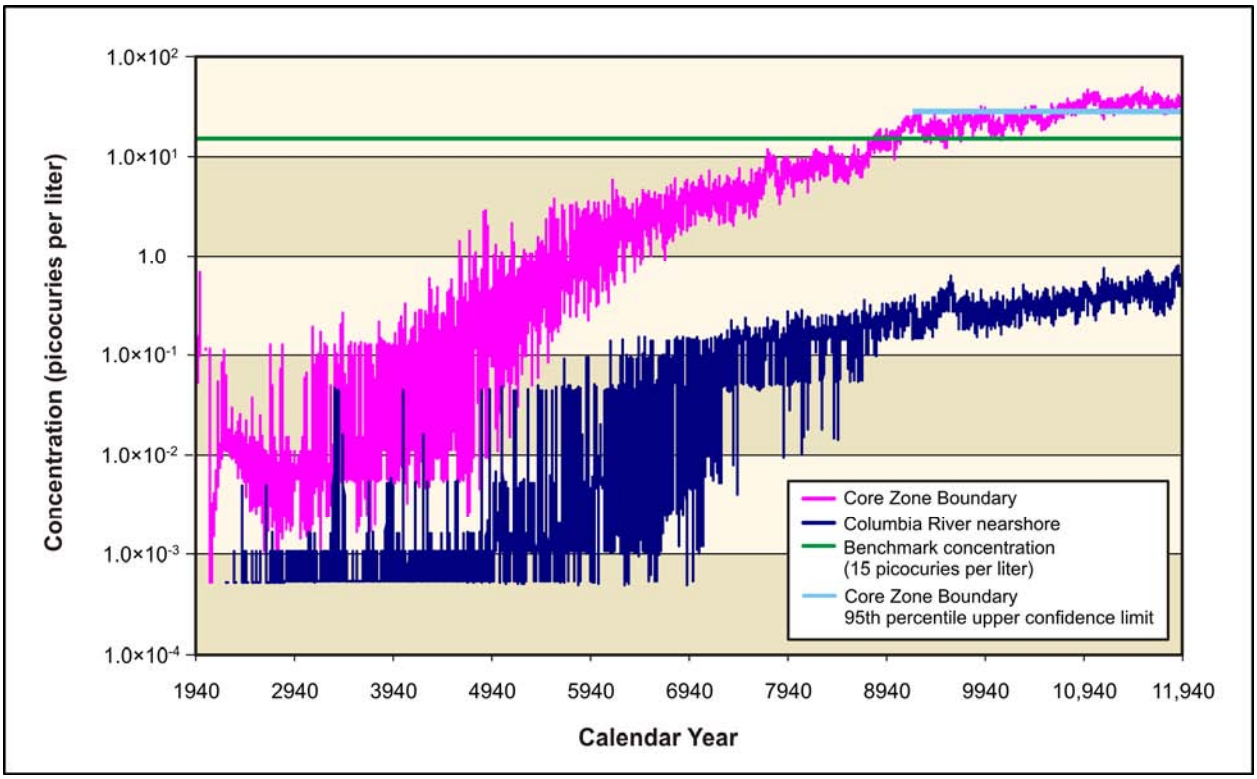


Figure 5–120. Tank Closure Alternative 4 Uranium-238 Concentration Versus Time

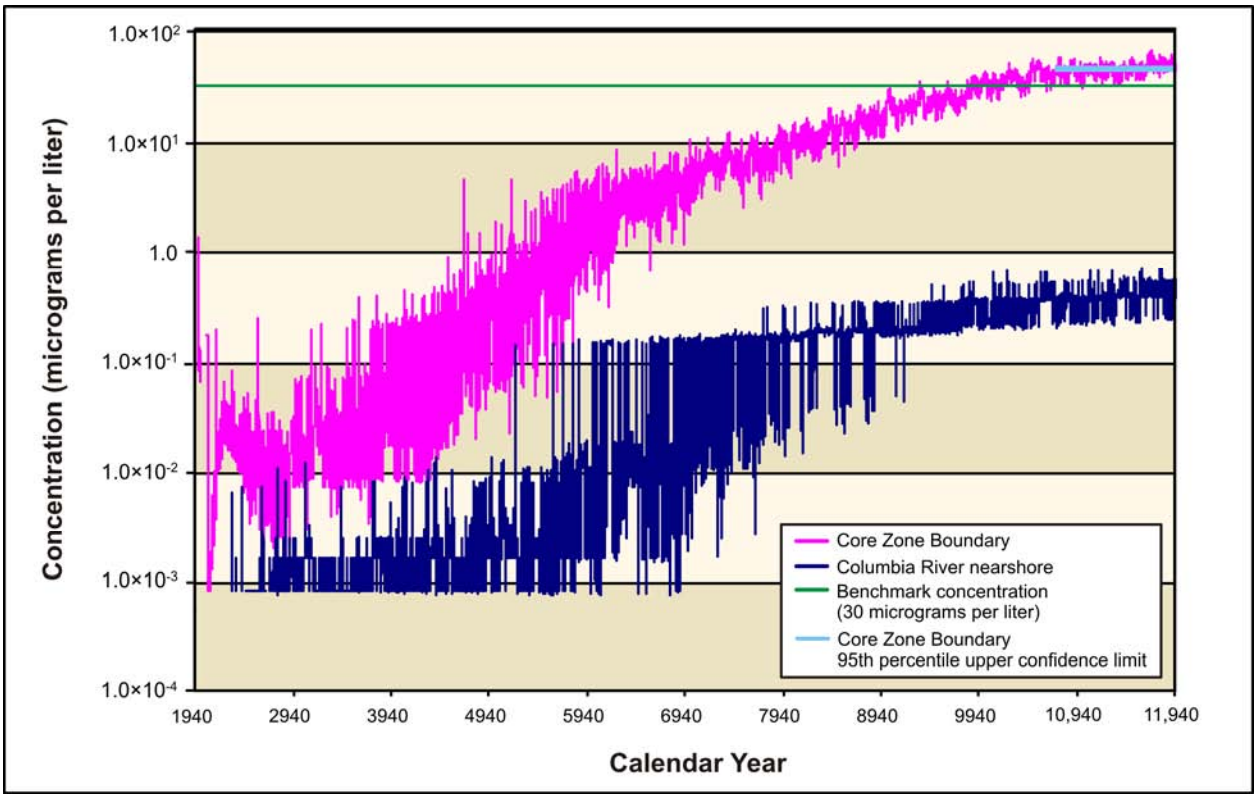
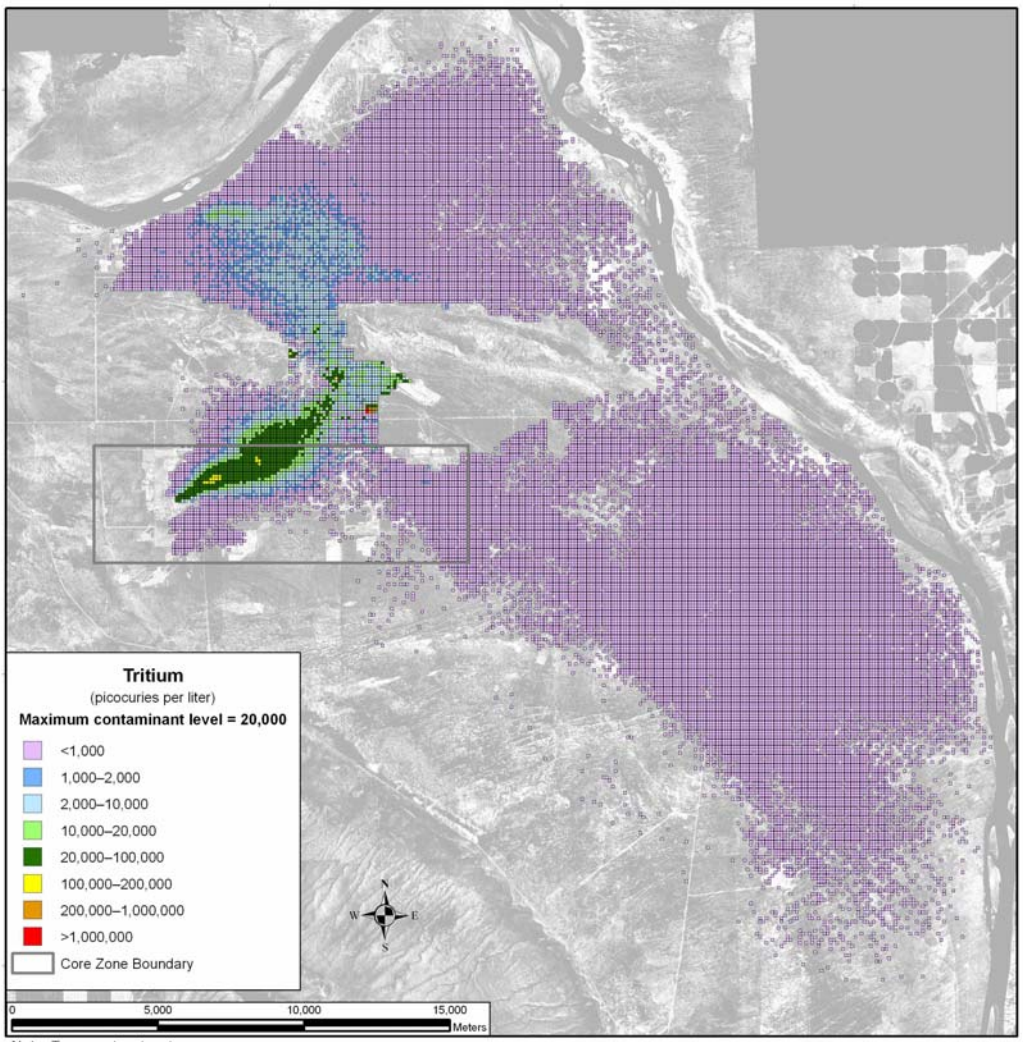


Figure 5–121. Tank Closure Alternative 4 Total Uranium Concentration Versus Time

5.1.1.7.5 Analysis of Spatial Distribution of Concentration

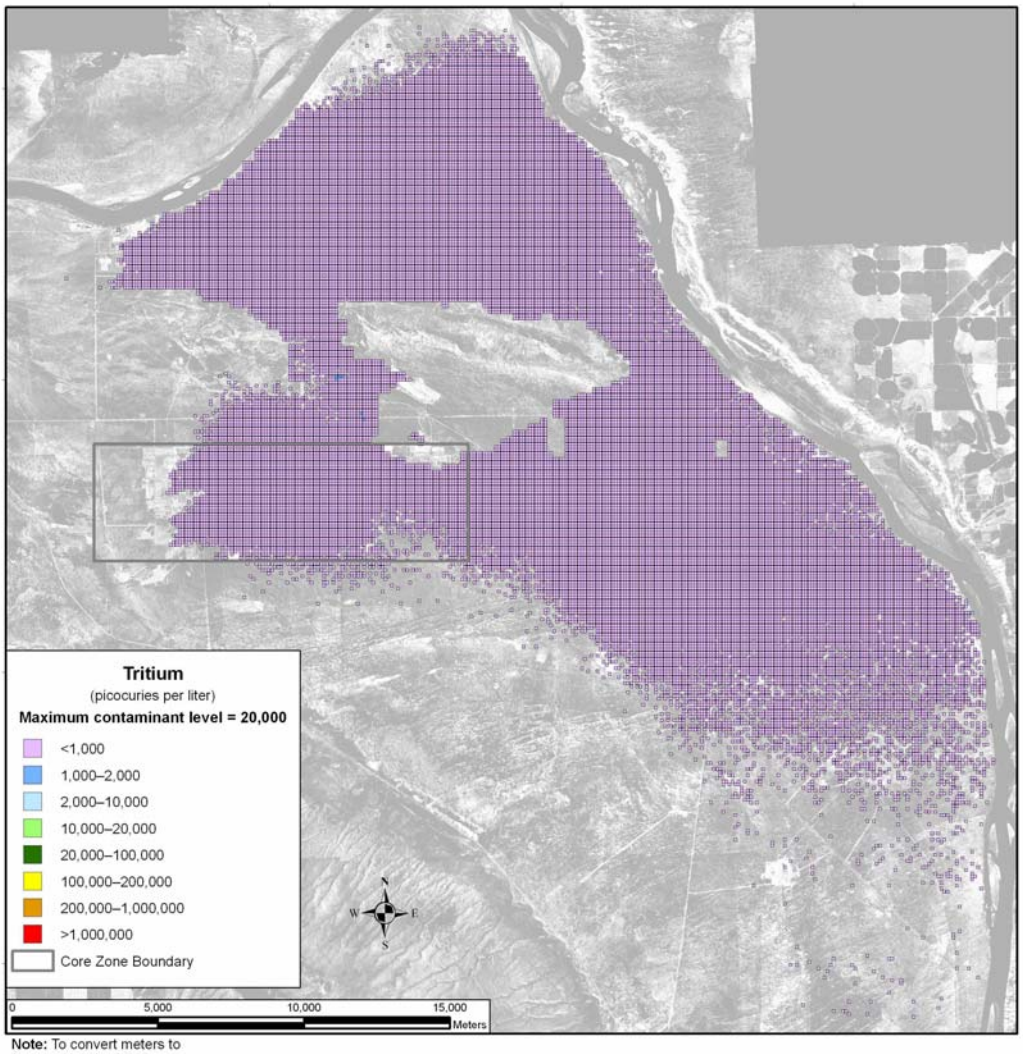
This section presents the impacts of Tank Closure Alternative 4 in terms of the spatial distribution of groundwater concentration at selected times. Concentrations of radionuclides are in picocuries per liter, chemicals in micrograms per liter (see Figures 5–122 through 5–146). Concentrations for each 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 5–122 shows the spatial distribution of groundwater concentration for tritium during CY 2005. Tritium concentrations are attenuated by radioactive decay to levels less than one-twentieth of the benchmark concentration by CY 2135 (see Figure 5–123).



Note: To convert meters to feet, multiply by 3.281

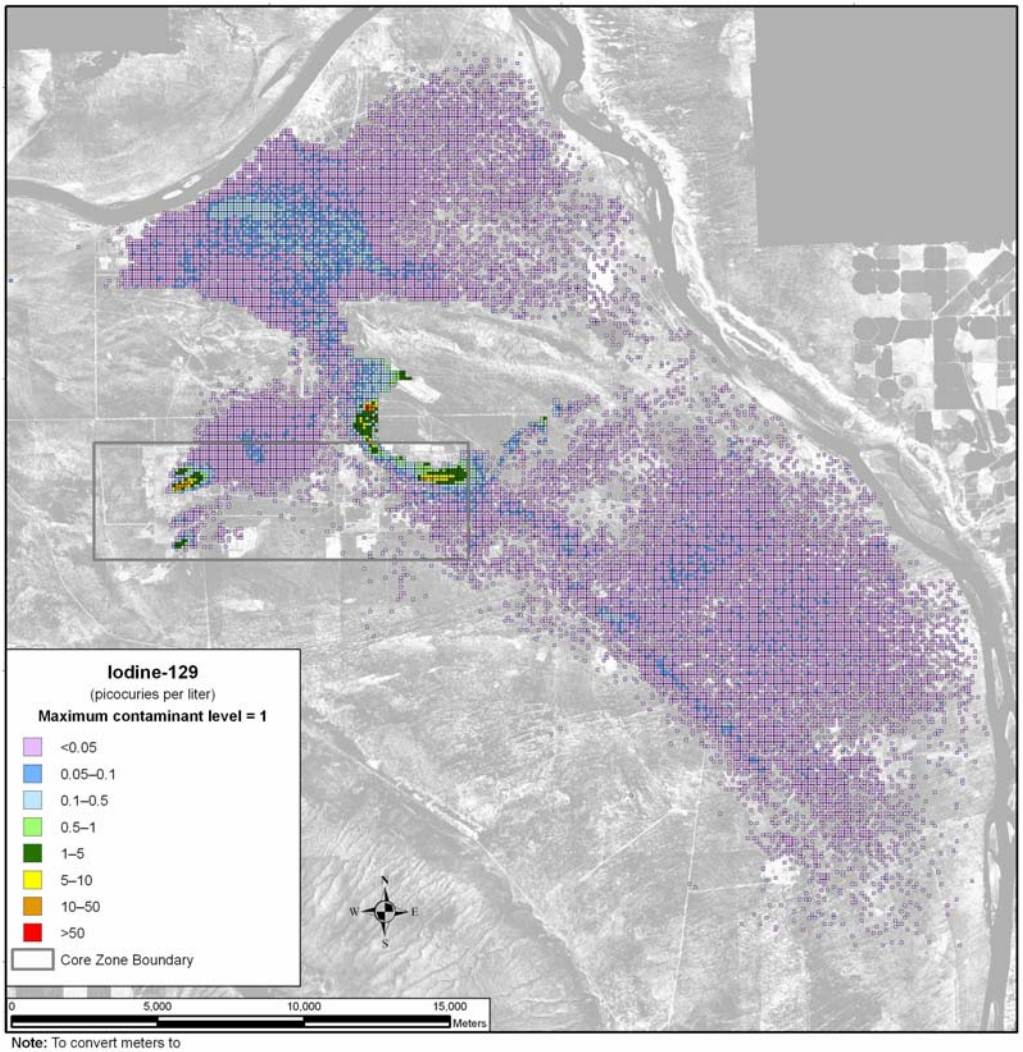
Figure 5–122. Tank Closure Alternative 4 Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

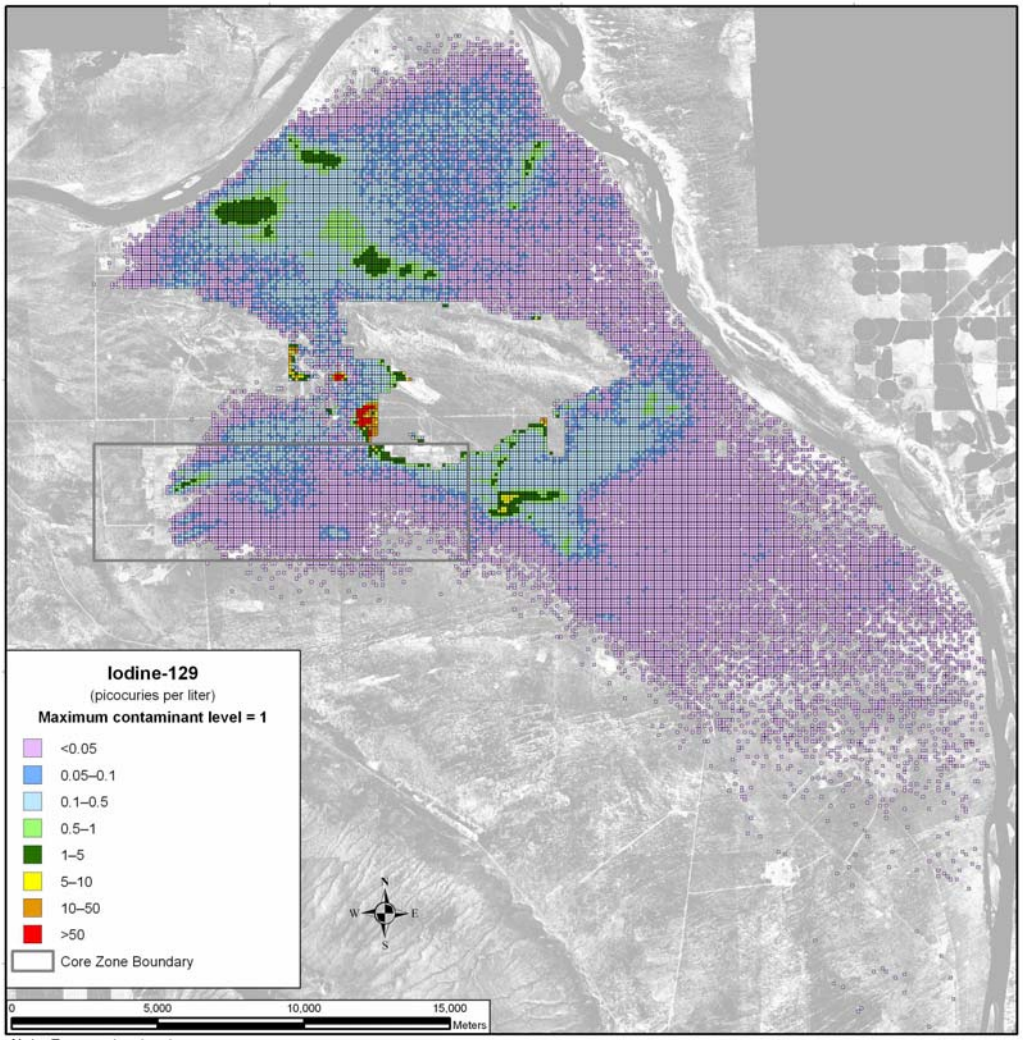
Figure 5–123. Tank Closure Alternative 4 Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2135

Plume distribution for iodine-129 during CY 2005 is shown in Figure 5–124. By CY 2135 (see Figure 5–125), areas of concentrations above the benchmark concentration exist east of the Core Zone Boundary, north of the 200-East Area, and in three separate areas north of Gable Gap. By CY 7140, most of the mass in the plume has reached the Columbia River, with only isolated pockets of high-concentration areas where the groundwater flow velocities are extremely small (see Figure 5–126). Technetium-99 (see Figures 5–127 through 5–129), chromium (see Figures 5–130 through 5–132), and nitrate (see Figures 5–133 through 5–135) 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).



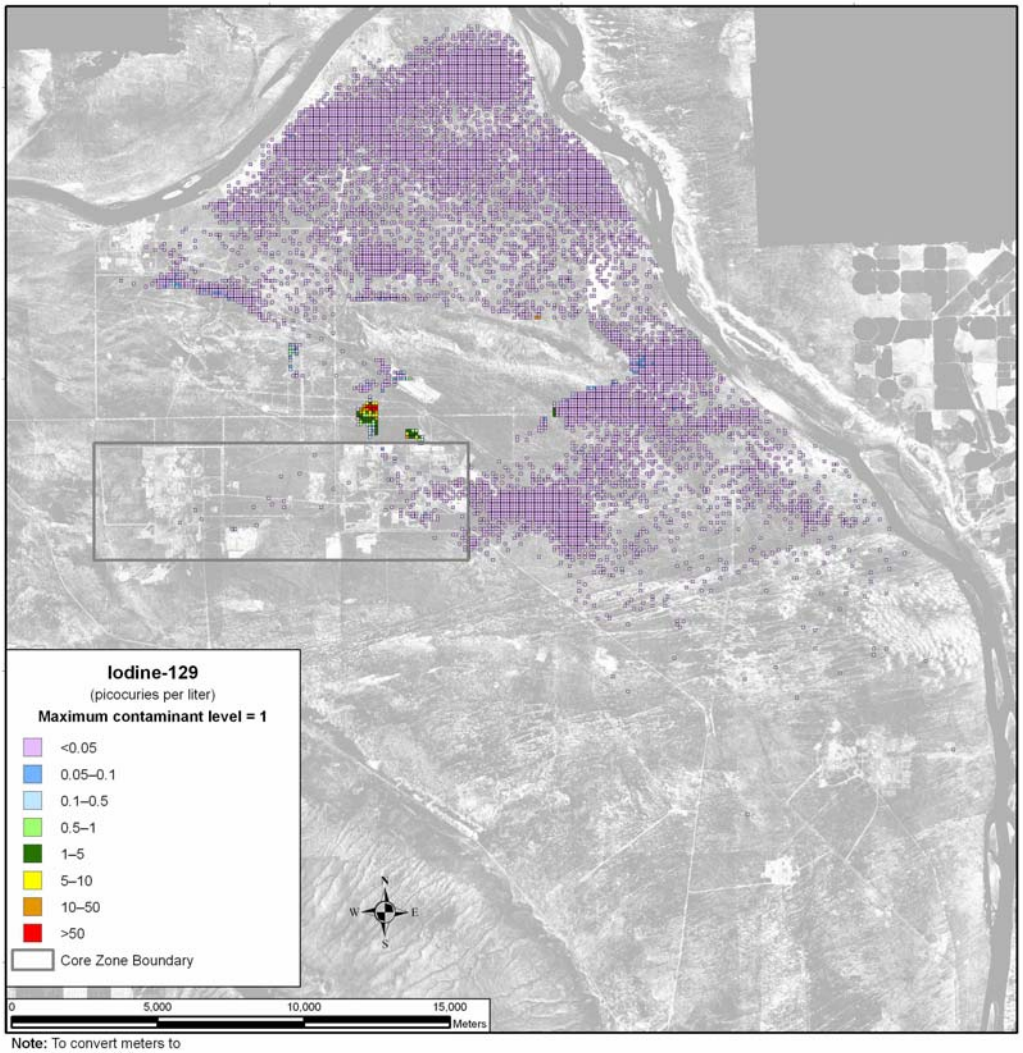
Note: To convert meters to feet, multiply by 3.281

Figure 5–124. Tank Closure Alternative 4 Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2005



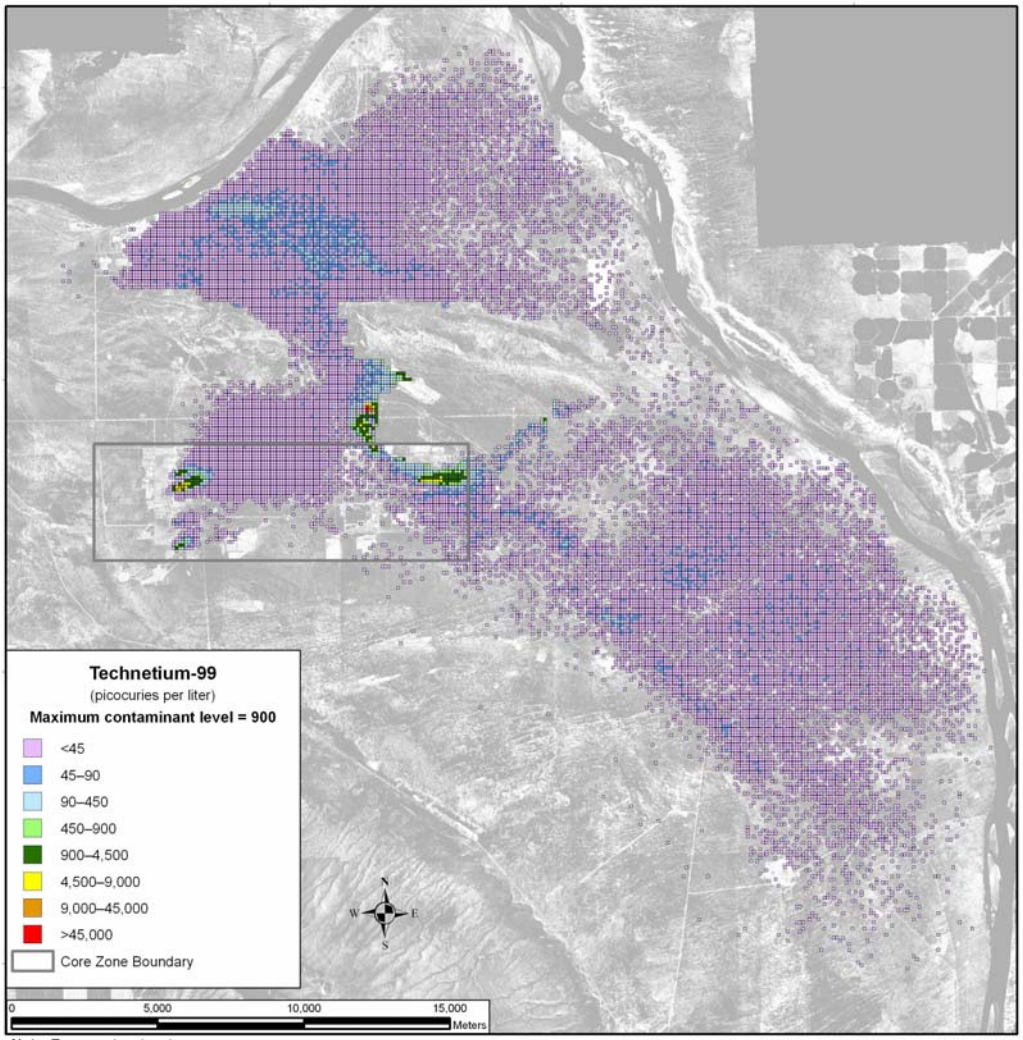
Note: To convert meters to feet, multiply by 3.281

Figure 5–125. Tank Closure Alternative 4 Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2135



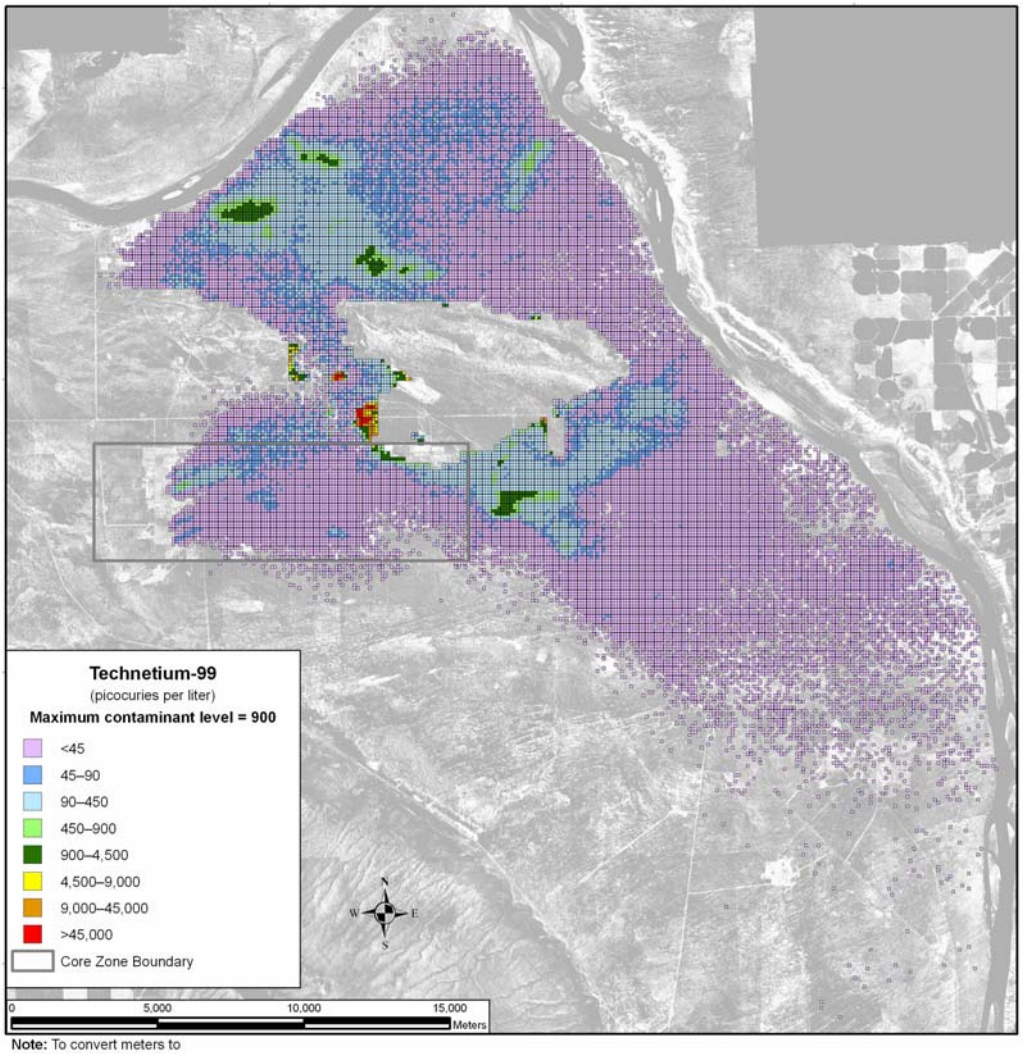
Note: To convert meters to feet, multiply by 3.281

Figure 5–126. Tank Closure Alternative 4 Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140



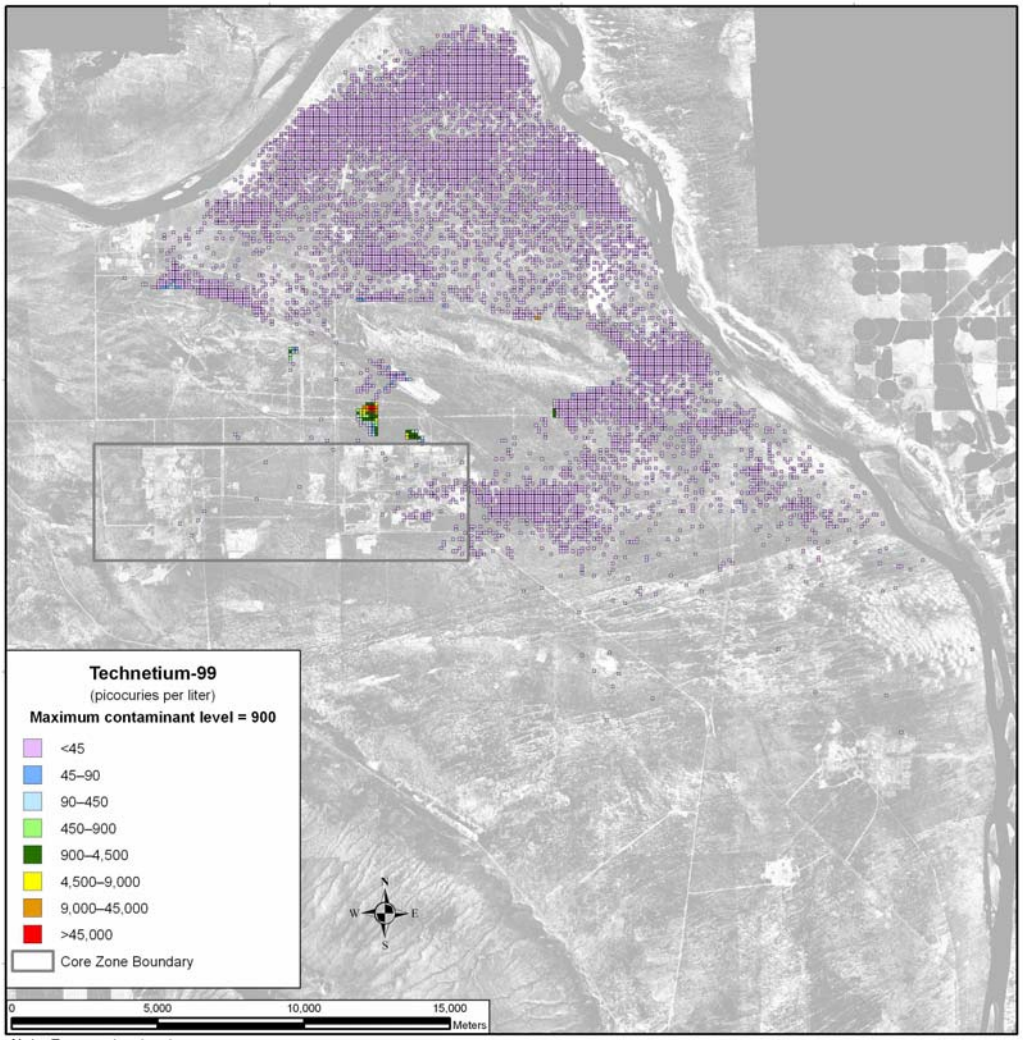
Note: To convert meters to feet, multiply by 3.281

Figure 5–127. Tank Closure Alternative 4 Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2005



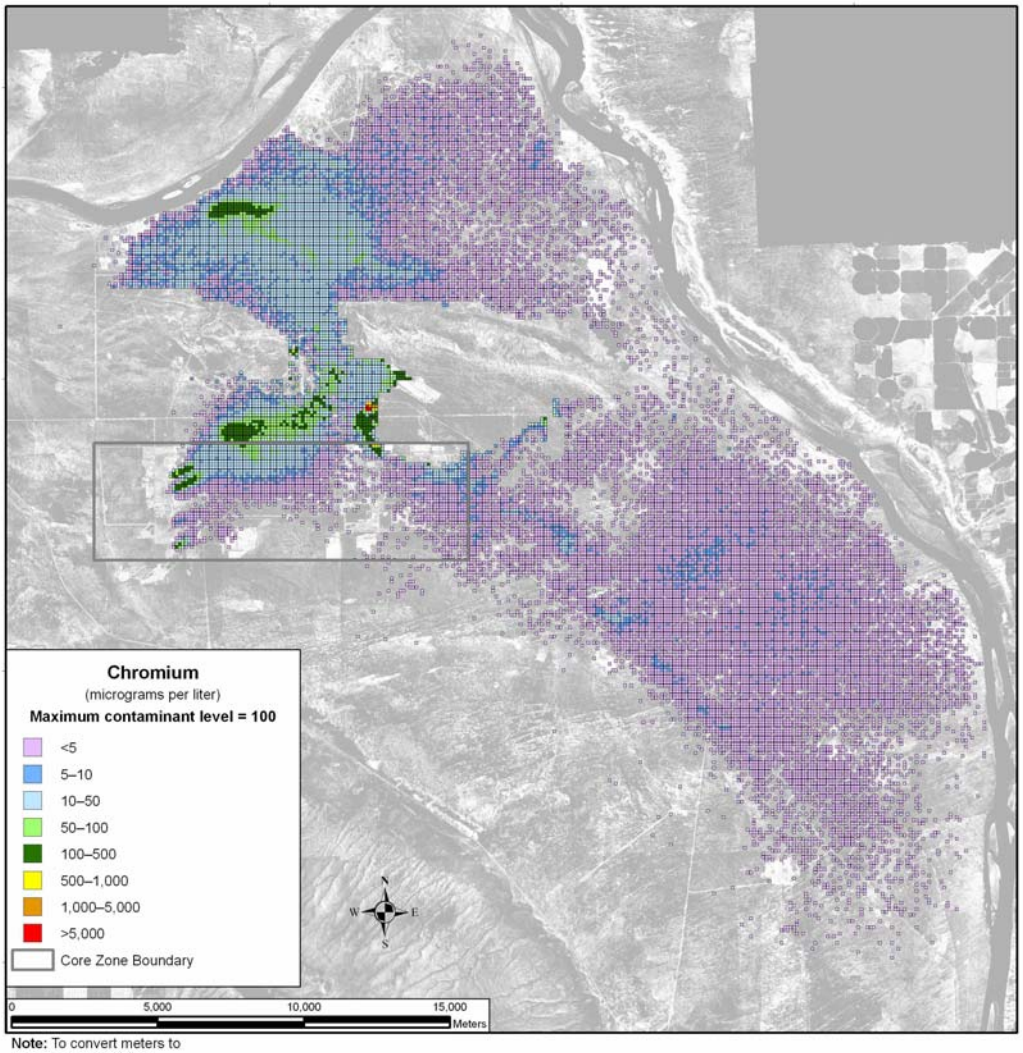
Note: To convert meters to feet, multiply by 3.281

Figure 5–128. Tank Closure Alternative 4 Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2135



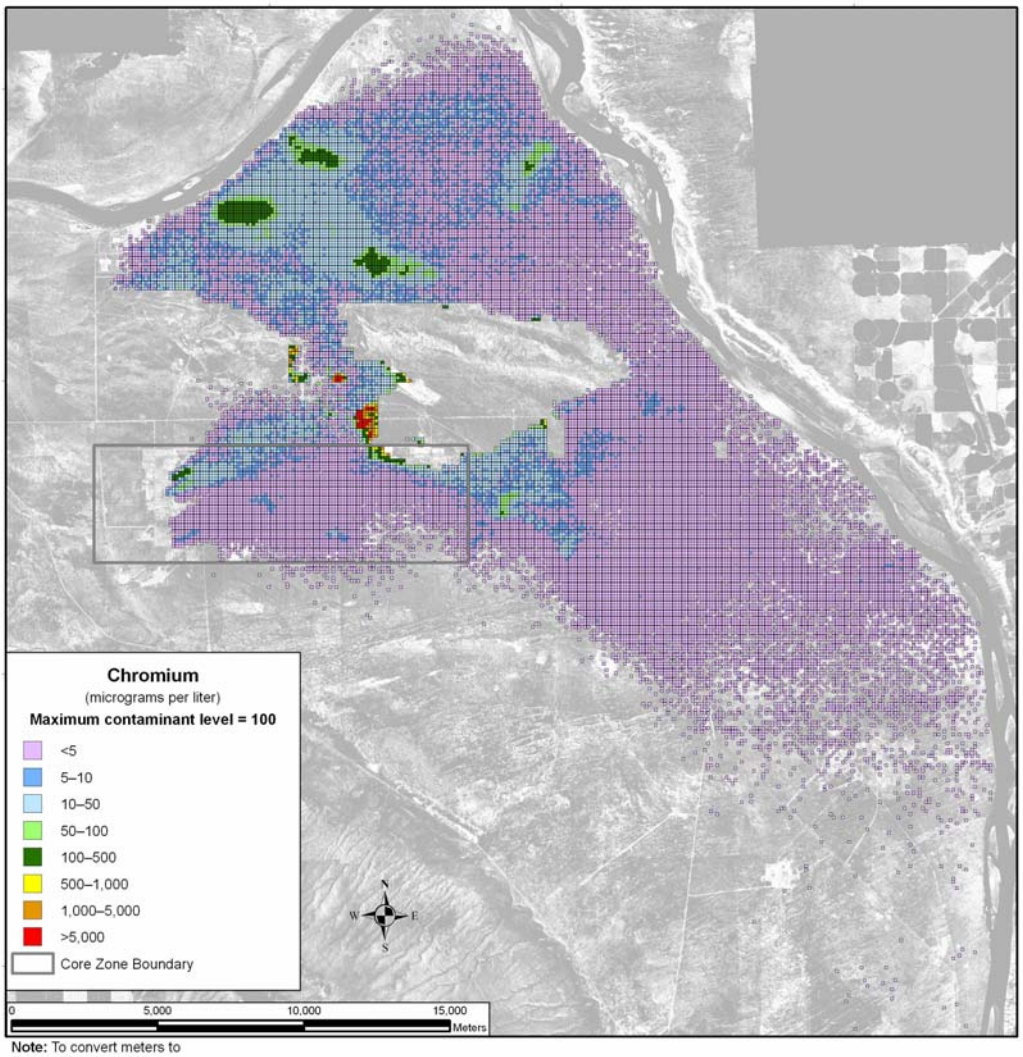
Note: To convert meters to feet, multiply by 3.281

Figure 5–129. Tank Closure Alternative 4 Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140



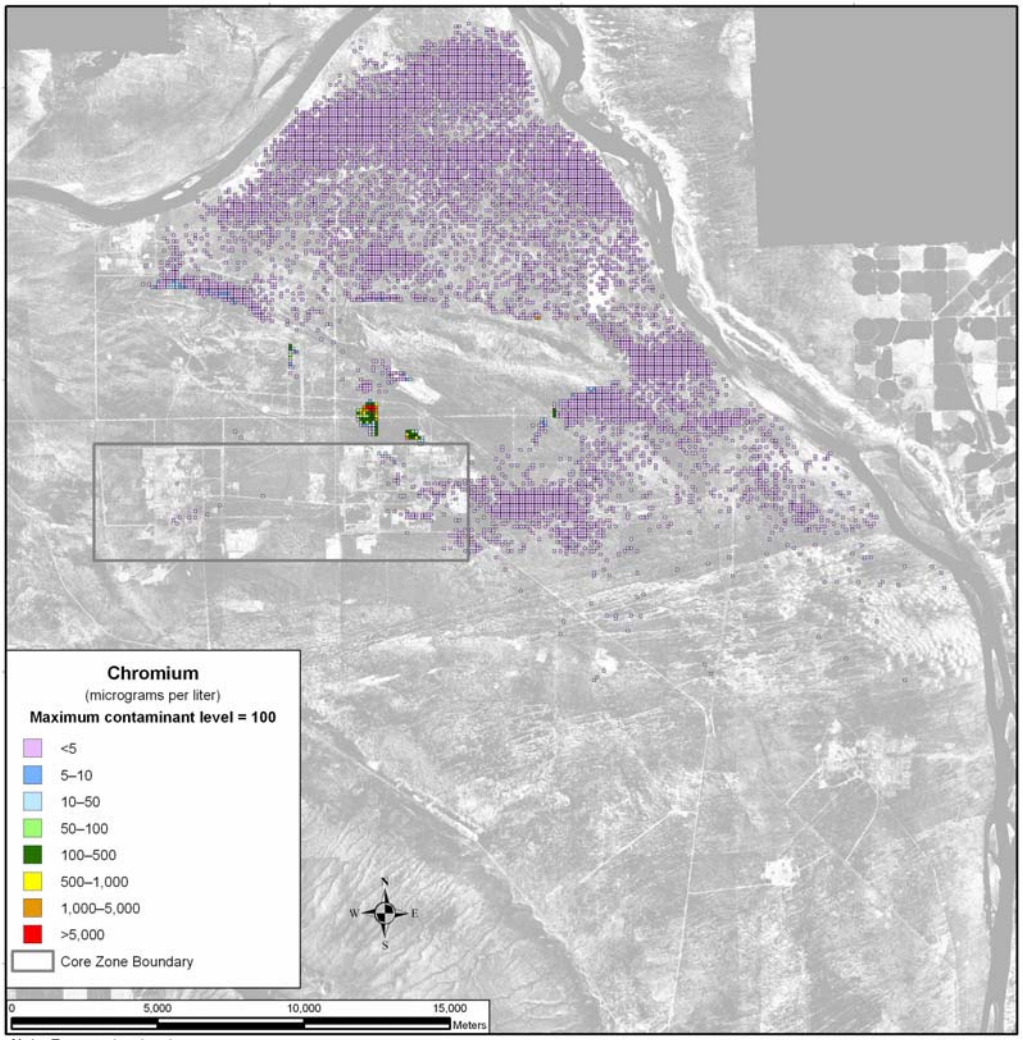
Note: To convert meters to feet, multiply by 3.281

Figure 5–130. Tank Closure Alternative 4 Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 2005



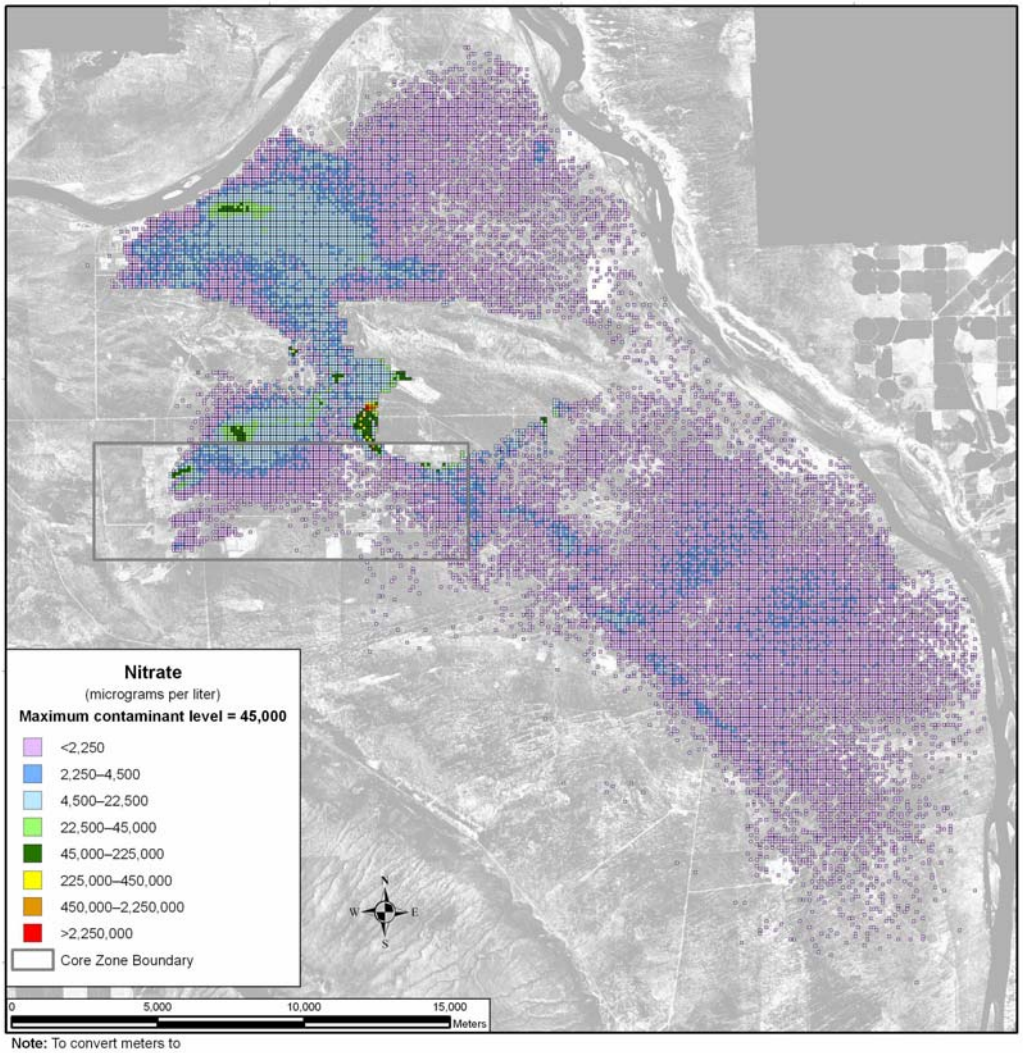
Note: To convert meters to feet, multiply by 3.281

Figure 5–131. Tank Closure Alternative 4 Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 2135



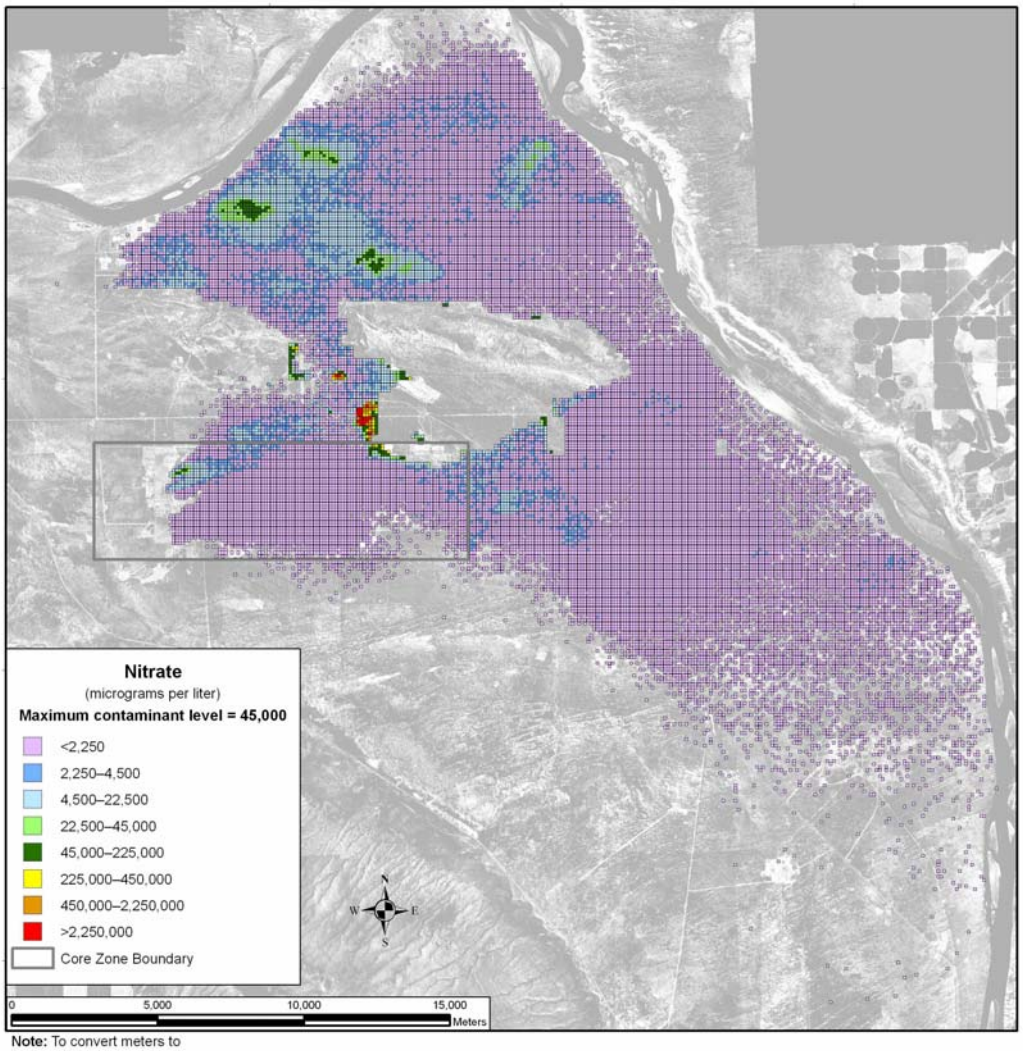
Note: To convert meters to feet, multiply by 3.281

Figure 5–132. Tank Closure Alternative 4 Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 7140



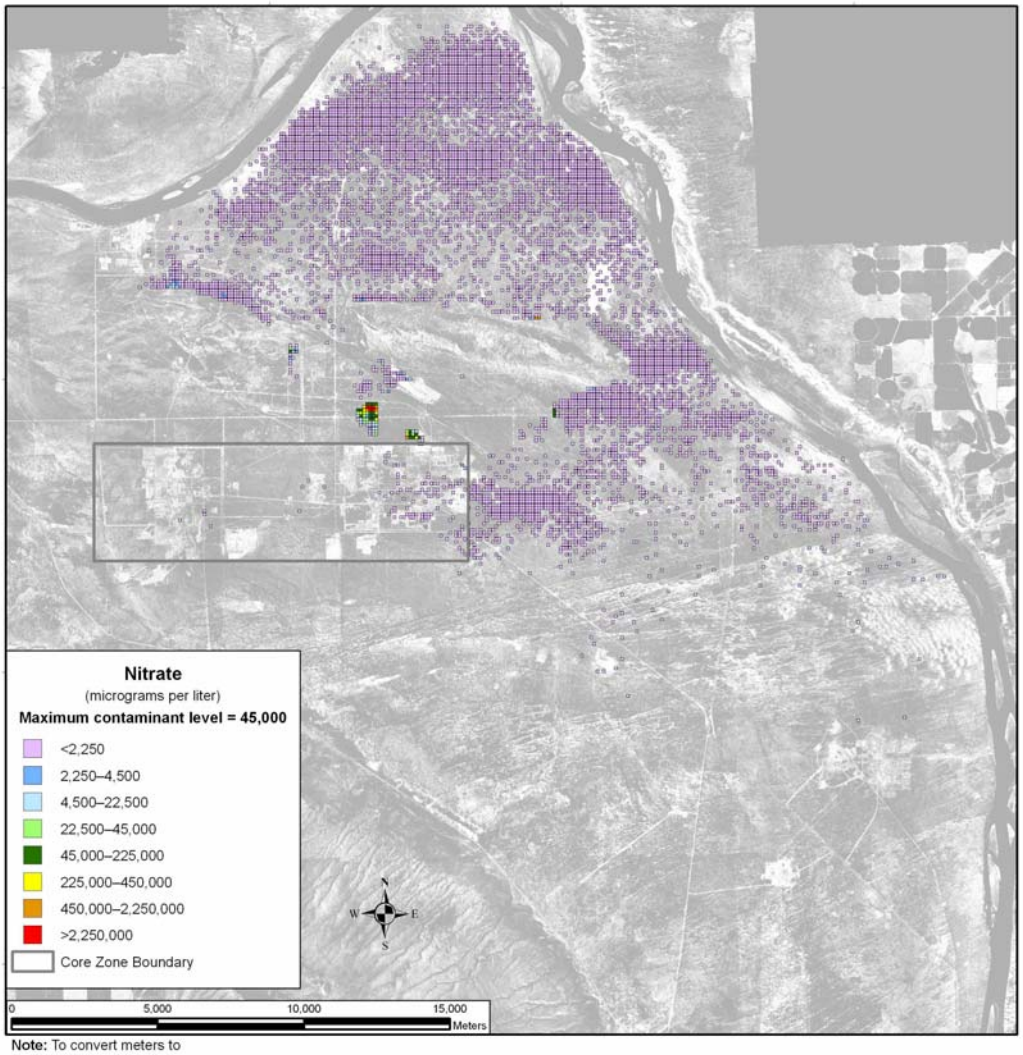
Note: To convert meters to feet, multiply by 3.281

Figure 5–133. Tank Closure Alternative 4 Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

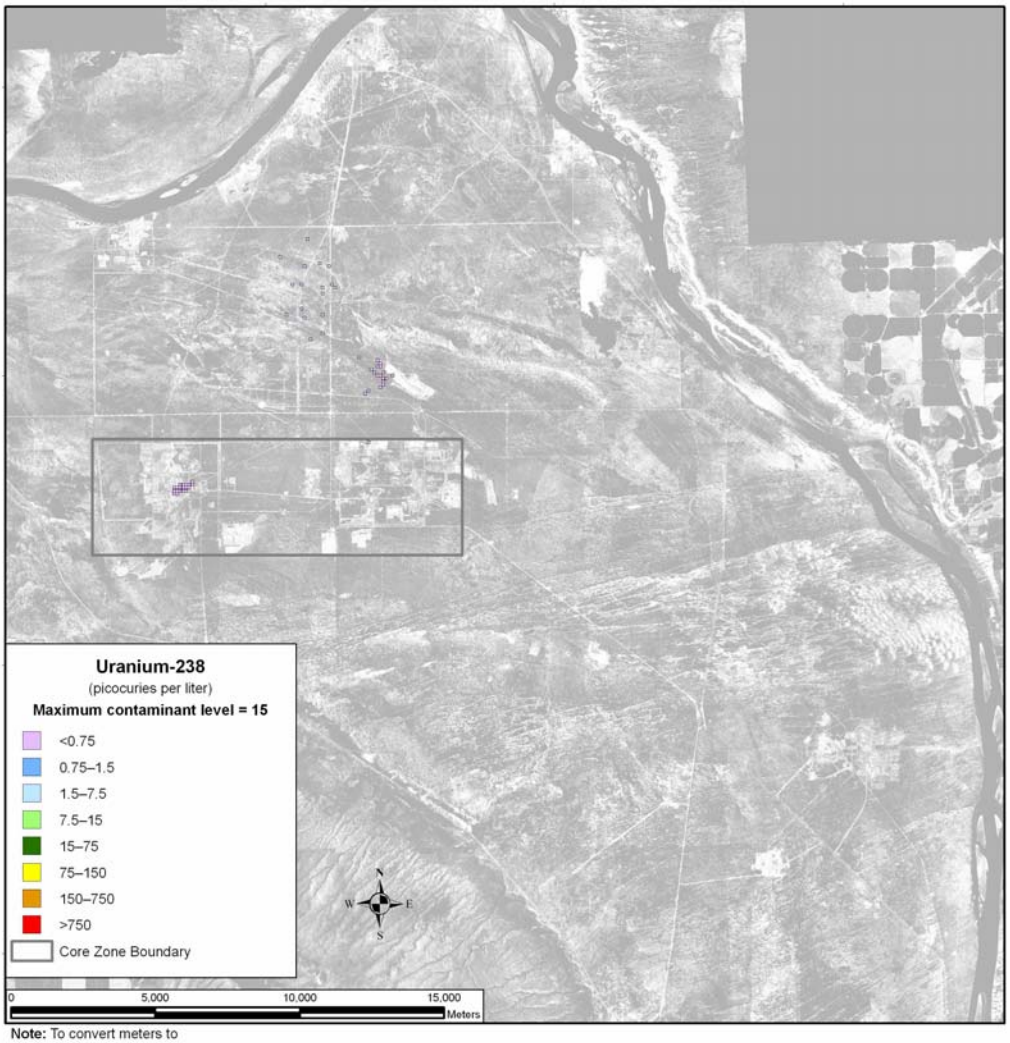
Figure 5–134. Tank Closure Alternative 4 Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281

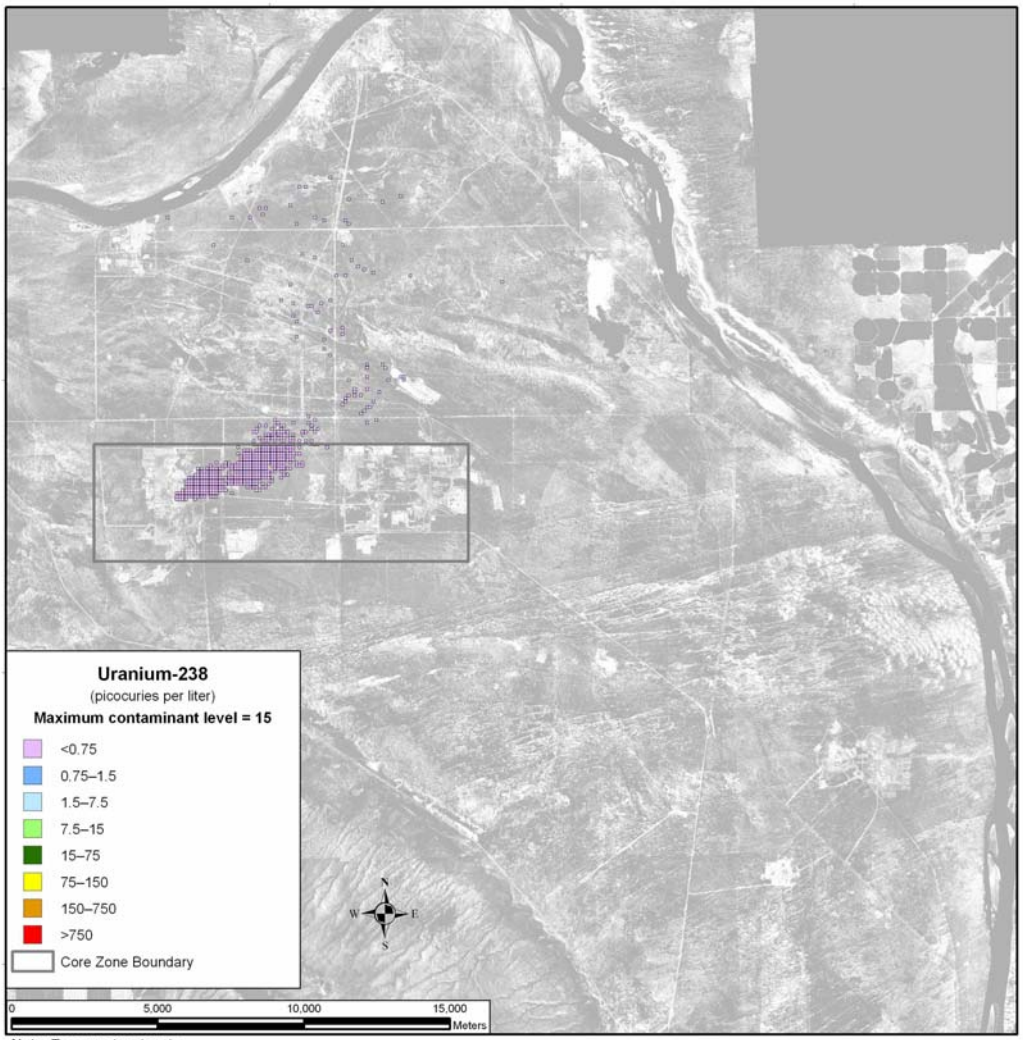
Figure 5–135. Tank Closure Alternative 4 Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 7140

Uranium-238 and total uranium show a different spatial distribution in the analysis over time. These COPCs are 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. The distribution of uranium-238 during CY 2005 is shown in Figure 5–136. By CY 2135 (see Figure 5–137), the area of the plume has grown, but there are no significant increases in peak concentration. By CY 7140 (see Figure 5–138), some areas of higher concentration begin to appear in the western part of the Core Zone Boundary and in the area north of the Core Zone Boundary. At CY 11,885 (see Figure 5–139), the greatest development of the plume during the analysis period is seen, resulting primarily from releases during the past-practice period. At this point, a small area of high concentrations has developed just north of the 200-East Area. Figures 5–140 through 5–143 show the corresponding results for total uranium, which has a similar distribution.



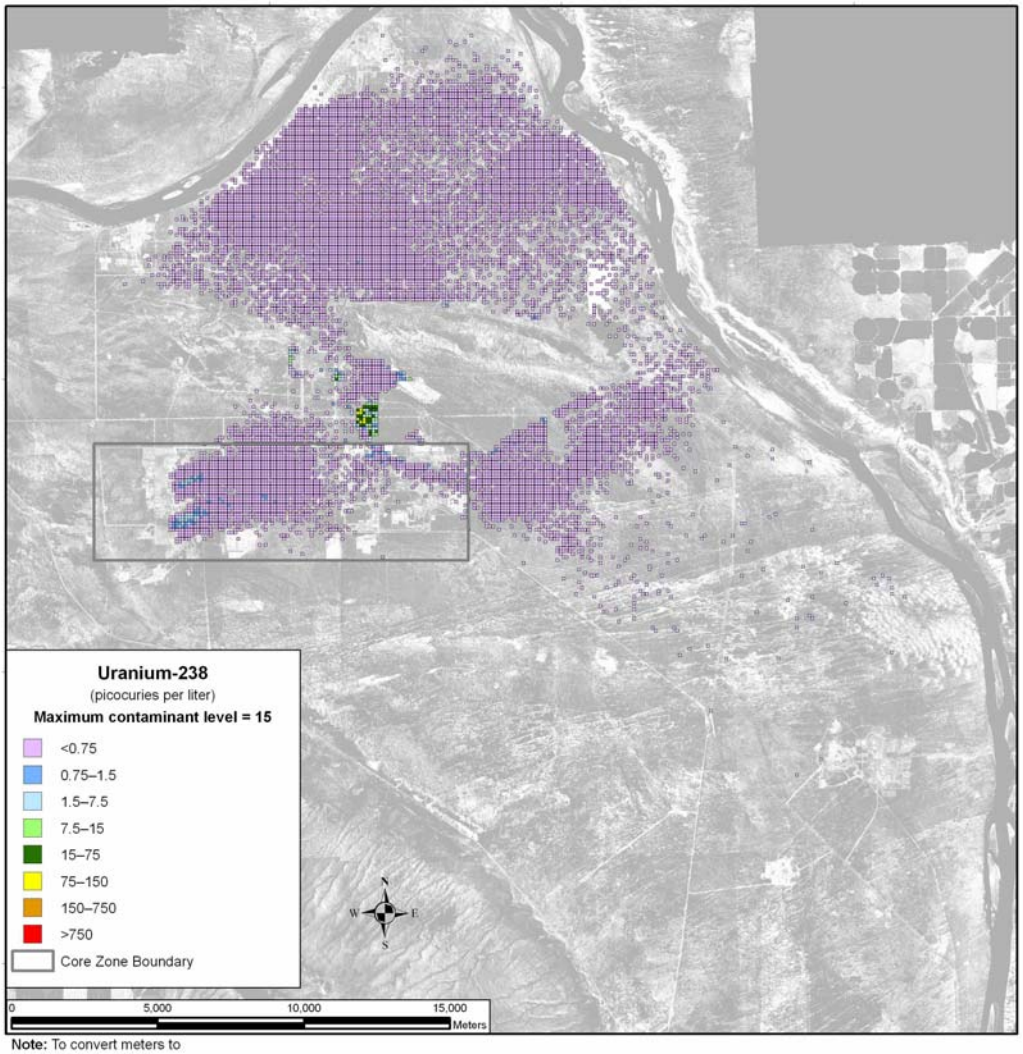
Note: To convert meters to feet, multiply by 3.281

Figure 5–136. Tank Closure Alternative 4 Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

Figure 5–137. Tank Closure Alternative 4 Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281

Figure 5–138. Tank Closure Alternative 4 Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 7140

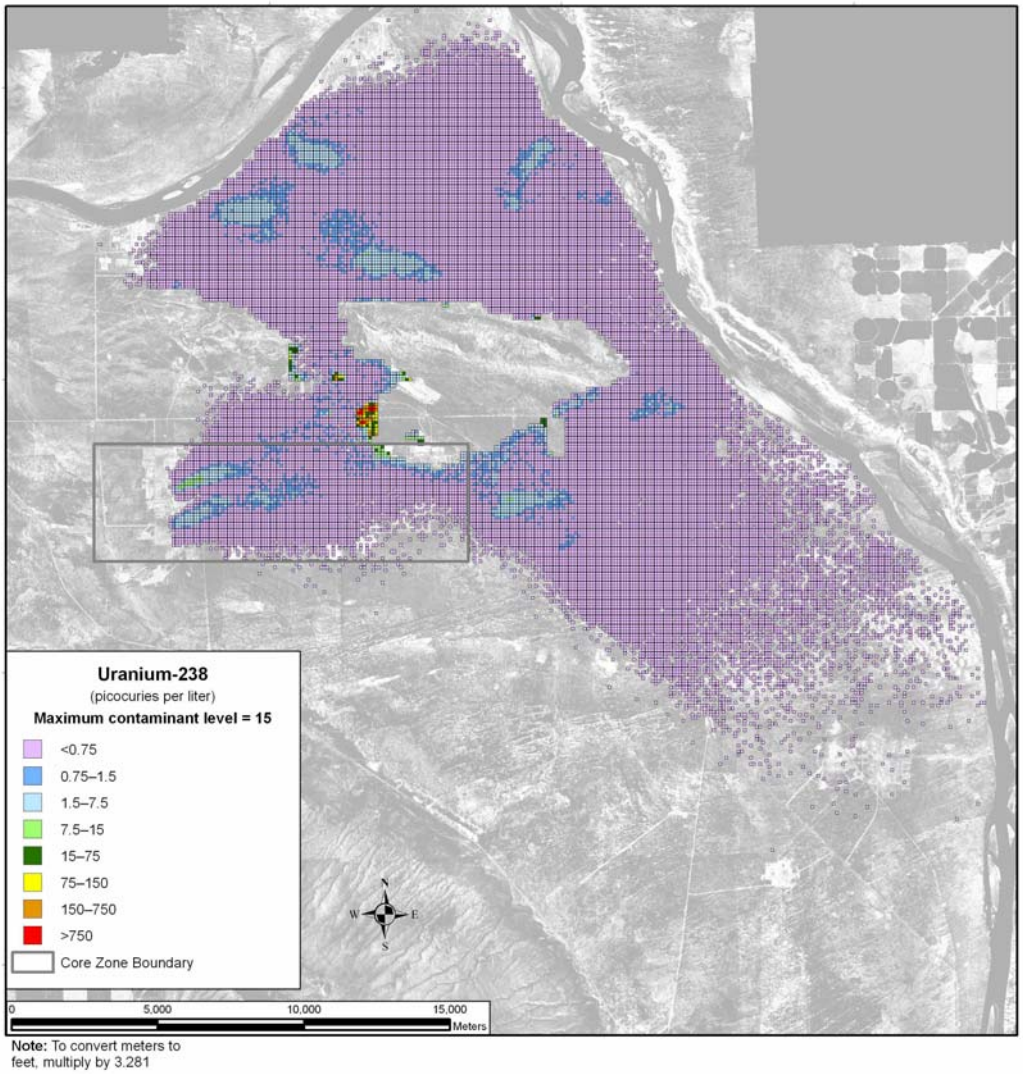
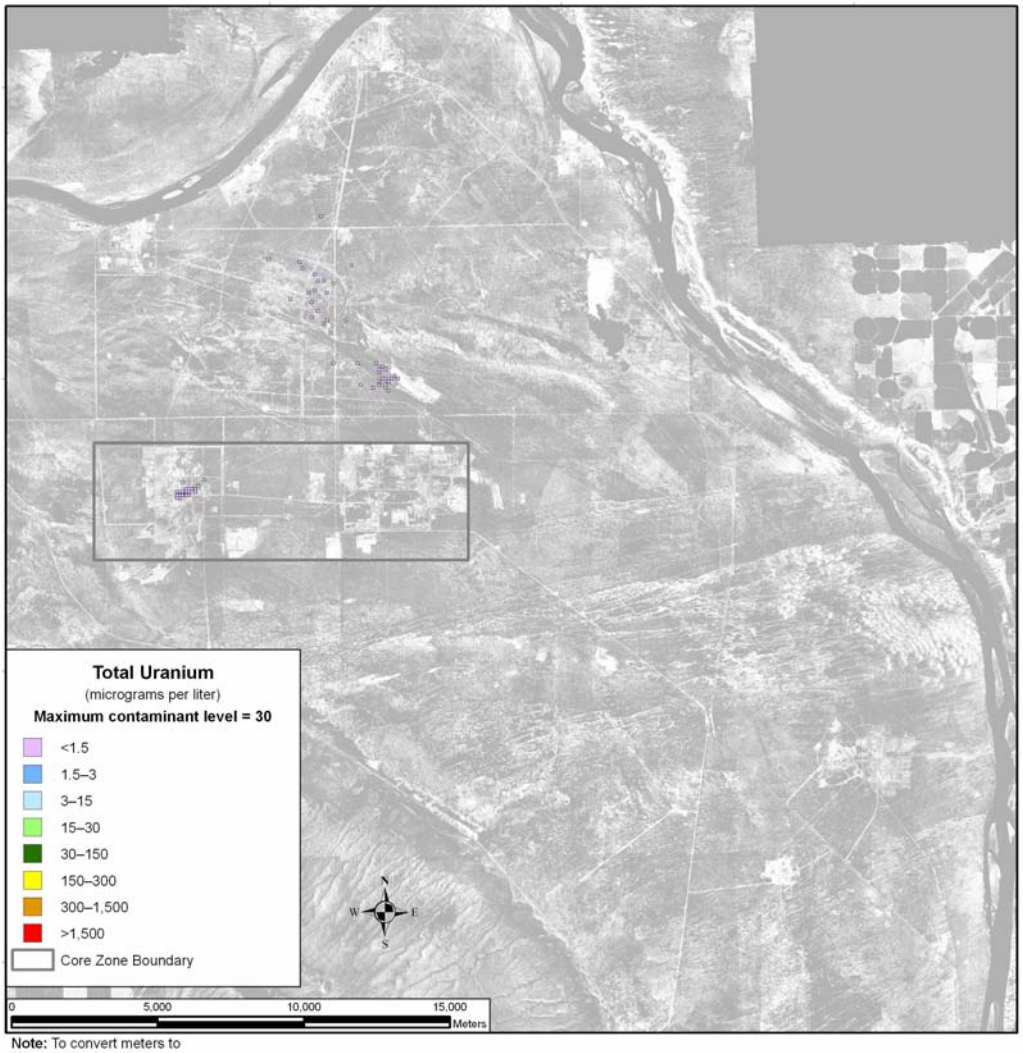
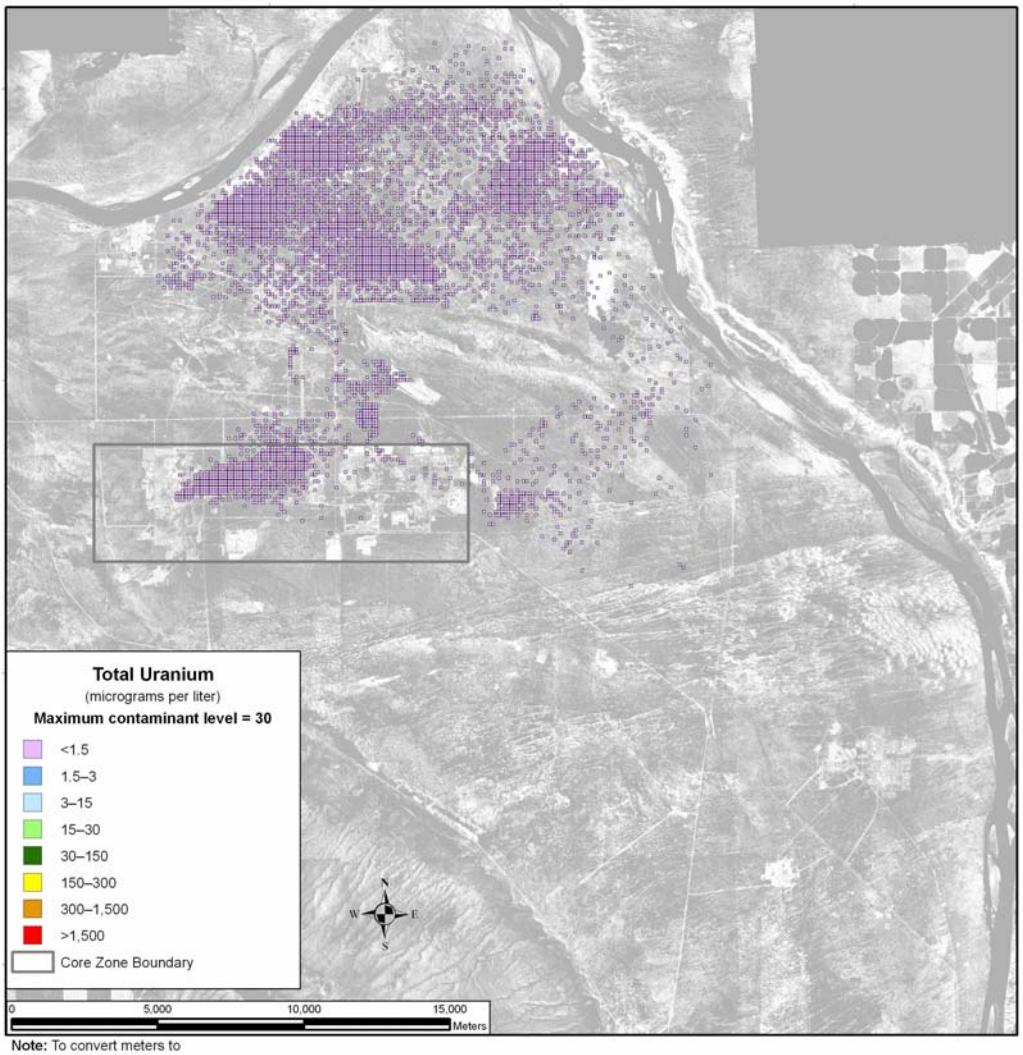


Figure 5–139. Tank Closure Alternative 4 Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 11,885



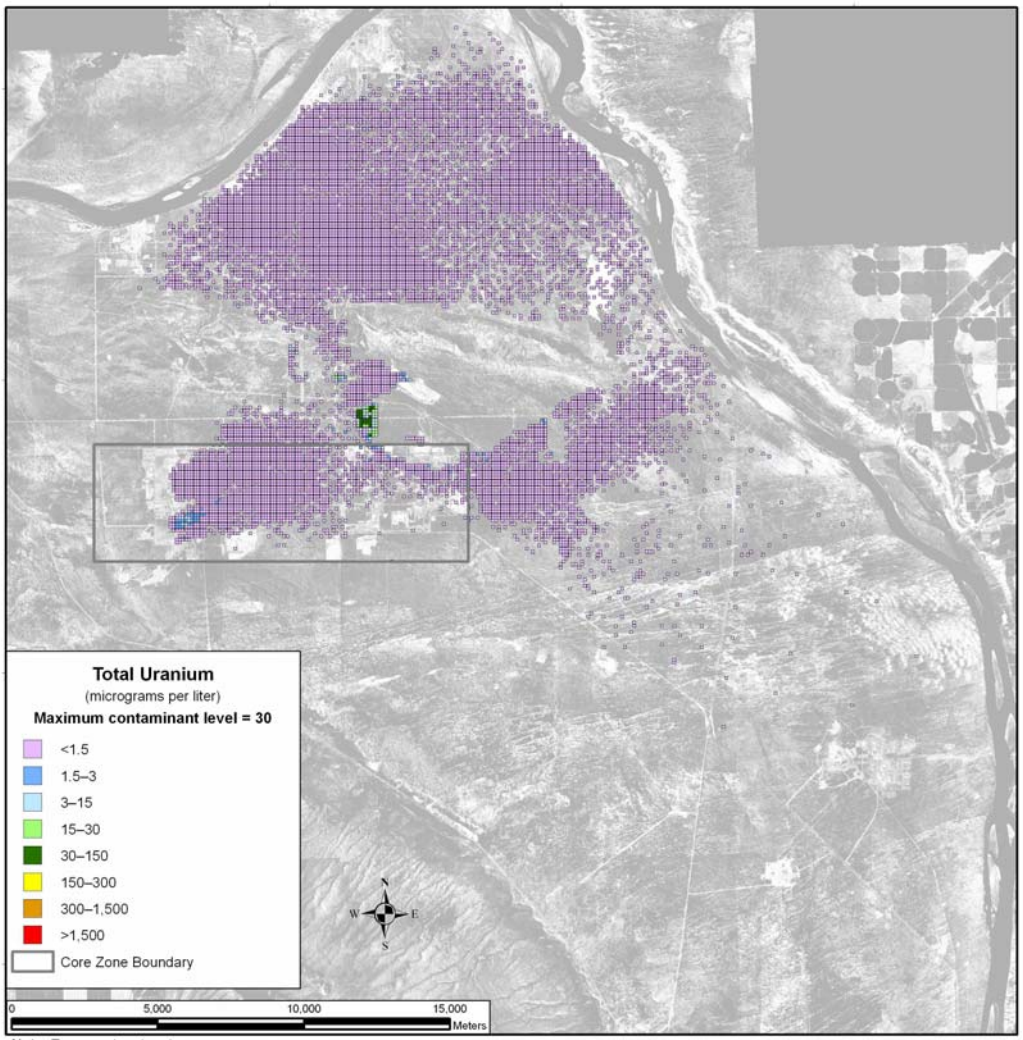
Note: To convert meters to feet, multiply by 3.281

Figure 5–140. Tank Closure Alternative 4 Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 2005



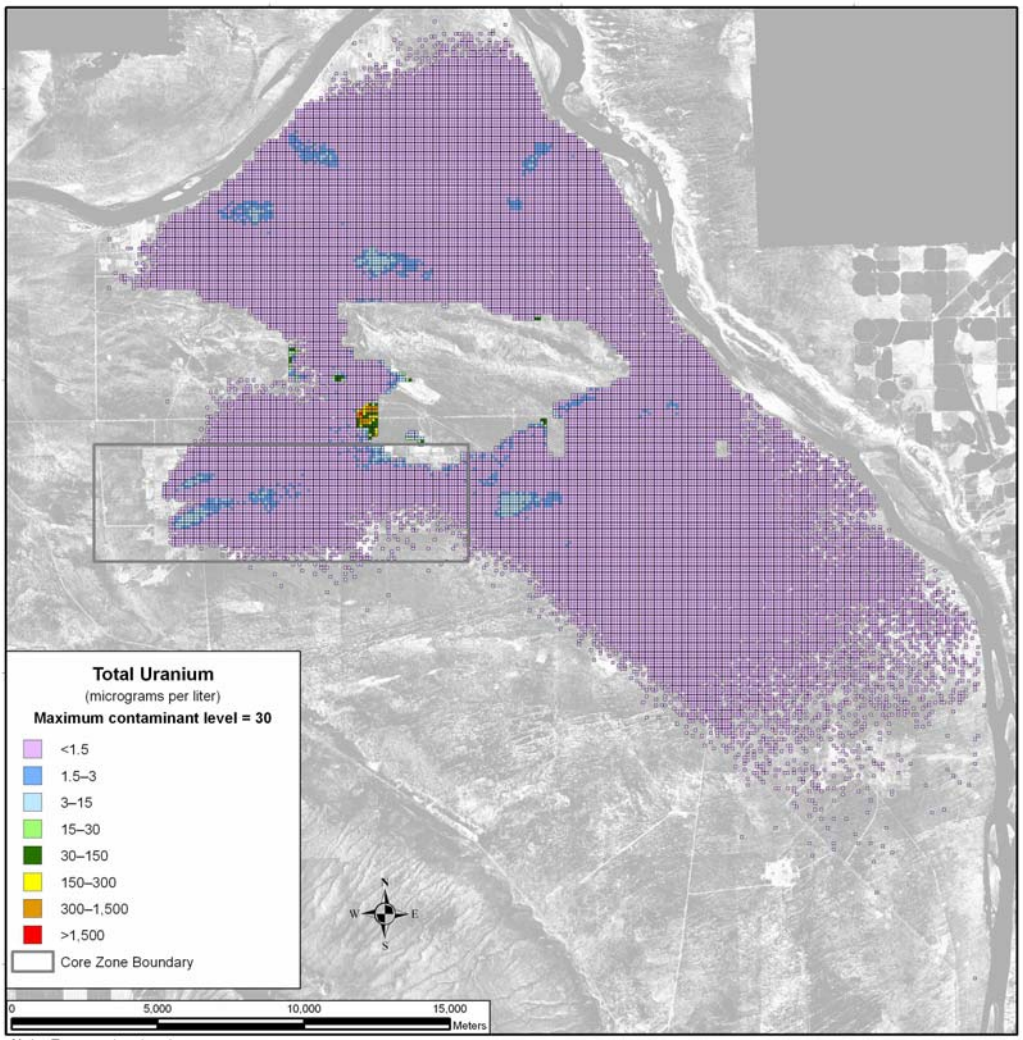
Note: To convert meters to feet, multiply by 3.281

Figure 5–141. Tank Closure Alternative 4 Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 3890



Note: To convert meters to feet, multiply by 3.281

Figure 5–142. Tank Closure Alternative 4 Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281

Figure 5–143. Tank Closure Alternative 4 Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 11,885

Figures 5–144 through 5–146 show the area covered by concentrations above the benchmark concentration for iodine-129, technetium-99, and uranium-238. Iodine-129 spikes early in the simulation, covering a peak area of just over 4 square kilometers (1.5 square miles) around CY 2135. The total area covered by the iodine-129 plume that is above the benchmark concentration drops below 1.1 square kilometers (0.4 square miles) around CY 3890, continuing its decline to 0.5 square kilometers (0.2 square miles) by CY 9740 and remaining near that level for the remainder of the simulation. Technetium-99 shows a similar trend, peaking at just over 8 square kilometers (3 square miles) in CY 2070 and reaching 0.5 square kilometers (0.2 square miles) in CY 7790. Uranium-238 shows a distinctly different pattern, without any area above the benchmark concentration until CY 5840. From CY 5840 until the end of the simulation, areas of uranium-238 concentrations above the benchmark concentration slowly increase, never exceeding 1.1 square kilometers (0.4 square miles).

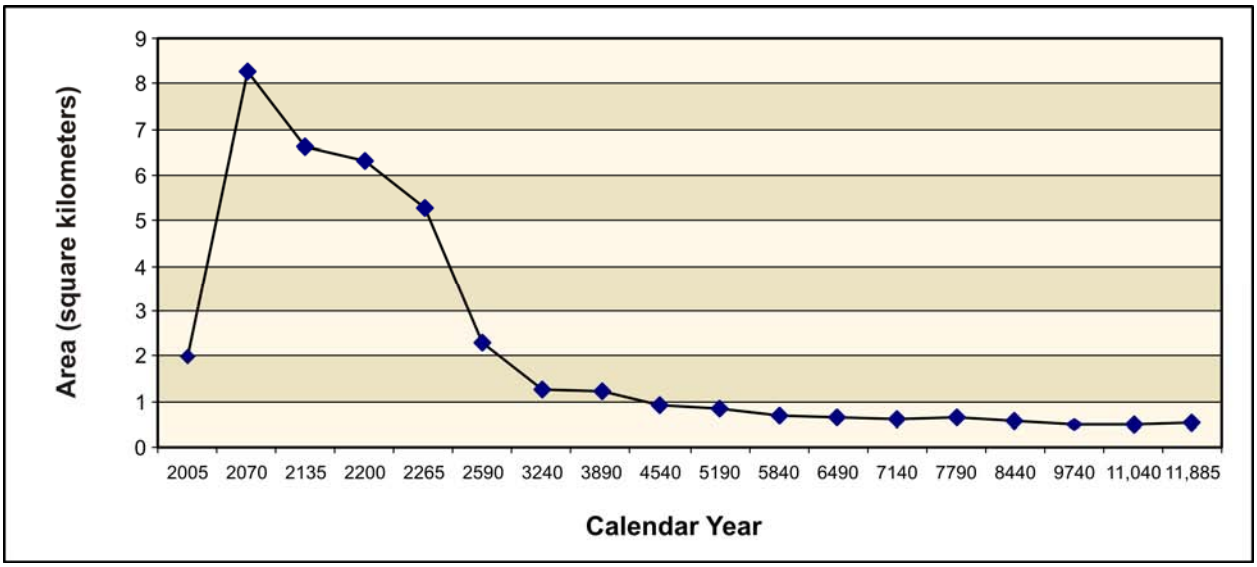


Figure 5–144. Tank Closure Alternative 4 Total Area of Groundwater Iodine-129 Concentration Exceeding the Benchmark Concentration as a Function of Time

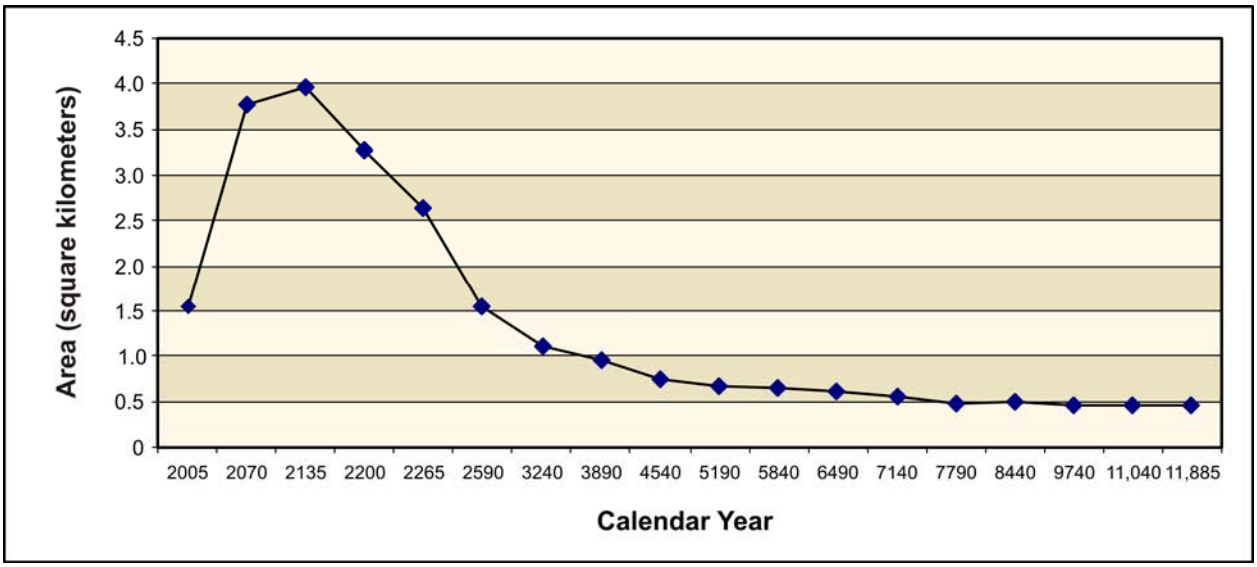


Figure 5–145. Tank Closure Alternative 4 Total Area of Groundwater Technetium-99 Concentration Exceeding the Benchmark Concentration as a Function of Time

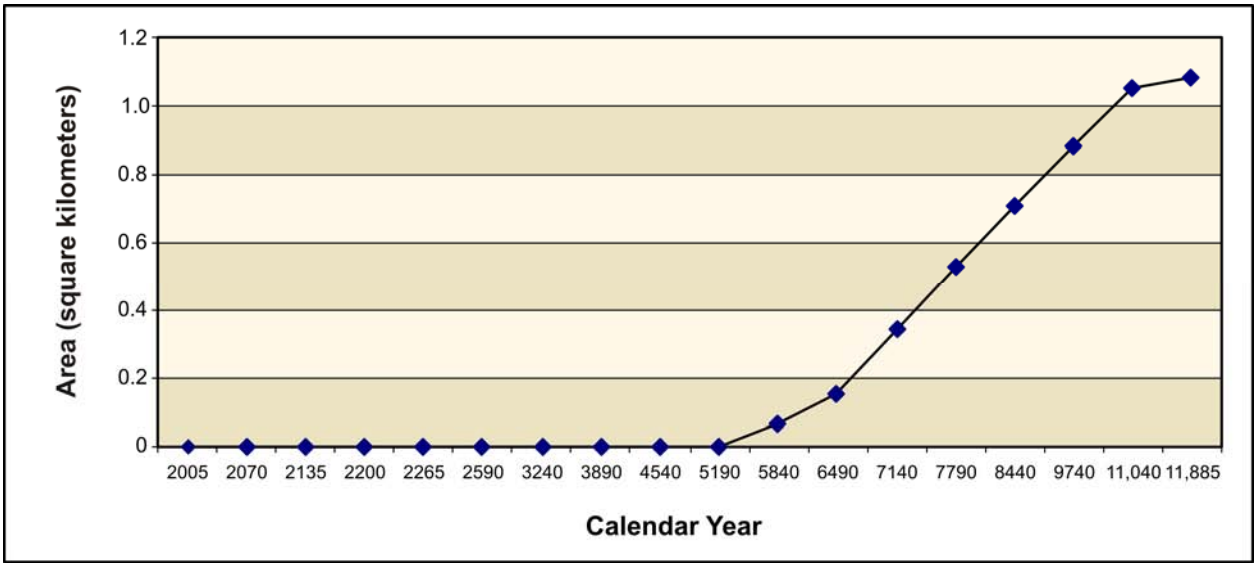


Figure 5–146. Tank Closure Alternative 4 Total Area of Groundwater Uranium-238 Concentration Exceeding the Benchmark Concentration as a Function of Time

5.1.1.7.6 Summary of Impacts

Under Tank Closure Alternative 4, discharges to cribs and trenches (ditches) and past leaks are the predominant contributors. Other tank farm sources, available after the remediation period, are a secondary contributor.

For the conservative tracers, concentrations at the Core Zone Boundary exceed benchmark standards by about one order of magnitude during most of the period of analysis. Concentrations at the Columbia River are about two to three orders of magnitude smaller. The intensities and areas of these groundwater plumes peak around CY 2070.

For tritium, concentrations at the Core Zone Boundary exceed the benchmark by about three orders of magnitude during the first 100 years of the period of analysis. Concentrations at the Columbia River approach the benchmark during this time. Attenuation by radioactive decay is a predominant mechanism that limits the intensity and duration of groundwater impacts of tritium. After CY 2050, tritium impacts are essentially negligible.

For uranium-238 and total uranium, limited mobility is an important factor governing the timeframes and scale of groundwater impacts. The concentrations of these retarded species exceed the benchmark concentration at the Core Zone Boundary beyond CY 8000, and remain below the benchmark concentration at the Columbia River nearshore. The intensity and area of the contamination plume continue to increase until the end of the analysis period.

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

This section describes the groundwater analysis results for Tank Closure Alternative 5, including long-term groundwater impacts of sources from 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.

5.1.1.8.1 Actions and Timeframes Influencing Groundwater Impacts

Summaries of the proposed actions and timelines for Tank Closure Alternative 5 are provided in Chapter 2, Section 2.5. For the long-term groundwater impact analysis, three major periods were identified for Tank Closure Alternative 5, 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 would be 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. Refer to Tank Closure Alternative 1 (see Section 5.1.1) for groundwater impacts during the past-practice period.

- The retrieval period was assumed to start in 2008 and end in CY 2139. During this period, 90 percent of the waste would be retrieved from the tanks. A retrieval loss of 15,140 liters (4,000 gallons) per tank was assumed for all SSTs, with no leakage from DSTs or miscellaneous underground storage tanks. The SST farm system would be landfill-closed with a Hanford barrier. Releases that occurred during the past-practice period would continue to migrate through the vadose zone and groundwater system.

- The post–administrative control period was assumed to start in CY 2140 and continue through the 10,000-year period of analysis until CY 11,940. During this post–administrative control period, releases that occurred during the past-practice period would continue to migrate through the vadose zone and groundwater system. In addition, all remaining waste at the SST farms (other tank farm sources) would be released to the vadose zone at the start of the post–administrative control period.

5.1.1.8.2 COPC Drivers

A total of 19 COPCs were analyzed for Tank Closure Alternative 5. 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 5 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 5 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, they become major contributors toward the end of the period of analysis. 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^{-13}, 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 5.

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.

5.1.1.8.3 Analysis of Release and Mass Balance

This section presents the impacts of Tank Closure Alternative 5 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 5–147 through 5–152). Three subtotals are plotted representing releases from cribs and trenches (ditches), past leaks, and other tank farm sources. 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 5–147 shows the estimated release to the vadose zone for the radiological risk drivers and Figure 5–148, the chemical hazard drivers. For all three types of sources, the release to the vadose zone is controlled by the inventory (i.e., 90 percent of the inventory was removed during the period of analysis by supplemental treatment technologies). The predominant sources for tritium 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 other tank farm sources. This suggests that other tank farm sources, which are released in the analysis during the post–administrative control period, are an important impact driver under Tank Closure Alternative 5.

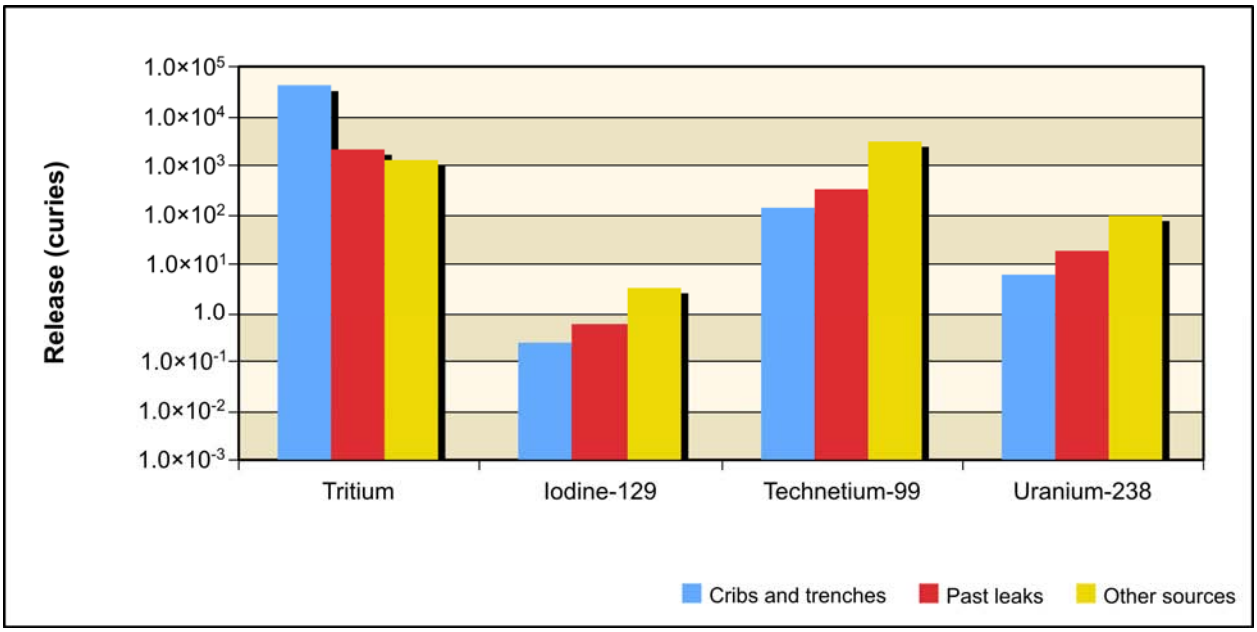


Figure 5–147. Tank Closure Alternative 5 Releases of Radiological Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

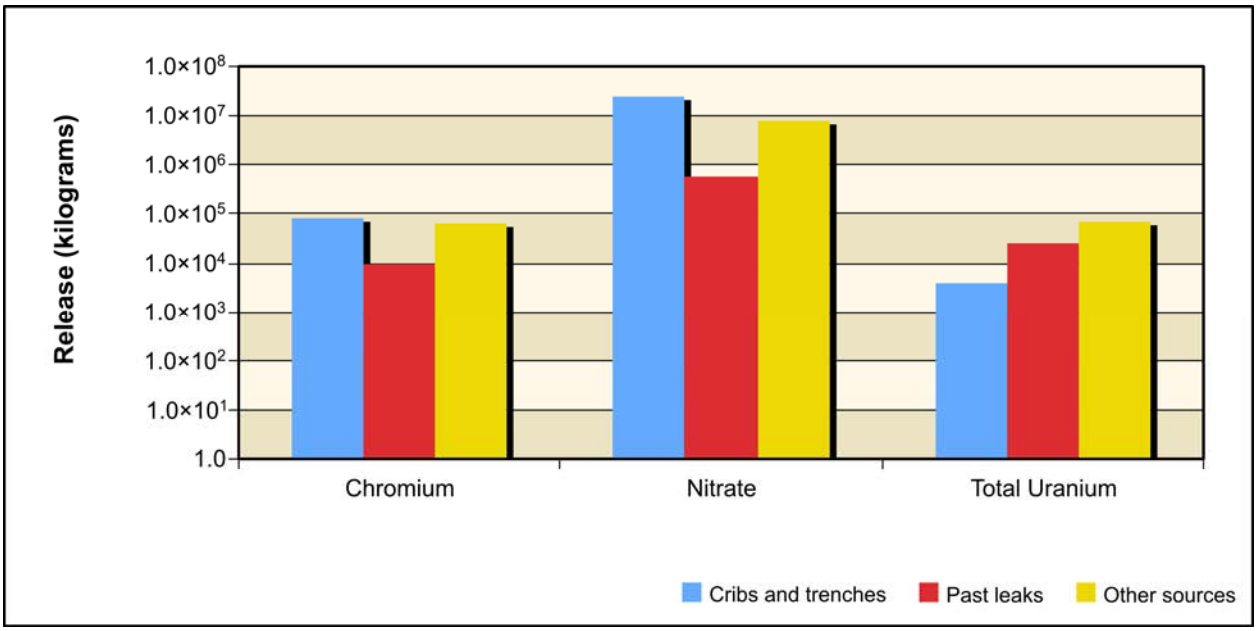


Figure 5–148. Tank Closure Alternative 5 Releases of Chemical Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

Figure 5–149 shows the estimated release to groundwater for the radiological risk drivers and Figure 5–150, 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, chromium, and nitrate), the amount released to groundwater is essentially equal to the amount released to the vadose zone.

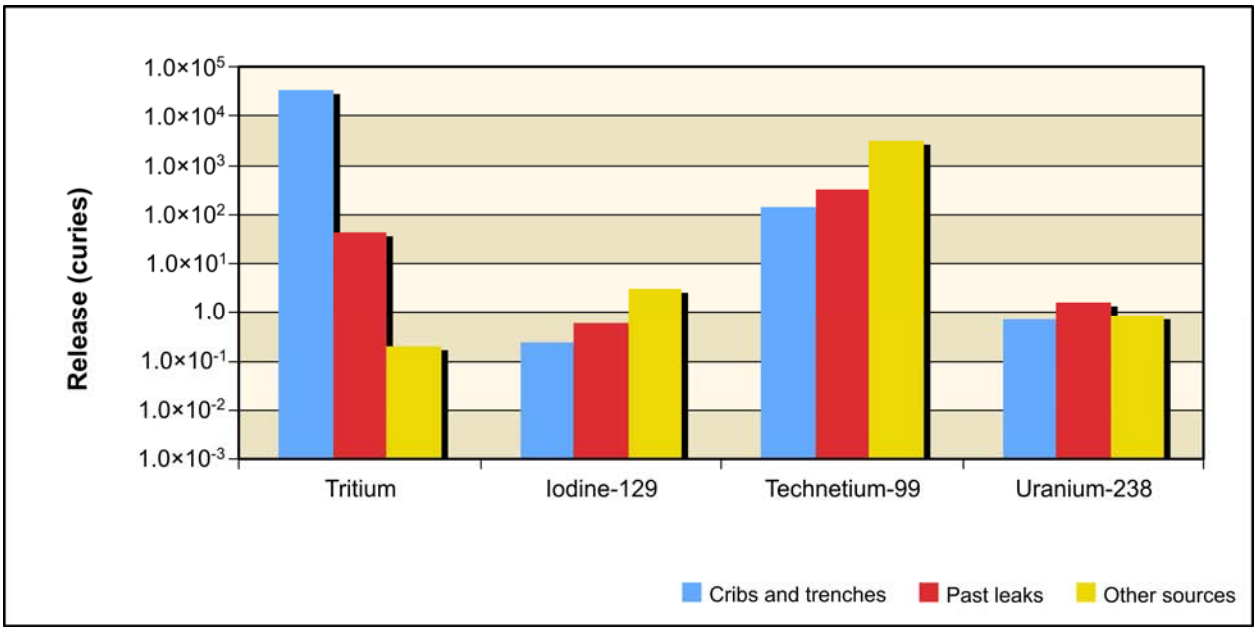


Figure 5–149. Tank Closure Alternative 5 Releases of Radiological Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

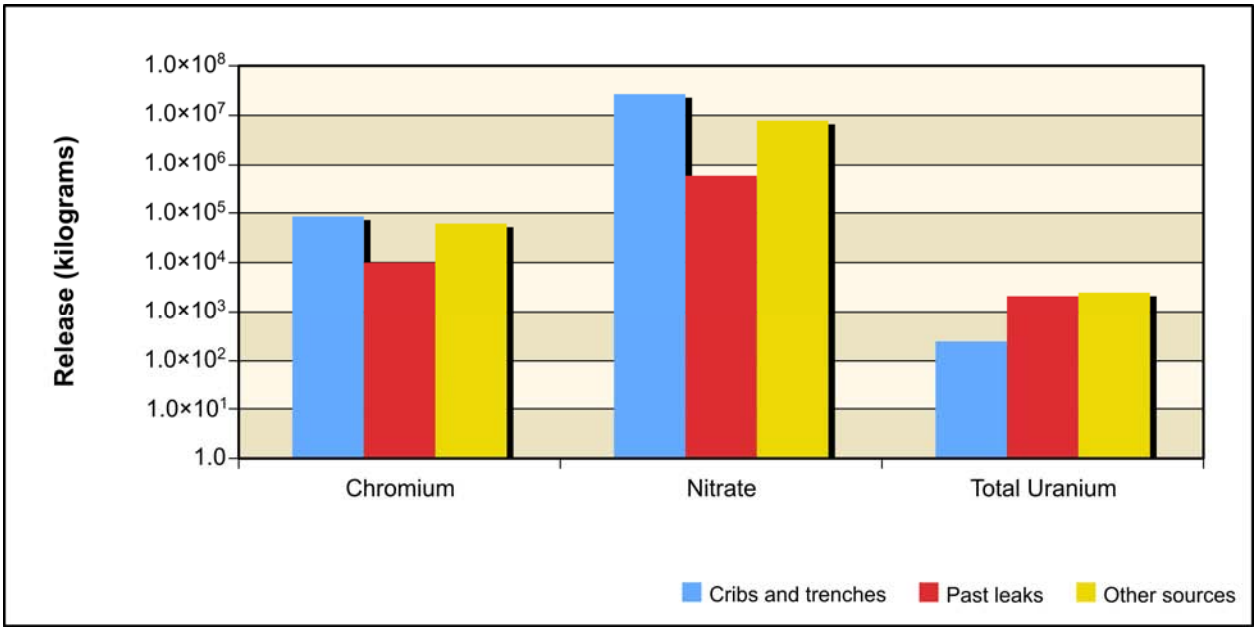


Figure 5–150. Tank Closure Alternative 5 Releases of Chemical Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

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) and past leaks, where moisture movement through the vadose zone is relatively rapid (because of the volume of water associated with the source), about 10 percent of the total inventory reached groundwater during the period of analysis; for other tank farm sources, only about 2 percent reached groundwater.

For tritium, the amount released to groundwater is attenuated by radioactive decay. For cribs and trenches (ditches), about 70 percent of the total inventory reached groundwater in the analysis; for past leaks, only 2 percent; and for other tank farm sources, only one-third of 1 percent reached the water table. 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 5–151 shows the estimated release to the Columbia River for the radiological risk drivers and Figure 5–152, 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. 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. Overall, about 25 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. Overall, only about 3 percent of the tritium released to groundwater reached the Columbia River during the period of analysis. 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.

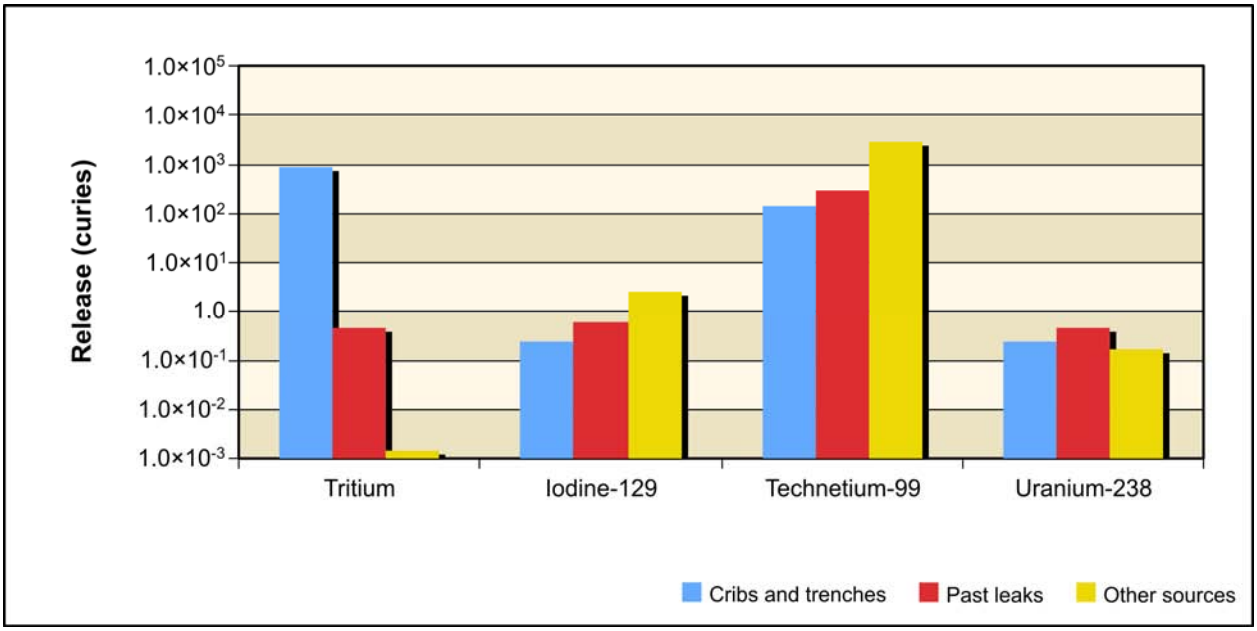


Figure 5–151. Tank Closure Alternative 5 Releases of Radiological Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

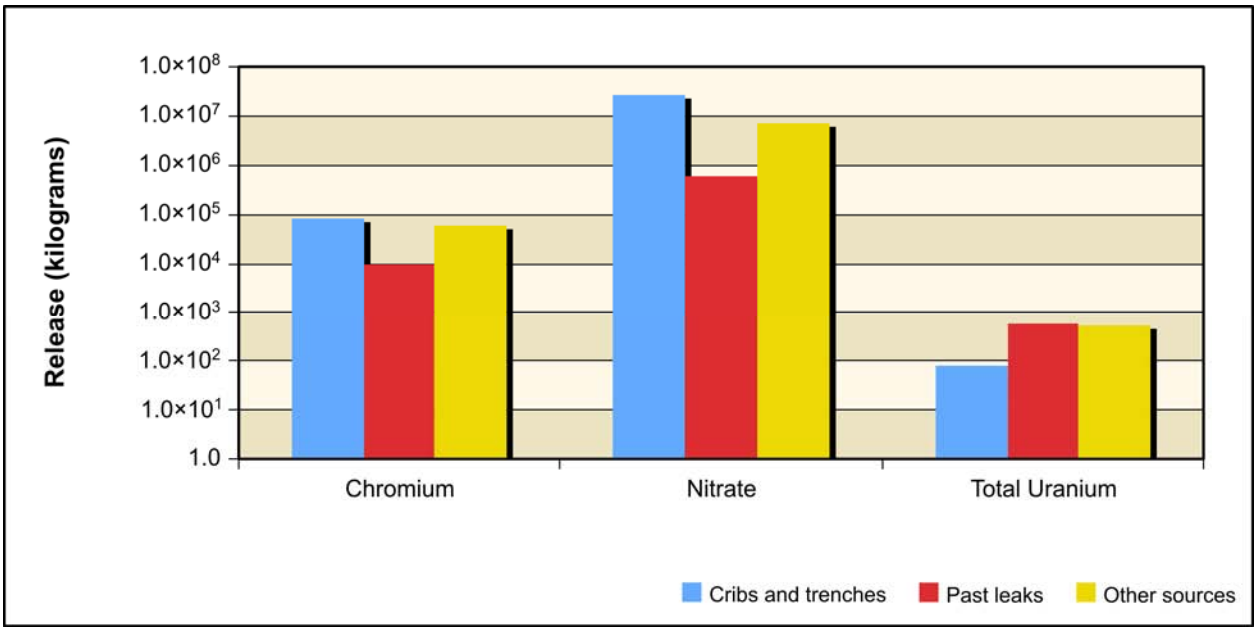


Figure 5–152. Tank Closure Alternative 5 Releases of Chemical Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

5.1.1.8.4 Analysis of Concentration Versus Time

This section presents the analysis of Tank Closure Alternative 5 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 Table 5–5 and Figures 5–153 through 5–159). 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 five orders of magnitude. Table 5–5 lists the maximum concentrations of the COPCs in the peak year after CY 2050 at the tank farm barriers, Core Zone Boundary, and Columbia River nearshore.

Figure 5–153 shows concentration versus time for tritium. Releases from cribs and trenches (ditches) cause groundwater concentrations to exceed benchmark concentrations by about two orders of magnitude for a short period of time during the early part of the period of analysis. During this time, groundwater concentrations at the Columbia River nearshore approach the benchmark concentration. Because the half-life of tritium is less than 13 years, radioactive decay rapidly attenuates groundwater concentration, and tritium is essentially not a factor at times later than CY 2100.

Figures 5–154 through 5–157 show concentration versus time for iodine-129, technetium-99, chromium, and nitrate (the conservative tracers). Releases from cribs and trenches (ditches) cause groundwater concentrations to exceed benchmark concentrations by about two to three orders of magnitude during the early part of the period of analysis. During this time, groundwater concentrations at the Columbia River nearshore approach but do not exceed the benchmark concentration. Releases from other tank farm sources cause groundwater concentrations at the Core Zone Boundary to exceed benchmark concentrations by about one order of magnitude during the middle and latter parts of the period of analysis (around CY 3000 to 5000). During this time, groundwater concentrations at the Columbia River nearshore do not approach the benchmark concentration.

Table 5–5. Tank Closure Alternative 5 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)	28	5,070	52	7,270	13	6,070	178	20,000
	(2051)	(2054)	(2050)	(2055)	(2050)	(2054)	(2050)	
Technetium-99	**3,040**	**22,500**	**3,340**	**15,300**	**1,780**	**35,700**	724	900
	(4338)	(2050)	(3931)	(2050)	(4022)	(4326)	(5017)	
Iodine-129	**3**	**42**	**5**	**19**	0.8	**34**	0.5	1
	(2059)	(2057)	(2050)	(2051)	(4694)	(2057)	(7030)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	1	**67**	**15**	**25**	9	**102**	1	15
	(11,845)	(11,739)	(11,727)	(11,780)	(11,750)	(11,735)	(11,594)	
Chemical in micrograms per liter								
Acetonitrile	8	0	2	0	0	12	1	100
	(4221)	(1940)	(4208)	(1940)	(1940)	(4510)	(4297)	
Chromium	29	**3,210**	**289**	**782**	36	**1,730**	35	100
	(4094)	(2055)	(2050)	(2050)	(3847)	(3891)	(2695)	
Nitrate	6,510	**1,540,000**	13,200	**133,000**	4,510	**1,010,000**	8,750	45,000
	(4099)	(2050)	(3586)	(2054)	(3794)	(2050)	(2450)	
Total uranium	0	**83**	**33**	15	15	**204**	1	30
	(11,795)	(11,798)	(11,473)	(11,815)	(11,821)	(11,805)	(11,935)	

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.

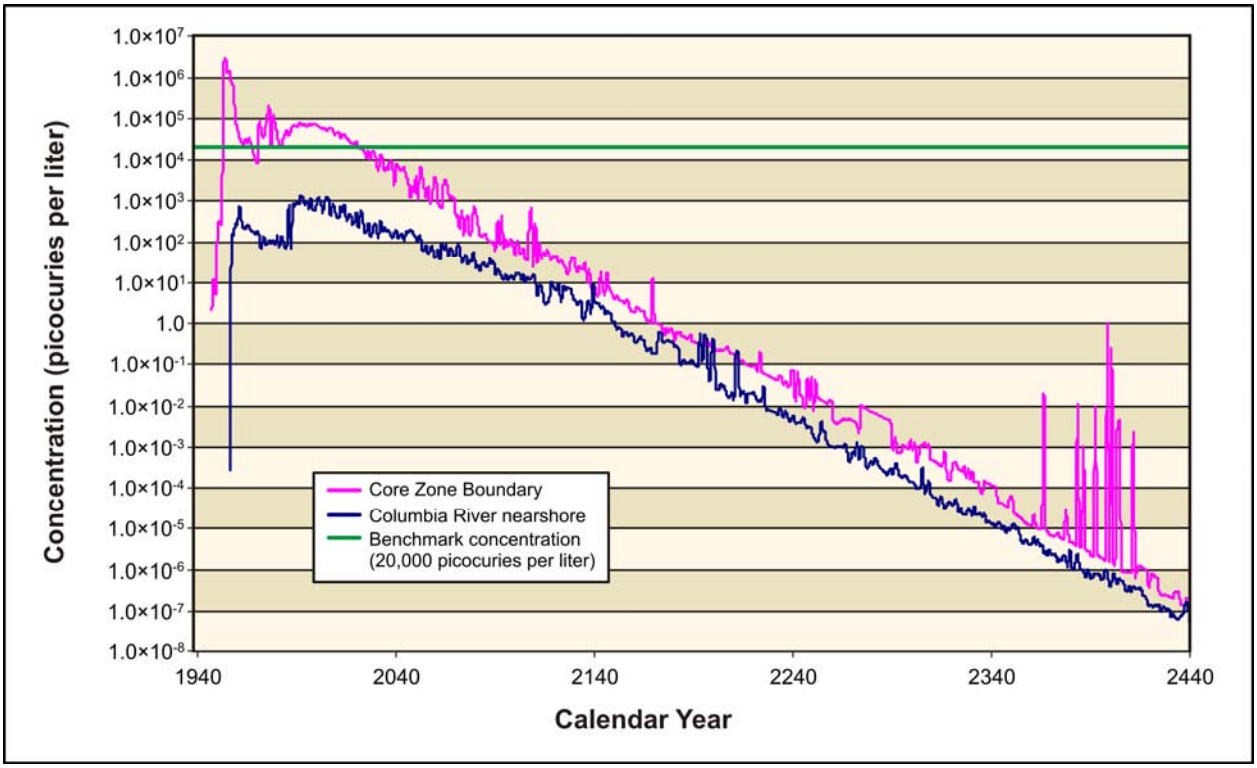


Figure 5–153. Tank Closure Alternative 5 Hydrogen-3 (Tritium) Concentration Versus Time

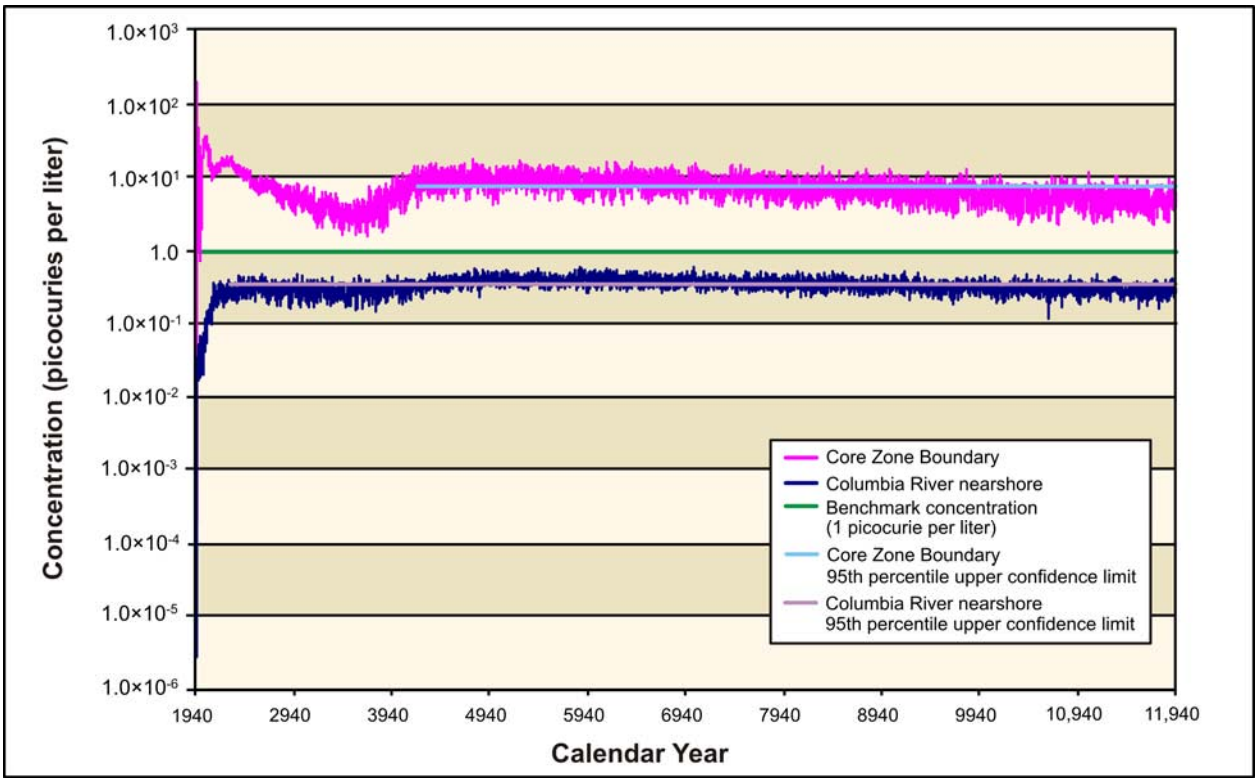


Figure 5–154. Tank Closure Alternative 5 Iodine-129 Concentration Versus Time

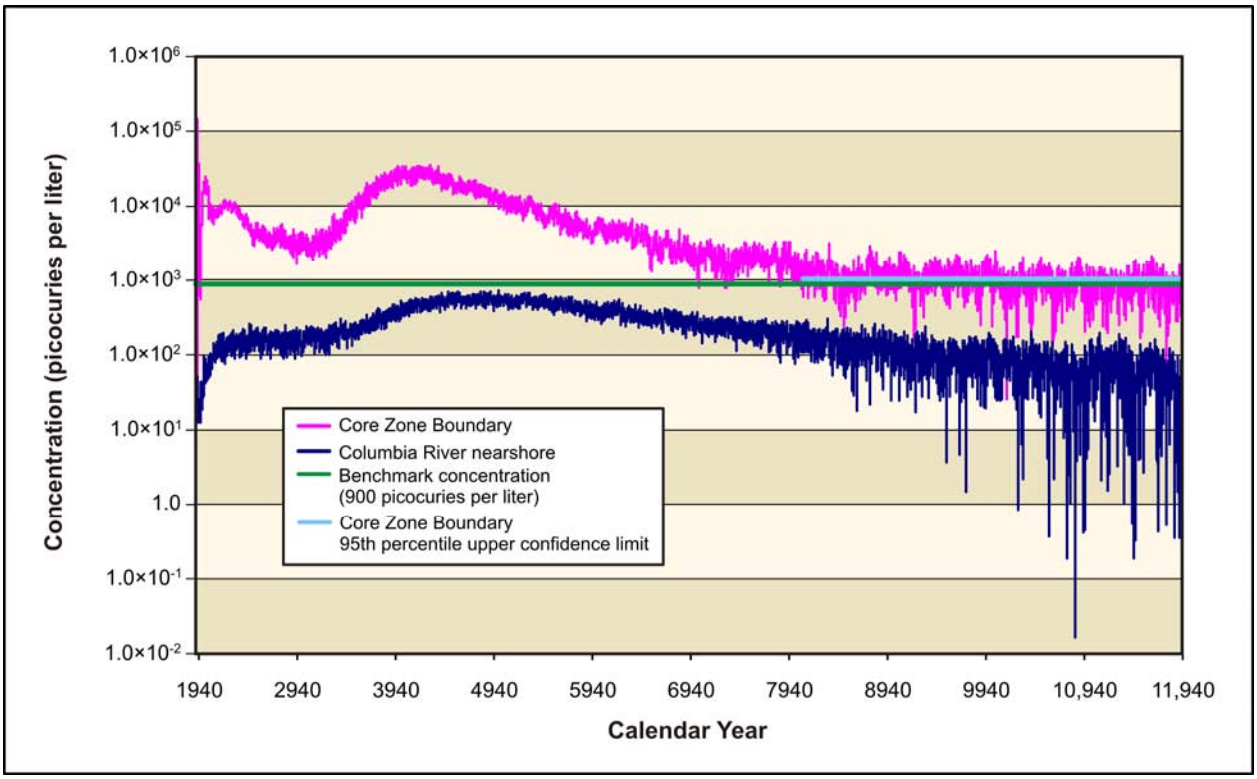


Figure 5–155. Tank Closure Alternative 5 Technetium-99 Concentration Versus Time

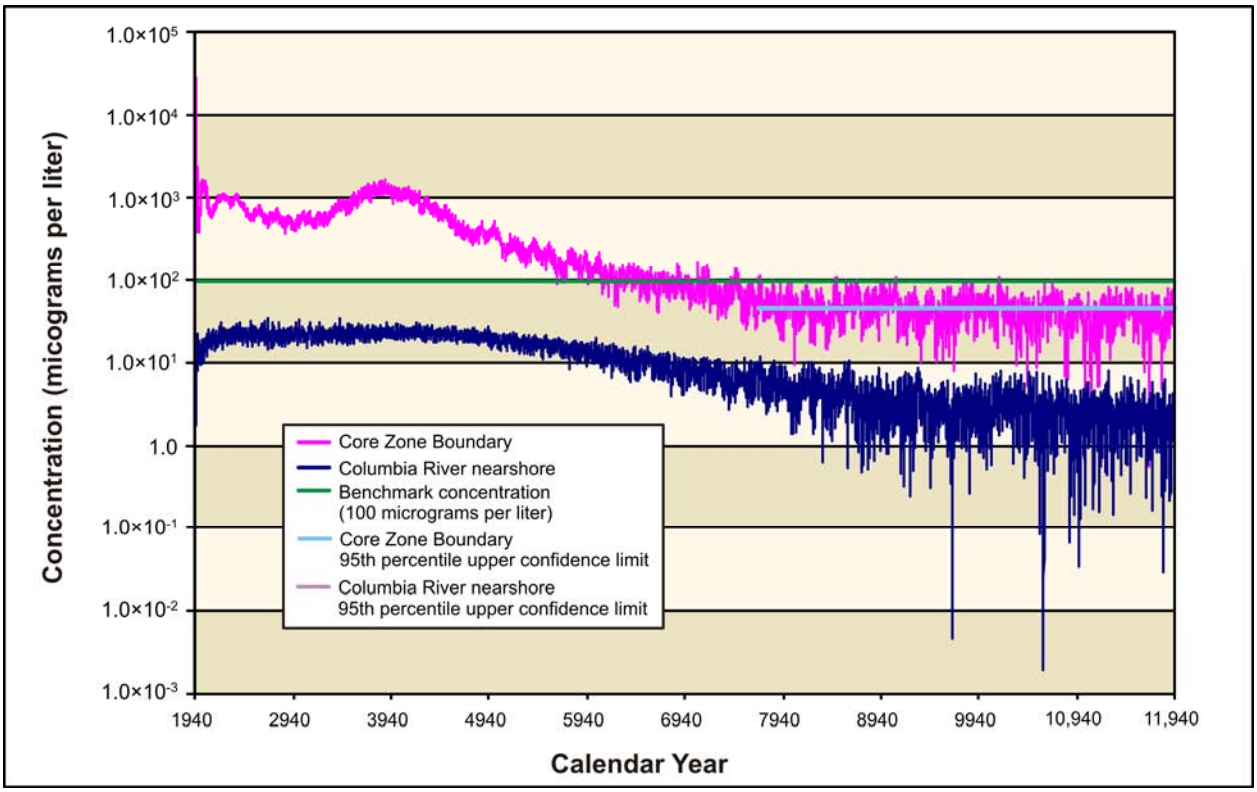


Figure 5–156. Tank Closure Alternative 5 Chromium Concentration Versus Time

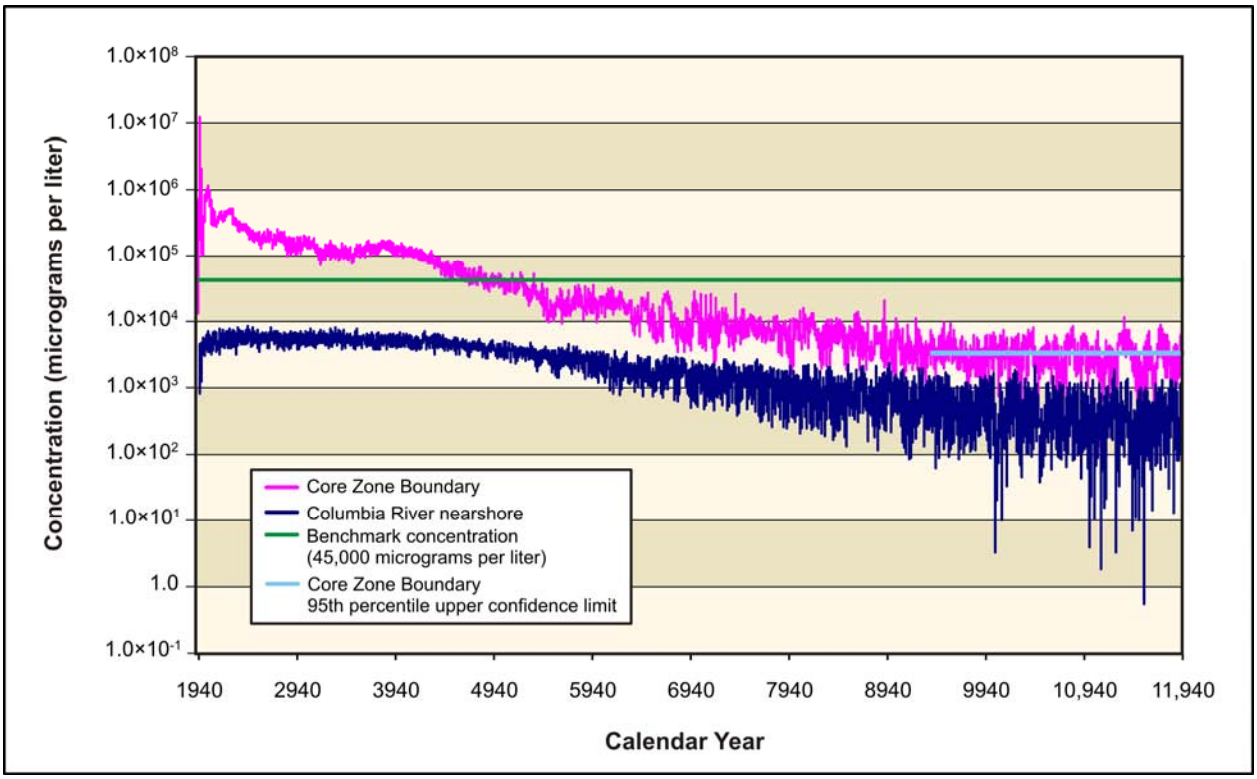


Figure 5–157. Tank Closure Alternative 5 Nitrate Concentration Versus Time

Figures 5–158 and 5–159 show concentration versus time for uranium-238 and total uranium. Early releases from cribs and trenches (ditches) result in groundwater concentrations that are one to two orders of magnitude lower than benchmark concentrations. Releases from other tank farm sources cause groundwater concentrations to rise, nearing benchmark concentrations by CY 8200 for uranium-238 and by CY 8400 for total uranium. Concentrations continue to rise throughout the duration of the period of analysis, exceeding benchmark concentrations by about one order of magnitude at the end of the period of analysis. Groundwater concentrations at the Columbia River nearshore rise throughout the period of analysis, nearing an order of magnitude less than the benchmark concentration by CY 11,940.

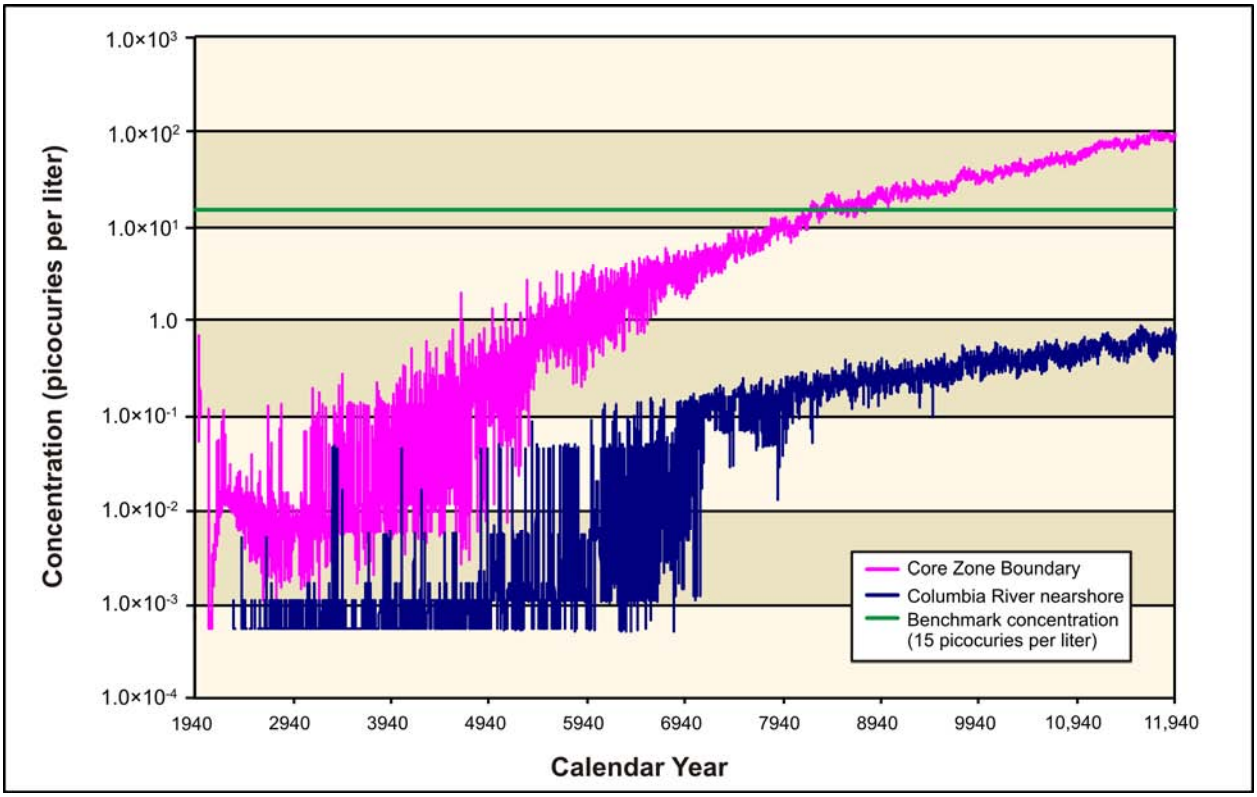


Figure 5–158. Tank Closure Alternative 5 Uranium-238 Concentration Versus Time

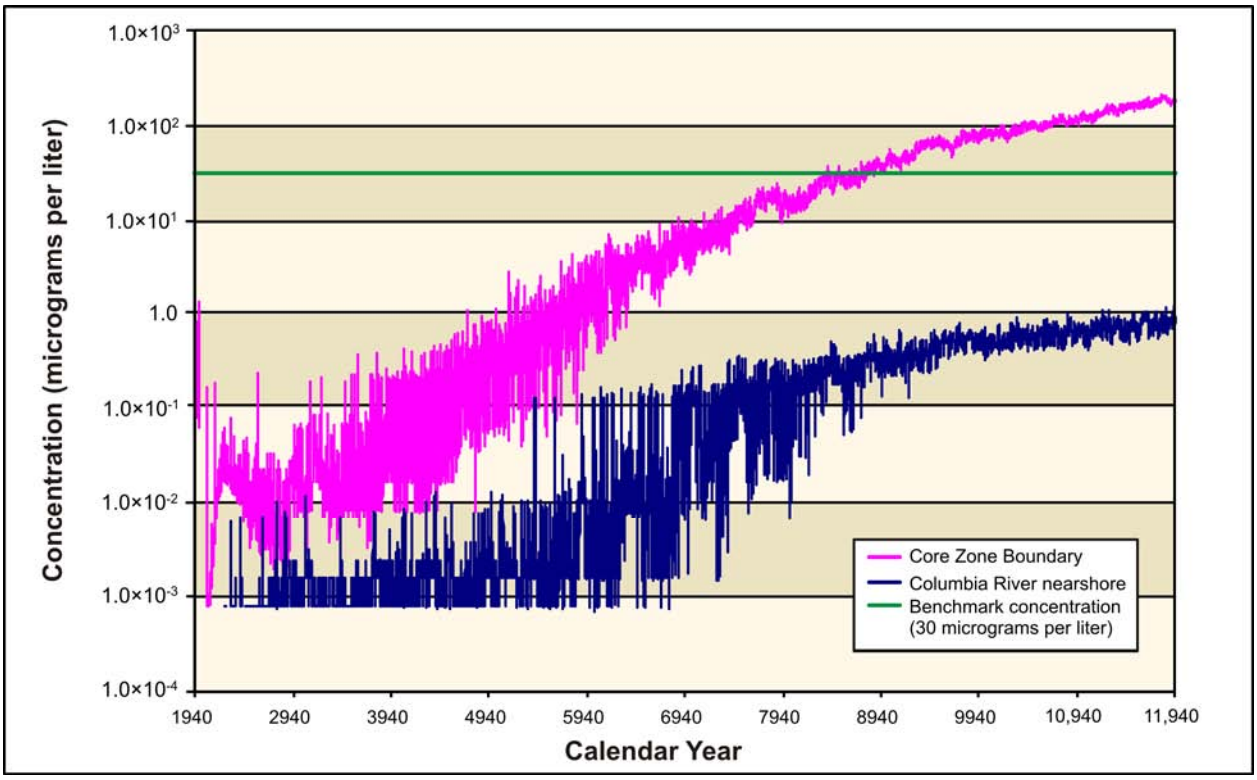
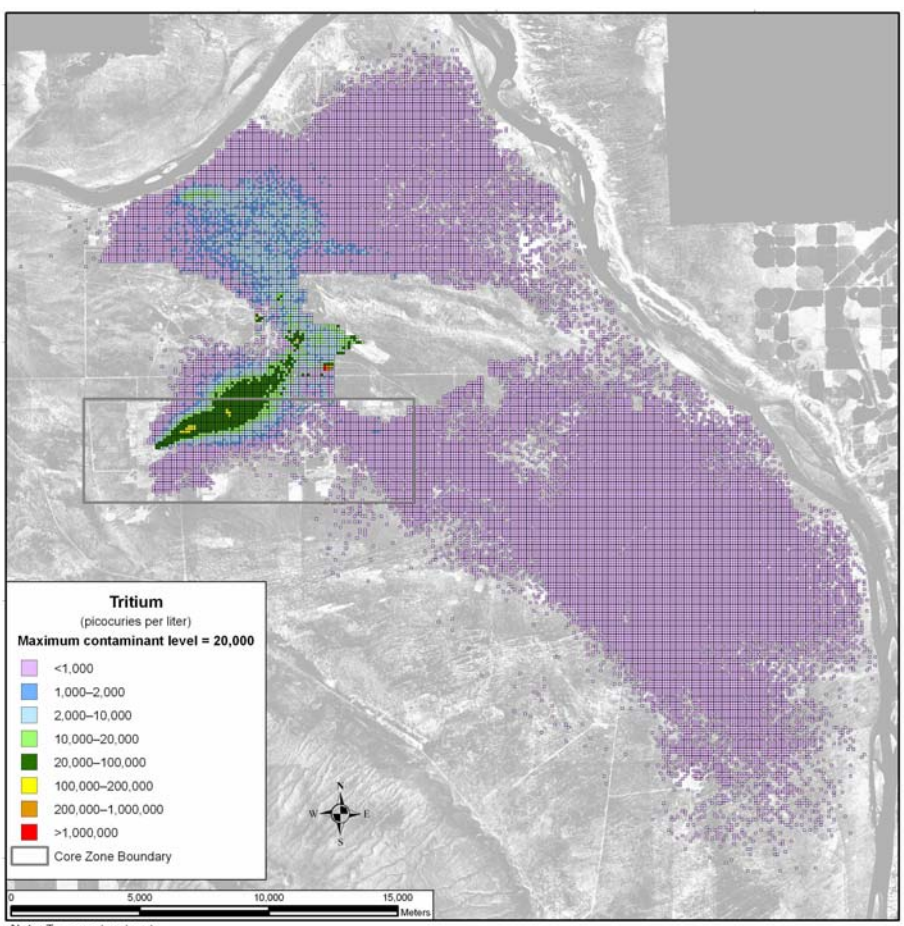


Figure 5–159. Tank Closure Alternative 5 Total Uranium Concentration Versus Time

5.1.1.8.5 Analysis of Spatial Distribution of Concentration

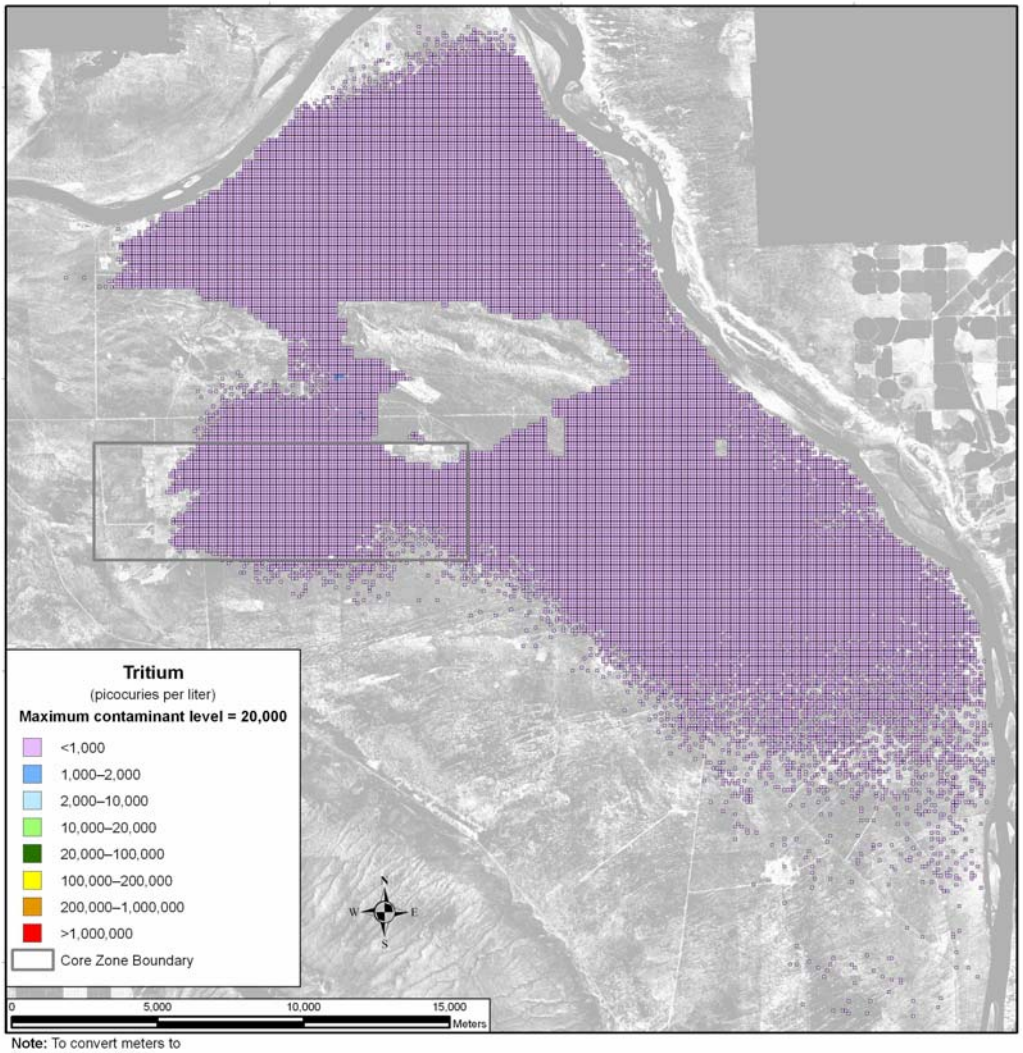
This section presents the impacts of Tank Closure Alternative 5 in terms of the spatial distribution of groundwater concentration at selected times. Concentrations of radionuclides are in picocuries per liter, chemicals in micrograms per liter (see Figures 5–160 through 5–182). Concentrations for each 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 5–160 shows the spatial distribution of groundwater concentration for tritium during CY 2005. Analysis 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. Tritium concentrations are attenuated by radioactive decay to levels less than one-twentieth of the benchmark concentration by CY 2135 (see Figure 5–161).



Note: To convert meters to feet, multiply by 3.281

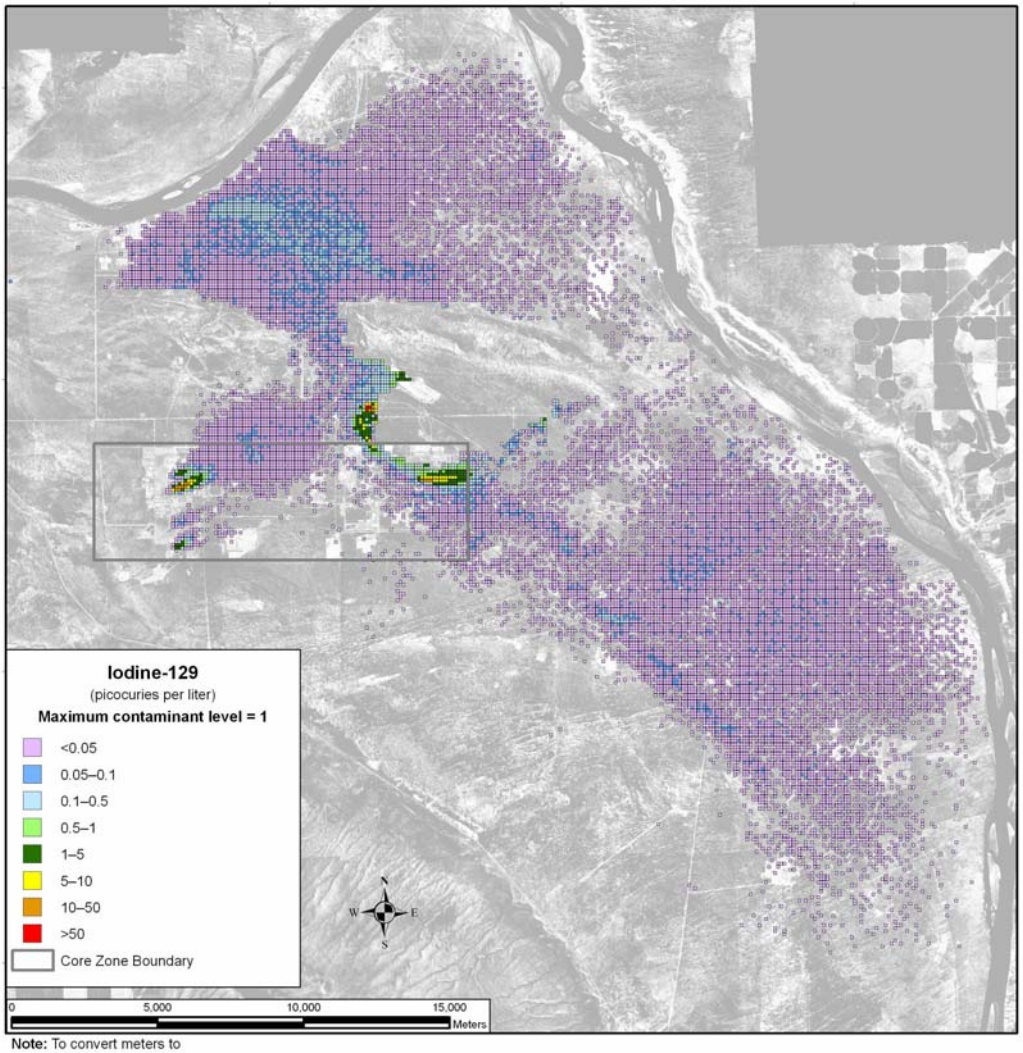
Figure 5–160. Tank Closure Alternative 5 Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

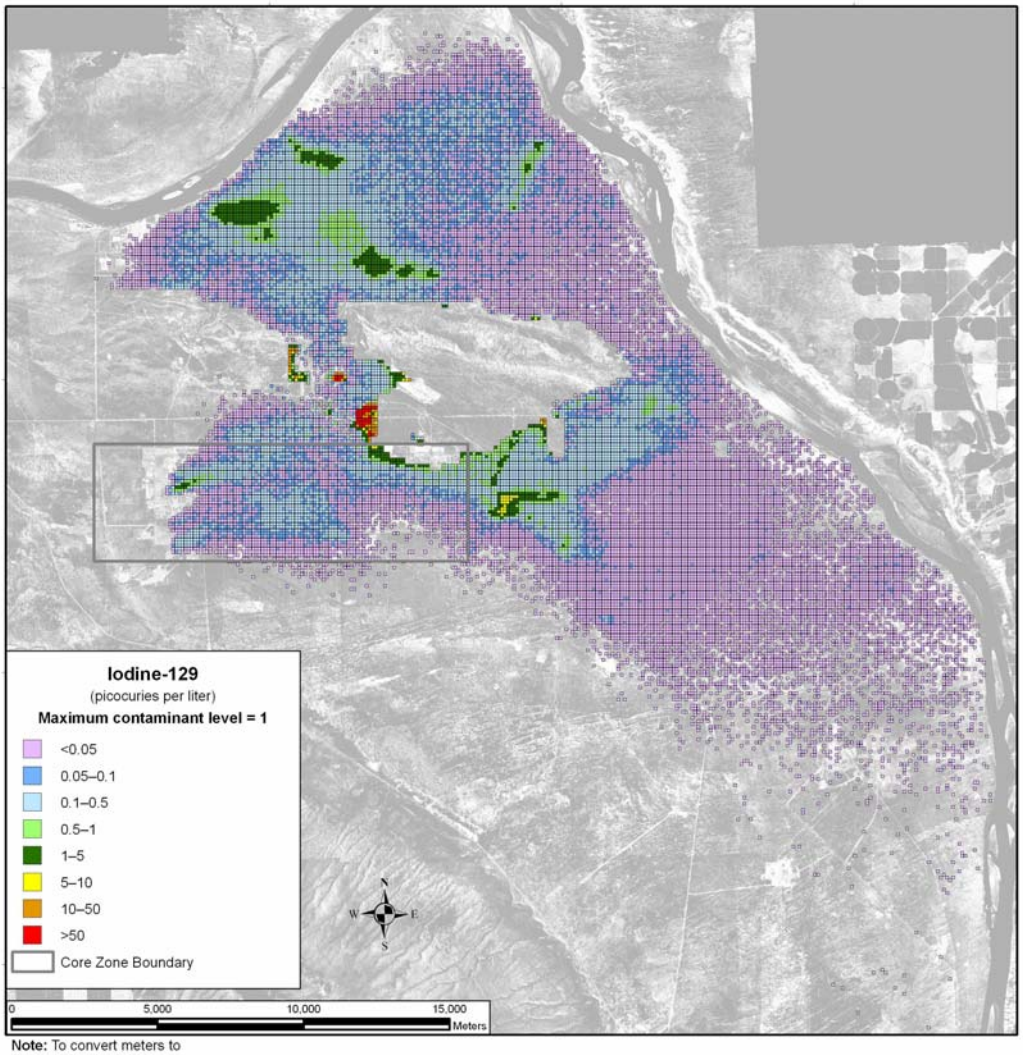
Figure 5–161. Tank Closure Alternative 5 Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2135

Figure 5–162 shows the spatial distribution of groundwater concentration for iodine-129 during CY 2005. 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, S 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. During CY 2135, releases from other tank farm sources create a large plume exceeding the benchmark concentration, extending from the A Barrier to the Columbia River (see Figure 5–163). By CY 7140, most of the mass in the plume has reached the Columbia River, with only isolated pockets of high-concentration areas where the groundwater flow velocities are extremely small (see Figure 5–164). Technetium-99 (see Figures 5–165 through 5–167), chromium (see Figures 5–168 through 5–170), and nitrate (see Figure 5–171 through 5–173) 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).



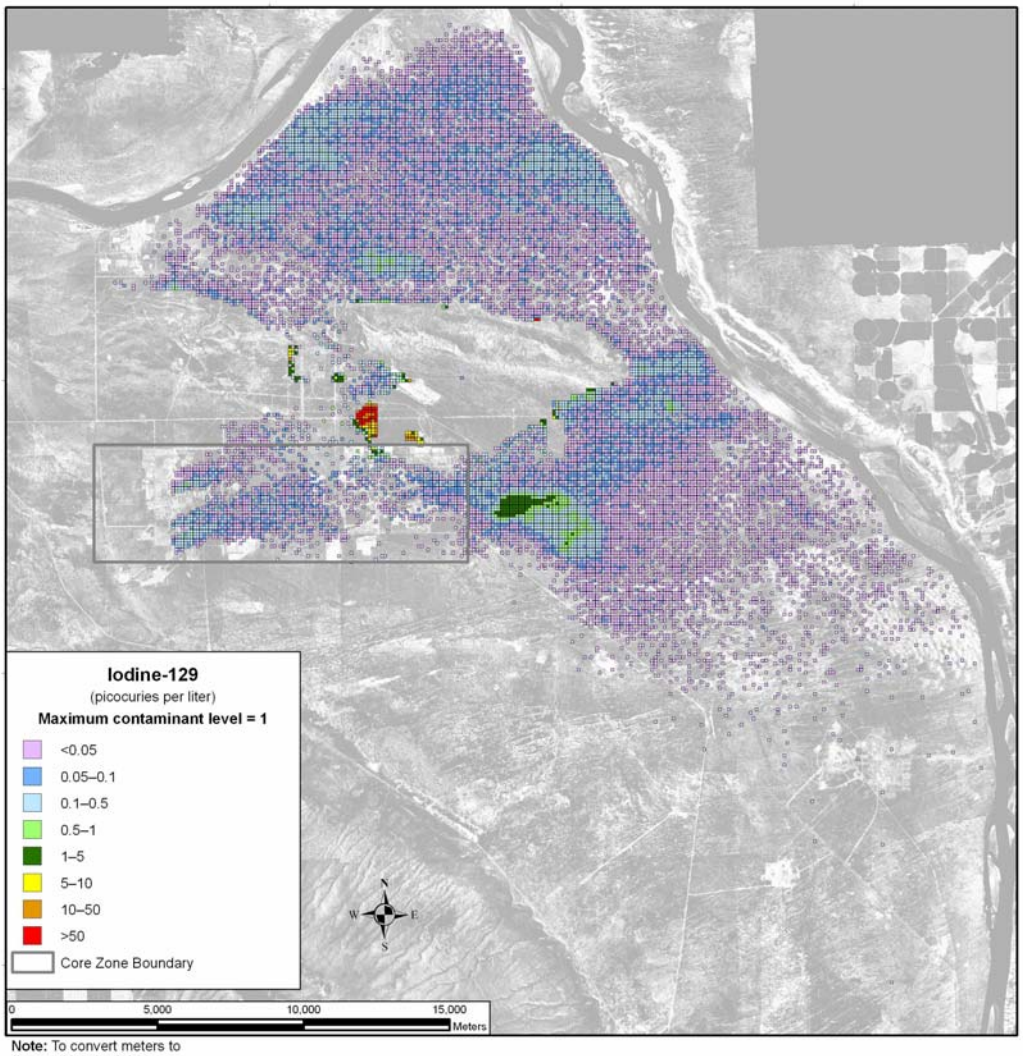
Note: To convert meters to feet, multiply by 3.281

Figure 5–162. Tank Closure Alternative 5 Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2005



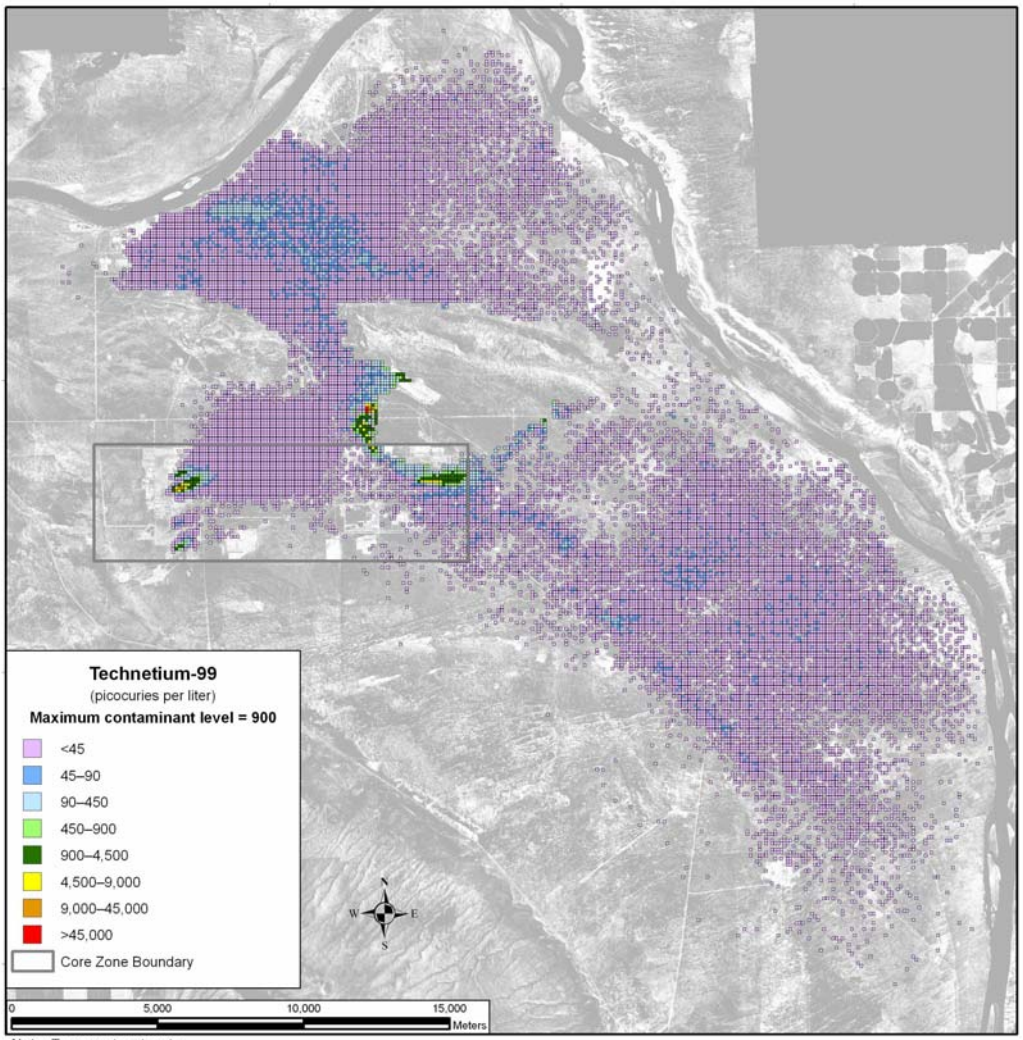
Note: To convert meters to feet, multiply by 3.281

Figure 5–163. Tank Closure Alternative 5 Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2135



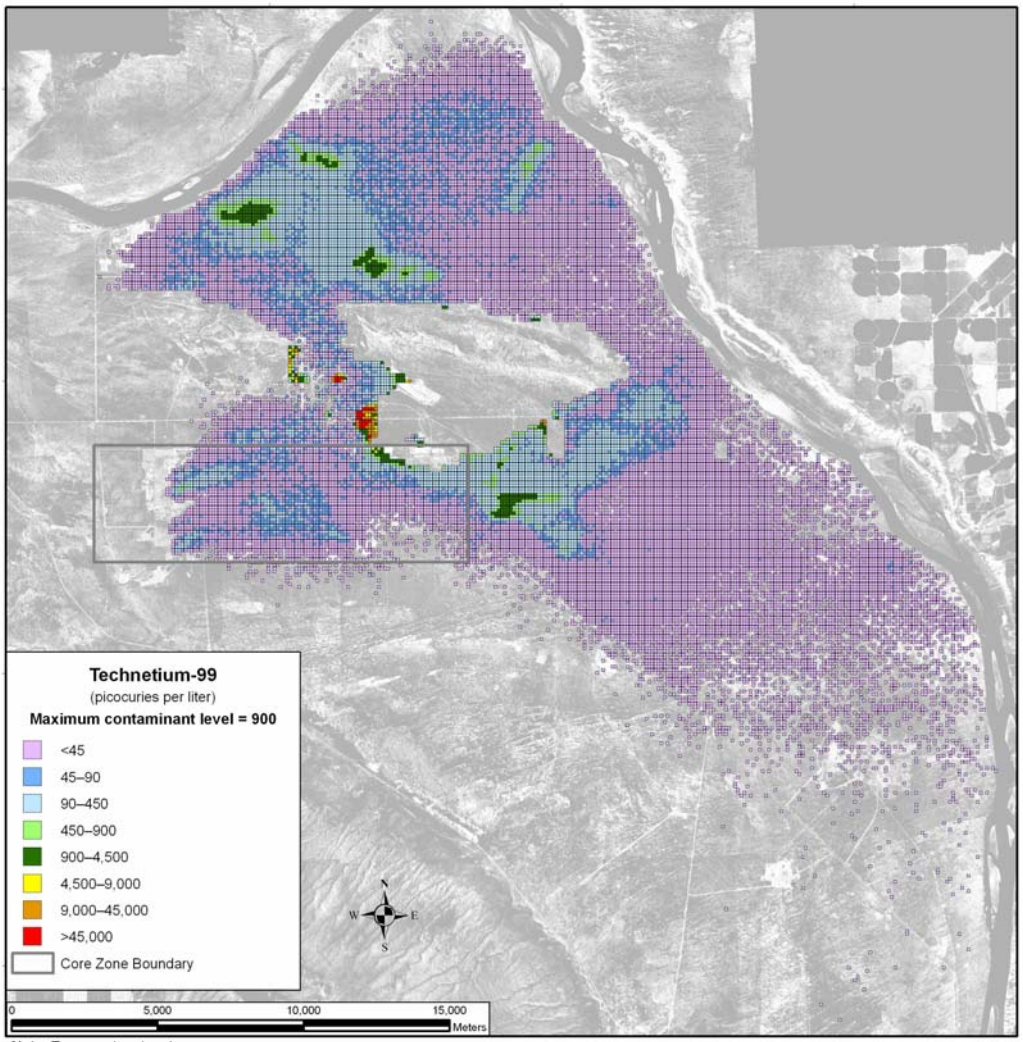
Note: To convert meters to feet, multiply by 3.281

Figure 5–164. Tank Closure Alternative 5 Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140



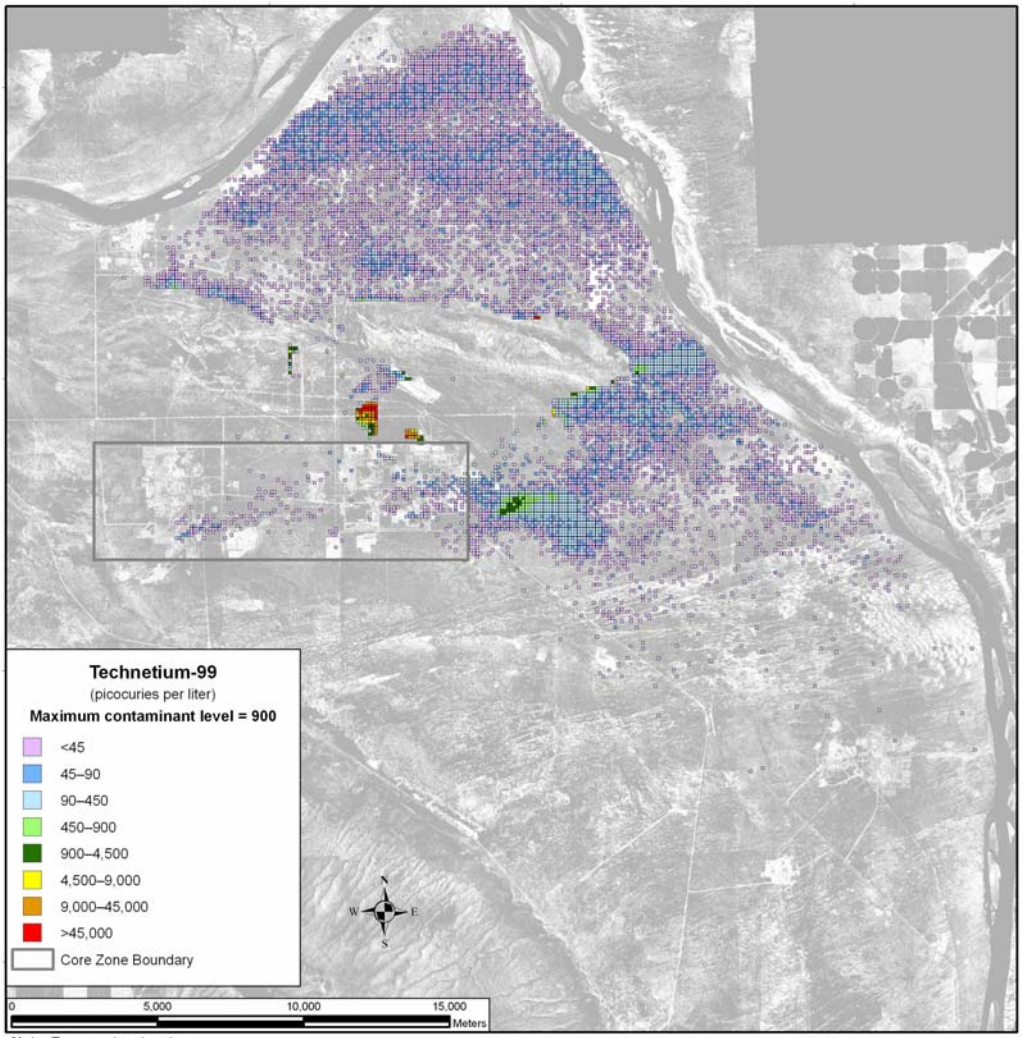
Note: To convert meters to feet, multiply by 3.281

Figure 5–165. Tank Closure Alternative 5 Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2005



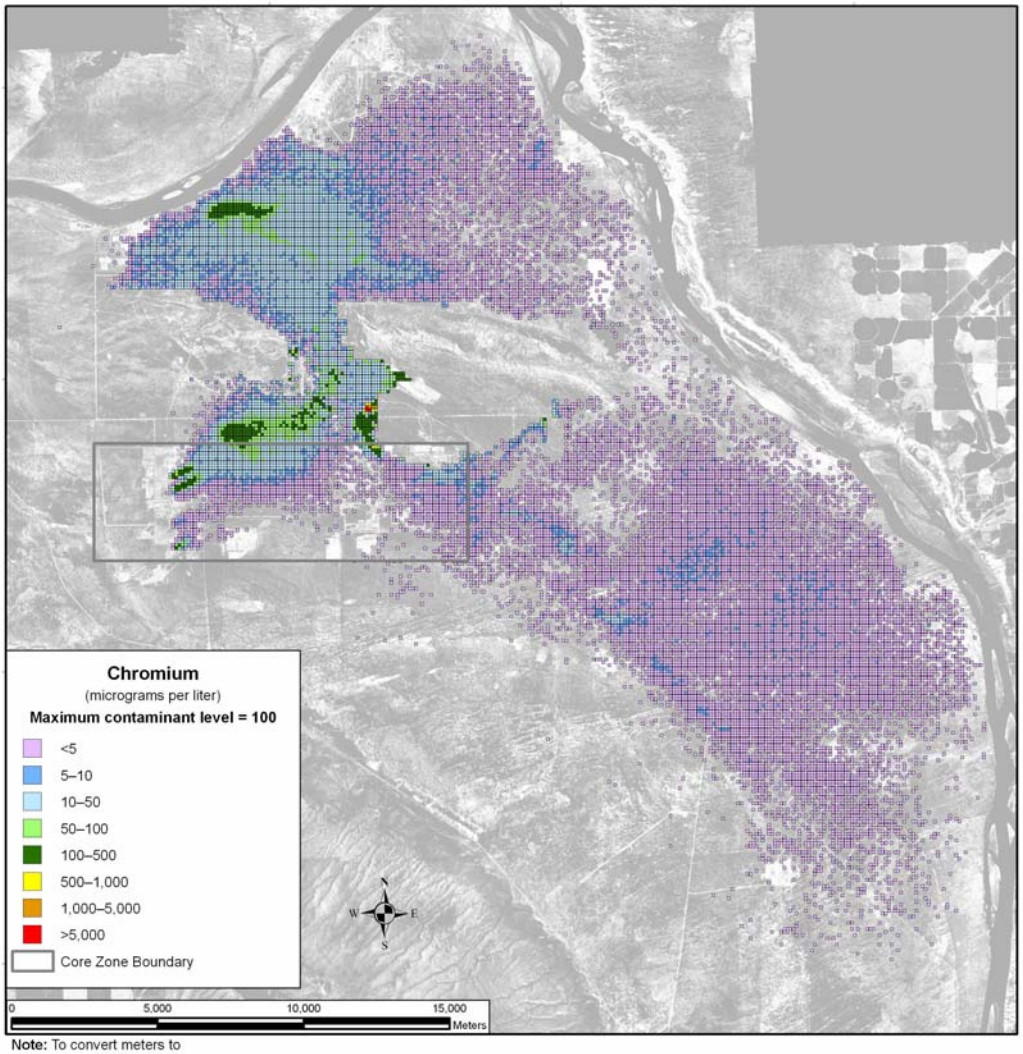
Note: To convert meters to feet, multiply by 3.281

Figure 5–166. Tank Closure Alternative 5 Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2135



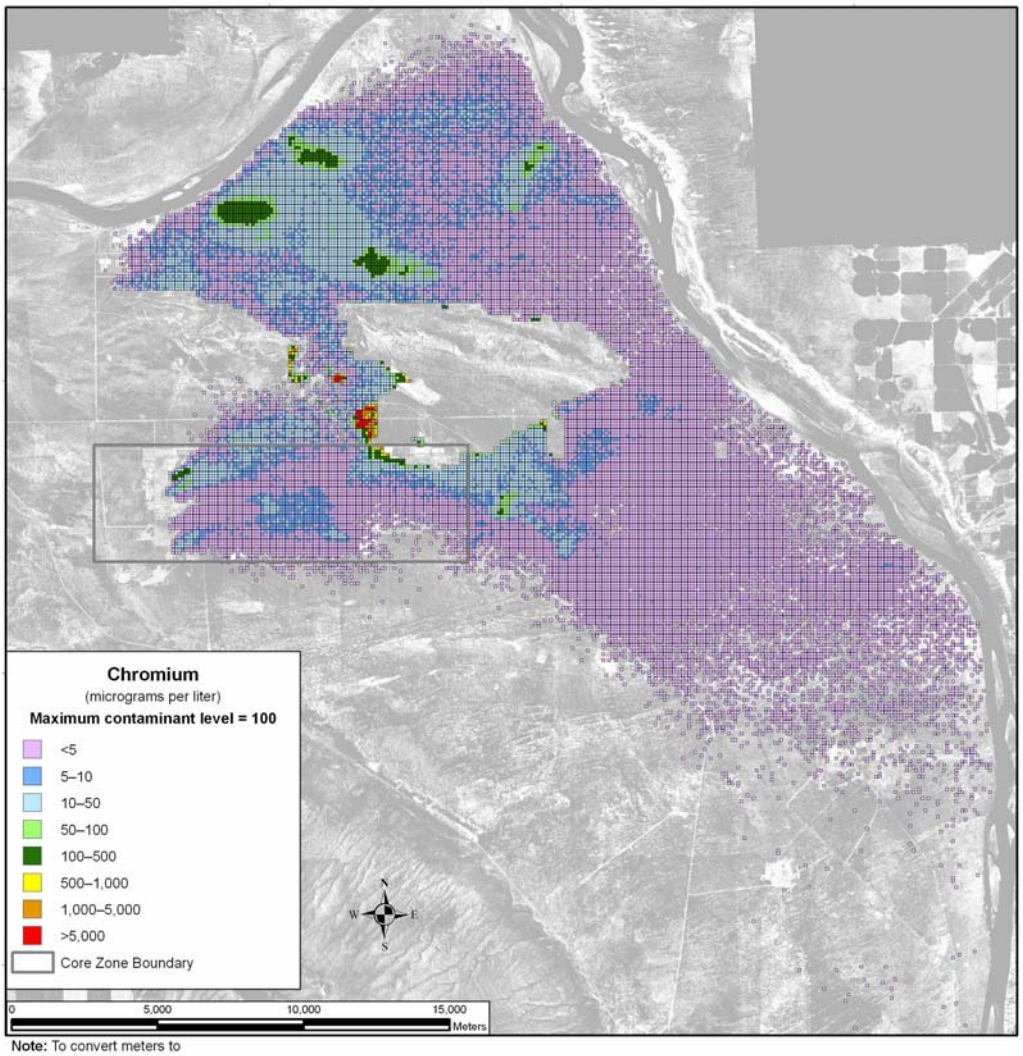
Note: To convert meters to feet, multiply by 3.281

Figure 5–167. Tank Closure Alternative 5 Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140



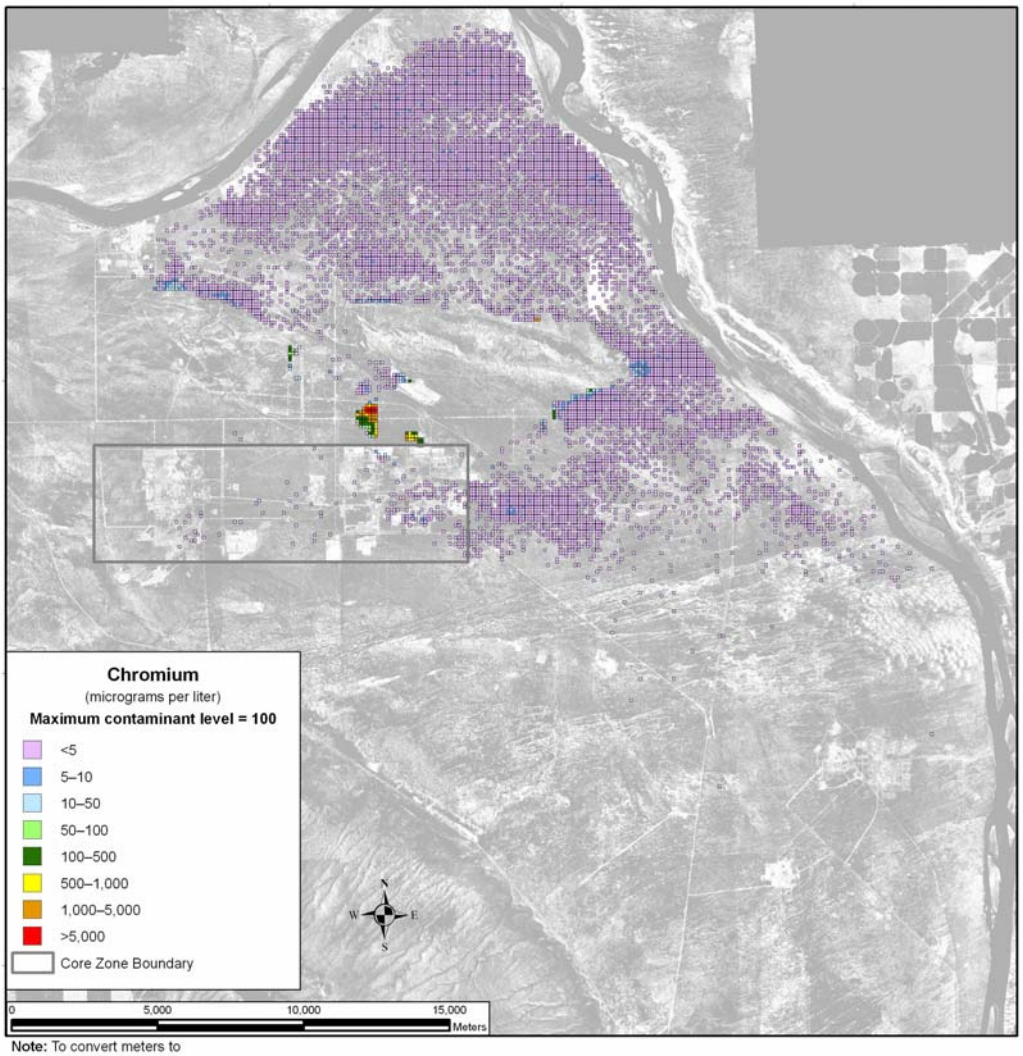
Note: To convert meters to feet, multiply by 3.281

Figure 5–168. Tank Closure Alternative 5 Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 2005



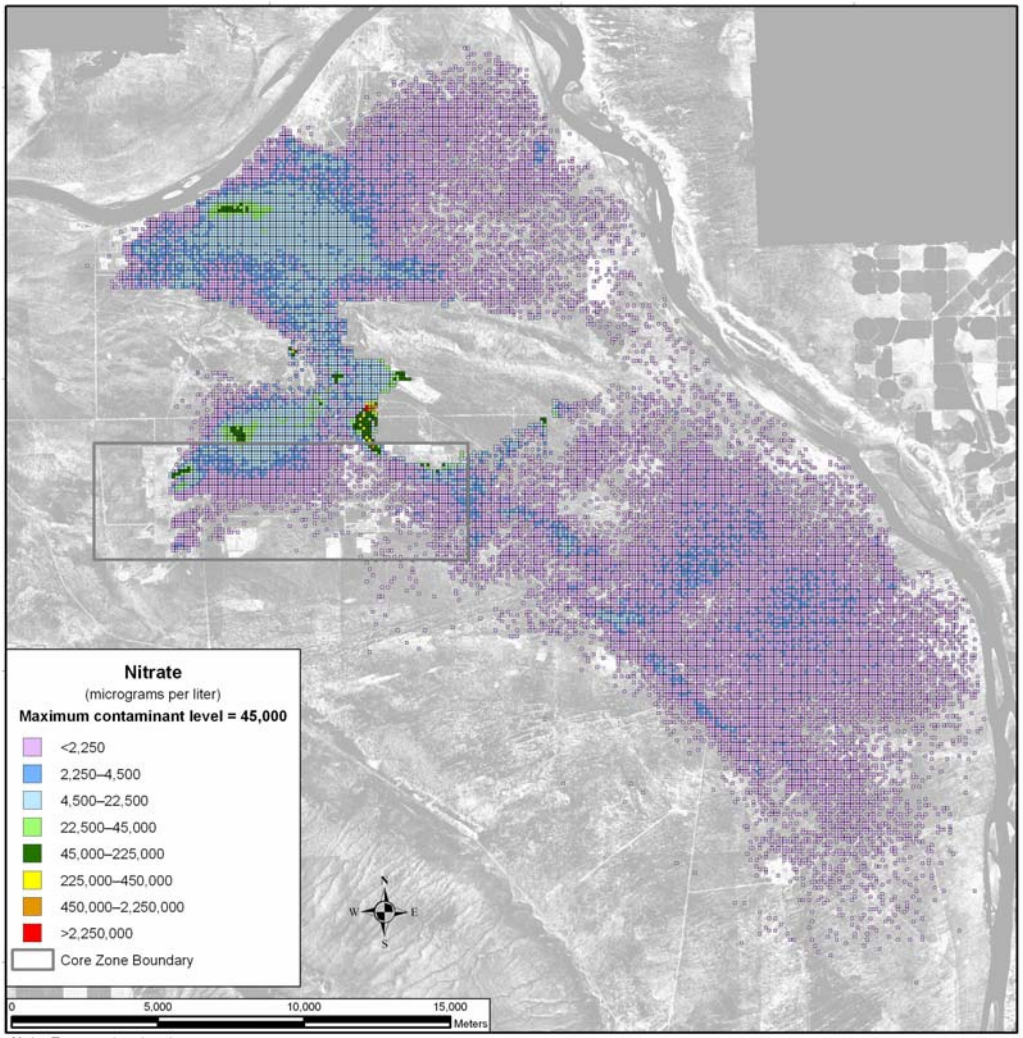
Note: To convert meters to feet, multiply by 3.281

Figure 5–169. Tank Closure Alternative 5 Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 2135



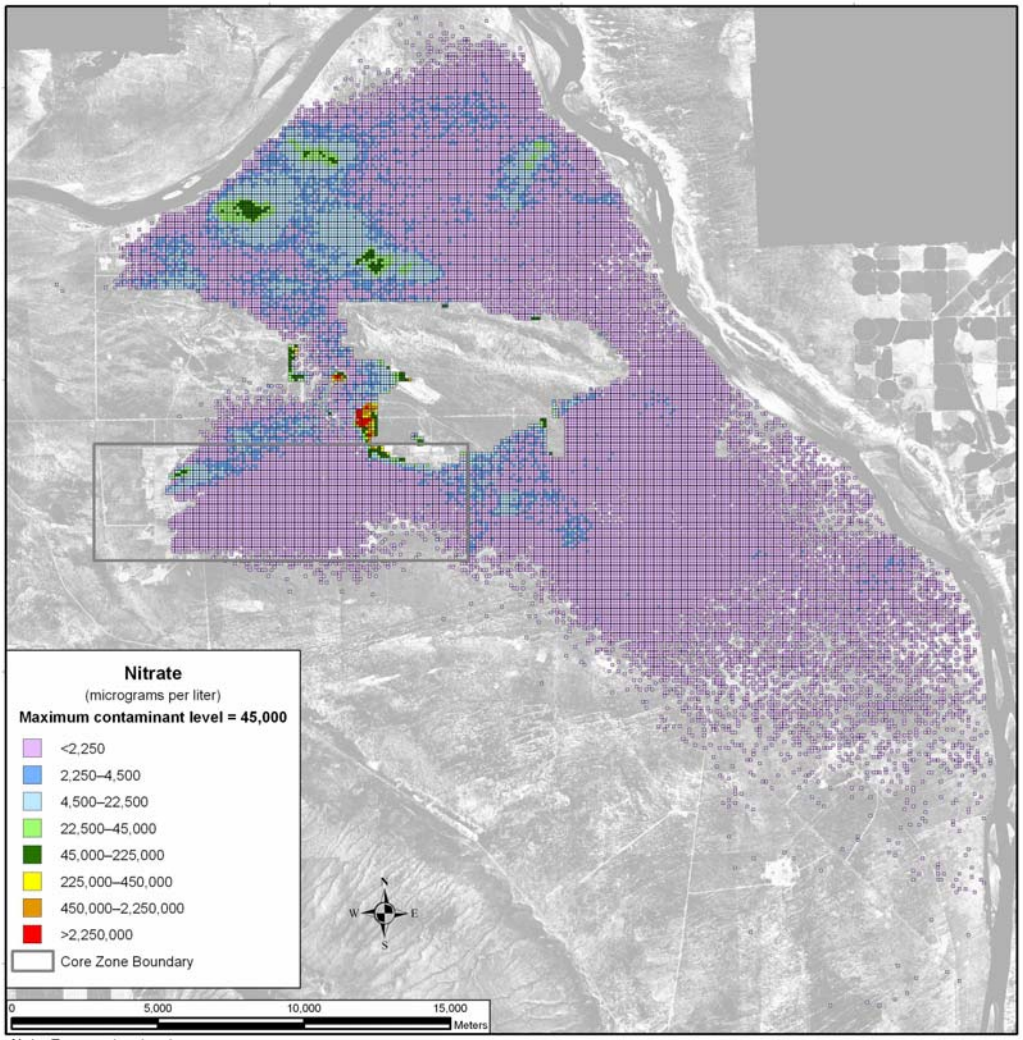
Note: To convert meters to feet, multiply by 3.281

Figure 5–170. Tank Closure Alternative 5 Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 7140



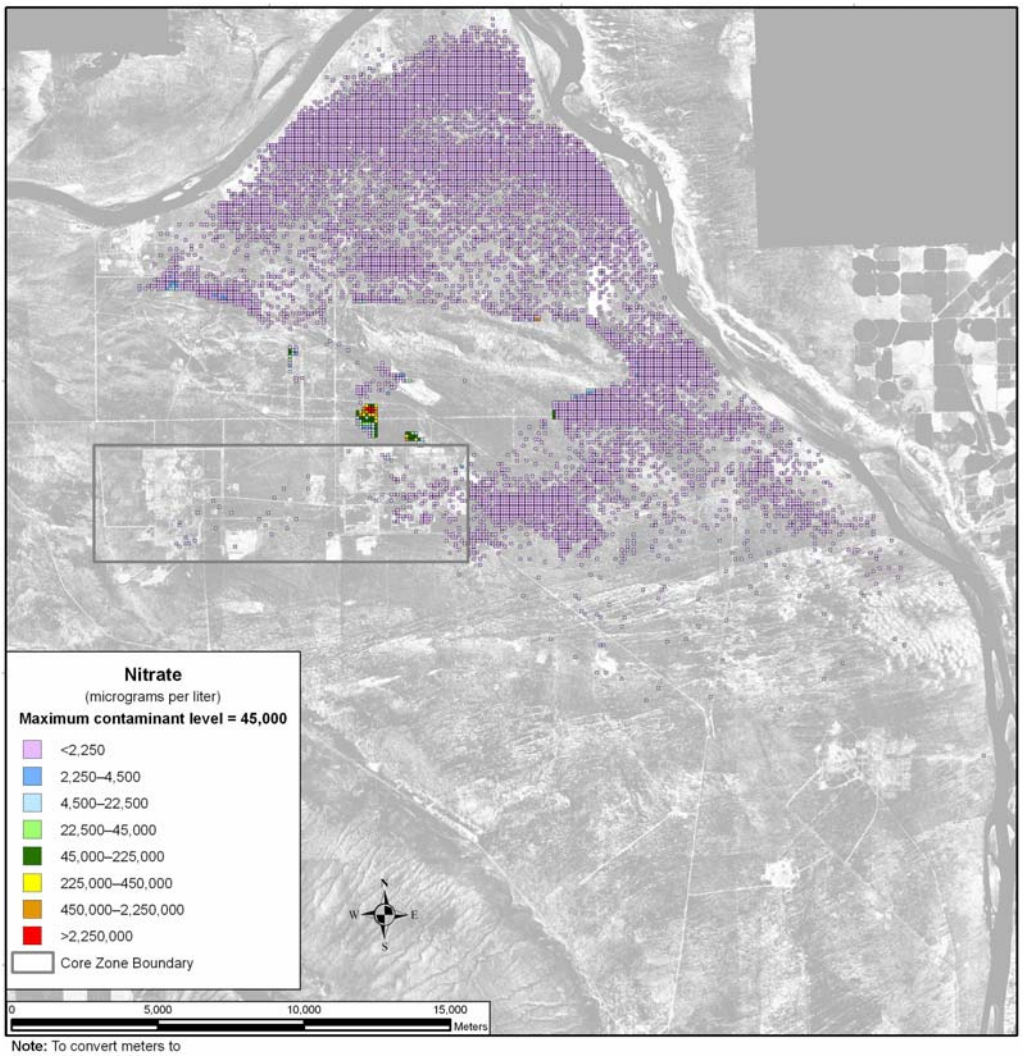
Note: To convert meters to feet, multiply by 3.281

Figure 5–171. Tank Closure Alternative 5 Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

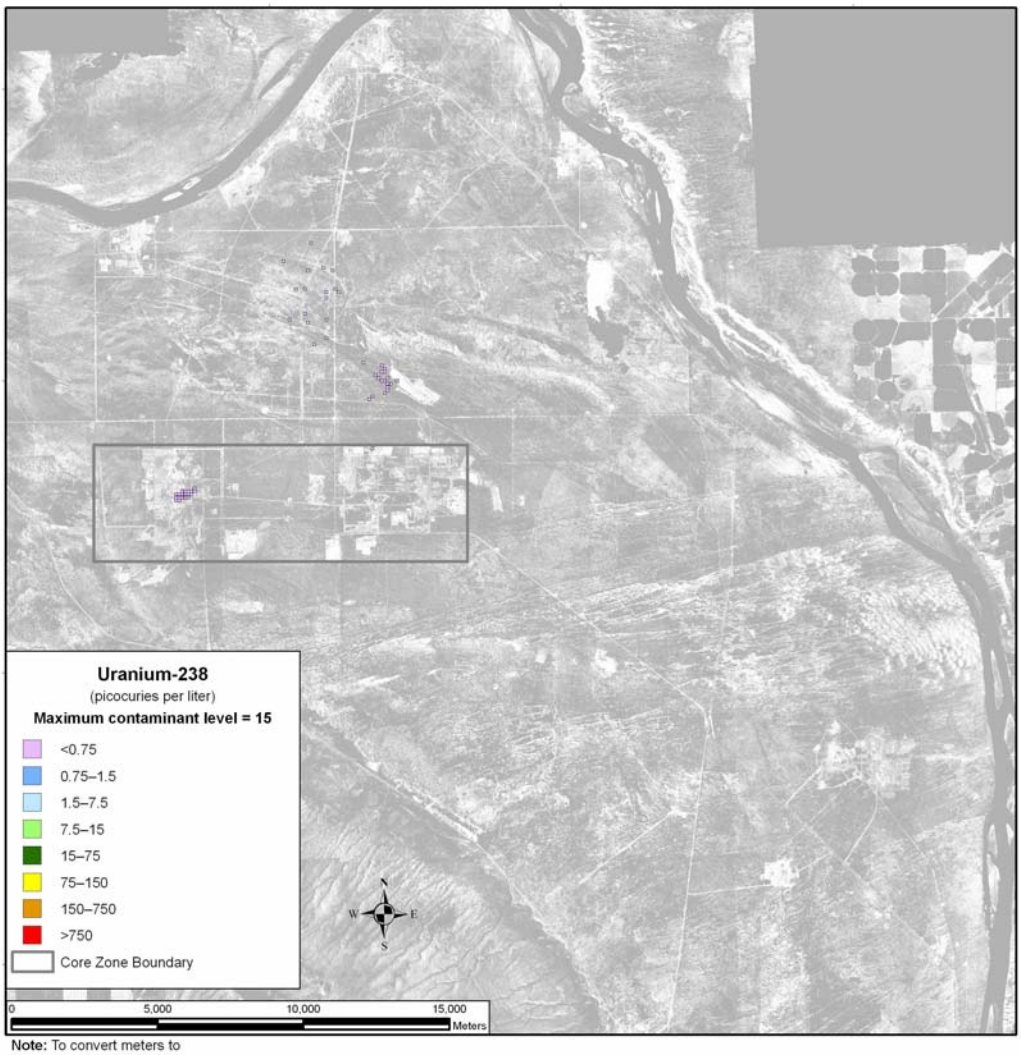
Figure 5–172. Tank Closure Alternative 5 Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281

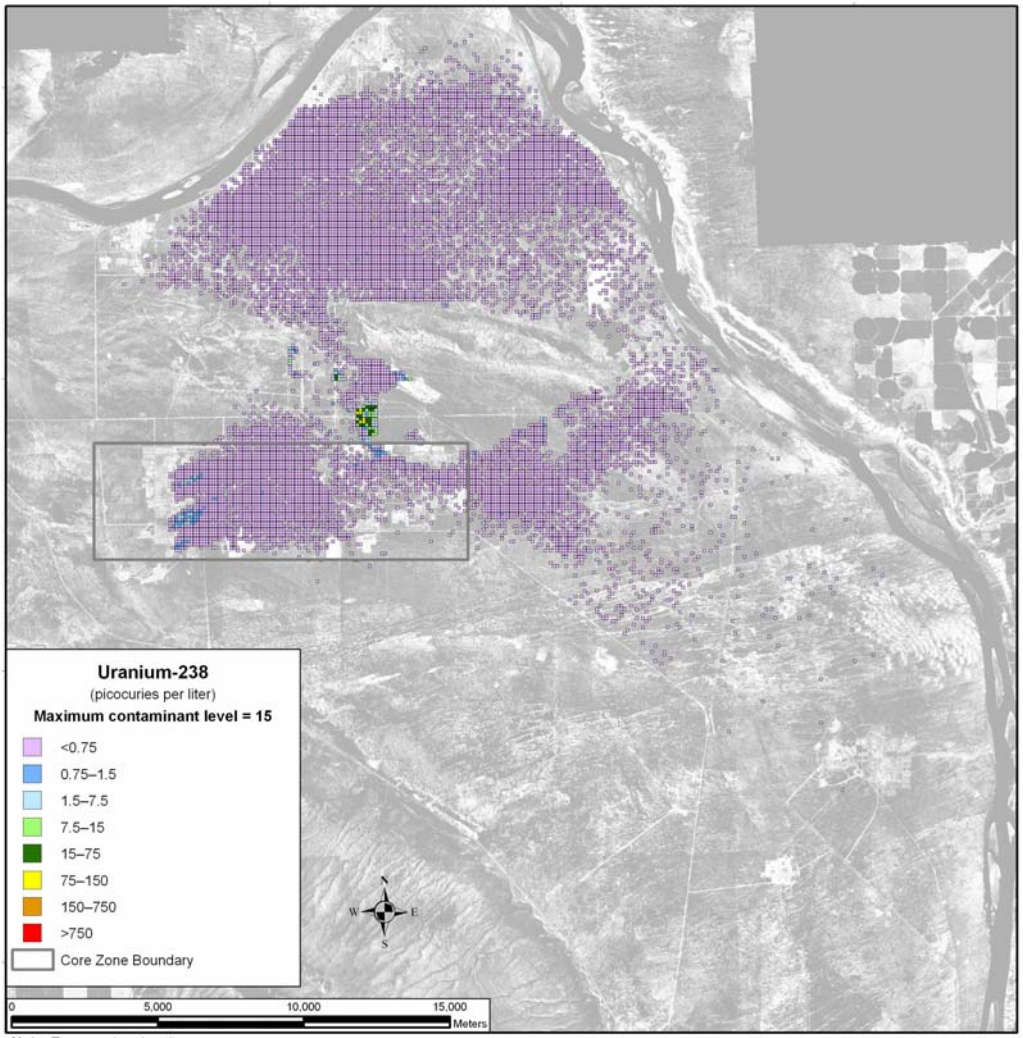
Figure 5–173. Tank Closure Alternative 5 Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 7140

Uranium-238 and total uranium show a different spatial distribution in the analysis over time. These COPCs are 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 5–174 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 (see Figure 5–175), the area of the plume has grown, but there are no significant increases in peak concentration. At CY 11,885 (see Figure 5–176), the greatest development of the plume during the analysis period is seen, resulting primarily from the release of other tank farm sources at the A and B Barriers. Figures 5–177 through 5–179 show the corresponding results for total uranium.



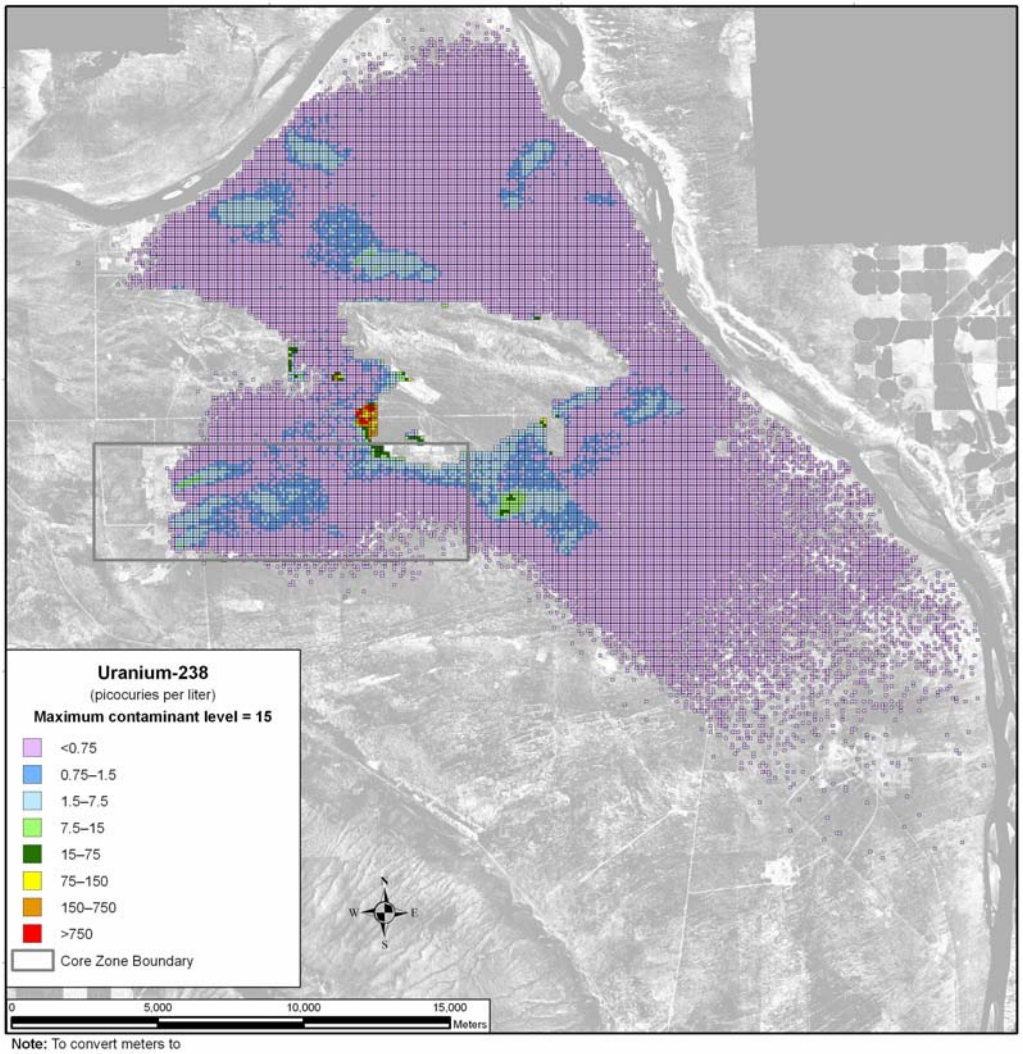
Note: To convert meters to feet, multiply by 3.281

Figure 5–174. Tank Closure Alternative 5 Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 2005



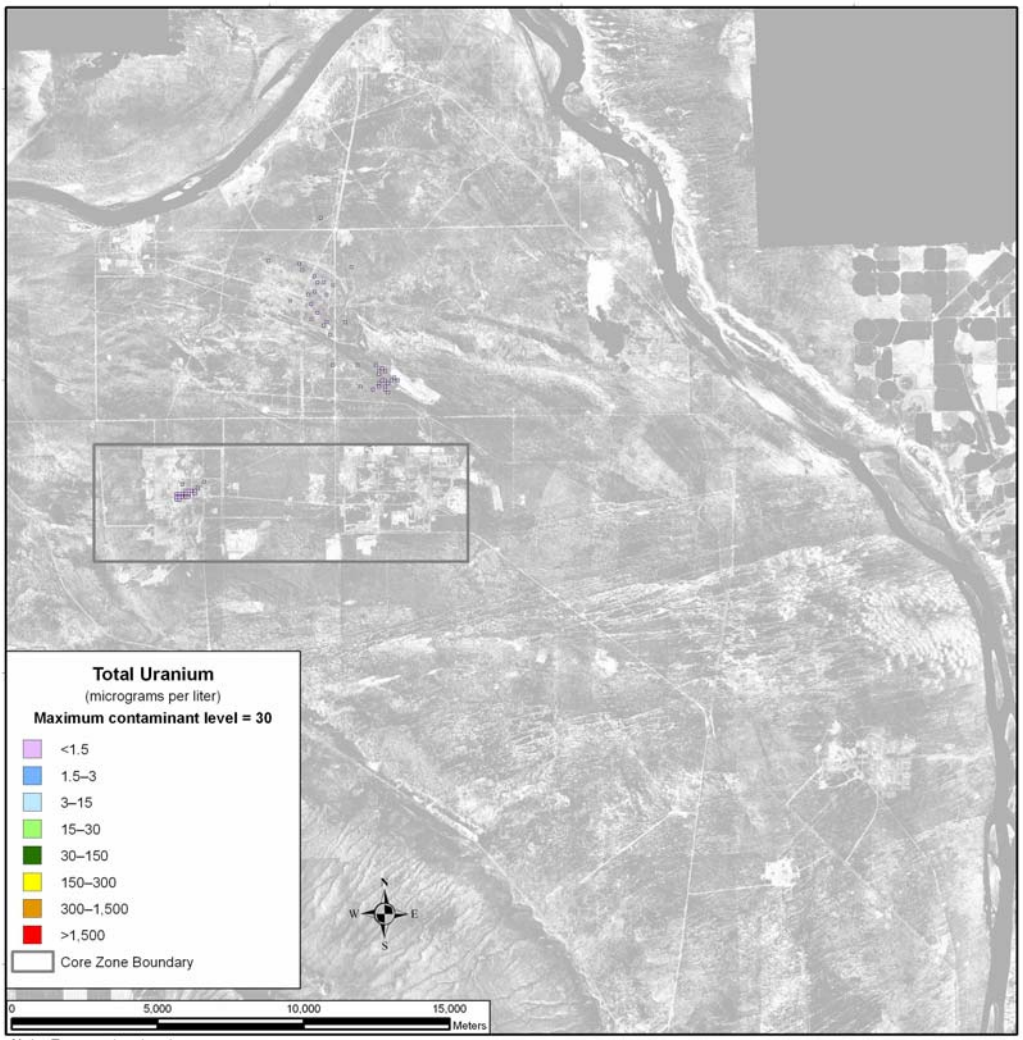
Note: To convert meters to feet, multiply by 3.281

Figure 5–175. Tank Closure Alternative 5 Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 7140



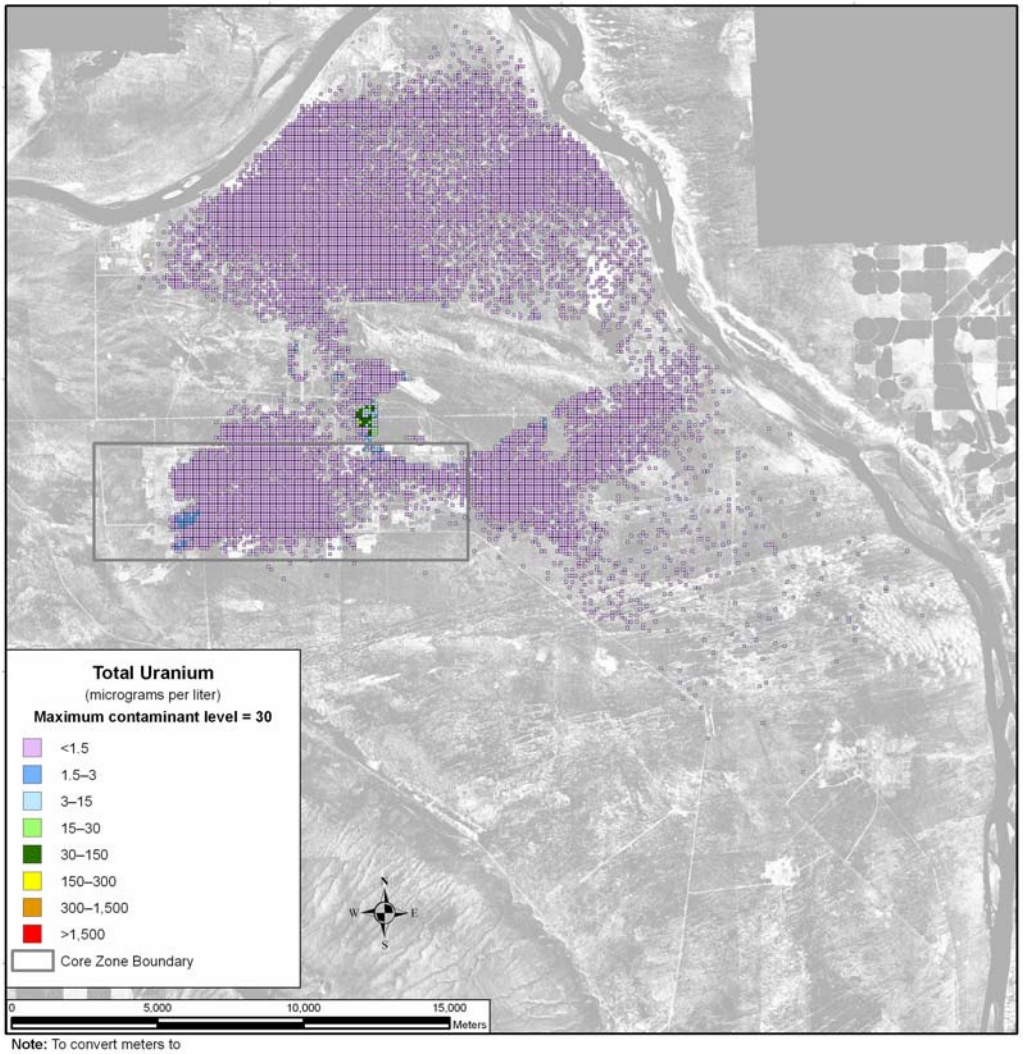
Note: To convert meters to feet, multiply by 3.281

Figure 5–176. Tank Closure Alternative 5 Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 11,885



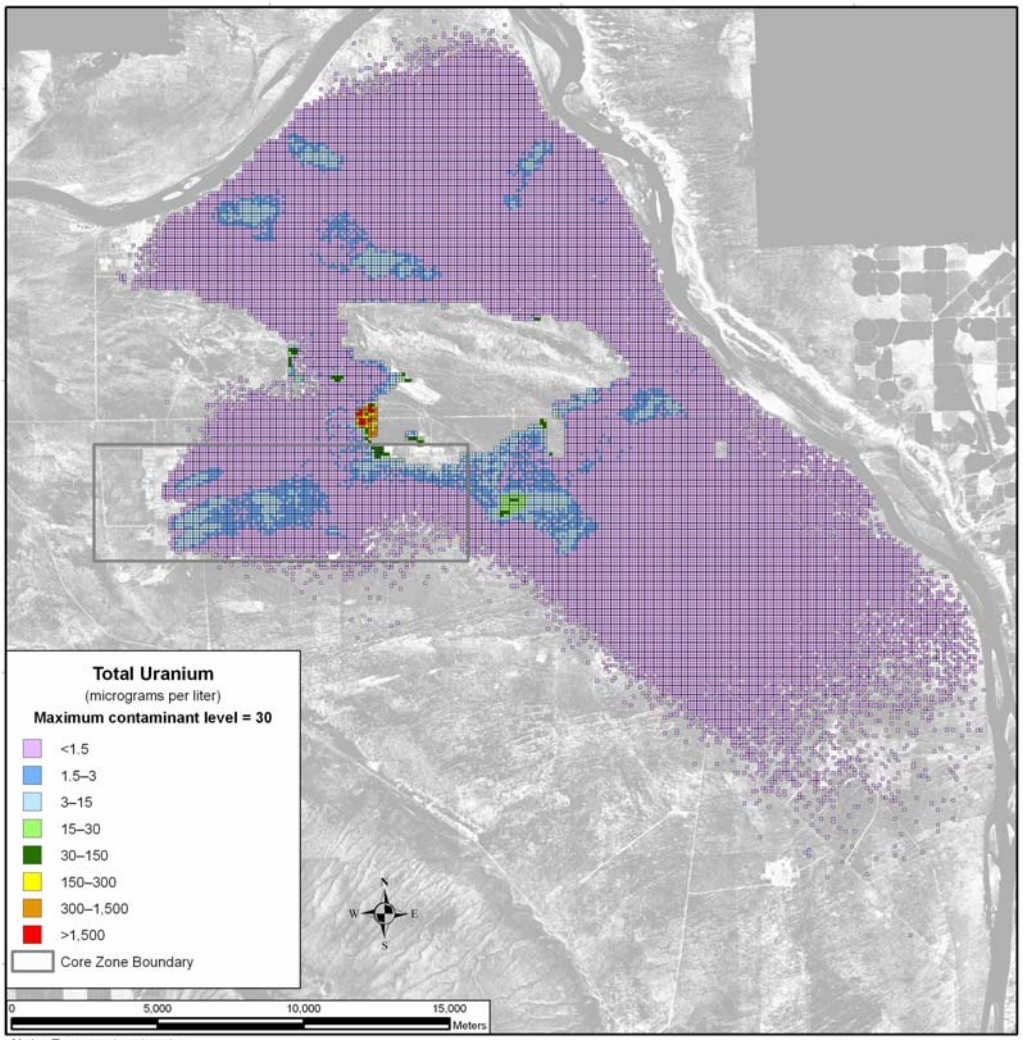
Note: To convert meters to feet, multiply by 3.281

Figure 5–177. Tank Closure Alternative 5 Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

Figure 5–178. Tank Closure Alternative 5 Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281

Figure 5–179. Tank Closure Alternative 5 Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 11,885

Figures 5–180 through 5–182 show the area covered by concentrations above the benchmark concentration for iodine-129, technetium-99, and uranium-238. Iodine-129 spikes early in the simulation, covering a peak area of just over 8 square kilometers (3 square miles) around CY 2070. The total area covered by the iodine-129 plume that is above the benchmark concentration drops below 2 square kilometers (0.77 square miles) by CY 3240. The plume then rises to almost 3 square kilometers (1.2 square miles) in CY 5190, after which it declines to less than 2 square kilometers (0.77 square miles) by CY 11,885. Technetium-99 shows a similar, more-gradual trend, peaking at over 4 square kilometers (1.5 square miles) in CY 2135, and decreasing to less than 2 square kilometers (0.77 square miles) in CY 3240. The plume then increases to greater than 10 square kilometers (3.8 square miles) in CY 4540, then declines rapidly to around 2 square kilometers (0.77 square miles), and then it levels off around 1 square kilometer (0.38 square miles) by CY 11,885. Uranium-238 shows a distinctly different pattern, without any area above the benchmark concentration until CY 5840. From CY 5840 until the end of the simulation, areas of uranium-238 concentrations above the benchmark concentration slowly increase, exceeding 1.4 square kilometers (0.54 square miles) at the end of the simulation.

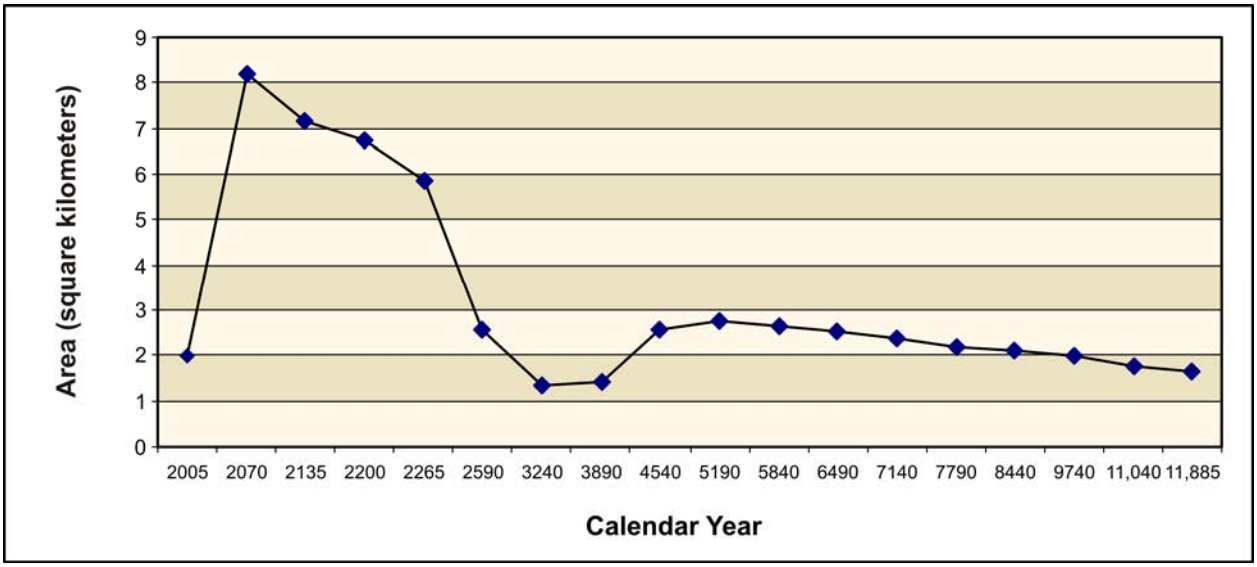


Figure 5–180. Tank Closure Alternative 5 Total Area of Groundwater Iodine-129 Concentration Exceeding the Benchmark Concentration as a Function of Time

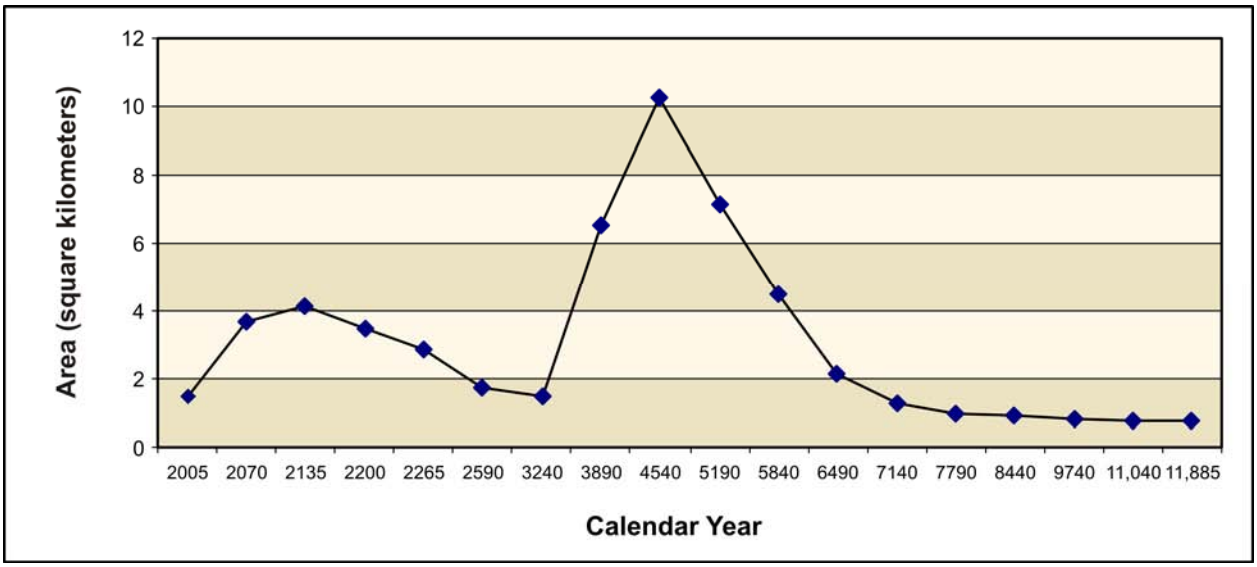


Figure 5–181. Tank Closure Alternative 5 Total Area of Groundwater Technetium-99 Concentration Exceeding the Benchmark Concentration as a Function of Time

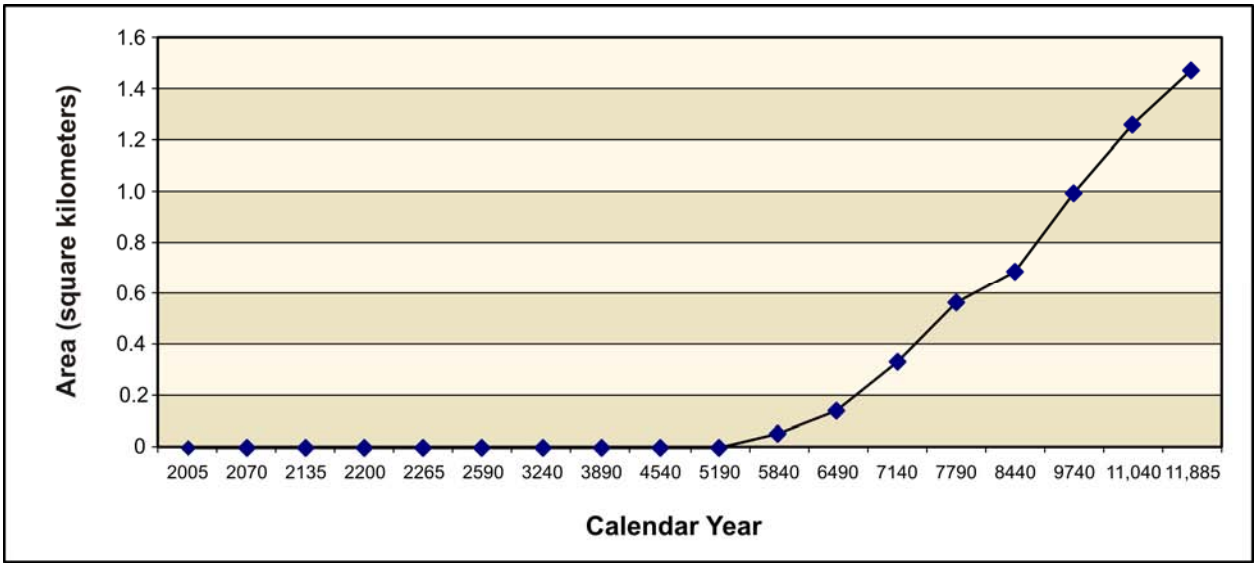


Figure 5–182. Tank Closure Alternative 5 Total Area of Groundwater Uranium-238 Concentration Exceeding the Benchmark Concentration as a Function of Time

5.1.1.8.6 Summary of Impacts

Under Tank Closure Alternative 5, in general, the inventory remaining in the tank farms, available for release to the environment at the start of the post–administrative control period, is the predominant contributor in the analysis. Discharges to cribs and trenches (ditches) and past leaks are a secondary contributor.

For the conservative tracers, concentrations at the Core Zone Boundary exceed benchmark standards by two to three orders of magnitude during most of the period of analysis. Concentrations at the Columbia River are about two orders of magnitude smaller. The intensities and areas of these groundwater plumes peak around CY 4540.

For tritium, concentrations at the Core Zone Boundary exceed the benchmark by about three orders of magnitude during the first 100 years of the period of analysis. Concentrations at the Columbia River approach the benchmark during this time. Attenuation by radioactive decay is a predominant mechanism that limits the intensity and duration of groundwater impacts of tritium. After CY 2100, tritium impacts are essentially negligible.

For uranium-238 and total uranium, limited mobility is an important factor governing the timeframes and scale of groundwater impacts. The concentrations of these retarded species exceed the benchmark concentration at the Core Zone Boundary beyond CY 8200, and approach the benchmark concentration at the Columbia River after CY 11,885. The peak intensity and area of the contamination plume are largest near the end of the period of analysis.

5.1.1.9 Tank Closure Alternative 6A: All Vitrification/No Separations; Clean Closure, Base and Option Cases

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

Under Tank Closure Alternative 6A, 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 6A, 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.

5.1.1.9.1 Actions and Timeframes Influencing Groundwater Impacts

Summaries of the proposed actions and timelines for Tank Closure Alternative 6A are provided in Chapter 2, Section 2.5. For the long-term groundwater impact analysis, three major periods were identified for Tank Closure Alternative 6A, 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 6A that are presented in this section would be common to all of the Tank Closure alternatives.

- The retrieval period was assumed to start in 2008 and end in CY 2250. 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 2251 and continue through the 10,000-year period of analysis until CY 11,940.

5.1.1.9.2 COPC Drivers

A total of 19 COPCs were analyzed for Tank Closure Alternative 6A. 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 6A 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 6A 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 6A.

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.

5.1.1.9.3 Analysis of Release and Mass Balance

This section presents the impacts of Tank Closure Alternative 6A 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 5–183 through 5–194). Two subtotals are plotted representing releases from cribs and trenches (ditches) and 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 5–183 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 5–184, 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 6A, Base Case.

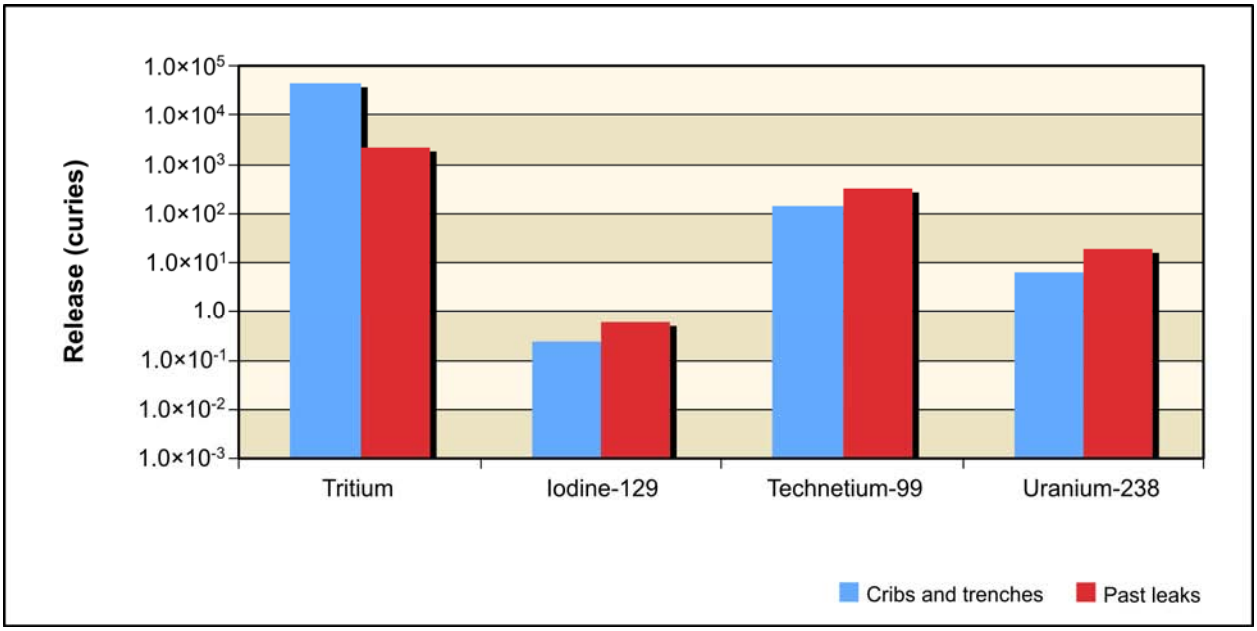


Figure 5–183. Tank Closure Alternative 6A, Base Case, Releases of Radiological Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

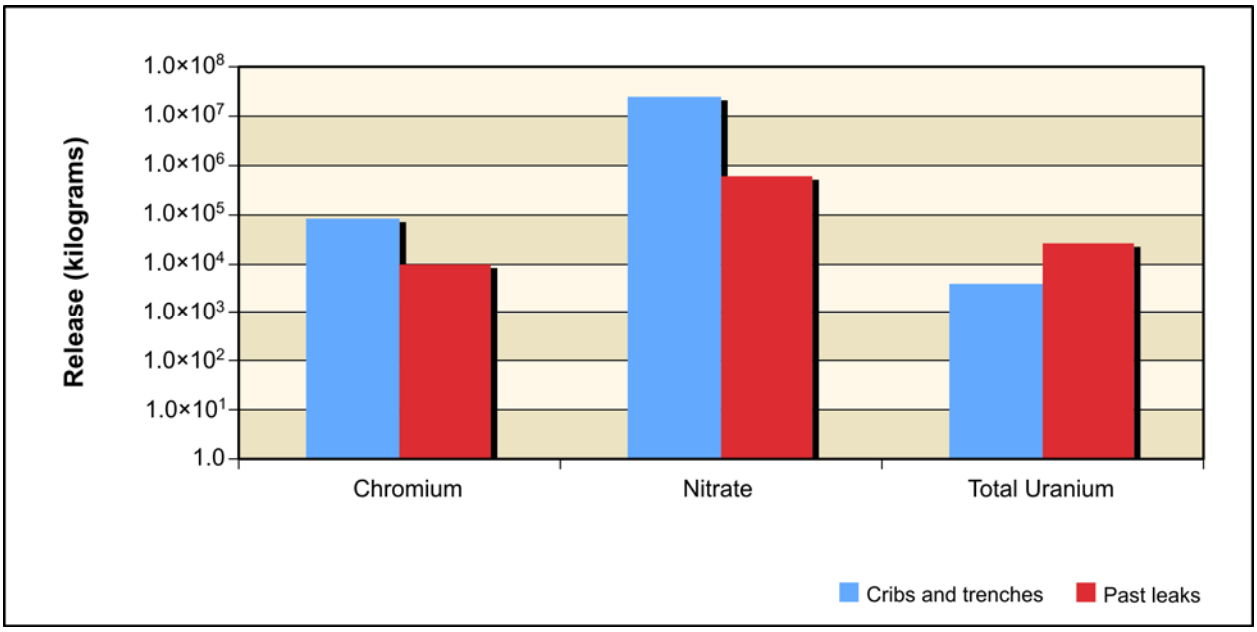


Figure 5–184. Tank Closure Alternative 6A, Base Case, Releases of Chemical Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

Figure 5–185 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 5–186, 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.

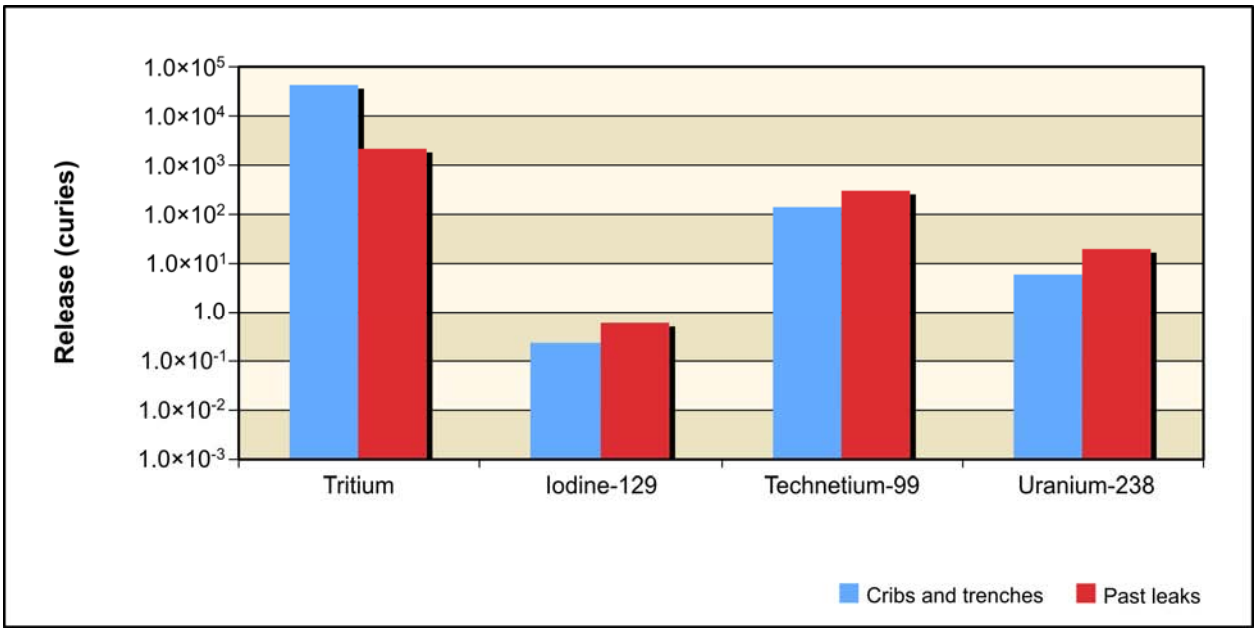


Figure 5–185. Tank Closure Alternative 6A, Option Case, Releases of Radiological Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

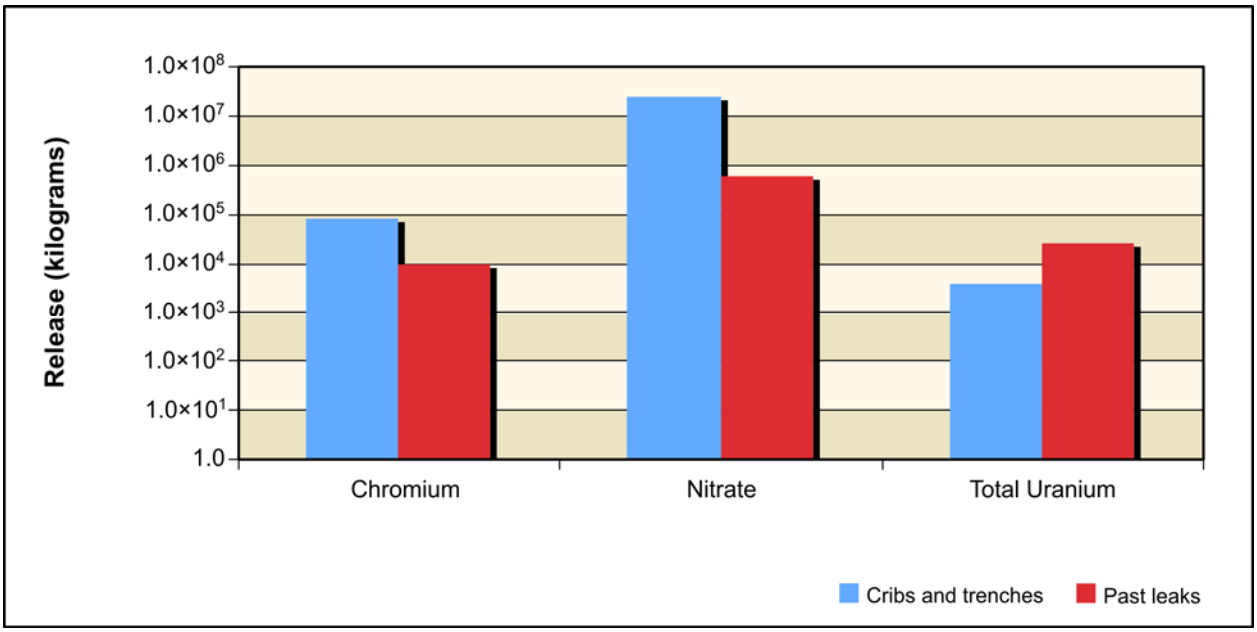


Figure 5–186. Tank Closure Alternative 6A, Option Case, Releases of Chemical Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

Figure 5–187 shows the estimated release to groundwater for the radiological risk drivers under the Base Case and Figure 5–188, 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.

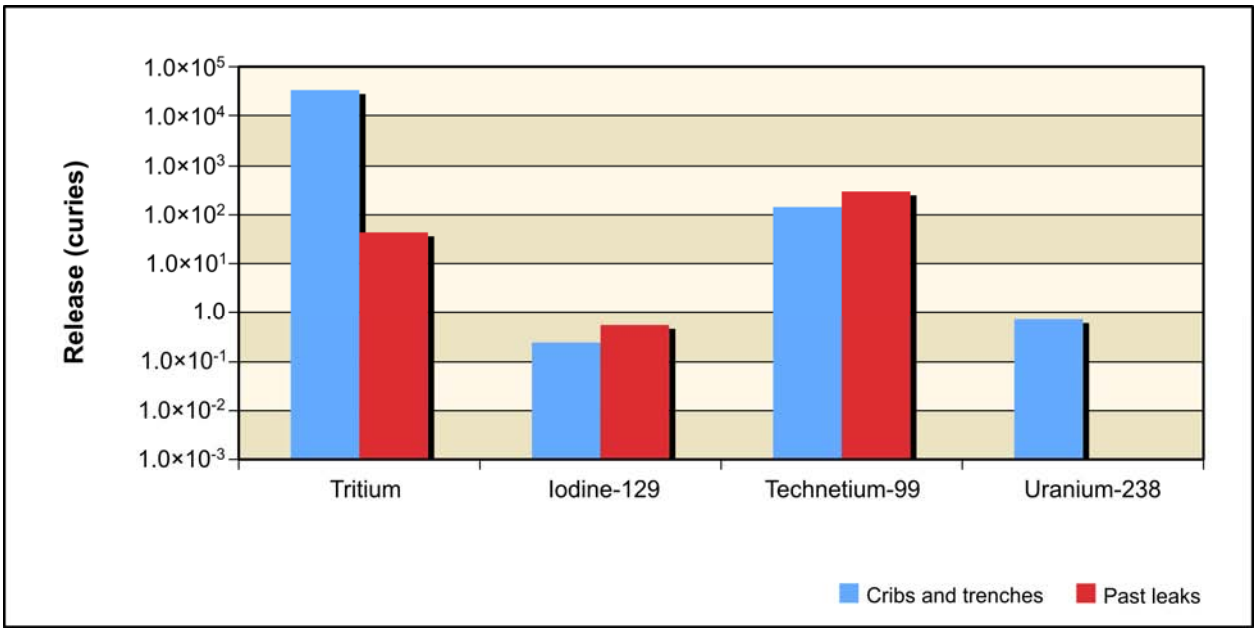


Figure 5–187. Tank Closure Alternative 6A, Base Case, Releases of Radiological Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

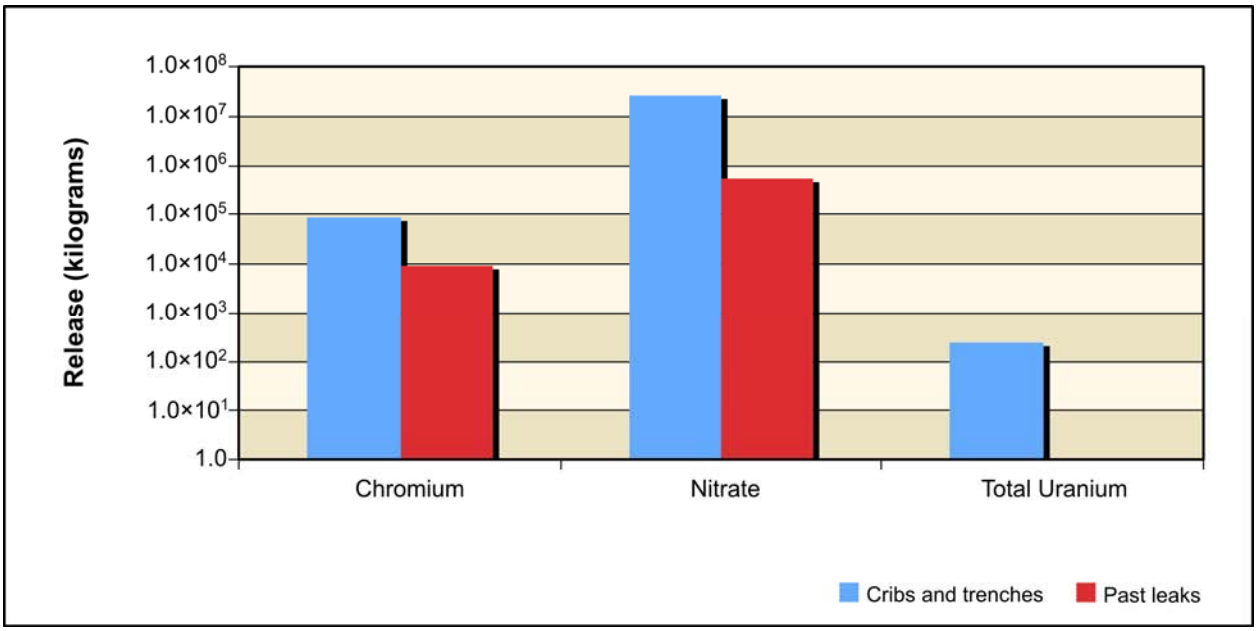


Figure 5–188. Tank Closure Alternative 6A, Base Case, Releases of Chemical Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

For uranium-238 and total uranium, the amount released to groundwater is less than that of the release to the vadose zone because of retardation. The amount of attenuation depends on the rate 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), about 10 percent 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.

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 5–189 shows the estimated release to groundwater for the radiological risk drivers under the Option Case and Figure 5–190, 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.

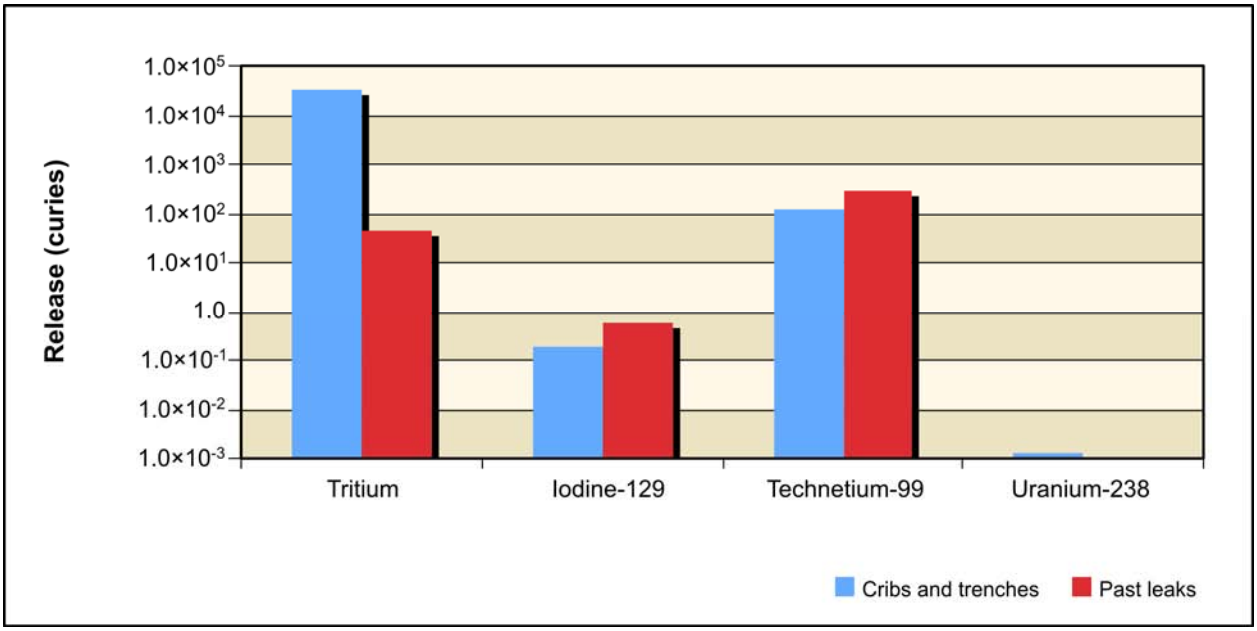


Figure 5–189. Tank Closure Alternative 6A, Option Case, Releases of Radiological Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

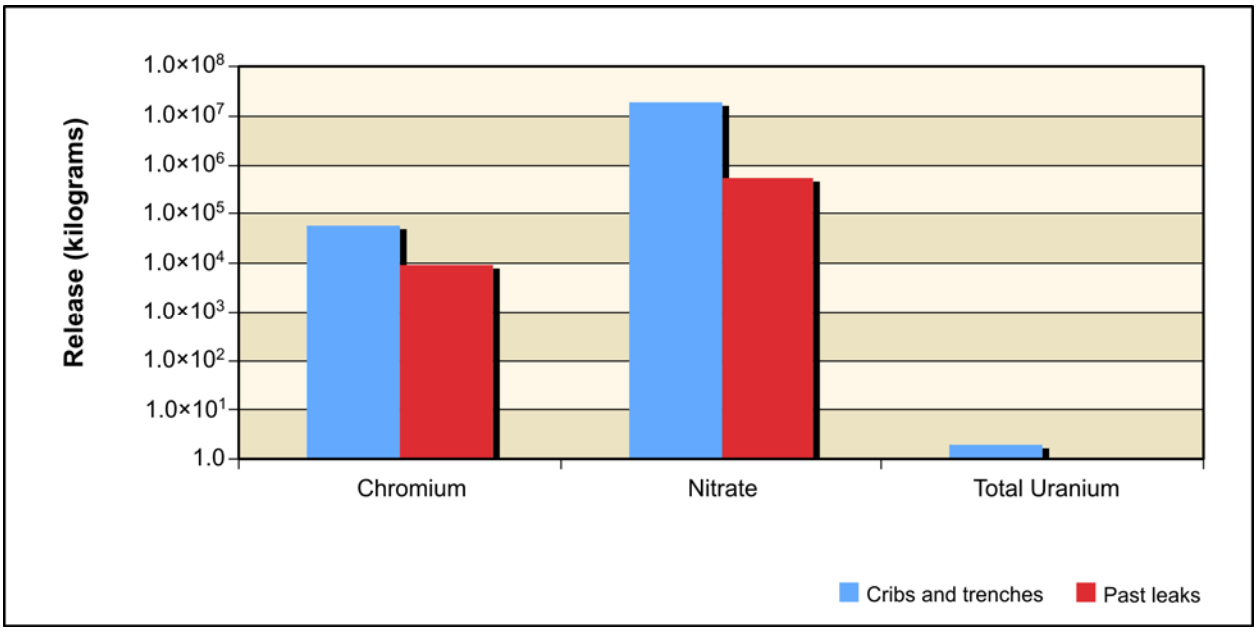


Figure 5–190. Tank Closure Alternative 6A, Option Case, Releases of Chemical Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

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.

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 5–191 shows the estimated release to the Columbia River for the radiological risk drivers under the Base Case and Figure 5–192, 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.

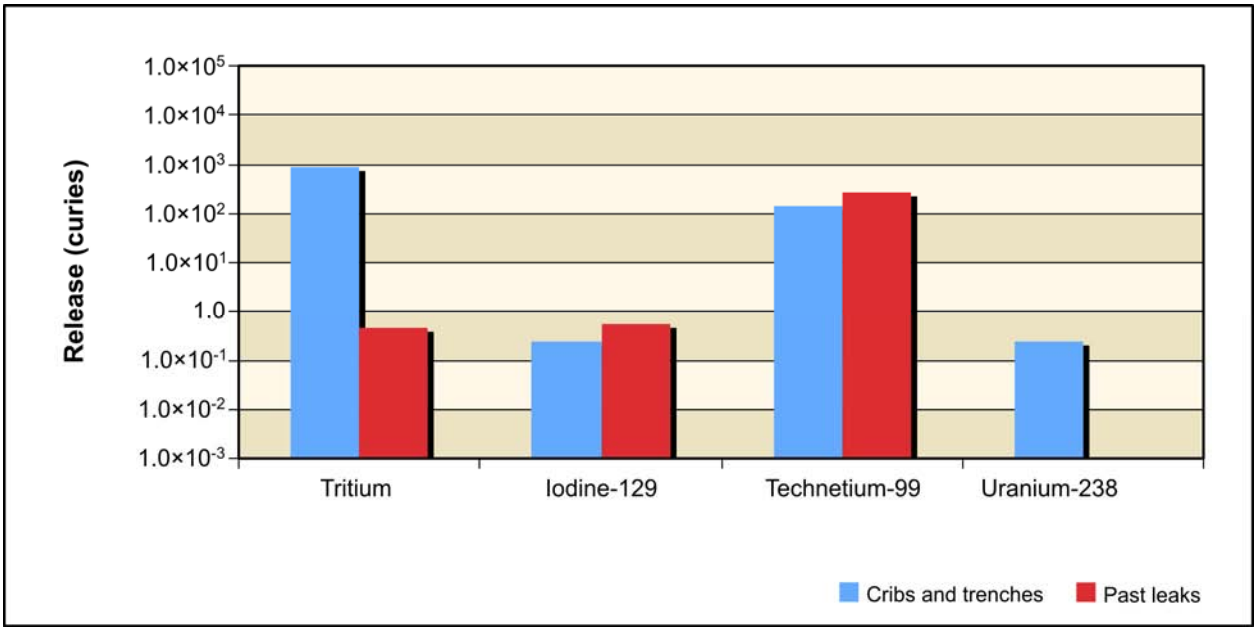


Figure 5–191. Tank Closure Alternative 6A, Base Case, Releases of Radiological Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

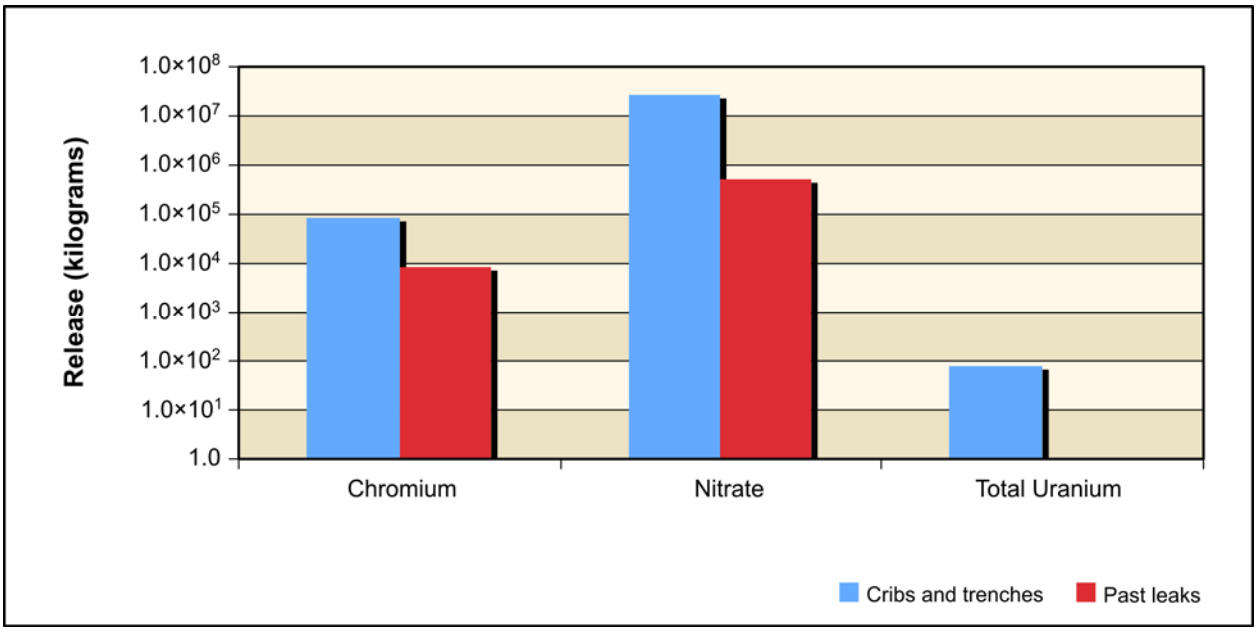


Figure 5–192. Tank Closure Alternative 6A, Base Case, Releases of Chemical Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

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. 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 5–193 shows the estimated release to the Columbia River for the radiological risk drivers under the Option Case and Figure 5–194, 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. 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 in the analysis. 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 in the analysis. For past leaks, only about 1 percent of the tritium released to groundwater reached the Columbia River in the analysis. 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 would be collected when the cribs and trenches (ditches) are removed and their deep plumes remediated.

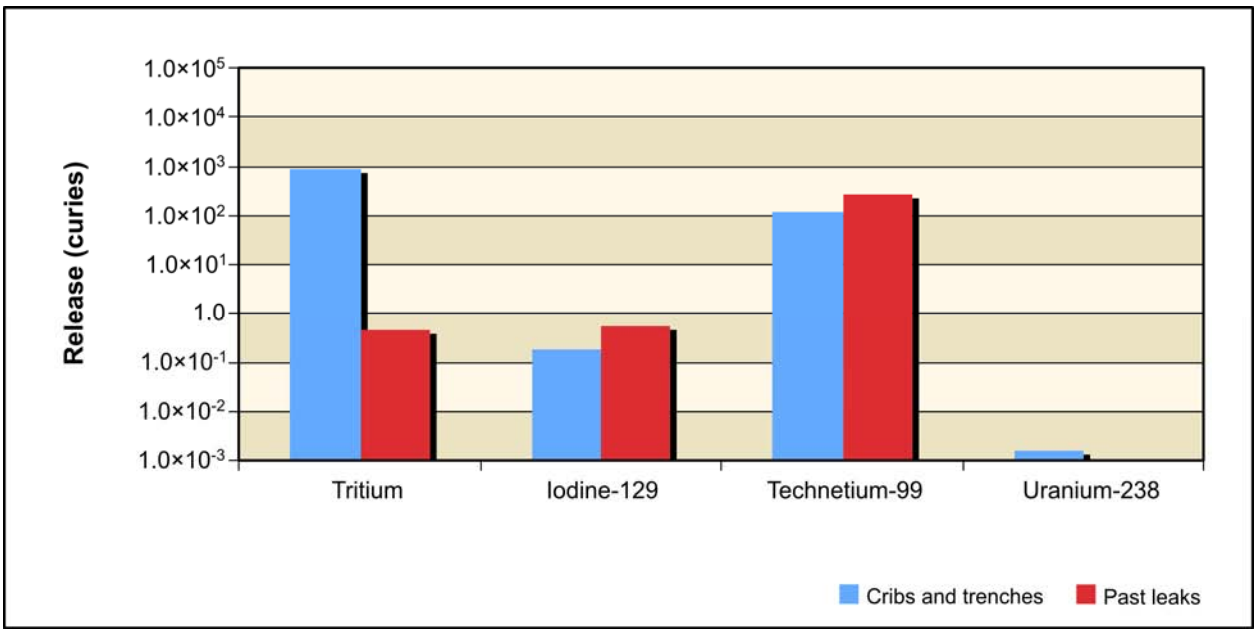


Figure 5–193. Tank Closure Alternative 6A, Option Case, Releases of Radiological Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

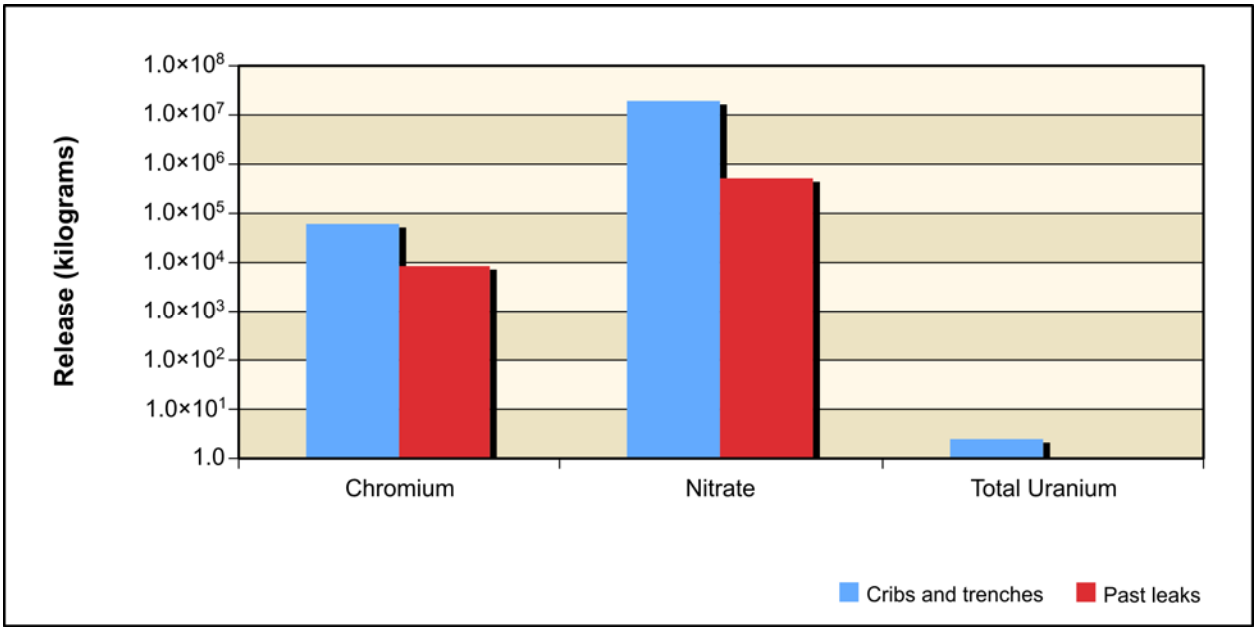


Figure 5–194. Tank Closure Alternative 6A, Option Case, Releases of Chemical Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

5.1.1.9.4 Analysis of Concentration Versus Time

This section presents the analysis of Tank Closure Alternative 6A 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 5–6 and 5–7 and Figures 5–195 through 5–208). 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 5–6 and 5–7 list the maximum concentrations under the Base and Option Cases for the COPCs in the peak year after CY 2050 at the tank farm barriers, Core Zone Boundary, and Columbia River nearshore.

Figure 5–195 shows the concentration versus time for tritium under the Base Case. Releases from cribs and trenches (ditches) causes 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.

Table 5–6. Tank Closure Alternative 6A, 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)	26	5,000	51	7,310	13	6,000	178	20,000
	(2052)	(2054)	(2050)	(2055)	(2052)	(2054)	(2050)	
Technetium-99	**1,350**	**29,100**	**2,680**	**15,200**	150	**24,700**	169	900
	(2056)	(2050)	(2050)	(2051)	(2064)	(2050)	(2515)	
Iodine-129	**3**	**41**	**5**	**31**	0.3	**31**	0.3	1
	(2053)	(2057)	(2050)	(2050)	(2070)	(2057)	(2579)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	0	**34**	0	13	0	10	0	15
	(1940)	(11,742)	(2166)	(11,780)	(1940)	(11,758)	(11,844)	
Chemical in micrograms per liter								
Chromium	8	**3,180**	**289**	**761**	10	**1,660**	33	100
	(2050)	(2050)	(2050)	(2050)	(2050)	(2050)	(2695)	
Nitrate	475	**1,540,000**	8,550	**133,000**	667	**1,010,000**	8,410	45,000
	(2051)	(2050)	(2050)	(2054)	(2054)	(2050)	(2450)	
Total uranium	0	10	0	4	0	7	0	30
	(2160)	(11,678)	(2166)	(11,755)	(2167)	(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 5–7. Tank Closure Alternative 6A, 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)	26	5,140	51	5,190	13	6,990	170	20,000
	(2052)	(2050)	(2050)	(2050)	(2052)	(2050)	(2057)	
Technetium-99	**1,350**	**25,000**	**2,680**	**15,200**	150	**21,000**	181	900
	(2056)	(2055)	(2050)	(2051)	(2064)	(2056)	(2502)	
Iodine-129	**3**	**45**	**5**	**31**	0.3	**35**	0.3	1
	(2053)	(2057)	(2050)	(2050)	(2070)	(2057)	(2308)	
Chemical in micrograms per liter								
Chromium	8	**3,790**	**289**	**772**	10	**1,660**	29	100
	(2050)	(2088)	(2050)	(2051)	(2050)	(2051)	(2256)	
Nitrate	475	**1,670,000**	8,550	**154,000**	667	**1,180,000**	7,930	45,000
	(2051)	(2056)	(2050)	(2102)	(2054)	(2056)	(2460)	

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.

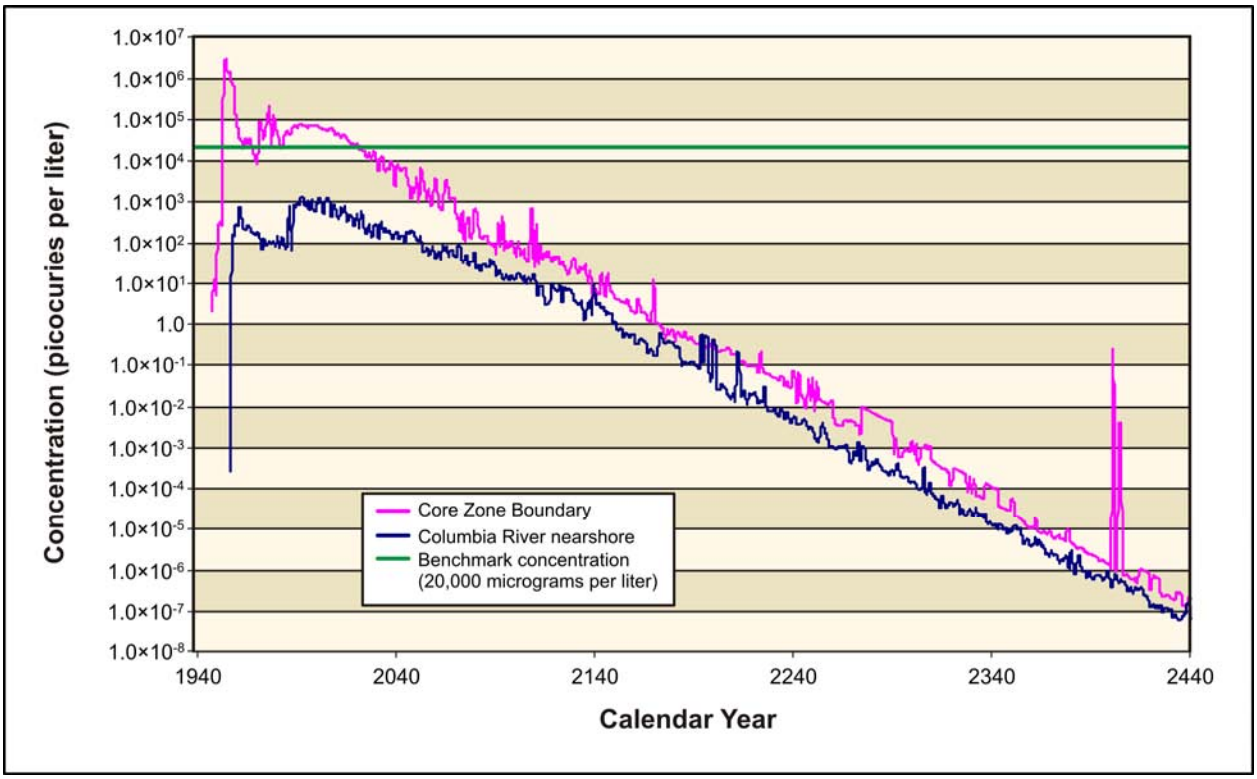


Figure 5–195. Tank Closure Alternative 6A, Base Case, Hydrogen-3 (Tritium) Concentration Versus Time

The concentration versus time for tritium under the Option Case is essentially identical to that of the Base Case (see Figure 5–196).

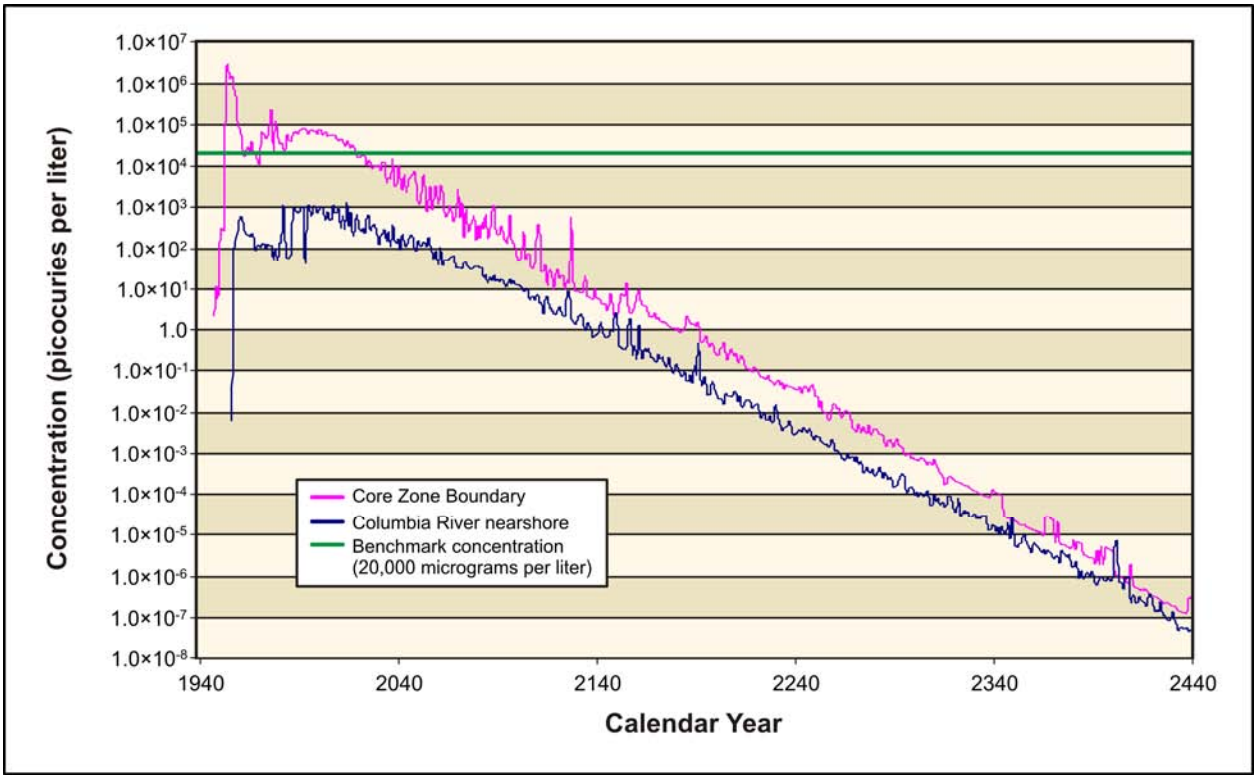


Figure 5–196. Tank Closure Alternative 6A, Option Case, Hydrogen-3 (Tritium) Concentration Versus Time

Figures 5–197 through 5–200 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 concentrations in the Columbia River nearshore never met or exceeded the benchmark but came to within about one-half to one order of magnitude.

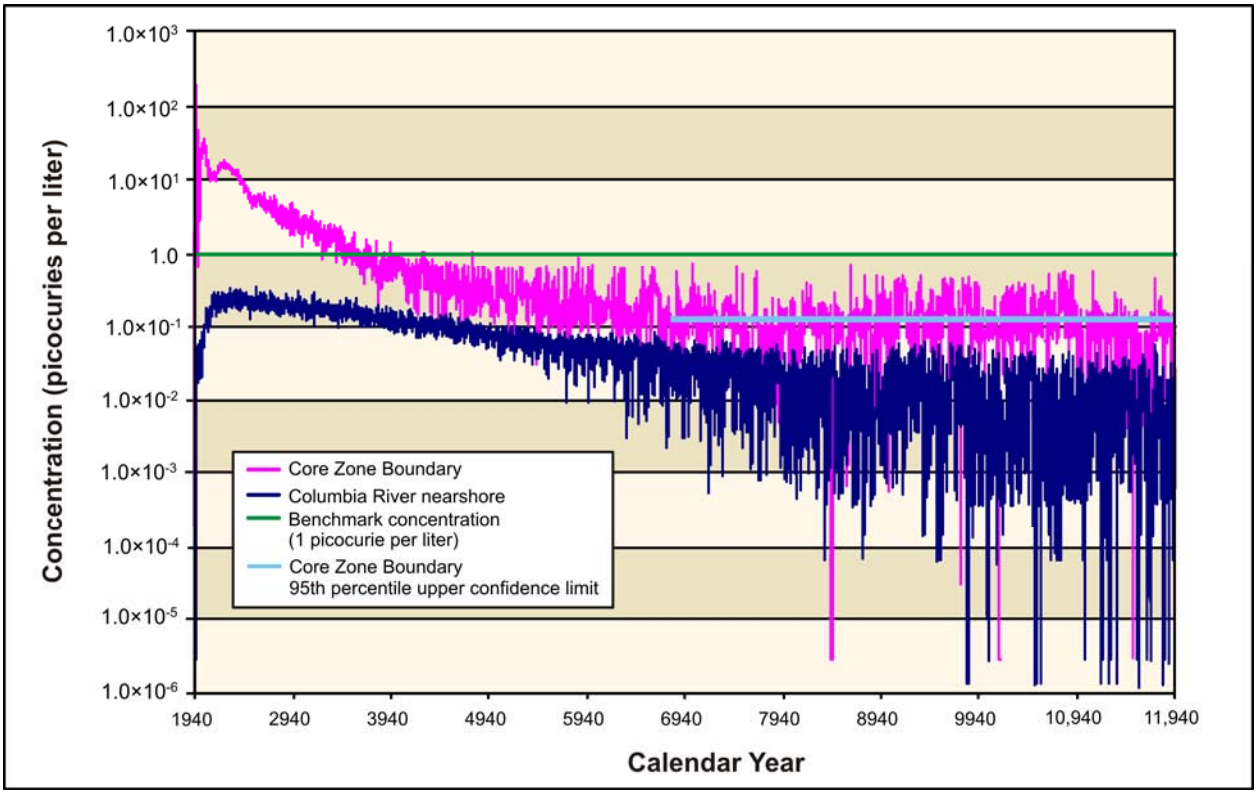


Figure 5–197. Tank Closure Alternative 6A, Base Case, Iodine-129 Concentration Versus Time

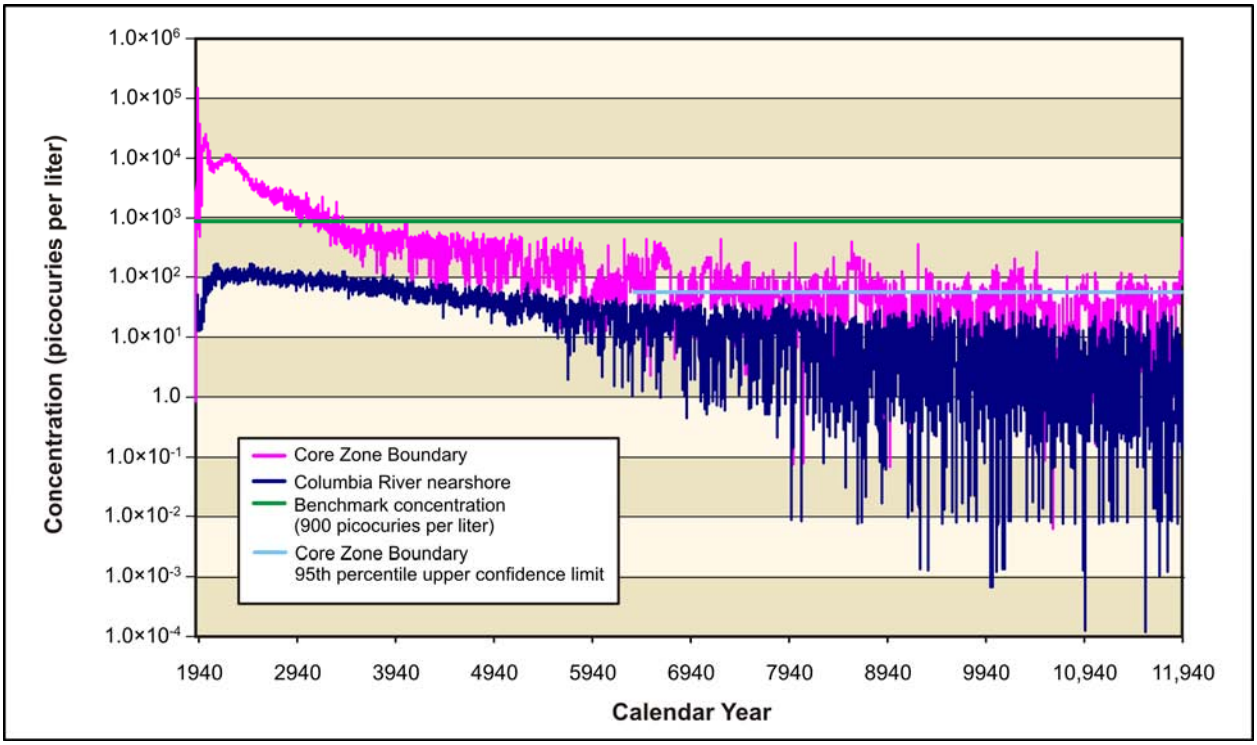


Figure 5–198. Tank Closure Alternative 6A, Base Case, Technetium-99 Concentration Versus Time

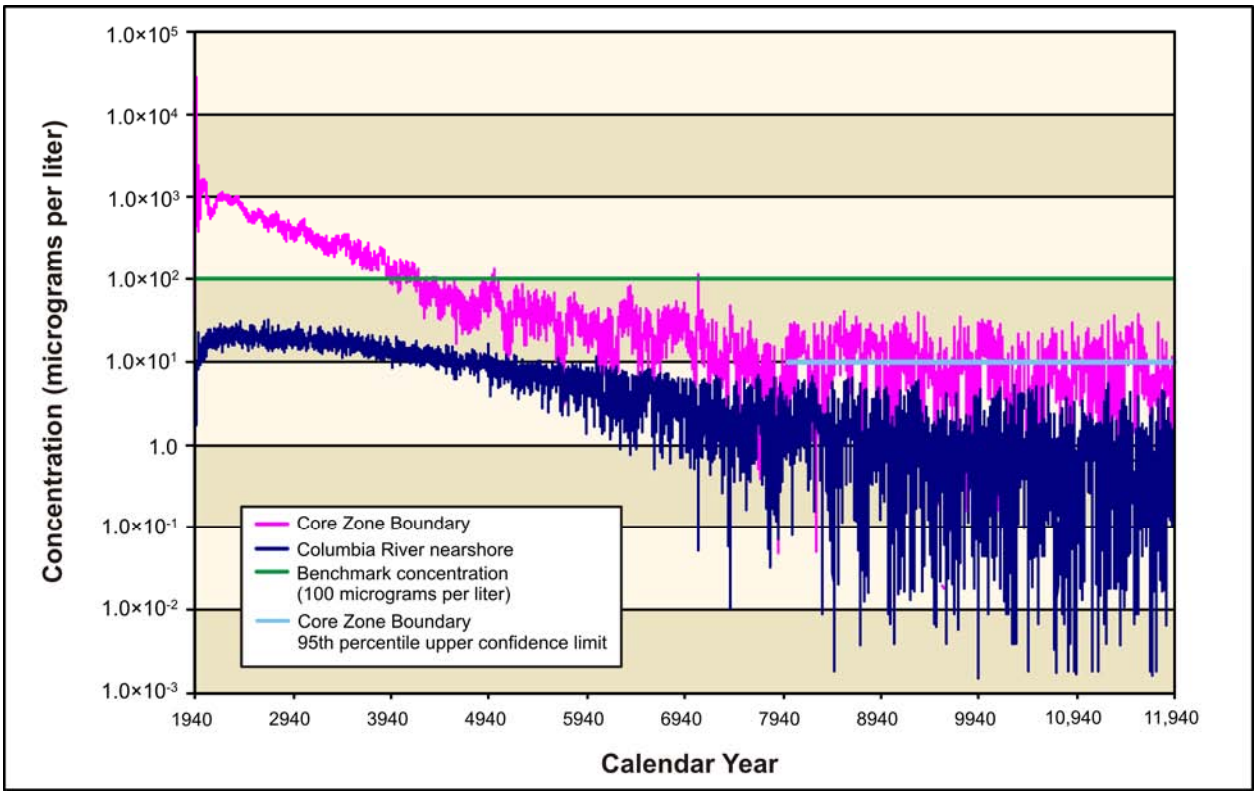


Figure 5–199. Tank Closure Alternative 6A, Base Case, Chromium Concentration Versus Time

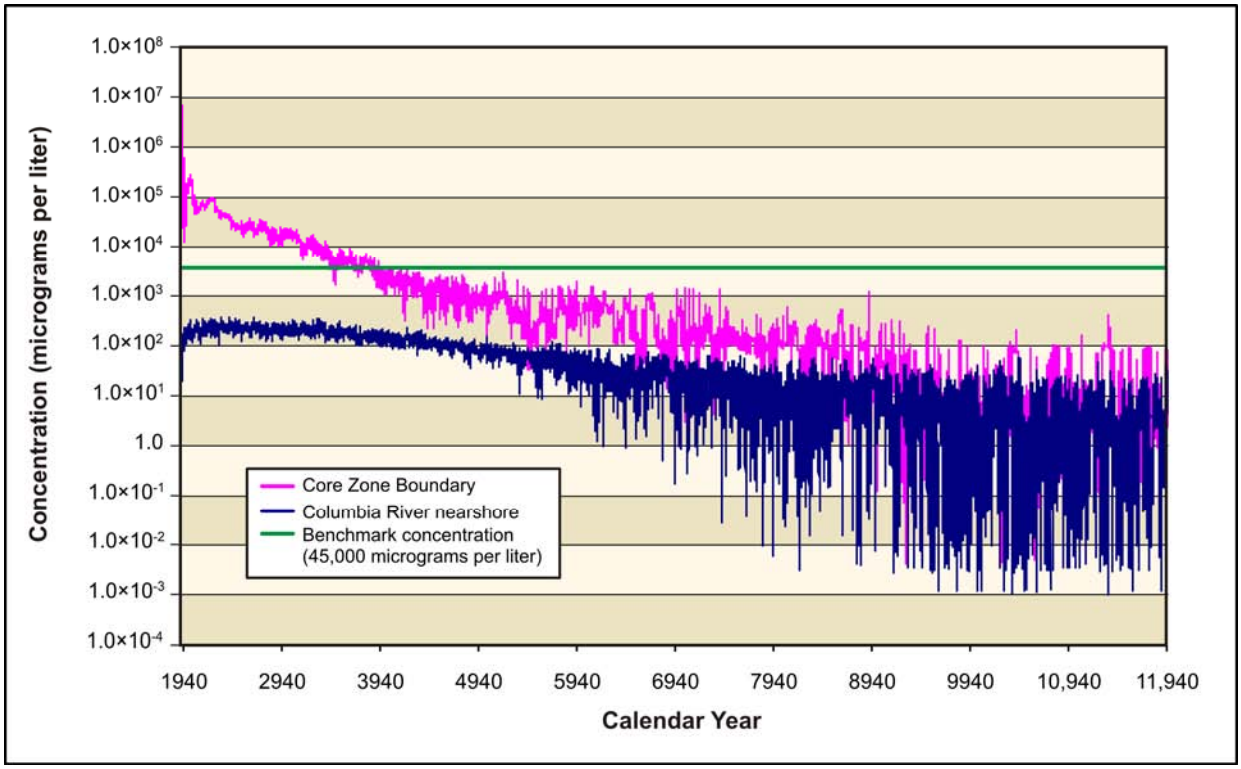


Figure 5–200. Tank Closure Alternative 6A, Base Case, Nitrate Concentration Versus Time

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 5–201 through 5–204).

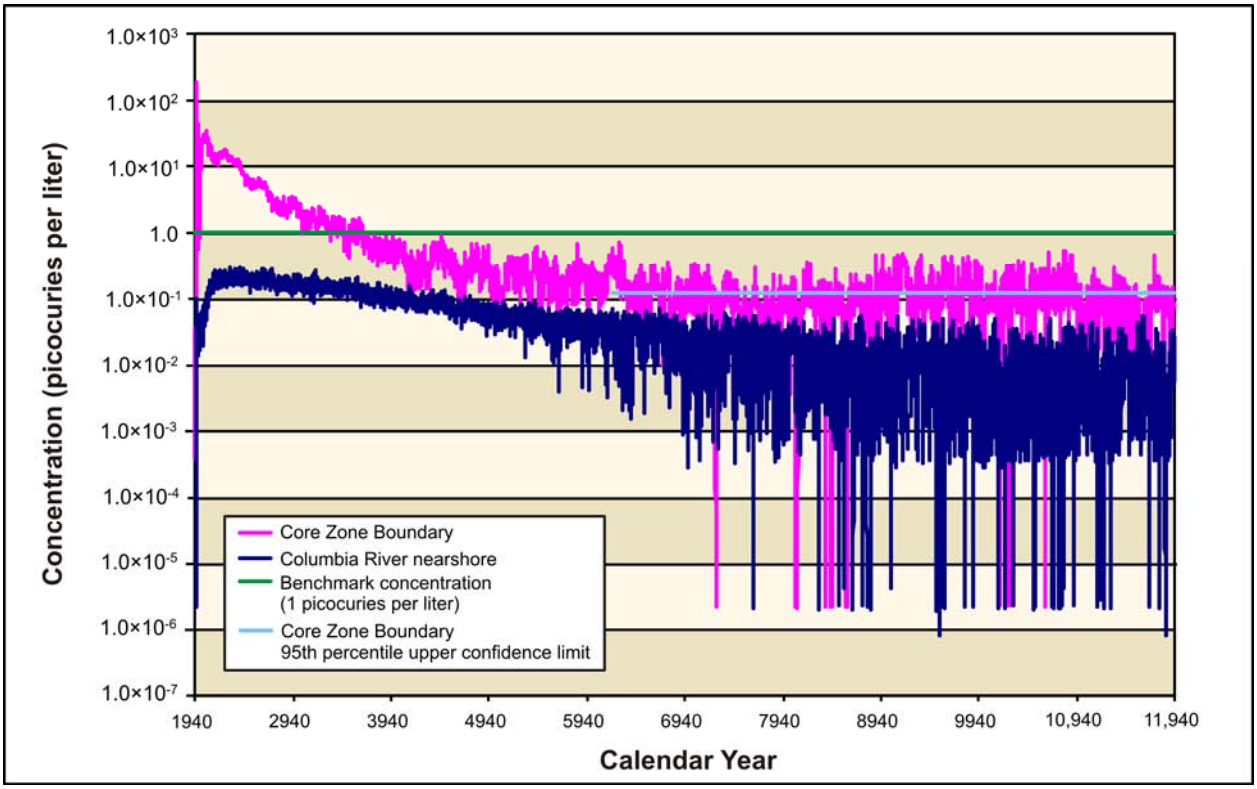


Figure 5–201. Tank Closure Alternative 6A, Option Case, Iodine-129 Concentration Versus Time

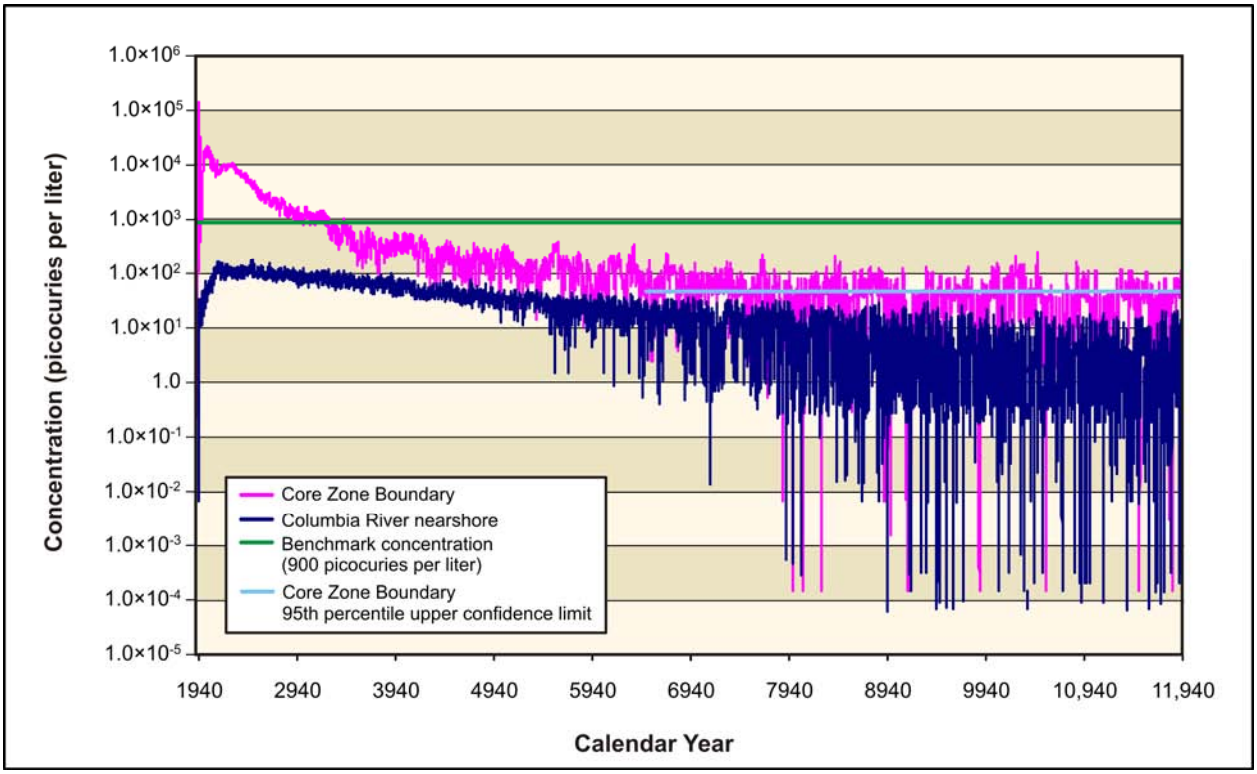


Figure 5–202. Tank Closure Alternative 6A, Option Case, Technetium-99 Concentration Versus Time

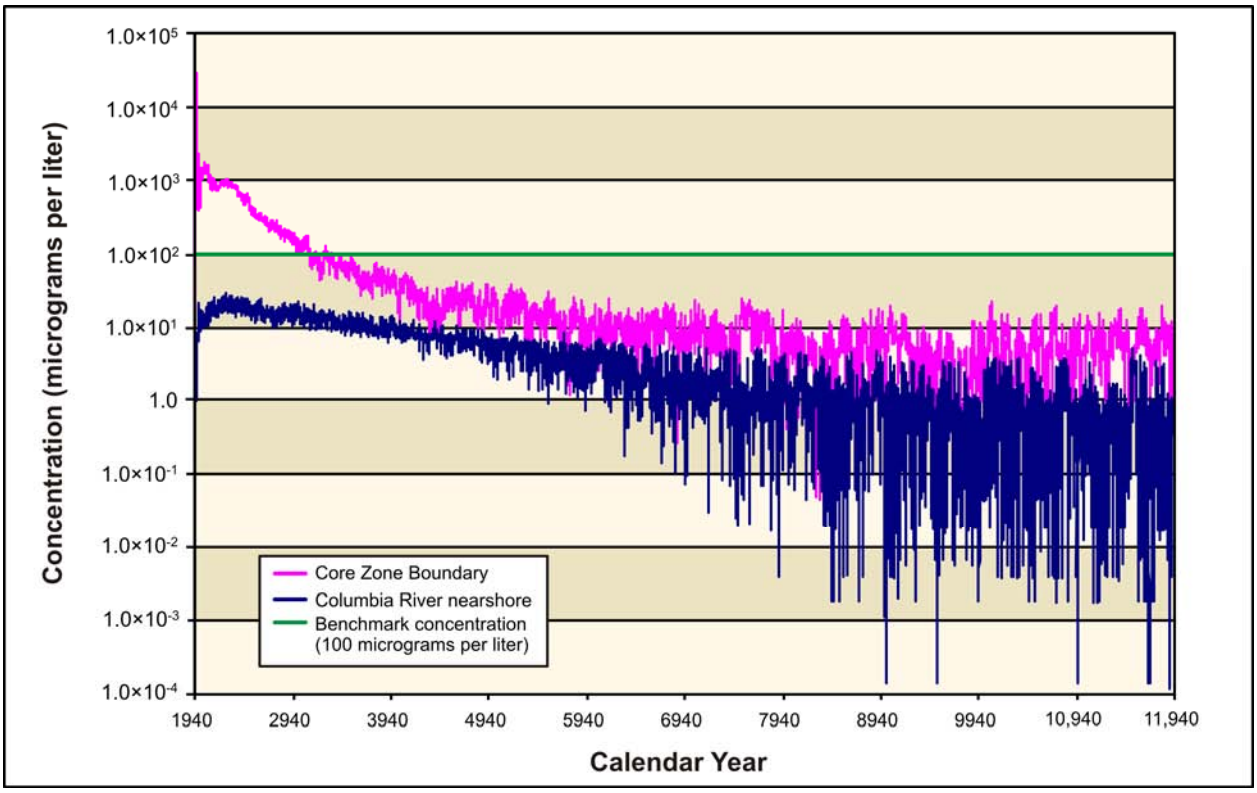


Figure 5–203. Tank Closure Alternative 6A, Option Case, Chromium Concentration Versus Time

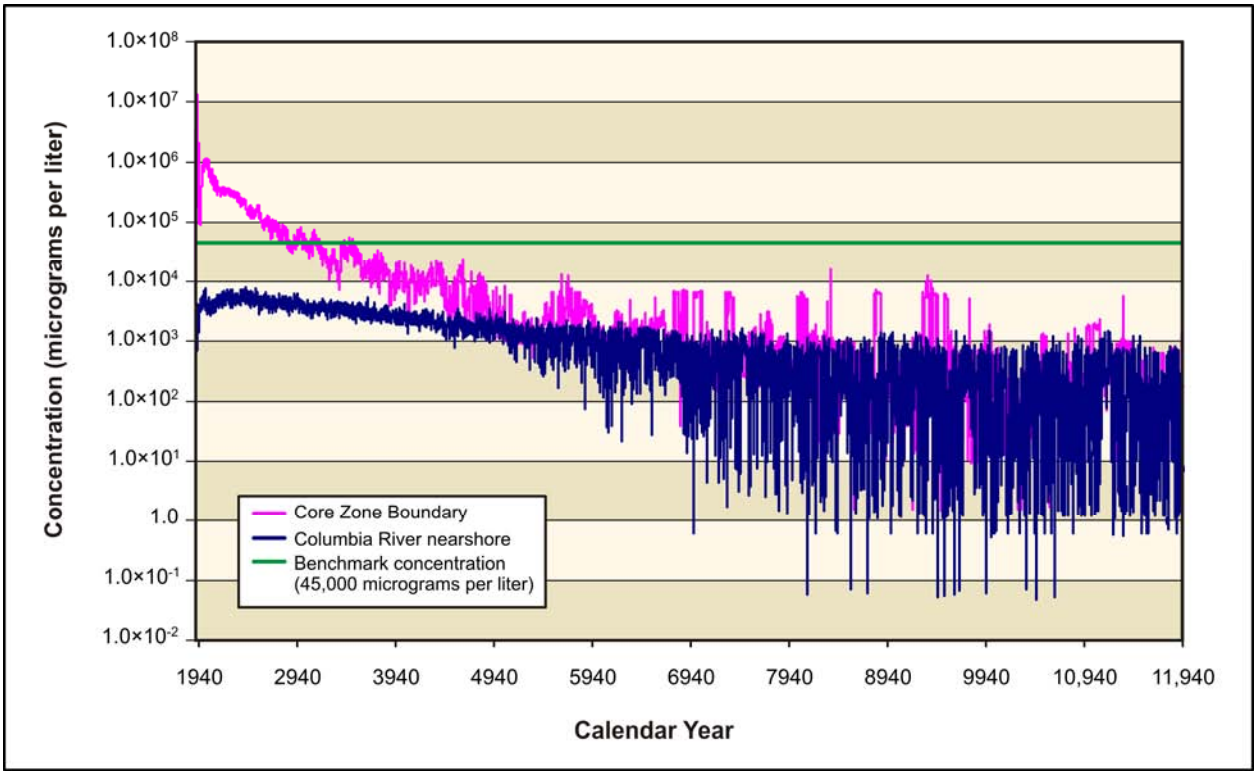


Figure 5–204. Tank Closure Alternative 6A, Option Case, Nitrate Concentration Versus Time

Figures 5–205 and 5–206 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 concentration 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 5–207). 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 5–208). The Columbia River nearshore concentrations of total uranium remained fairly constant at around four and a half orders of magnitude below the benchmark.

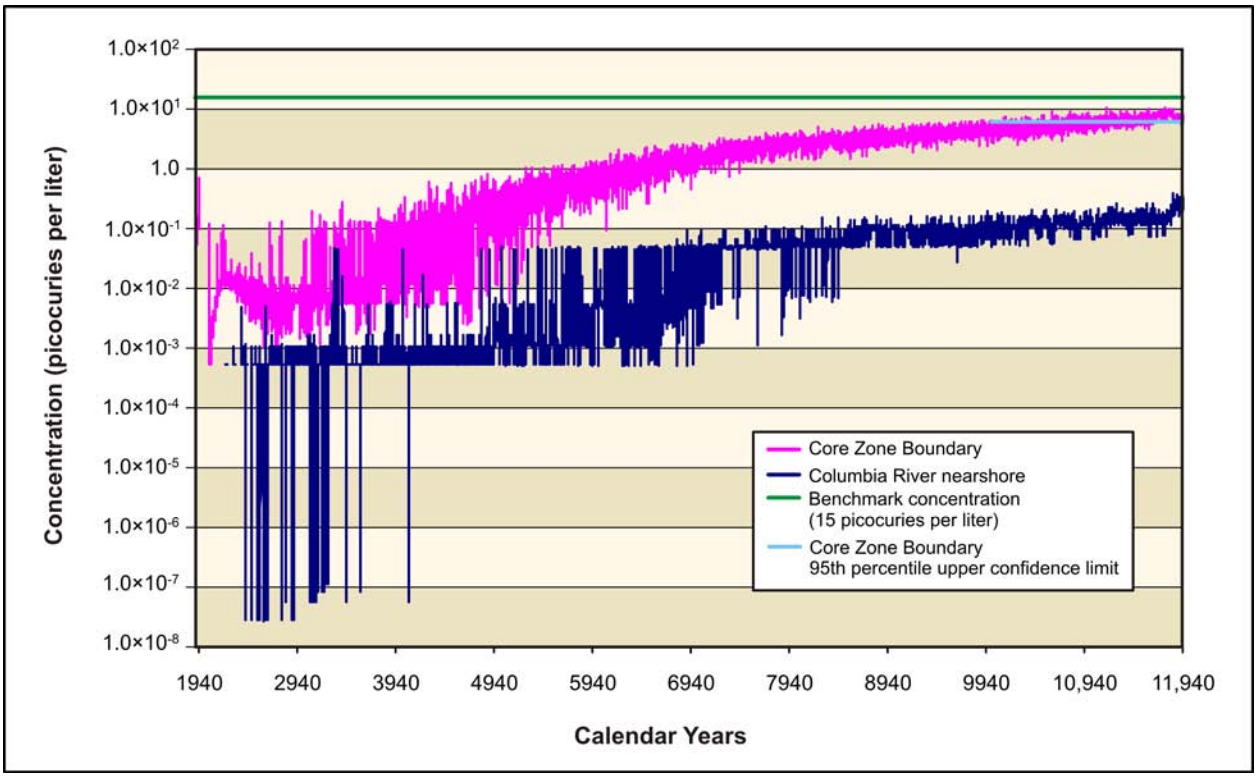


Figure 5–205. Tank Closure Alternative 6A, Base Case, Uranium-238 Concentration Versus Time

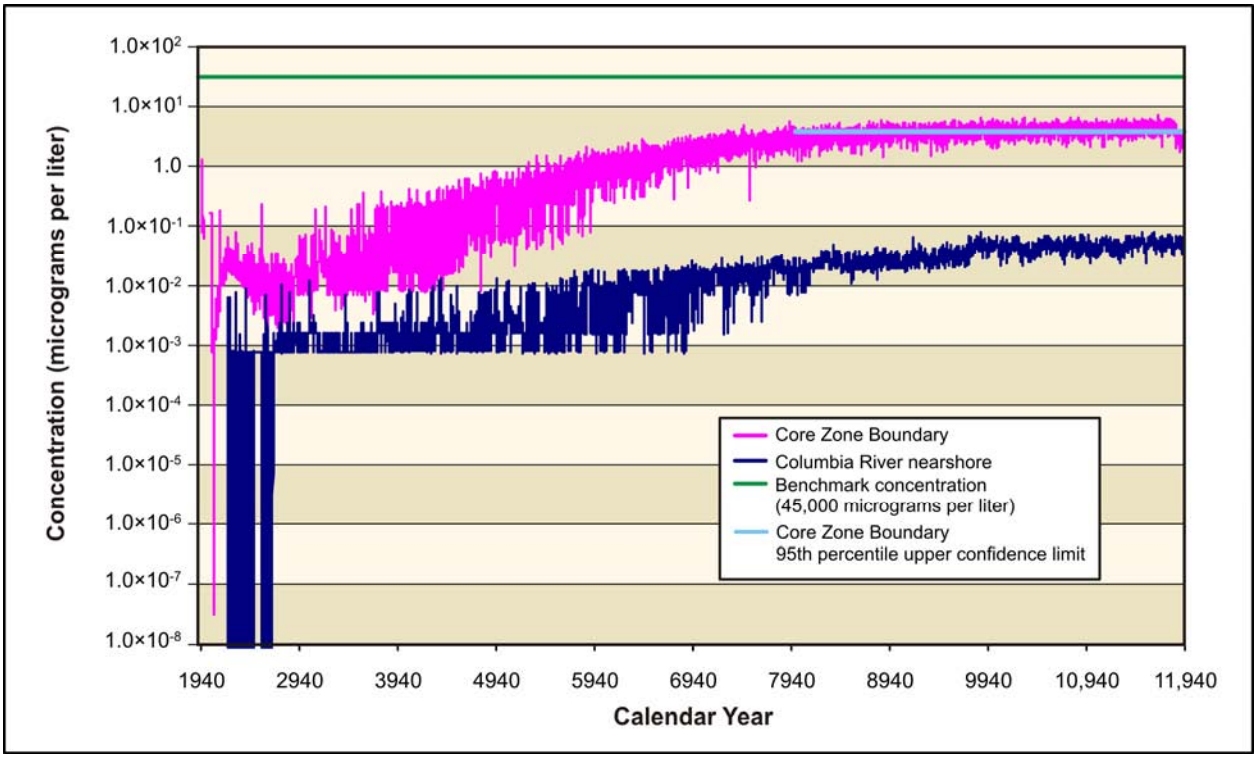


Figure 5–206. Tank Closure Alternative 6A, Base Case, Total Uranium Concentration Versus Time

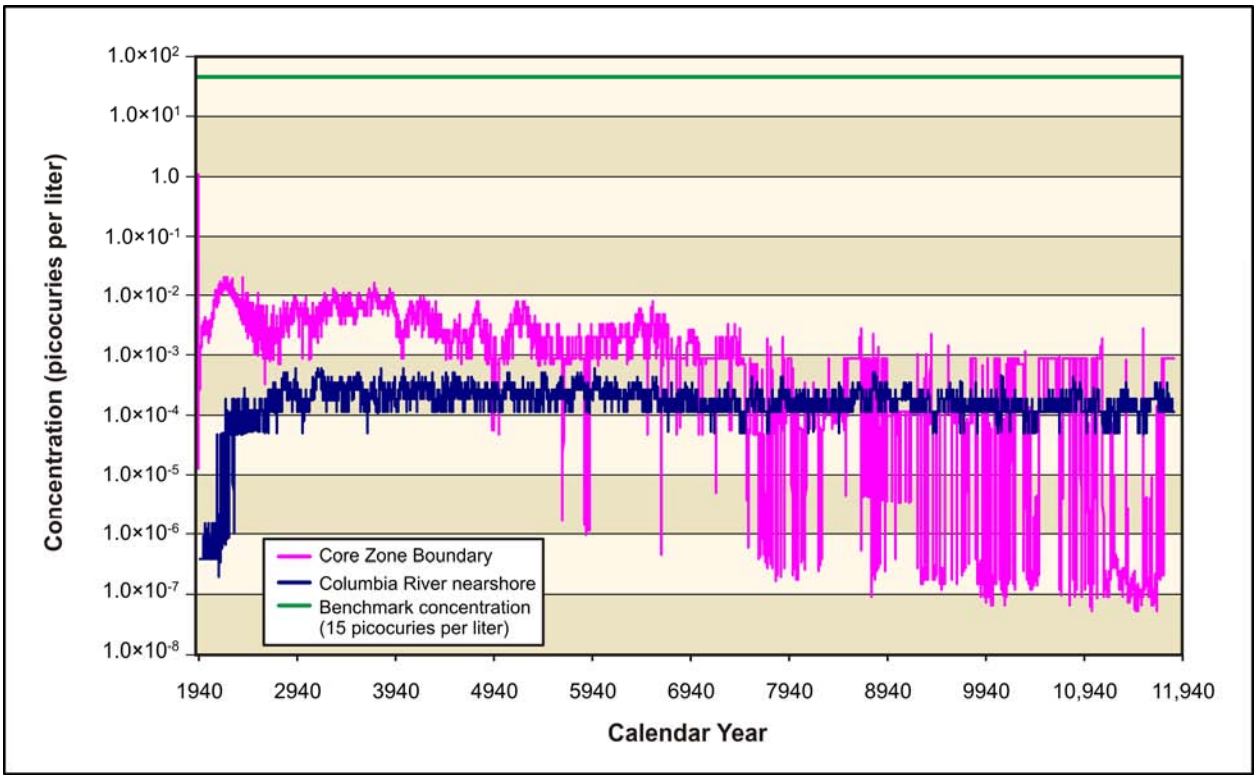


Figure 5–207. Tank Closure Alternative 6A, Option Case, Uranium-238 Concentration Versus Time

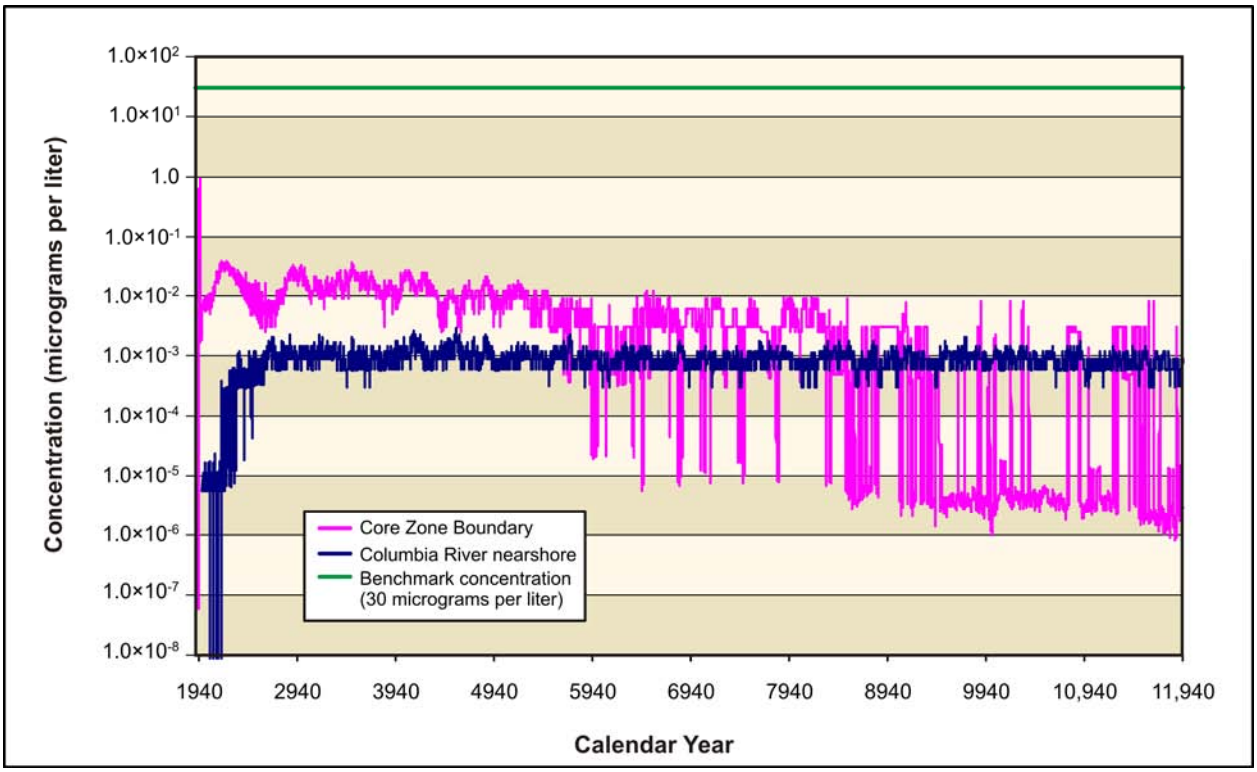


Figure 5–208. Tank Closure Alternative 6A, Option Case, Total Uranium Concentration Versus Time

5.1.1.9.5 Analysis of Spatial Distribution of Concentration

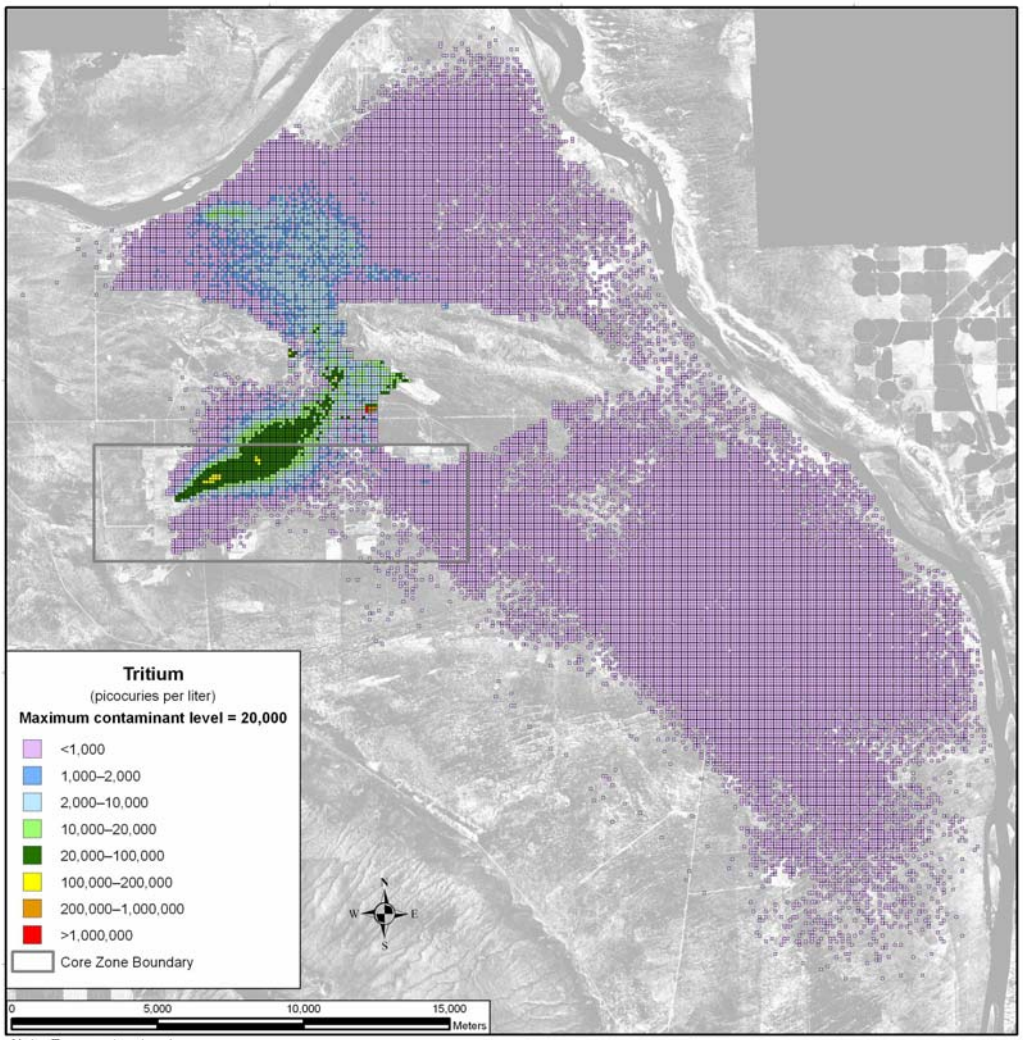
This section presents the impacts of Tank Closure Alternative 6A in terms of the spatial distribution of groundwater concentration at selected times. Concentrations of radionuclides are in picocuries per liter, chemicals in micrograms per liter (see Figures 5–209 through 5–253). Concentrations for each 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 5–209 shows the spatial distribution of groundwater concentration for tritium during CY 2005 under the Base Case, which would include use of a modified RCRA Subtitle C barrier. Analysis 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 concentration, 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 5–210).

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 5–211 and 5–212).

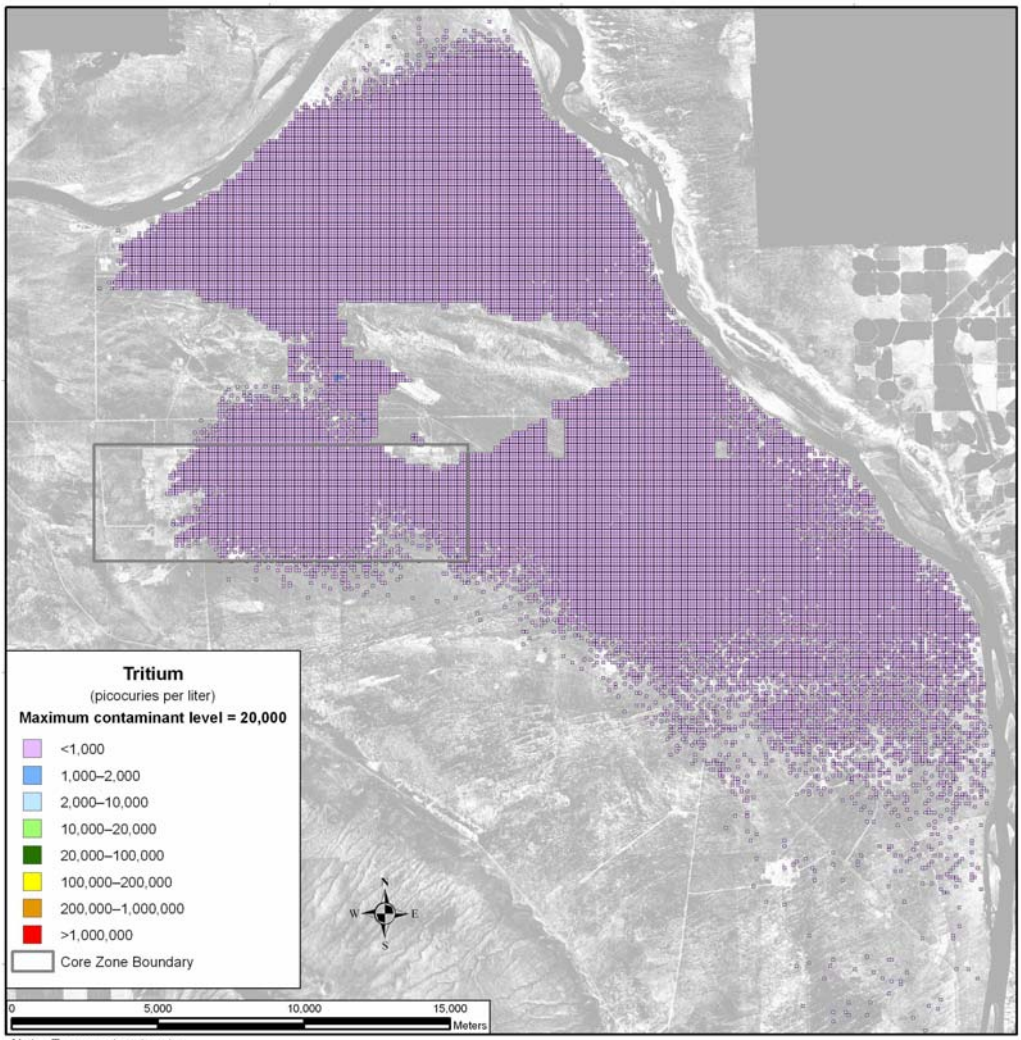
Figure 5–213 shows the spatial distribution of groundwater concentration for iodine-129 during CY 2005 under the Base Case. Analysis releases from cribs and trenches (ditches) and past leaks result in groundwater concentration plumes that exceed the benchmark concentration associated with the T Barrier, 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 5–214). In the plume north of Gable Gap, contaminant levels have begun to meet the benchmark concentration. In the east, just outside of the Core Zone Boundary, levels have risen to 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 5–215). Technetium-99 (see Figures 5–216 through 5–218), chromium (see Figures 5–219 through 5–221), and nitrate (see Figures 5–222 through 5–224) show similar spatial distributions at selected times. Iodine-129, technetium-99, chromium, and nitrate are all essentially conservative tracers (i.e., move at the rate of the pore water velocity) during the period of analysis.

The spatial distribution of groundwater concentrations of the conservative tracers under the Option Case is essentially identical to that under the Base Case (see Figures 5–225 through 5–236).



Note: To convert meters to feet, multiply by 3.281

Figure 5–209. Tank Closure Alternative 6A, 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 5–210. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2135

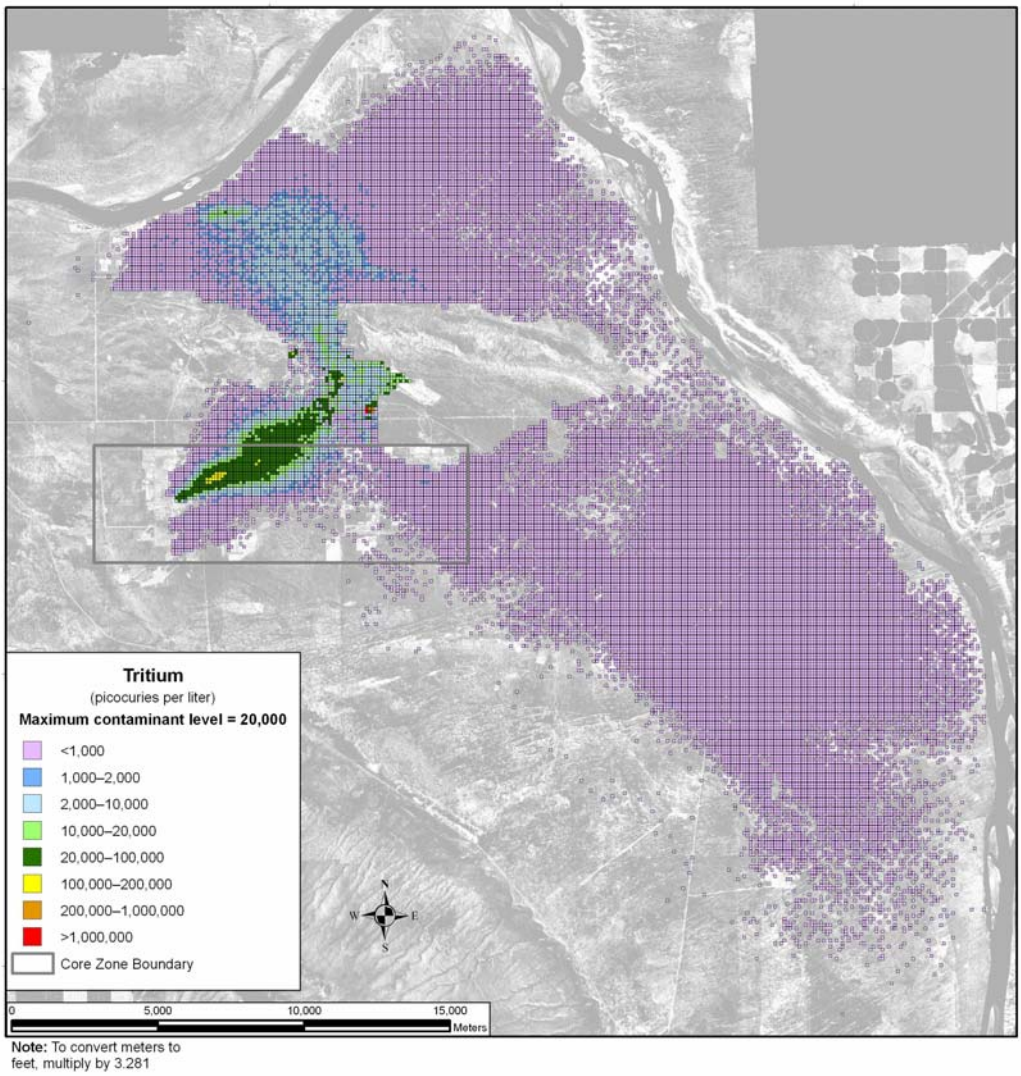
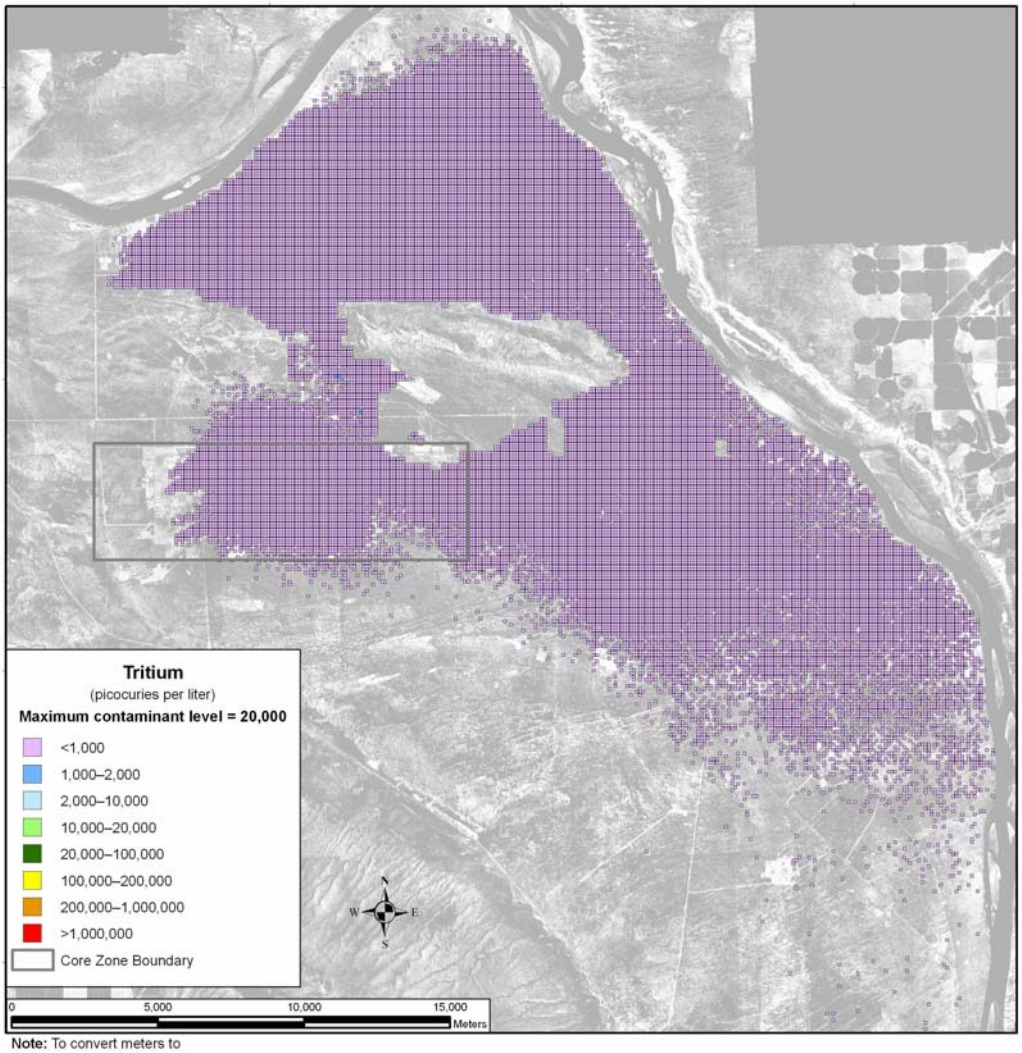
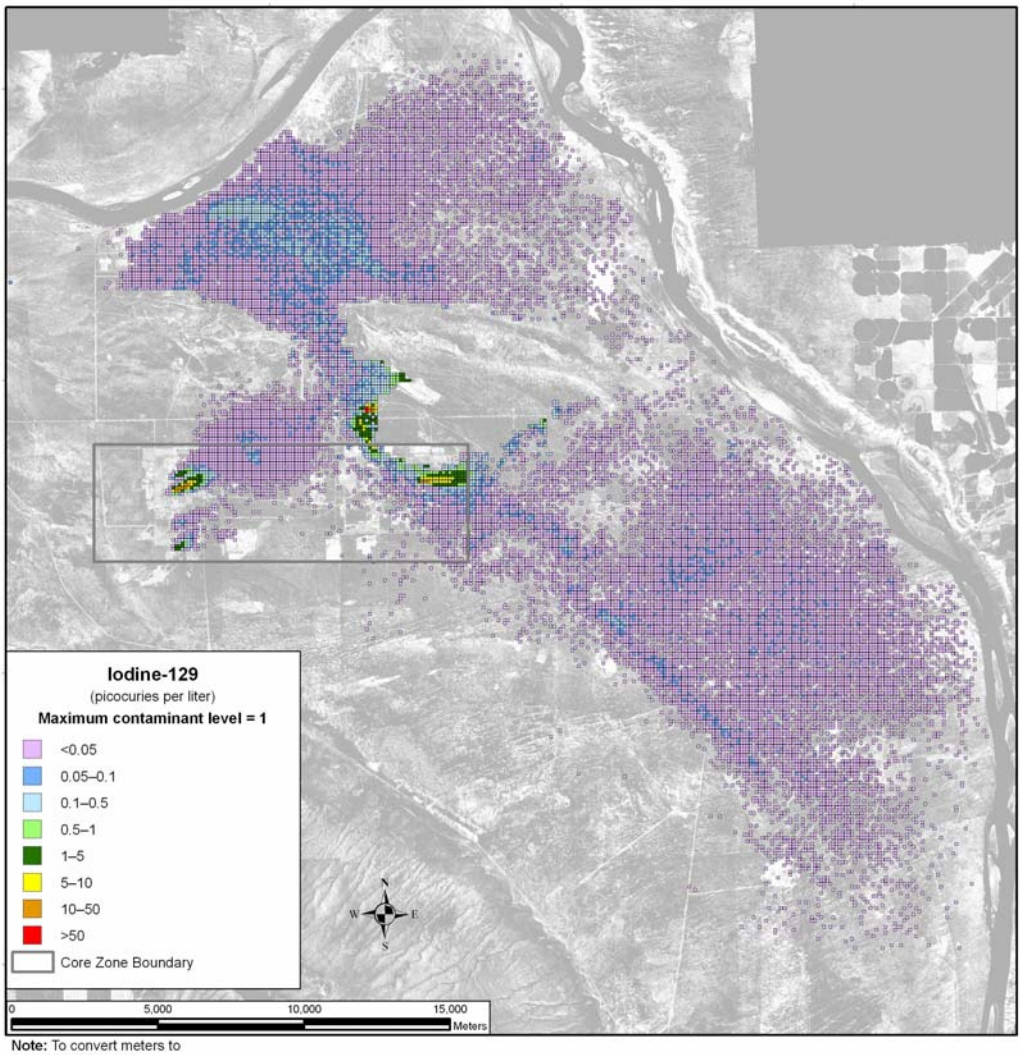


Figure 5–211. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

Figure 5–212. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281

Figure 5–213. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2005

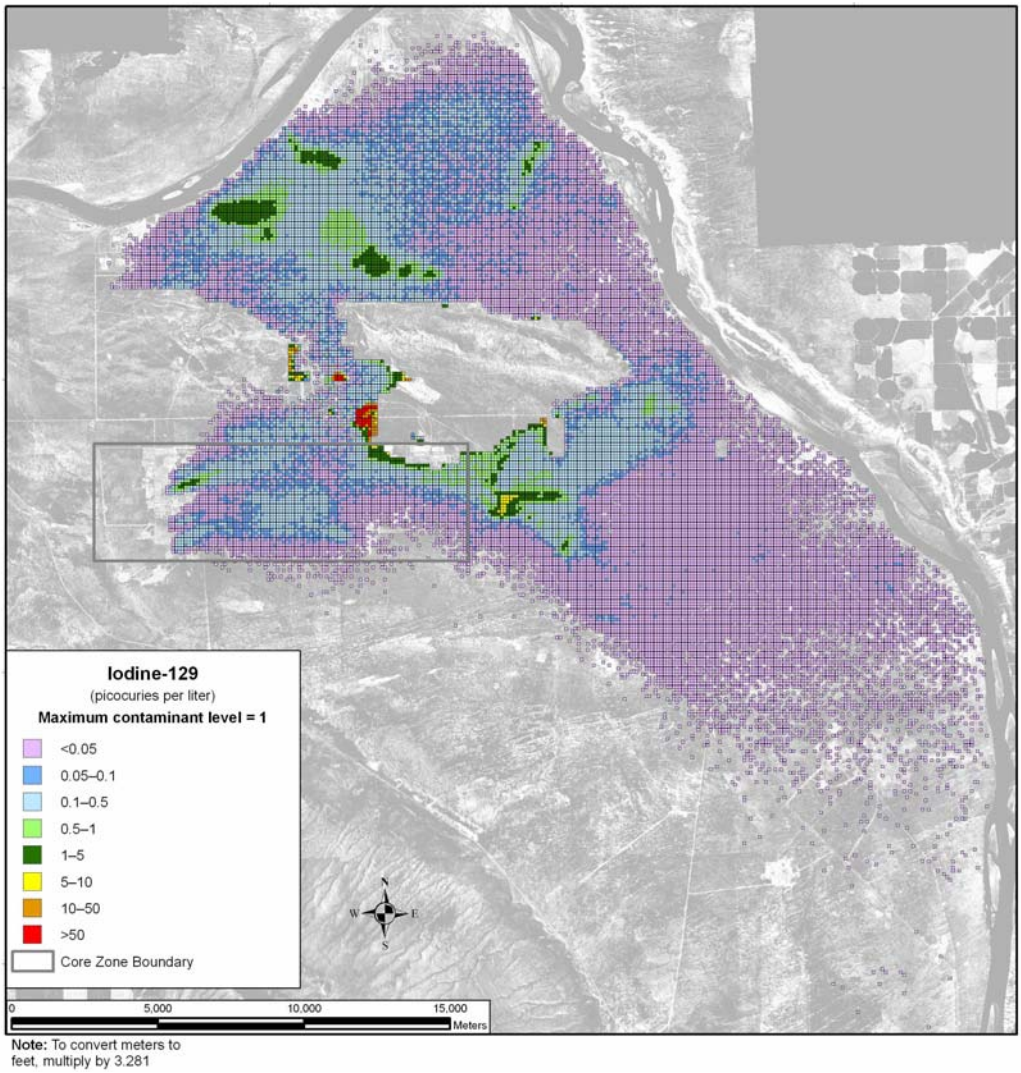
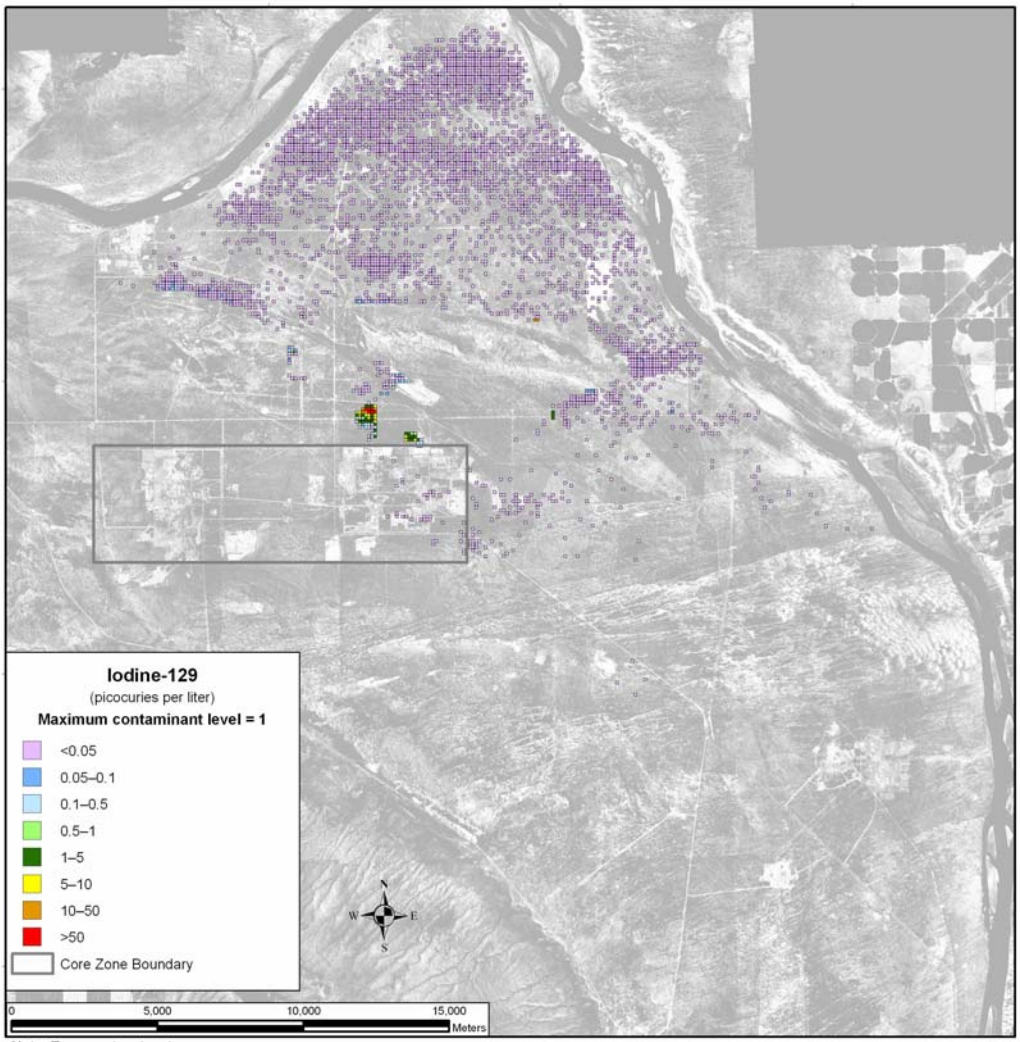
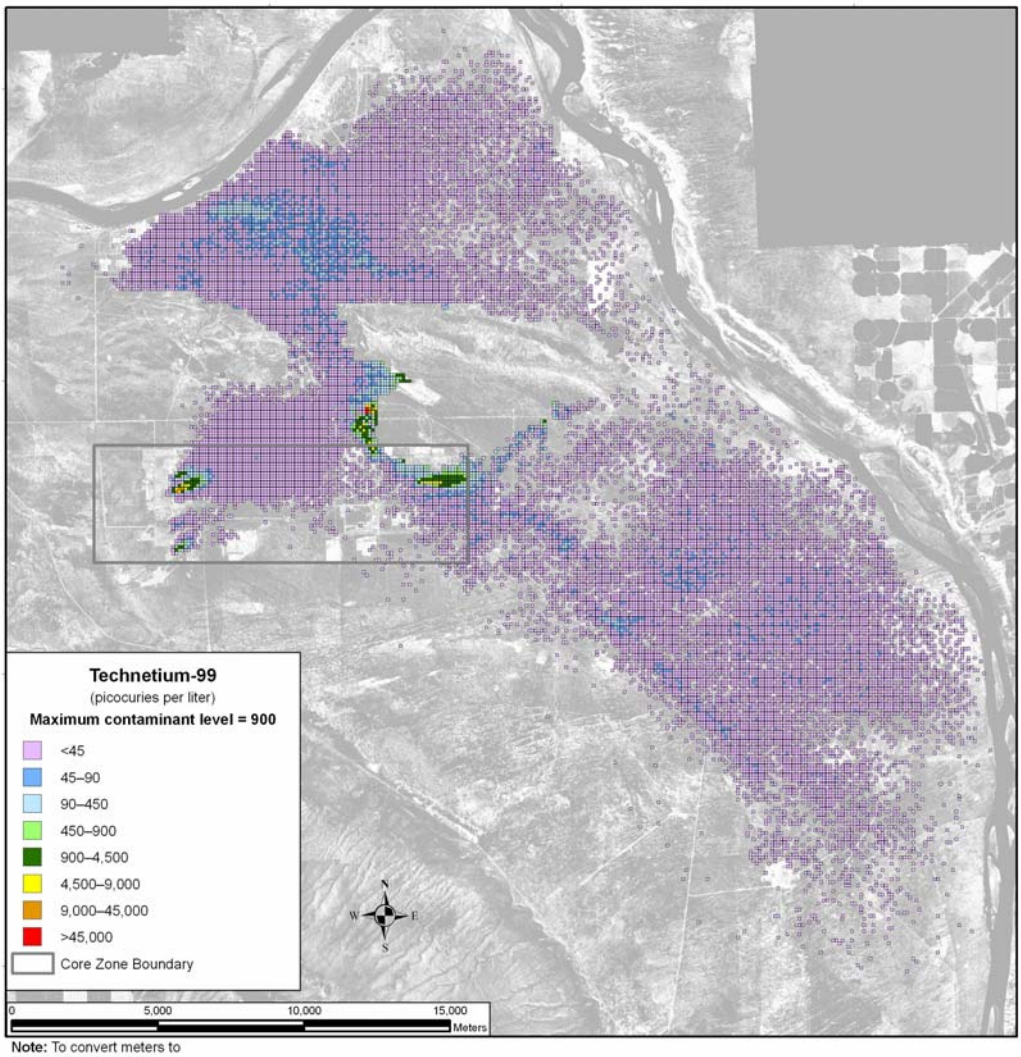


Figure 5–214. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281

Figure 5–215. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281

Figure 5–216. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2005

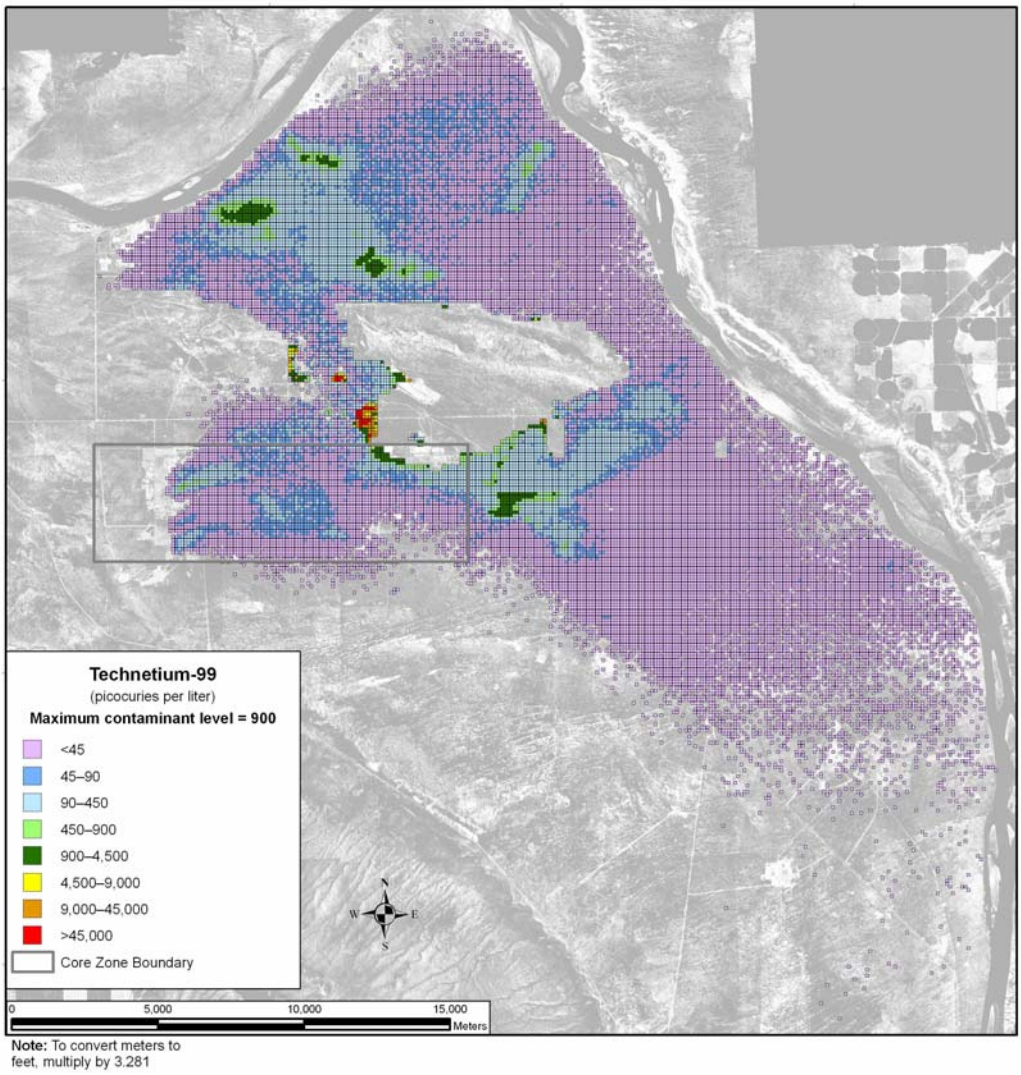


Figure 5–217. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2135

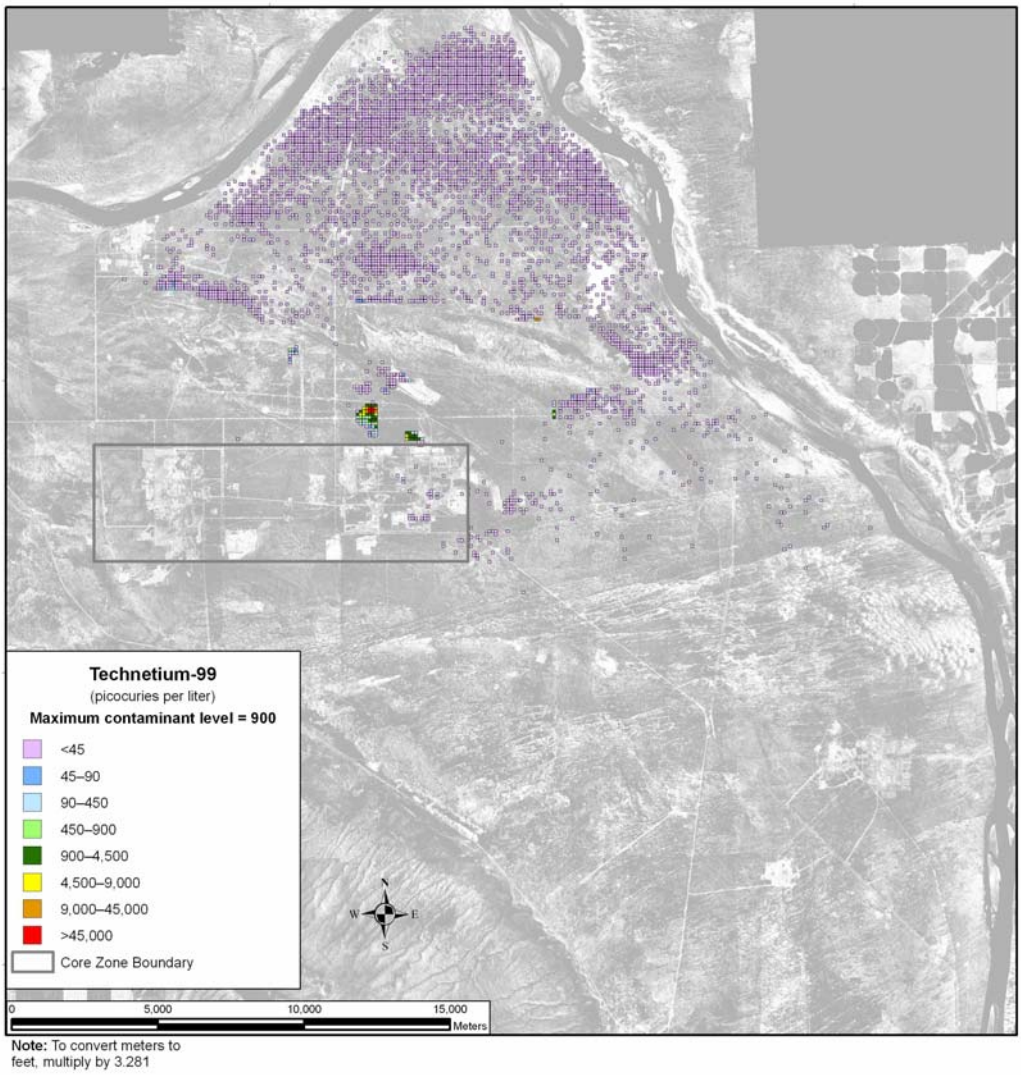
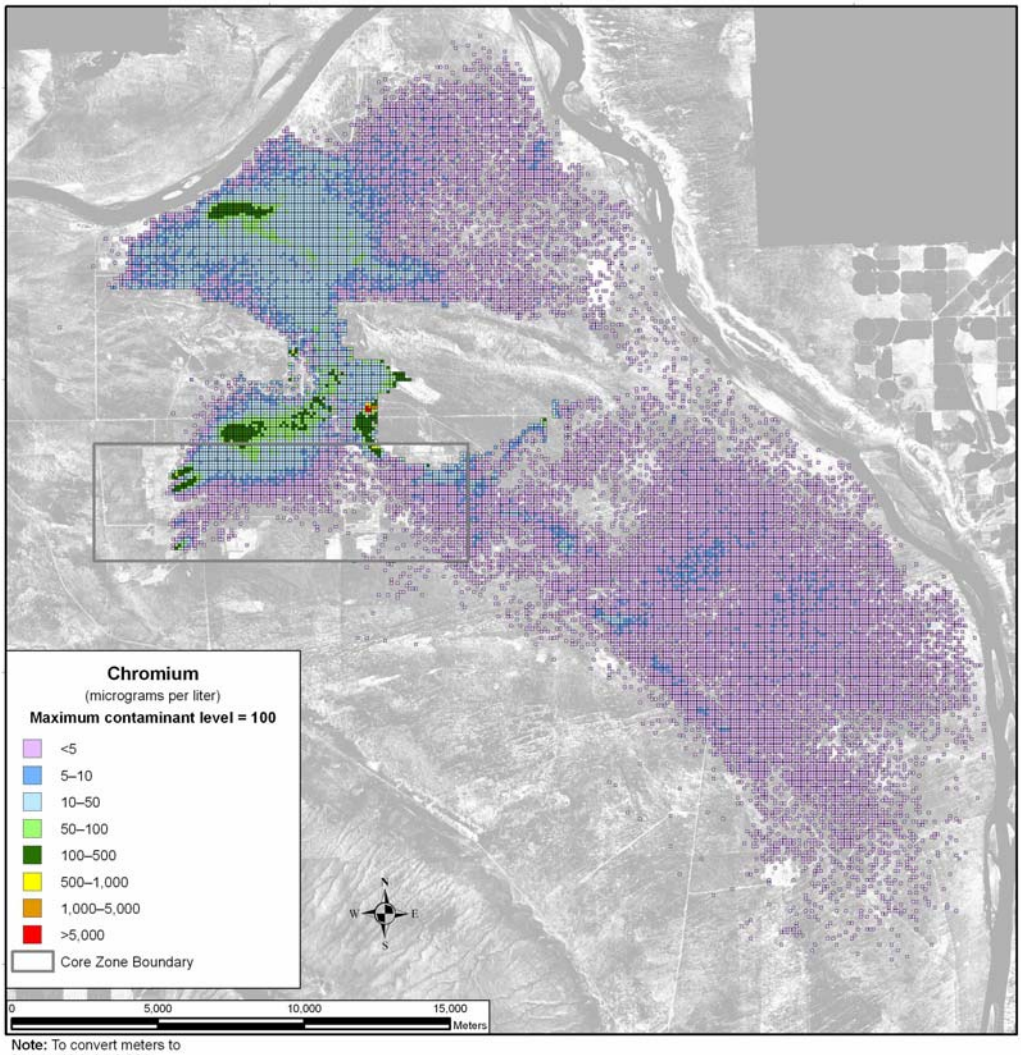


Figure 5–218. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281

Figure 5–219. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 2005

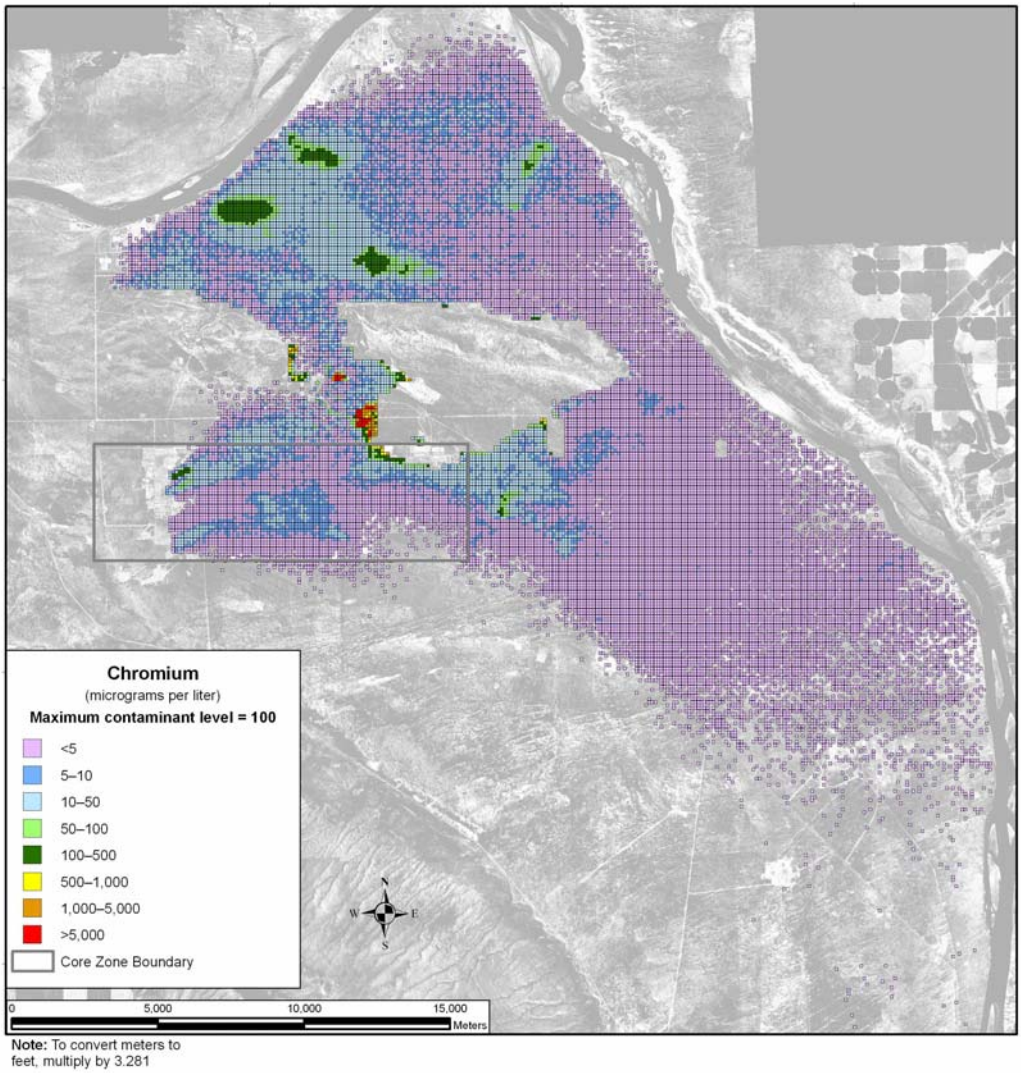
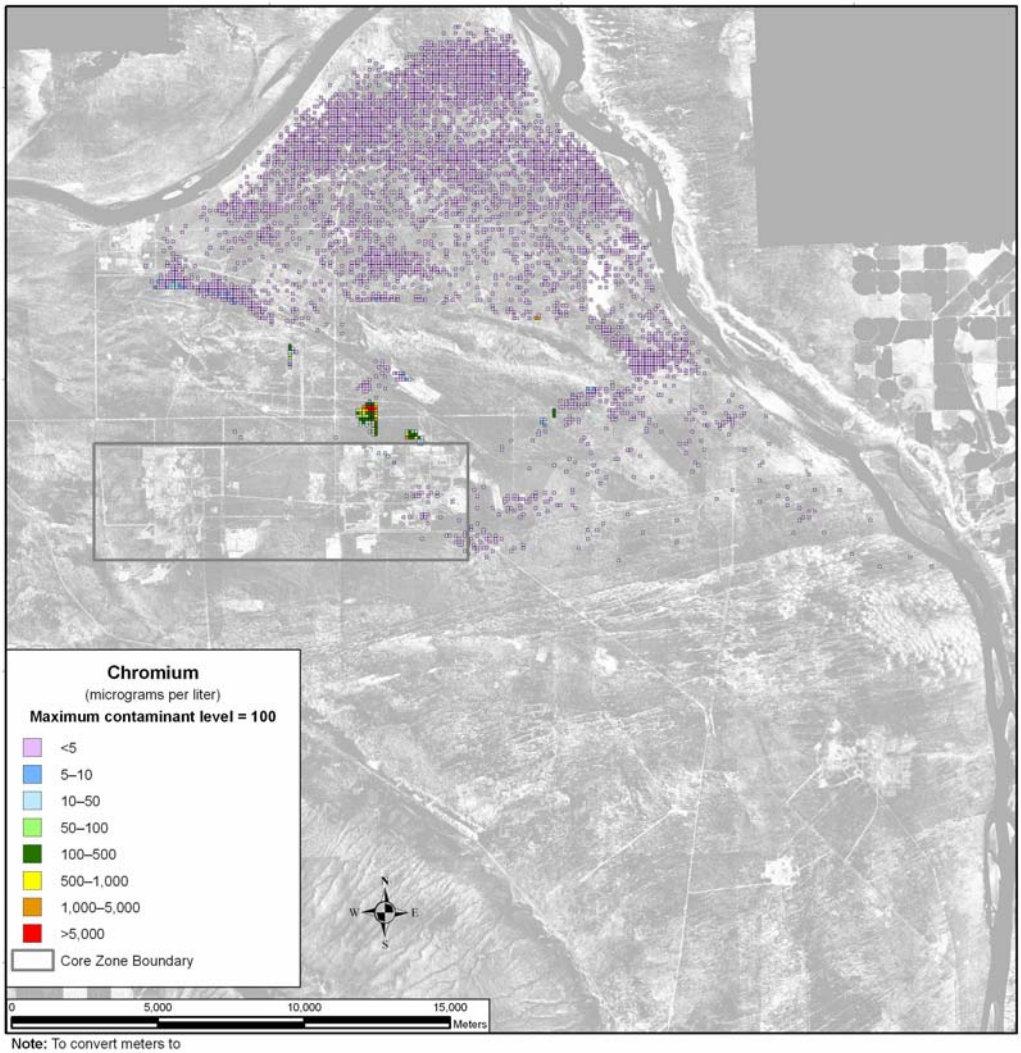
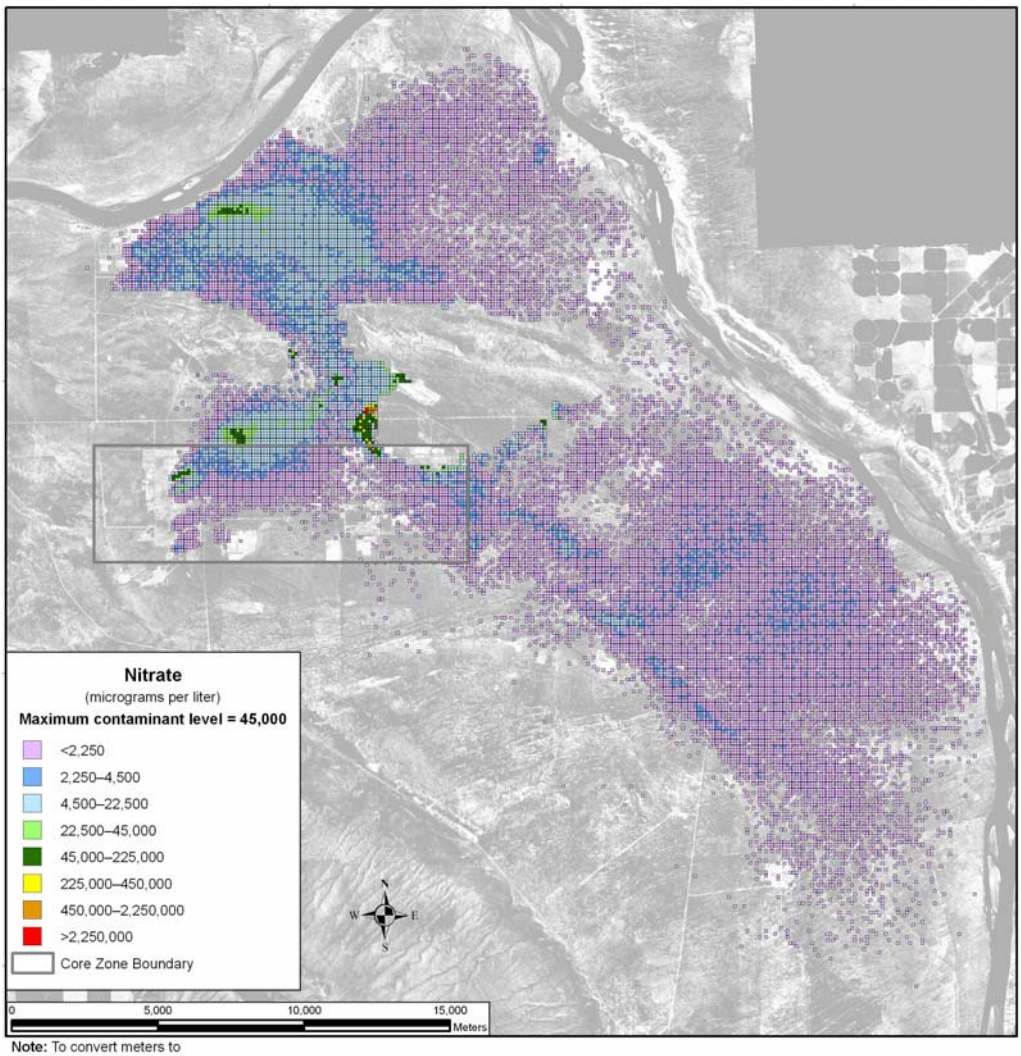


Figure 5–220. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281

Figure 5–221. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281

Figure 5–222. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2005

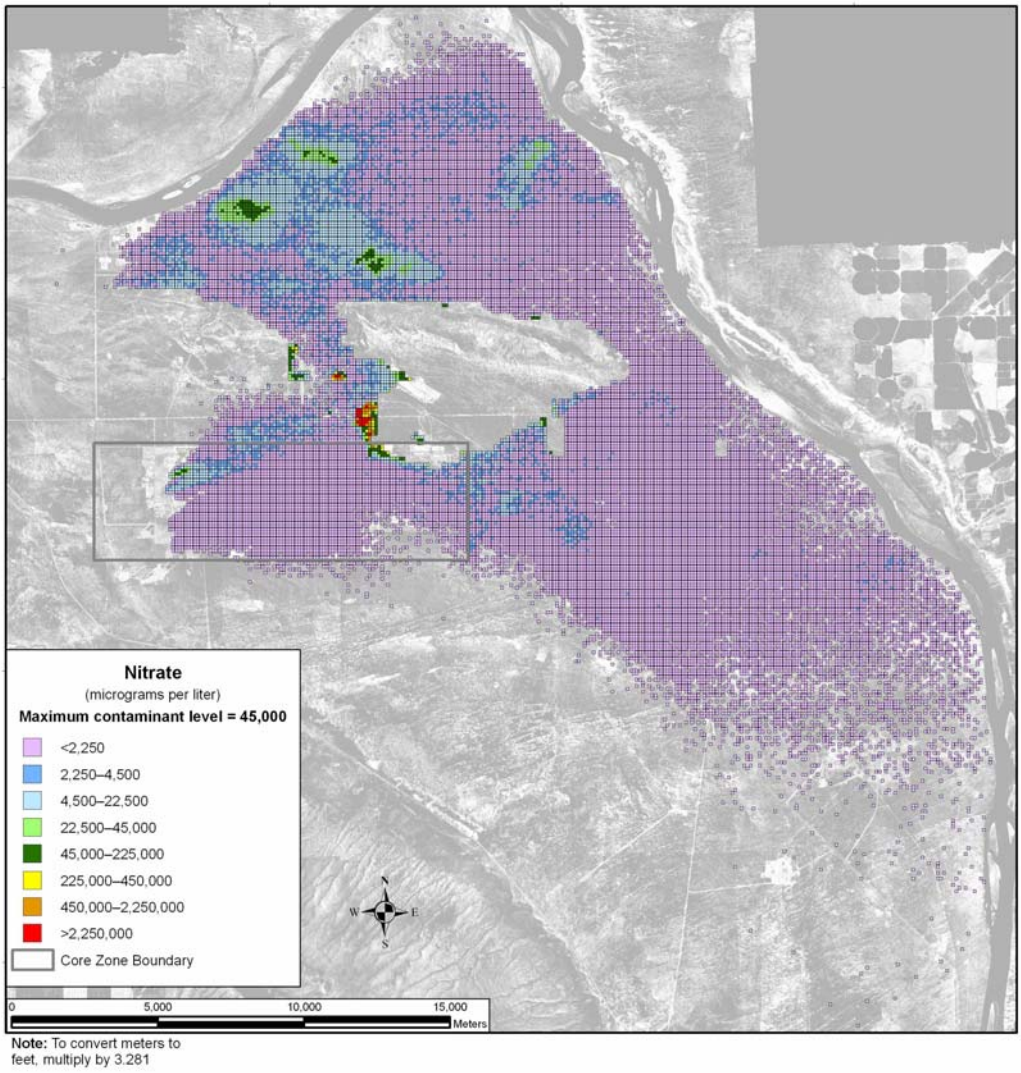
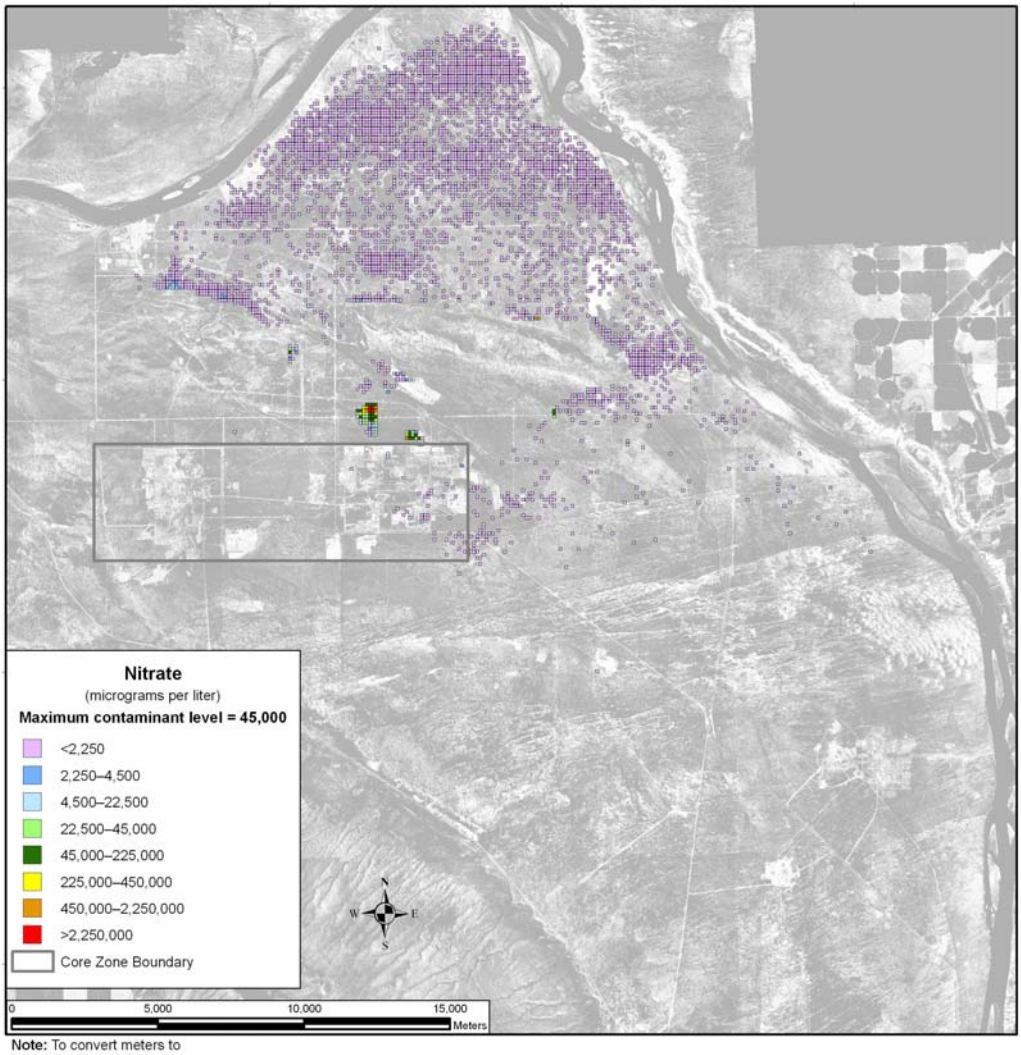


Figure 5–223. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281

Figure 5–224. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 7140

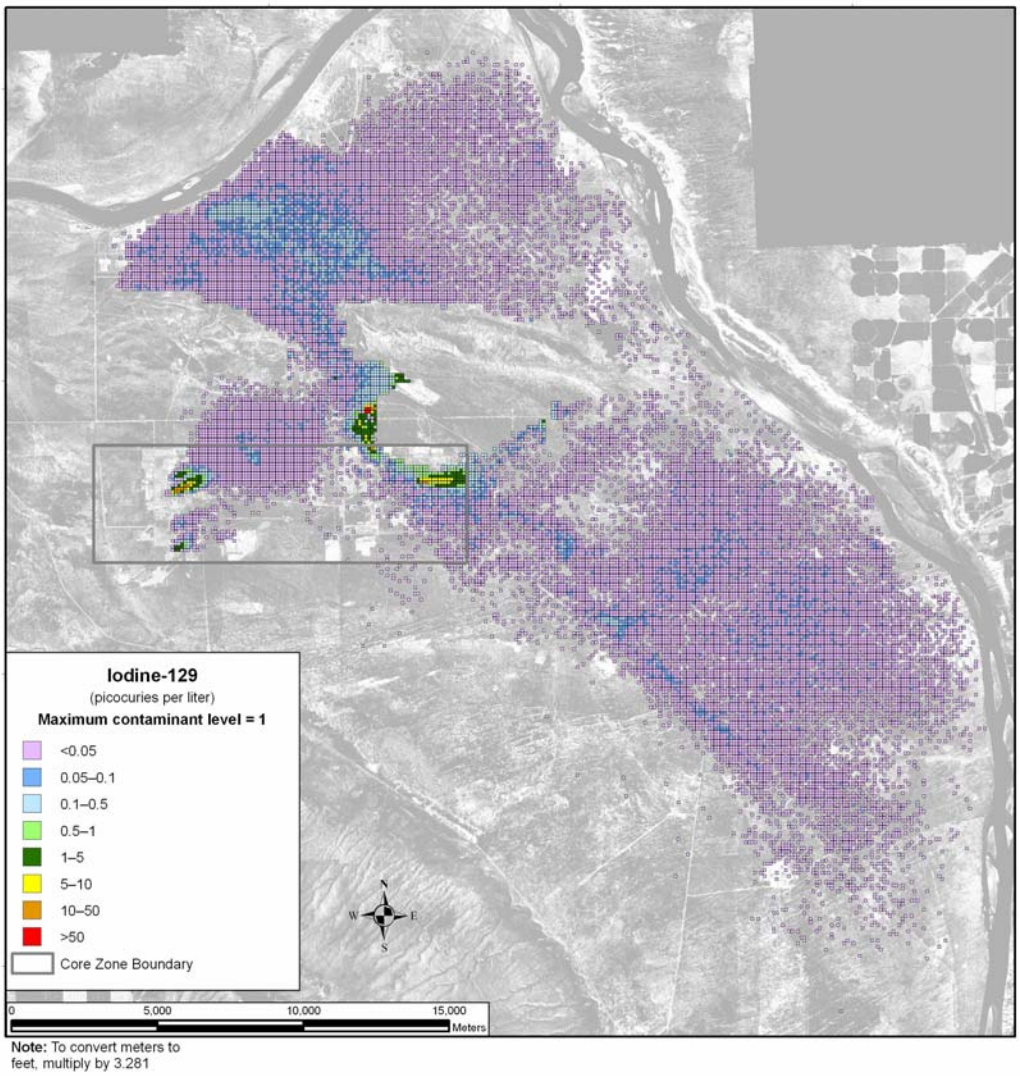
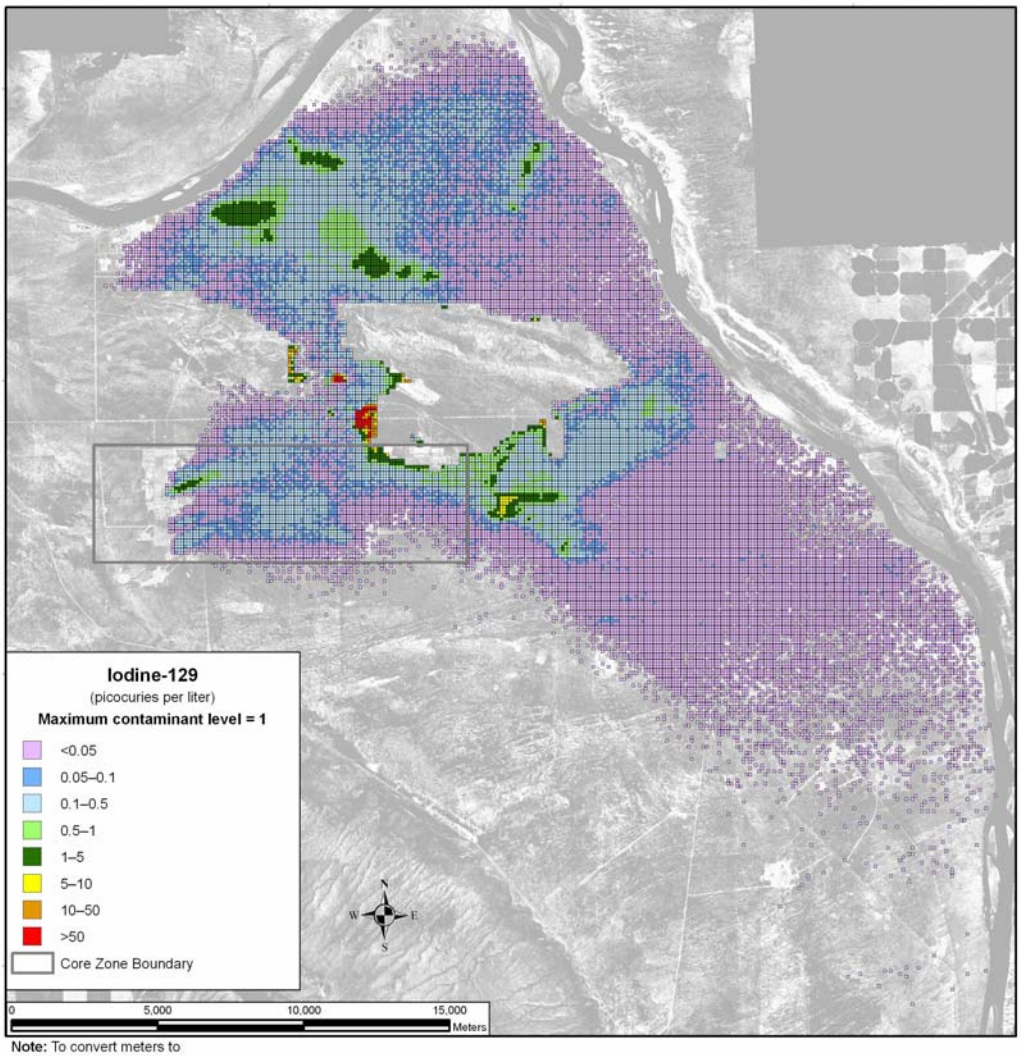
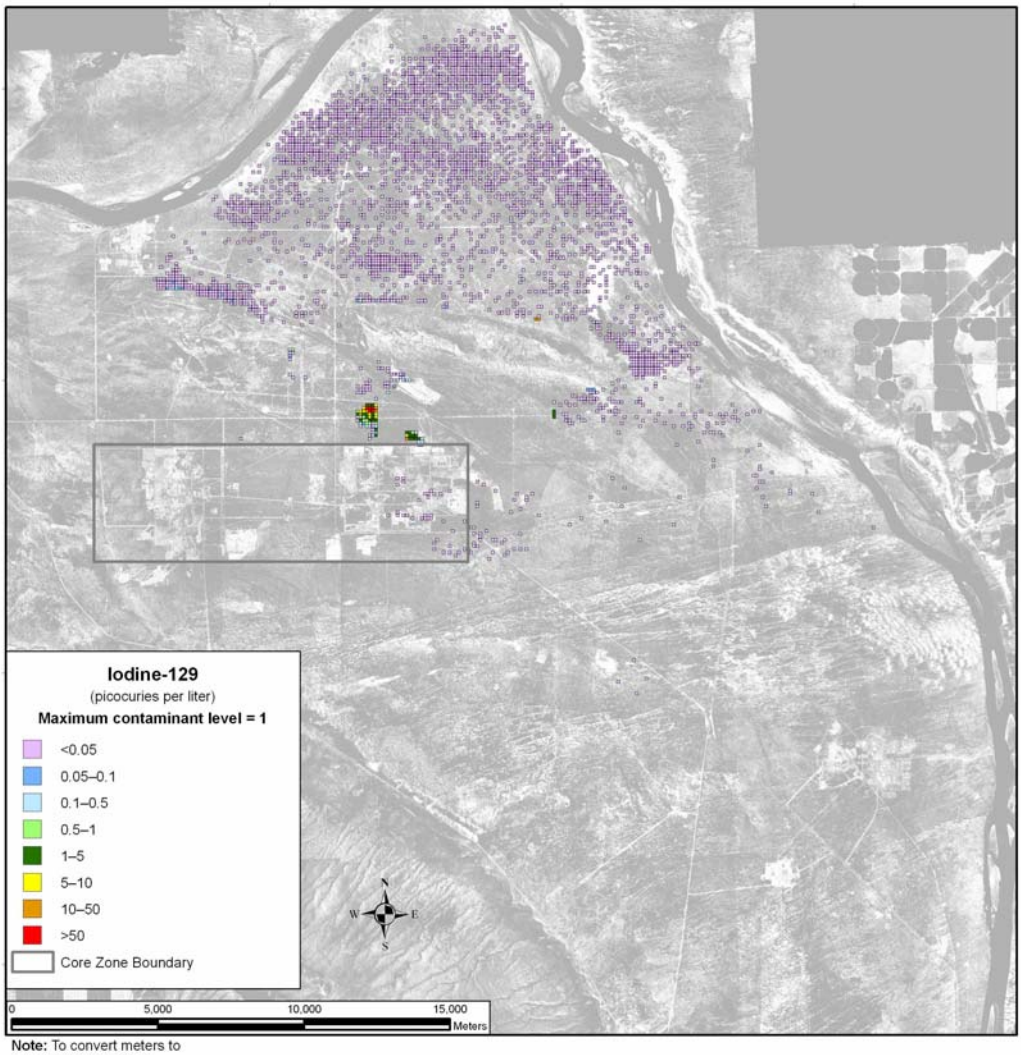


Figure 5–225. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2005



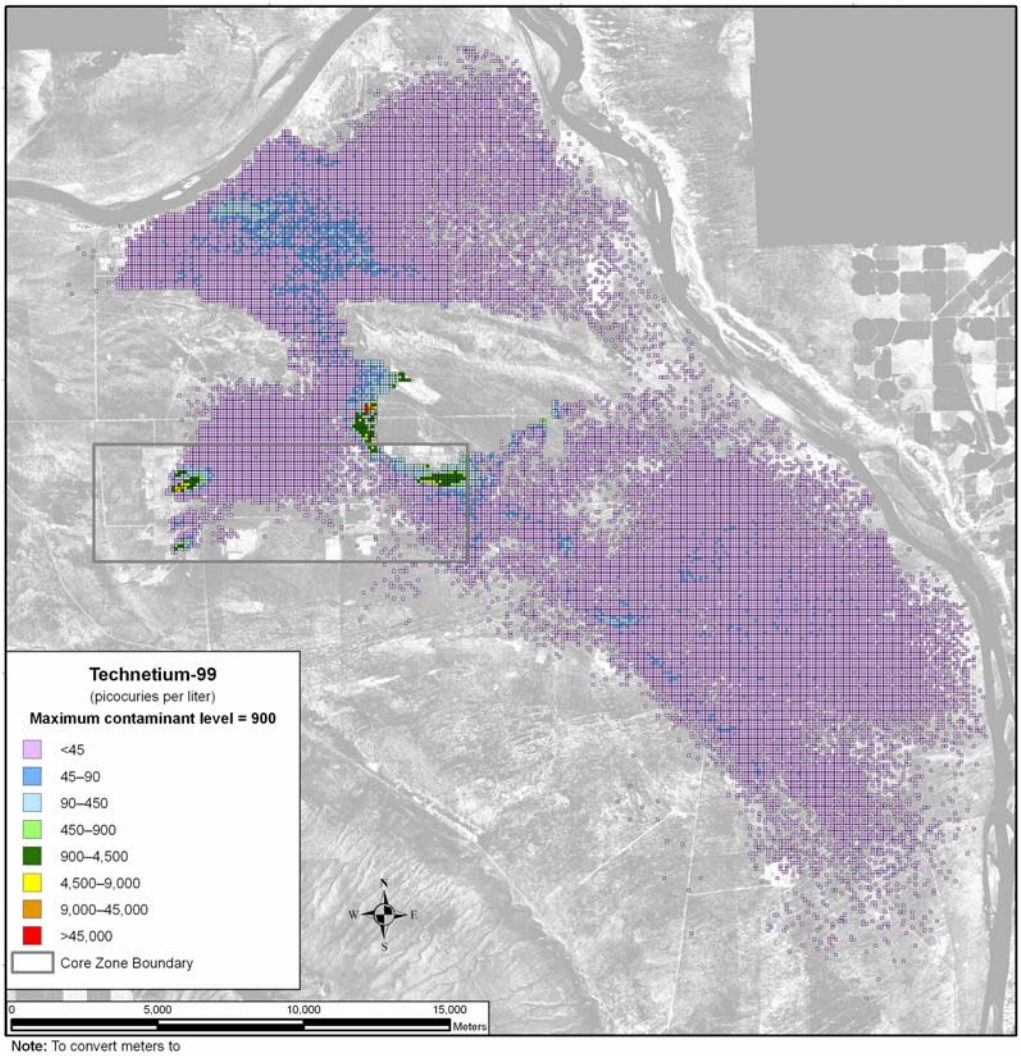
Note: To convert meters to feet, multiply by 3.281

Figure 5–226. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281

Figure 5–227. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281

Figure 5–228. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2005

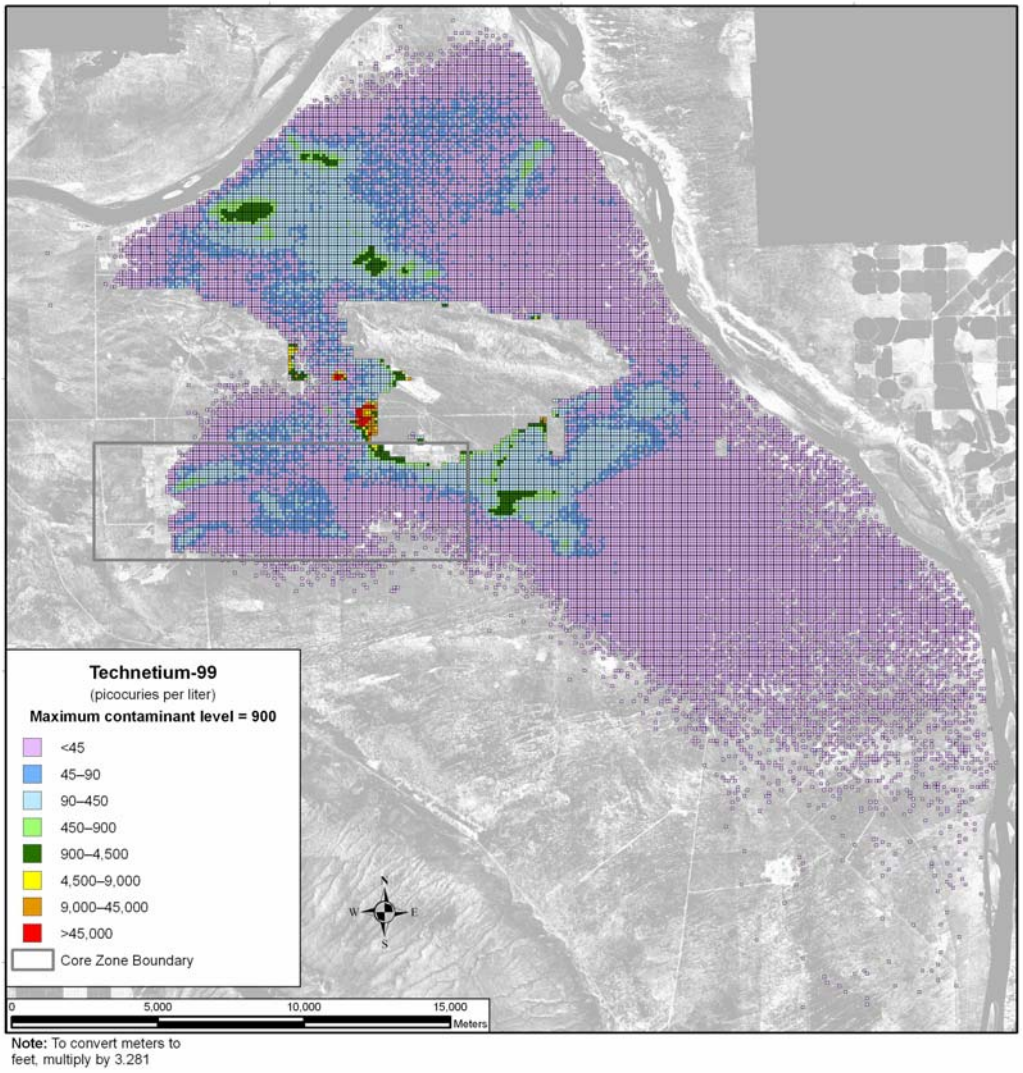
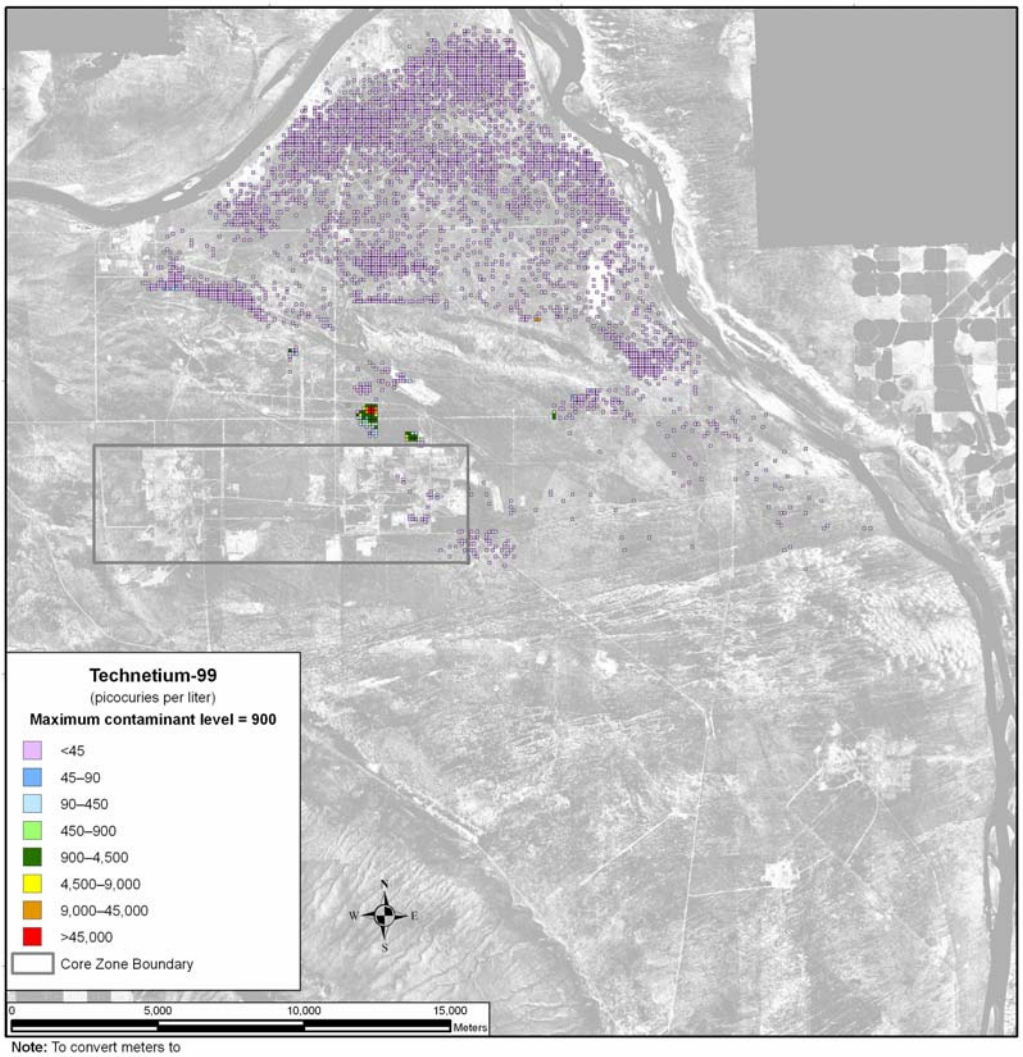
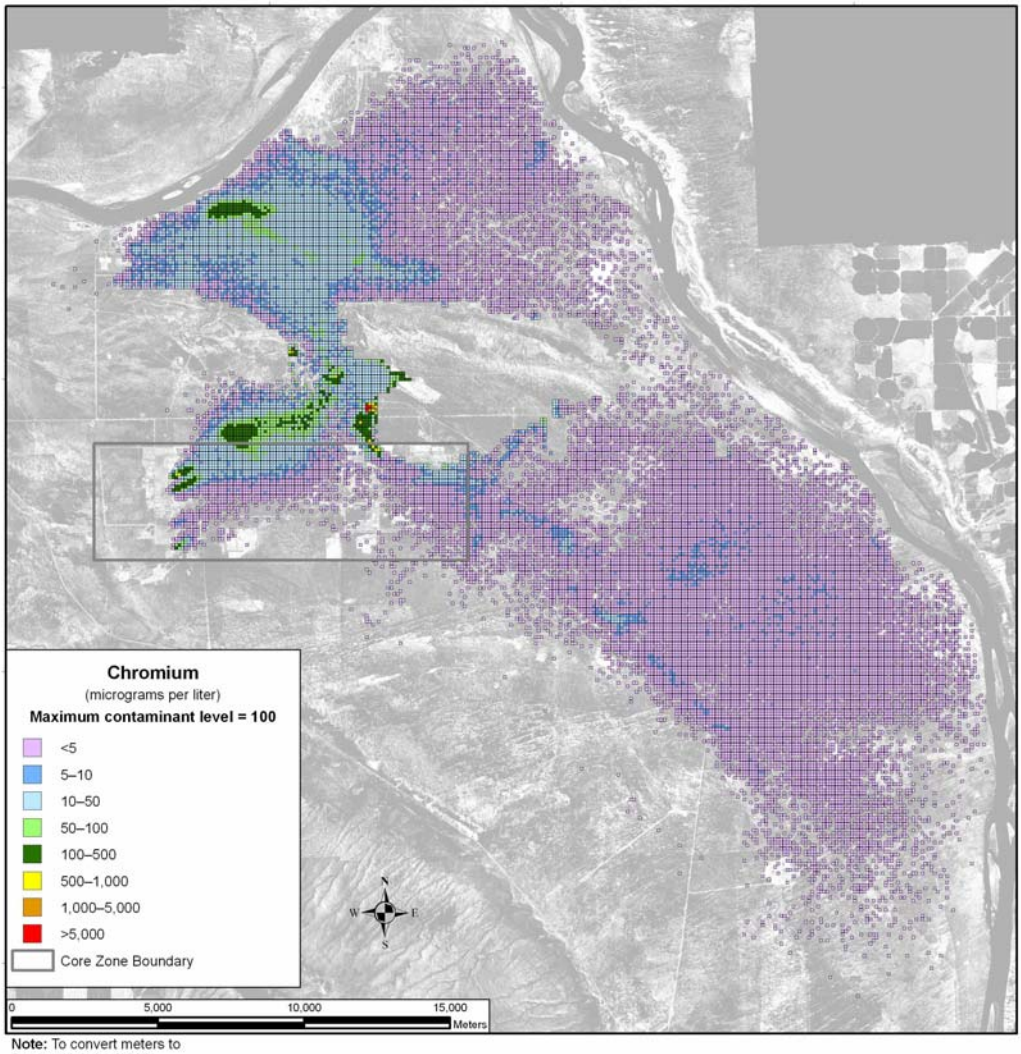


Figure 5–229. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2135



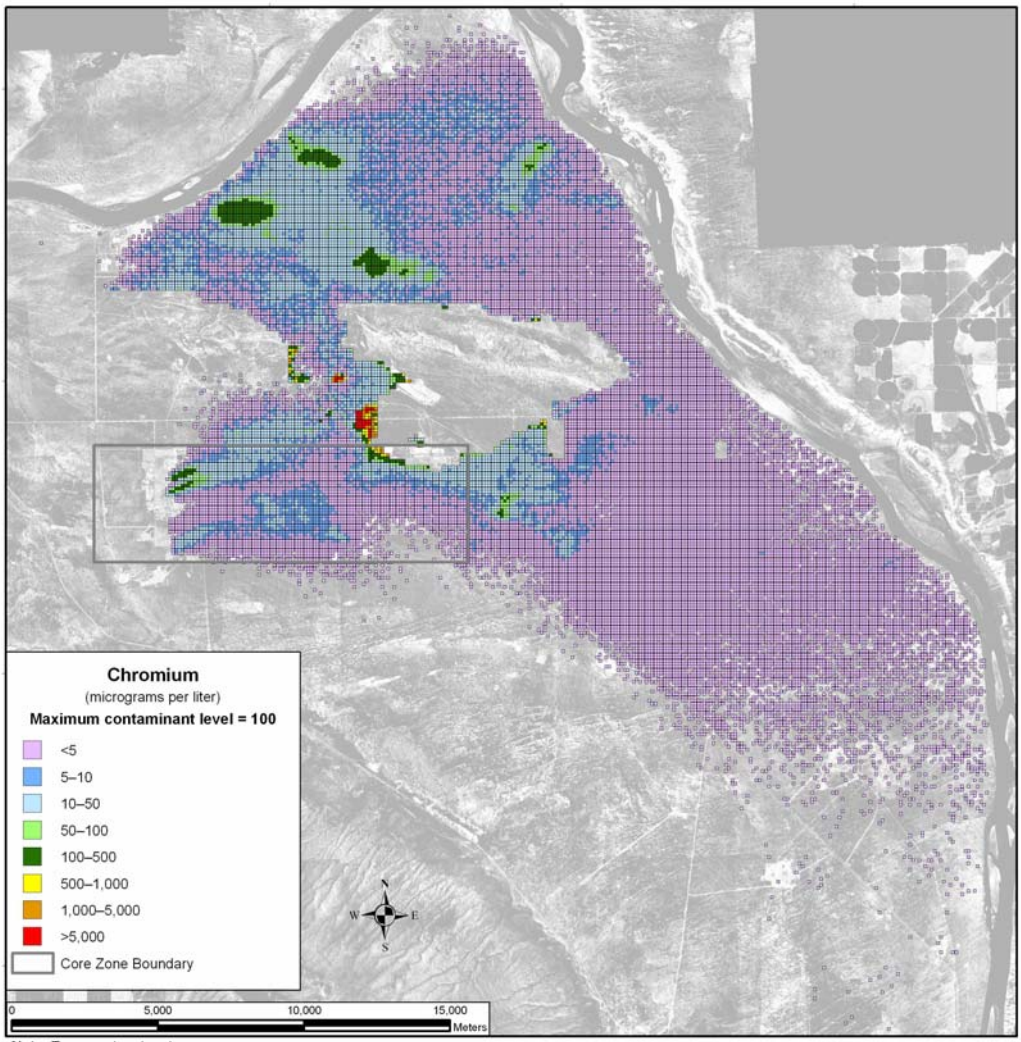
Note: To convert meters to feet, multiply by 3.281

Figure 5–230. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140



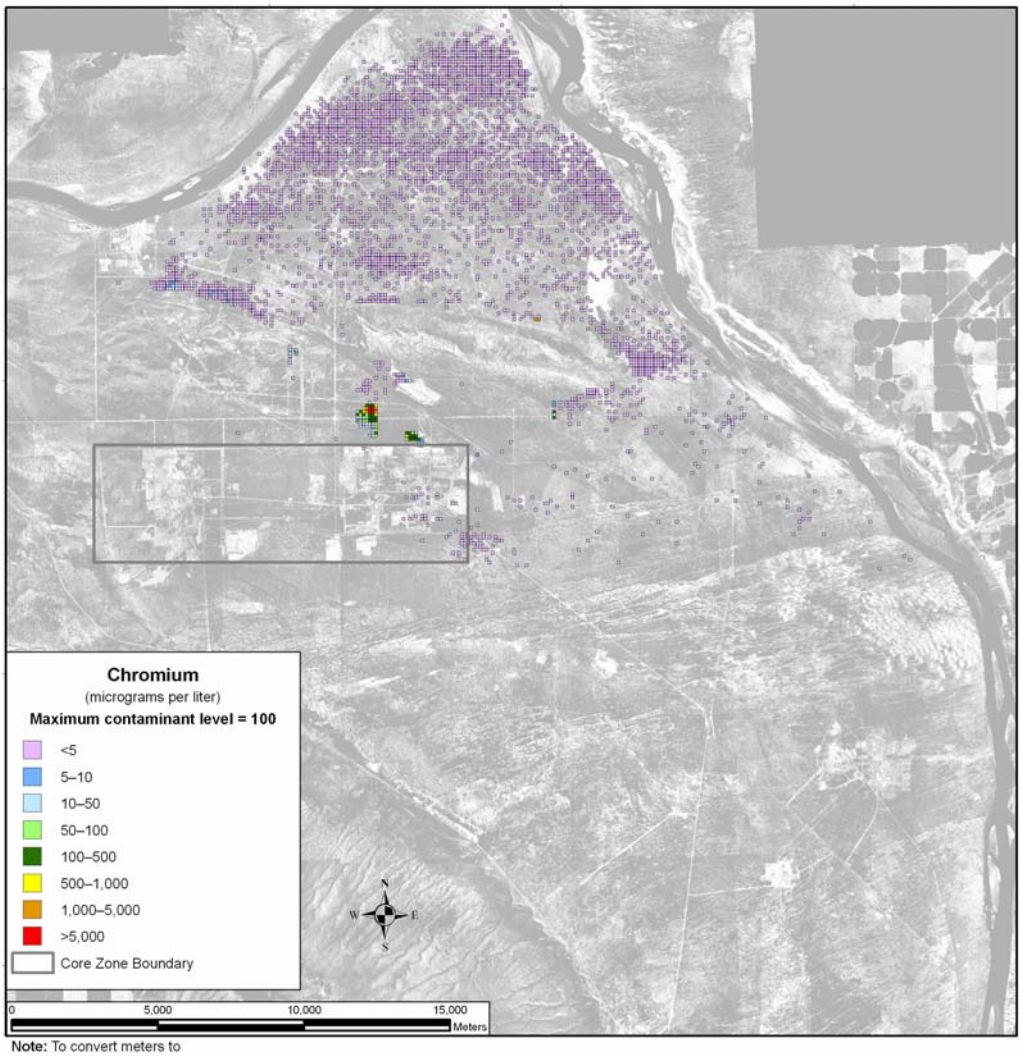
Note: To convert meters to feet, multiply by 3.281

Figure 5–231. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 2005



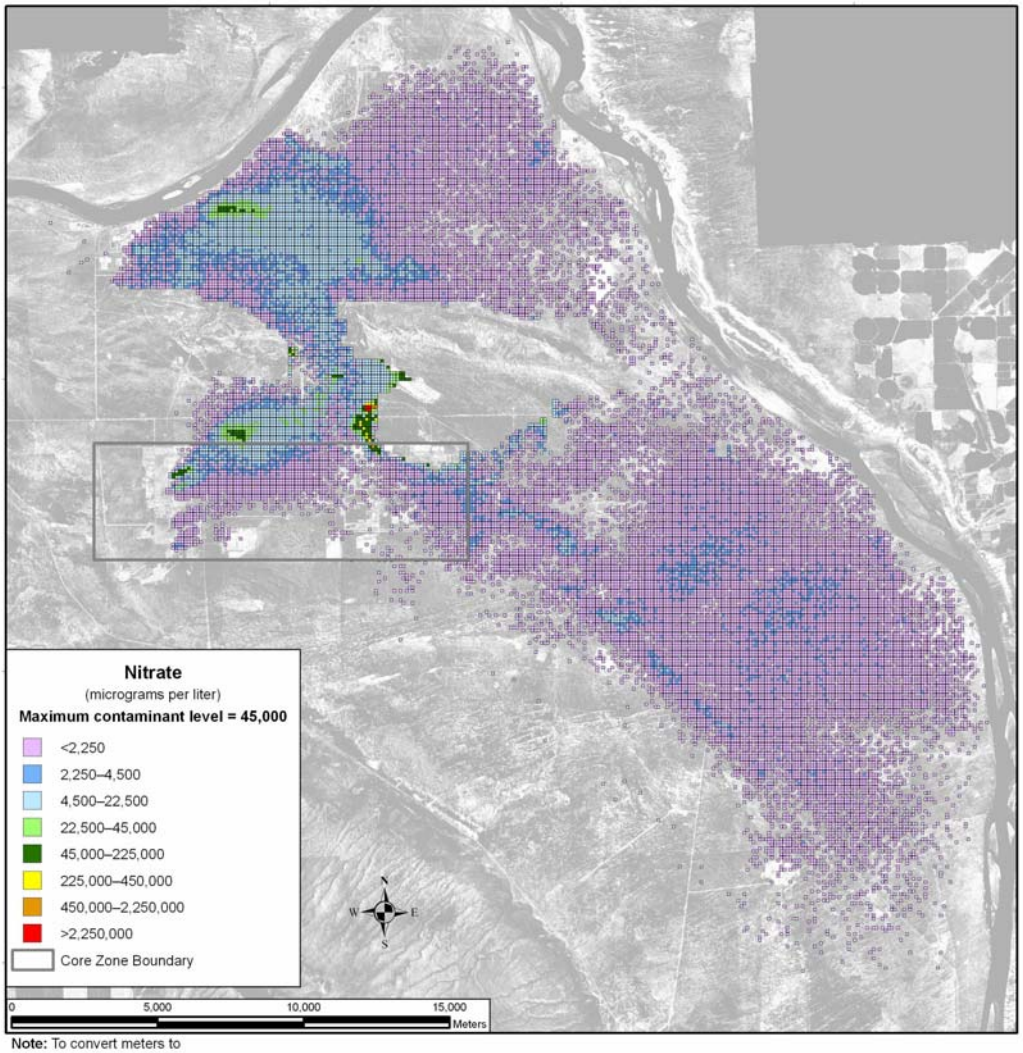
Note: To convert meters to feet, multiply by 3.281

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



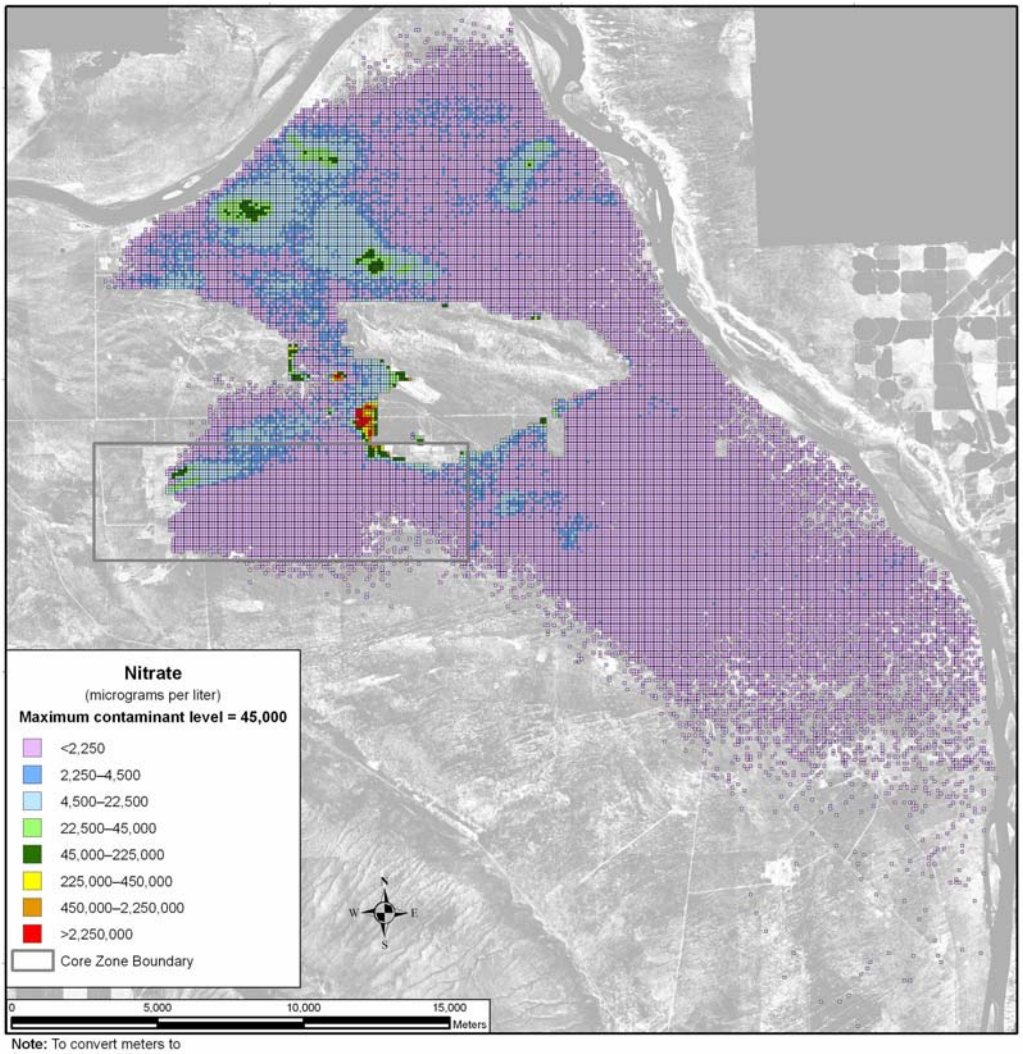
Note: To convert meters to feet, multiply by 3.281

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

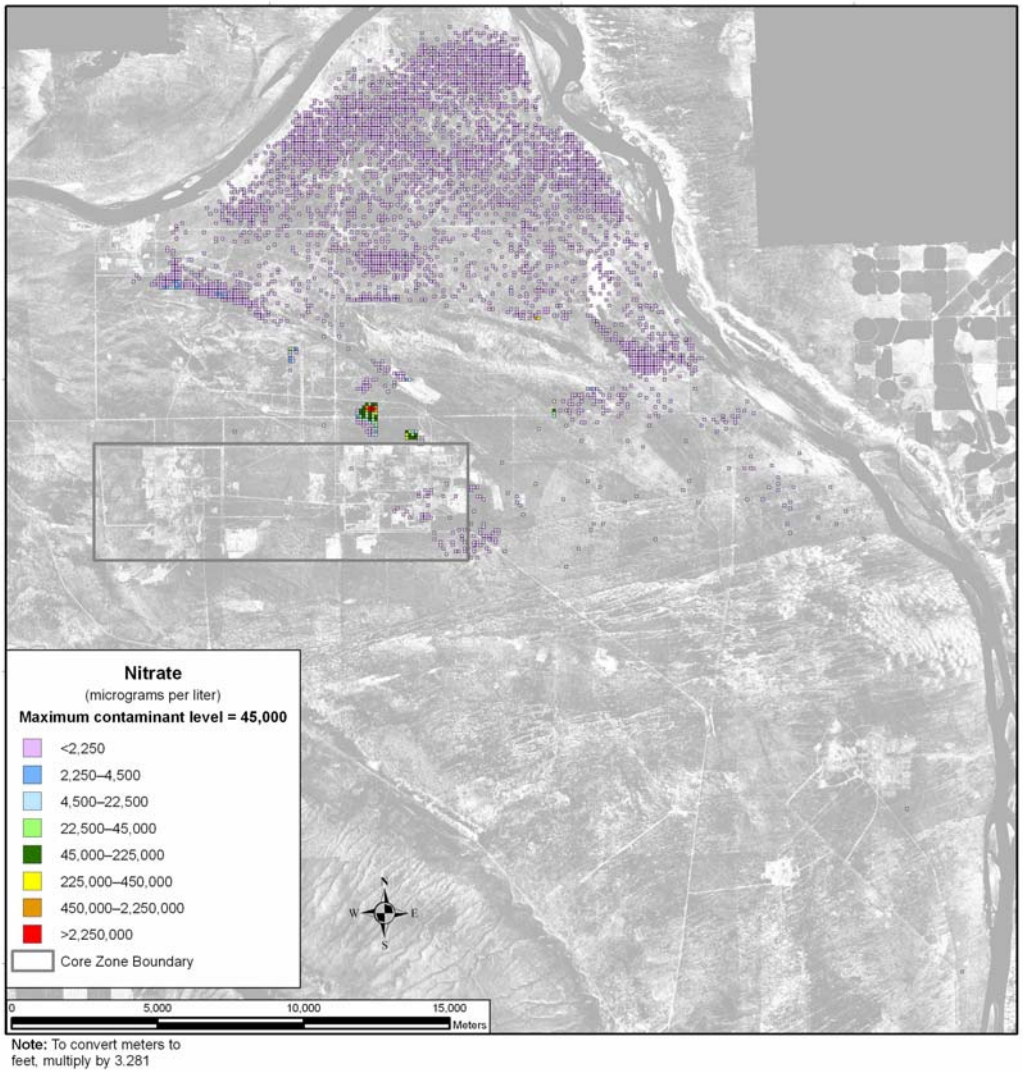
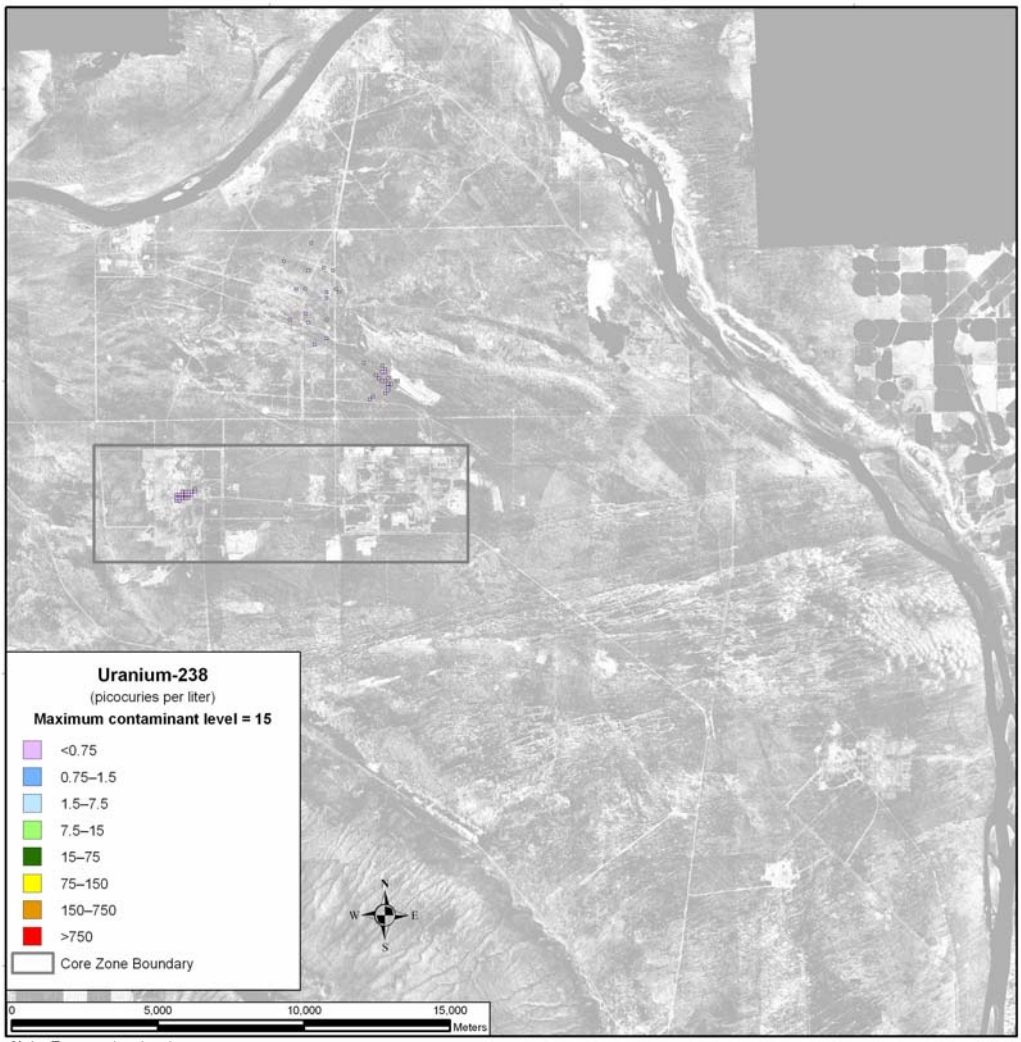


Figure 5–236. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 7140

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

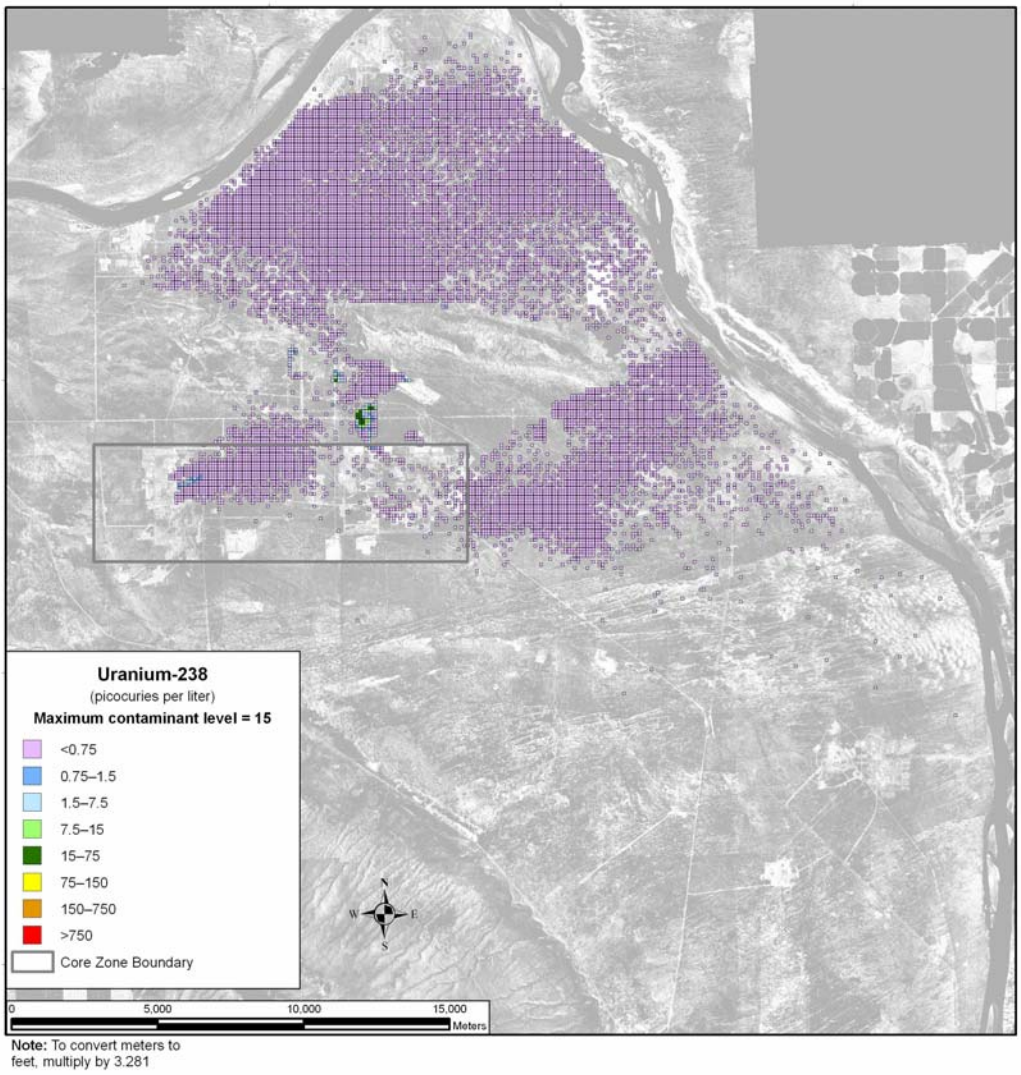
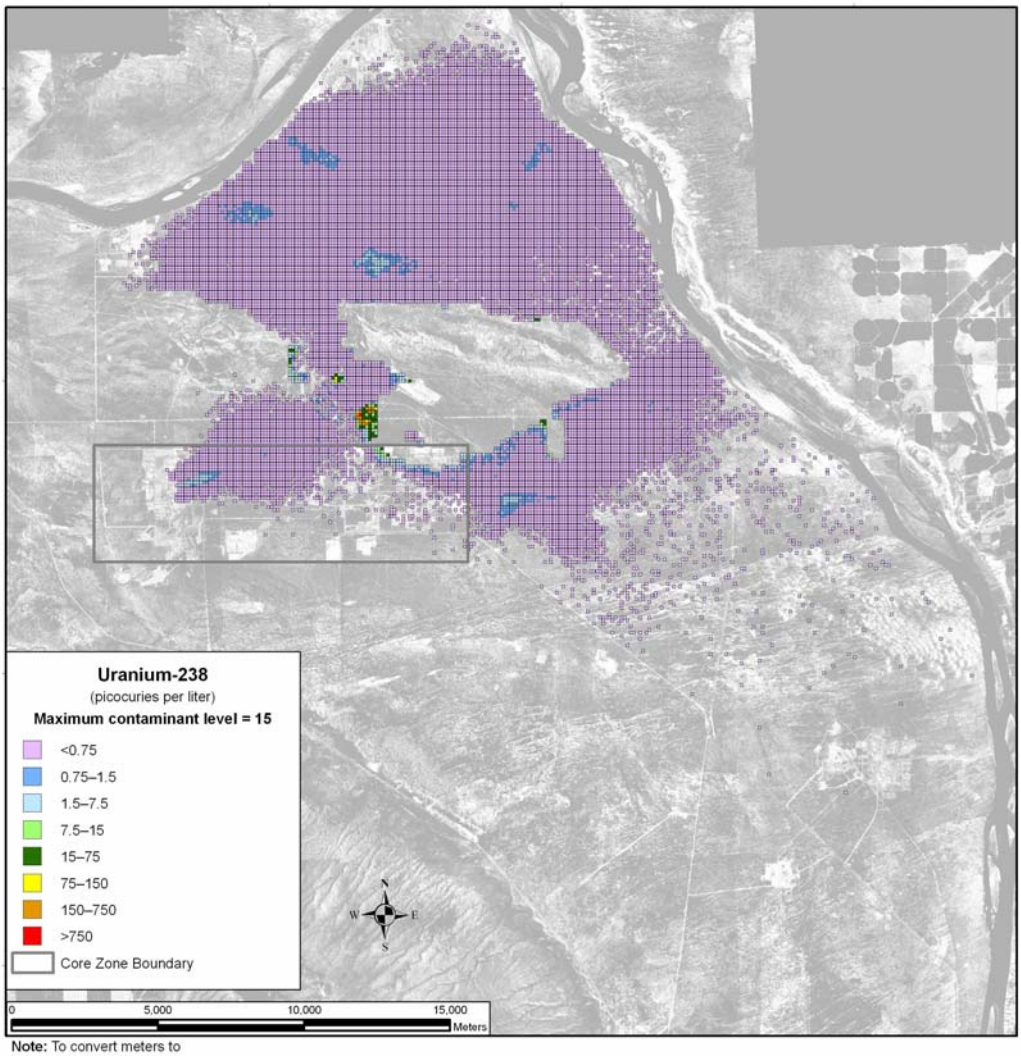


Figure 5–238. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 7140



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

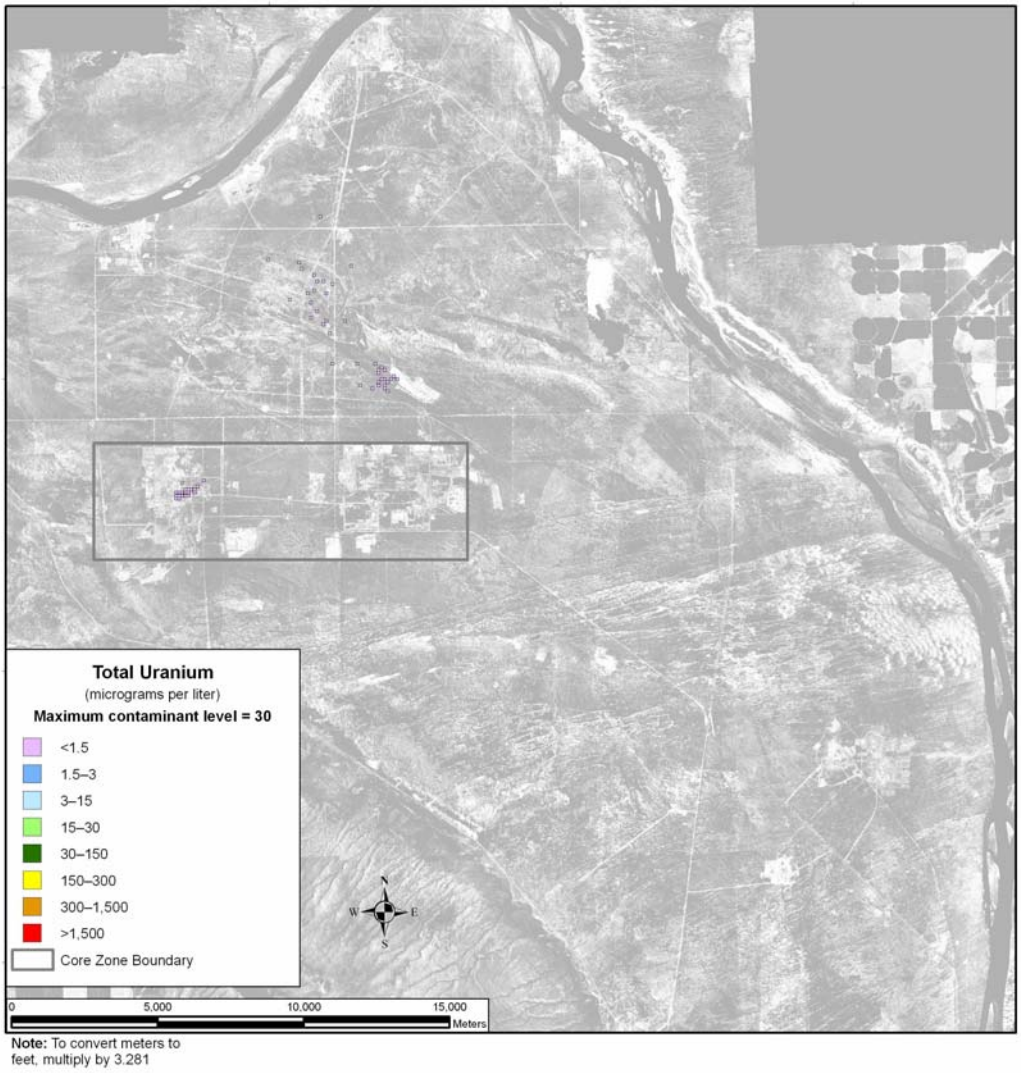
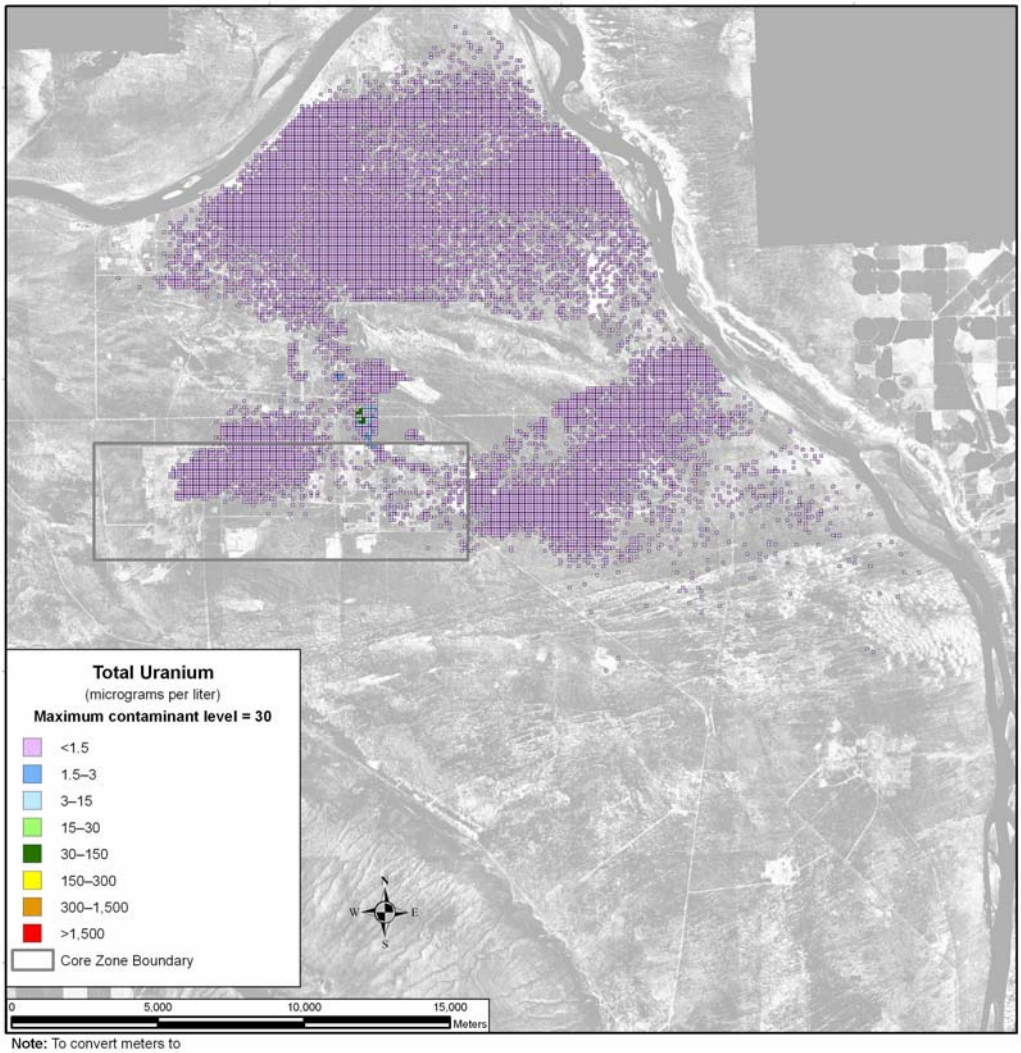
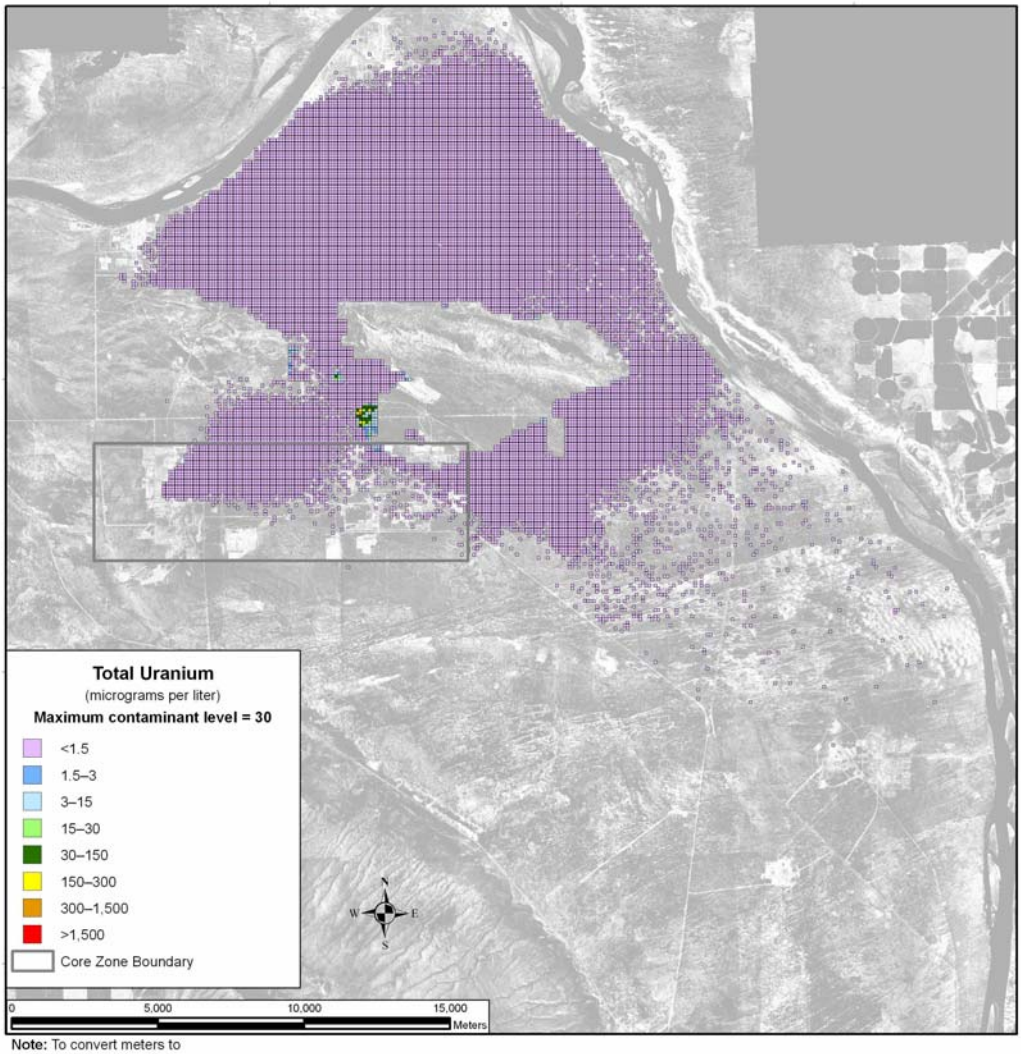


Figure 5–240. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

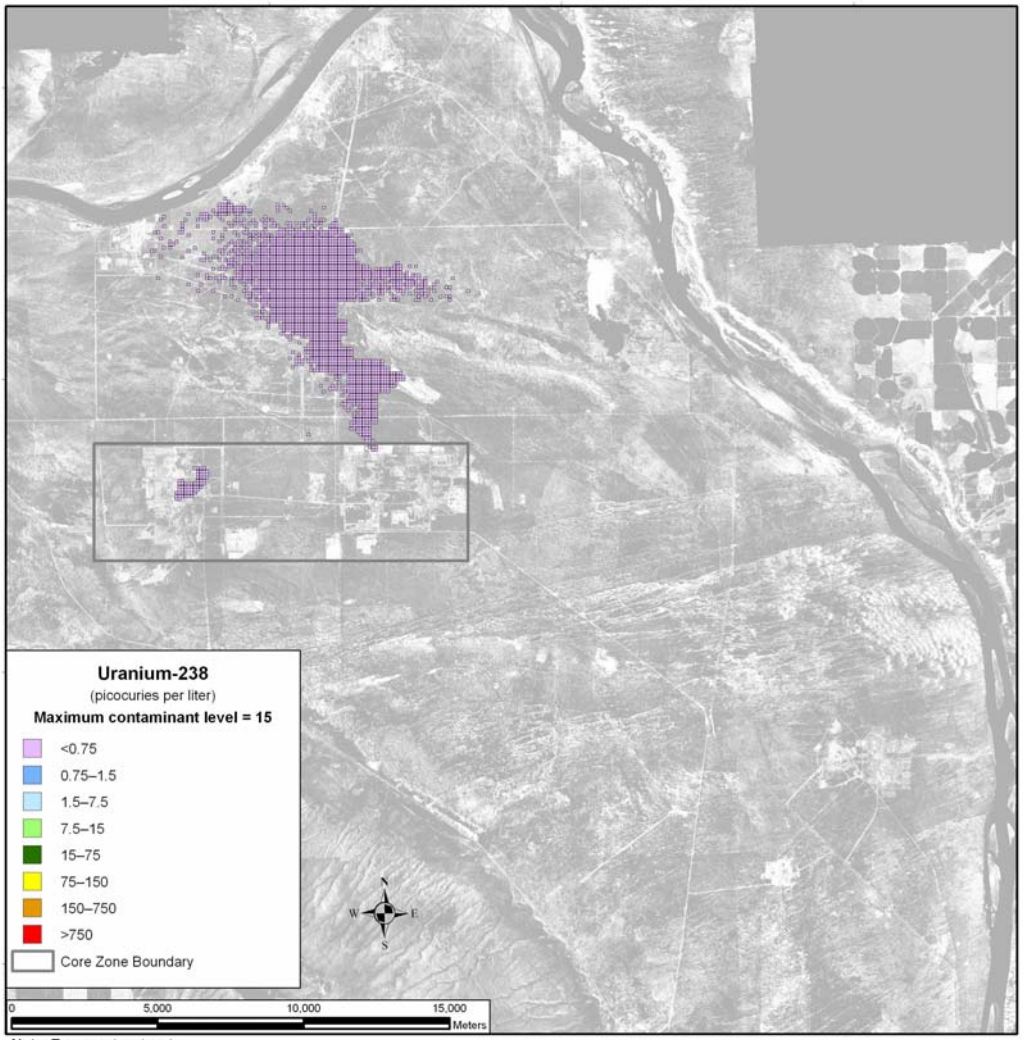
Figure 5–241. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281

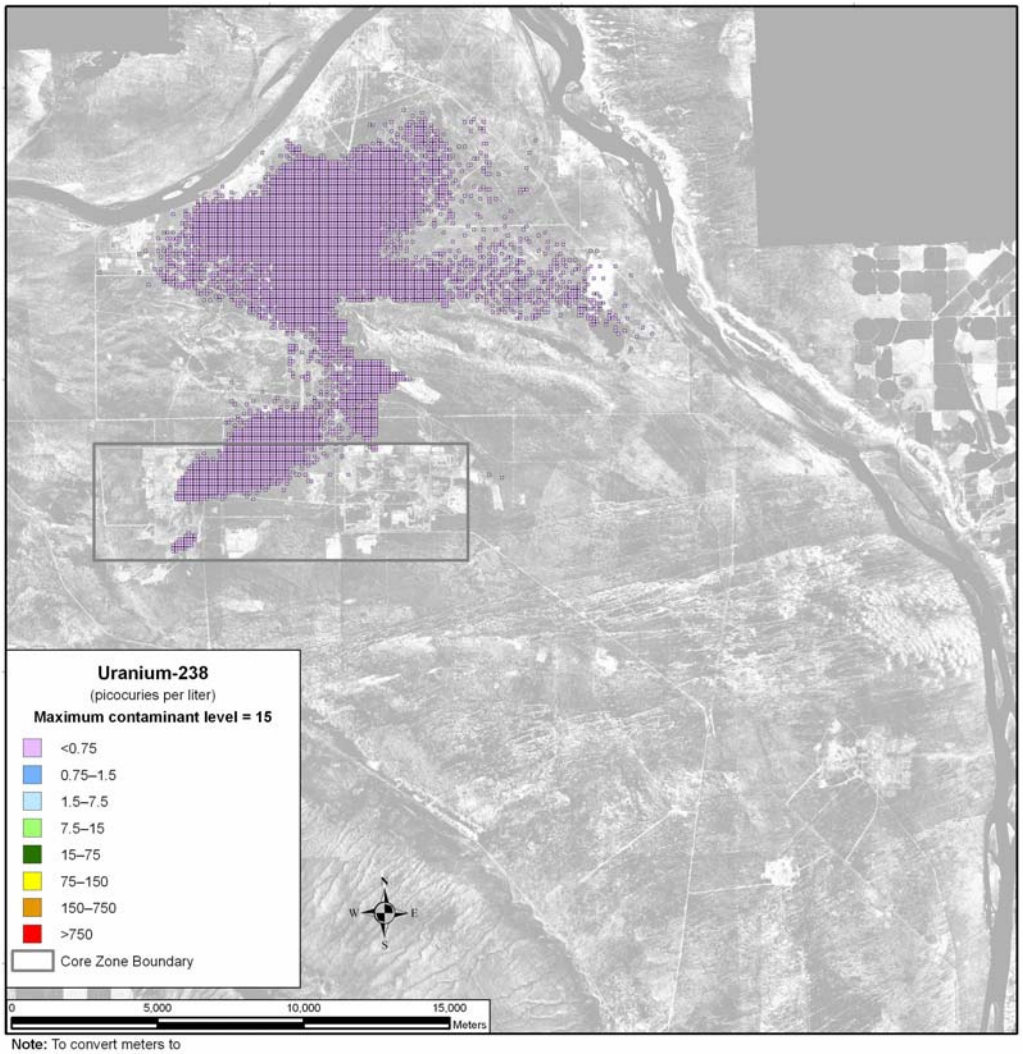
Figure 5–242. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 11,885

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

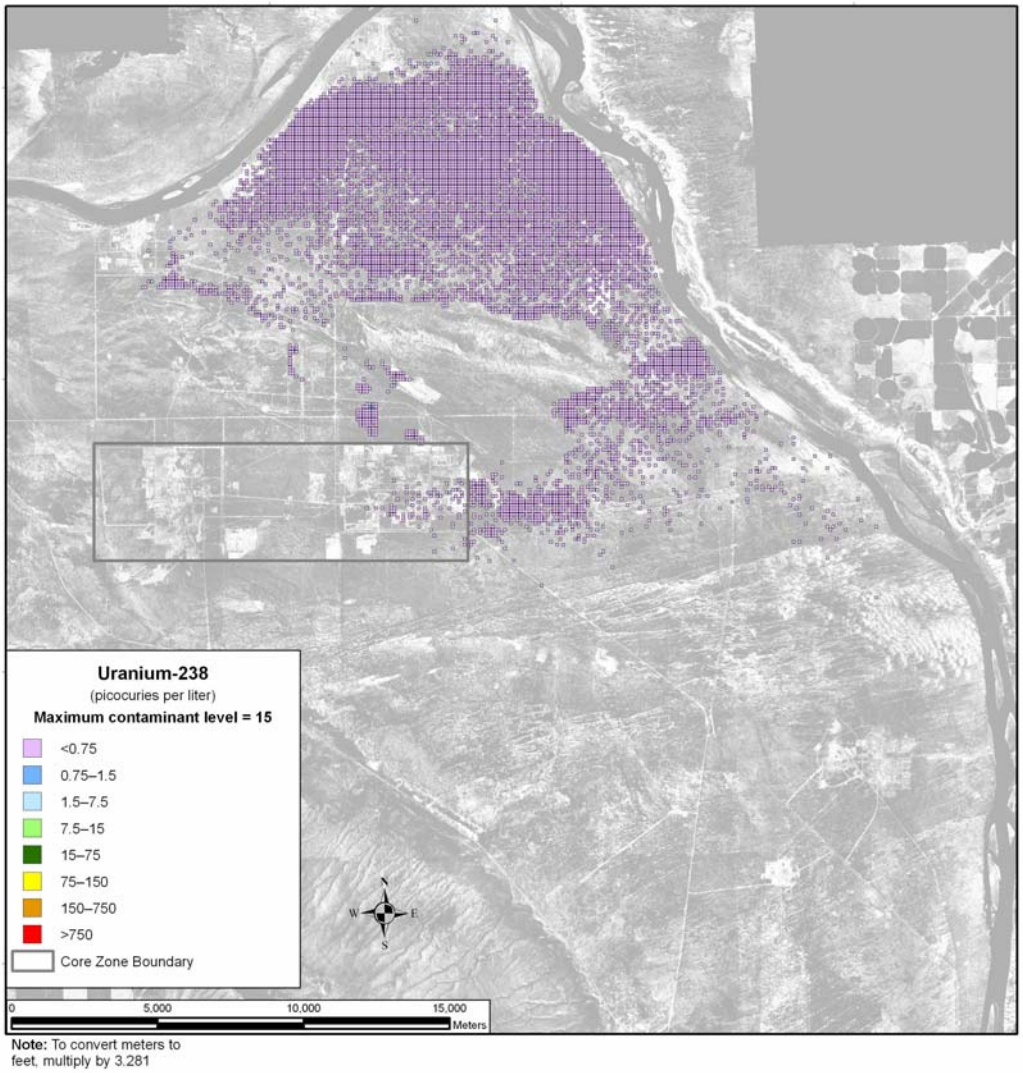


Figure 5–245. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 11,885

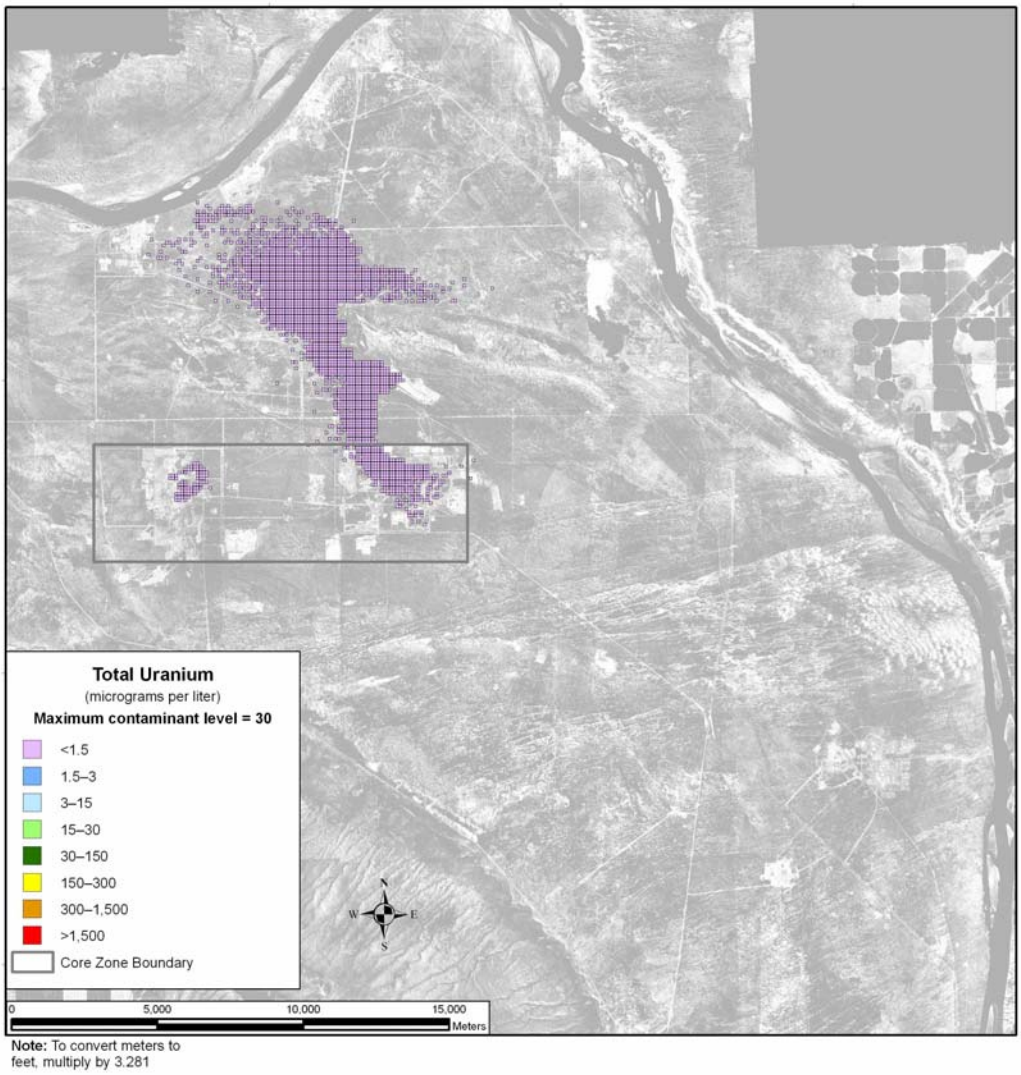
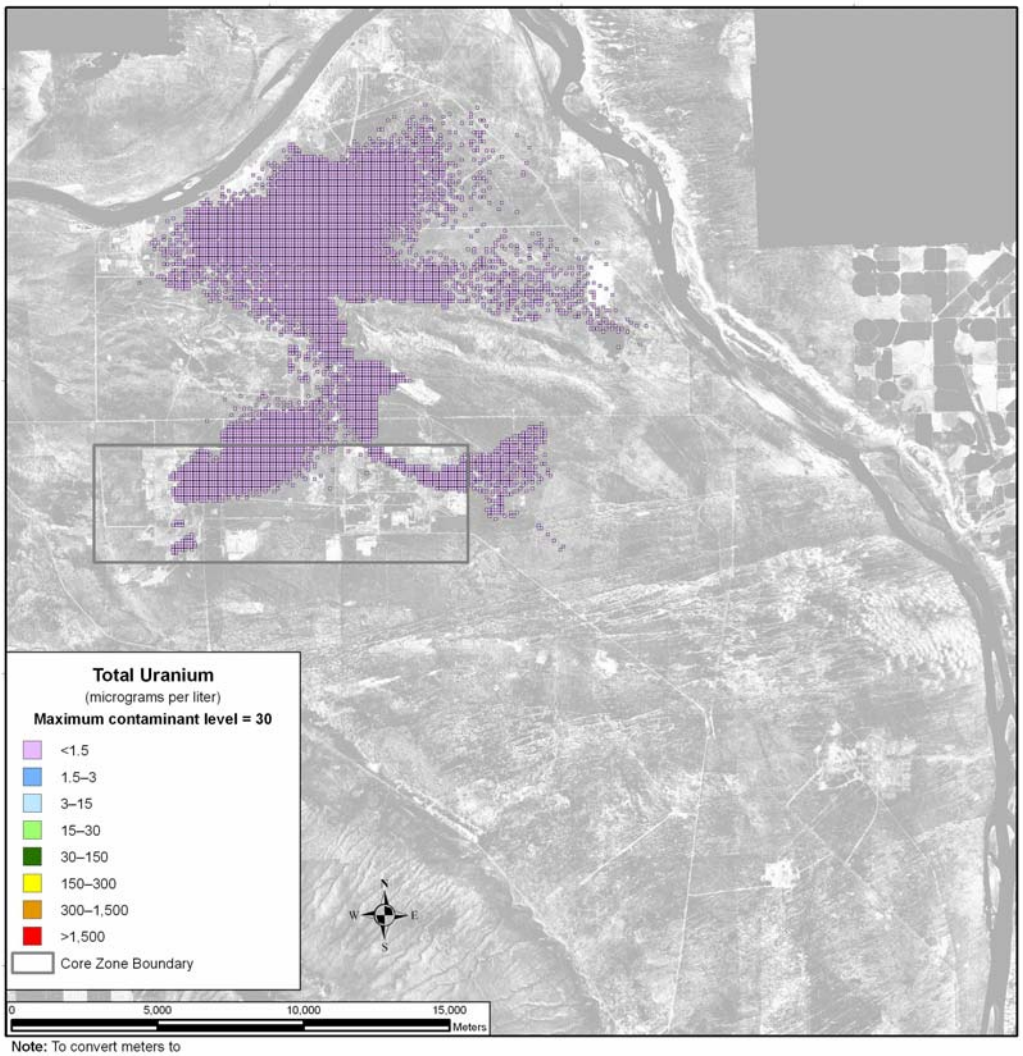
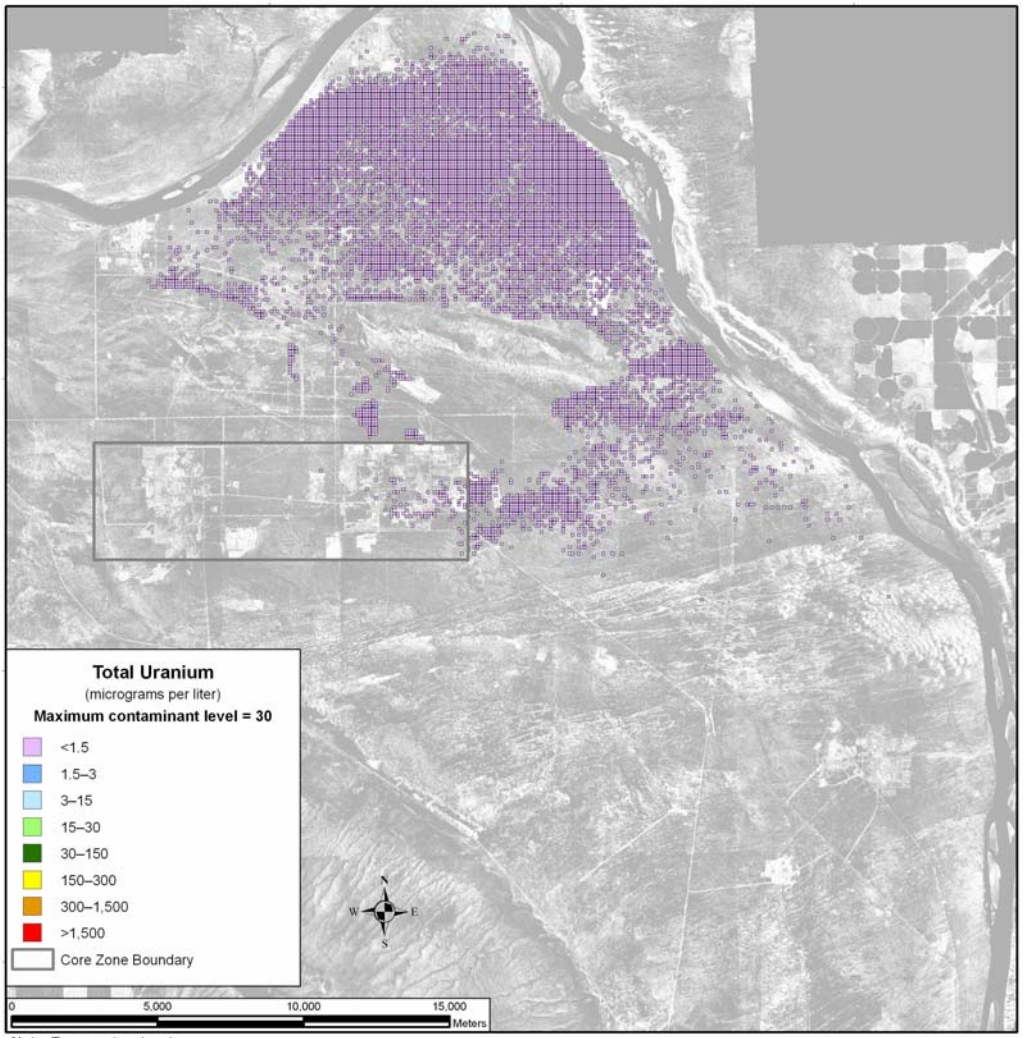


Figure 5–246. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 2005



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.

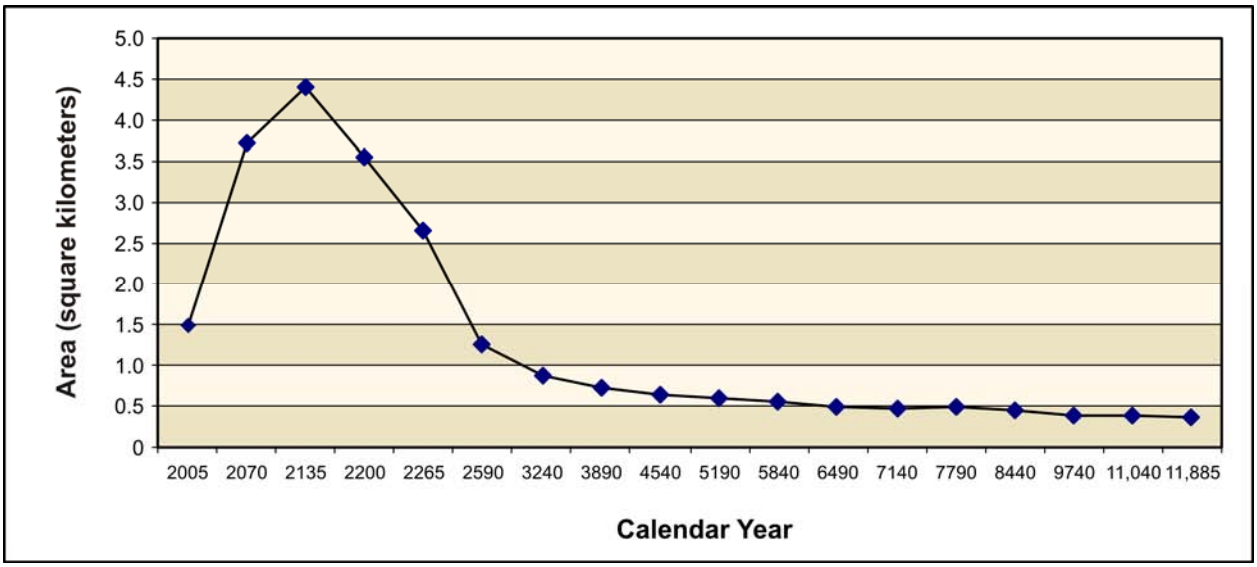


Figure 5–249. Tank Closure Alternative 6A, Base Case, Total Area of Groundwater Technetium-99 Concentration Exceeding the Benchmark Concentration as a Function of Time

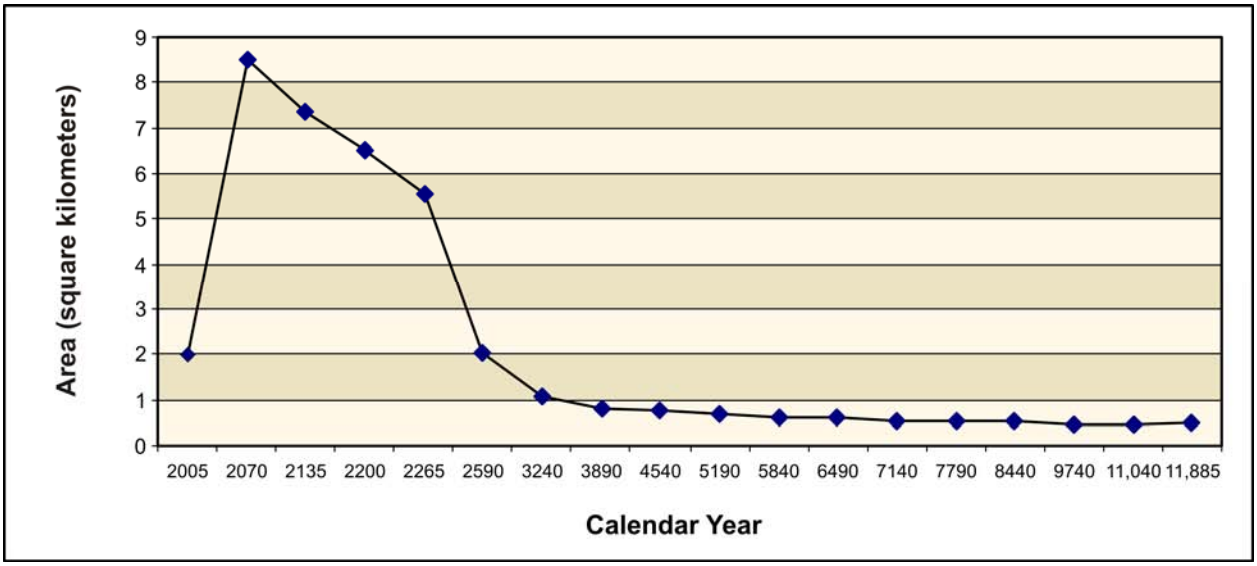


Figure 5–250. Tank Closure Alternative 6A, Base Case, Total Area of Groundwater Iodine-129 Concentration Exceeding the Benchmark Concentration as a Function of Time

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).

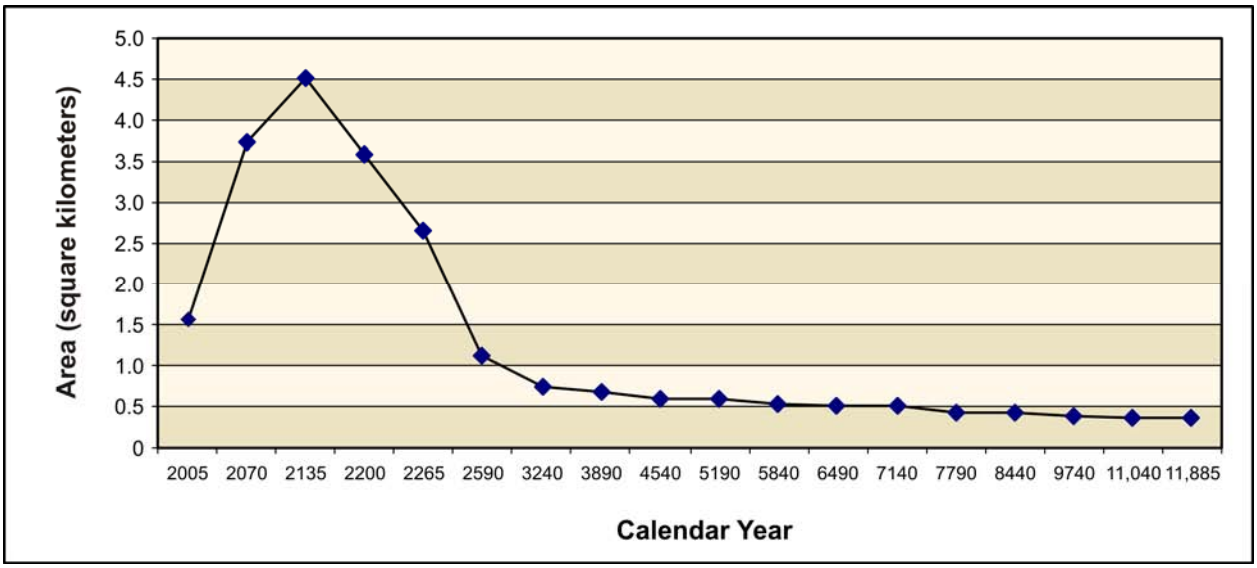


Figure 5–251. Tank Closure Alternative 6A, Option Case, Total Area of Groundwater Technetium-99 Concentration Exceeding the Benchmark Concentration as a Function of Time

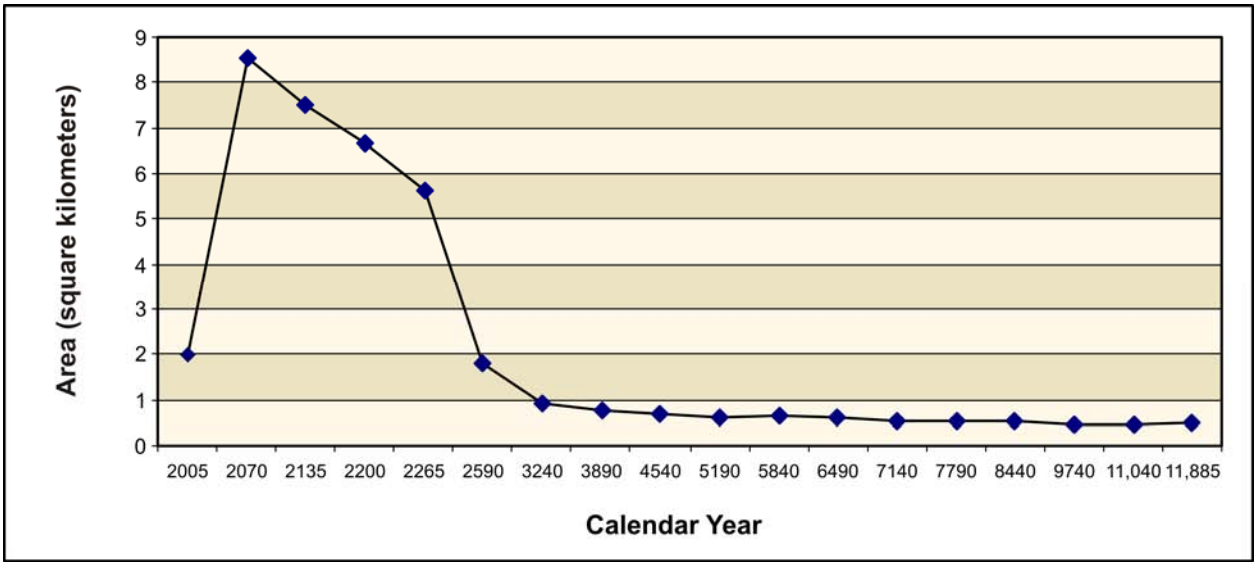


Figure 5–252. Tank Closure Alternative 6A, Option Case, Total Area of Groundwater Iodine-129 Concentration Exceeding the Benchmark Concentration as a Function of Time

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.

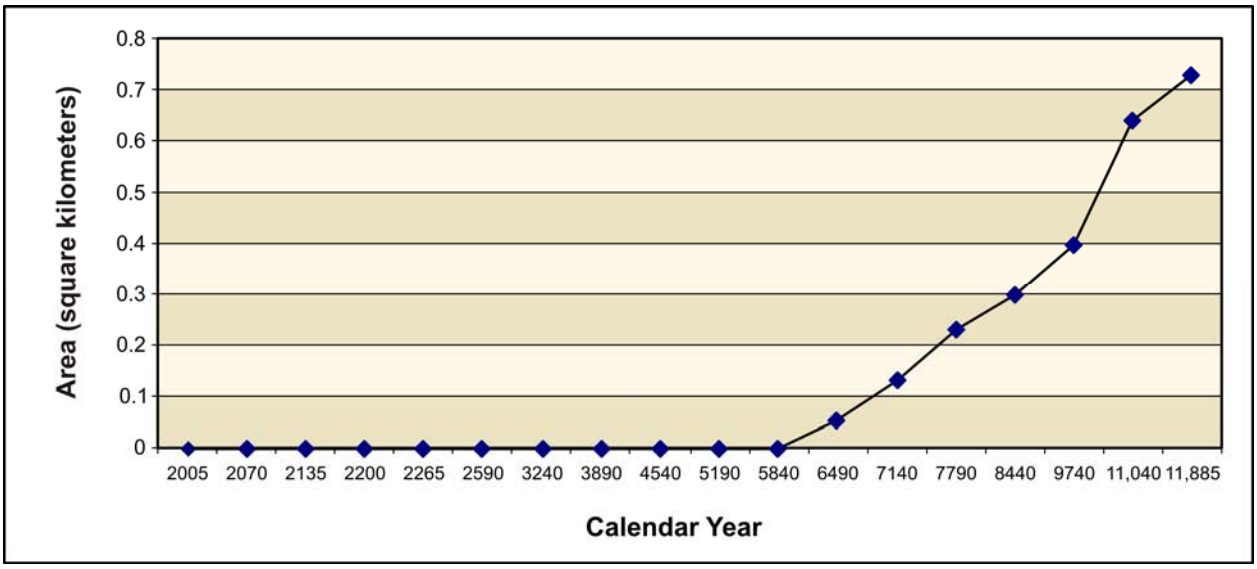


Figure 5–253. Tank Closure Alternative 6A, Base Case, Total Area of Groundwater Uranium-238 Concentration Exceeding the Benchmark Concentration as a Function of Time

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.

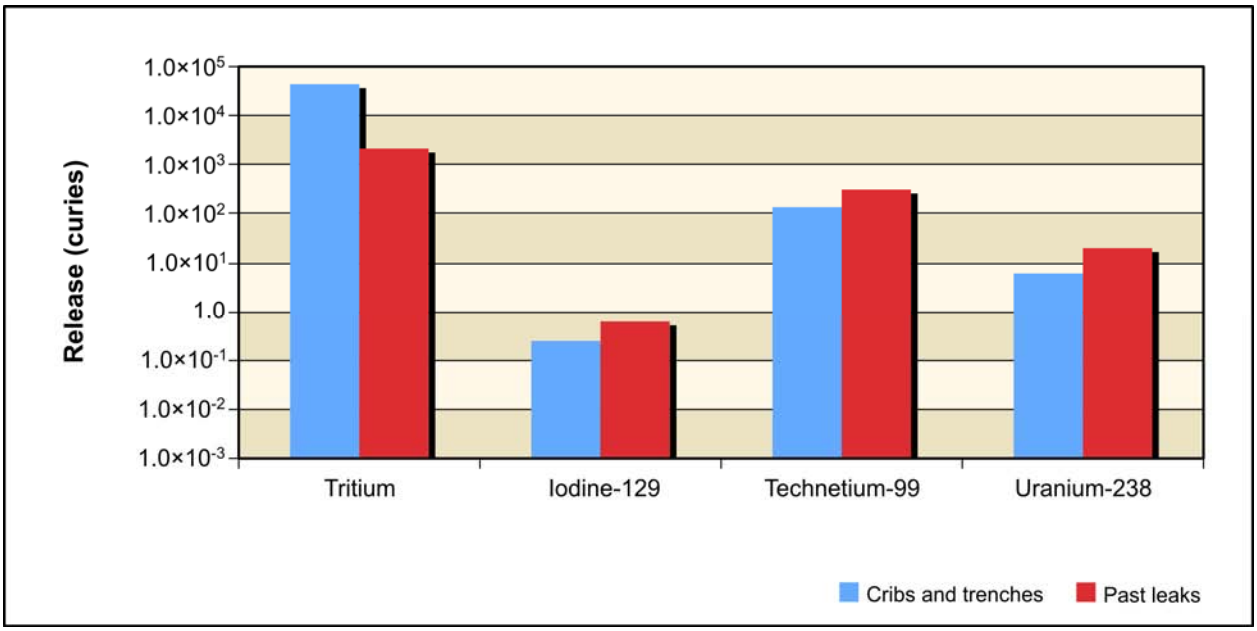


Figure 5–254. Tank Closure Alternative 6B, Base Case, Releases of Radiological Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

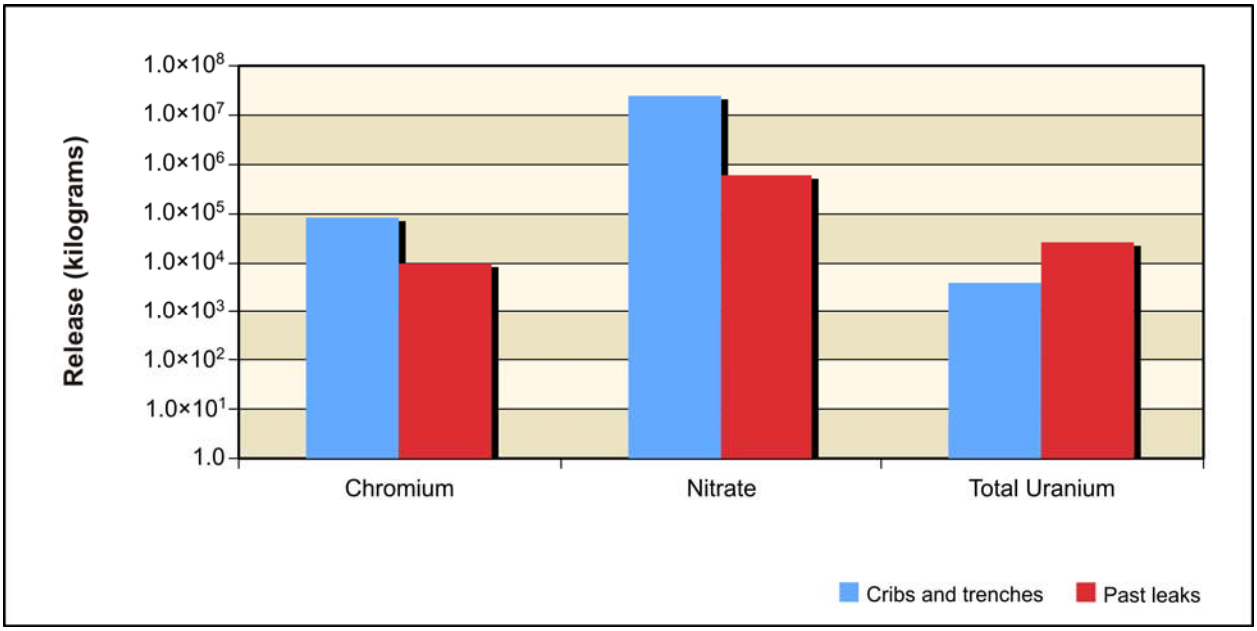


Figure 5–255. Tank Closure Alternative 6B, Base Case, Releases of Chemical Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

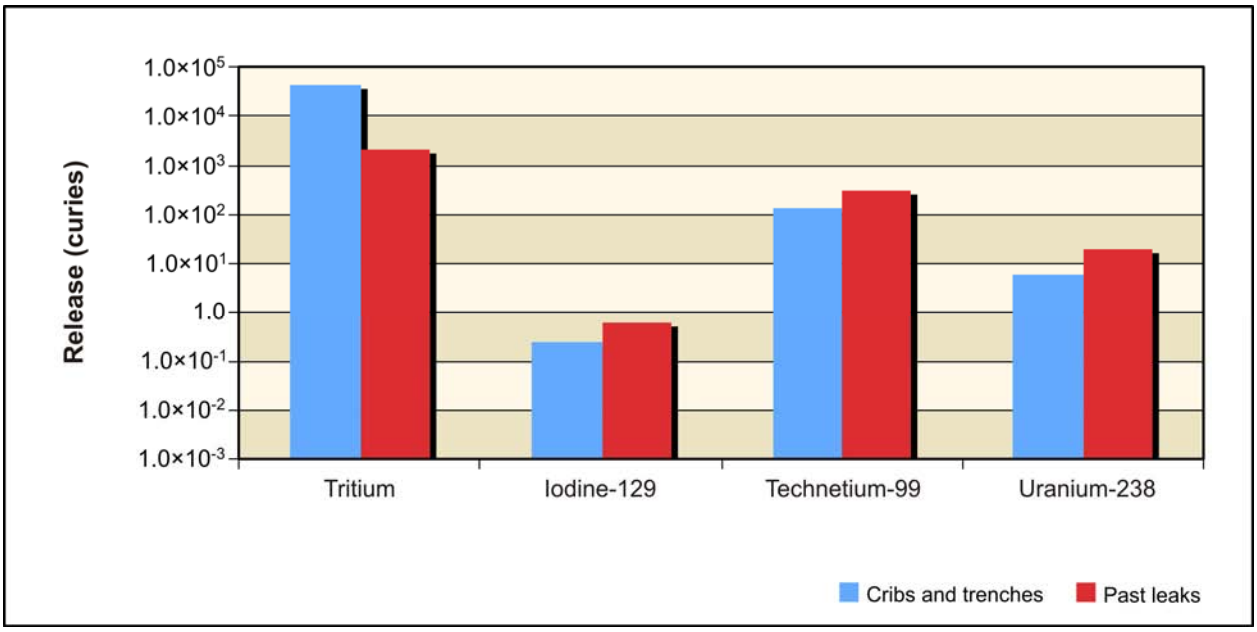


Figure 5–256. Tank Closure Alternative 6B, Option Case, Releases of Radiological Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

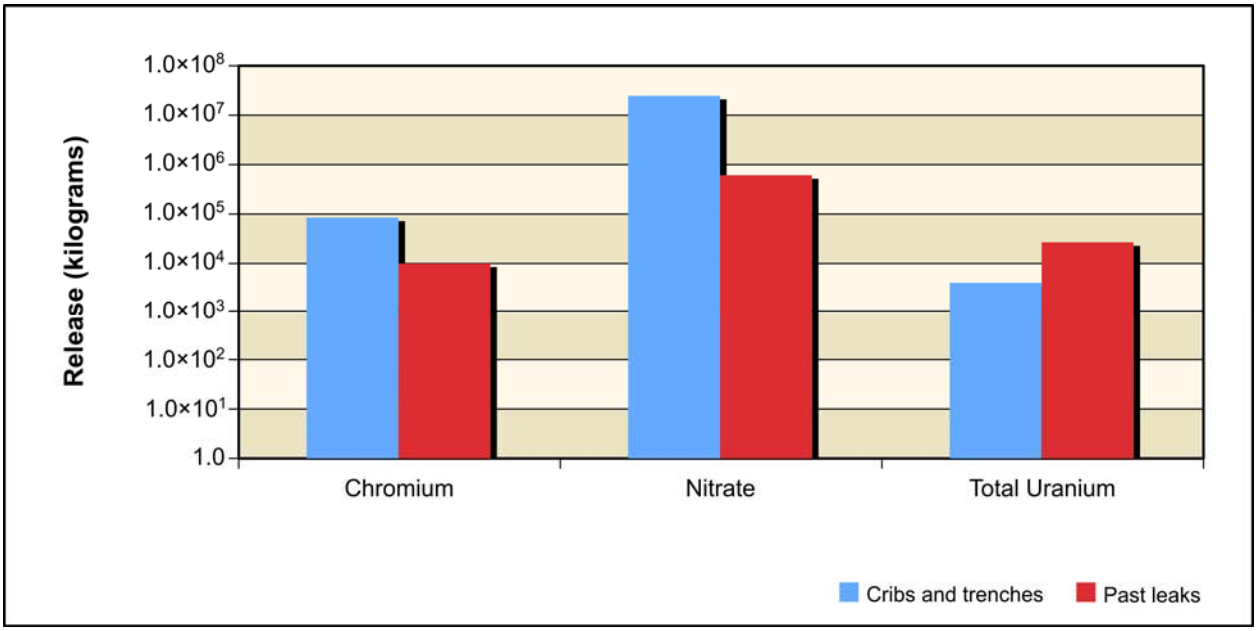


Figure 5–257. Tank Closure Alternative 6B, Option Case, Releases of Chemical Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

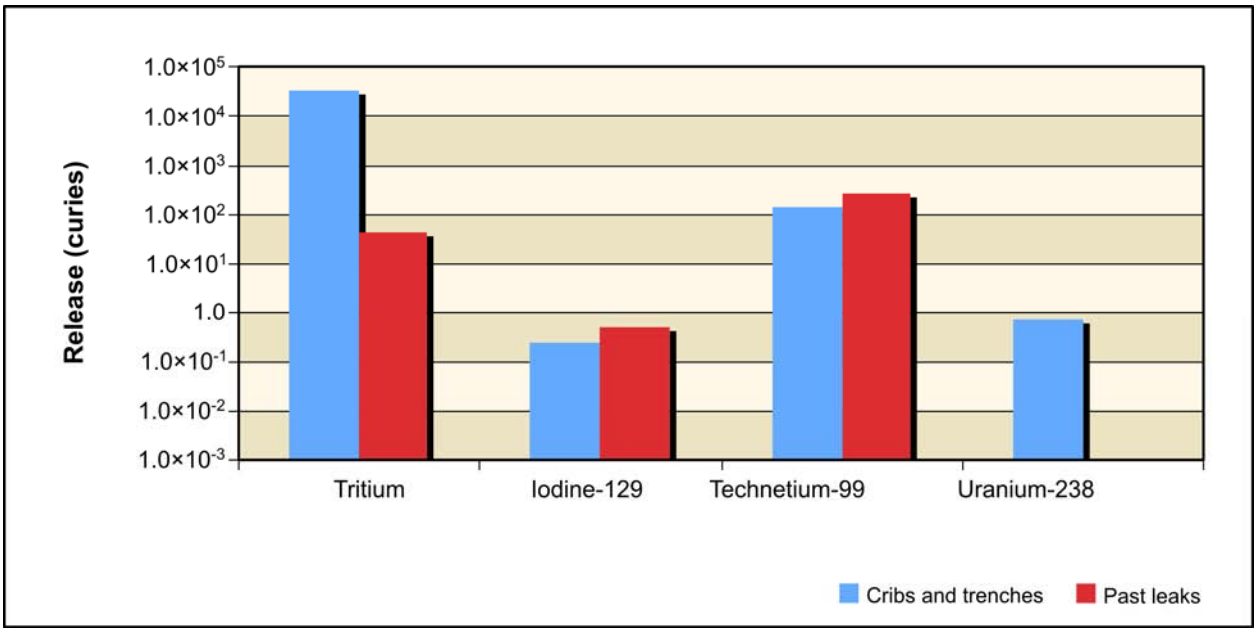


Figure 5–258. Tank Closure Alternative 6B, Base Case, Releases of Radiological Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

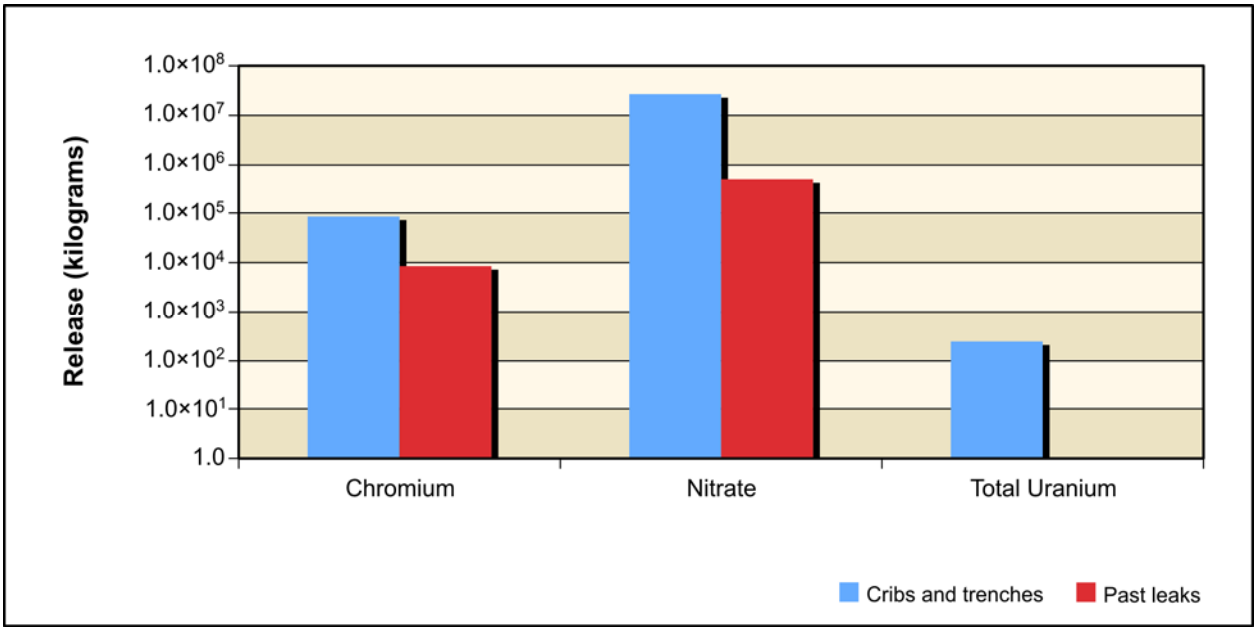


Figure 5–259. Tank Closure Alternative 6B, Base Case, Releases of Chemical Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

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.

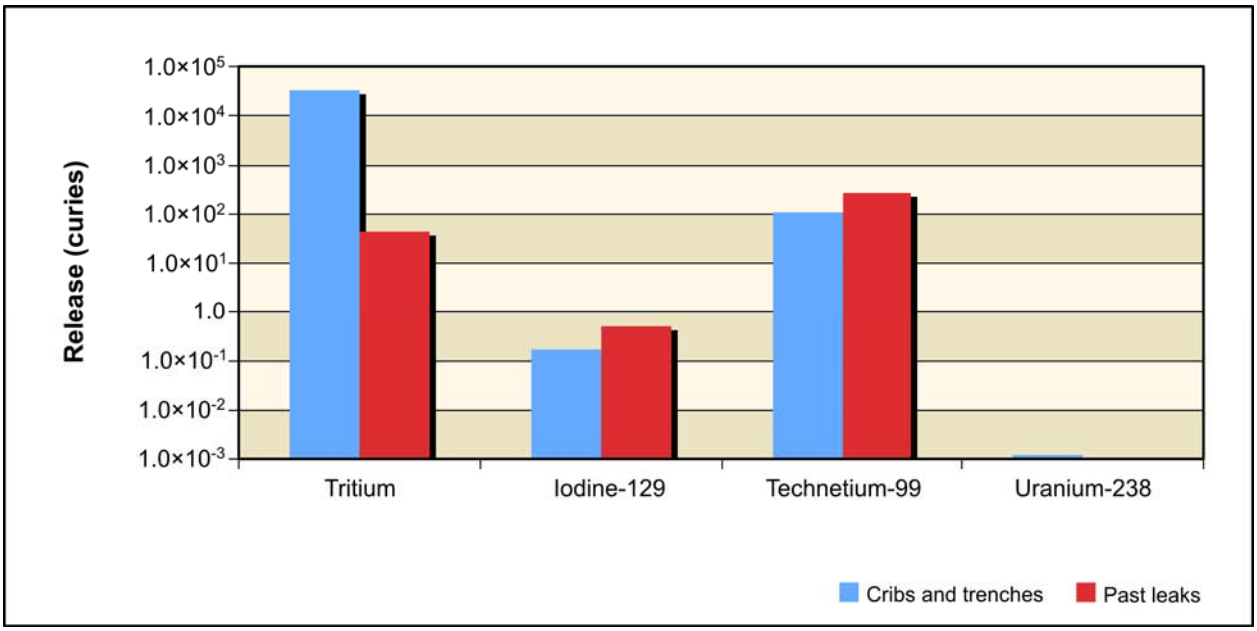


Figure 5–260. Tank Closure Alternative 6B, Option Case, Releases of Radiological Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

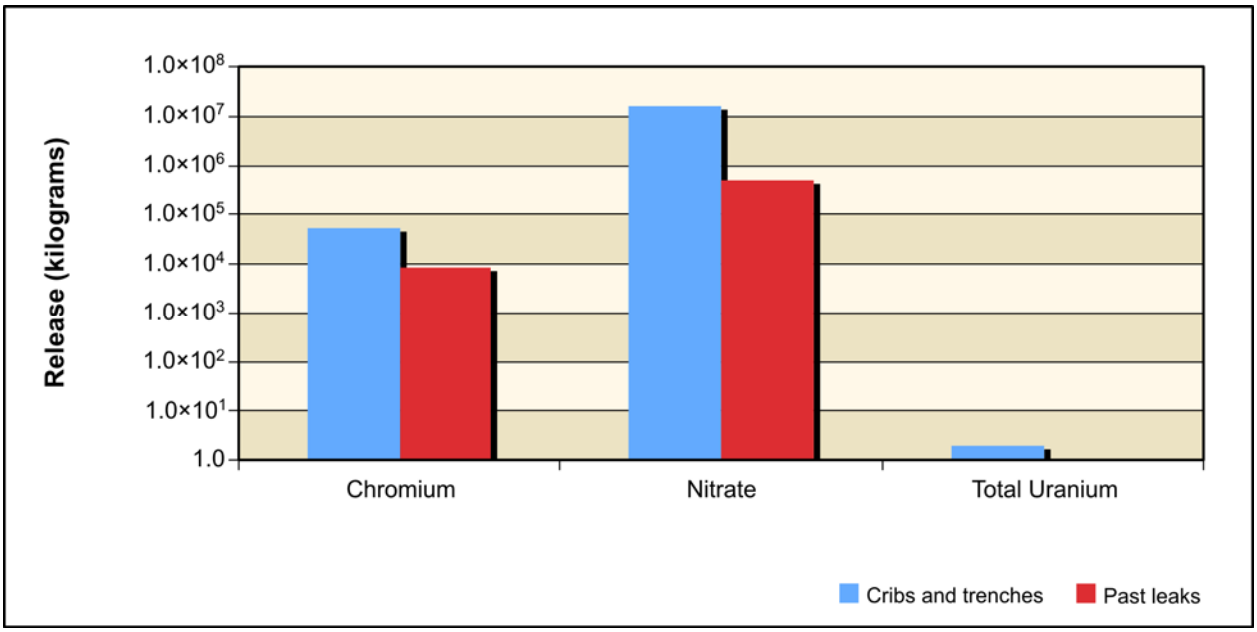


Figure 5–261. Tank Closure Alternative 6B, Option Case, Releases of Chemical Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

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.

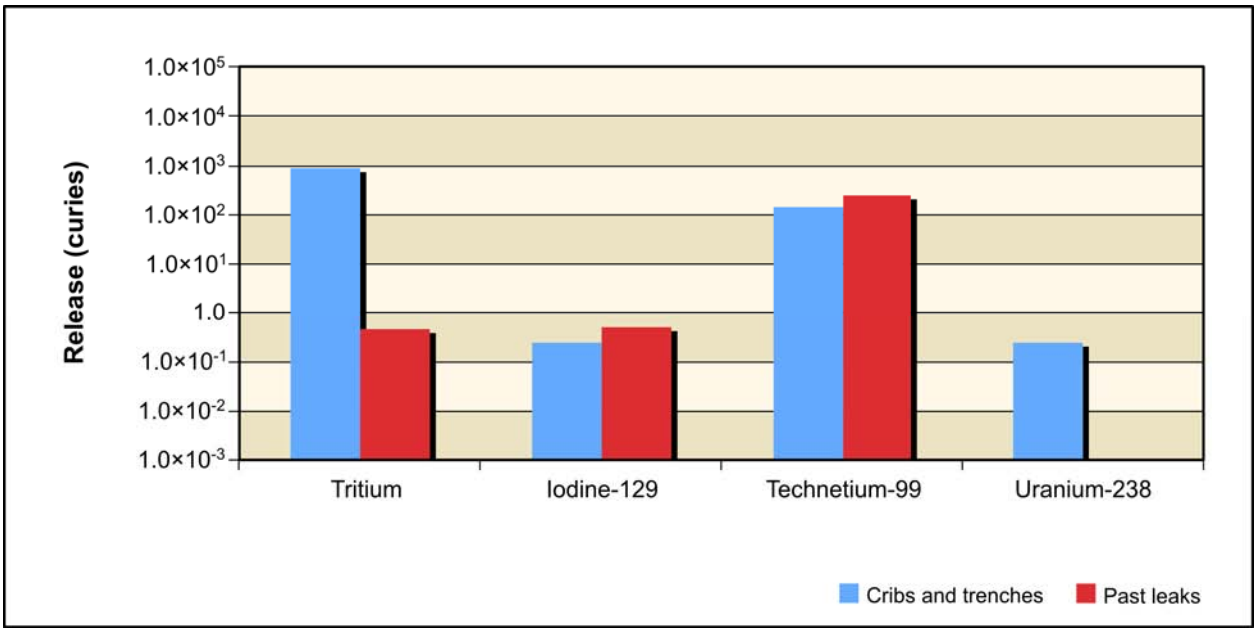


Figure 5–262. Tank Closure Alternative 6B, Base Case, Releases of Radiological Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

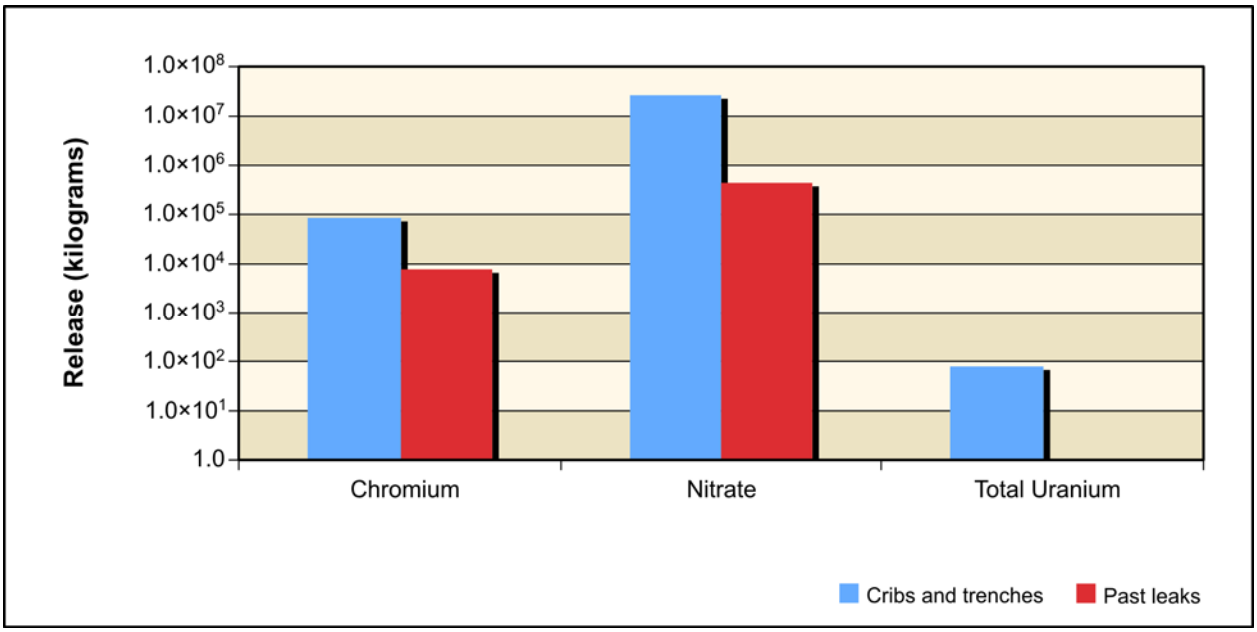


Figure 5–263. Tank Closure Alternative 6B, Base Case, Releases of Chemical Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

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.

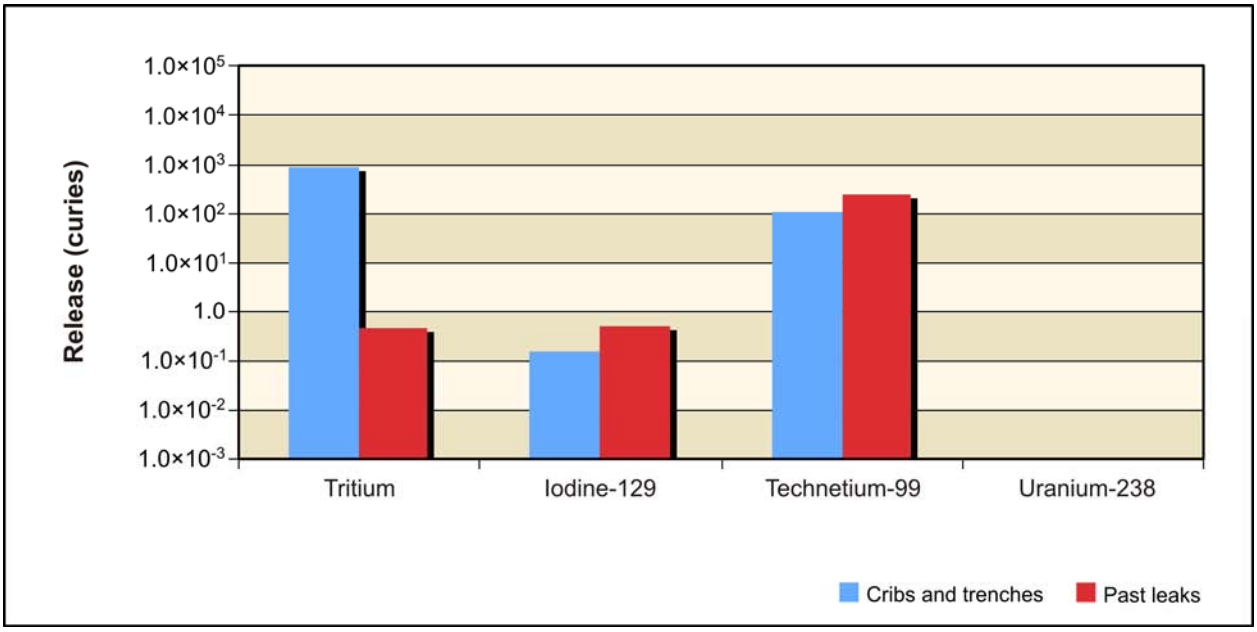


Figure 5–264. Tank Closure Alternative 6B, Option Case, Releases of Radiological Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

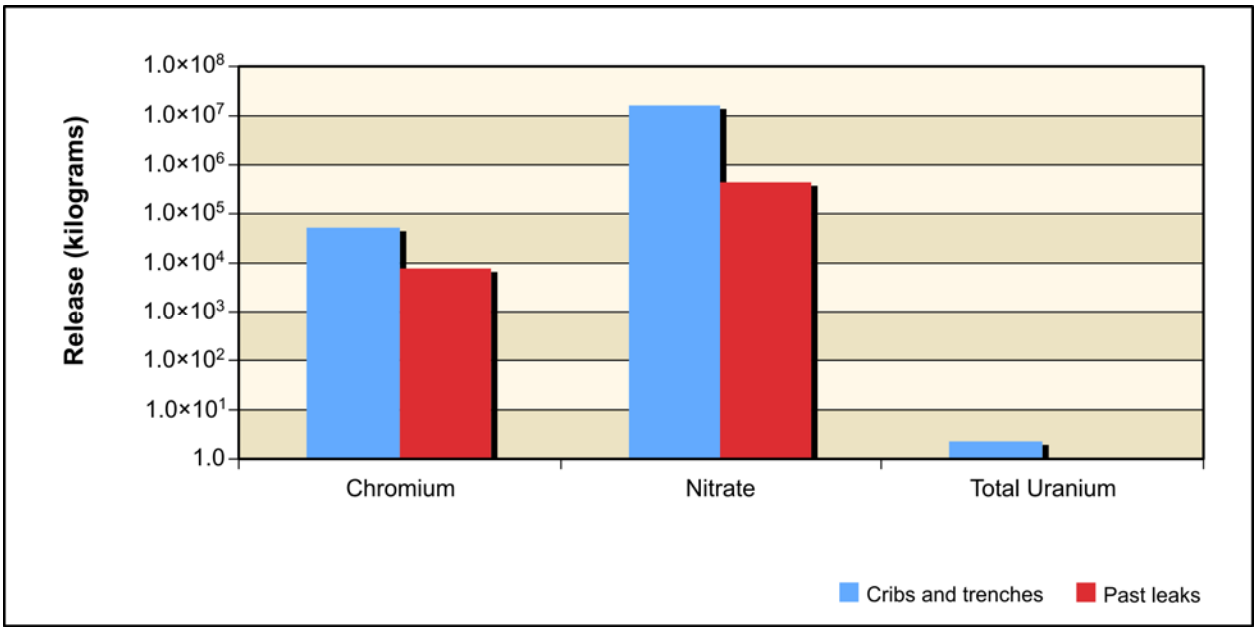


Figure 5–265. Tank Closure Alternative 6B, Option Case, Releases of Chemical Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

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.

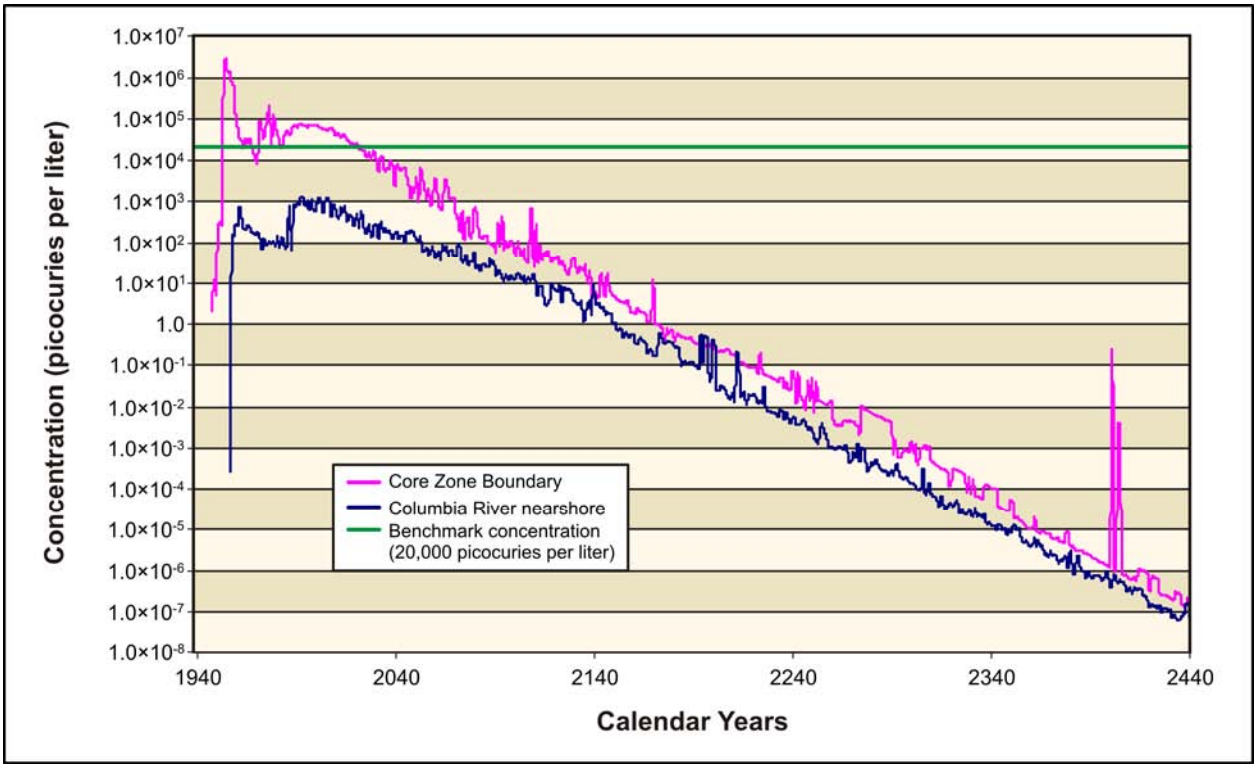


Figure 5–266. Tank Closure Alternative 6B, Base Case, Hydrogen-3 (Tritium) Concentration Versus Time

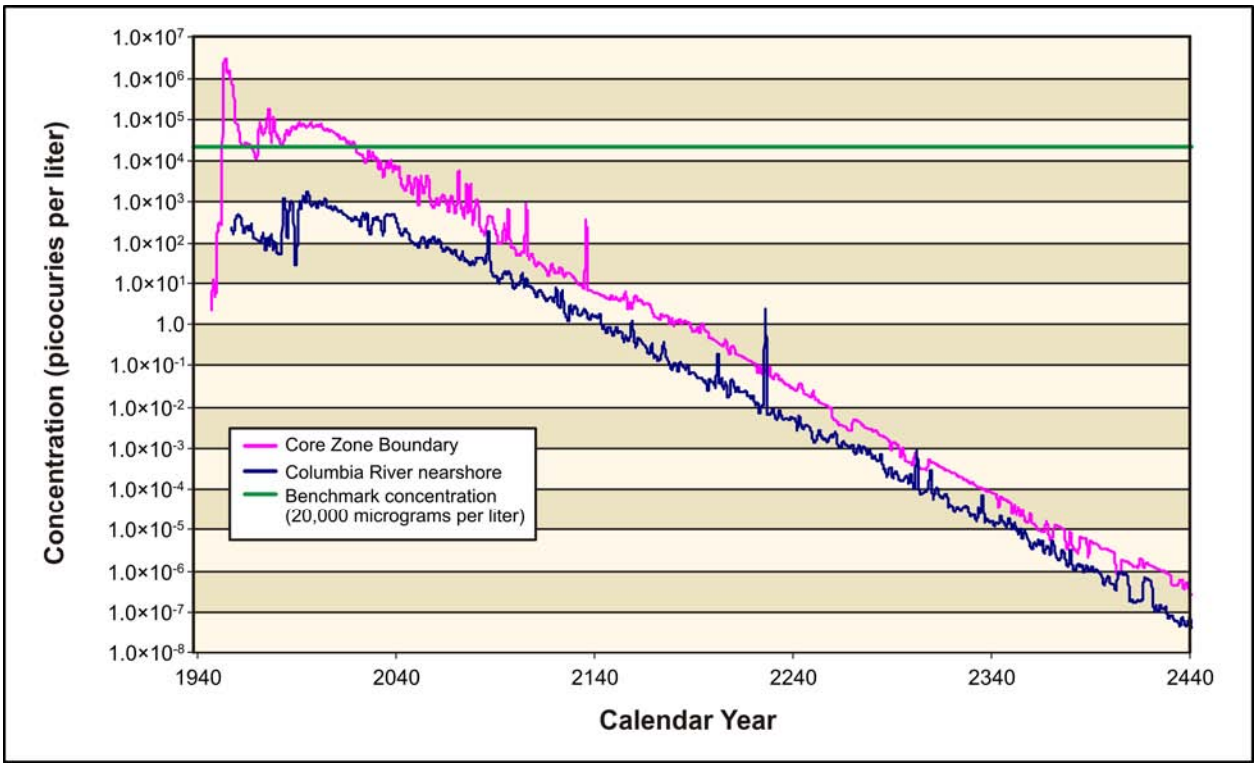


Figure 5–267. Tank Closure Alternative 6B, Option Case, Hydrogen-3 (Tritium) Concentration Versus Time

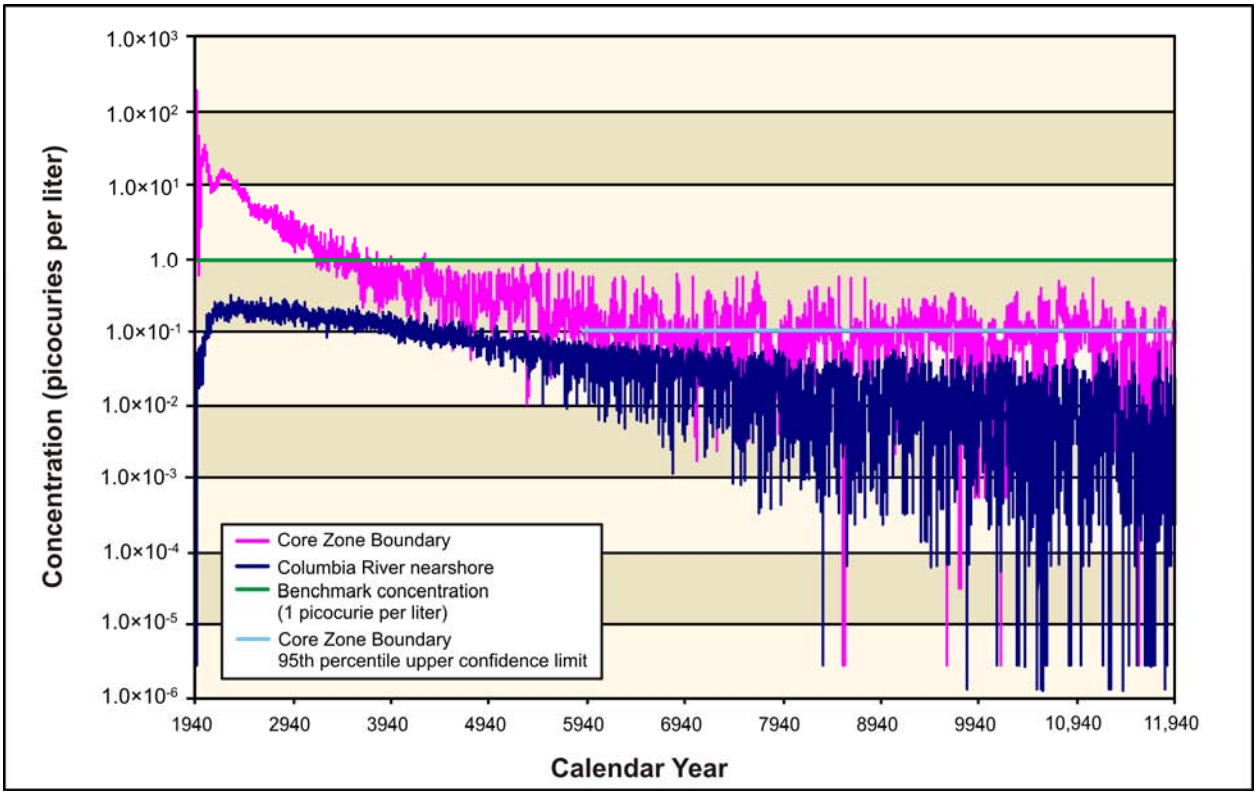


Figure 5–268. Tank Closure Alternative 6B, Base Case, Iodine-129 Concentration Versus Time

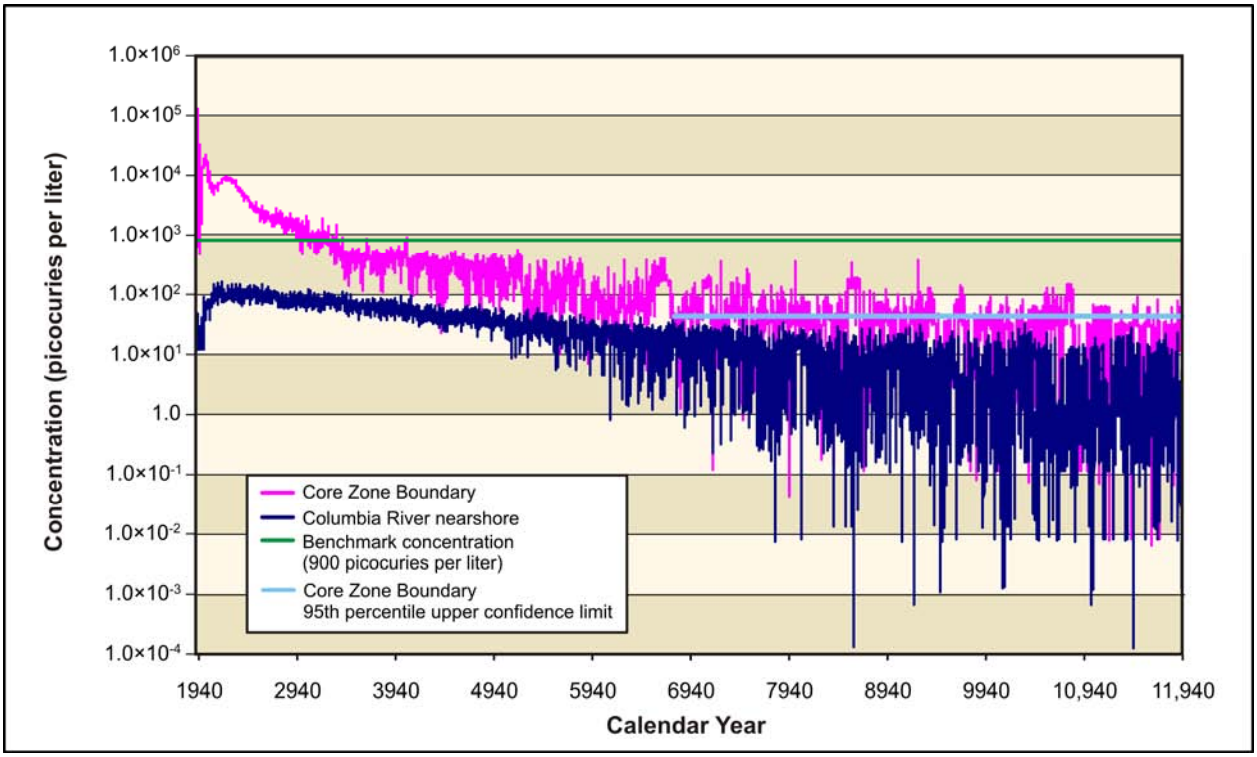


Figure 5–269. Tank Closure Alternative 6B, Base Case, Technetium-99 Concentration Versus Time

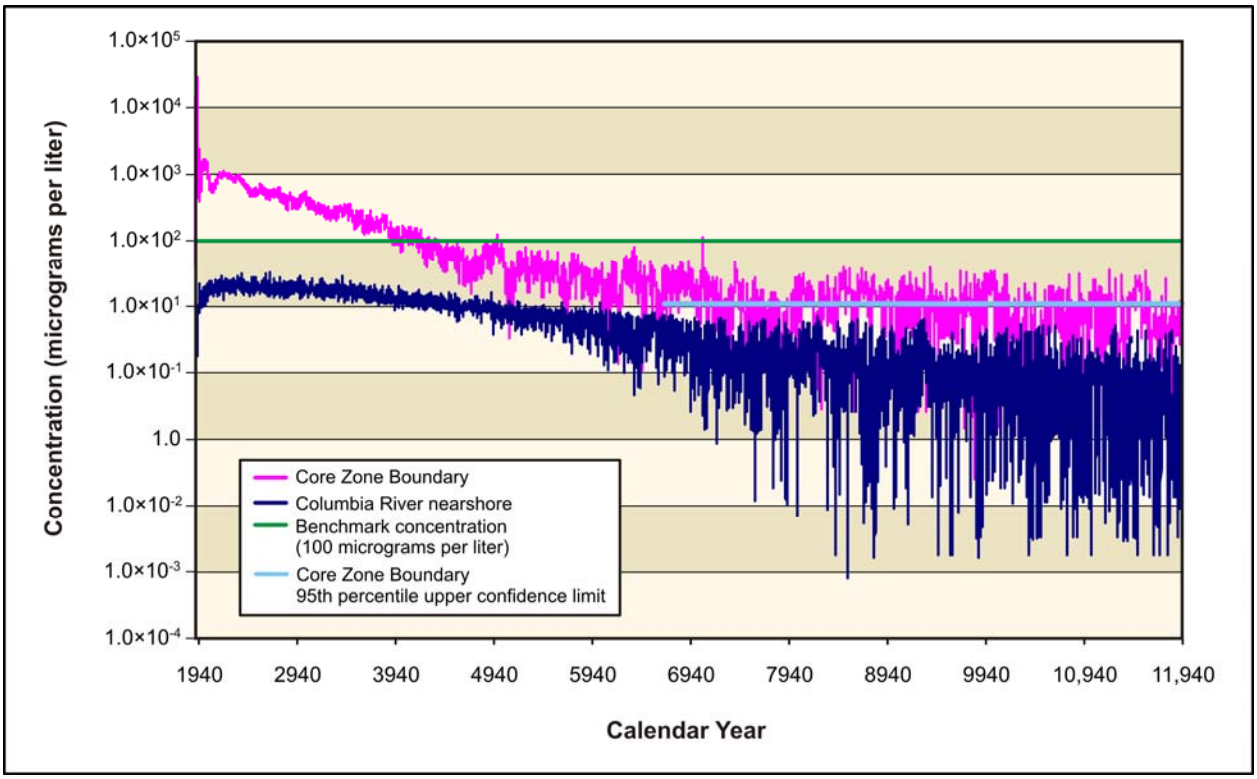


Figure 5–270. Tank Closure Alternative 6B, Base Case, Chromium Concentration Versus Time

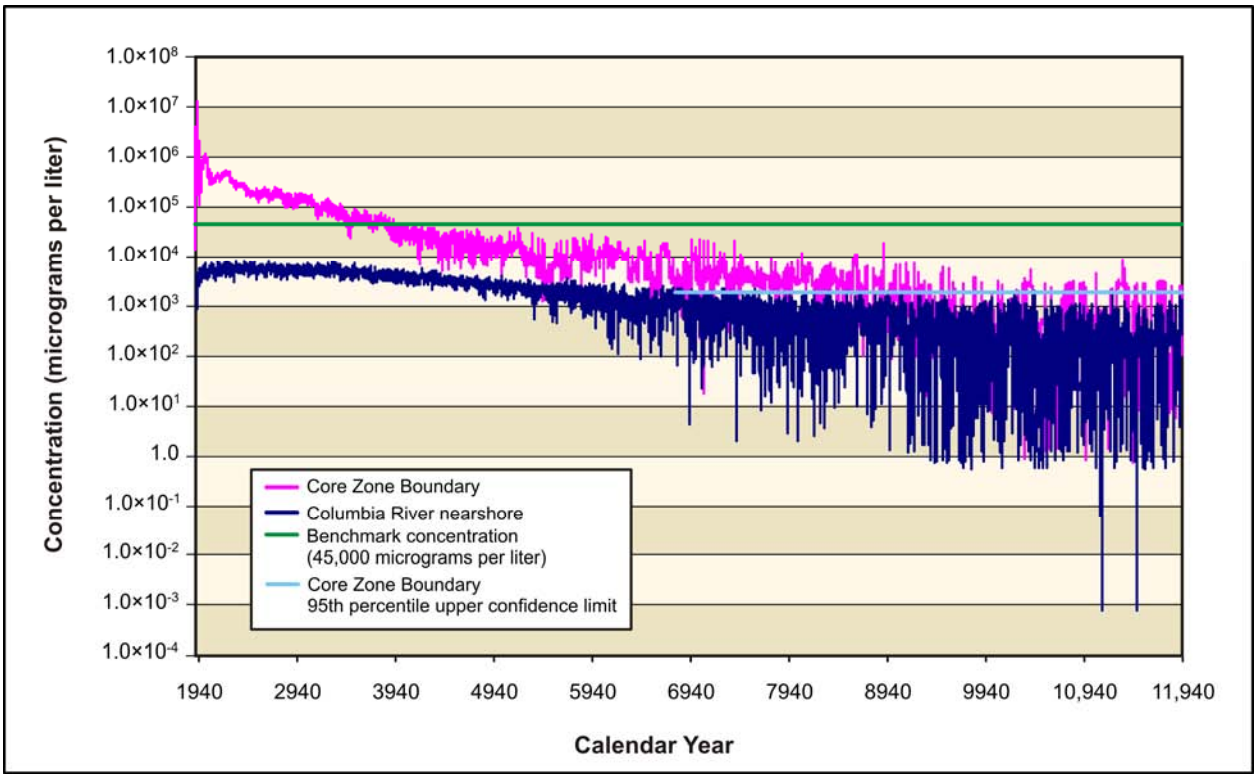


Figure 5–271. Tank Closure Alternative 6B, Base Case, Nitrate Concentration Versus Time

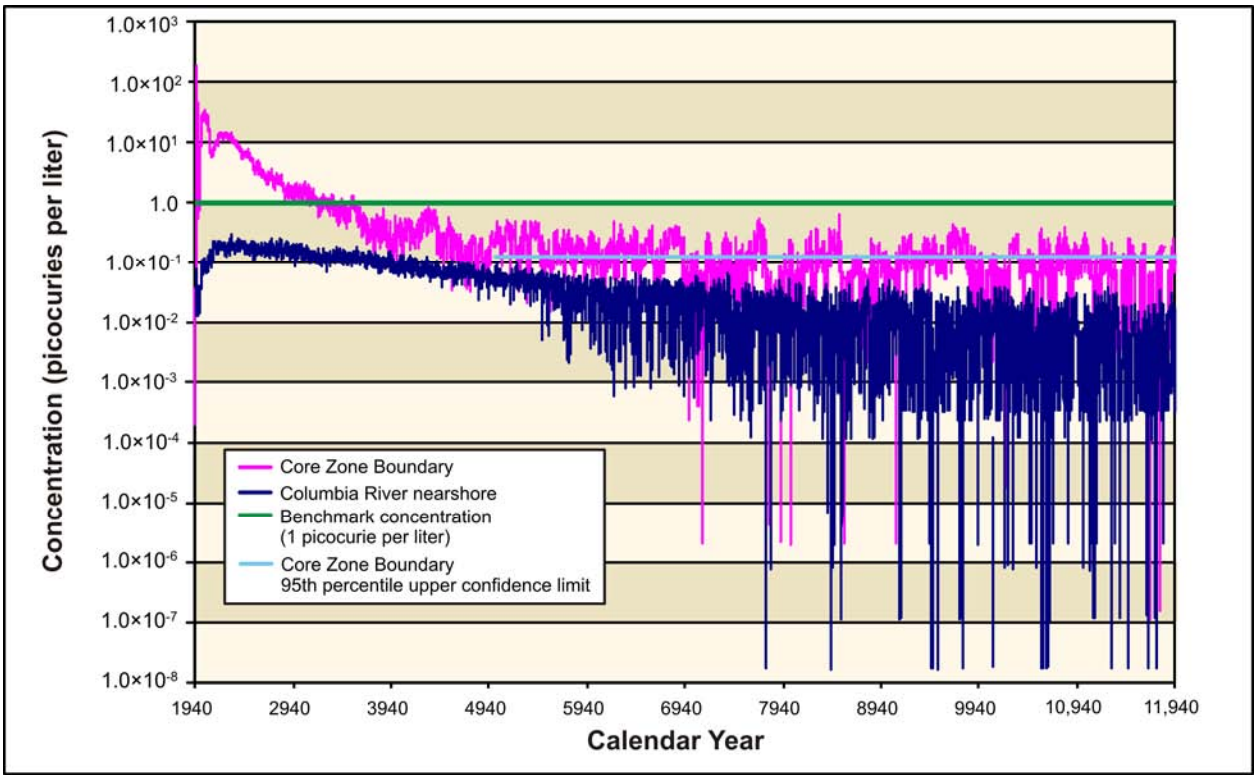


Figure 5–272. Tank Closure Alternative 6B, Option Case, Iodine-129 Concentration Versus Time

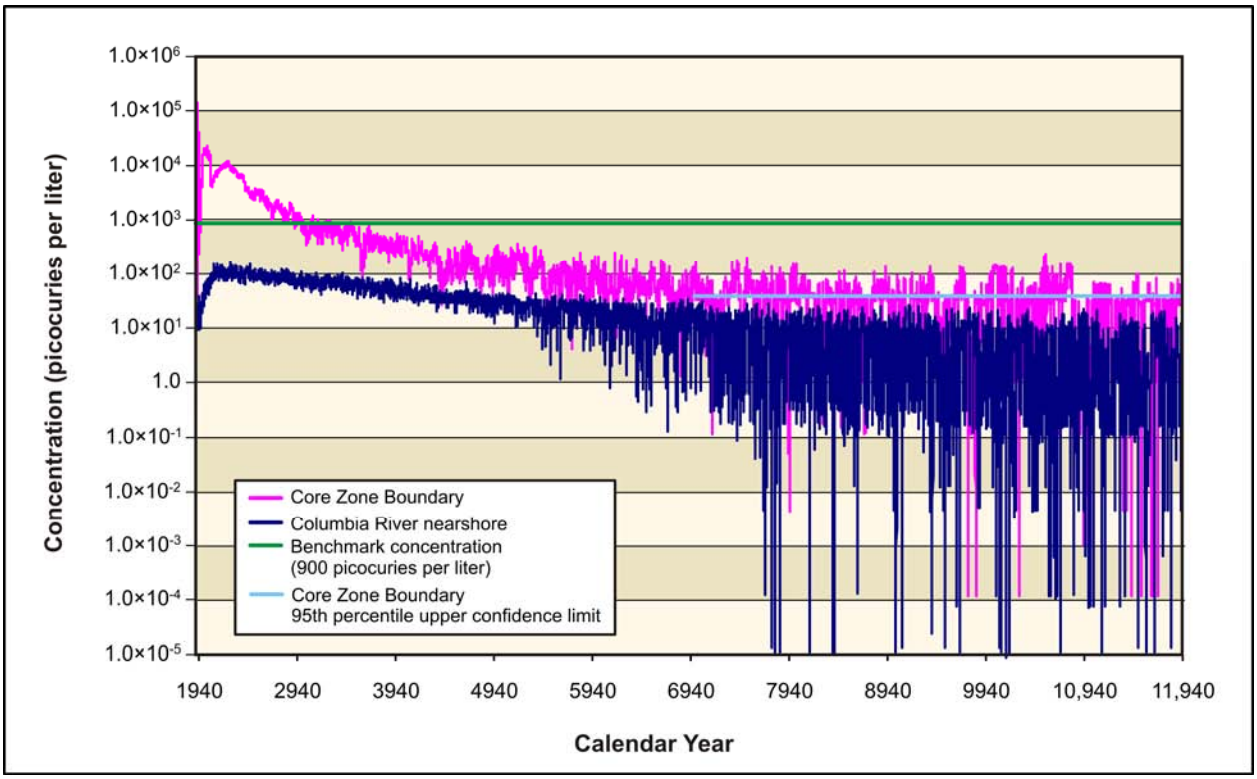


Figure 5–273. Tank Closure Alternative 6B, Option Case, Technetium-99 Concentration Versus Time

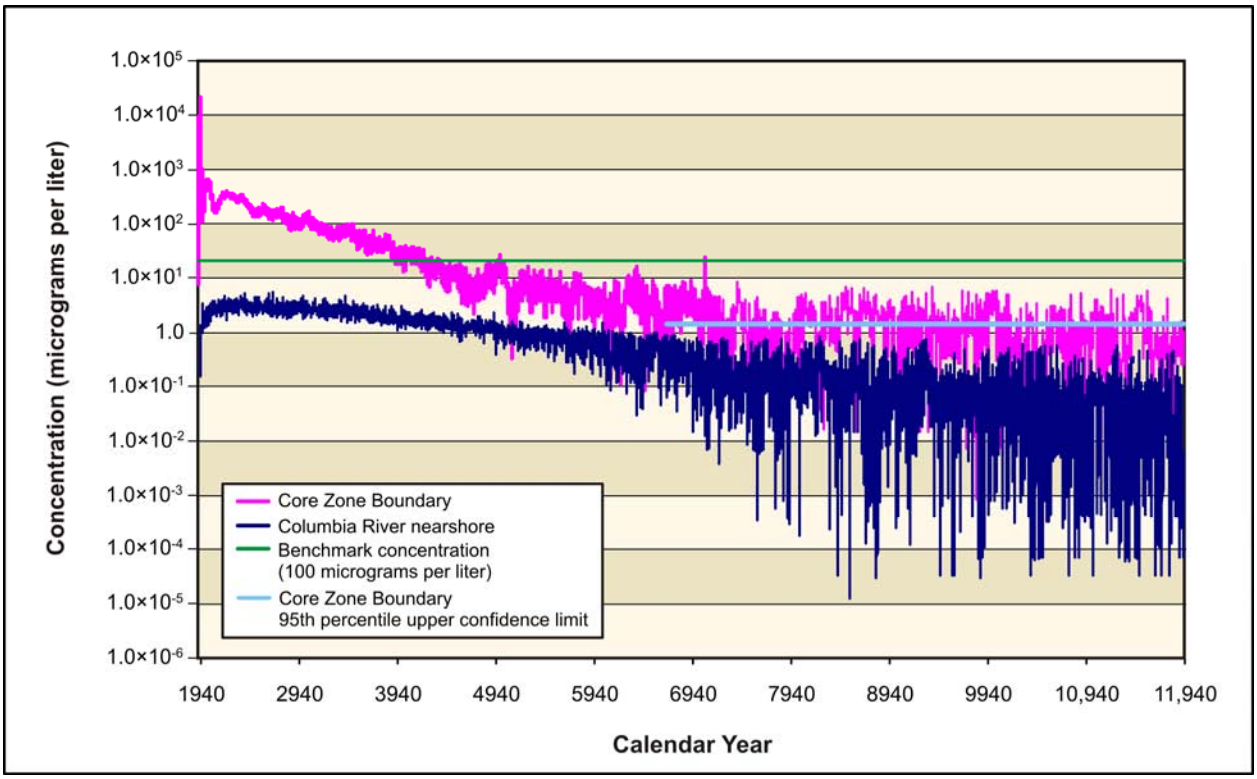


Figure 5–274. Tank Closure Alternative 6B, Option Case, Chromium Concentration Versus Time

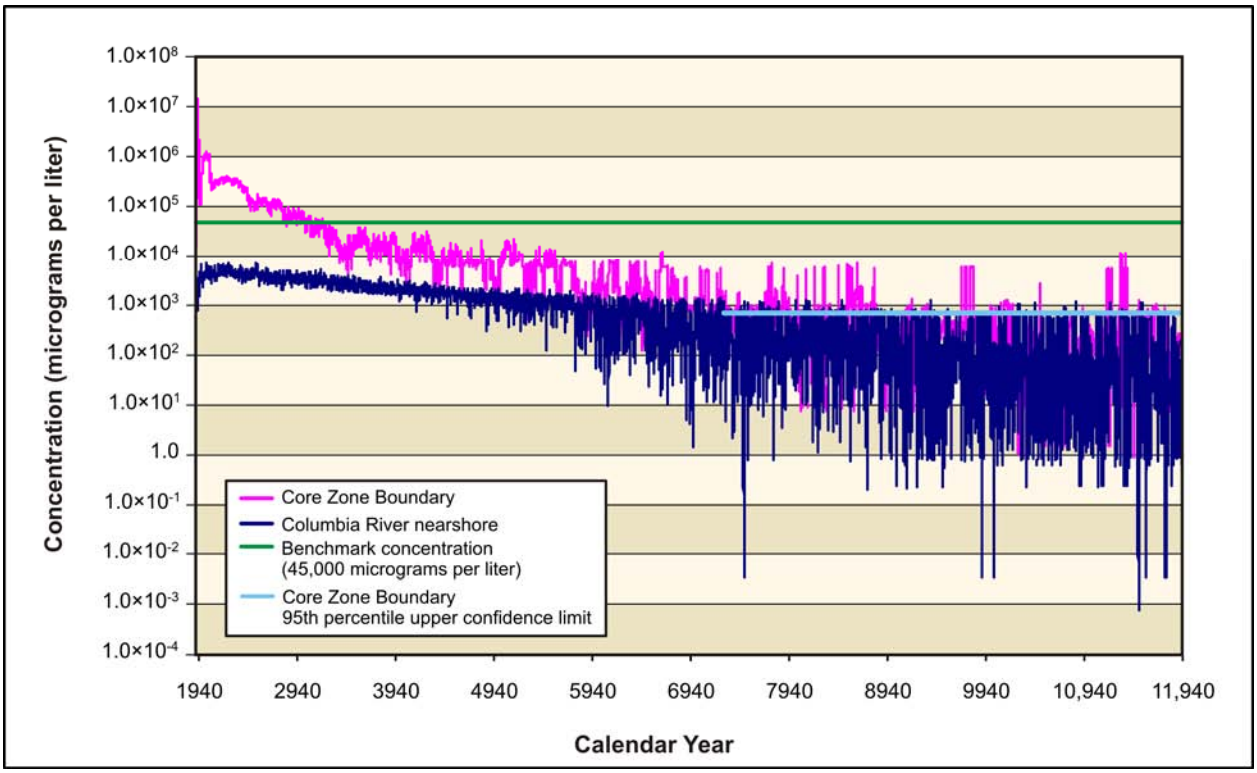


Figure 5–275. Tank Closure Alternative 6B, Option Case, Nitrate Concentration Versus Time

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.

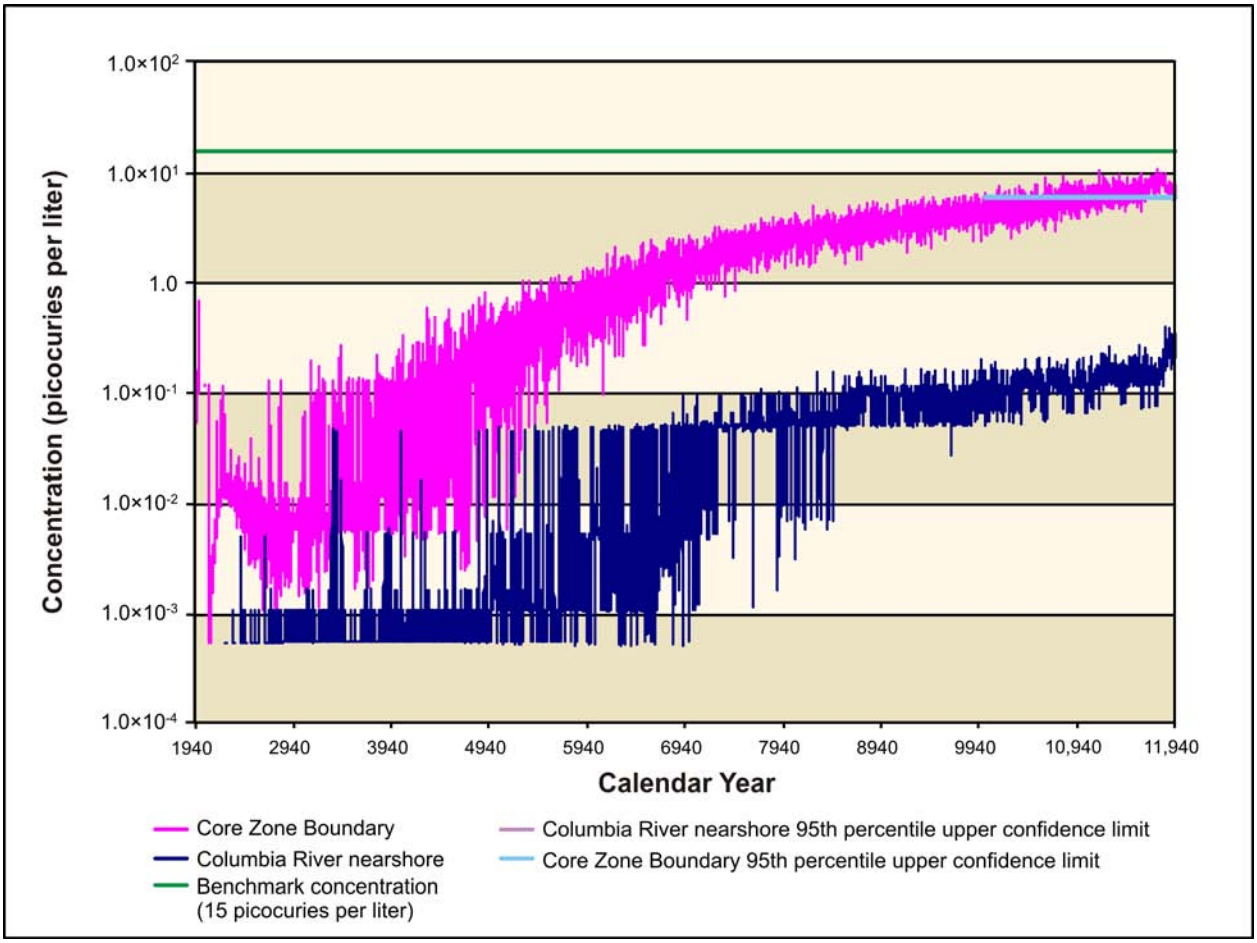


Figure 5–276. Tank Closure Alternative 6B, Base Case, Uranium-238 Concentration Versus Time

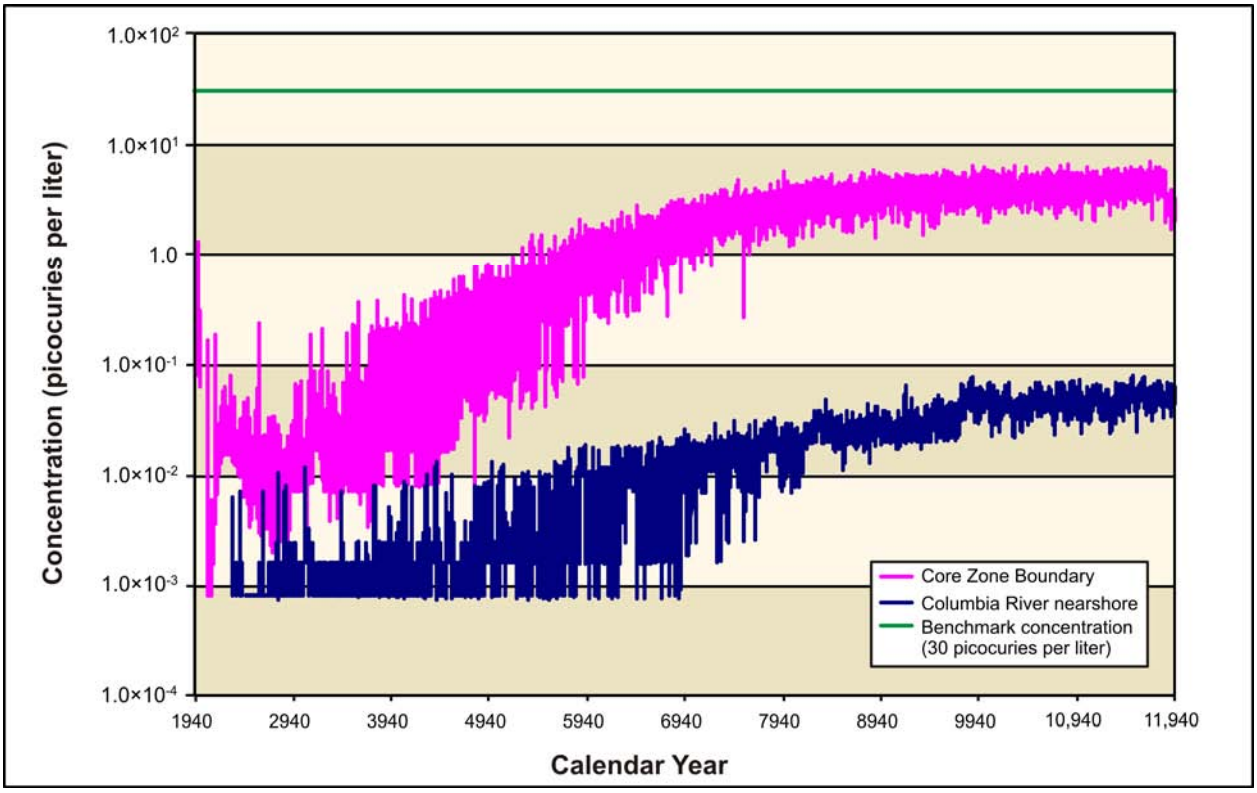


Figure 5–277. Tank Closure Alternative 6B, Base Case, Total Uranium Concentration Versus Time

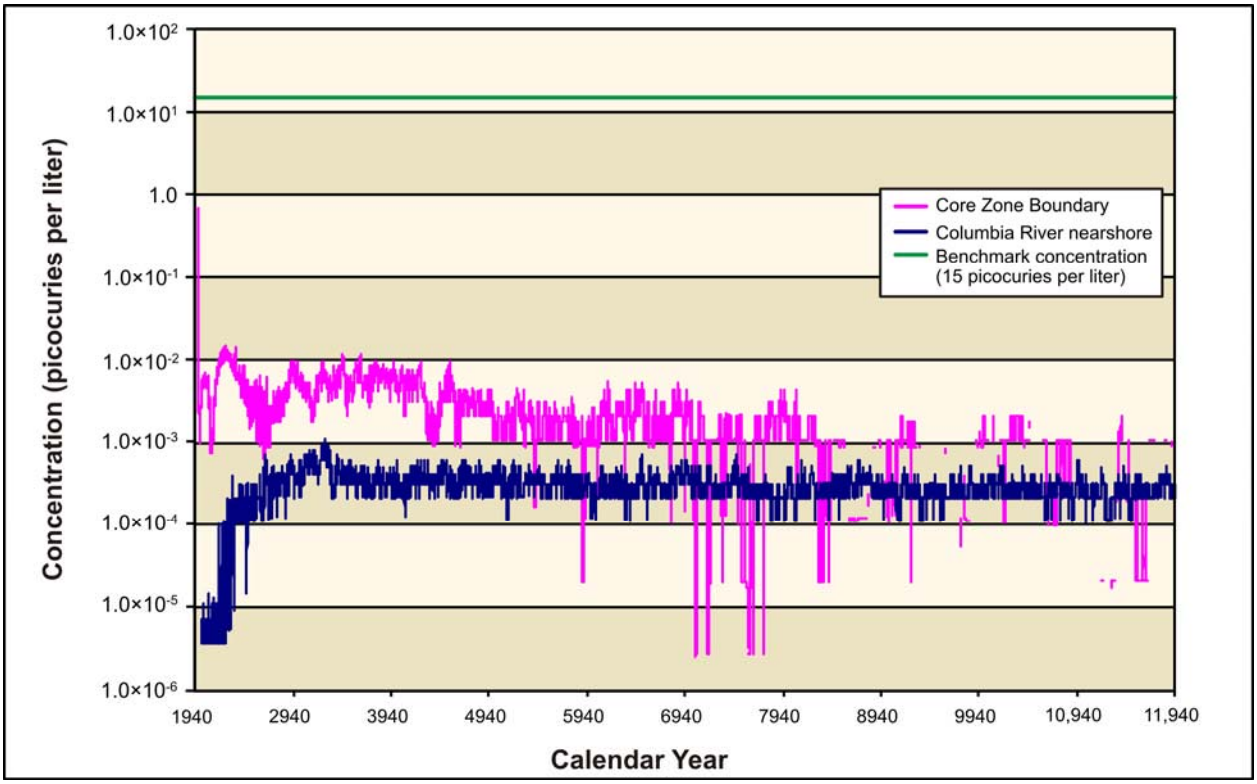


Figure 5–278. Tank Closure Alternative 6B, Option Case, Uranium-238 Concentration Versus Time

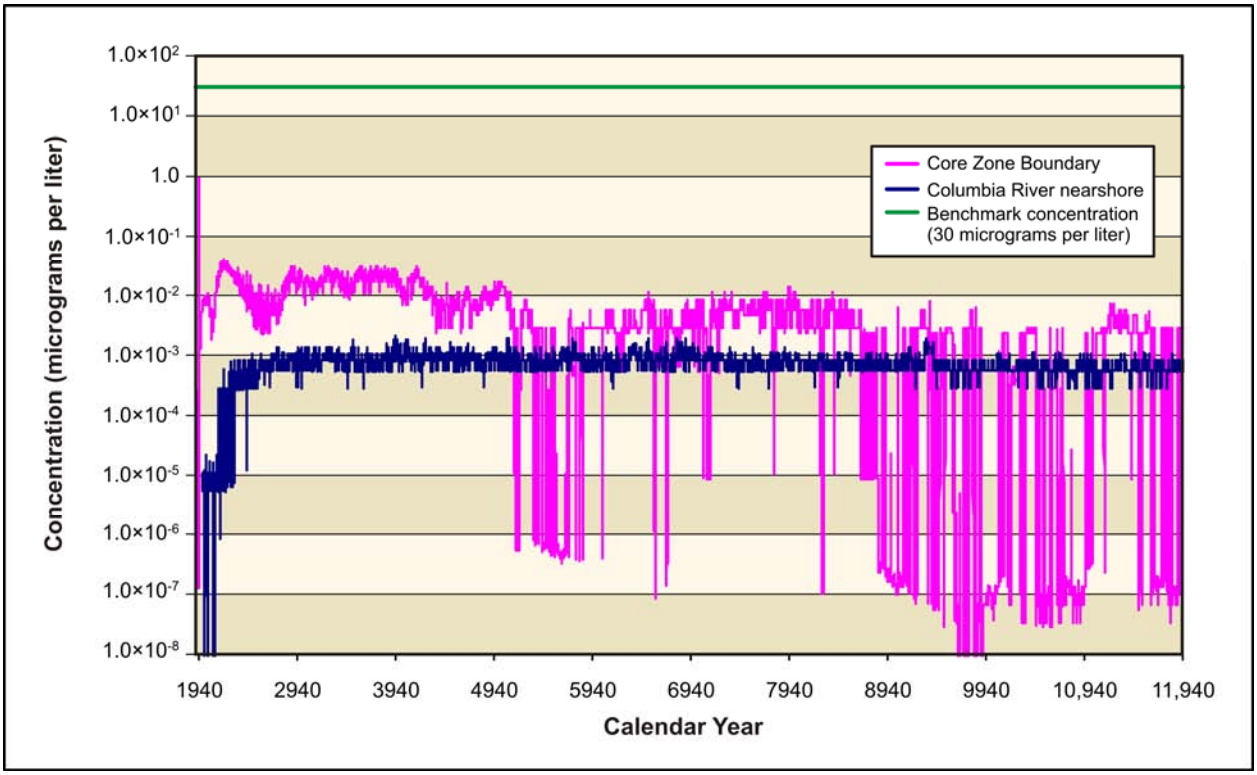


Figure 5–279. Tank Closure Alternative 6B, Option Case, Total Uranium Concentration Versus Time

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).

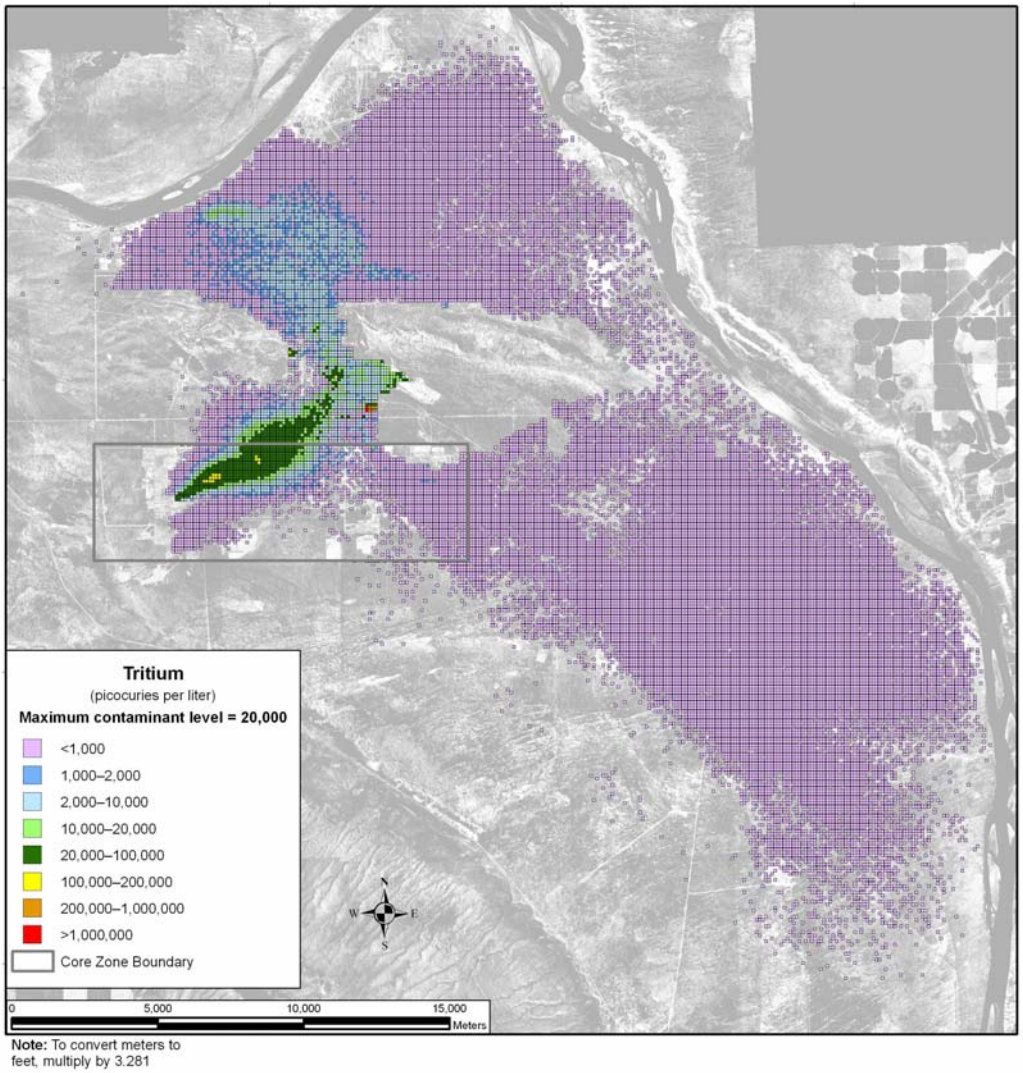
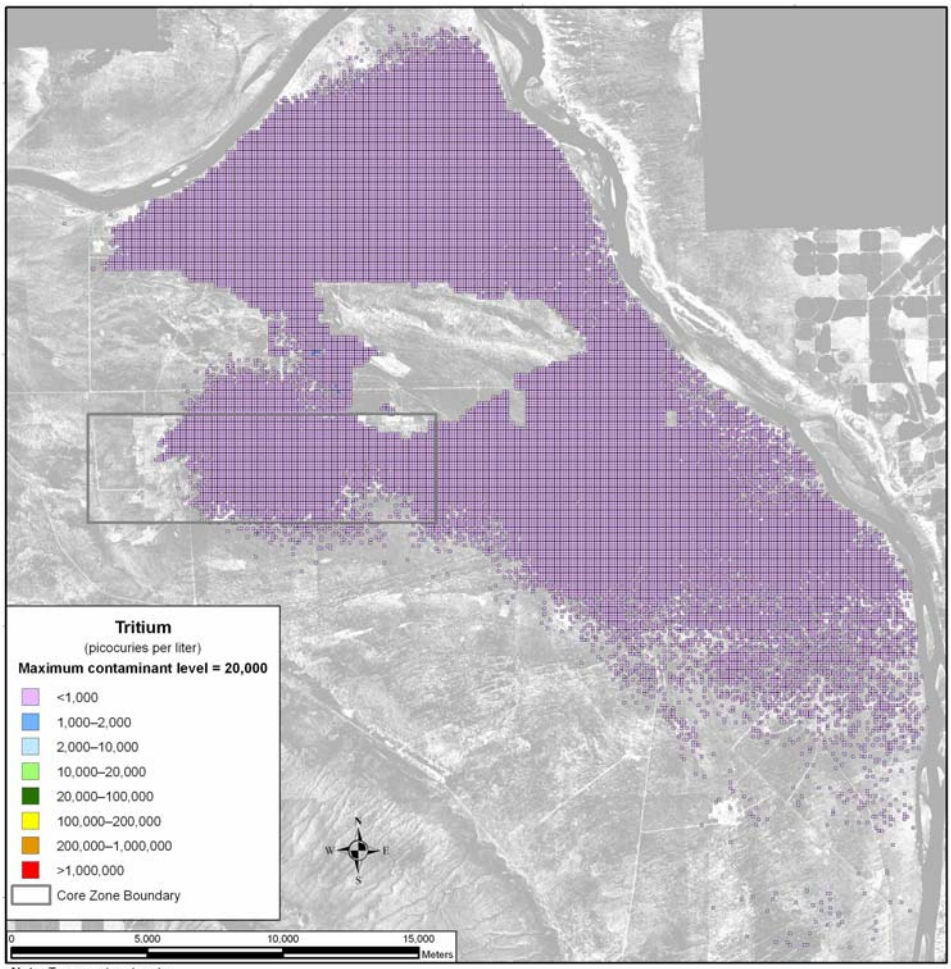


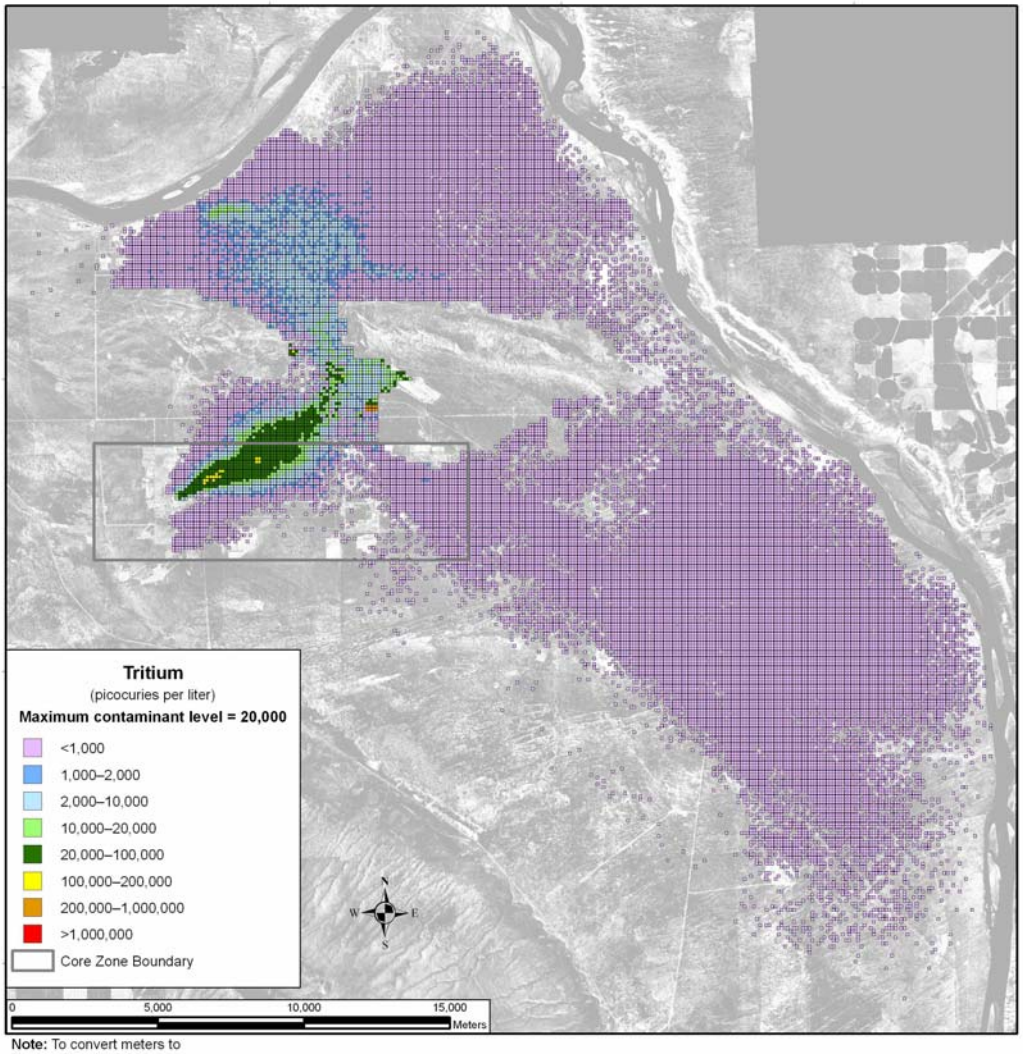
Figure 5–280. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

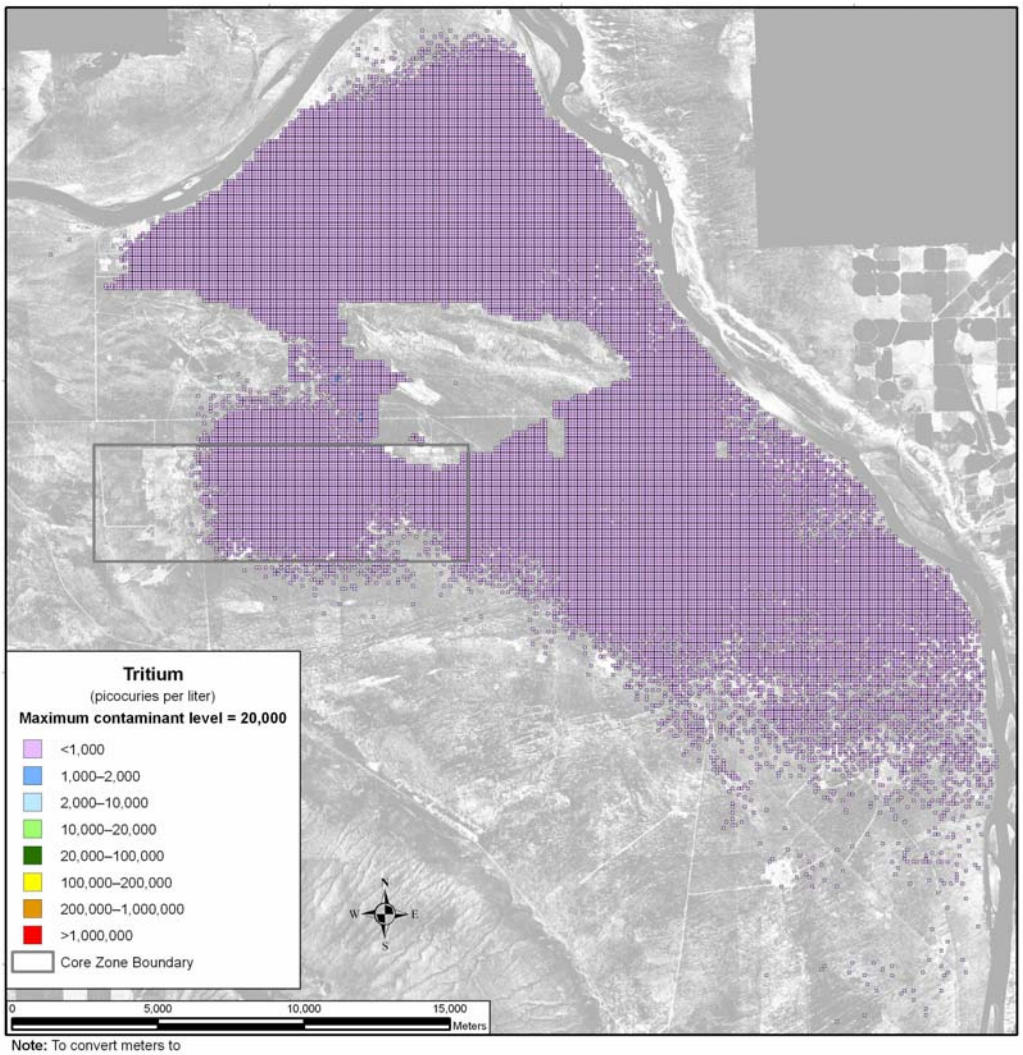
Figure 5–281. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2135

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

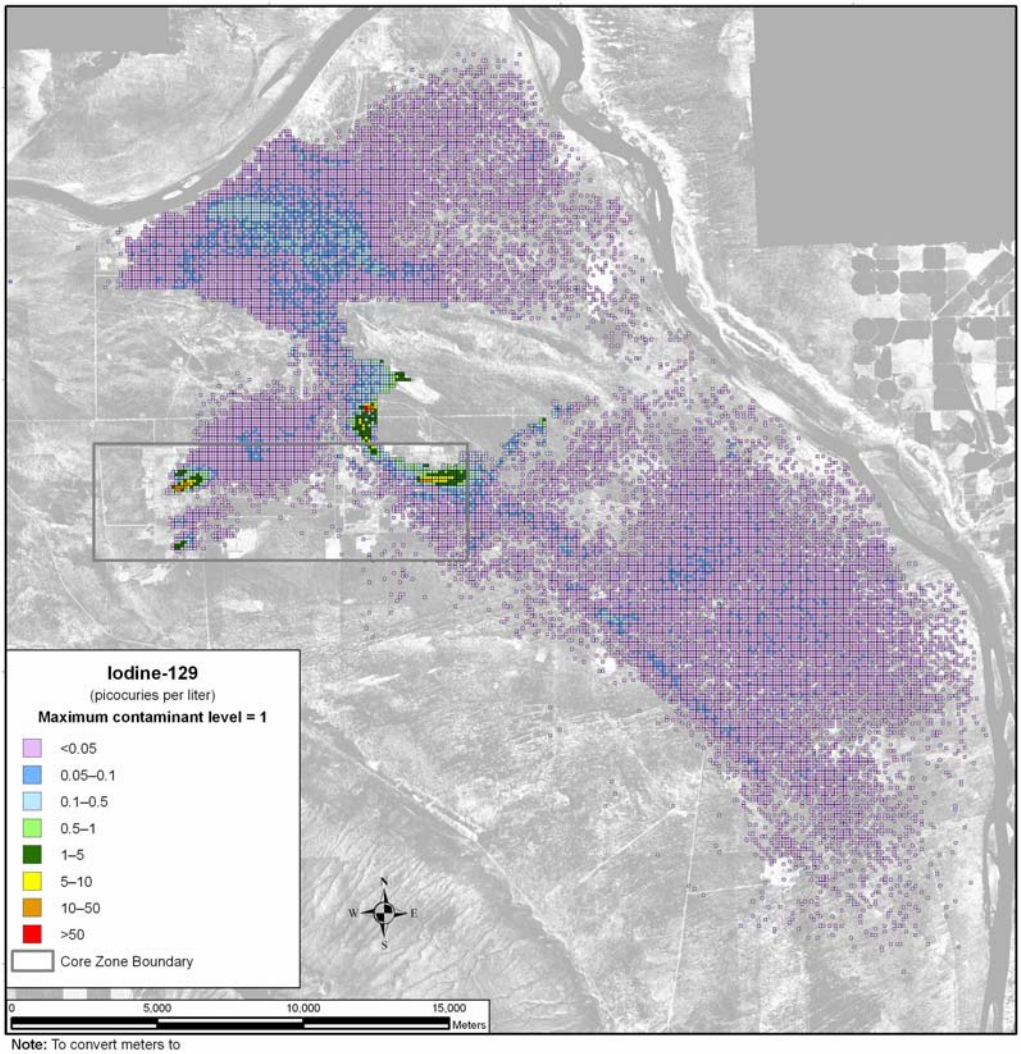
Figure 5–282. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

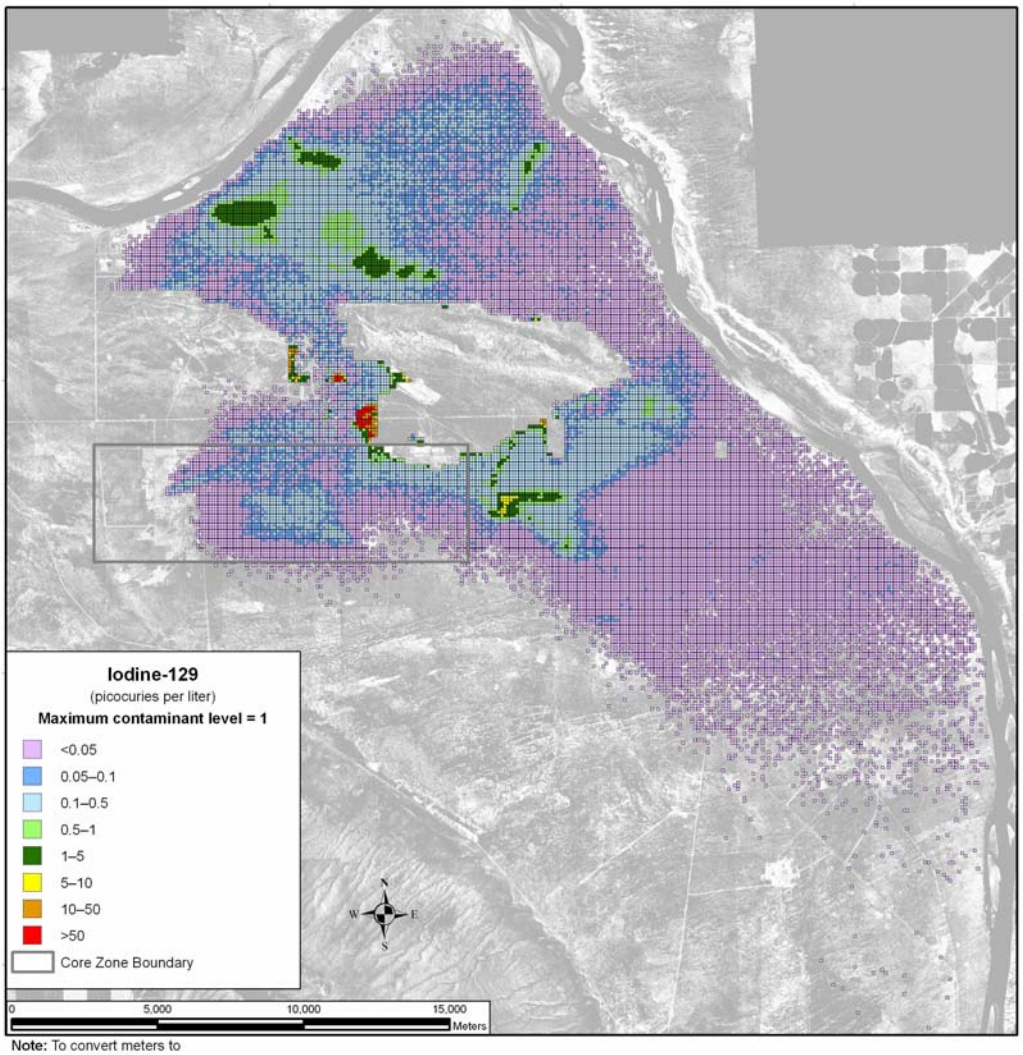
Figure 5–283. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2135

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).



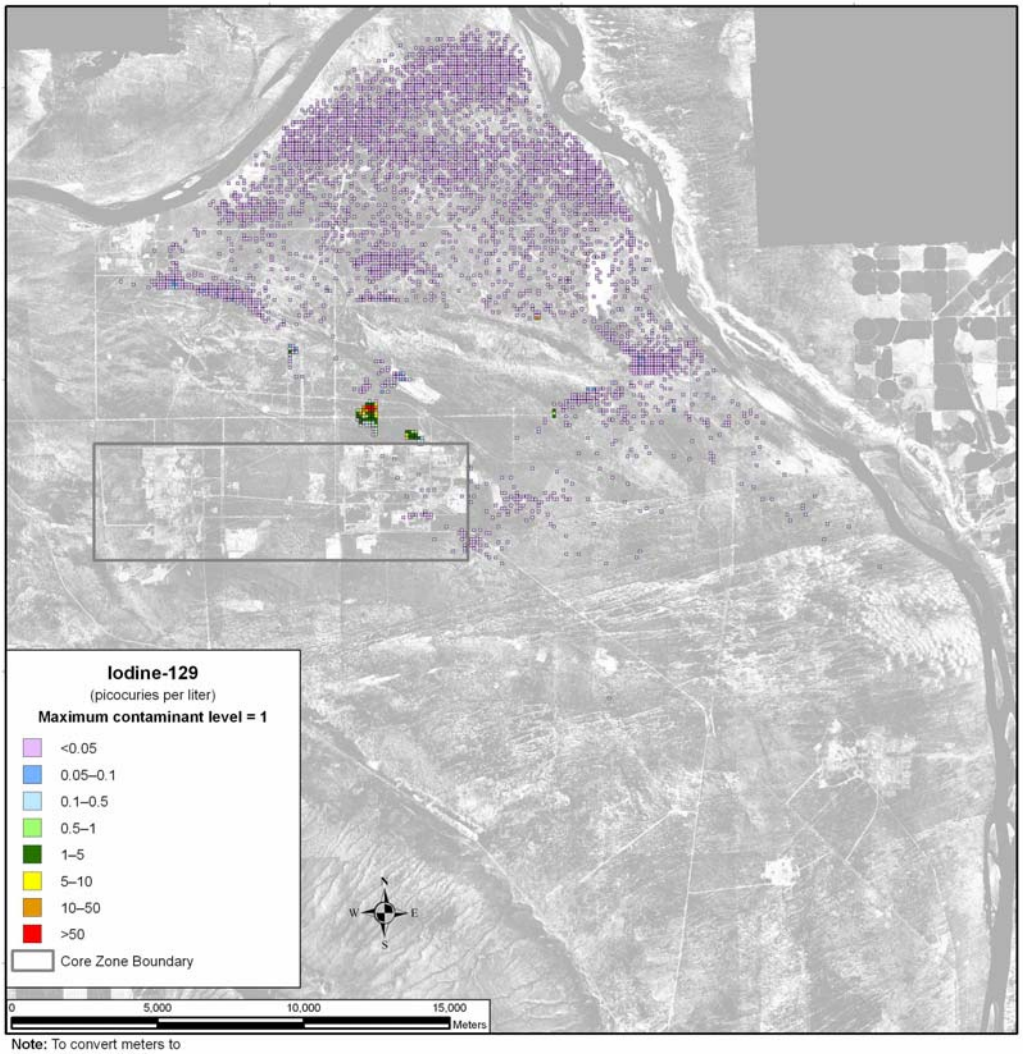
Note: To convert meters to feet, multiply by 3.281

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



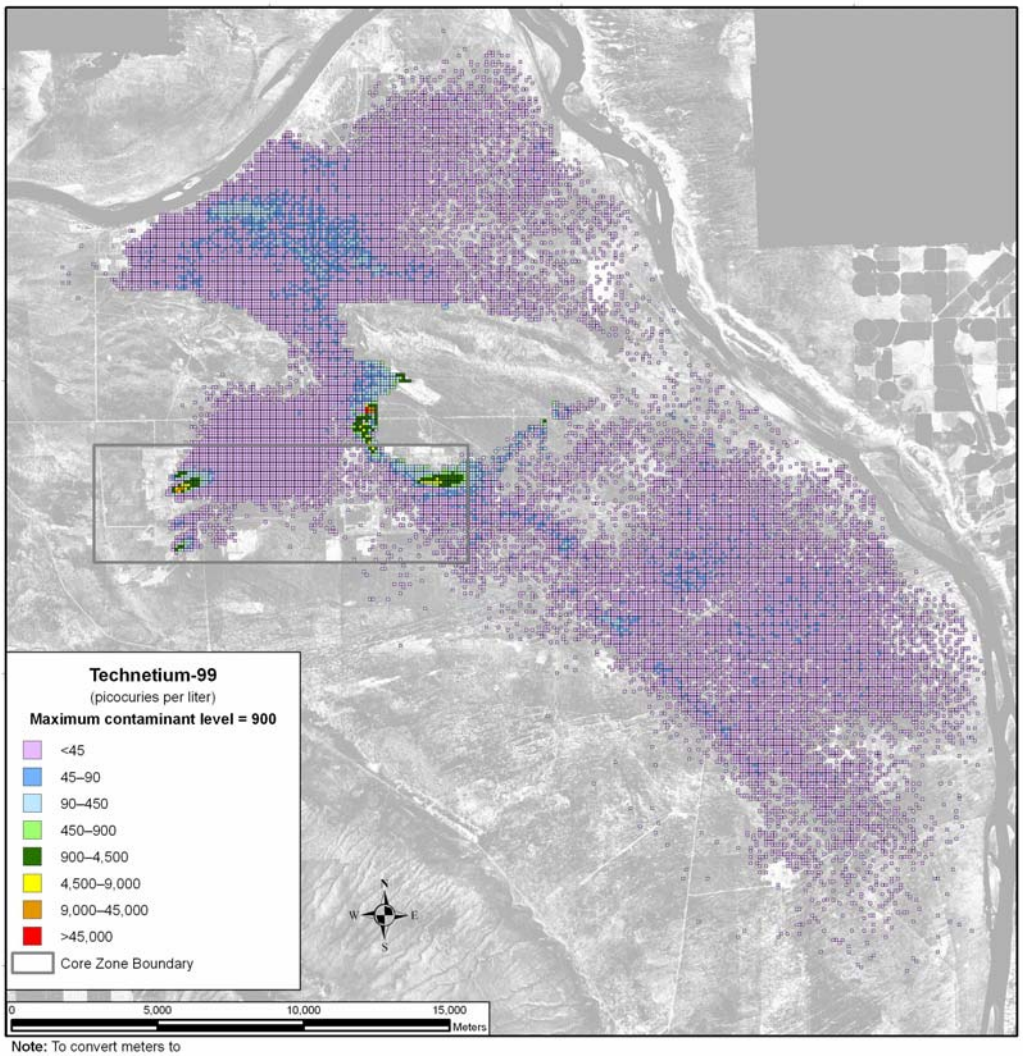
Note: To convert meters to feet, multiply by 3.281

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



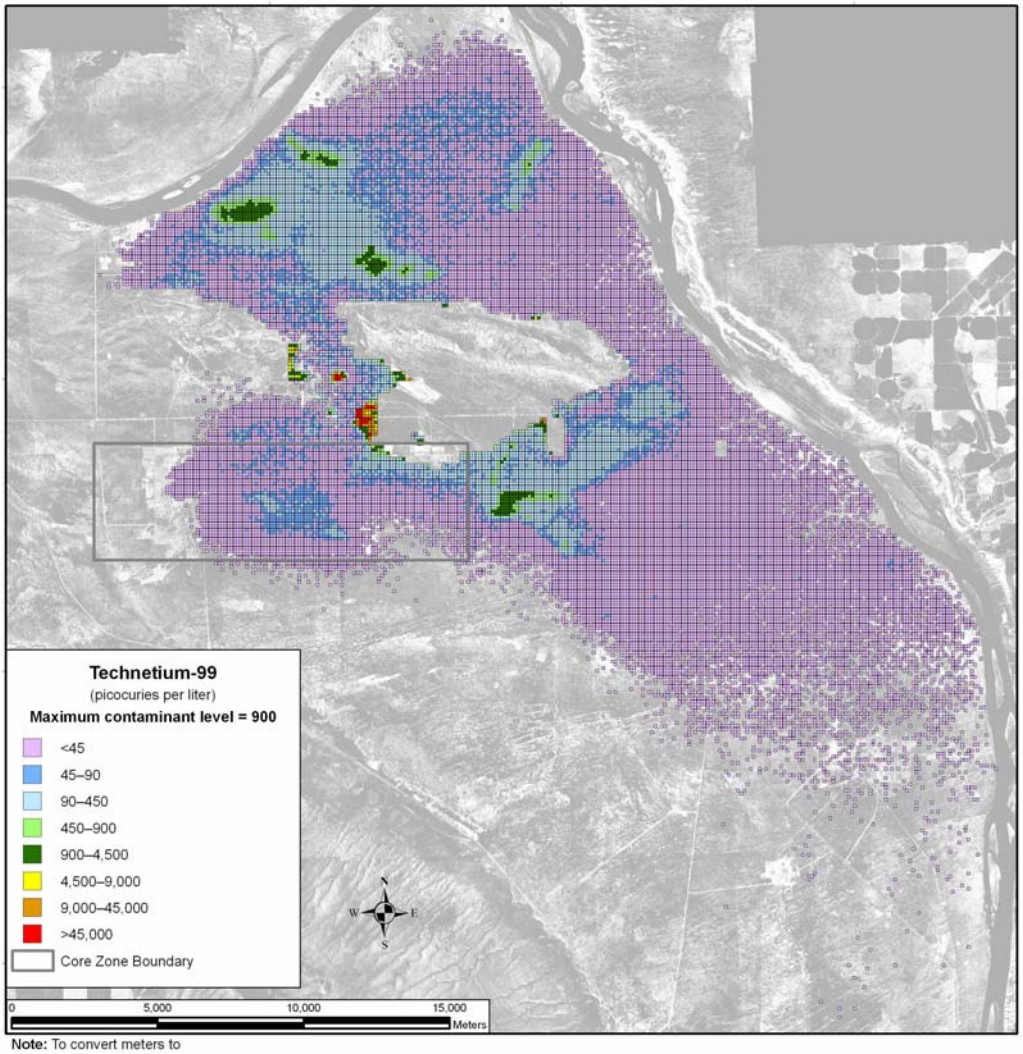
Note: To convert meters to feet, multiply by 3.281

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



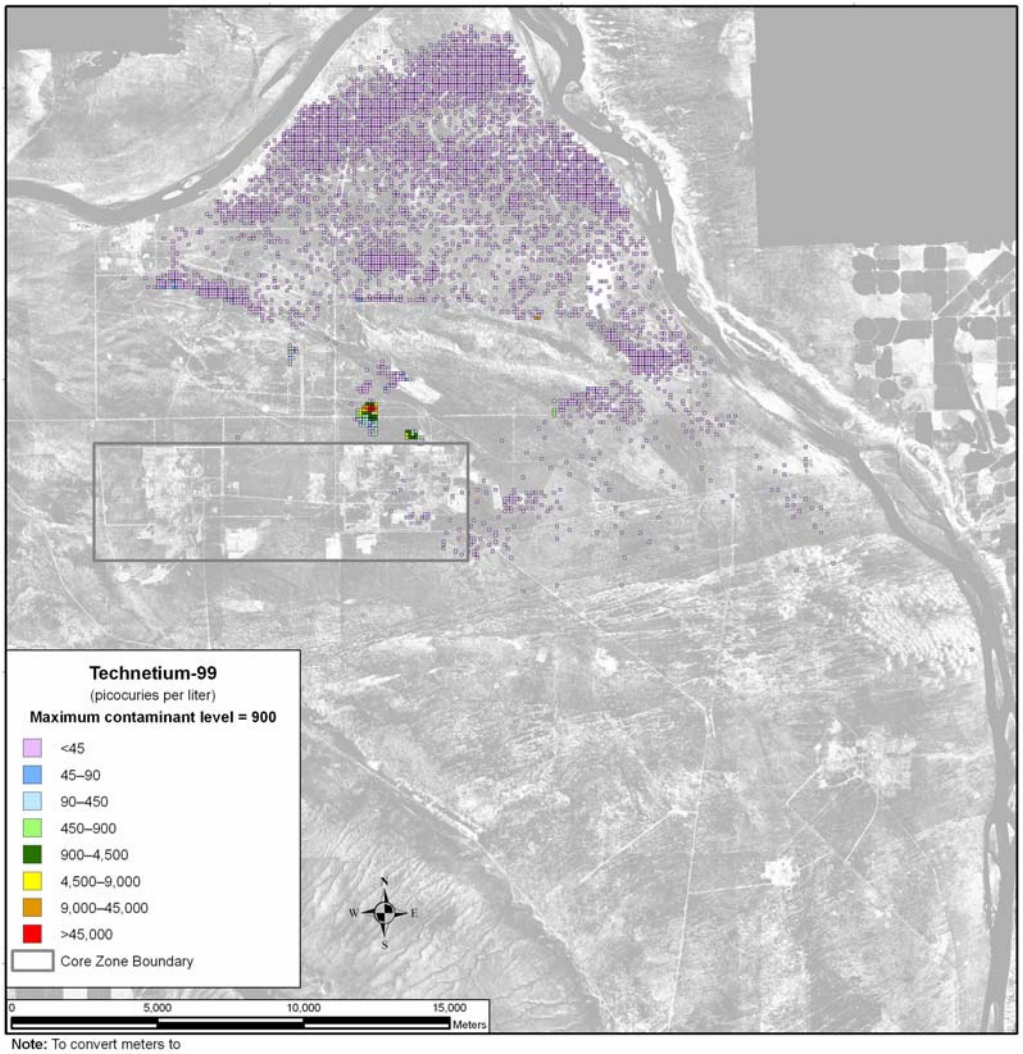
Note: To convert meters to feet, multiply by 3.281

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



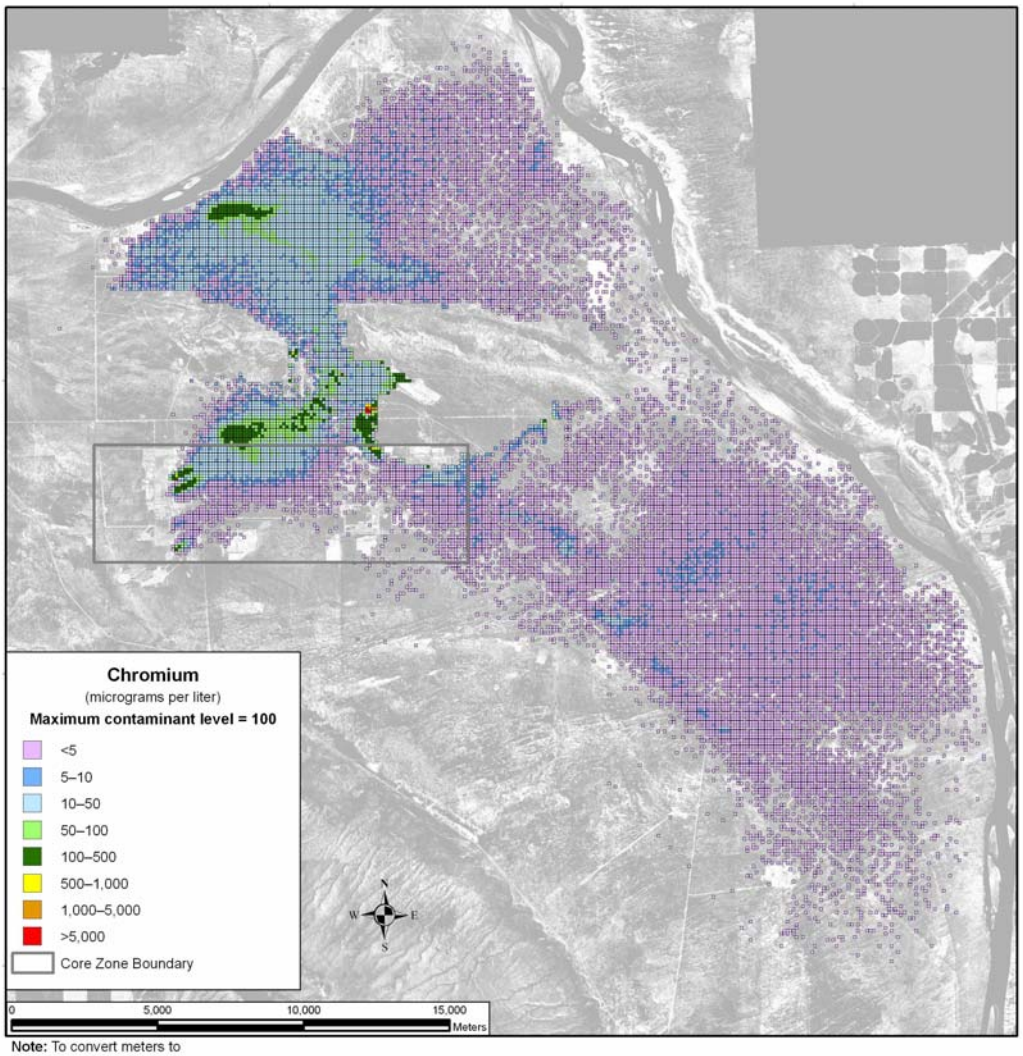
Note: To convert meters to feet, multiply by 3.281

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



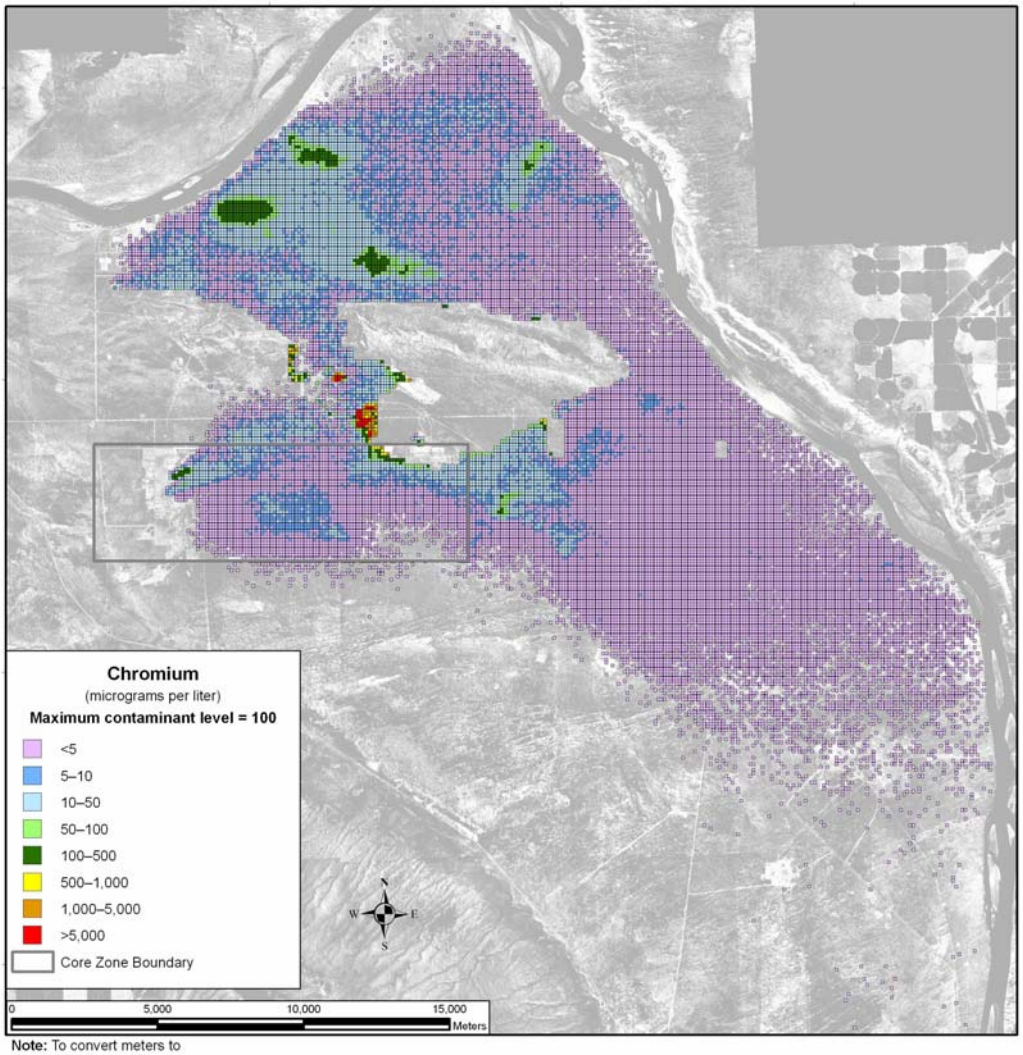
Note: To convert meters to feet, multiply by 3.281

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



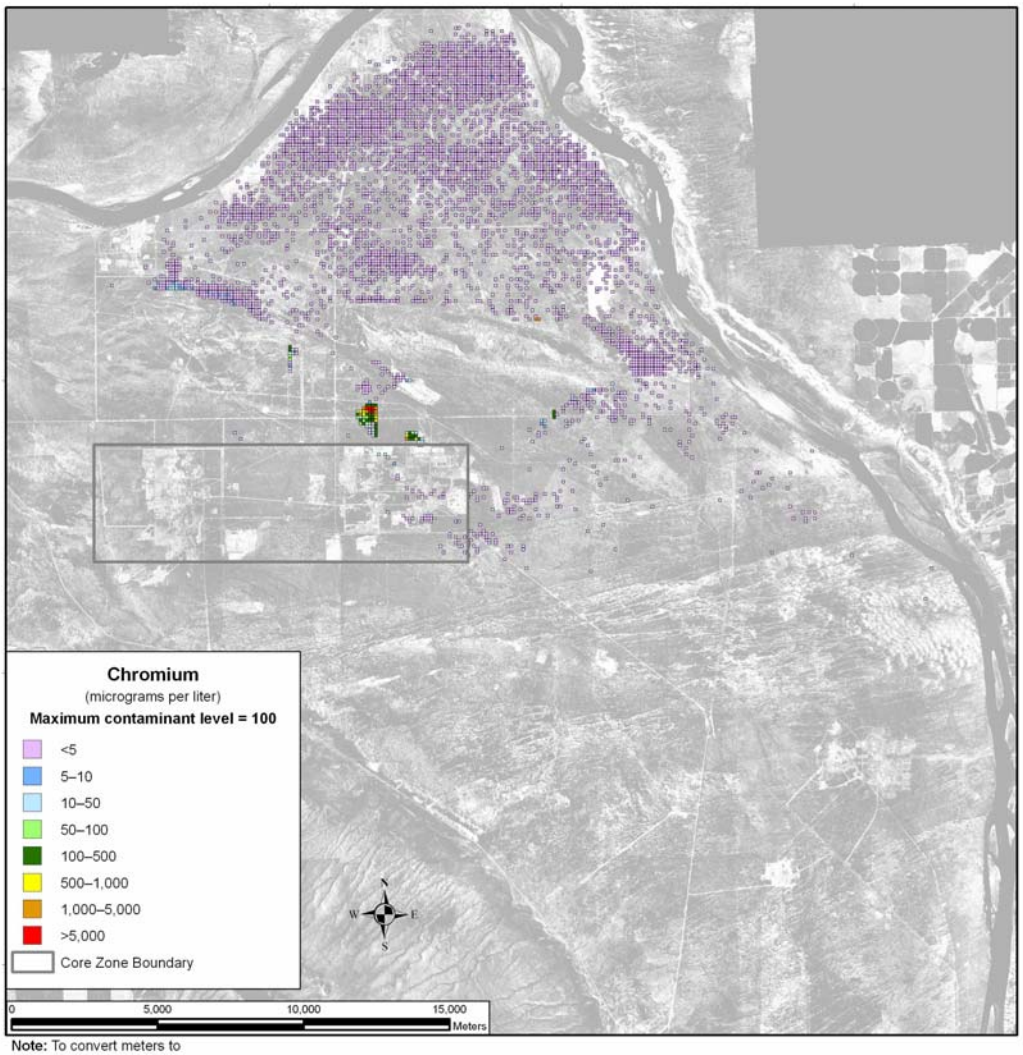
Note: To convert meters to feet, multiply by 3.281

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

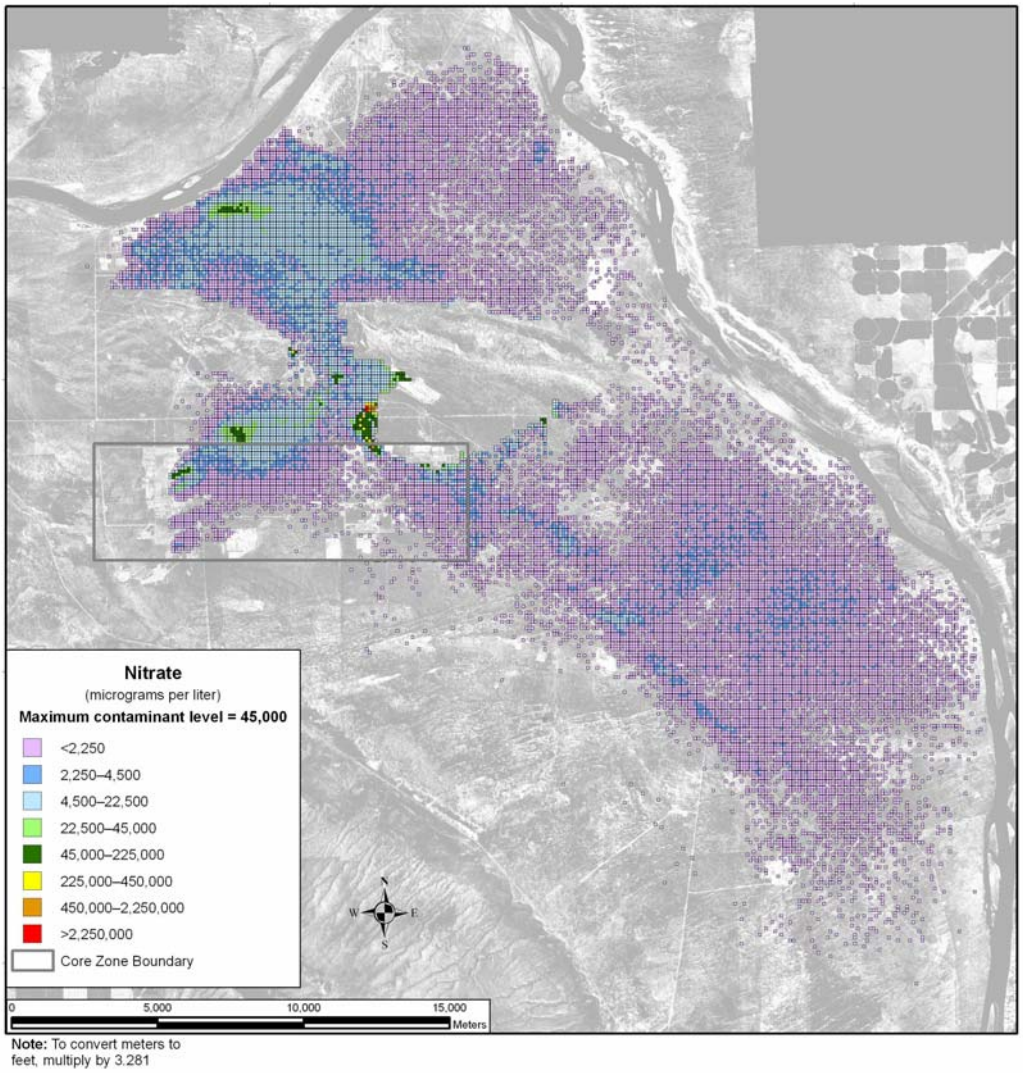
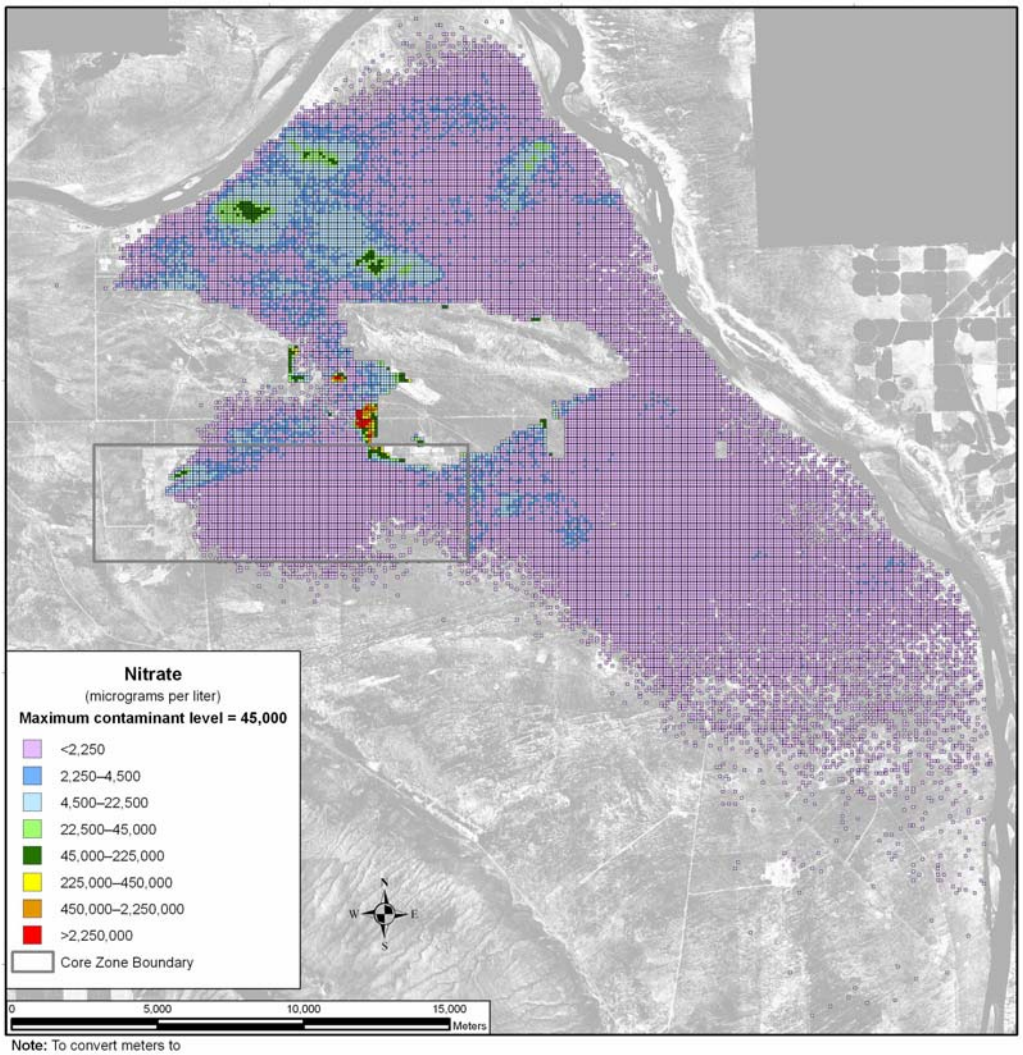
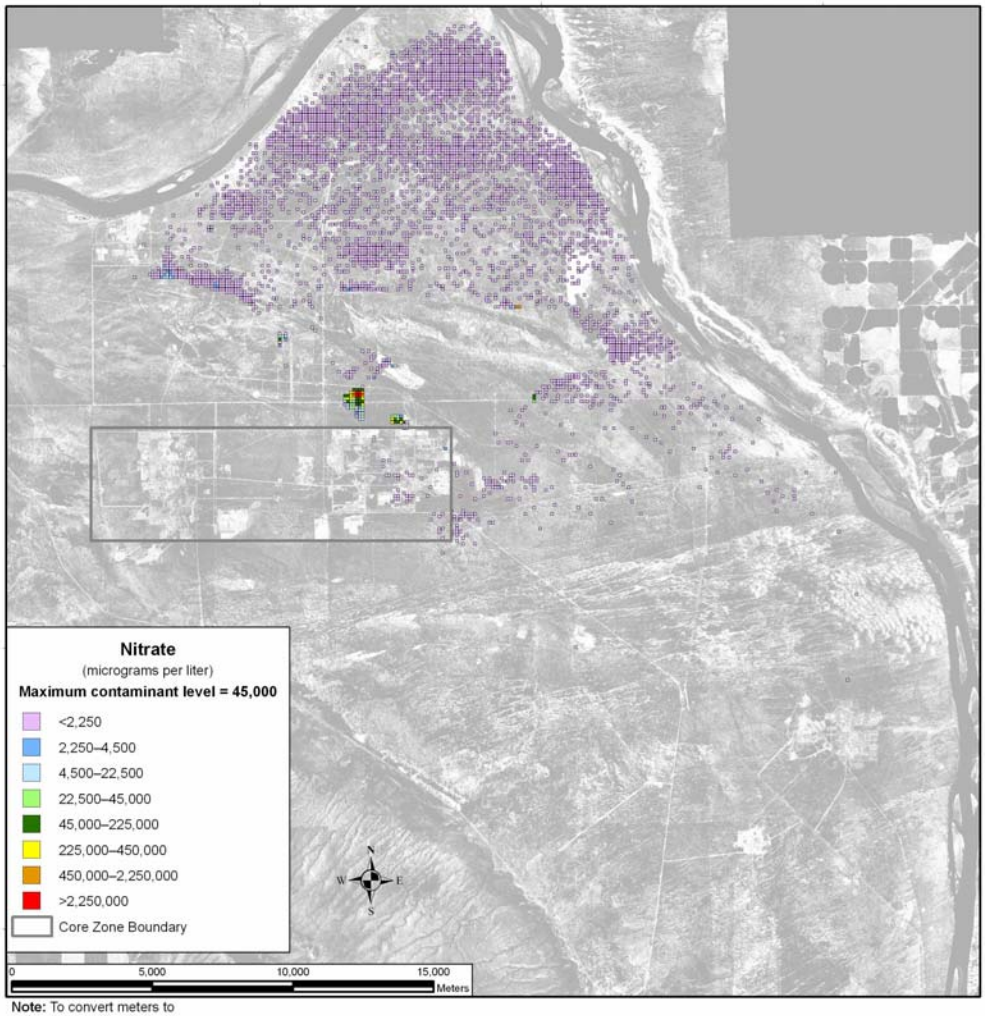


Figure 5–293. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2005



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).

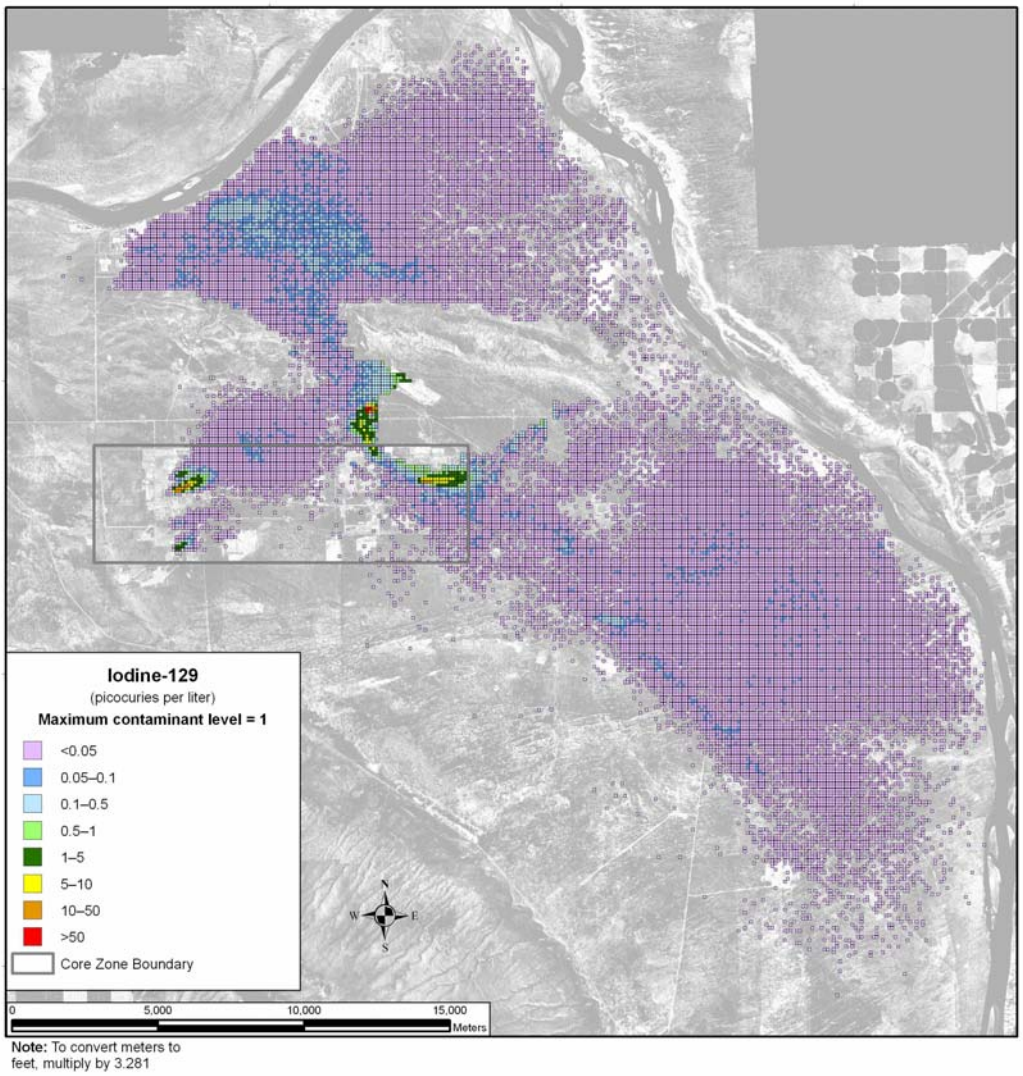
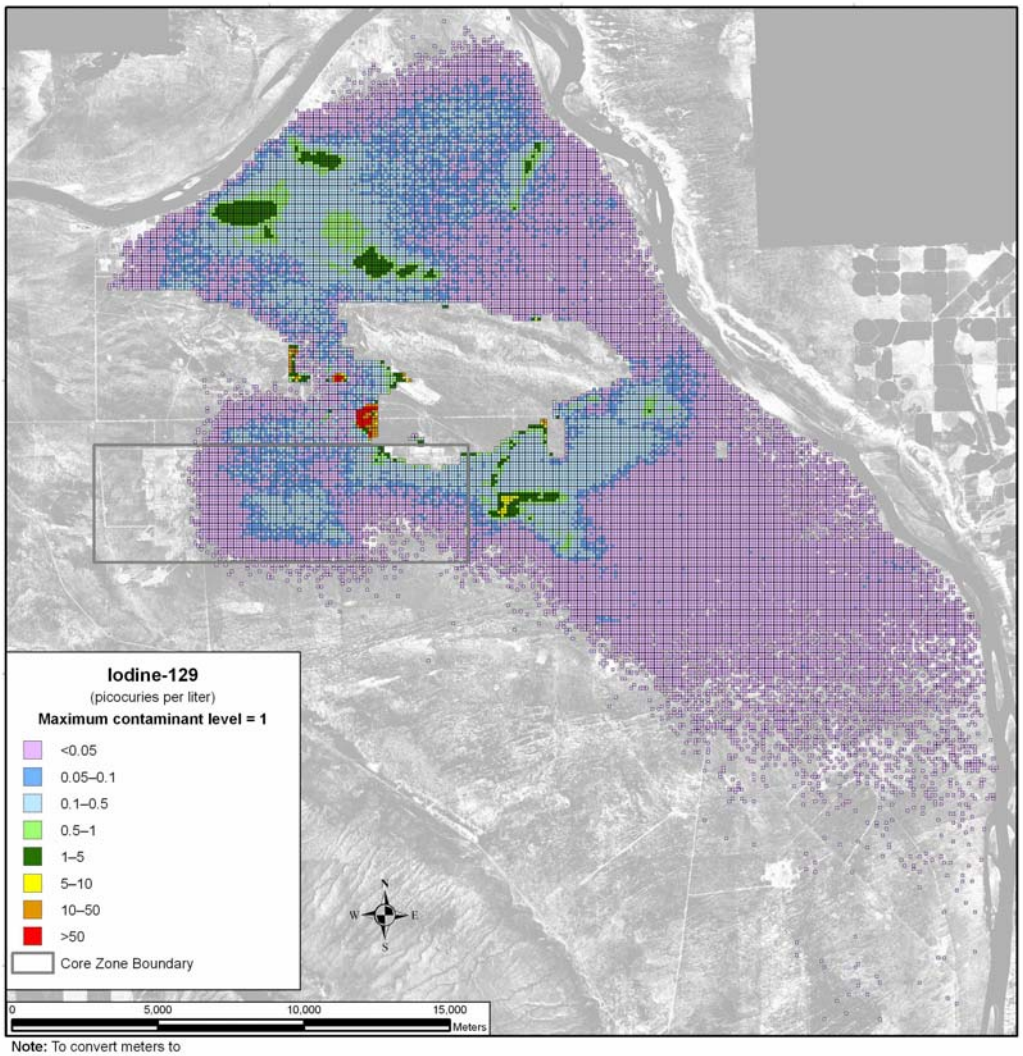
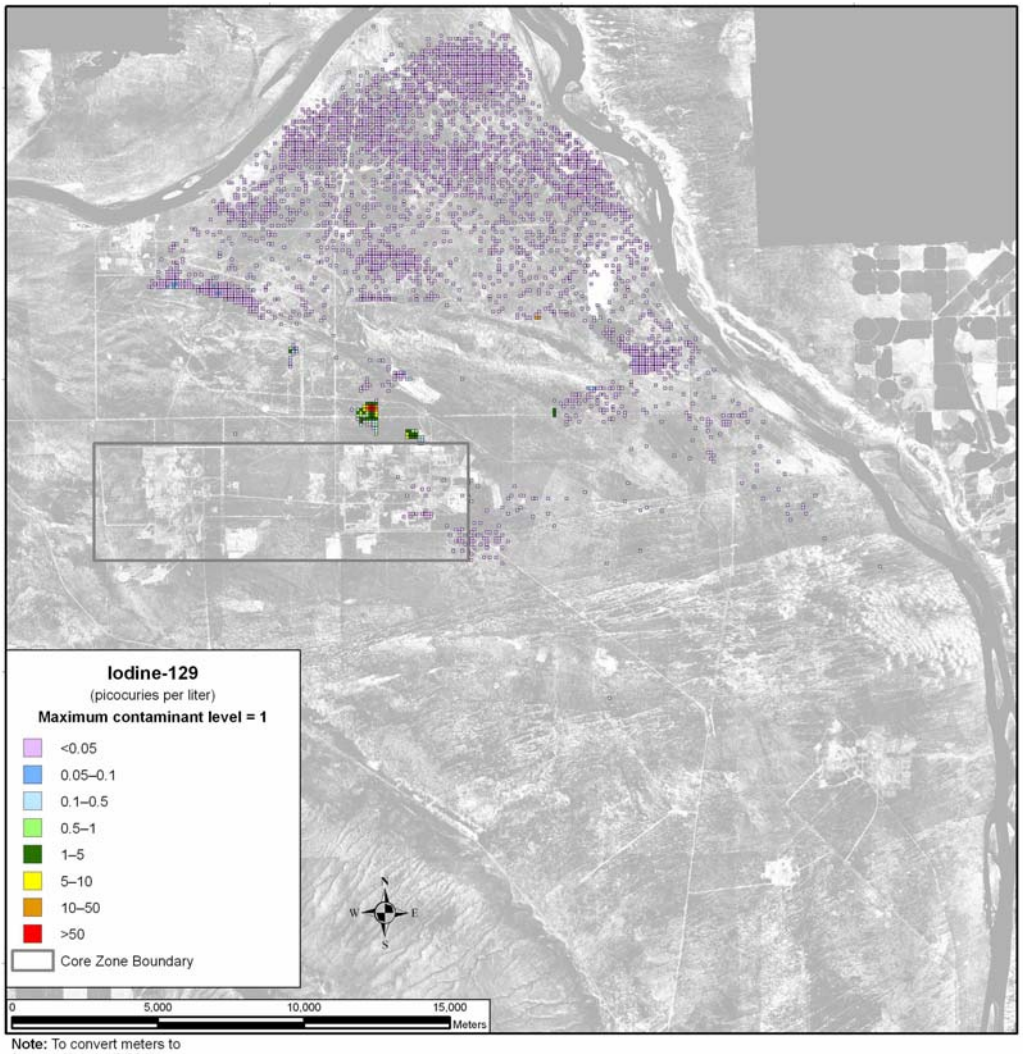


Figure 5–296. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2005



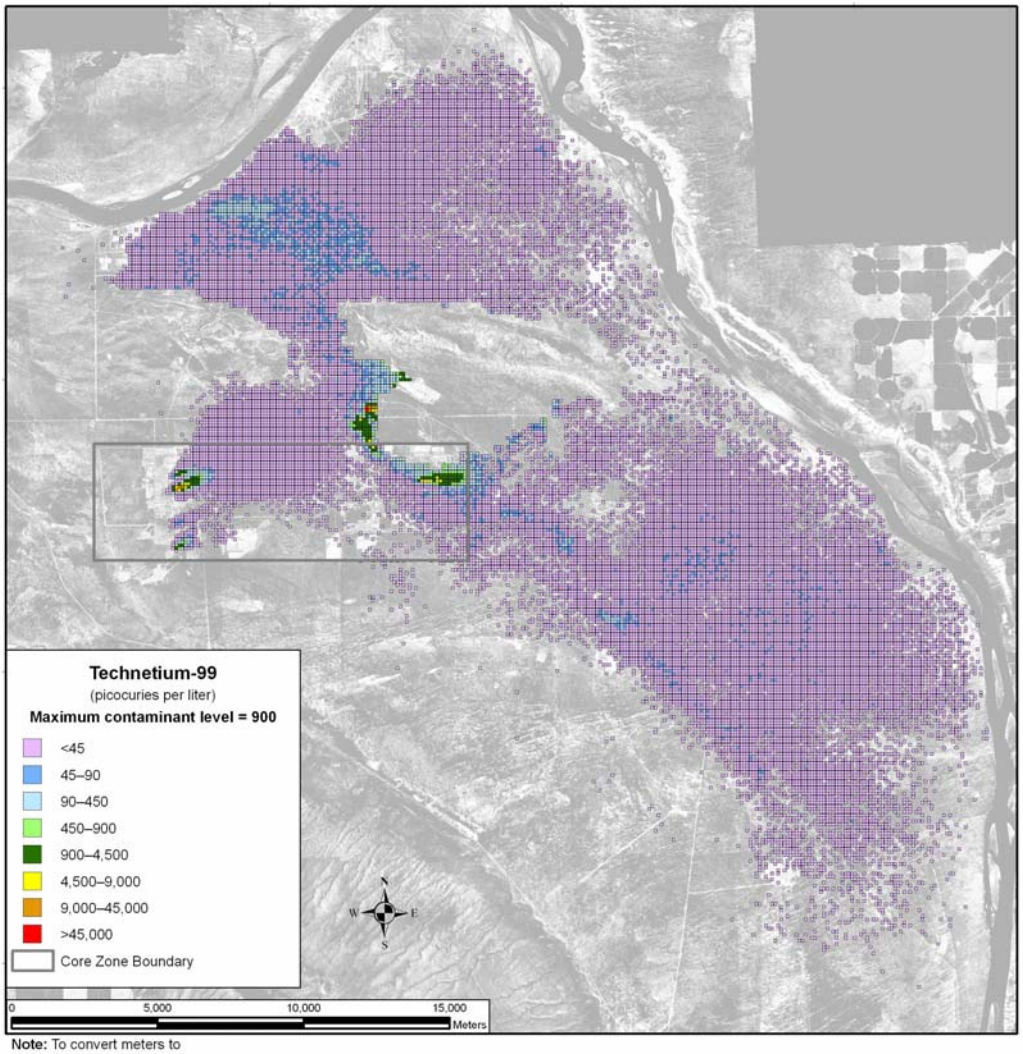
Note: To convert meters to feet, multiply by 3.281

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

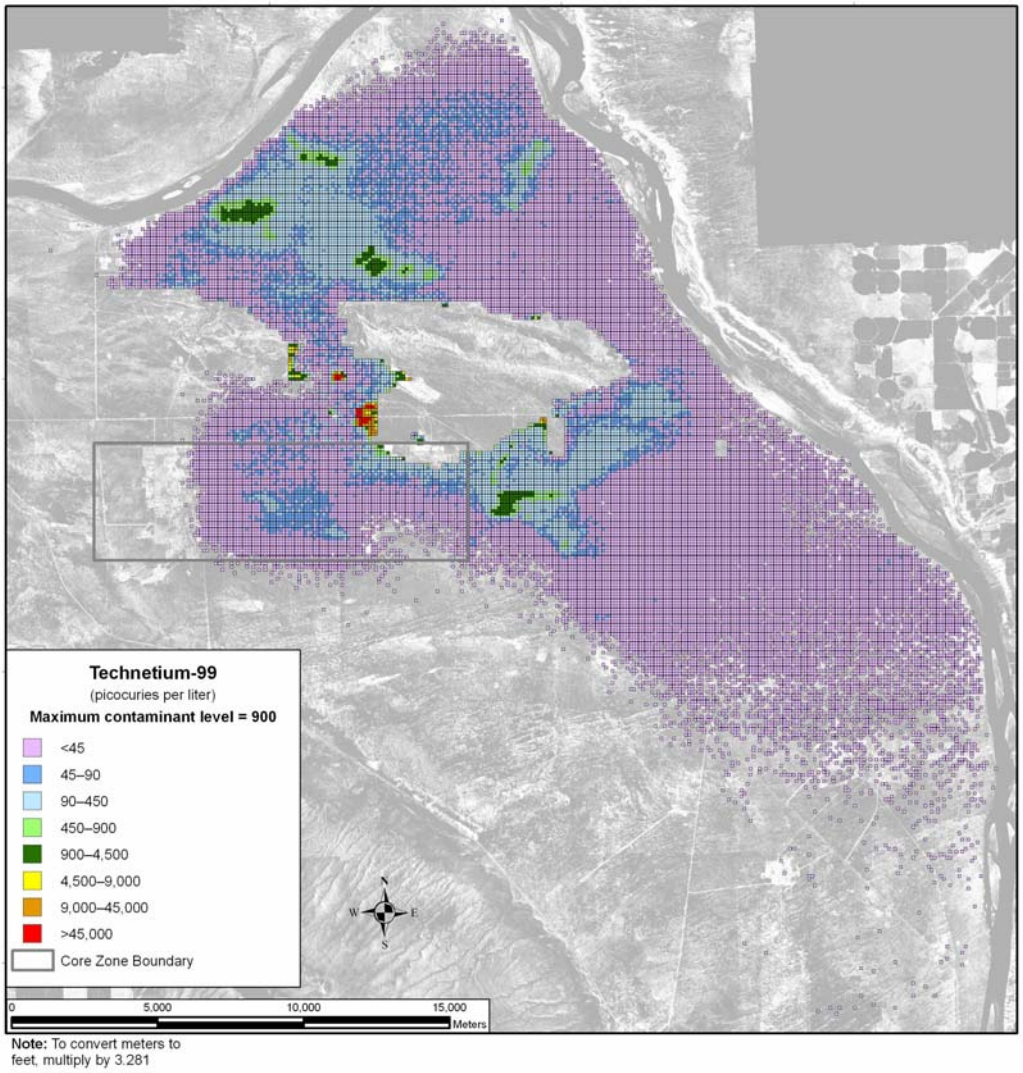
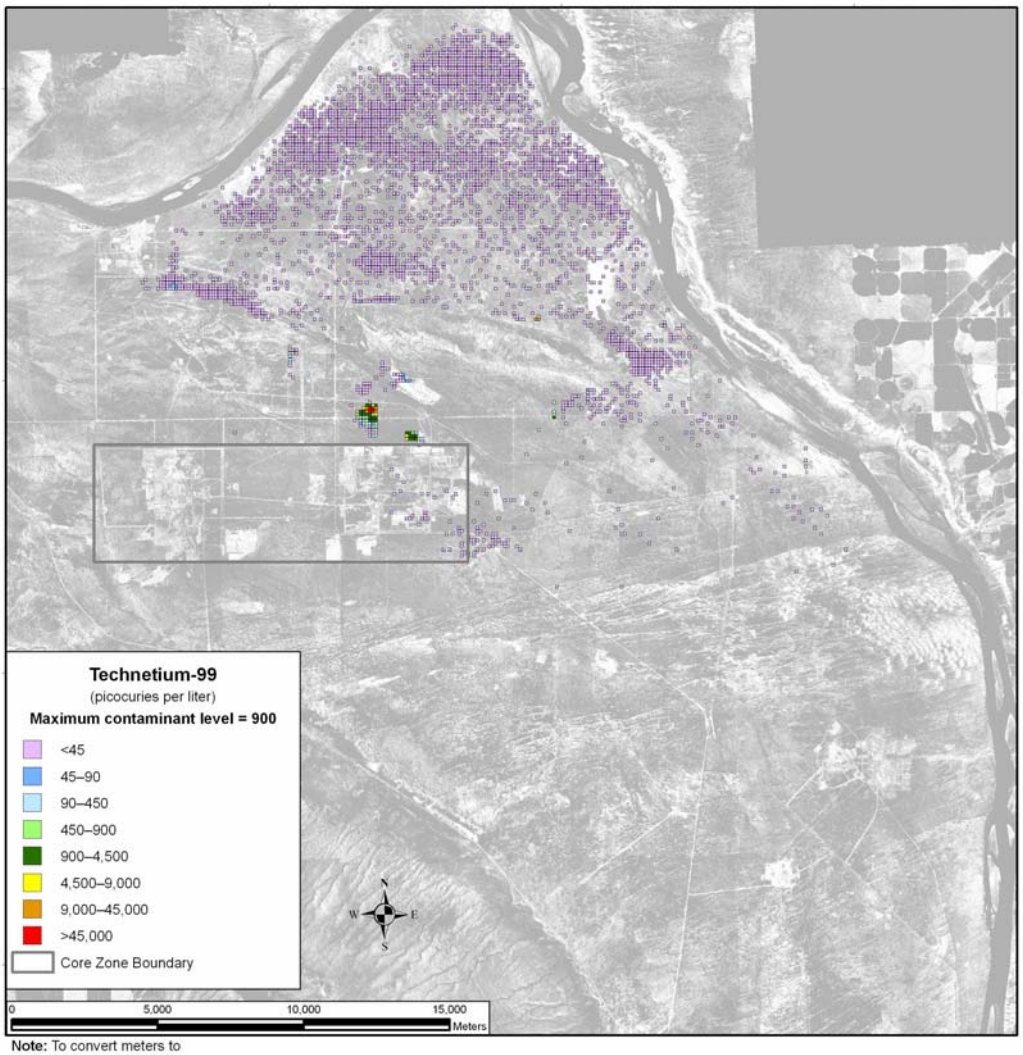


Figure 5–300. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2135



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

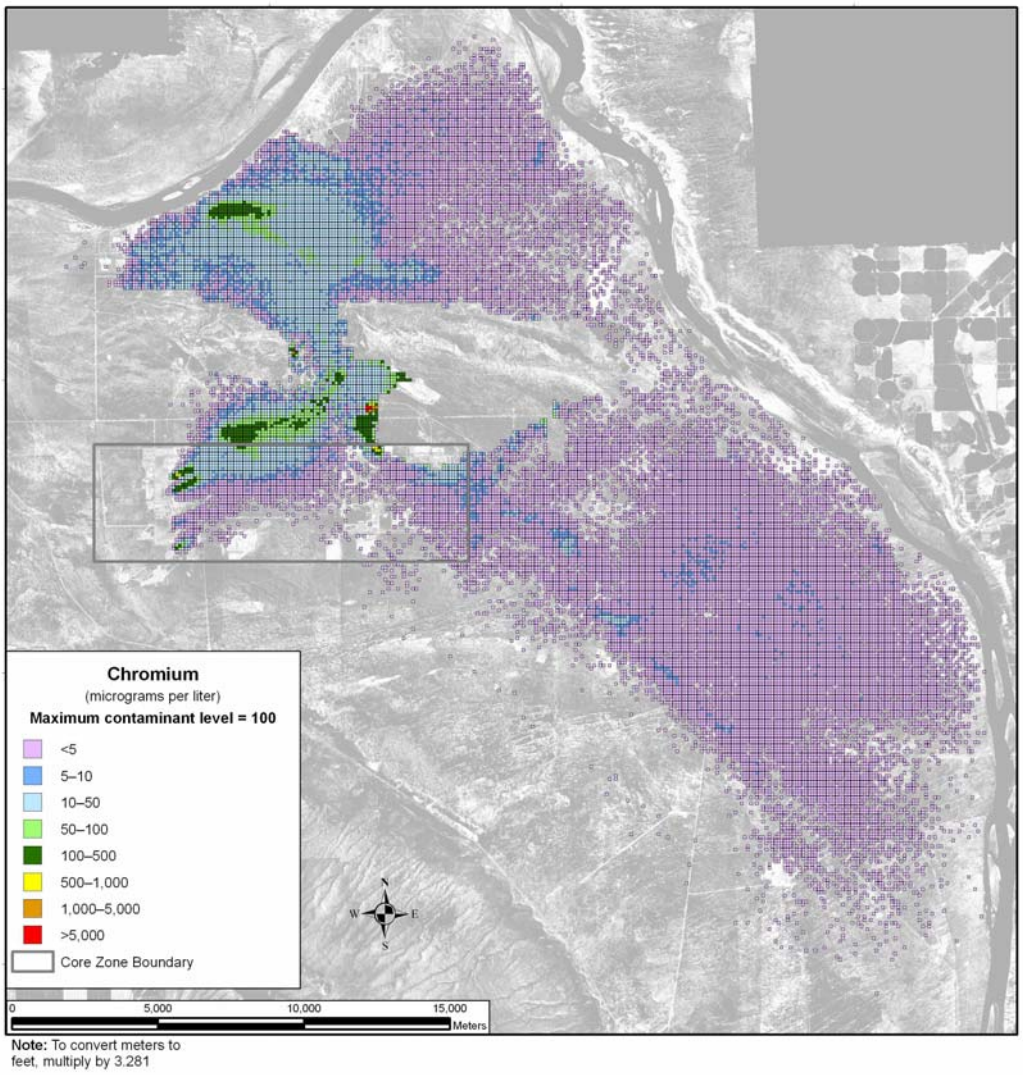
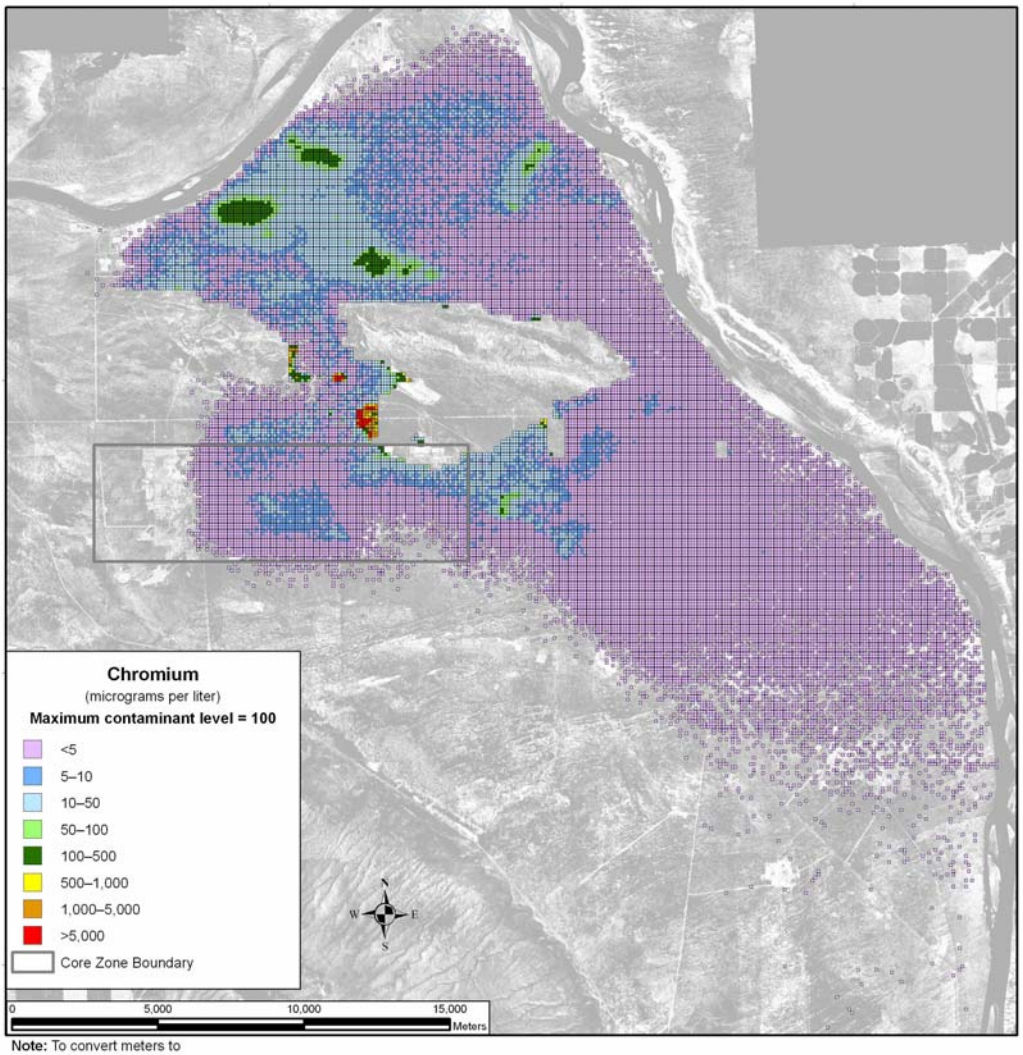
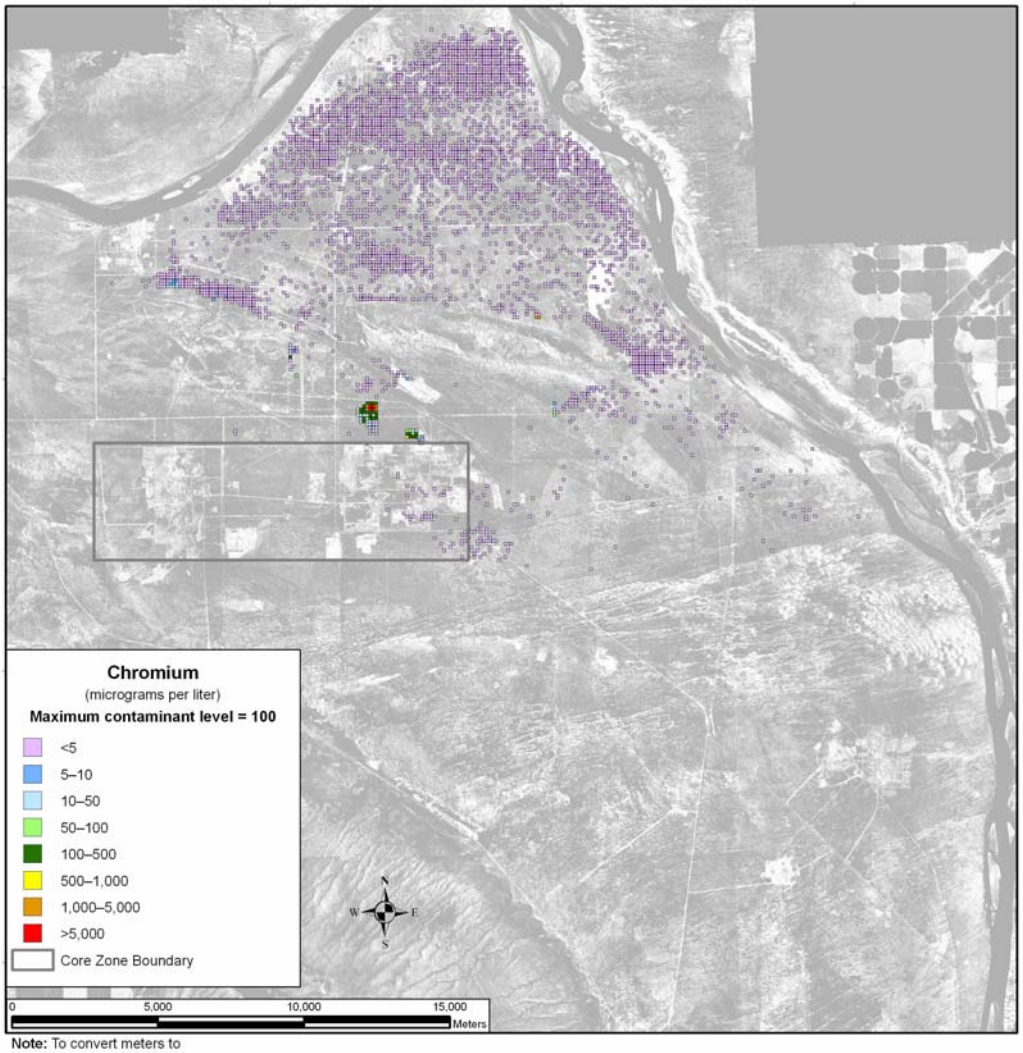


Figure 5–302. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 2005



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

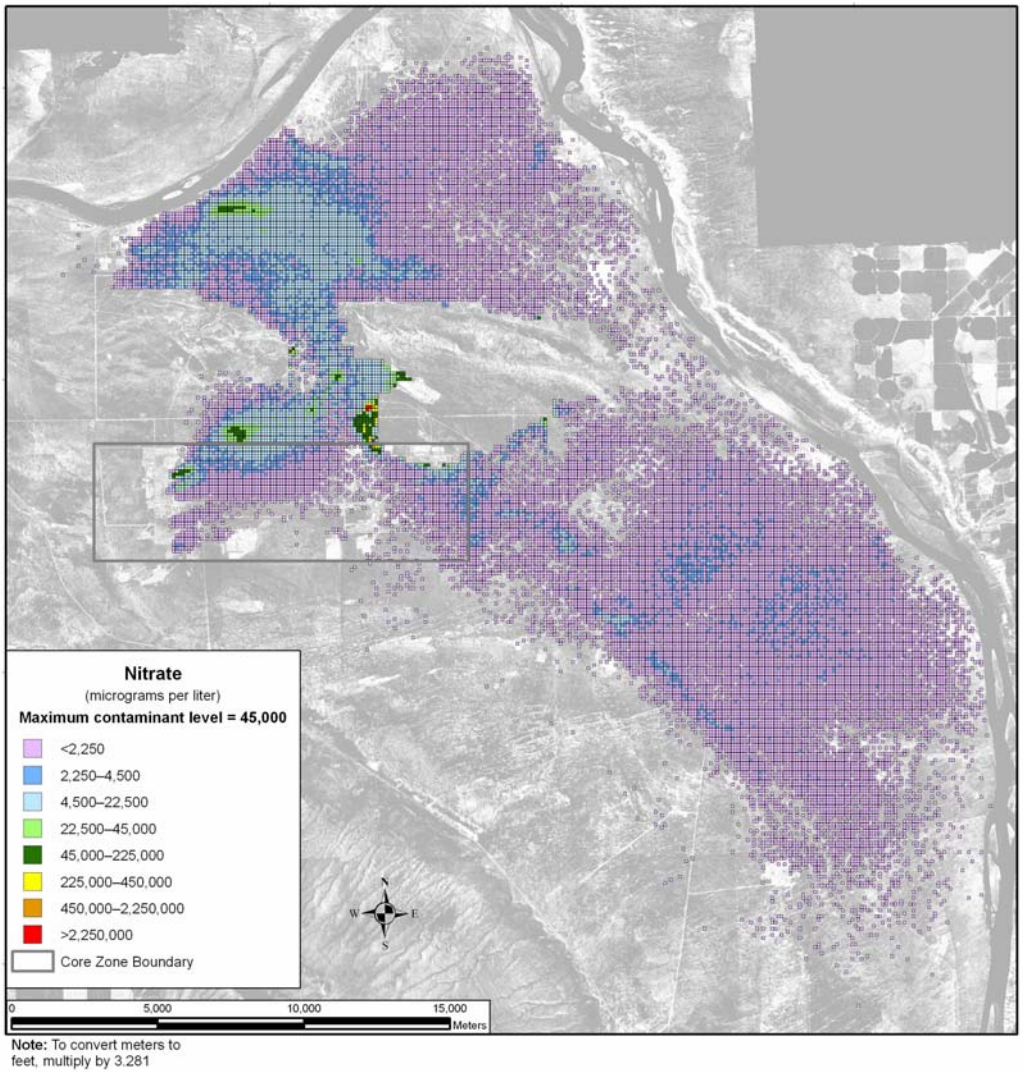
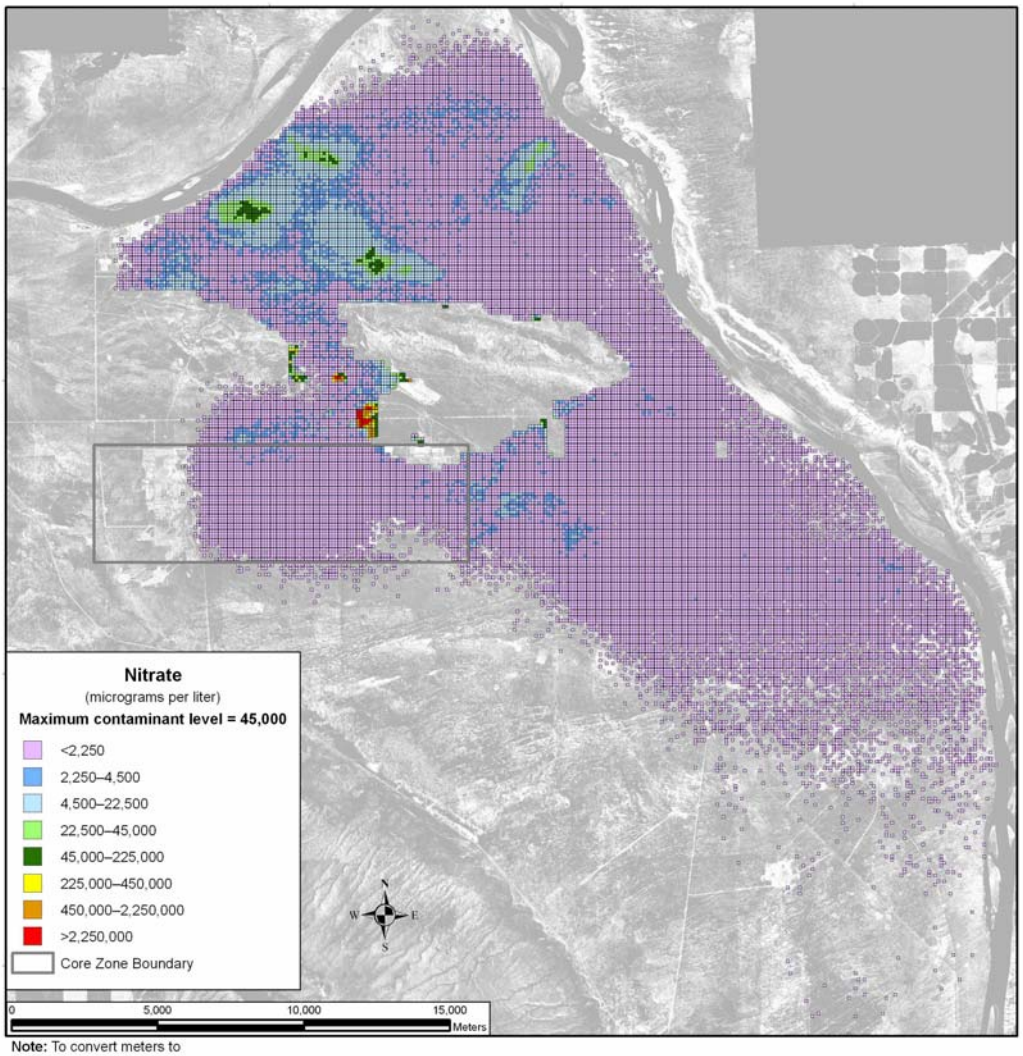
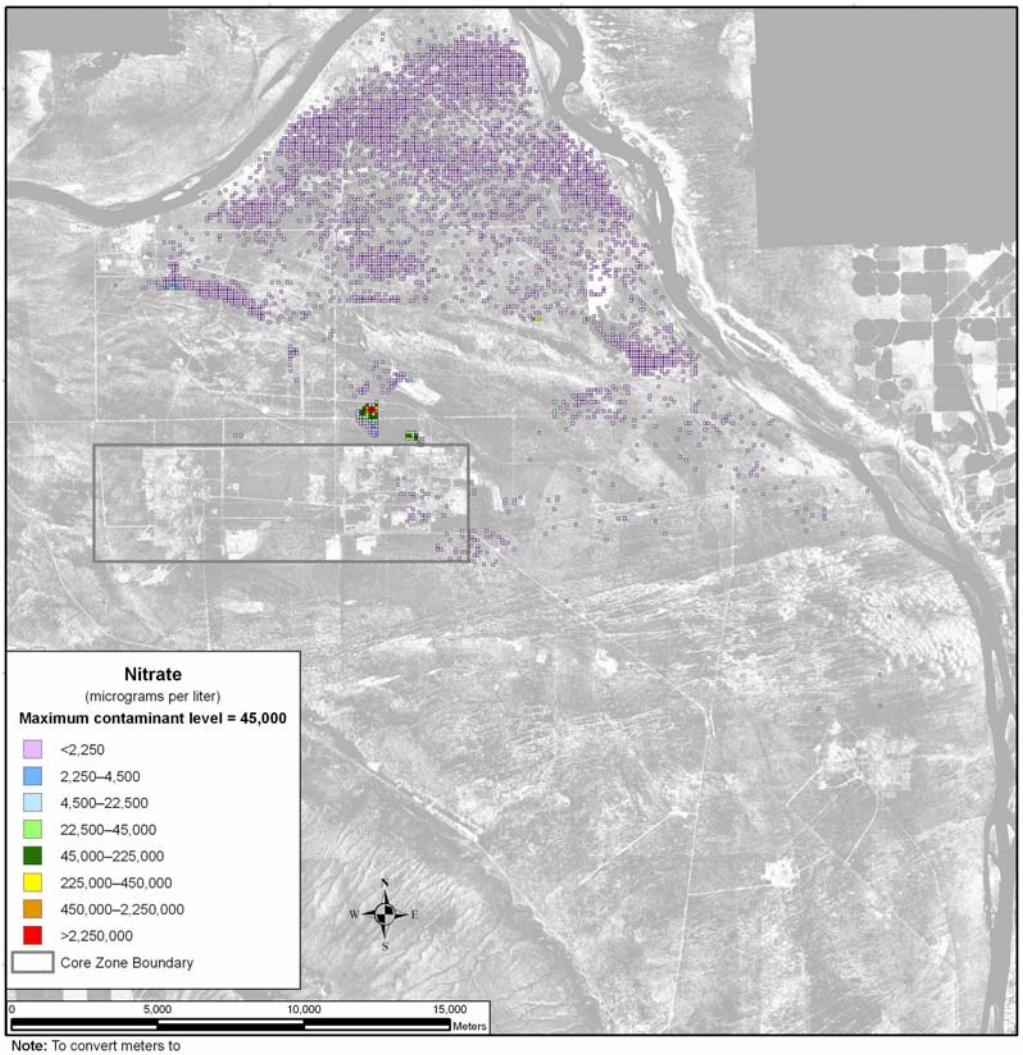


Figure 5–305. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

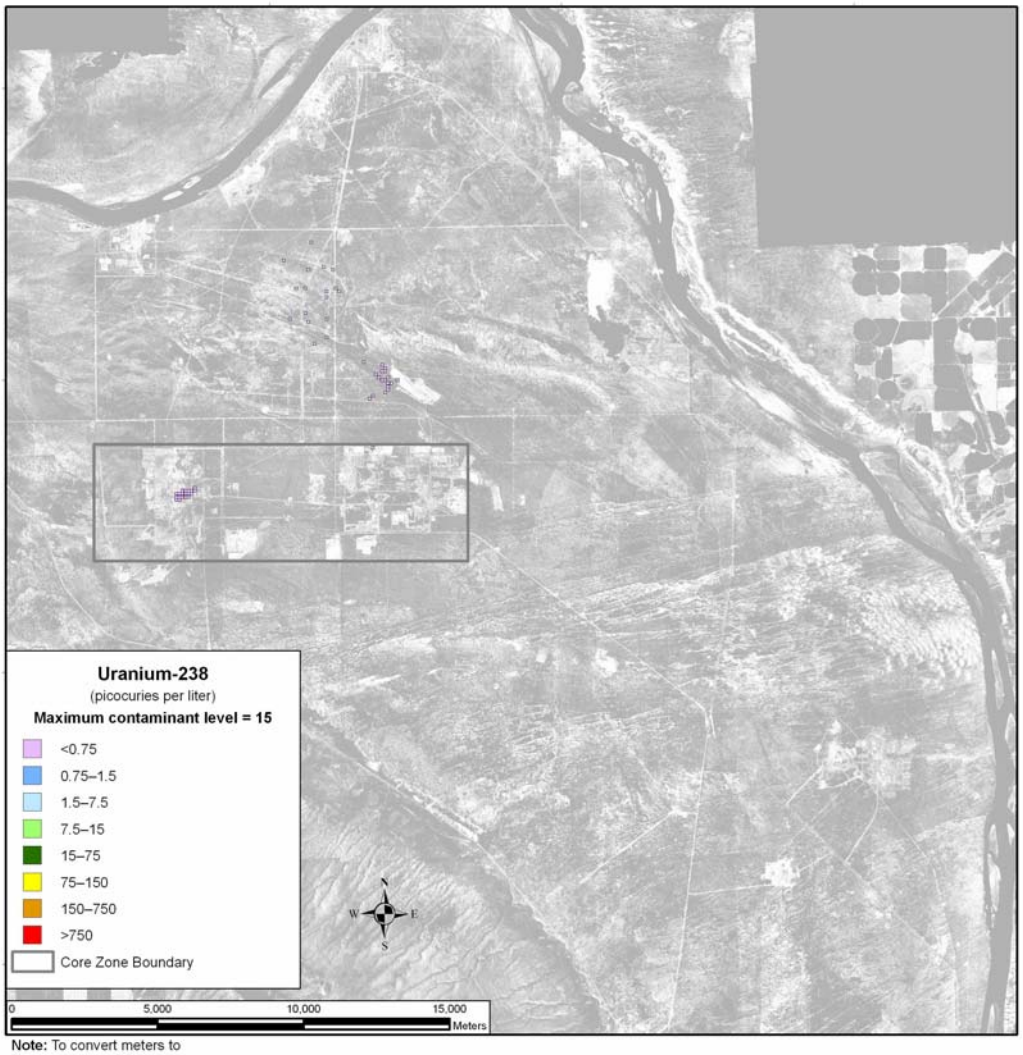
Figure 5–306. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281

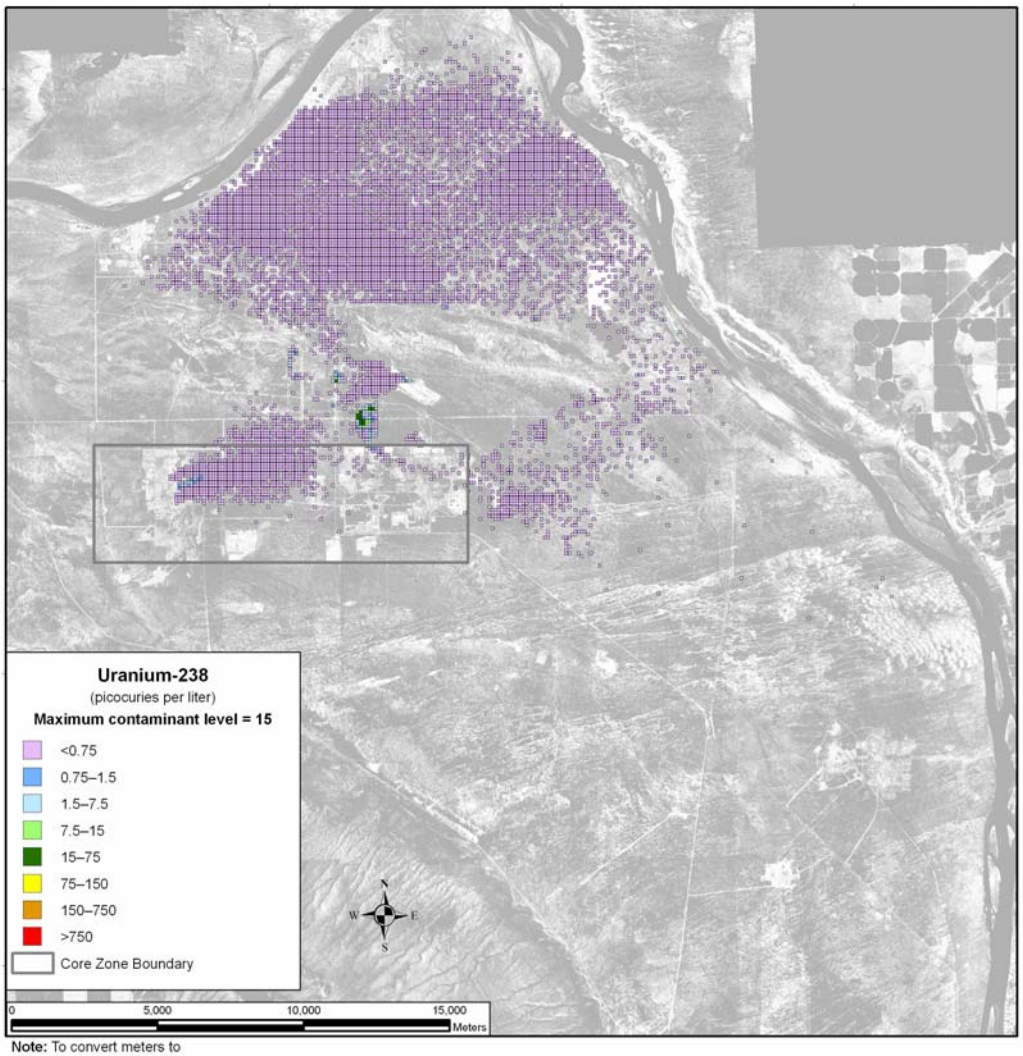
Figure 5–307. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 7140

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.



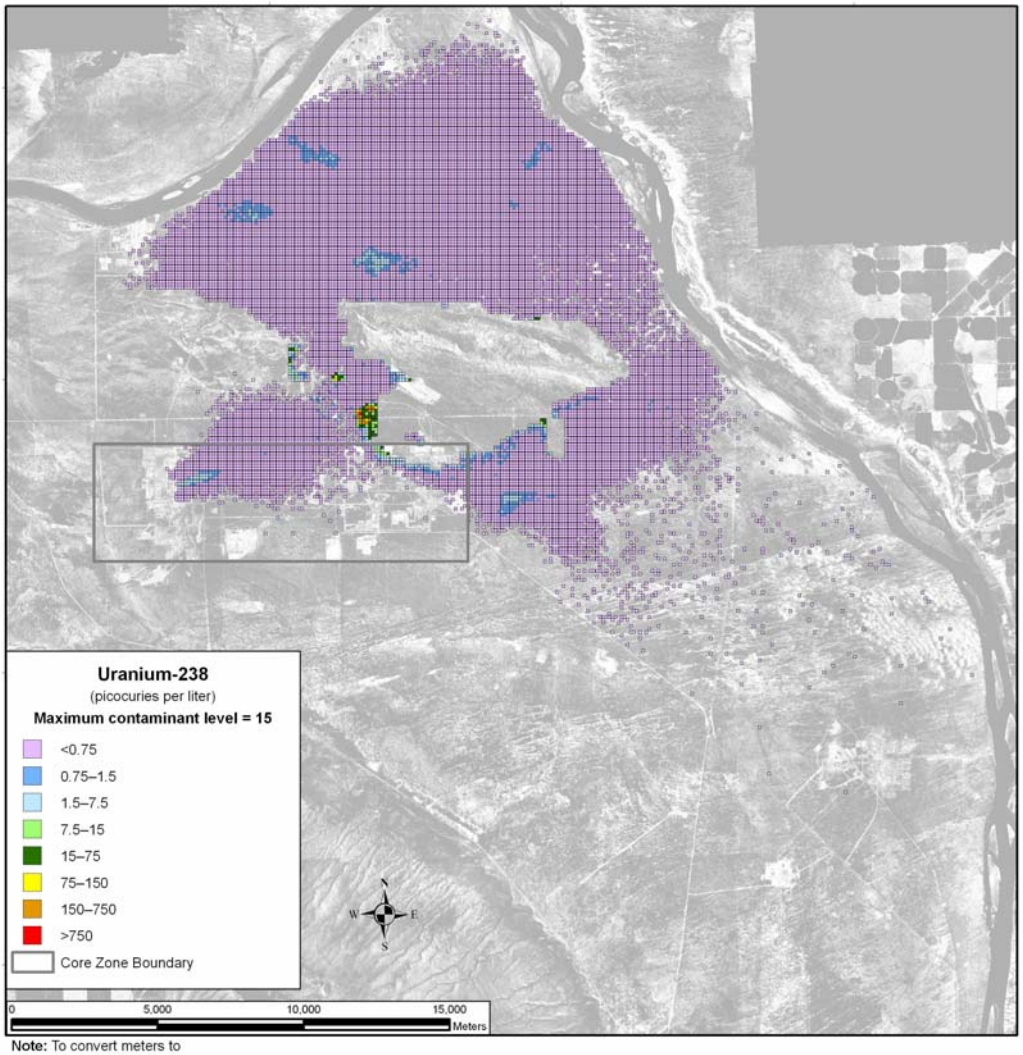
Note: To convert meters to feet, multiply by 3.281

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



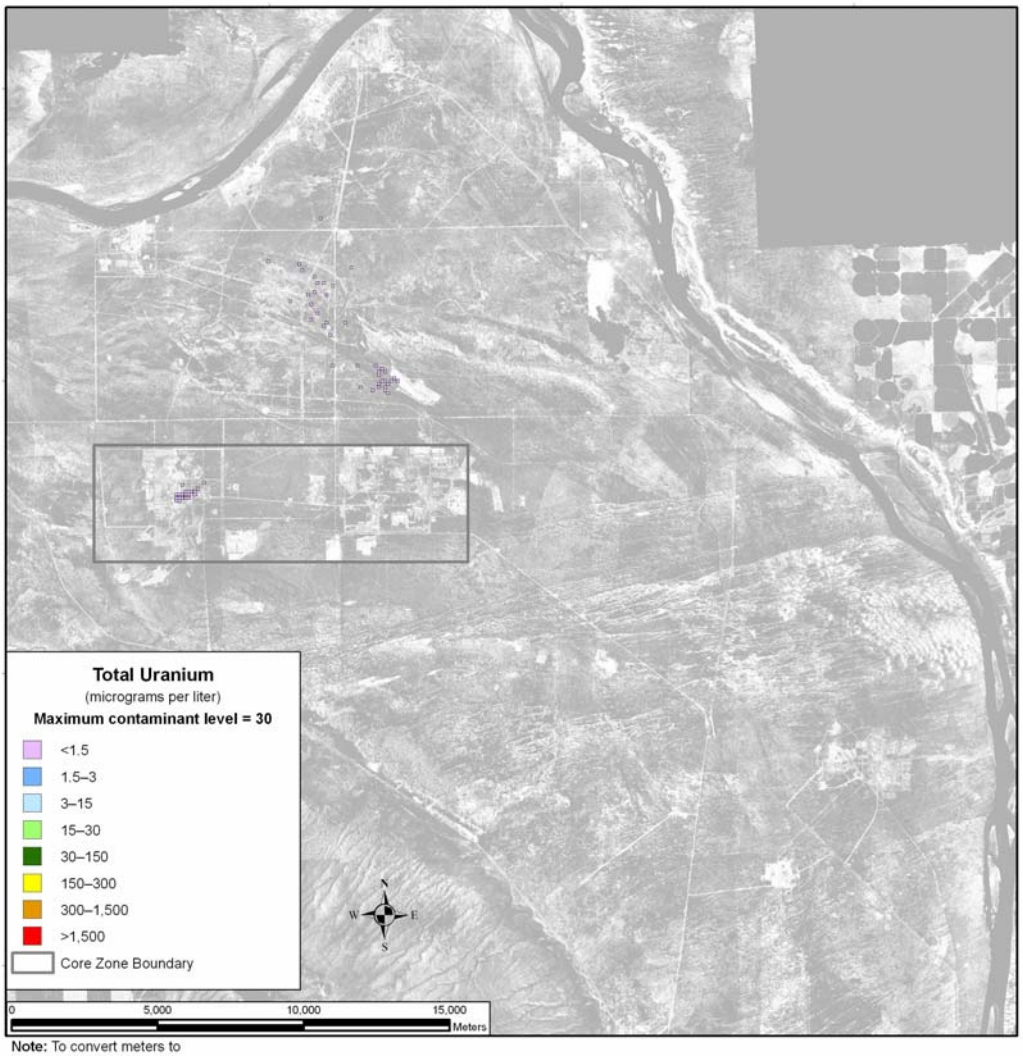
Note: To convert meters to feet, multiply by 3.281

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



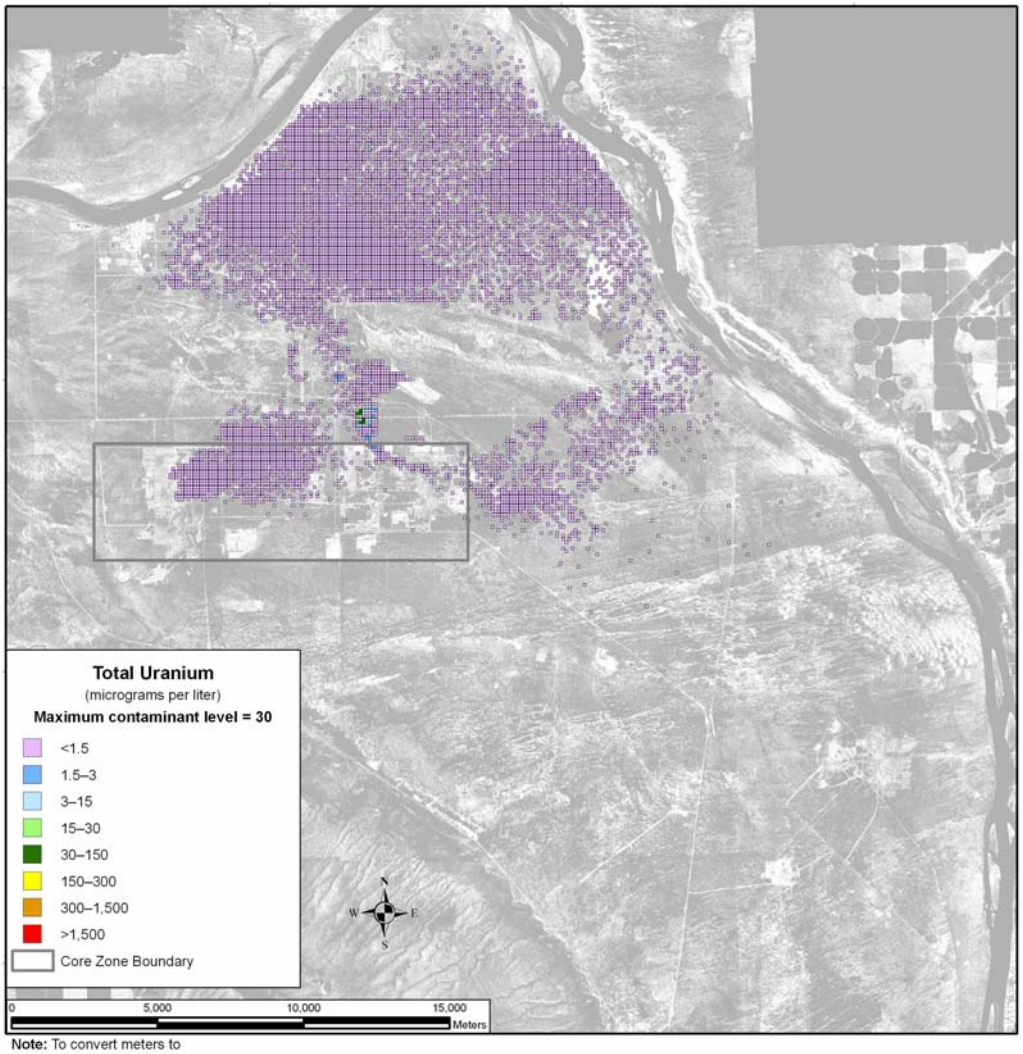
Note: To convert meters to feet, multiply by 3.281

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



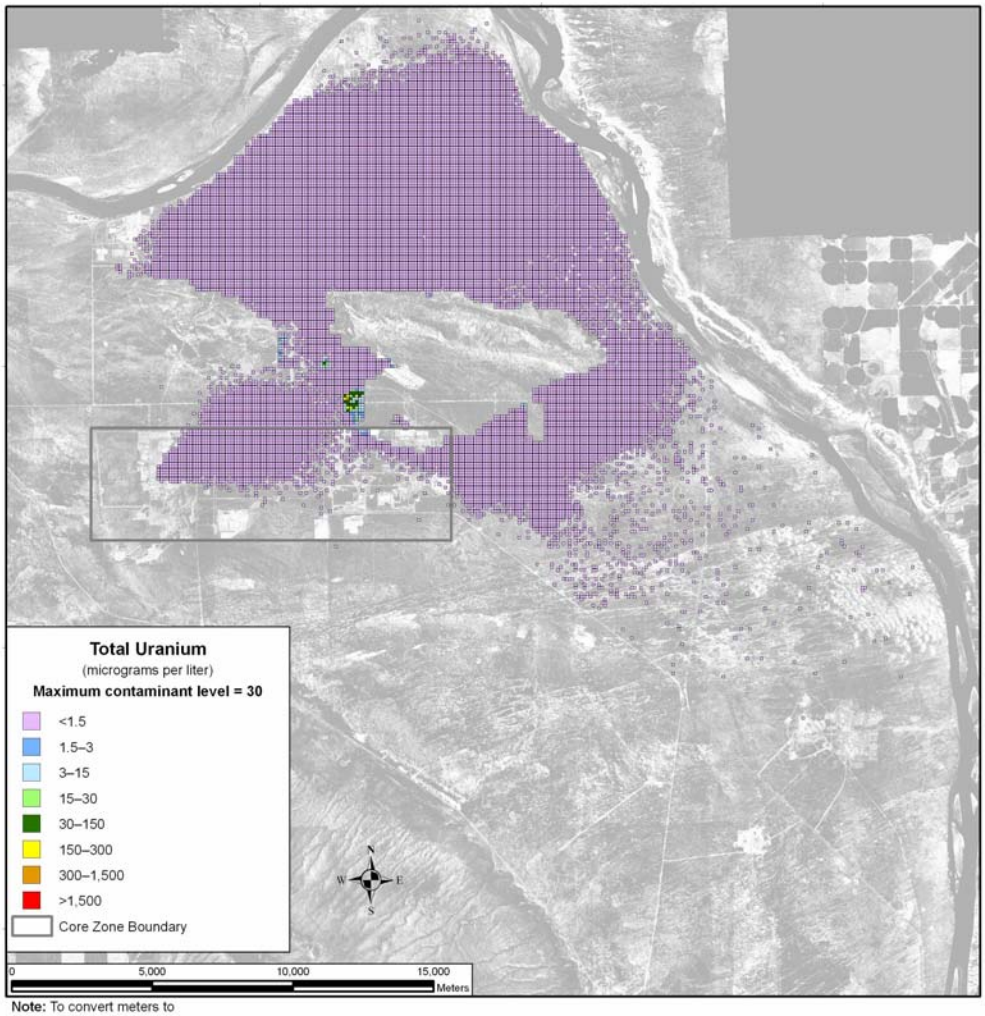
Note: To convert meters to feet, multiply by 3.281

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

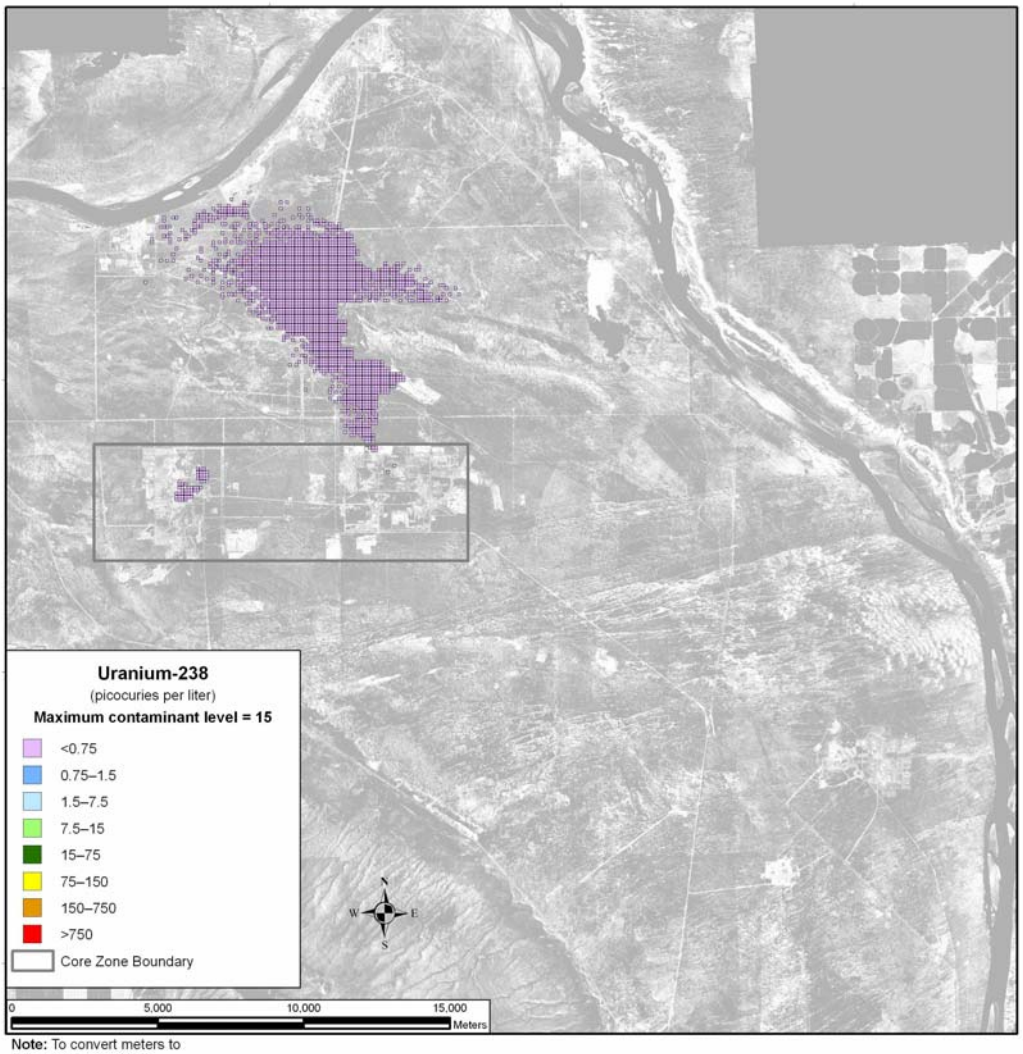
Figure 5–312. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281

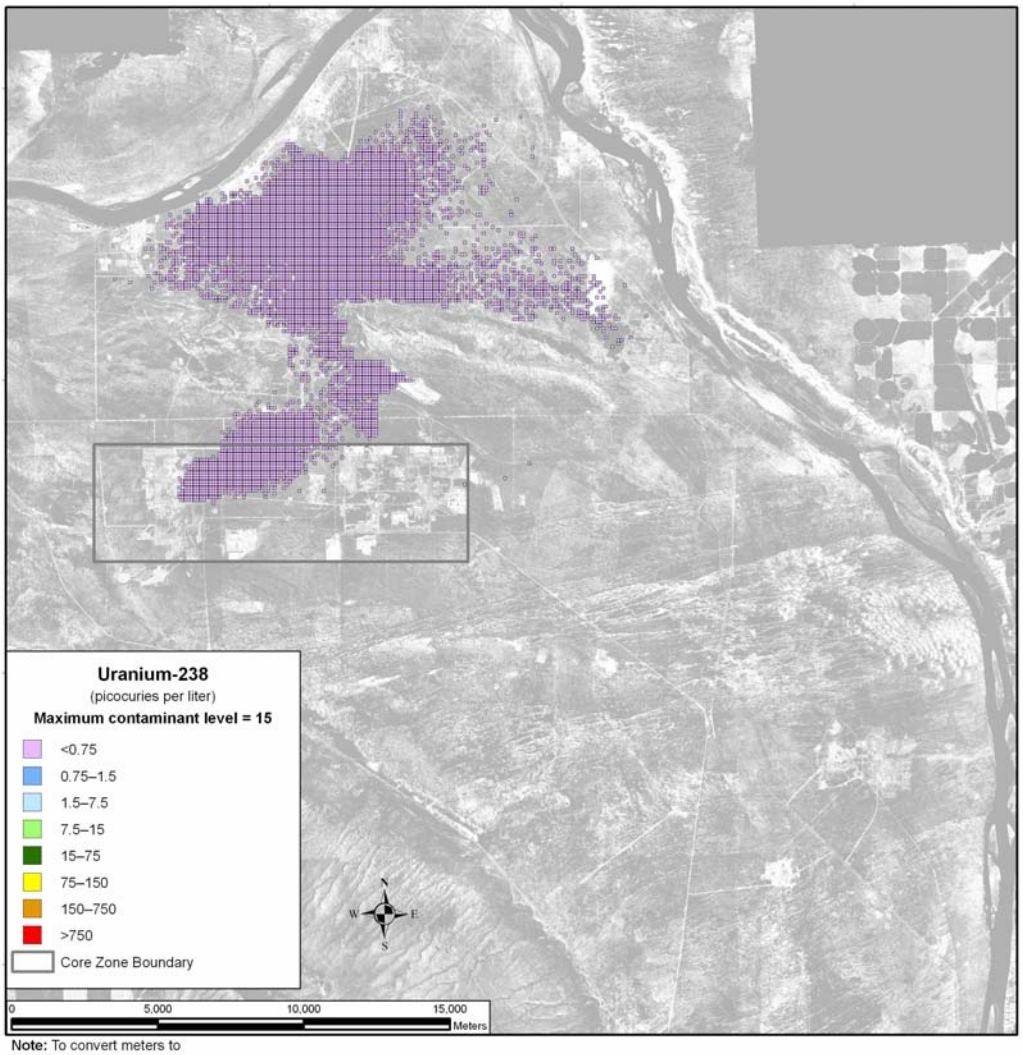
Figure 5–313. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 11,885

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.



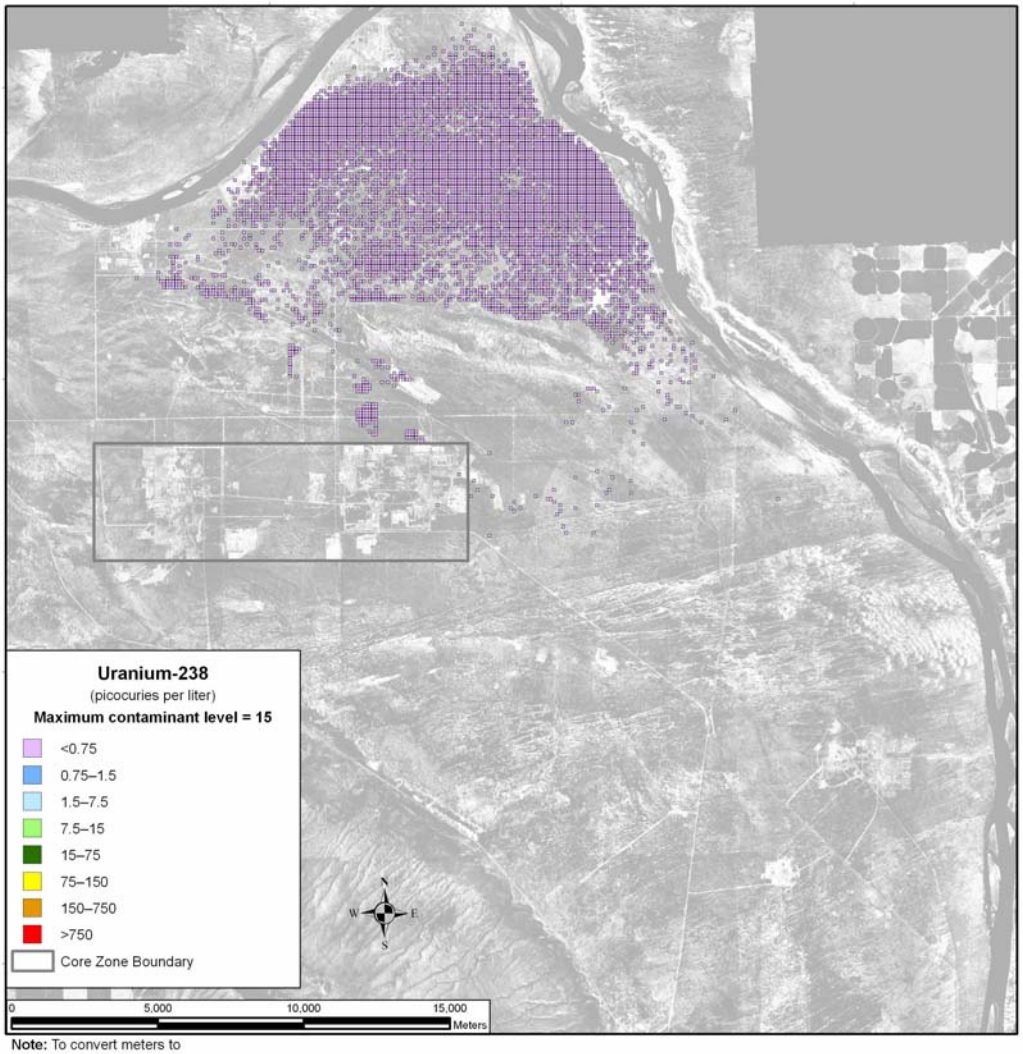
Note: To convert meters to feet, multiply by 3.281

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



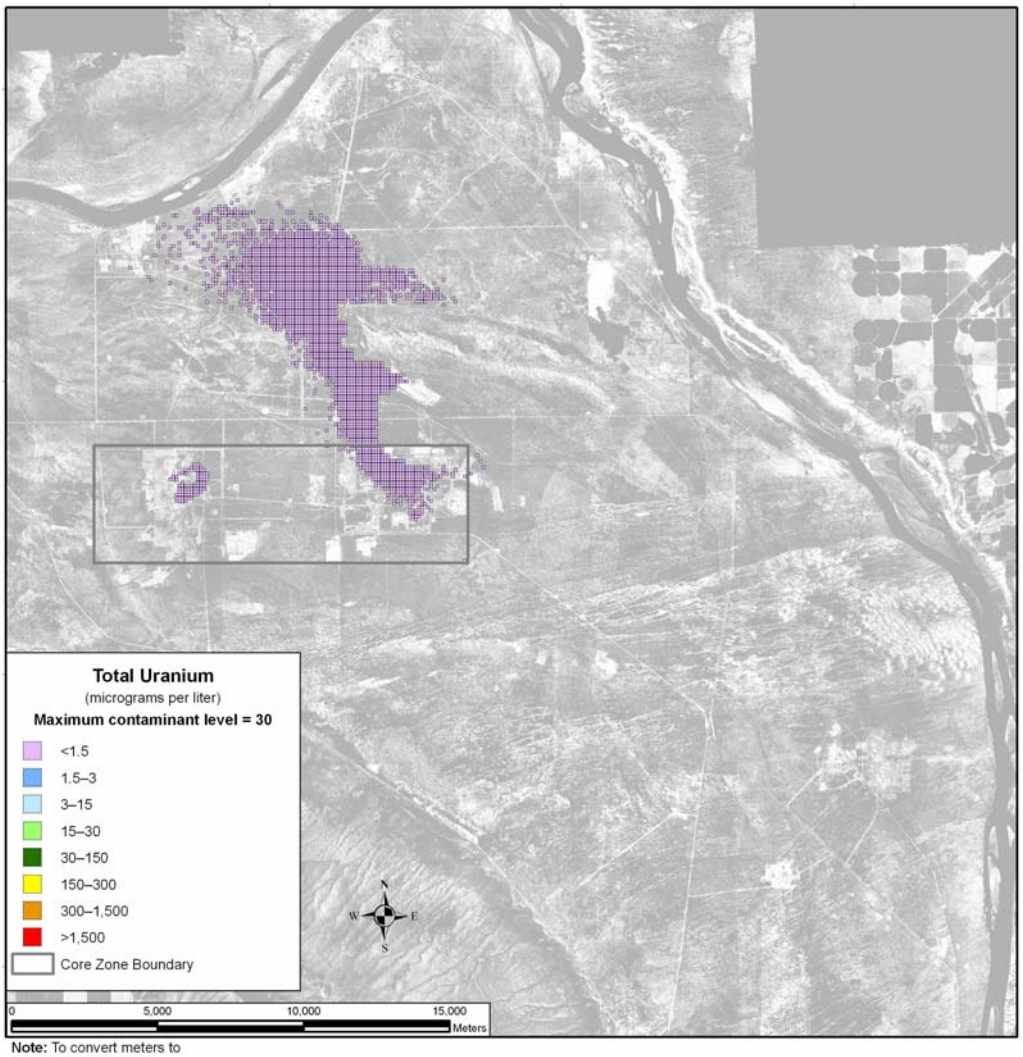
Note: To convert meters to feet, multiply by 3.281

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



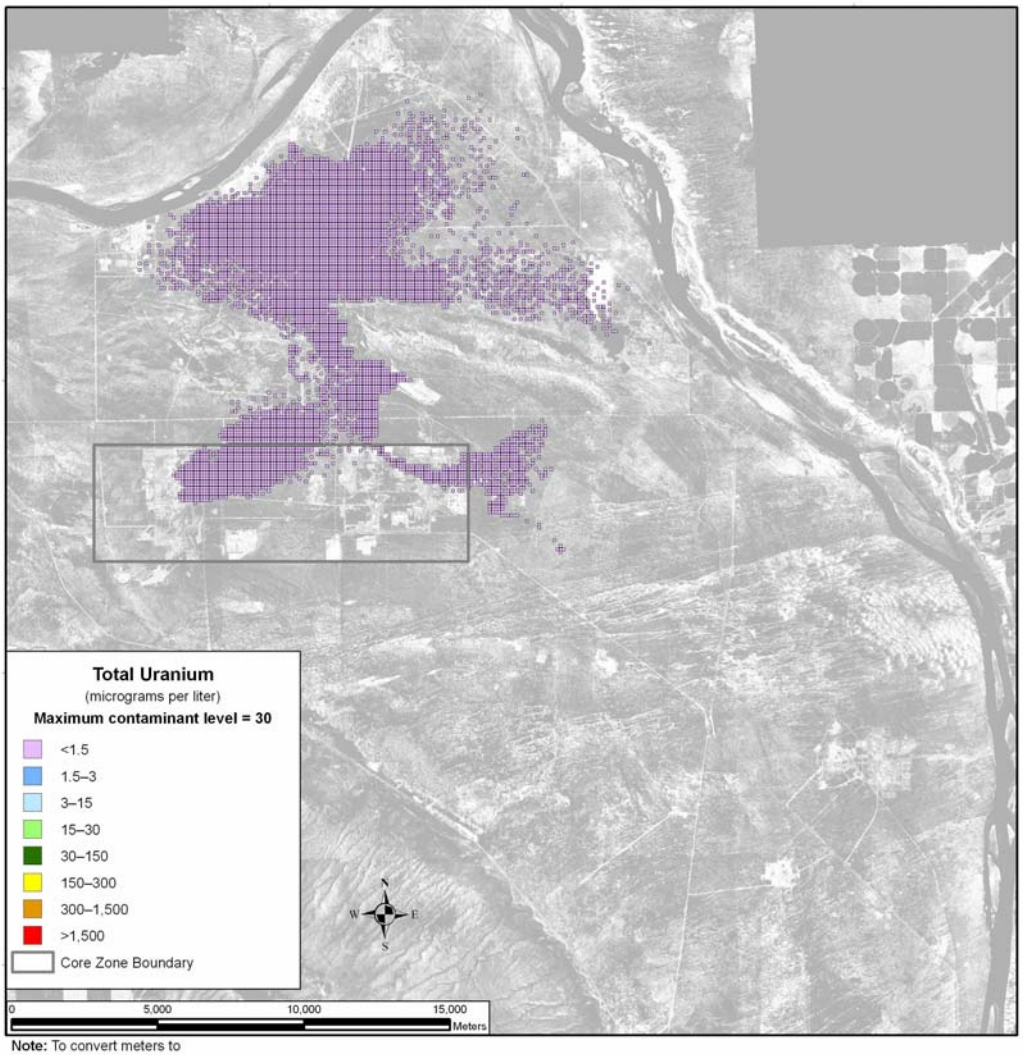
Note: To convert meters to feet, multiply by 3.281

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

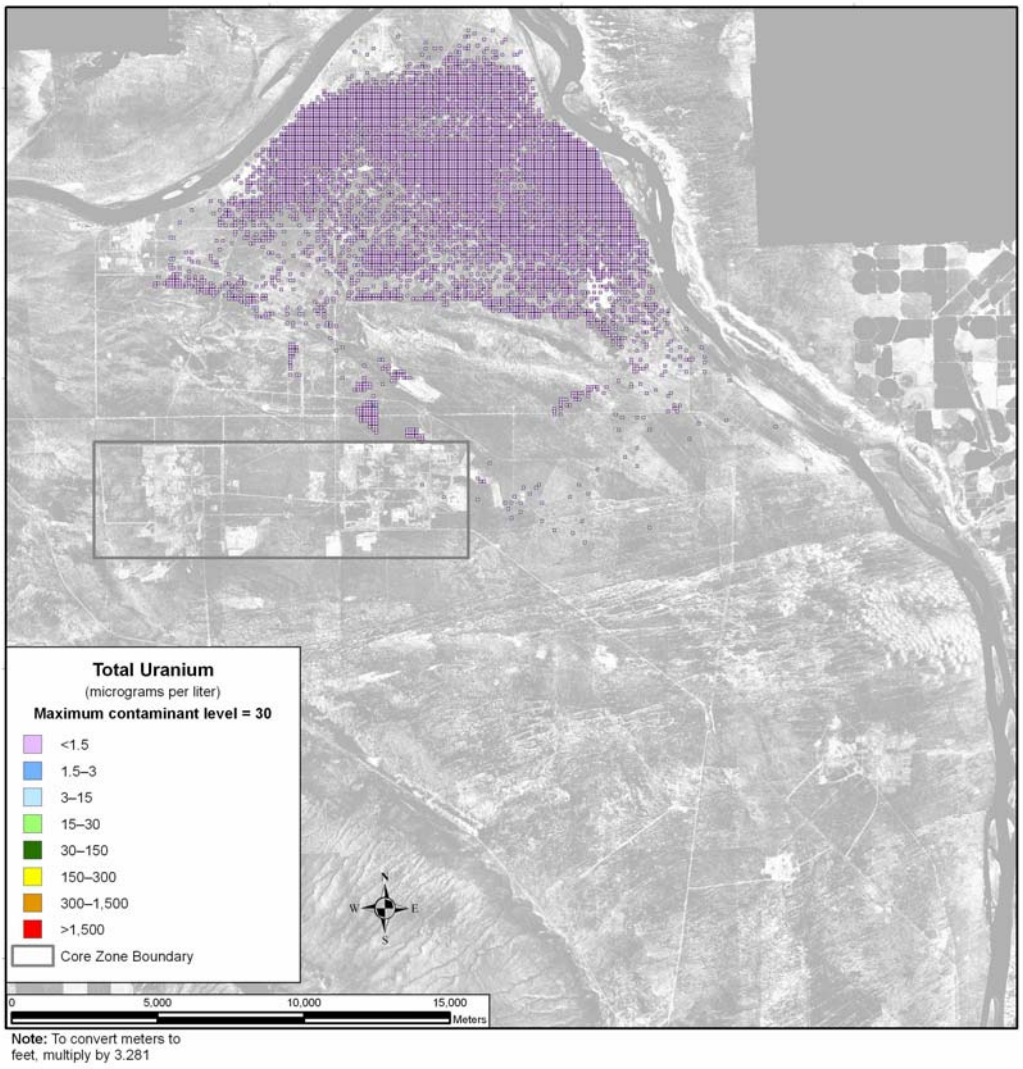


Figure 5–319. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 11,885

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.

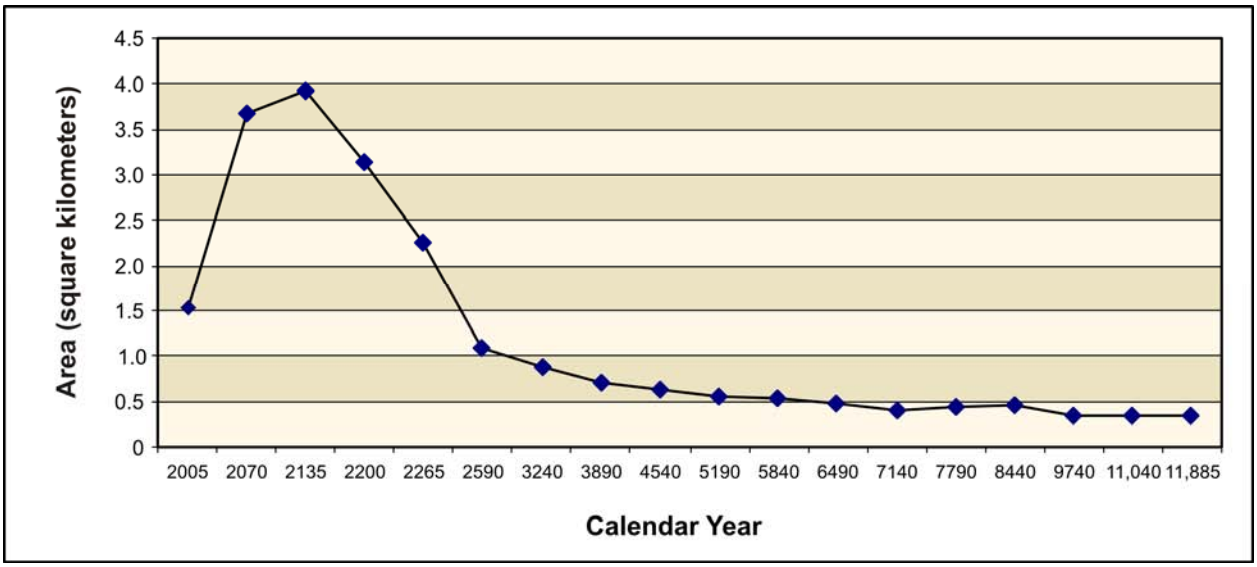


Figure 5–320. Tank Closure Alternative 6B, Base Case, Total Area of Groundwater Technetium-99 Concentration Exceeding the Benchmark Concentration as a Function of Time

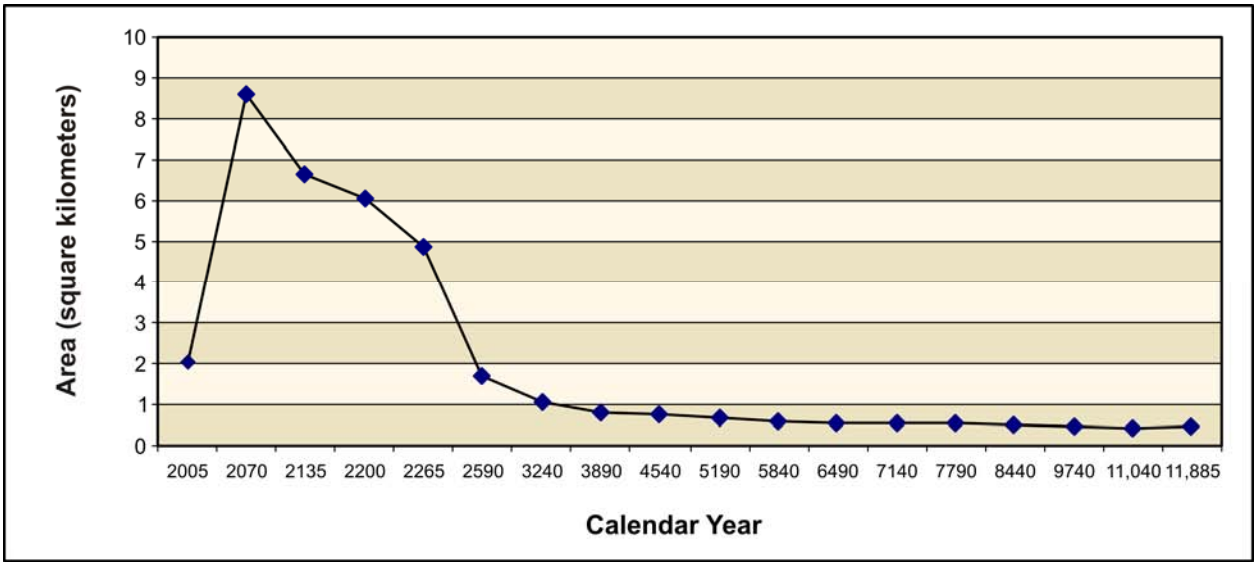


Figure 5–321. Tank Closure Alternative 6B, Base Case, Total Area of Groundwater Iodine-129 Concentration Exceeding the Benchmark Concentration as a Function of Time

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).

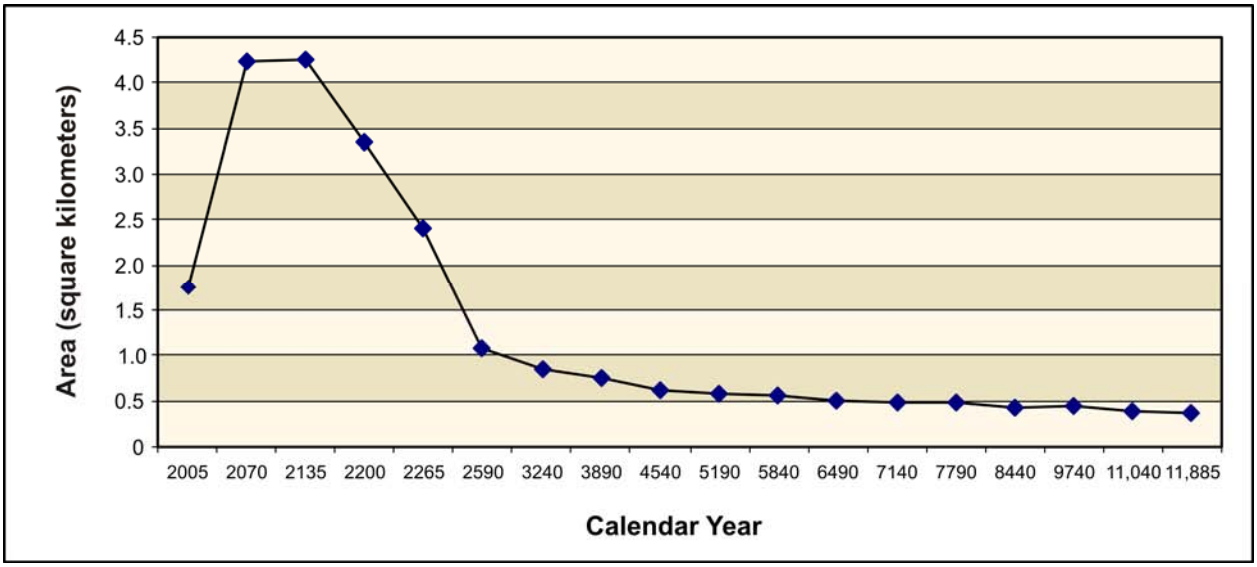


Figure 5–322. Tank Closure Alternative 6B, Option Case, Total Area of Groundwater Technetium-99 Concentration Exceeding the Benchmark Concentration as a Function of Time

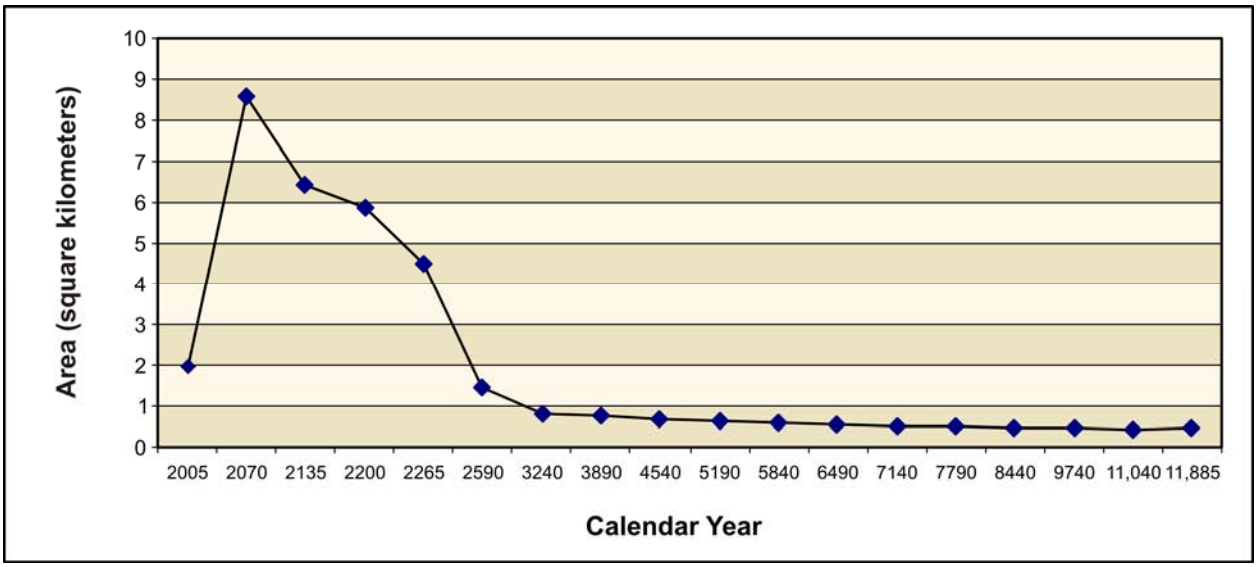


Figure 5–323. Tank Closure Alternative 6B, Option Case, Total Area of Groundwater Iodine-129 Concentration Exceeding the Benchmark Concentration as a Function of Time

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).

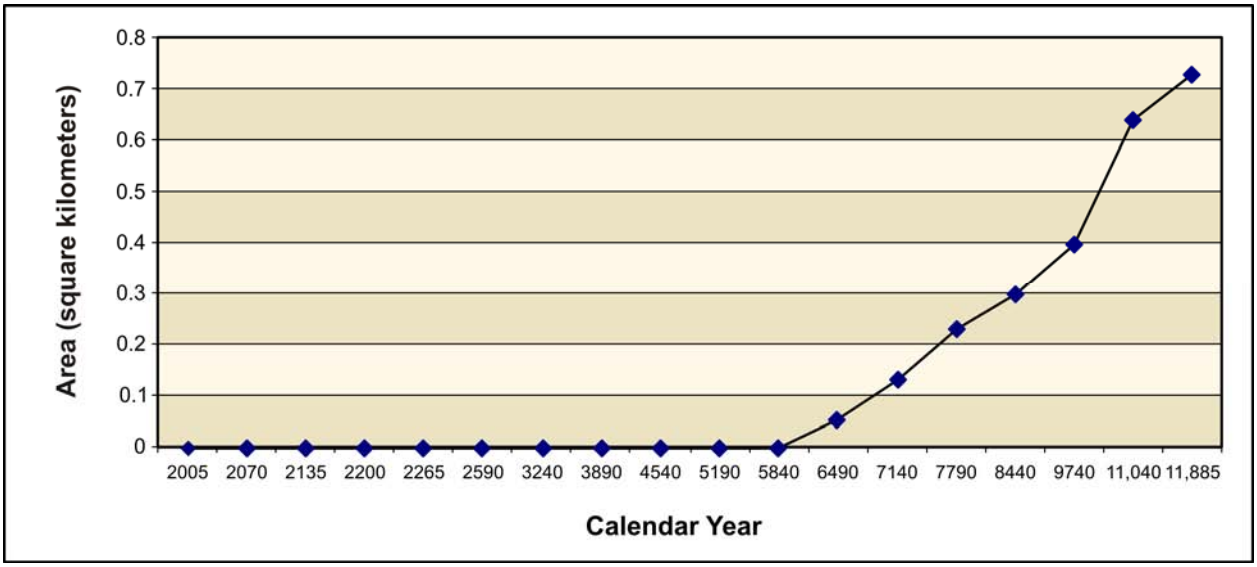


Figure 5–324. Tank Closure Alternative 6B, Base Case, Total Area of Groundwater Uranium-238 Concentration Exceeding the Benchmark Concentration as a Function of Time

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.

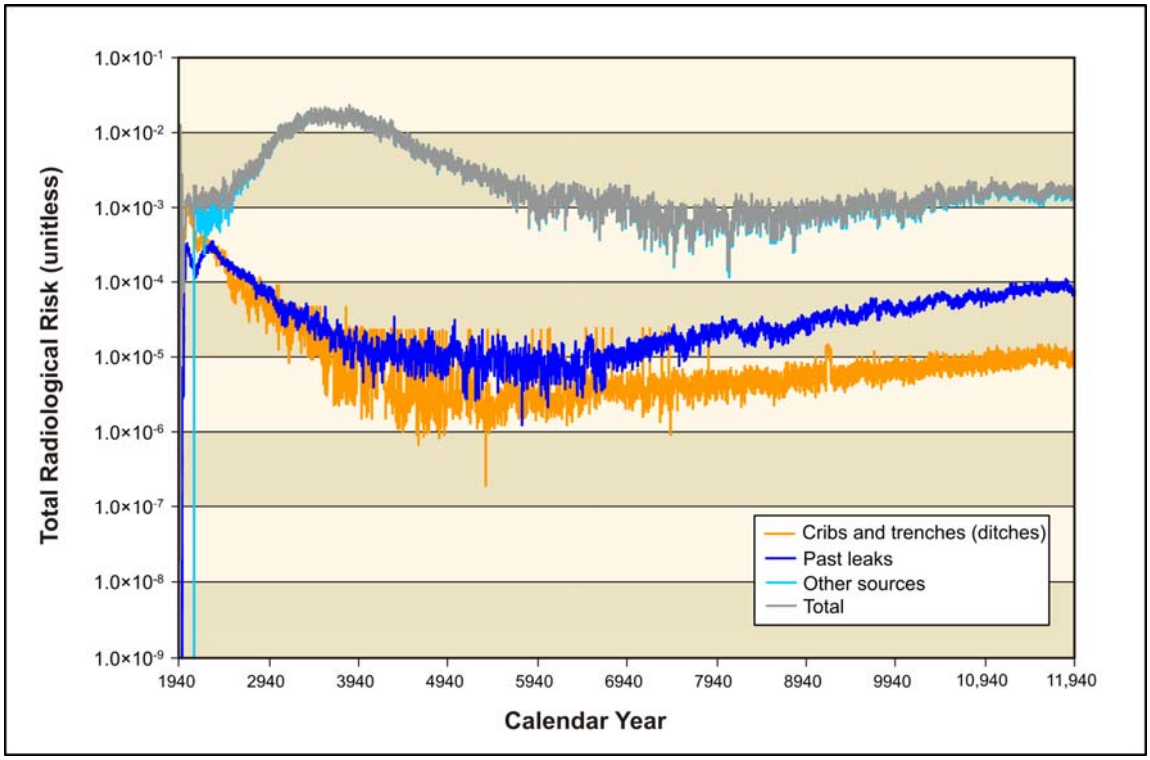


Figure 5–325. Tank Closure Alternative 1 Time Series of Radiological Risk for the Drinking-Water Well User at the Core Zone Boundary

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.

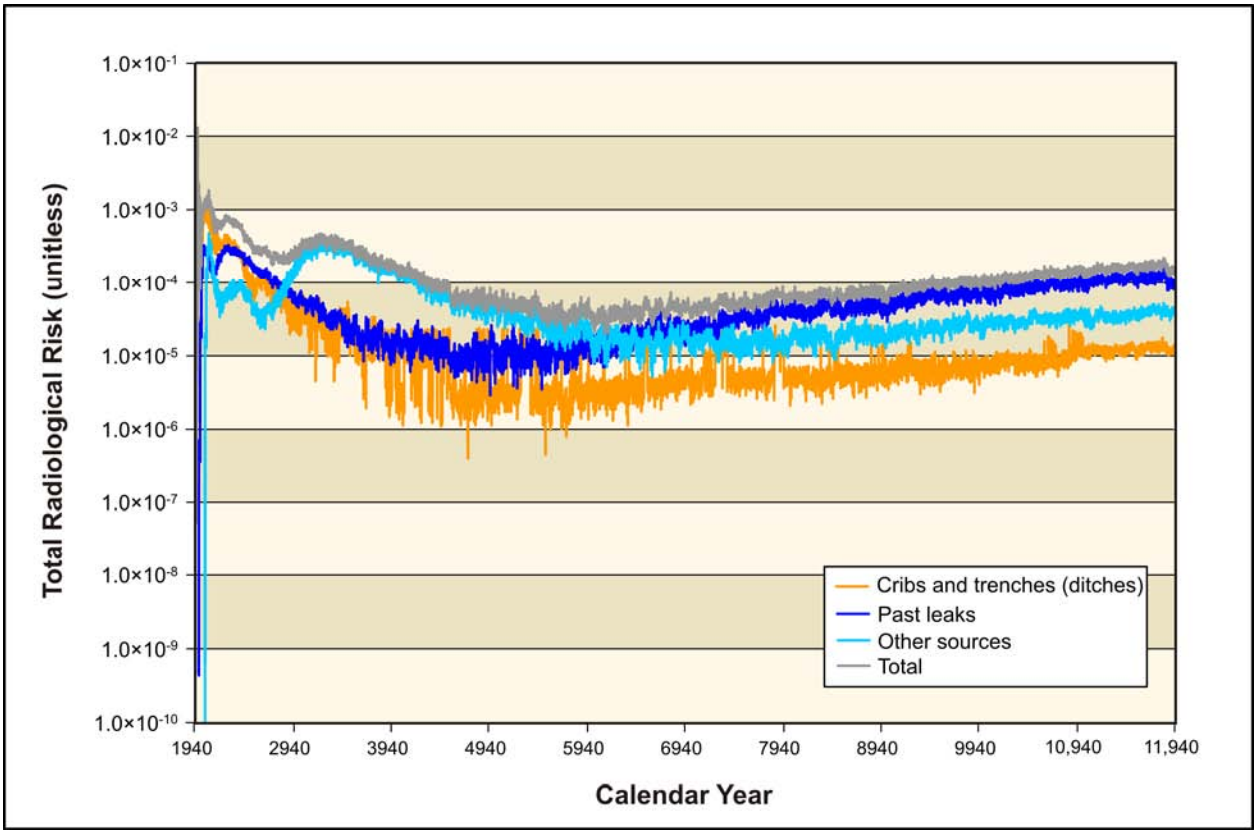


Figure 5–326. Tank Closure Alternative 2A Time Series of Radiological Risk for the Drinking-Water Well User at the Core Zone Boundary

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.

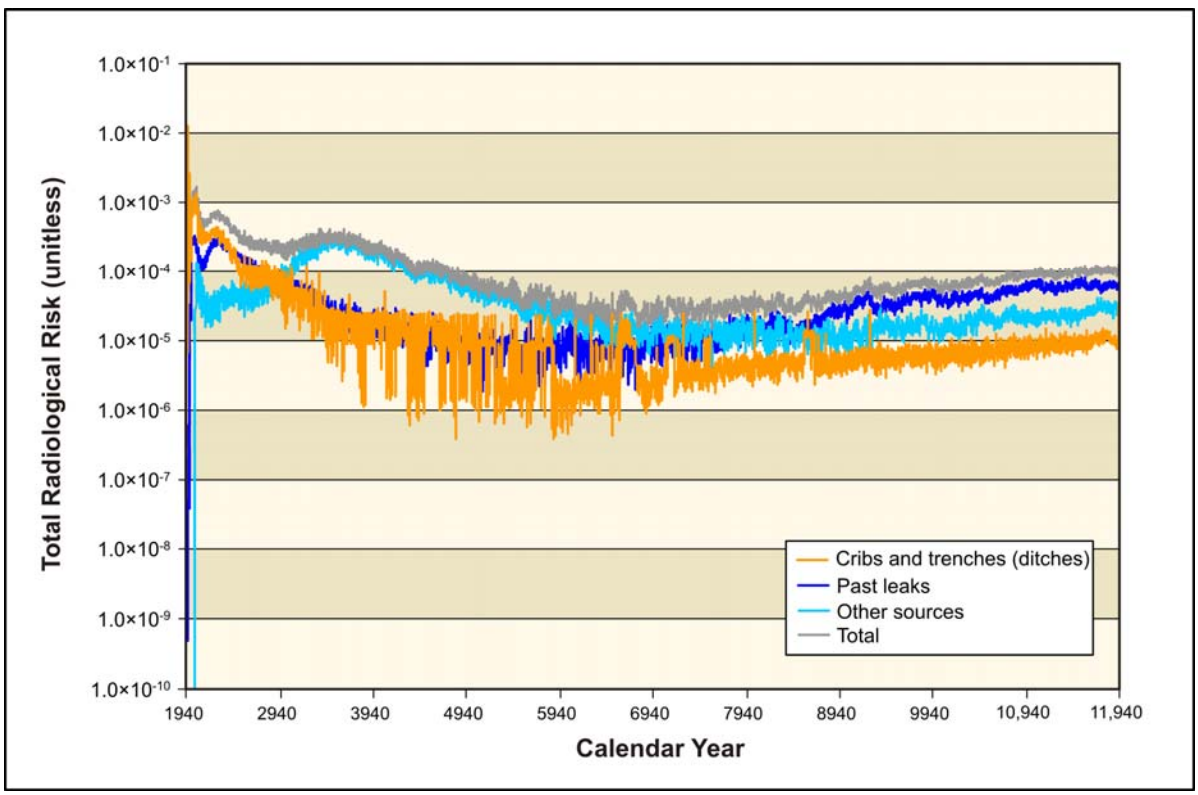


Figure 5–327. Tank Closure Alternative 2B Time Series of Radiological Risk for the Drinking-Water Well User at the Core Zone Boundary

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.

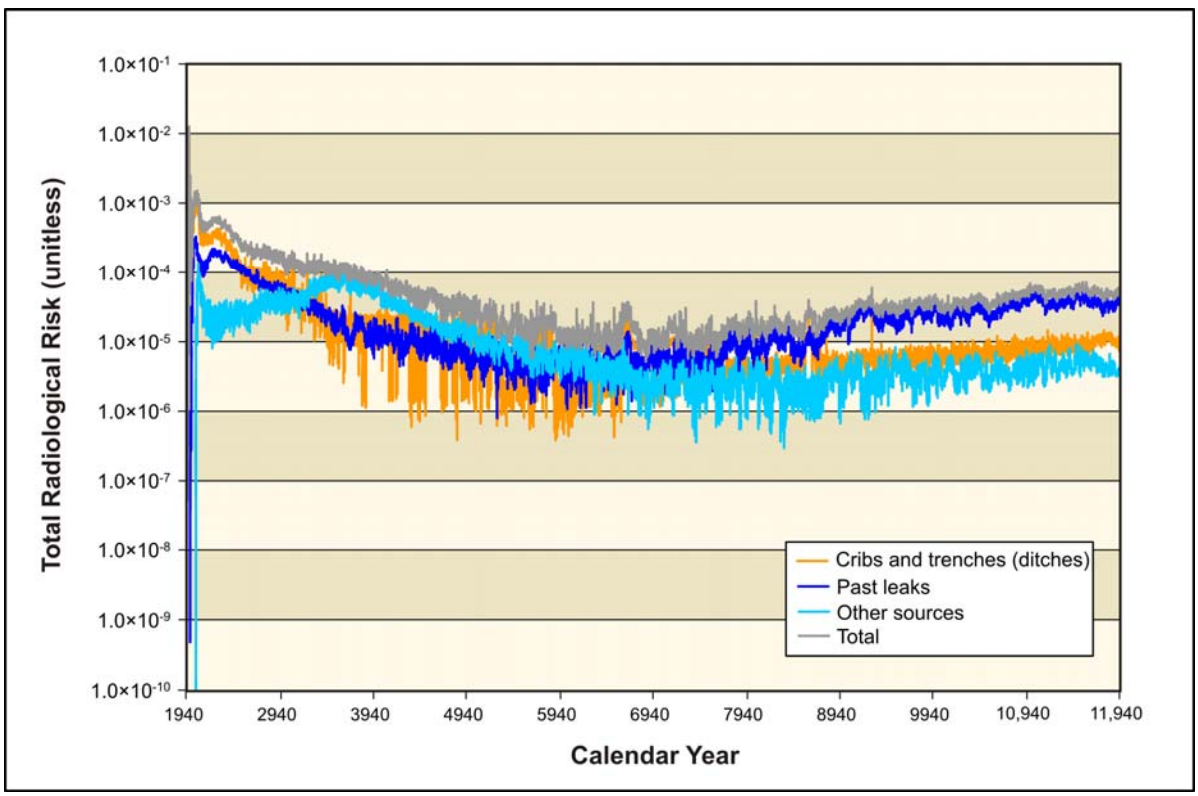


Figure 5–328. Tank Closure Alternative 4 Time Series of Radiological Risk for the Drinking-Water Well User at the Core Zone Boundary

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.

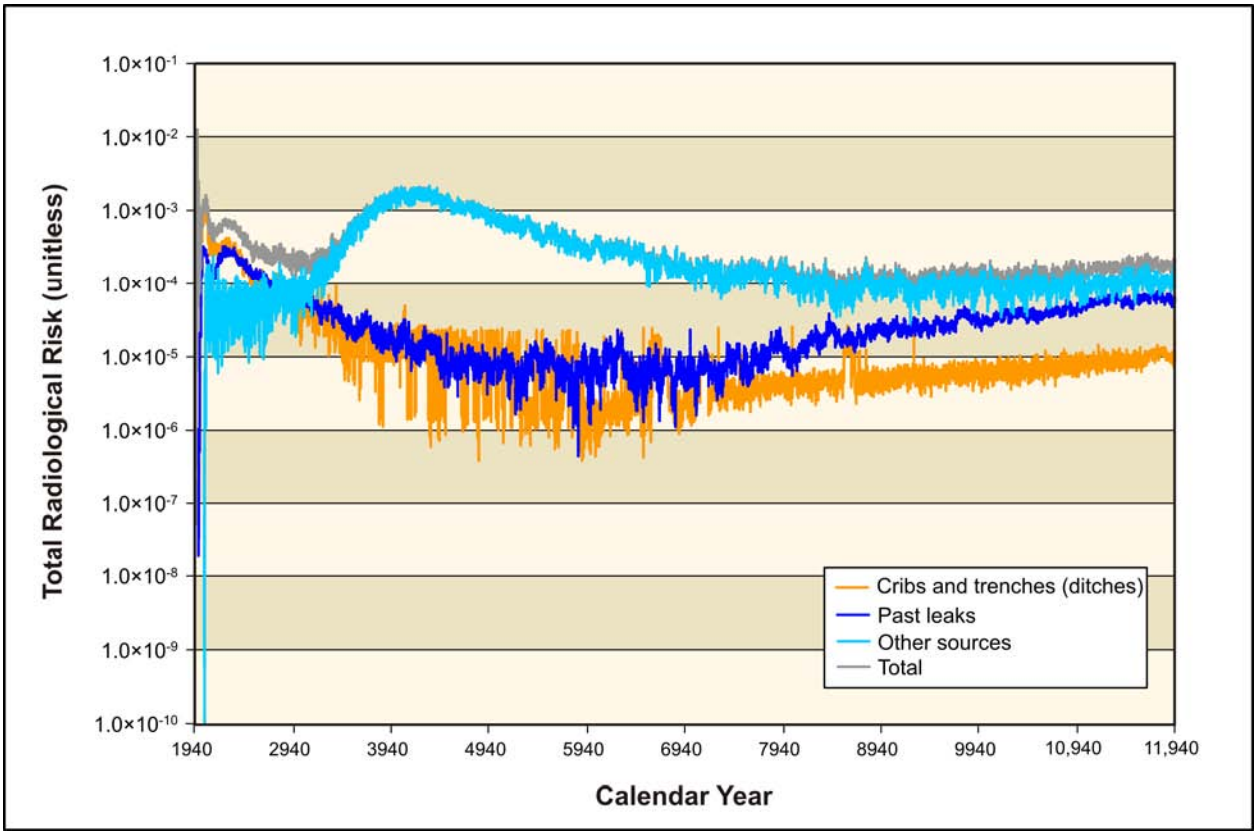


Figure 5–329. Tank Closure Alternative 5 Time Series of Radiological Risk for the Drinking-Water Well User at the Core Zone Boundary

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.

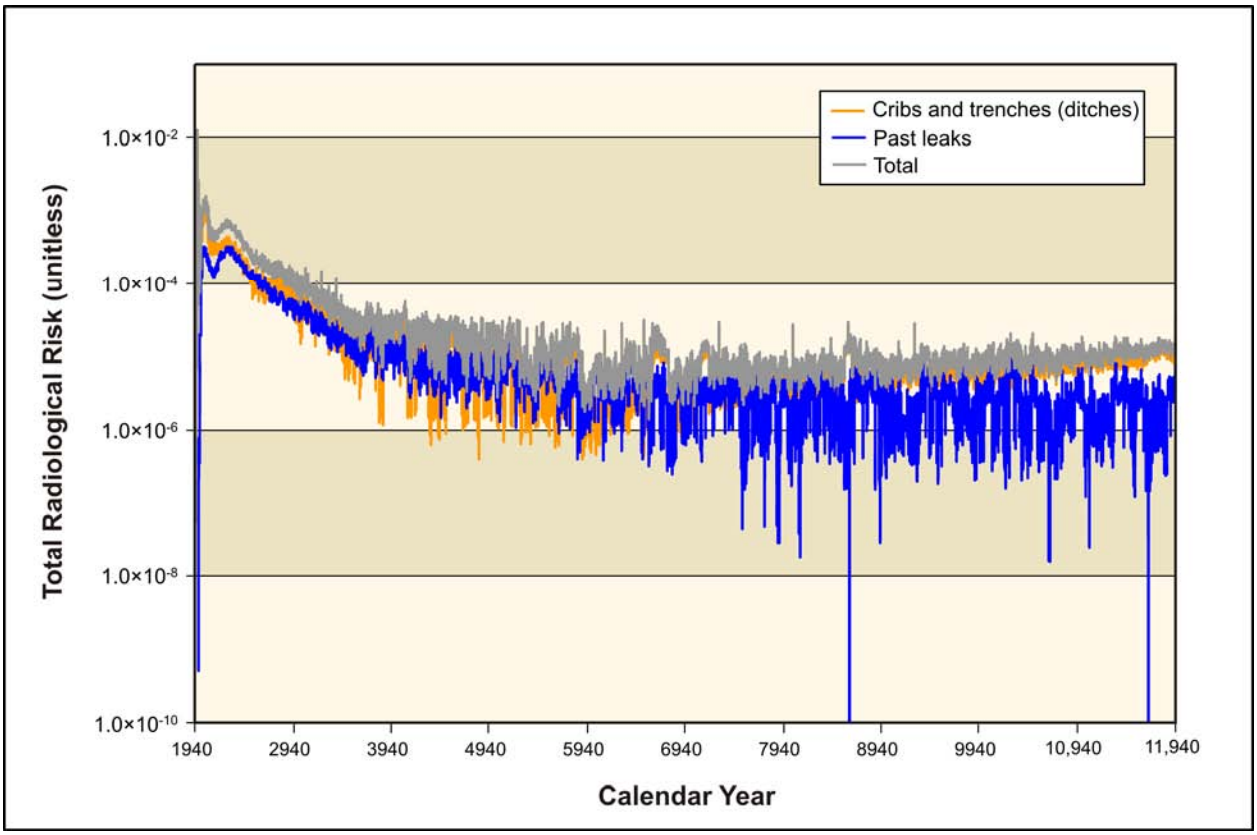


Figure 5–330. Tank Closure Alternative 6A, Base Case, Time Series of Radiological Risk for the Drinking-Water Well User at the Core Zone Boundary

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.

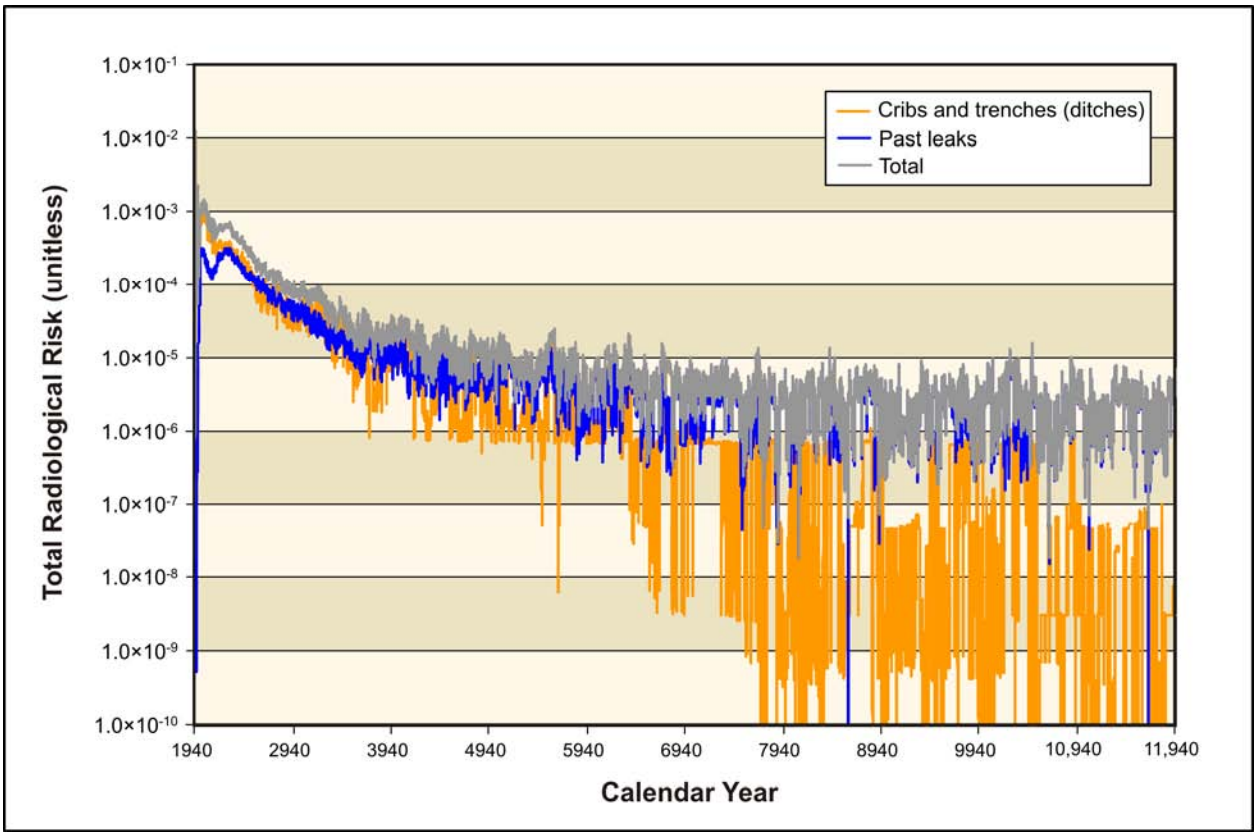


Figure 5–331. Tank Closure Alternative 6A, Option Case, Time Series of Radiological Risk for the Drinking-Water Well User at the Core Zone Boundary

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}	$\mathbf{1.52\times10^{2}}$	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}	$\mathbf{1.66\times10^{2}}$	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	$\mathbf{3.92\times10^{2}}$	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}	$\mathbf{1.23\times10^{2}}$	1.57×10^{1}	1.39×10^{1}	6.77×10^{1}	5.59	4.71
3C	1.67×10^{1}	2.33	$\mathbf{3.92\times10^{2}}$	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}	$\mathbf{1.57\times10^{2}}$	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}	$\mathbf{1.49\times10^{2}}$	$\mathbf{1.49\times10^{2}}$	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}	$\mathbf{2.70\times10^{2}}$	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}	$\mathbf{2.74\times10^{2}}$	3.48×10^{1}	4.26×10^{1}	9.18×10^{1}	7.58	6.39
6B, Base	7.33	1.02	$\mathbf{1.72\times10^{2}}$	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	$\mathbf{1.71\times10^{2}}$	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	$\mathbf{1.71\times10^{2}}$	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.

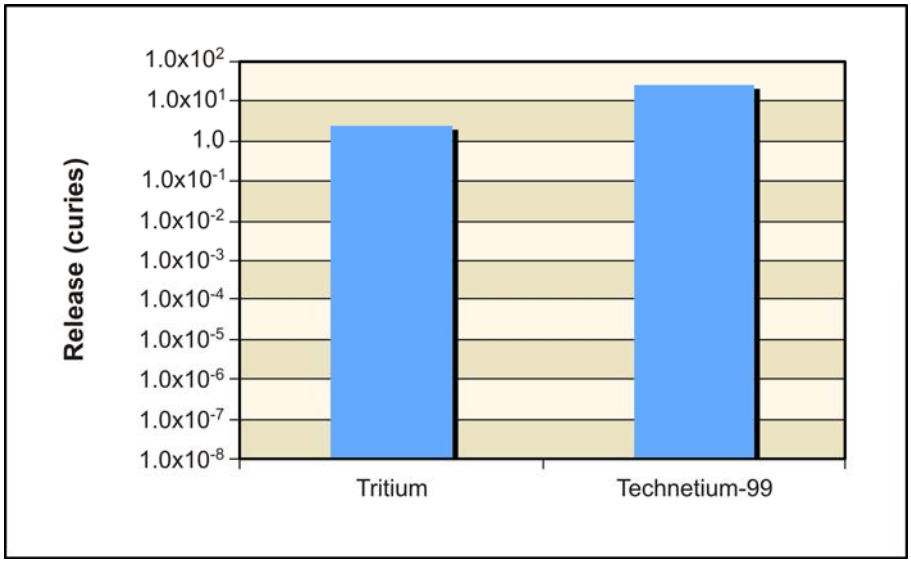


Figure 5–332. FFTF Decommissioning Alternative 1 Releases of Radiological Constituent of Potential Concern to Vadose Zone from Sources Inside the Fast Flux Test Facility Barrier

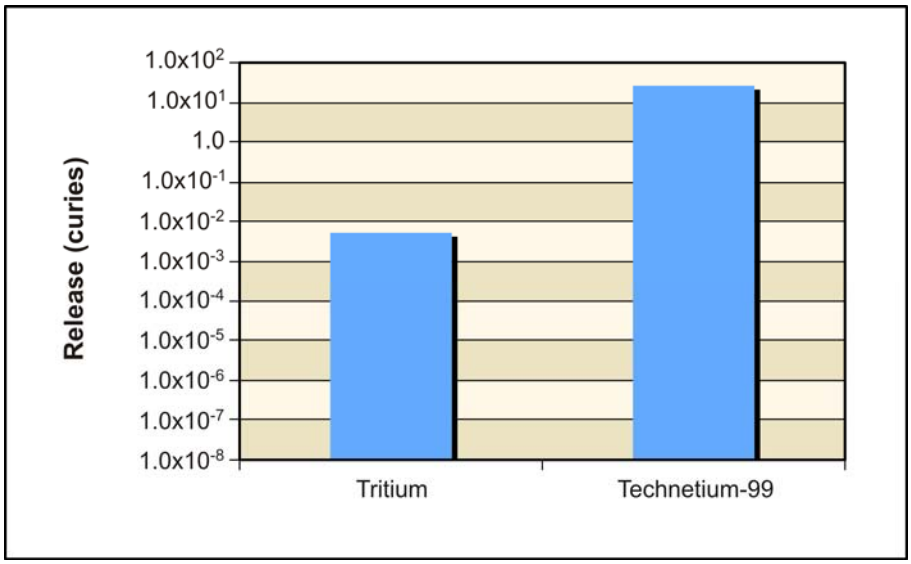


Figure 5–333. FFTF Decommissioning Alternative 1 Releases of Radiological Constituent of Potential Concern to Groundwater from Sources Inside the Fast Flux Test Facility Barrier

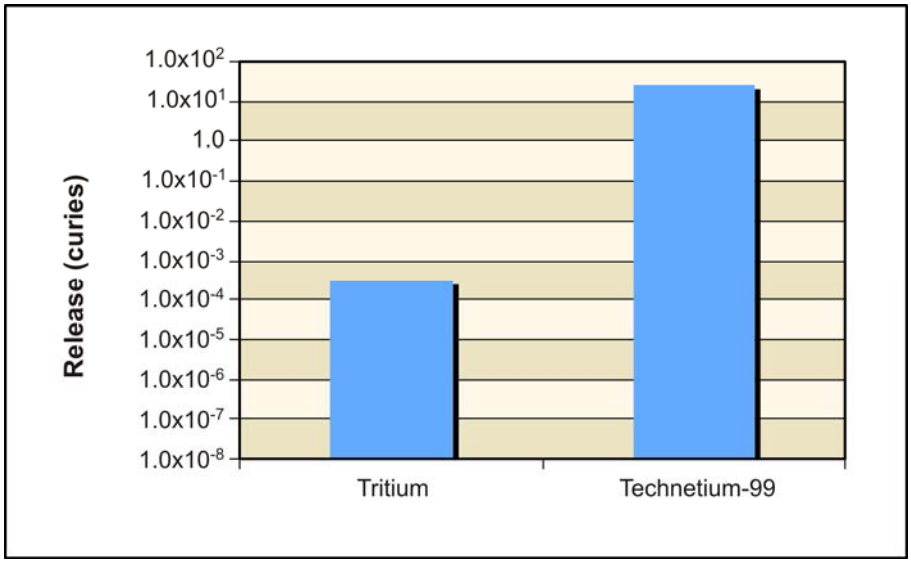


Figure 5–334. FFTF Decommissioning Alternative 1 Releases of Radiological Constituent of Potential Concern to Columbia River from Sources Inside the Fast Flux Test Facility Barrier

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.

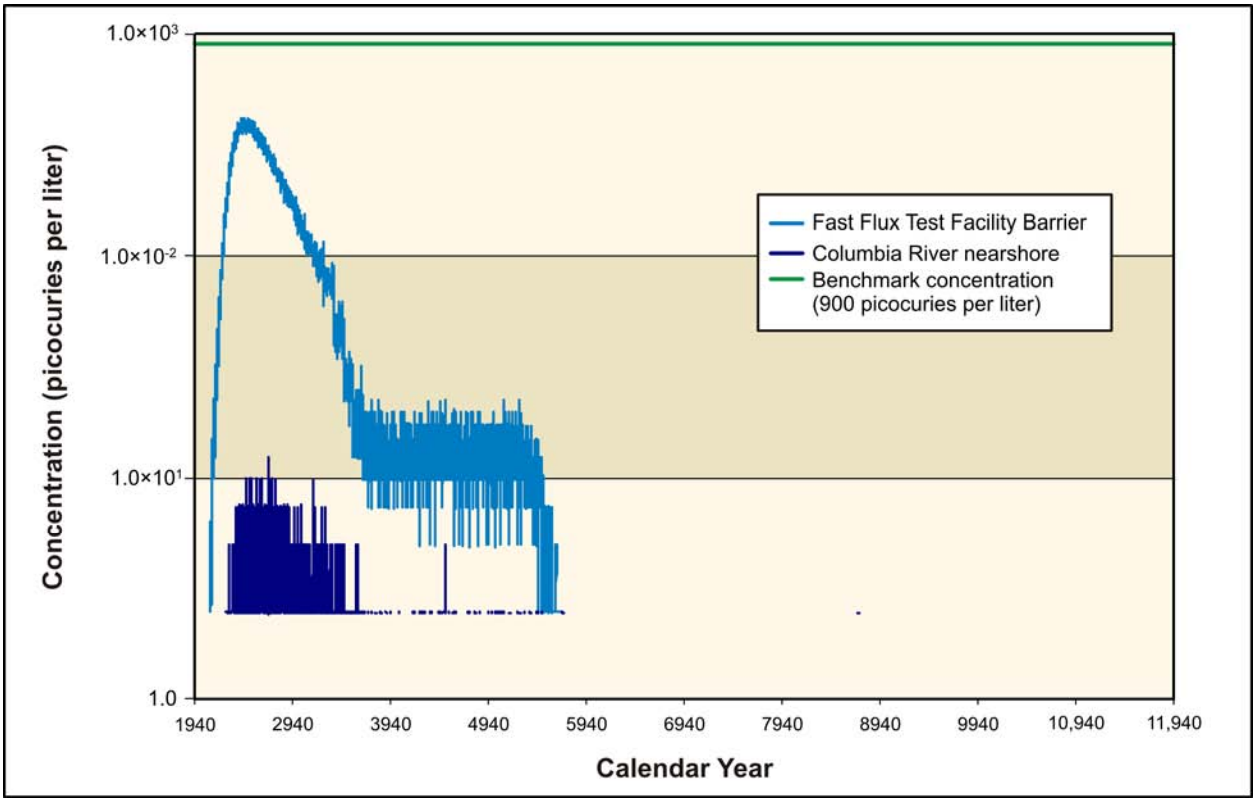


Figure 5–335. FFTF Decommissioning Alternative 1 Technetium-99 Concentration Versus Time

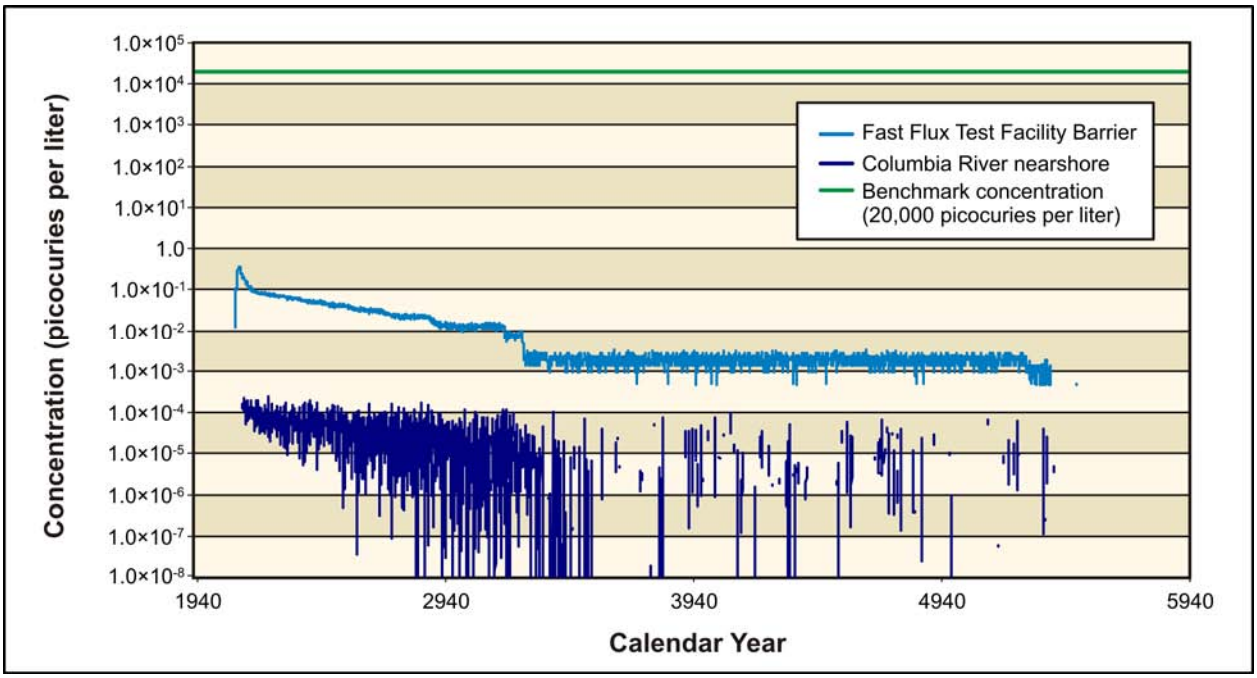


Figure 5–336. FFTF Decommissioning Alternative 1 Hydrogen-3 (Tritium) Concentration Versus Time

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.

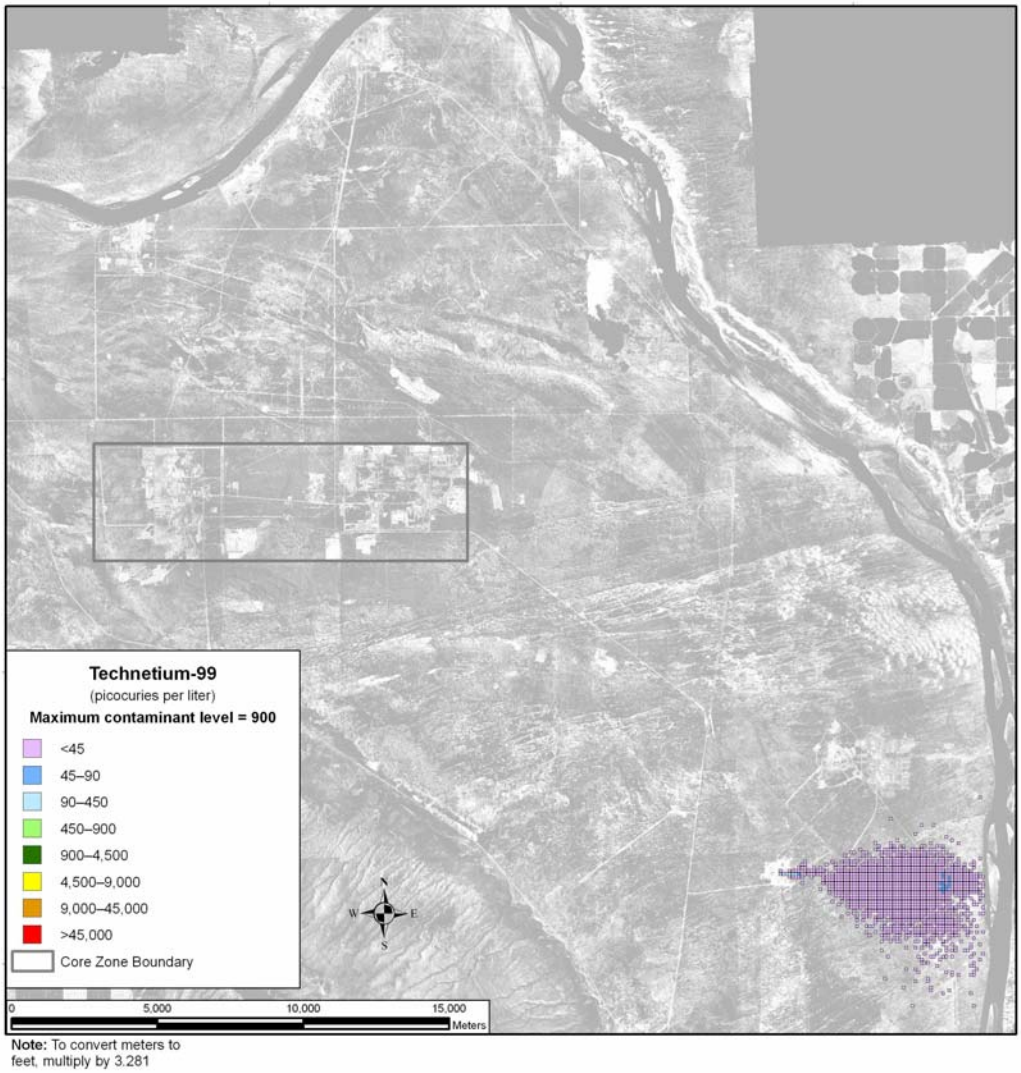


Figure 5–337. FFTF Decommissioning Alternatives 1 and 2 Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2590

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.

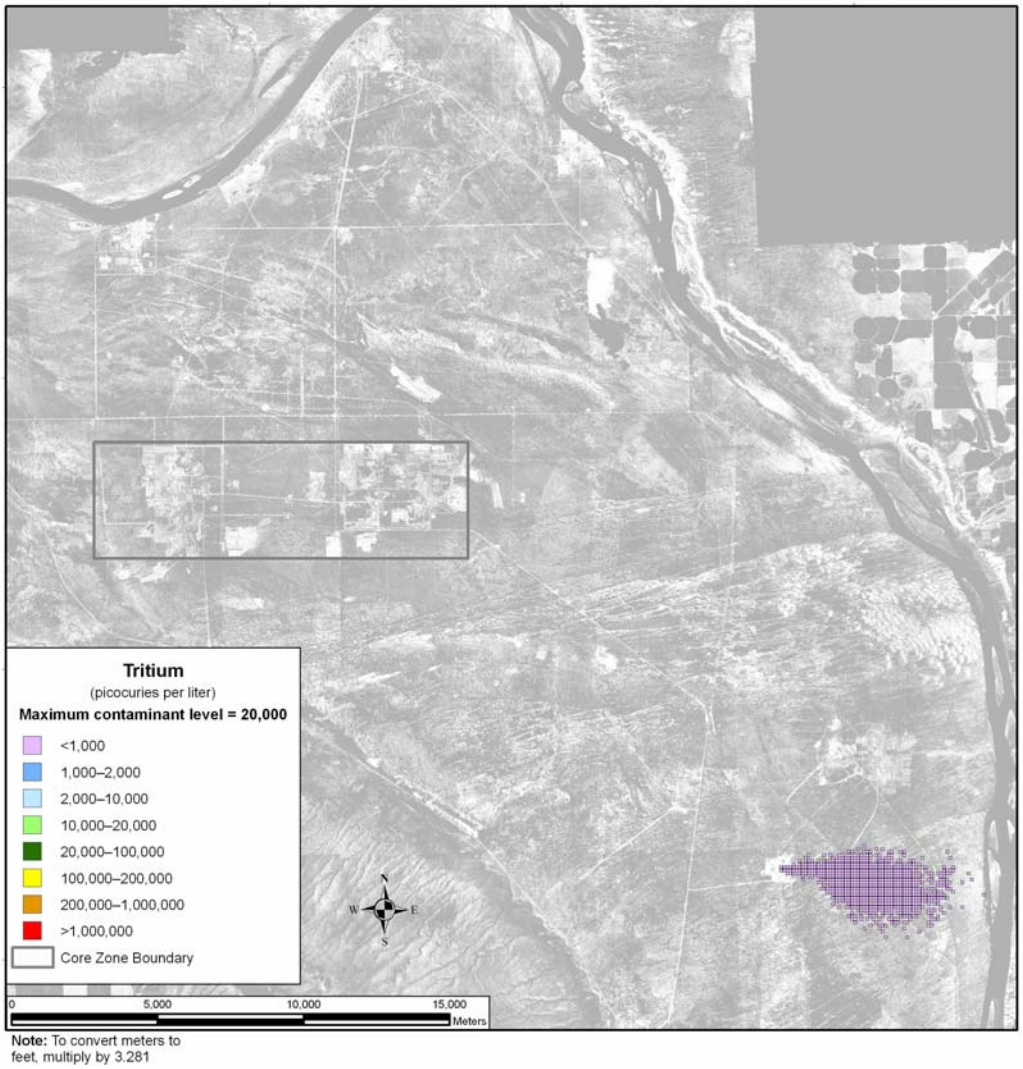


Figure 5–338. FFTF Decommissioning Alternative 1 Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2135

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.

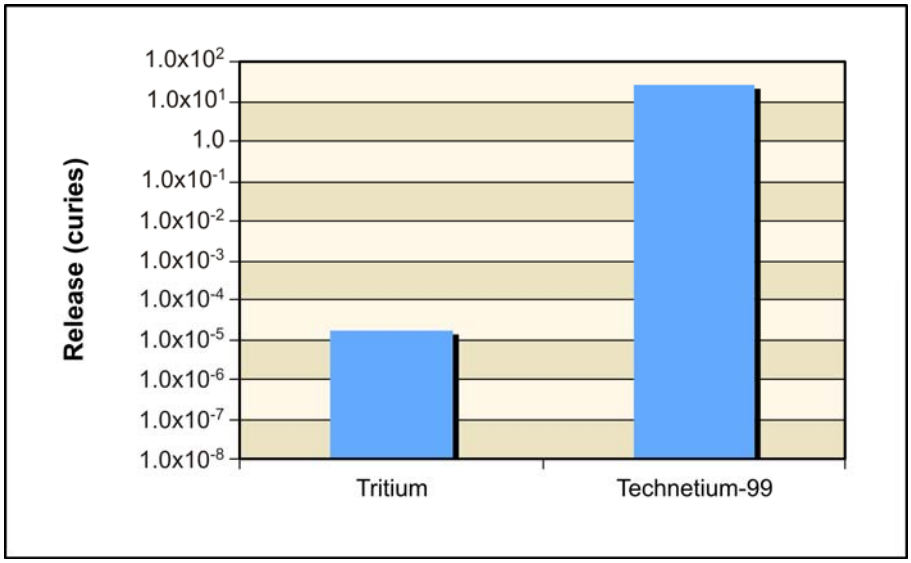


Figure 5–339. FFTF Decommissioning Alternative 2 Releases of Radiological Constituent of Potential Concern to Vadose Zone from Sources Inside the Fast Flux Test Facility Barrier

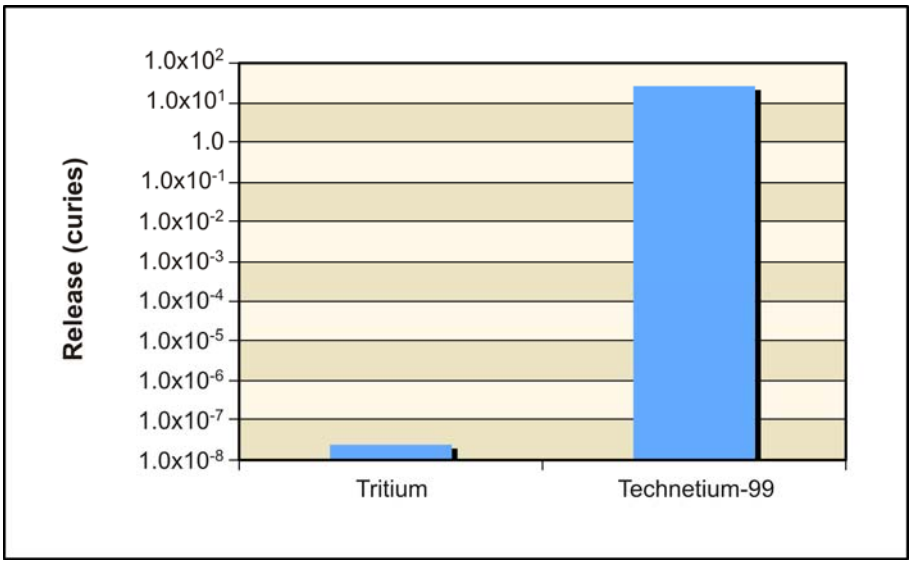


Figure 5–340. FFTF Decommissioning Alternative 2 Releases of Radiological Constituent of Potential Concern to Groundwater from Sources Inside the Fast Flux Test Facility Barrier

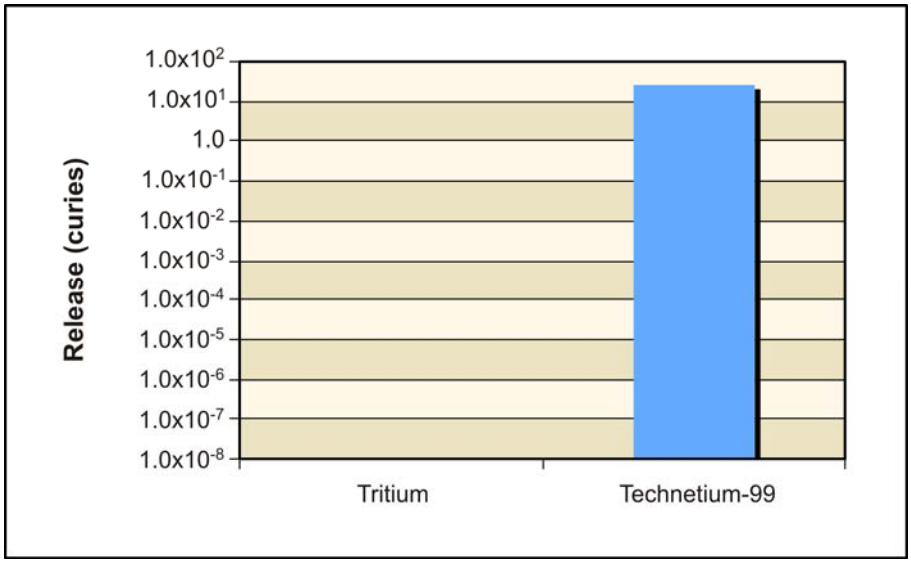


Figure 5–341. FFTF Decommissioning Alternative 2 Releases of Radiological Constituent of Potential Concern to Columbia River from Sources Inside the Fast Flux Test Facility Barrier

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.

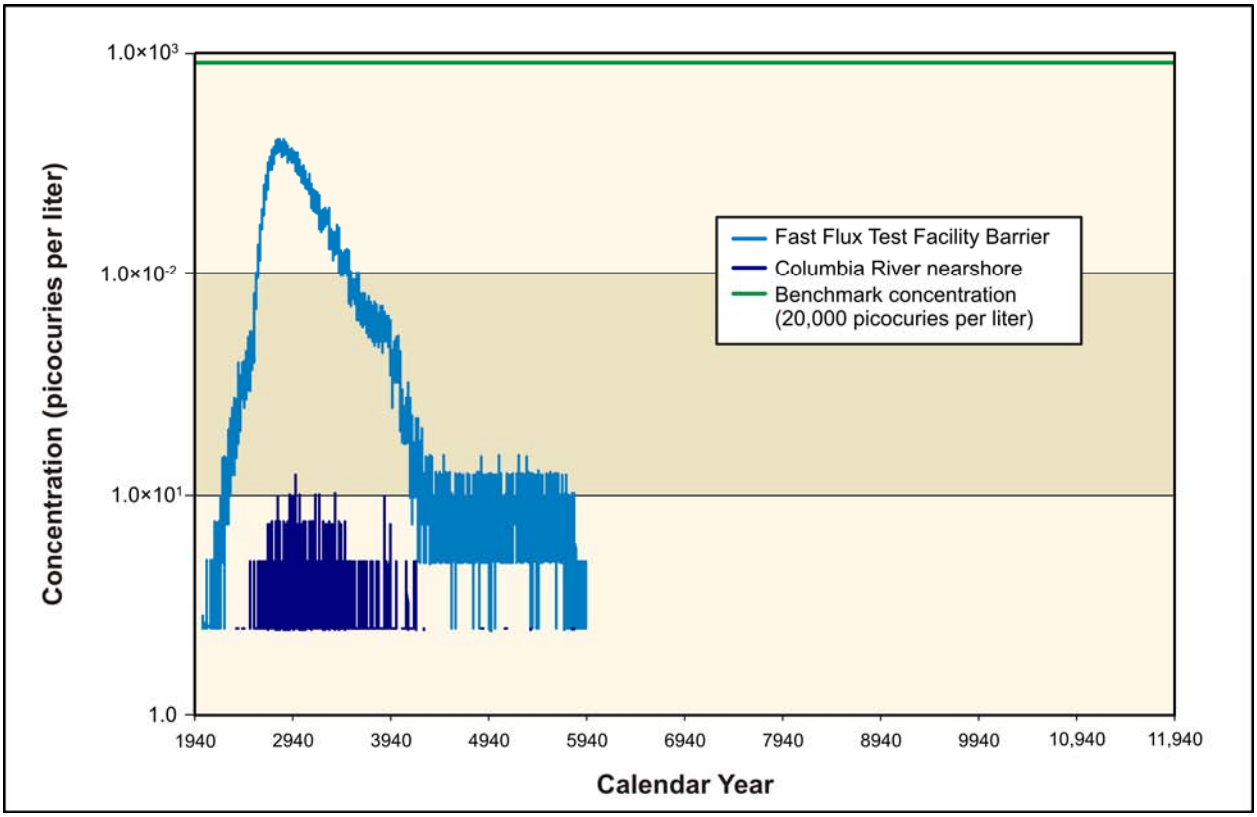


Figure 5–342. FFTF Decommissioning Alternative 2 Technetium-99 Concentration Versus Time

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.

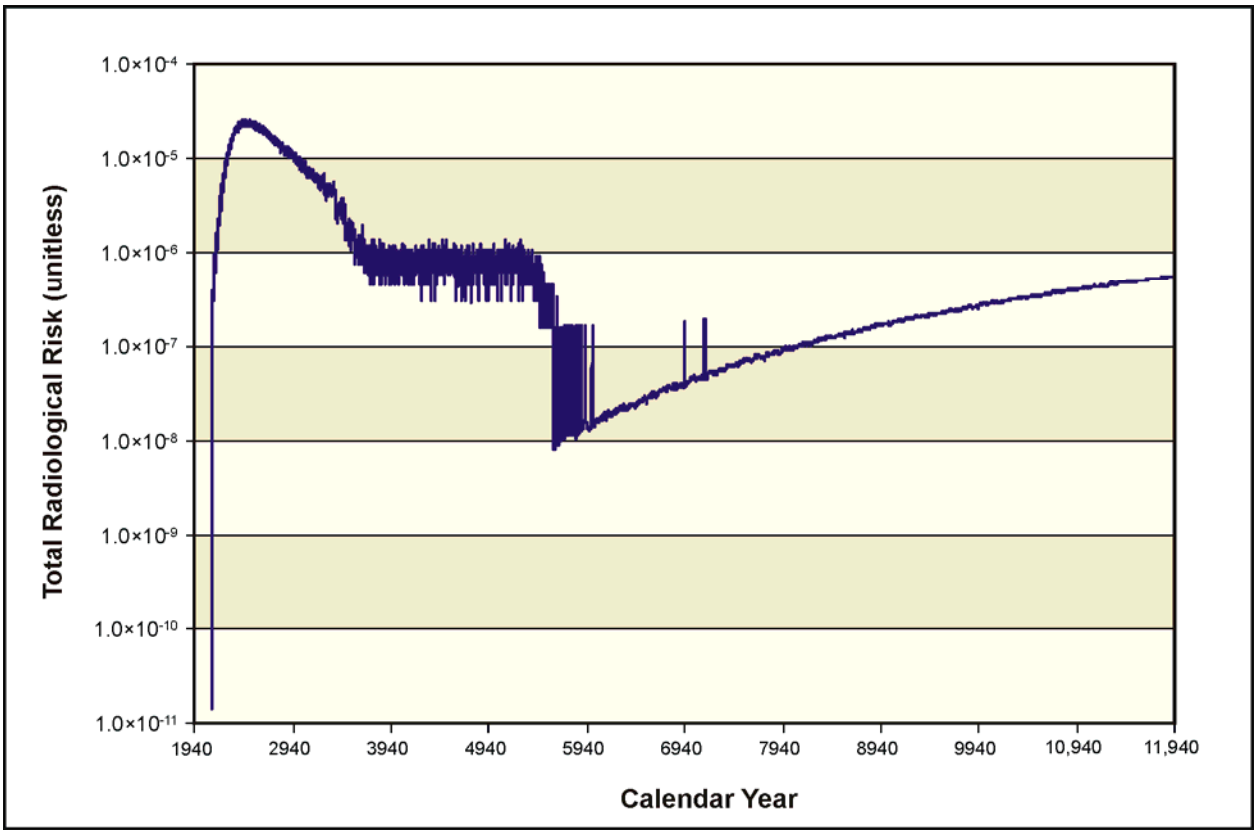


Figure 5–343. FFTF Decommissioning Alternative 1 Total Radiological Risk for Fast Flux Test Facility Barrier Drinking-Water Well User Versus Time

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.

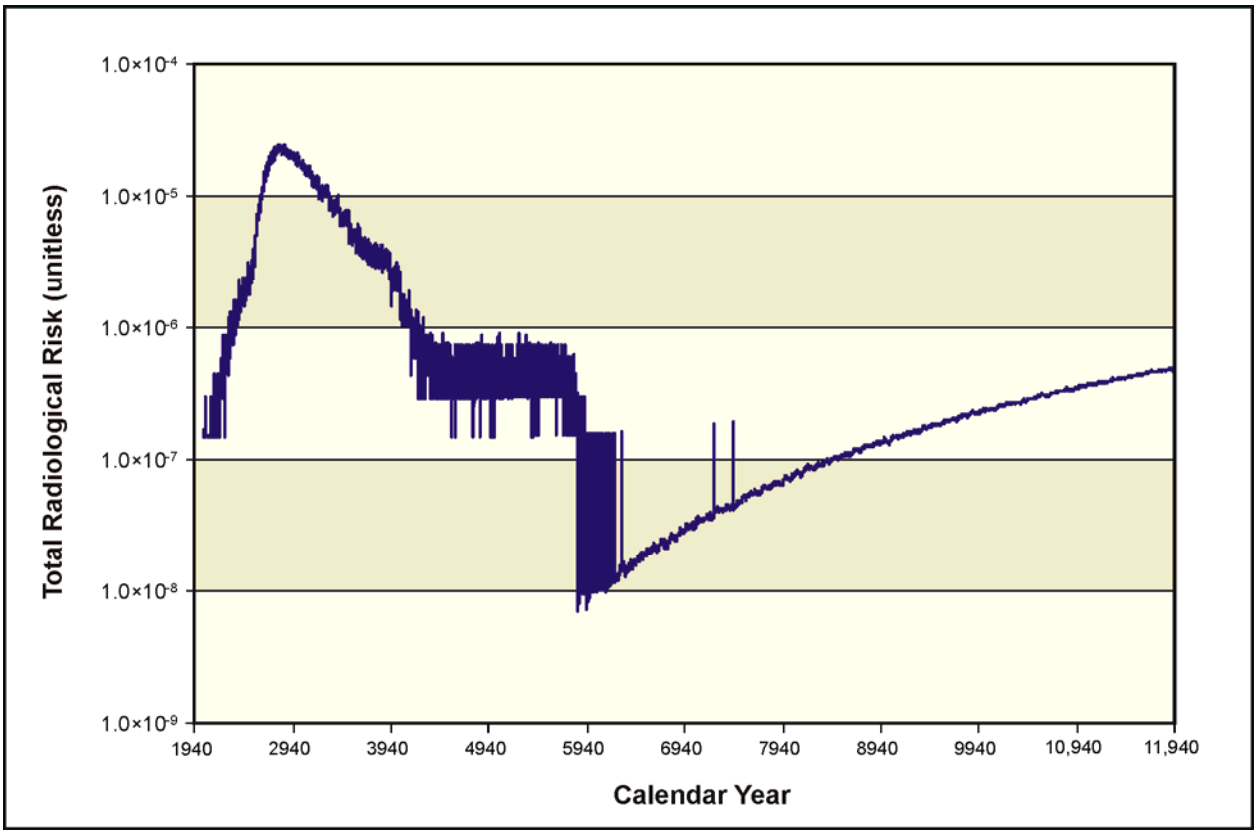


Figure 5–344. FFTF Decommissioning Alternative 2 Total Radiological Risk for Fast Flux Test Facility Barrier Drinking-Water Well User Versus Time

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}	$\mathbf{2.12\times10^{3}}$	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.