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 implementing reasonable alternatives for each of the following: (1) tank waste retrieval, treatment, and disposal 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 of 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. Impact analyses are grouped first by resource area or discipline (e.g., groundwater) 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; a comparison of the environmental effects among alternatives is presented in Chapter 2, Section 2.7.

The long-term impacts 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 Appendices F and 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.

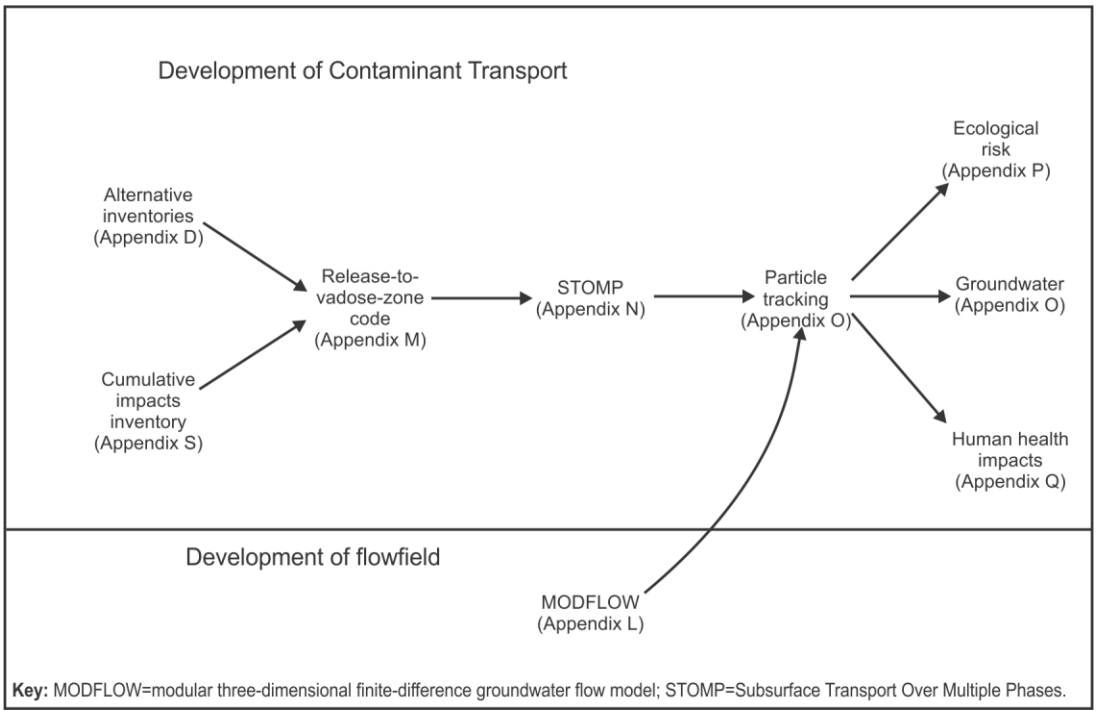


Figure 5–1. Groundwater Modeling Process

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. 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 output from the release-to-vadose-zone code (see Appendix M) is an input file to the vadose zone model STOMP [Subsurface Transport Over Multiple Phases] computer code (White and Oostrom 2000, 2006), which is described in Appendix N.

The STOMP model uses an integrated-volume finite-difference approach to solve nonlinear water and solute transport governing equations 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. The contaminant fluxes to the aquifer are used as inputs to the groundwater contaminant transport (see Appendix O).

A groundwater flow field was developed to determine the direction and rate of water movement in the aquifer, that is, where contaminants entering groundwater will go and how long it will take to move a given contaminant from the point where it enters 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 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 2–79, and Appendix O, Figure O–1.

The results of the groundwater contaminant transport runs have been compiled into tables, charts, graphs, and maps depicting the long-term impacts of the alternatives. These depictions are presented for the Tank Closure alternatives, FFTF Decommissioning alternatives, and Waste Management alternatives in Sections 5.1, 5.2, and 5.3, respectively. There are some features of these depictions that are common to all alternatives. The following paragraphs present and discuss these common features as an aid to evaluating the alternatives.

A series of bar charts is provided for each alternative showing the total release of key constituents throughout the entire 10,000-year period of analysis. Charts are provided for release of constituents to the vadose zone, to the water table (beneath the vadose zone), and to the Columbia River nearshore. These charts have two purposes: (1) to facilitate comparisons across alternatives of the total load of contaminants to selected portions of the environment and (2) to facilitate evaluation of the ultimate fate (within the 10,000-year period of analysis) of each of the constituents. The *x* axis of these charts merely separates constituents, while the *y* axis represents the total release in curies (for radionuclides) or kilograms (for chemicals). Each constituent is further divided by source type, and the source types are

color coded and keyed to the legend. Note that the *y* axis is logarithmic; specifically, each interval given represents a factor of 10 change in total release.

A table is provided for each alternative listing the estimated future maximum concentration of key constituents at the nearfield barriers (i.e., the tank farm barriers under the Tank Closure alternatives; the Fast Flux Test Facility (FFTF) barrier under the FFTF Decommissioning alternatives; and the 200-East Area Integrated Disposal Facility [IDF-East], 200-West Area Integrated Disposal Facility [IDF-West], and River Protection Project Disposal Facility [RPPDF] barriers under the Waste Management alternatives), the Core Zone Boundary, and the Columbia River nearshore. These tables have two purposes: (1) to facilitate comparisons across alternatives of the maximum impacts on selected portions of the environment and (2) to facilitate evaluation of the intensity of impact (throughout the 10,000-year period of analysis) of each of the constituents. The tables contain a row for each radionuclide and chemical and a column for each barrier applicable to the alternative. The rightmost column provides the benchmark concentration for the constituent for reference. The maximum concentrations estimated for each radionuclide and chemical during calendar years (CYs) 2050 through 11,940 are tabulated, together with the calendar year during which the maximum is achieved. In instances in which the concentration in the year of peak impact is negligibly small, the concentration is reported as zero and the year of peak impact is reported as identified in the analysis. Concentrations that would exceed the benchmark are shown in boldface.

A series of concentration-versus-time graphs is provided for key constituents. These graphs show the maximum contaminant concentration associated with nearfield barriers (depending on type of alternative), the Core Zone Boundary, and the Columbia River nearshore. These graphs have two purposes: (1) to facilitate comparisons across alternatives of the intensity of impact on selected portions of the environment and (2) to facilitate evaluation of the duration of impact for each of the constituents. The *x* axis shows CYs 1940 through 11,940 (for certain short-lived radionuclides, the *x* axis has been expanded for clarity). The *y* axis shows the concentration. Note that the *y* axis is logarithmic; specifically, each interval given represents a factor of 10 change in concentration. A horizontal green line that indicates the benchmark concentration has been added to each graph. The maximum concentration associated with each radionuclide and chemical is shown regardless of the location of occurrence; this location can and does change over the lifetime of the simulation. Note also that this plot combines the results of a number of individual sources. The reader is strongly cautioned that the interpretation of this graph cannot be done in the standard framework of a concentration-versus-time plot from a monitoring well downgradient from a single source. The reader will also note fluctuations in the concentration-versus-time plots. These fluctuations are not the result of model instability; rather, they are the result of the particle-tracking model simulating a continuous plume with a finite number of particles. For this *Final TC & WM EIS*, the number of particles in each individual simulation was increased from 100,000 to 1,000,000 to increase the resolution of the simulation and decrease the fluctuations.

A series of maps of spatial distributions of contaminant plumes is provided for key constituents at selected times. The purpose of these maps is to show (1) the areas of impact for each constituent and (2) the evolution of the contaminant plumes as a function of time. These maps are color coded, with the color representing the contaminant concentration. The color codes are arranged in a temperature ramp from cool (low concentration) to hot (high concentration); note that the concentration ranges for each color are organized in factors of 2, 5, 10, and 50 around the benchmark (or one-half, one-fifth, one-tenth, and one-twentieth of the benchmark concentration). The Core Zone Boundary is shown in light gray.

Finally, a series of graphs is provided for key constituents showing the area of exceedance (relative to the benchmark) as a function of time. The purpose of these graphs is to show the evolution of the area of exceedance at a finer timescale than can be shown in the spatial distribution maps. The *x* axis shows time in calendar years. The *y* axis shows area in square kilometers. This graph is obtained from the spatial distribution maps discussed in the preceding paragraph by counting all of the rectangular areas that have

concentrations greater than the benchmark. Note that in general, the total figure of exceedance is not contiguous.

5.1 TANK CLOSURE ALTERNATIVES

This section describes the potential long-term environmental impacts associated with implementing 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 impacts 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 analysis purposes 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 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. Except 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) is 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 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 impacts 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 presented in this section are 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, but this discussion 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 contributions 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.

In this *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington (TC & WM EIS)*, dissolved radionuclides and chemicals moving through the unconfined aquifer beneath the Hanford Site are considered to be affected by advection, dispersion, decay, and retardation. Advection is the bulk movement of solutes under the influence of the groundwater flow field. Dispersion is the spreading of the contaminant plume about the center of mass of the plume caused by inhomogeneities in the flow field at a scale smaller than an individual cell in the flow field calculation (i.e., 200 meters). Decay is the transformation of a solute into another isotopic or chemical form; the primary example of this in this *TC & WM EIS* is radioactive decay. Retardation is the interaction of a dissolved solute with the aquifer solid materials (e.g., adsorption onto solid surfaces.) The net effect of retardation is to lower aqueous concentrations and slow the movement of the plume through the aquifer. Solutes that are affected primarily by advection and dispersion are called conservative tracers; the aqueous mass of these solutes is conserved and their plumes trace out pathlines in the flow field.

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, and their solute (or aqueous) concentrations are attenuated by

interaction with the solid aquifer materials. 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 the total amount of COPCs released to the vadose zone, groundwater, and the Columbia River during the 10,000-year period of analysis. Releases of radionuclides are totaled in curies; chemicals, in kilograms (see Figures 5–2 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 within the same series of figures.

Figure 5–2 shows the estimated release to the vadose zone of 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 is released during the period of analysis). The predominant sources of 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 (i.e., unplanned releases inside the tank farms, retrieval losses, ancillary equipment, and tank farm residuals). 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. Of the other tank farm sources, the inventories resident in the tanks (also referred to as "tank residuals") are the dominant sources of COPC drivers (relative to unplanned releases or releases from tank ancillary equipment).

[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.

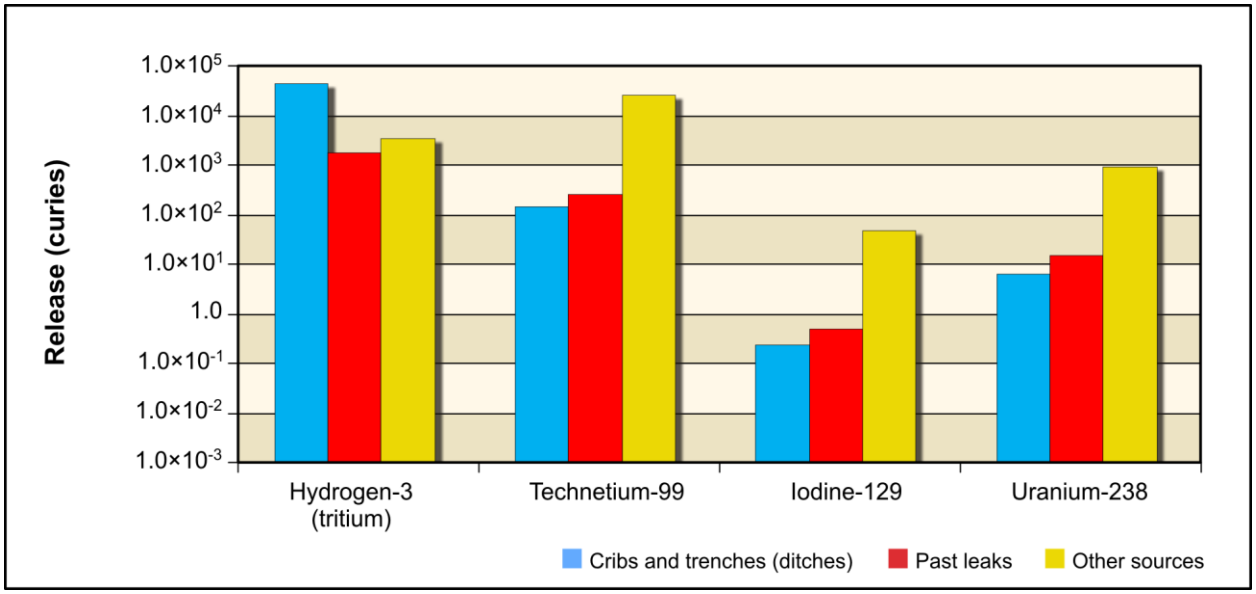


Figure 5–2. Tank Closure Alternative 1 Releases of Radioactive Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

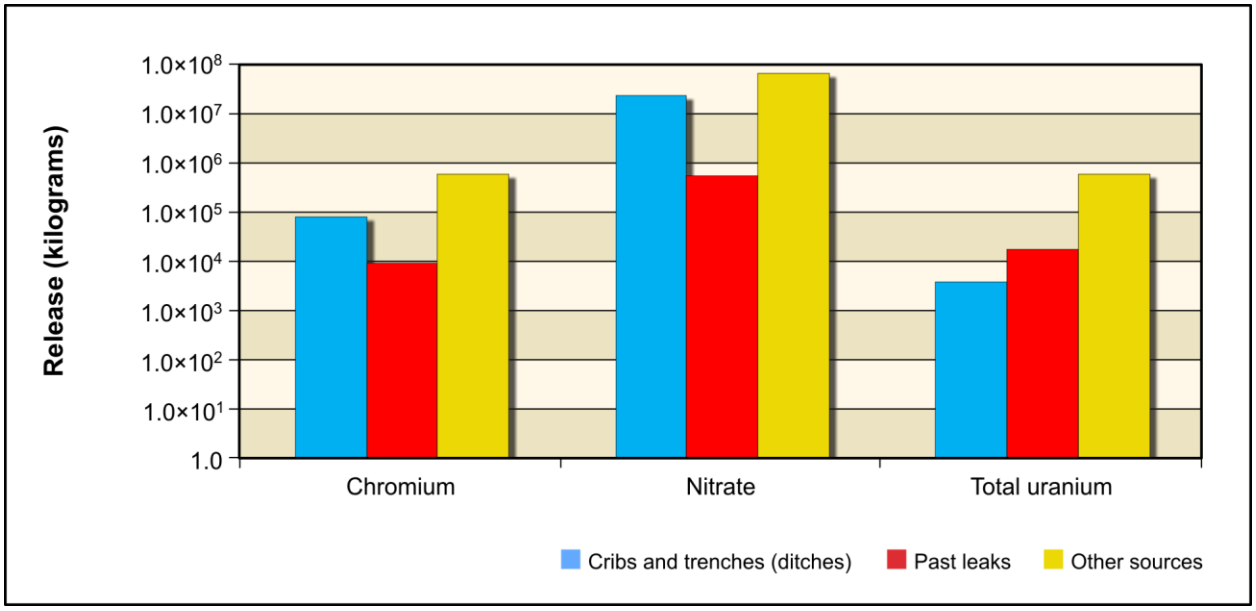


Figure 5–3. Tank Closure Alternative 1 Releases of Chemical Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

Figure 5–4 shows the estimated release to groundwater of 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.

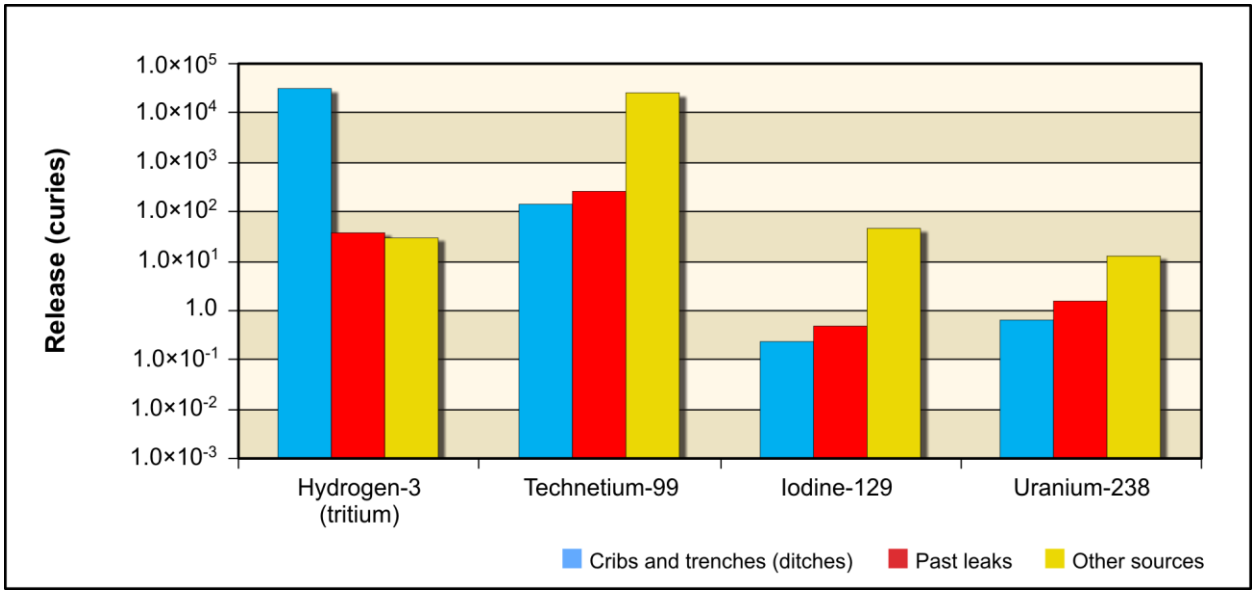


Figure 5–4. Tank Closure Alternative 1 Releases of Radioactive Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

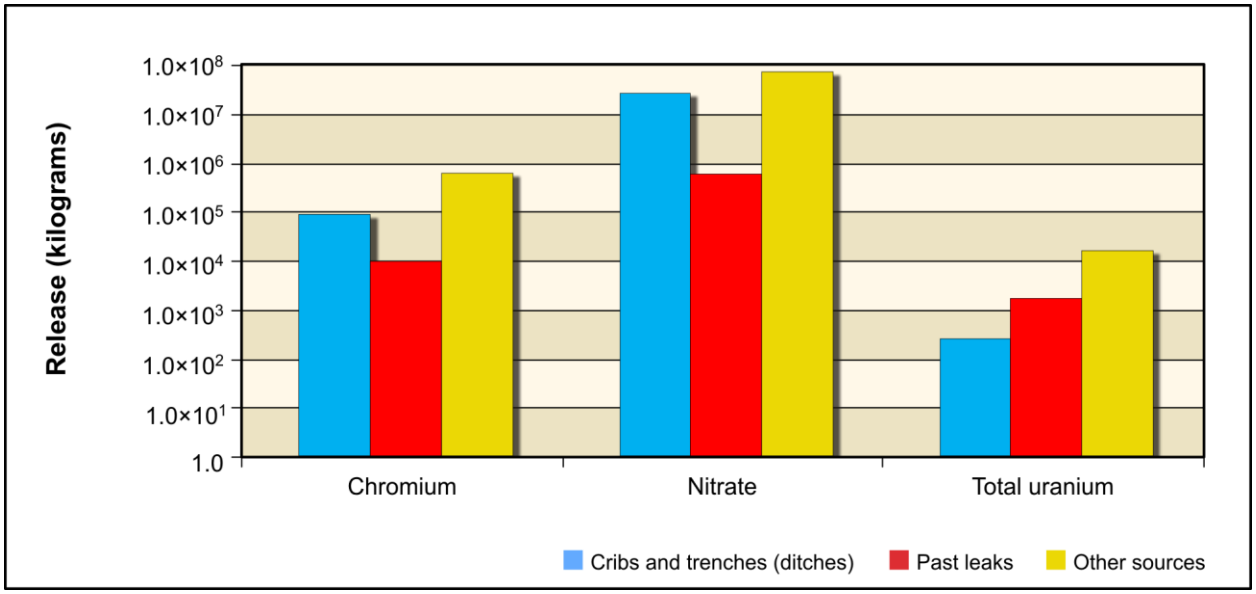


Figure 5–5. Tank Closure Alternative 1 Releases of Chemical Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

For tritium, the amount released to groundwater is attenuated by radioactive decay in the vadose zone. For releases from cribs and trenches (ditches), about 70 percent of the total inventory of tritium reaches groundwater in the analysis; for past leaks, only 2 percent; and for other tank farm sources, less than 1 percent reaches 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 released 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 releases from 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 uranium-238 inventory and 6 percent of the total uranium inventory reach groundwater during the period of analysis. For past leaks, about 10 percent of the uranium-238 inventory and 9 percent of the total uranium inventory reach groundwater during the period of analysis. For other tank farm sources, about 1 percent of the uranium-238 inventory and 3 percent of the total uranium inventory reach groundwater during the period of analysis. These results also suggest that uranium-238 and total uranium impacts on groundwater 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 of 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.

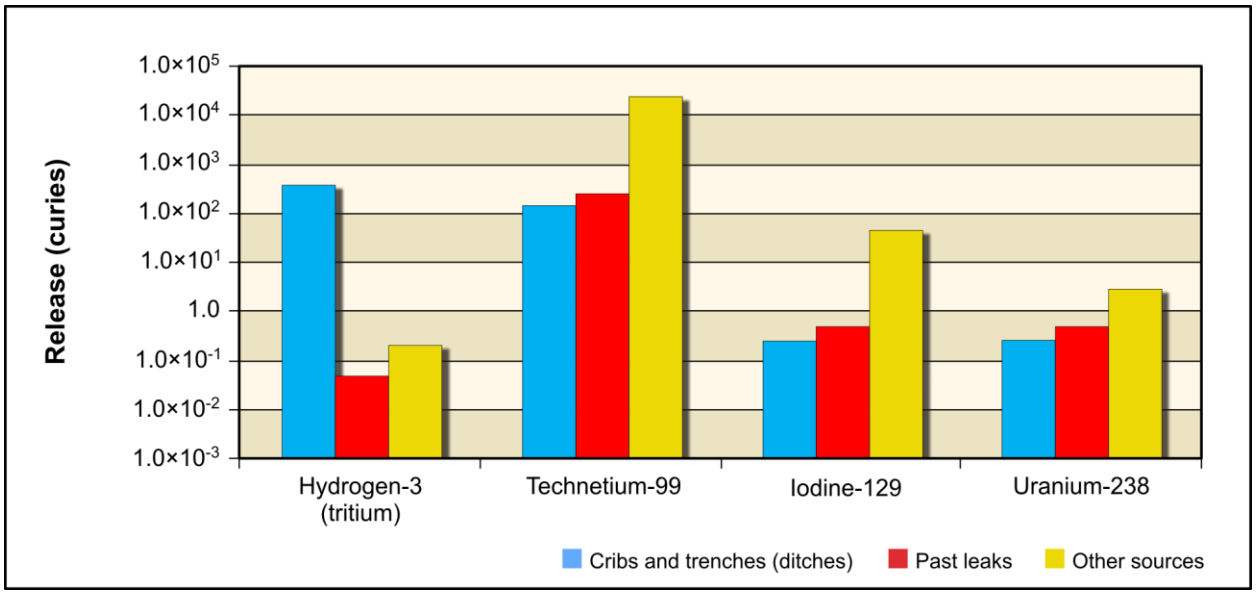


Figure 5–6. Tank Closure Alternative 1 Releases of Radioactive Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

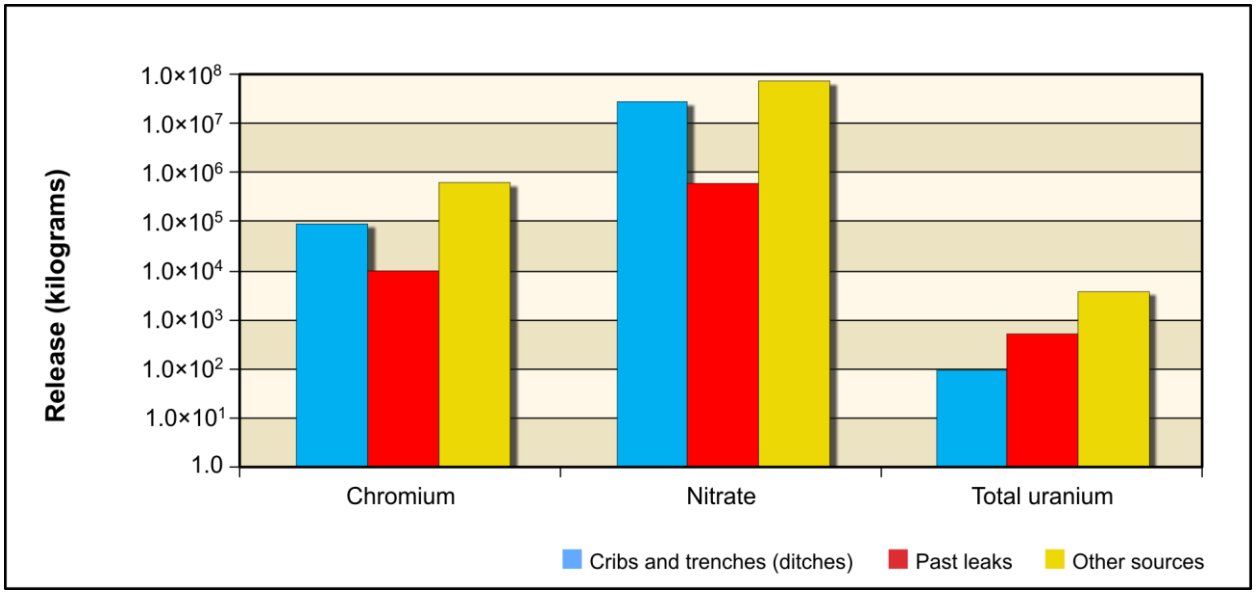


Figure 5–7. Tank Closure Alternative 1 Releases of Chemical Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

For uranium-238 and total uranium, the amount released to the Columbia River is less than that released to groundwater because of retardation. Overall, about 25 percent of the amount released to groundwater during the period of analysis reaches the Columbia River.

For tritium, the amount released to the Columbia River is attenuated by radioactive decay. Overall, only about 1 percent of the tritium released to groundwater reaches 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 nearshore. 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 of each radionuclide and chemical is also shown. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over five orders of magnitude within the same series of figures. 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, note 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 multiple sources (typically on the order of 30) at a variable location (the location of the highest peak concentration along the line of analysis). (See Appendix O, Section O.1, for more-detailed discussion on multiple sources.) Therefore, attempts to simply interpolate or extrapolate 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. The results indicate that technetium-99 and iodine-129 exceed their respective benchmarks at all of the barrier locations, the Core

Zone Boundary, and the Columbia River nearshore. Chromium exceeds the benchmark concentration at all tank farm barriers and the Core Zone Boundary and approaches the benchmark at the Columbia River nearshore. Nitrate exceeds the benchmark at three of the barriers and the Core Zone Boundary but not the Columbia River nearshore. Uranium-238 and total uranium only exceed the benchmark at the B Barrier and the Core Zone Boundary. Uranium-238 and total uranium do not impact the Columbia River nearshore above the benchmark concentration during the 10,000 period of analysis.

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 (picocuries per liter)								
Hydrogen-3 (tritium)	1,820 (2121)	349 (2064)	1,290 (2128)	2,640 (2051)	14 (2050)	639 (2123)	502 (2050)	20,000
Technetium-99	**41,700** (2121)	**26,500** (3957)	**22,800** (3072)	**6,480** (2050)	**9,830** (3985)	**26,500** (3957)	**1,700** (2999)	900
Iodine-129	**38.5** (2123)	**58.8** (3577)	**29.1** (3136)	**26.1** (4560)	**19.6** (4118)	**58.8** (3577)	**6.8** (4840)	1
Uranium isotopes (includes U-233, -234, -235, -238)	5 (11,810)	**32** (11,777)	4 (11,819)	7 (11,799)	6 (11,817)	**32** (11,777)	1 (11,928)	15
Chemical (micrograms per liter)								
Acetonitrile	56 (2126)	9 (3056)	27 (3042)	0 (1940)	0 (3215)	34 (2141)	4 (3120)	100
Chromium	**323** (3710)	**864** (3882)	**541** (3242)	**336** (2036)	**208** (4027)	**864** (3882)	84 (4498)	100
Nitrate	**46,900** (2136)	**187,000** (2066)	37,900 (3435)	**62,000** (2056)	22,500 (3957)	**187,000** (2066)	16,200 (2111)	45,000
Total uranium	7 (11,823)	**41** (11,778)	5 (11,827)	9 (11,840)	8 (11,816)	**41** (11,778)	1 (11,931)	30

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 Core Zone Boundary groundwater concentrations to exceed benchmark concentrations by one to two orders of magnitude for a short period of time during the early part of the period of analysis. This time period is represented by the first series of sharp inflections in the curve for the Core Zone Boundary from approximately CY 1955 until CY 1980. During this time, groundwater concentrations at the Columbia River nearshore approach the benchmark concentration. The later broad inflection occurring in about CY 2100 represents the beginning of the tritium contribution from tank residuals. 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.

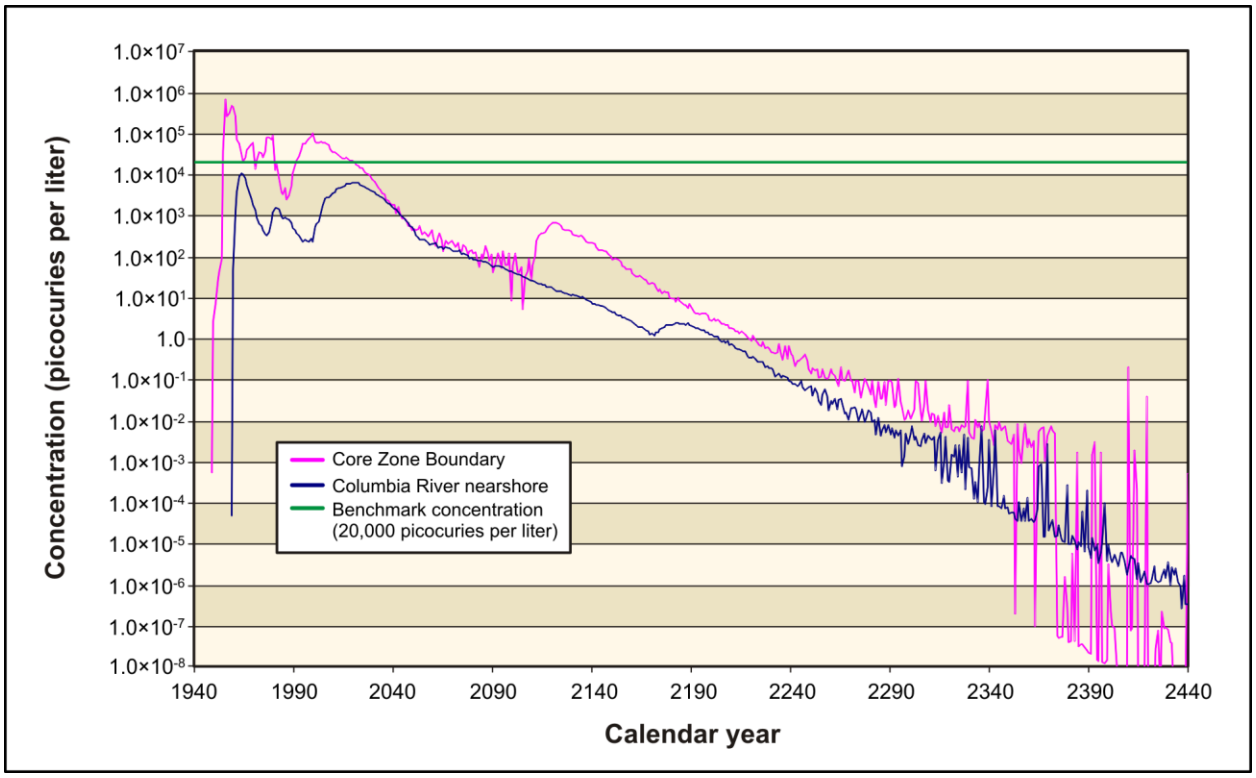


Figure 5–8. Tank Closure Alternative 1 Hydrogen-3 (Tritium) Concentration Versus Time

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 at the Core Zone Boundary to exceed benchmark concentrations by about one to two orders of magnitude during the early part of the period of analysis. This early time period is represented by the multiple sharp inflections in the Core Zone Boundary curve that occur approximately between CYs 1955 and 1980. The iodine-129 signature also occurs at the Columbia River nearshore at a later time. During this time period, groundwater concentrations at the Columbia River nearshore briefly reach the benchmark concentration. The next peak in the Core Zone Boundary curve that forms a single broader inflection at approximately CY 2005 is the signature of the tank leak contribution of iodine-129. The benchmark concentration is exceeded by less than an order of magnitude. The iodine-129 signature is echoed in the Columbia River nearshore curve but occurs at a concentration just above the benchmark and at a later time because of the increased travel distance from the Core Zone Boundary to the Columbia River nearshore. Releases from other tank farm sources cause groundwater concentrations to exceed benchmark concentrations by one to two orders of magnitude. The dominant contributor of iodine-129 from the other tank farm sources is the tank residuals. Tank residuals are represented by a sharp increase in concentration occurring at the Core Zone Boundary beginning in CY 2107, followed by a long period of elevated concentrations that exceed the benchmark by one to two orders of magnitude. The signature of the tank farm residual release is echoed in the Columbia River nearshore curve but is delayed and peaks at a concentration less than an order of magnitude above the benchmark. Both the Core Zone Boundary and Columbia River nearshore concentration curves taper off to below the benchmark concentration around CY 7500. Technetium-99, chromium, and nitrate concentrations show similar curves, where concentrations are approximately equivalent to the benchmark during the time period of releases from cribs and trenches (ditches).

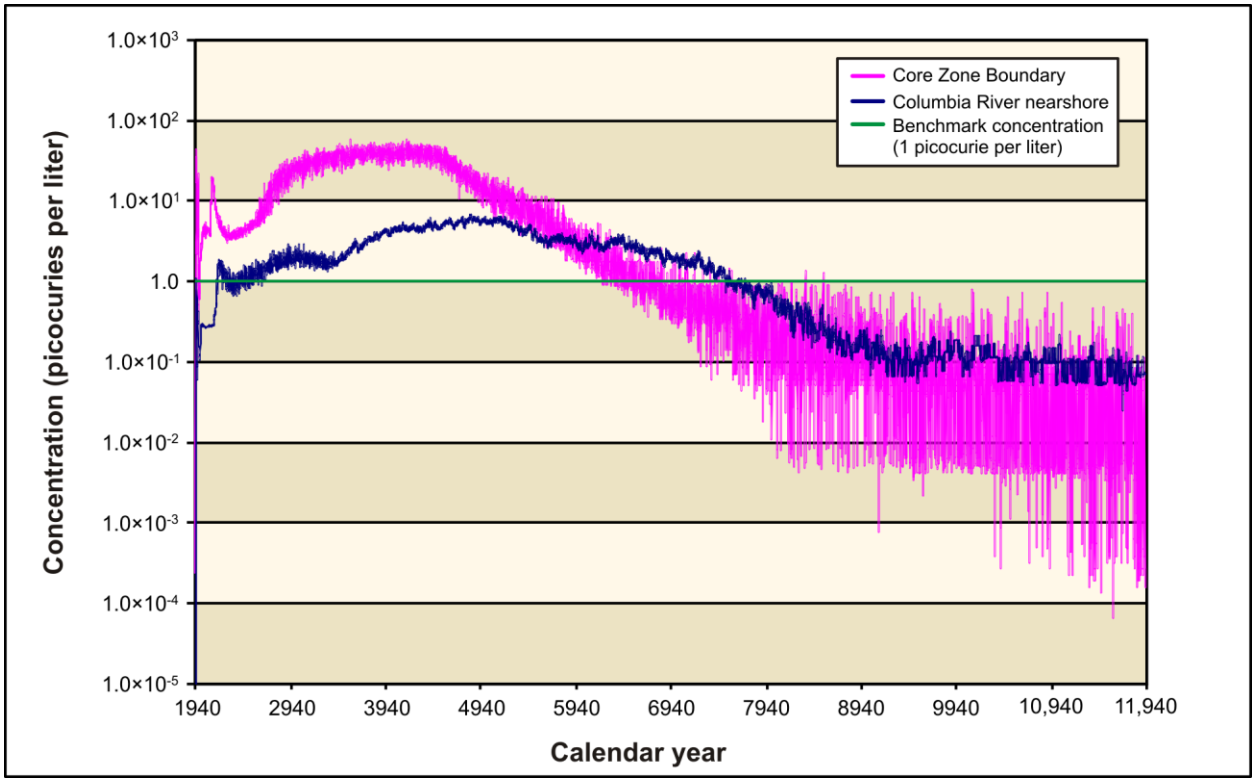


Figure 5–9. Tank Closure Alternative 1 Iodine-129 Concentration Versus Time

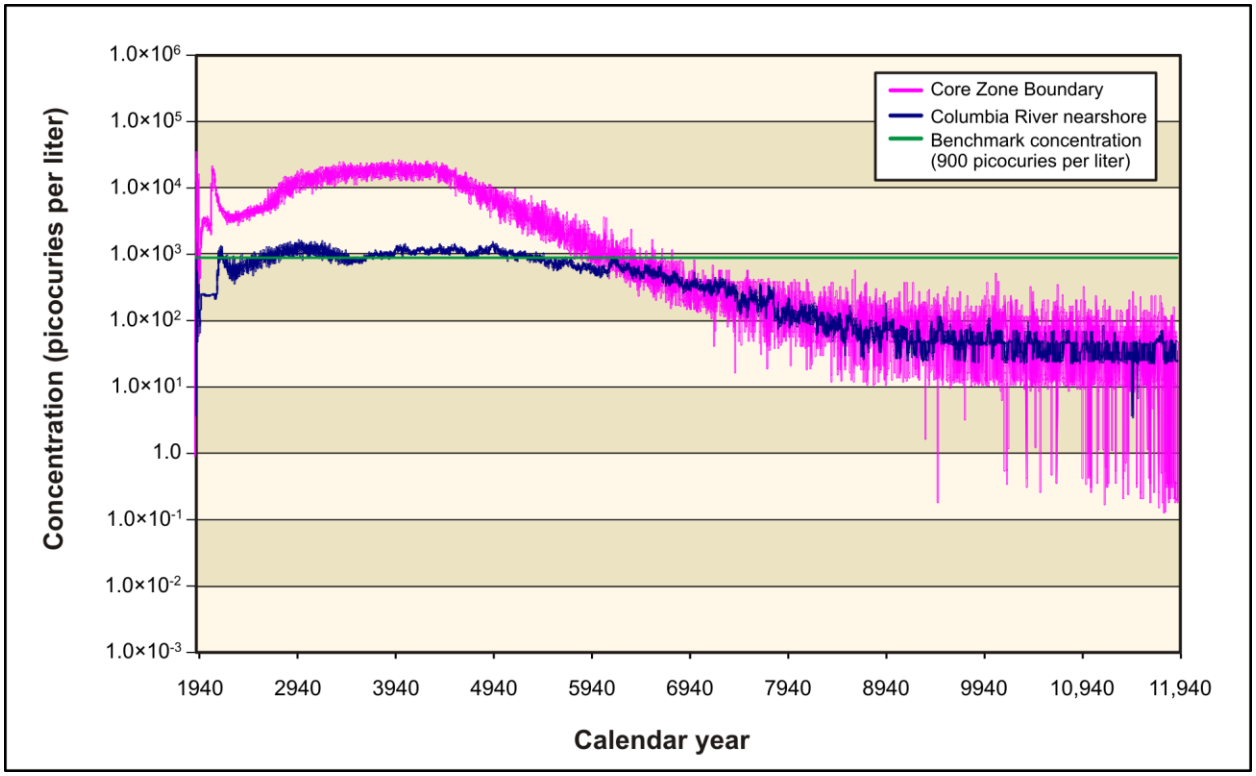


Figure 5–10. Tank Closure Alternative 1 Technetium-99 Concentration Versus Time

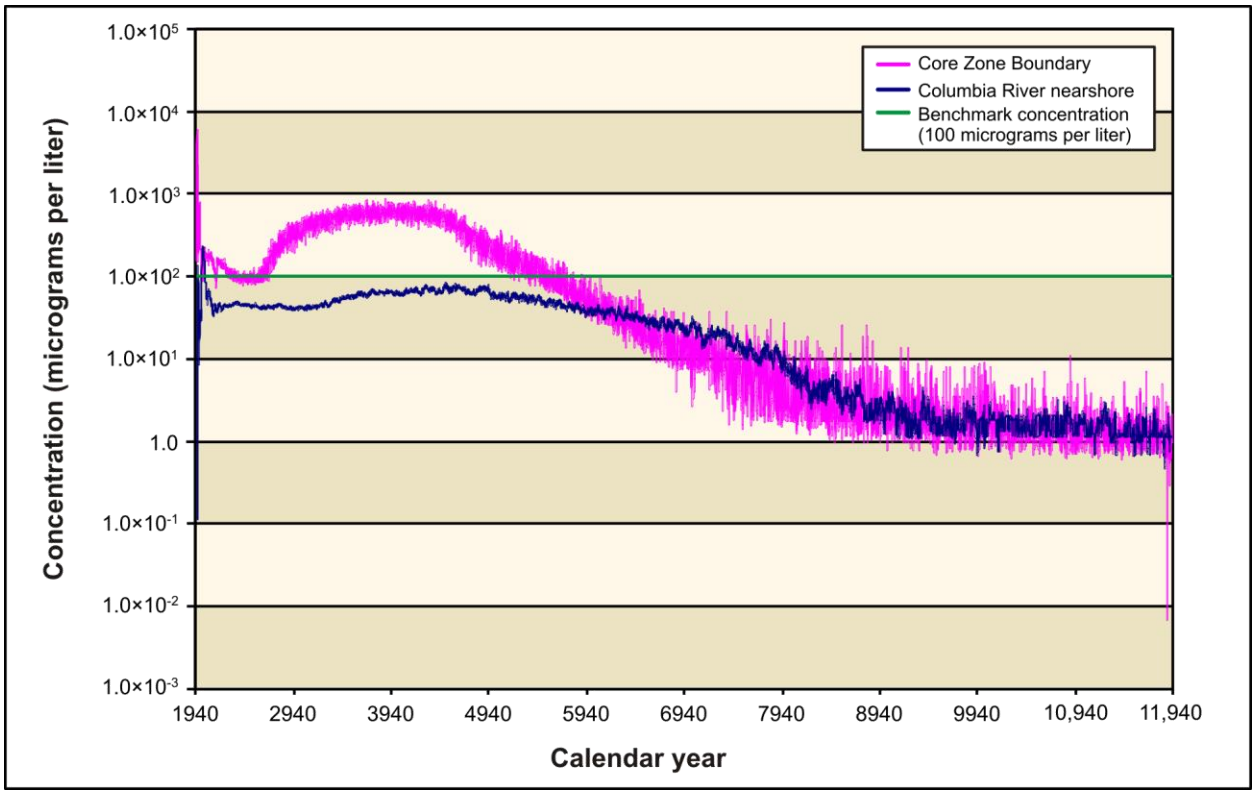


Figure 5–11. Tank Closure Alternative 1 Chromium Concentration Versus Time

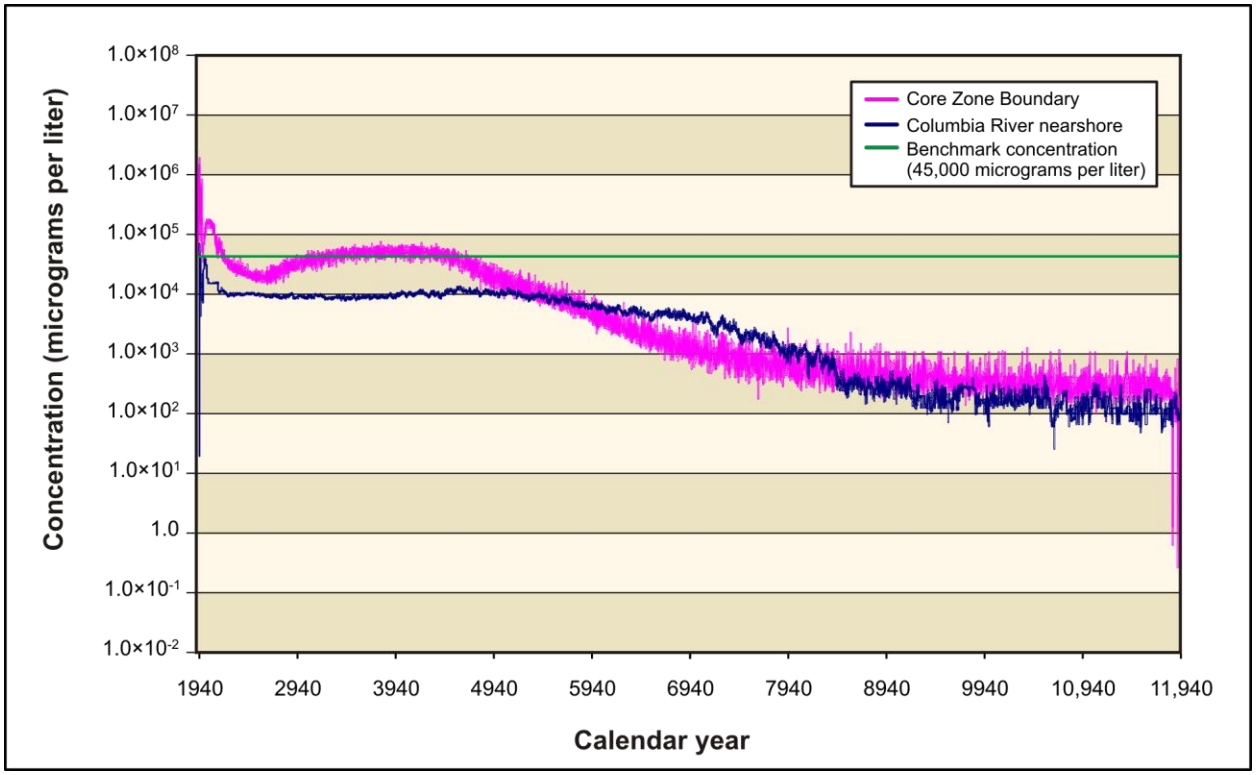


Figure 5–12. Tank Closure Alternative 1 Nitrate Concentration Versus Time

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 approximately two orders of magnitude lower than benchmark concentrations. Releases from other tank farm sources cause groundwater concentrations to rise, surpassing benchmark concentrations around CY 11,000. Groundwater concentrations at the Columbia River nearshore rise throughout the period of analysis, but remain one to two orders of magnitude below the benchmark concentration by CY 11,940.

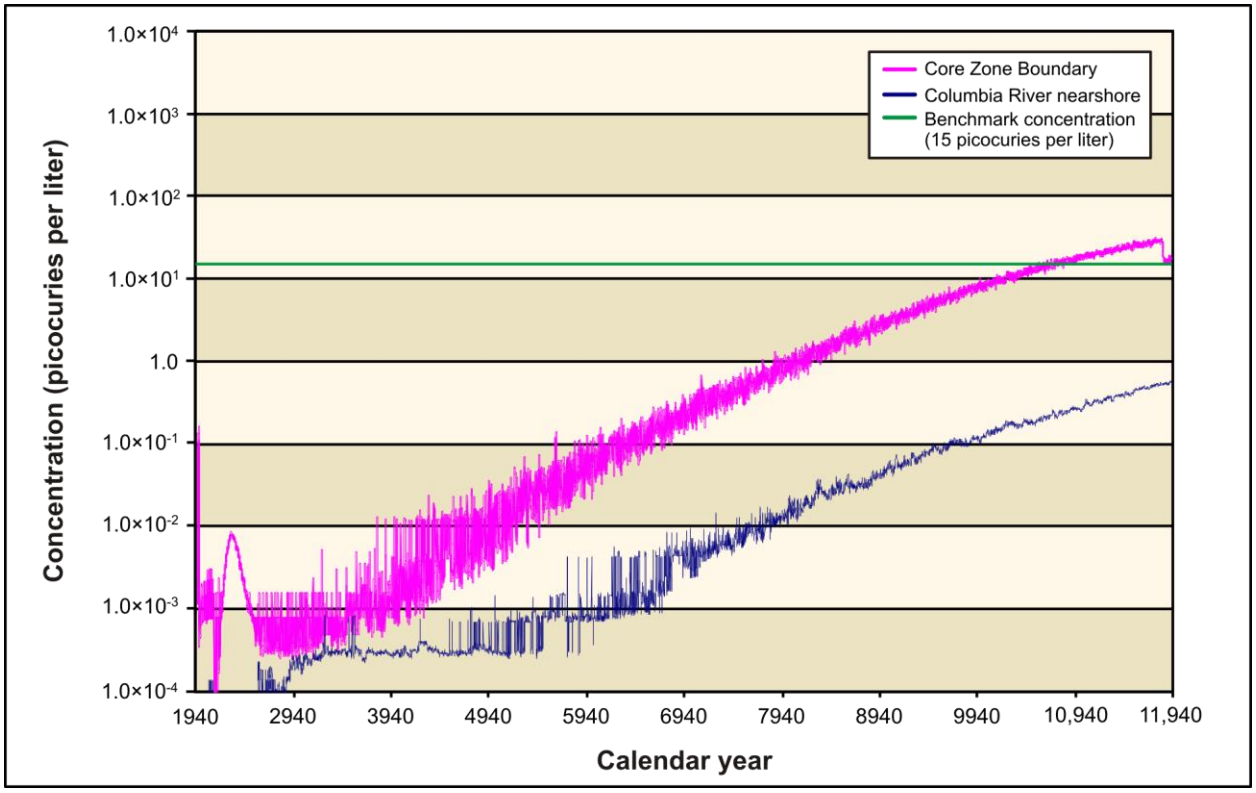


Figure 5–13. Tank Closure Alternative 1 Uranium-238 Concentration Versus Time

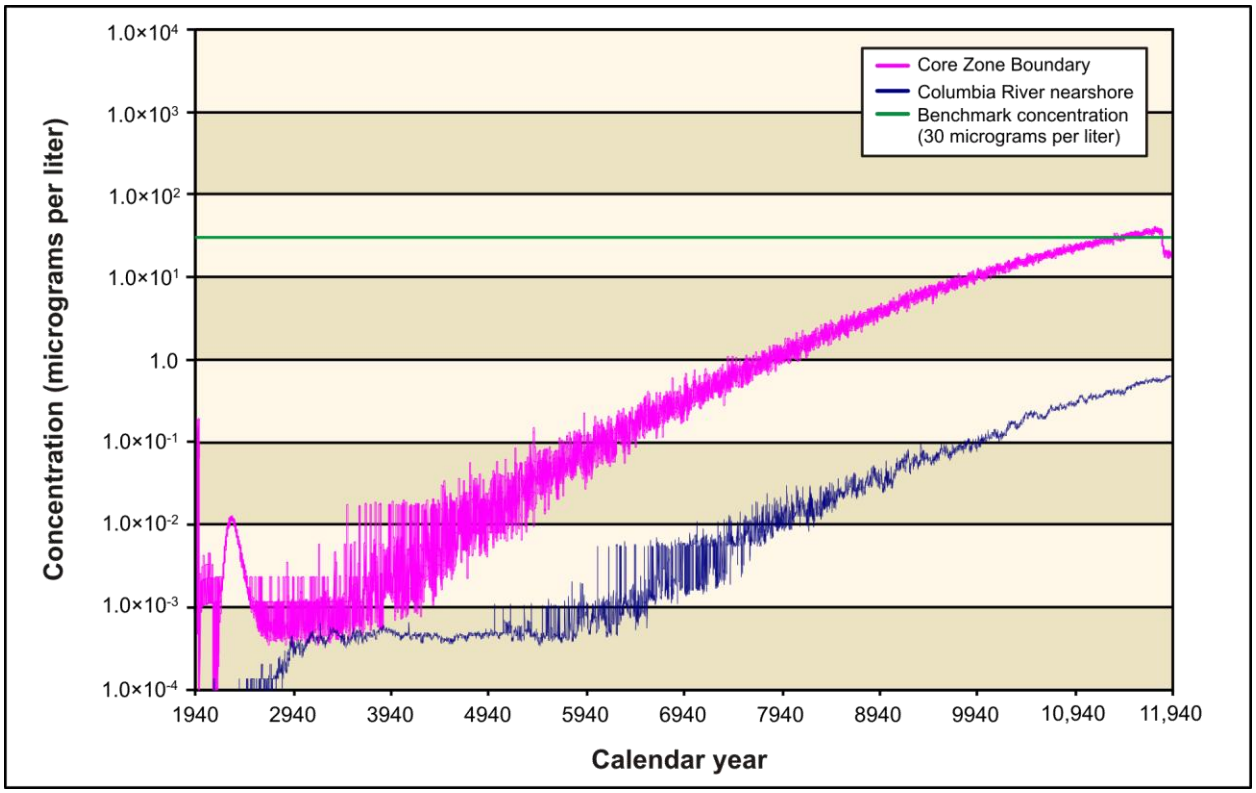
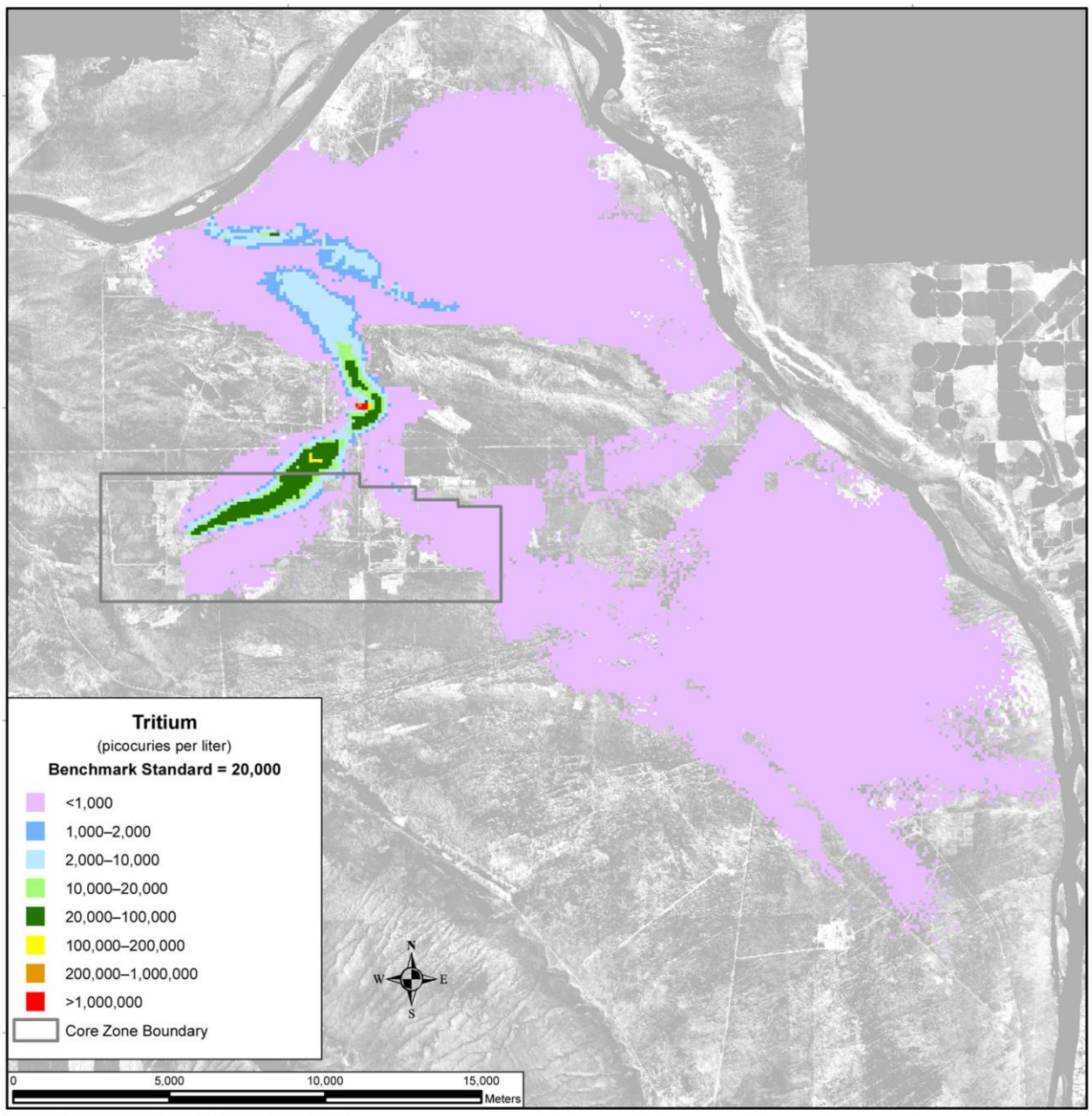


Figure 5–14. Tank Closure Alternative 1 Total Uranium Concentration Versus Time

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 COPC driver concentrations in groundwater at selected times. Concentrations of radionuclides are in picocuries per liter; chemicals, in micrograms per liter (see Figures 5–15 through 5–36). Concentrations of 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 the "benchmark standard" 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 tritium concentrations in groundwater in CY 2010. 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, crosses the Core Zone Boundary, and continues toward the Gable Mountain–Gable Butte Gap (Gable Gap). Peak concentrations in this plume are about 5 to 10 times greater than the benchmark and are 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 indicated by Figure 5–8.

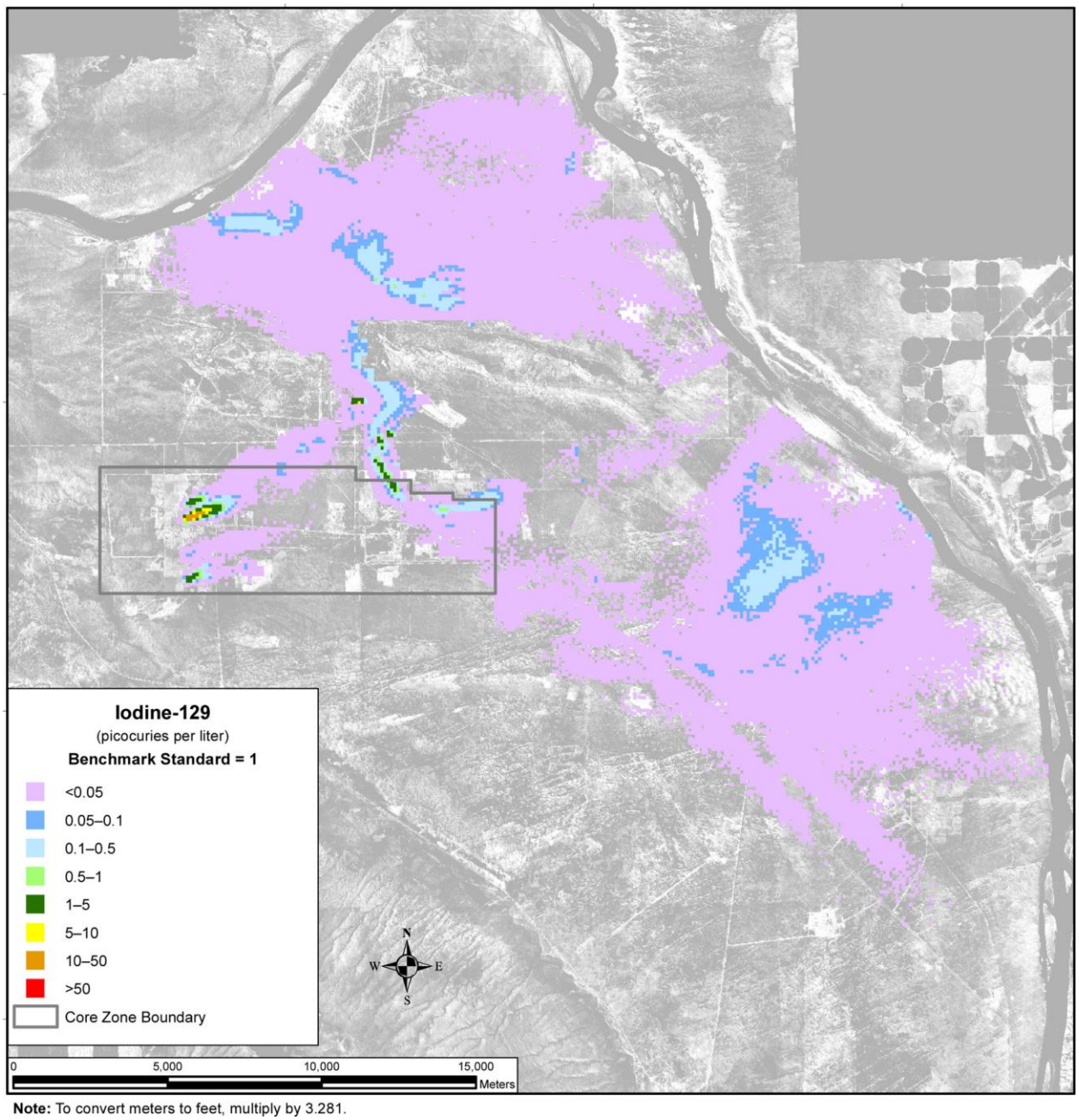


Note: To convert meters to feet, multiply by 3.281.

Figure 5–15. Tank Closure Alternative 1 Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration, Calendar Year 2010

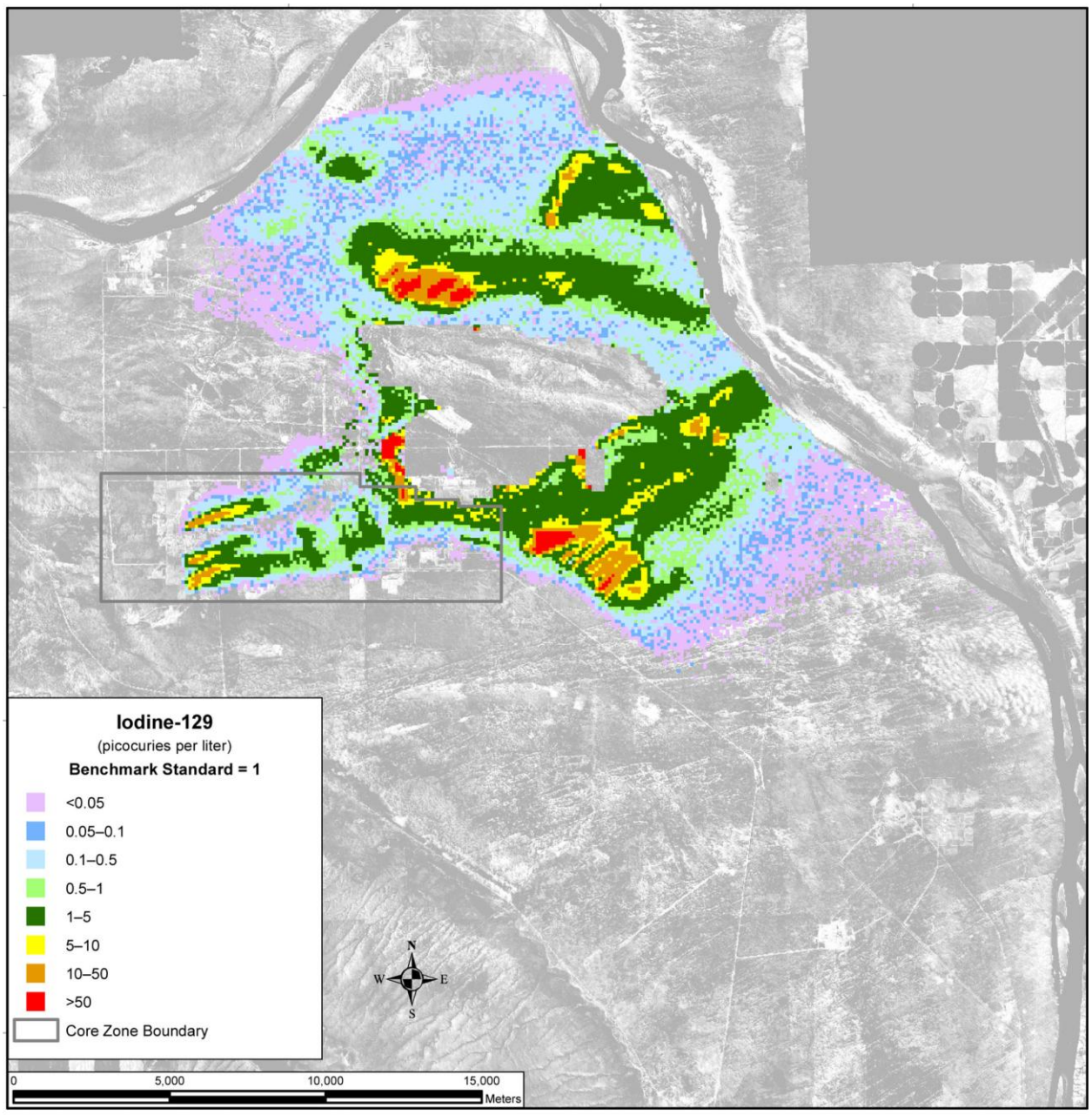
Figure 5–16 shows the spatial distribution of iodine-129 concentrations in groundwater in CY 2010. Releases from cribs and trenches (ditches) and past leaks result in groundwater concentration plumes that are at or exceed the benchmark concentration at the A, B, and T Barriers. Peak concentrations in this plume are about 10 to 50 times greater than the benchmark and are mostly contained within the Core Zone Boundary. Around CY 3890, releases from other tank farm sources create a large plume with peak concentrations over 50 times greater than the benchmark, extending from the A Barrier to the Columbia River. During this same time, a plume is evident that extends from the Core Zone Boundary north through Gable Gap (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 5–22 show the spatial distribution of technetium-99 concentrations in groundwater in the same years presented for iodine-129, CYs 2010, 3890, and 7140. Figure 5–23 shows 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.



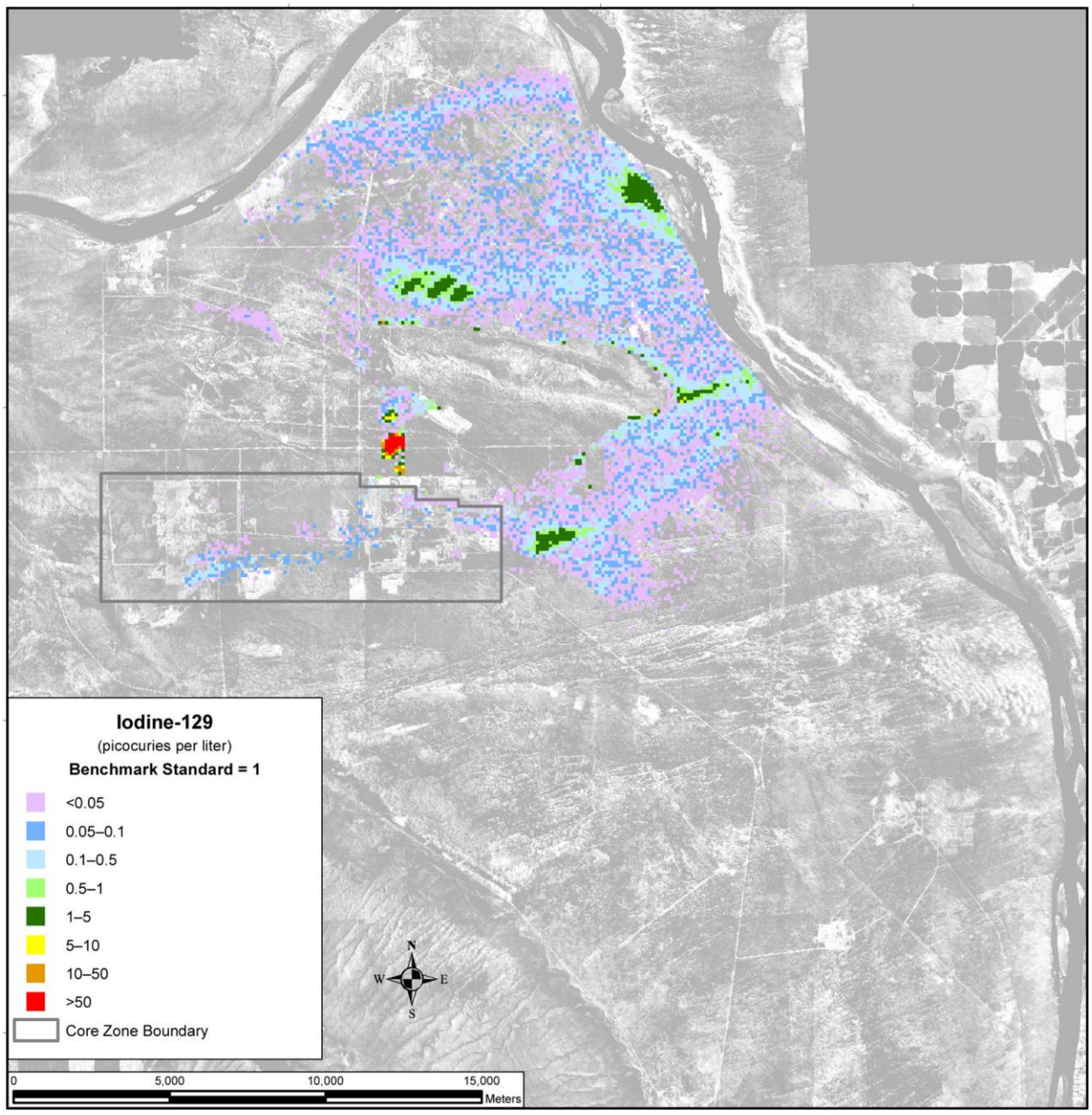
Note: To convert meters to feet, multiply by 3.281.

Figure 5–16. Tank Closure Alternative 1 Spatial Distribution of Groundwater Iodine-129 Concentration, Calendar Year 2010



Note: To convert meters to feet, multiply by 3.281.

Figure 5–17. Tank Closure Alternative 1 Spatial Distribution of Groundwater Iodine-129 Concentration, 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, Calendar Year 7140

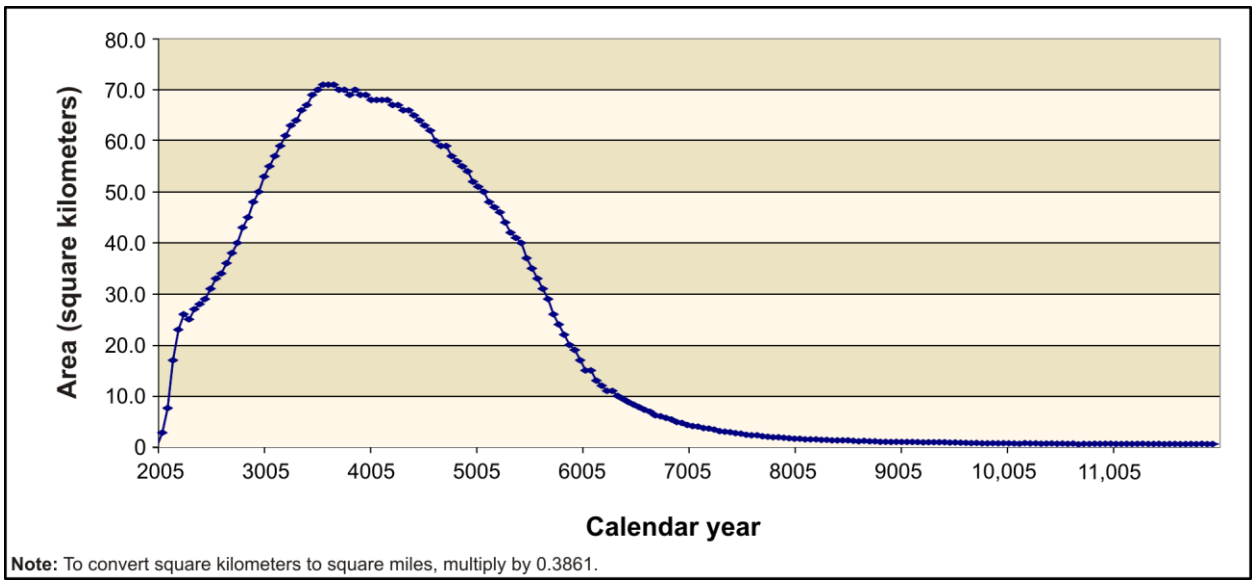
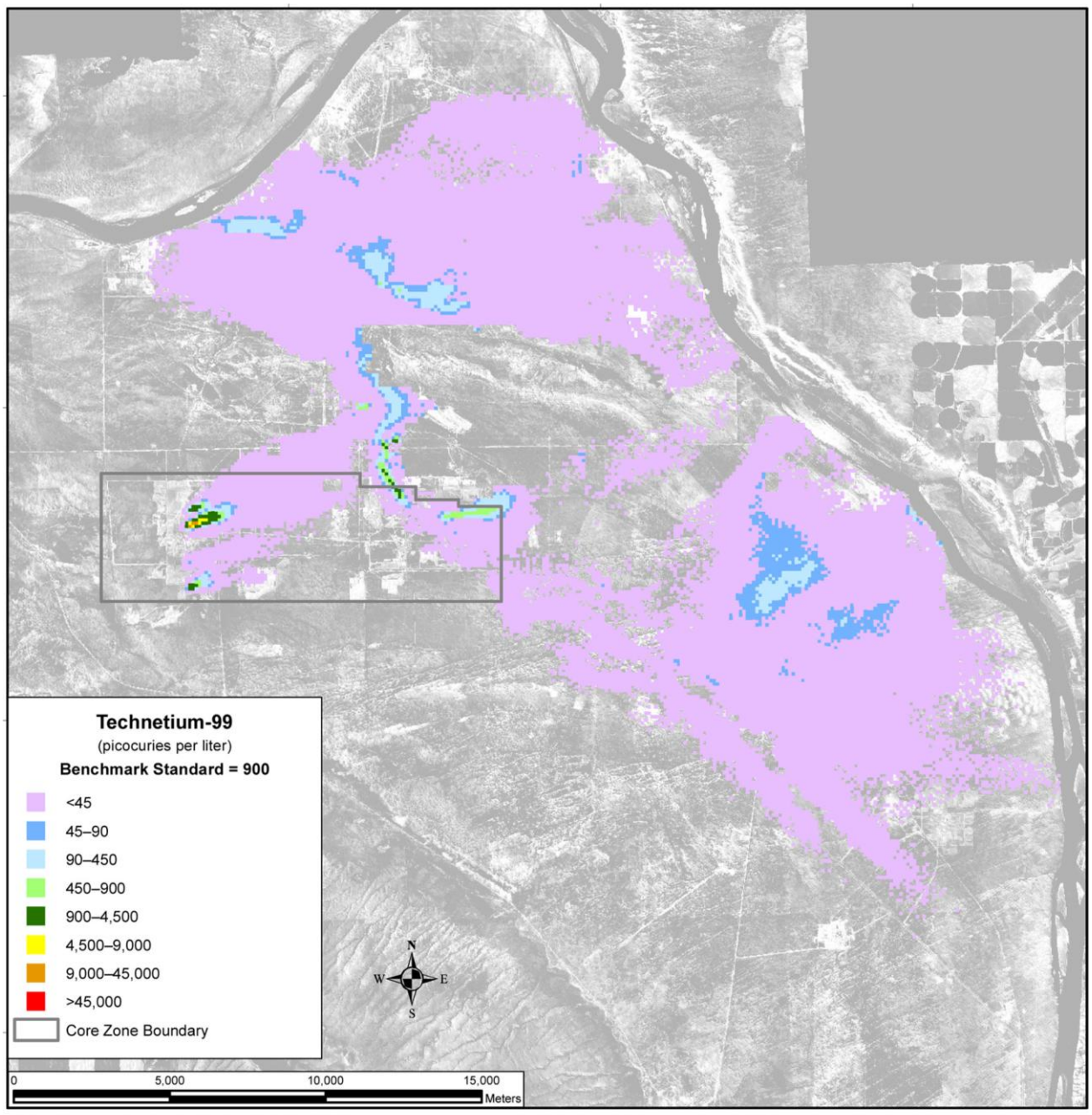
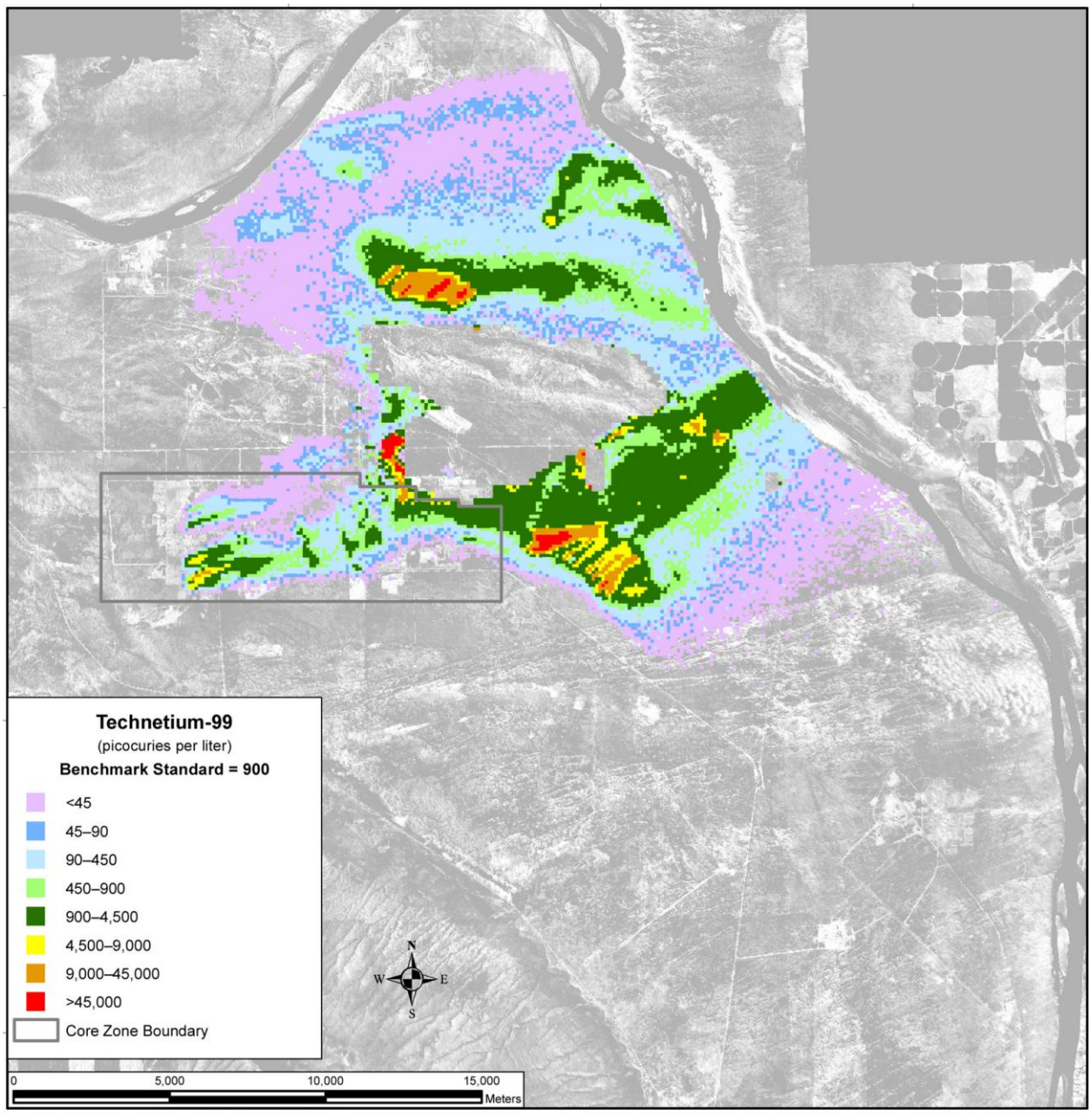


Figure 5–19. Tank Closure Alternative 1 Total Area of Groundwater Iodine-129 Concentration Exceeding the Benchmark Concentration as a Function of Time



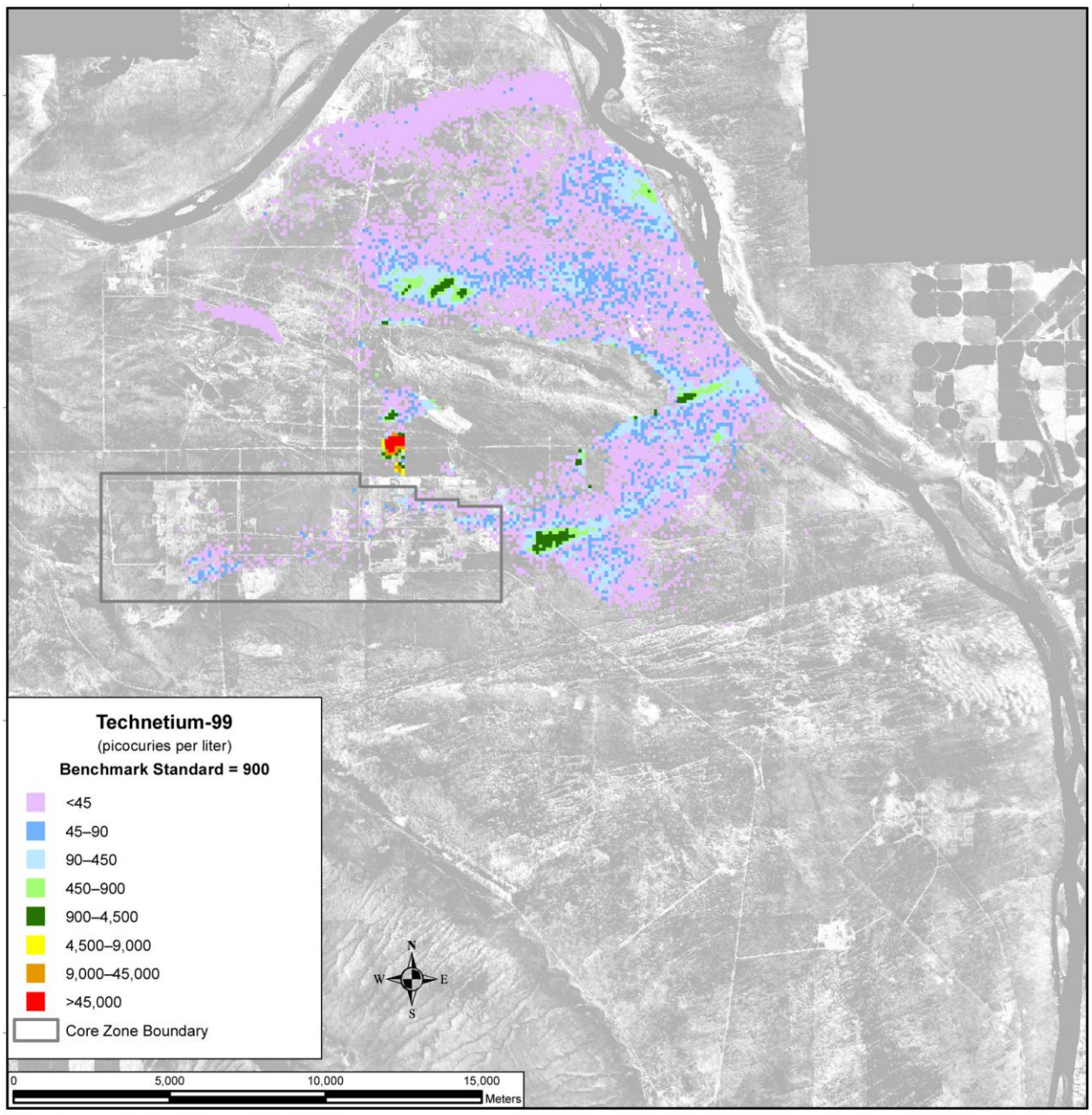
Note: To convert meters to feet, multiply by 3.281.

Figure 5–20. Tank Closure Alternative 1 Spatial Distribution of Groundwater Technetium-99 Concentration, Calendar Year 2010



Note: To convert meters to feet, multiply by 3.281.

Figure 5–21. Tank Closure Alternative 1 Spatial Distribution of Groundwater Technetium-99 Concentration, 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, Calendar Year 7140

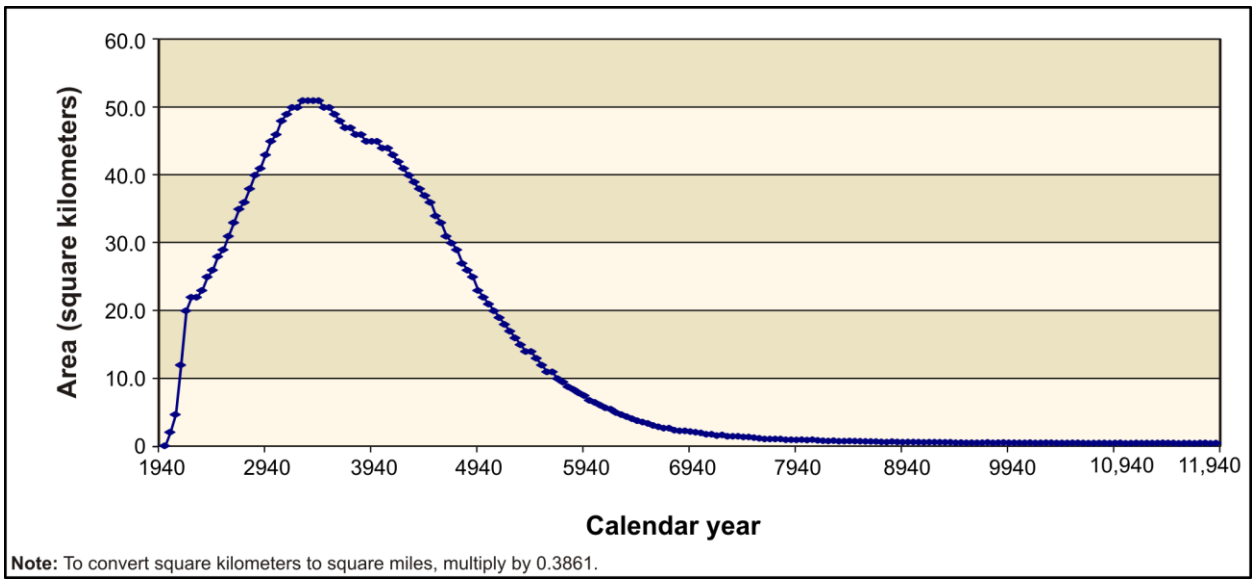
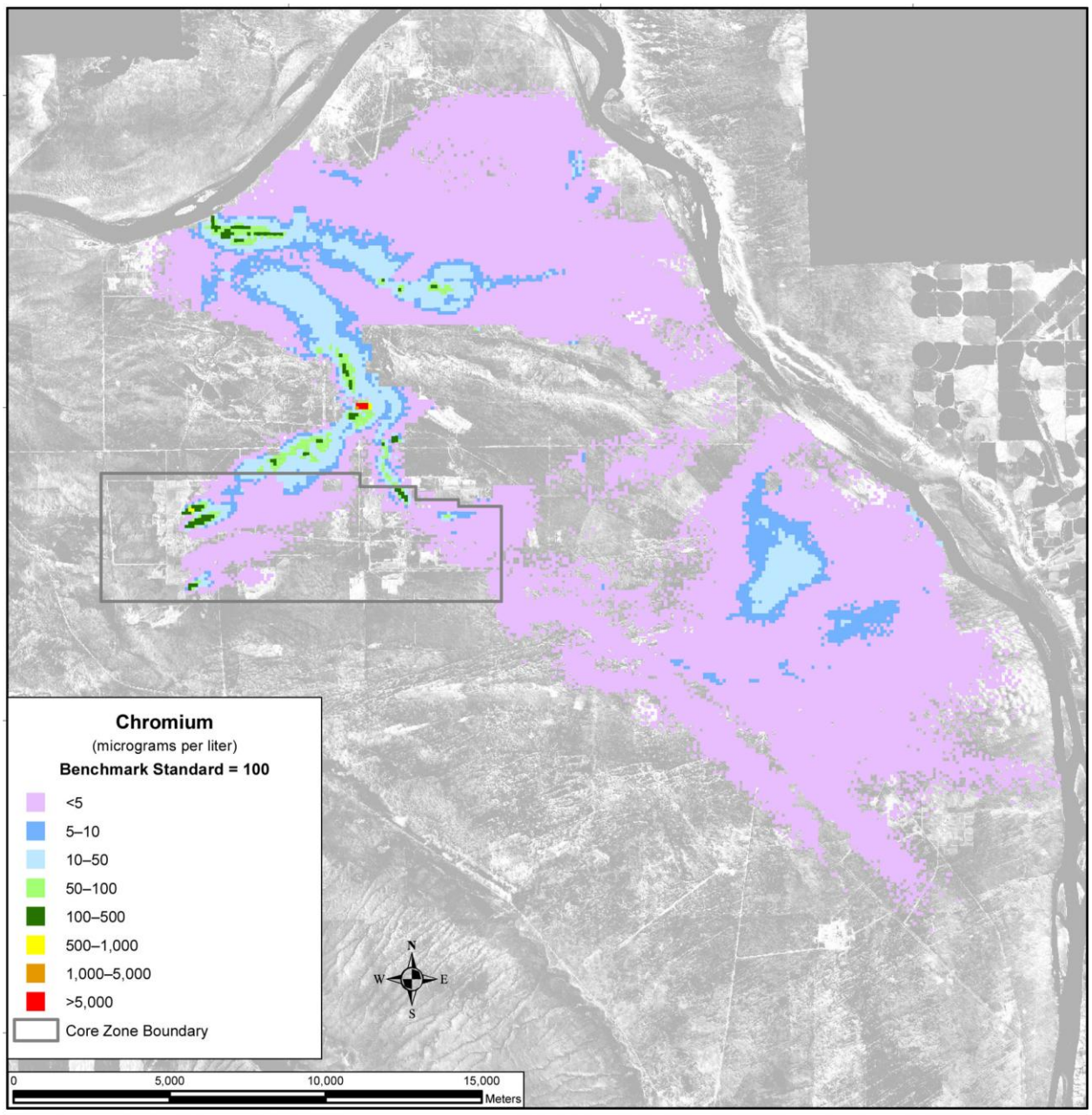
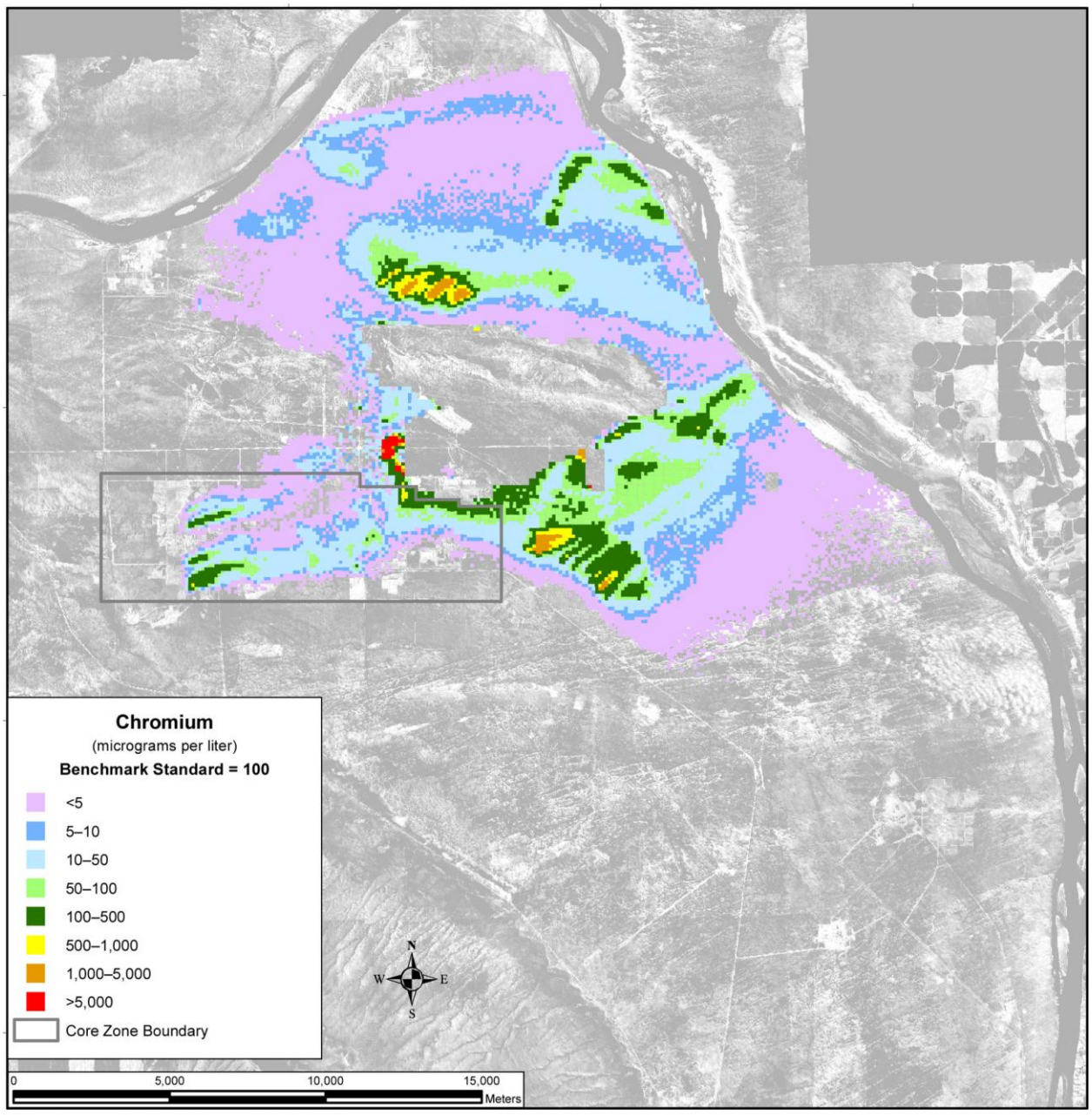


Figure 5–23. Tank Closure Alternative 1 Total Area of Groundwater Technetium-99 Concentration Exceeding the Benchmark Concentration as a Function of Time



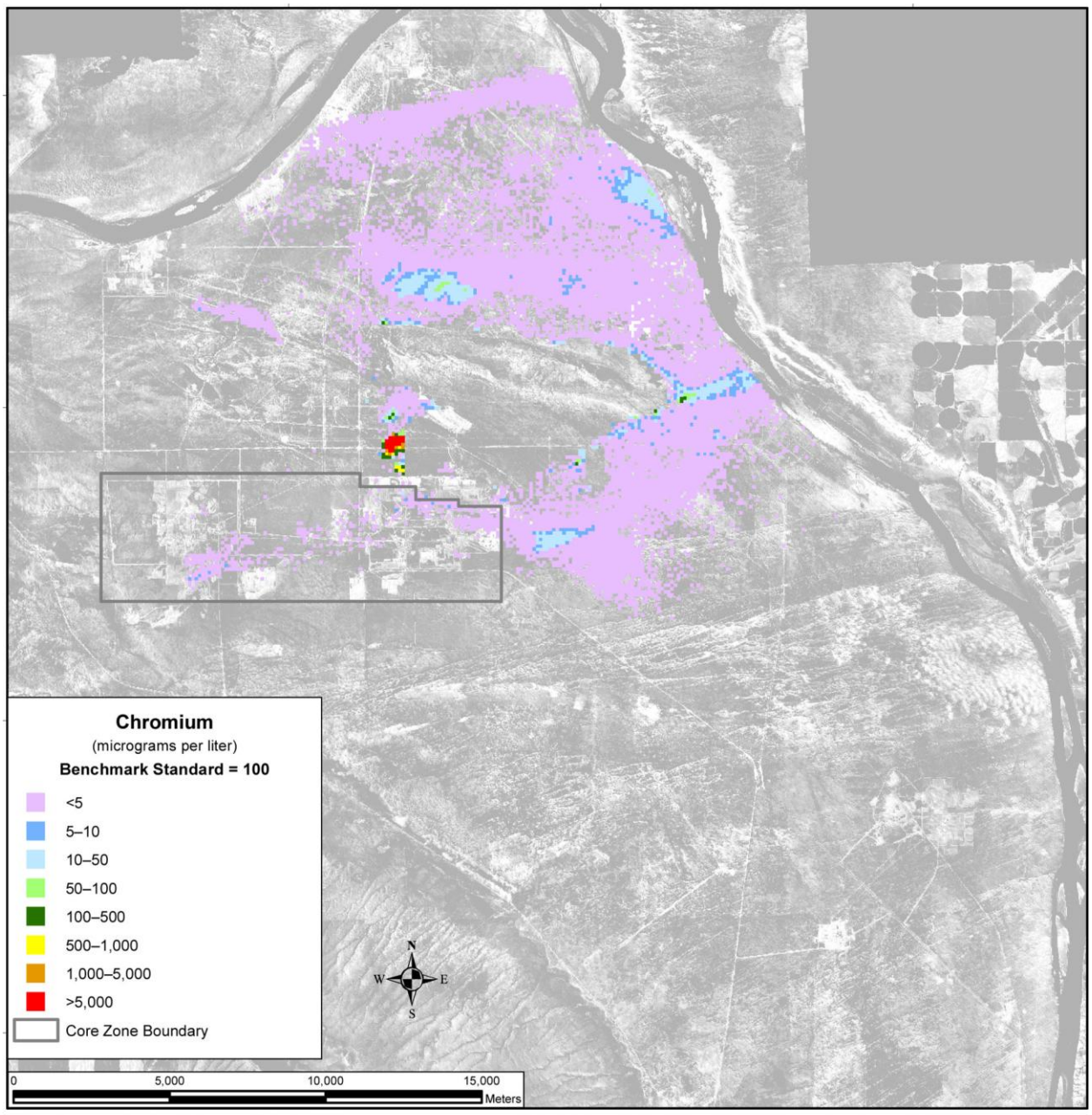
Note: To convert meters to feet, multiply by 3.281.

Figure 5–24. Tank Closure Alternative 1 Spatial Distribution of Groundwater Chromium Concentration, Calendar Year 2010



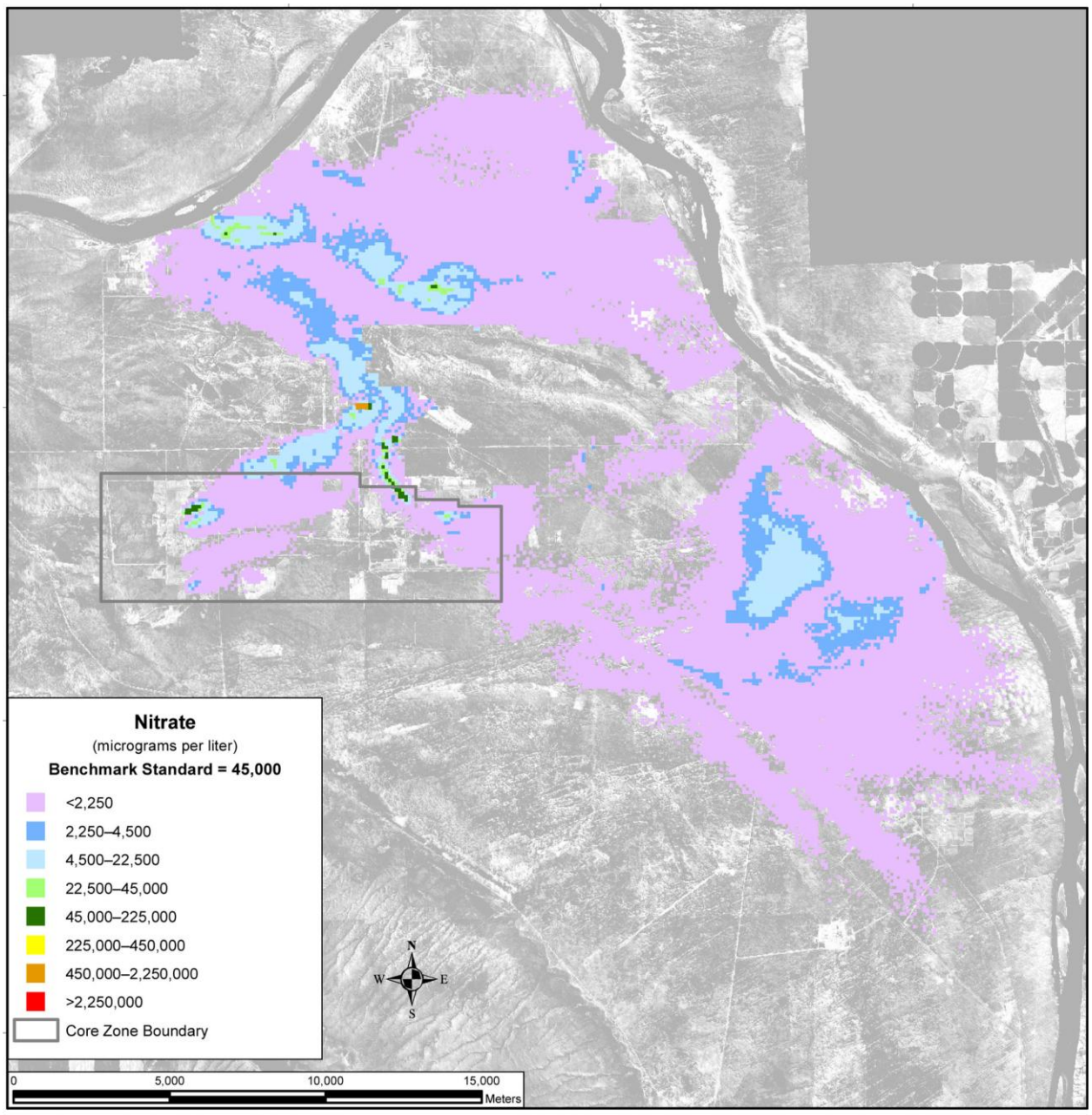
Note: To convert meters to feet, multiply by 3.281.

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



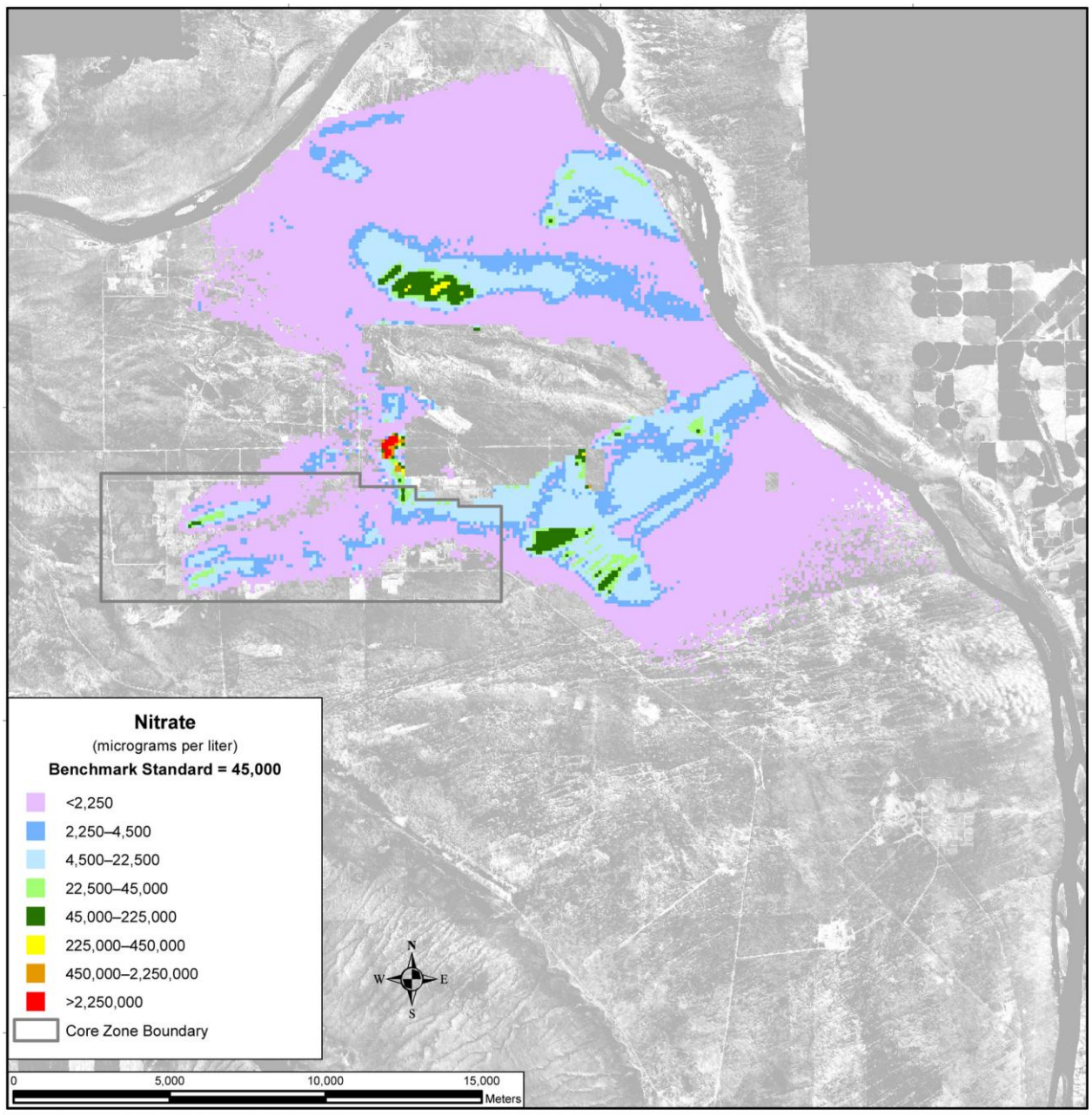
Note: To convert meters to feet, multiply by 3.281.

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



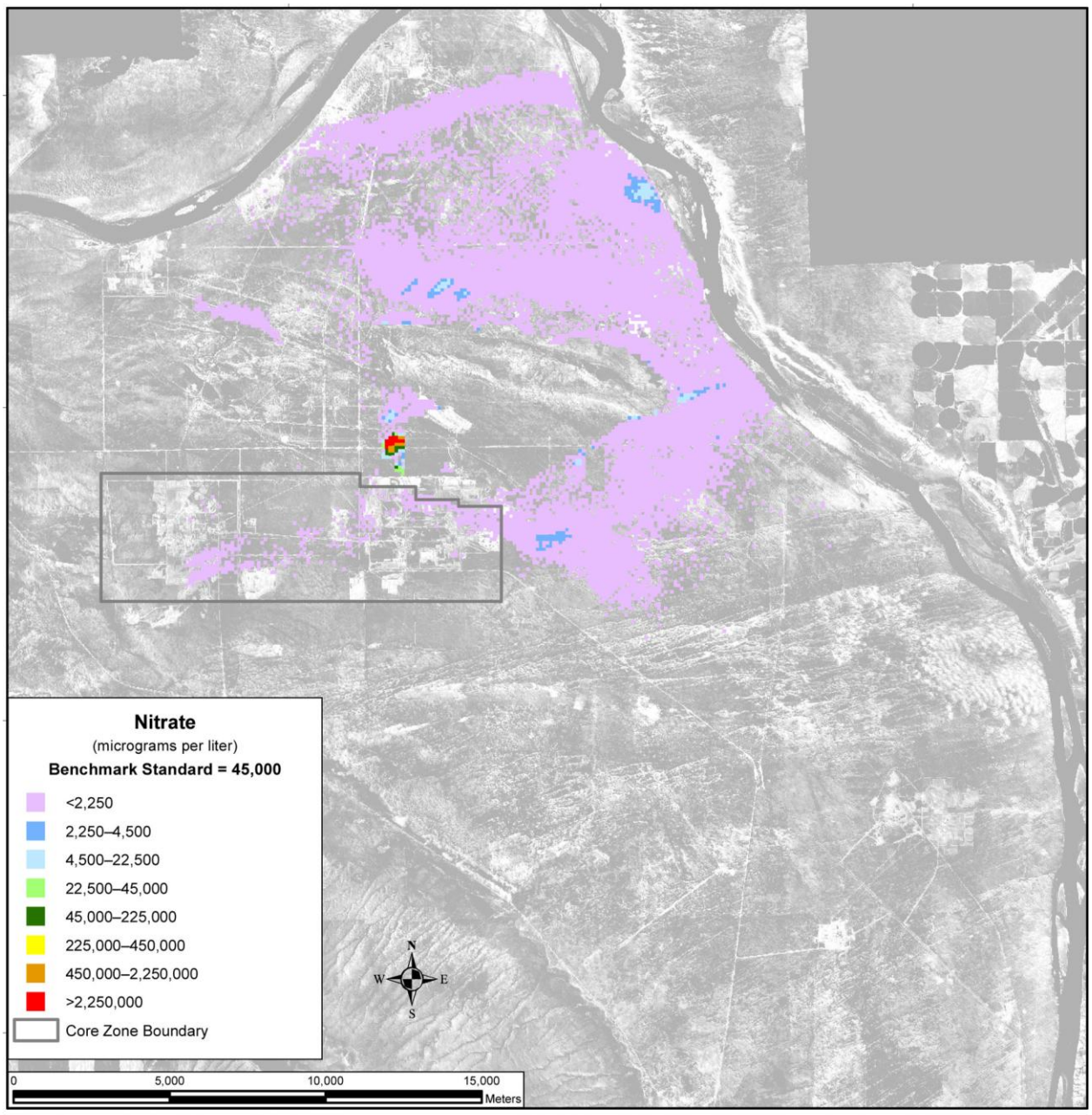
Note: To convert meters to feet, multiply by 3.281.

Figure 5–27. Tank Closure Alternative 1 Spatial Distribution of Groundwater Nitrate Concentration, Calendar Year 2010



Note: To convert meters to feet, multiply by 3.281.

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

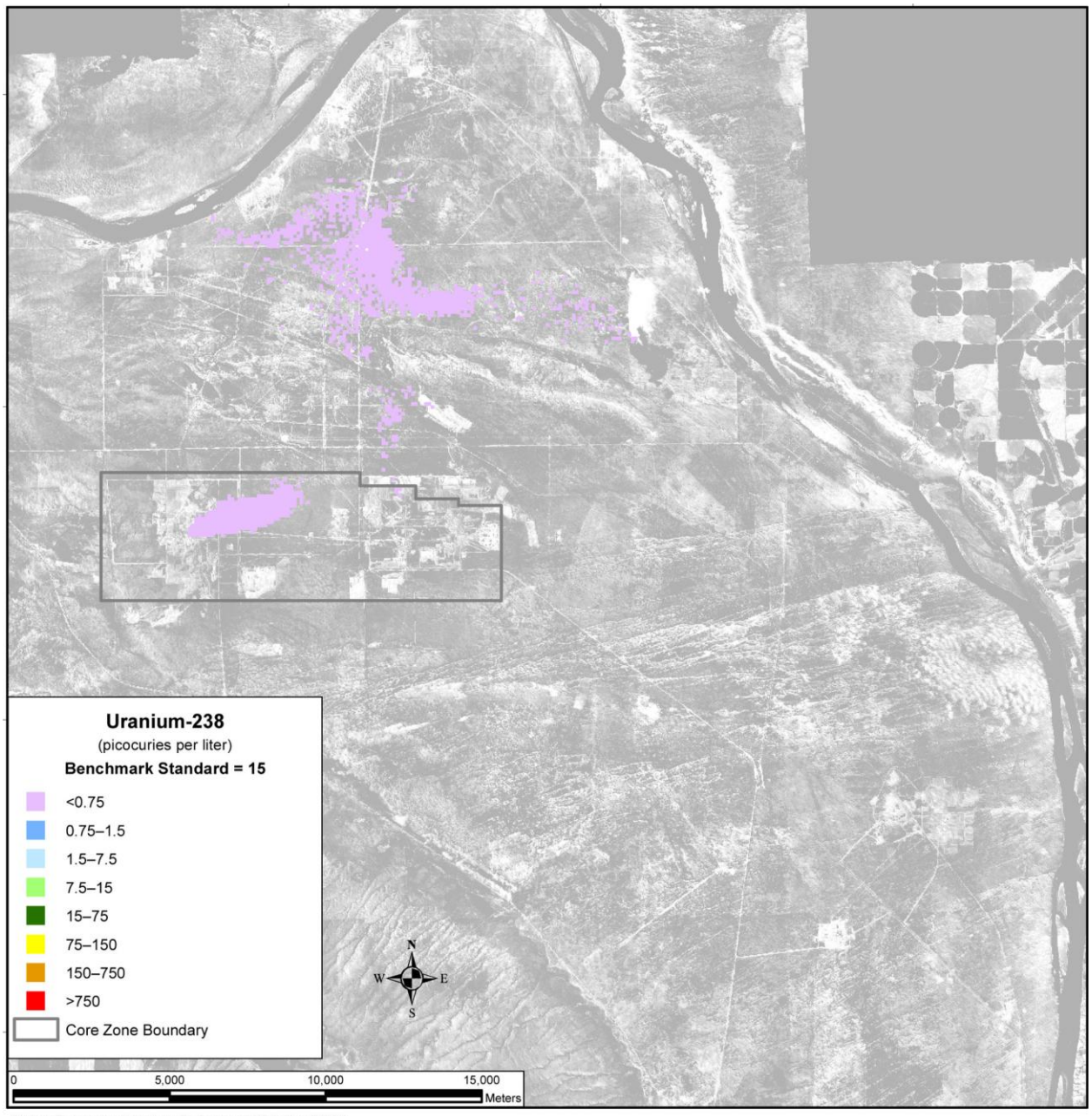


Note: To convert meters to feet, multiply by 3.281.

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

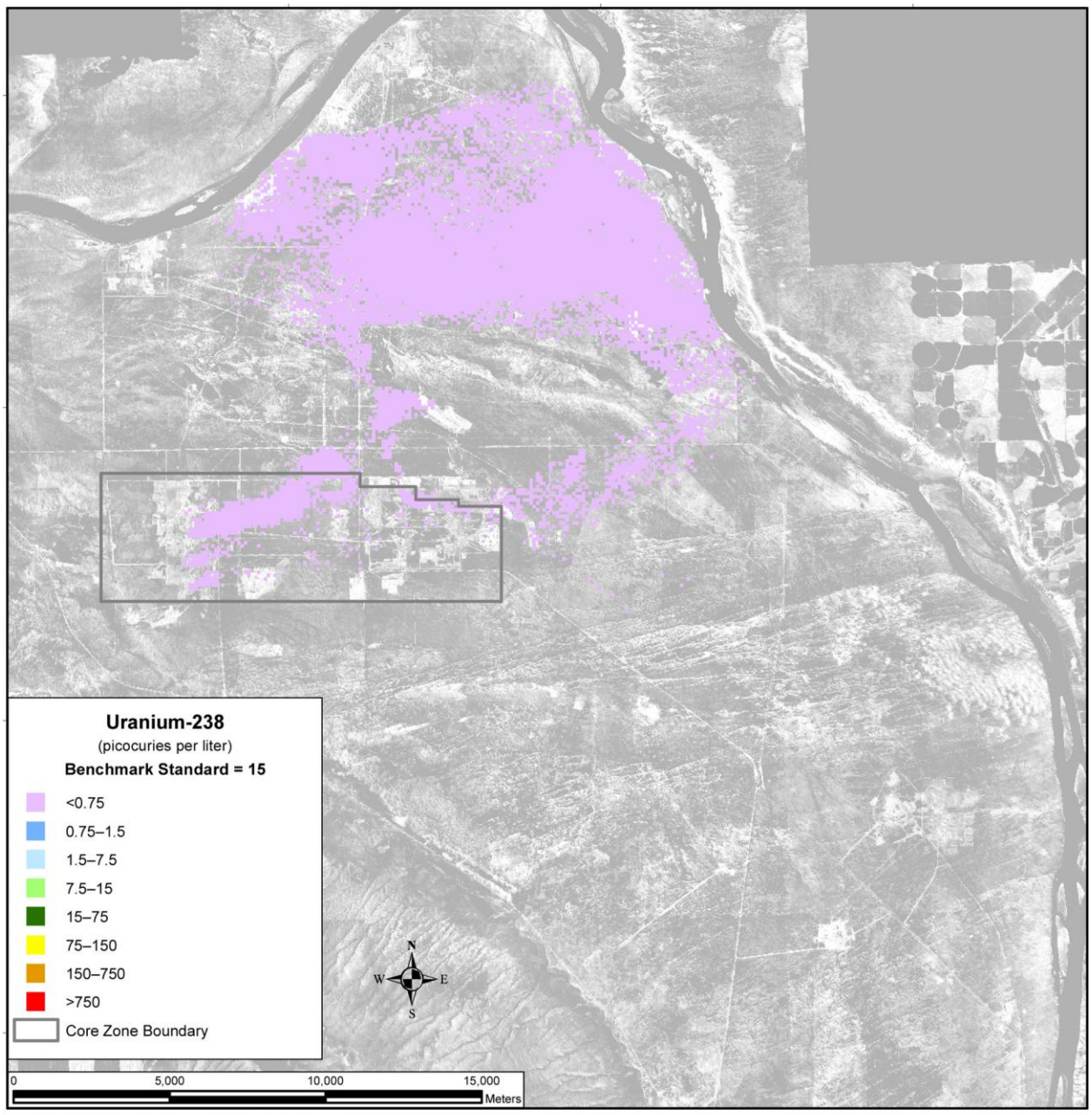
Uranium-238 and total uranium show a different spatial distribution in the analysis over time. These COPCs are not as mobile as those discussed above, moving about seven times more slowly than the pore-water velocity. In addition, the aqueous concentrations of these constituents are attenuated by interaction with the solid phase aquifer materials. 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 in CY 2135. There is a small plume associated with releases from cribs and trenches (ditches) and past leaks at the T Barrier that is less than one-twentieth of the benchmark concentration; this plume occurs from the Core Zone Boundary and extends to the north side of Gable Mountain. By CY 3890 (see Figure 5–31), the area of the plume has grown, but there are no significant increases in peak concentration. In CY 11,940 (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.



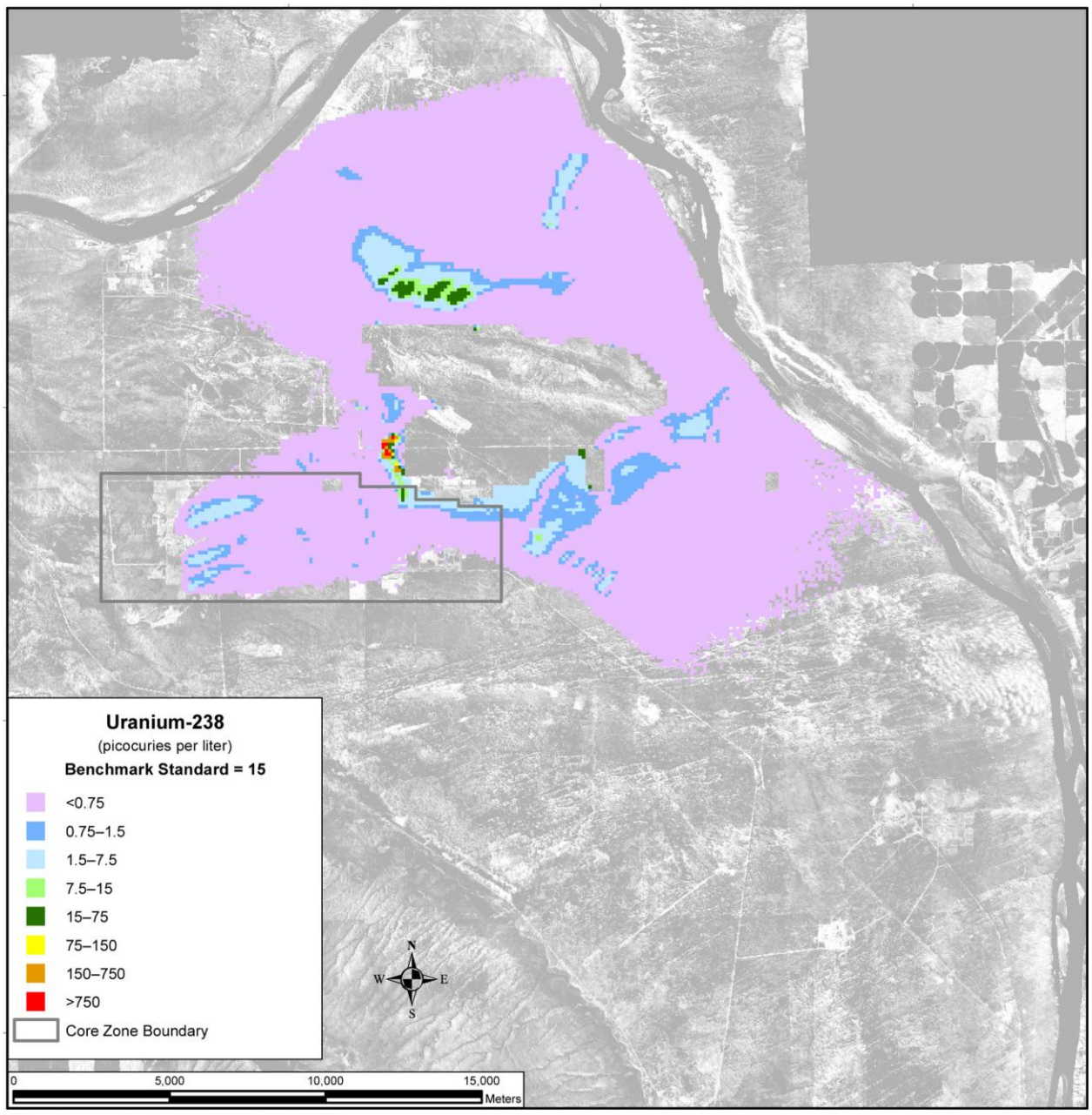
Note: To convert meters to feet, multiply by 3.281.

Figure 5–30. Tank Closure Alternative 1 Spatial Distribution of Groundwater Uranium-238 Concentration, 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, 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, Calendar Year 11,940

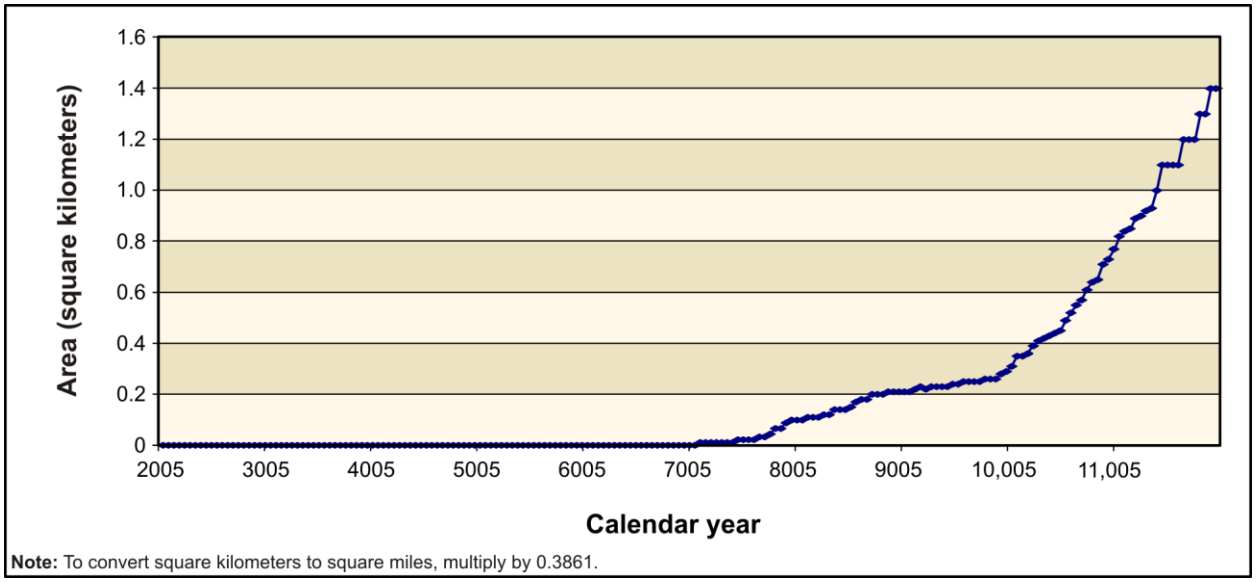
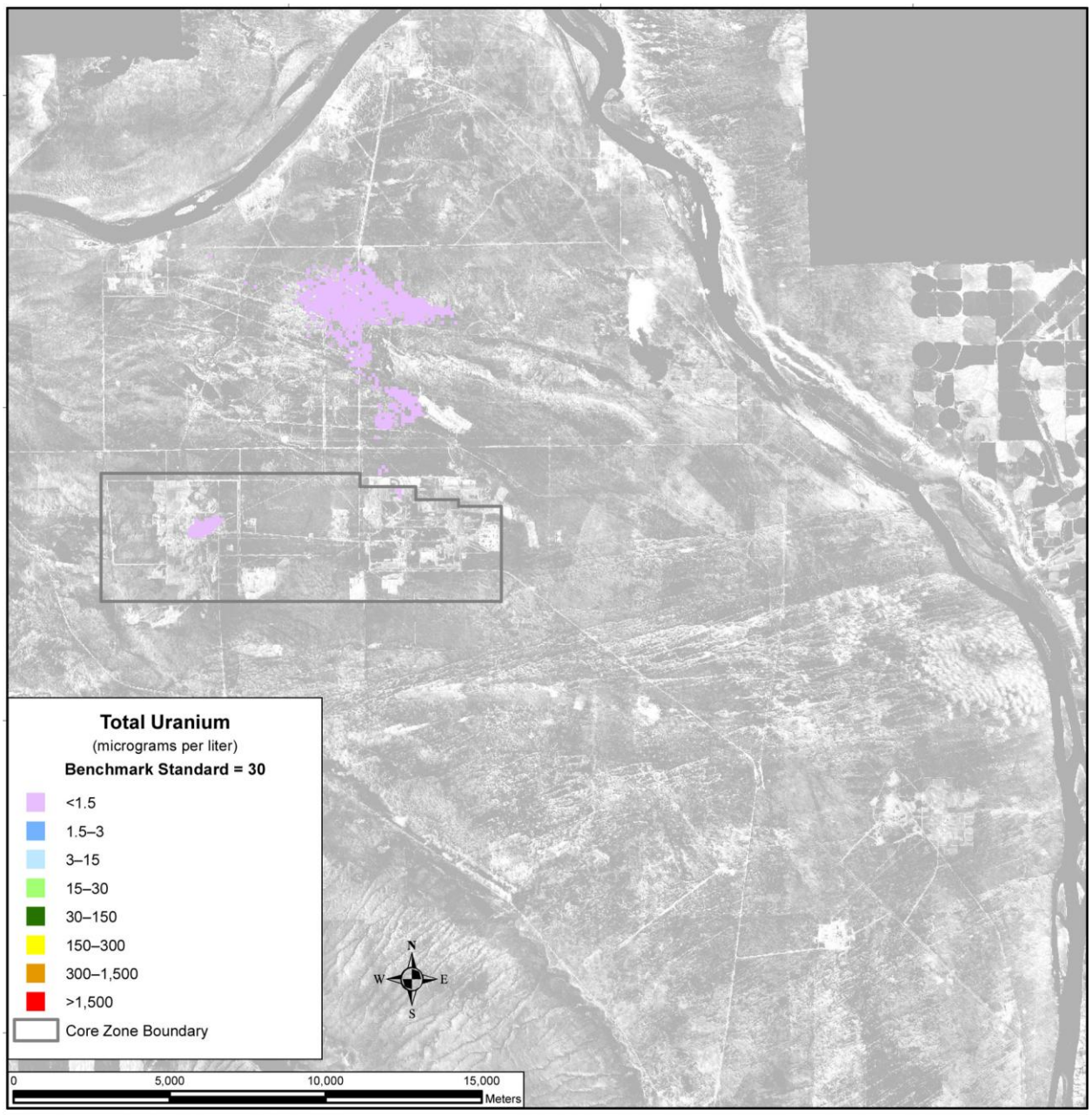
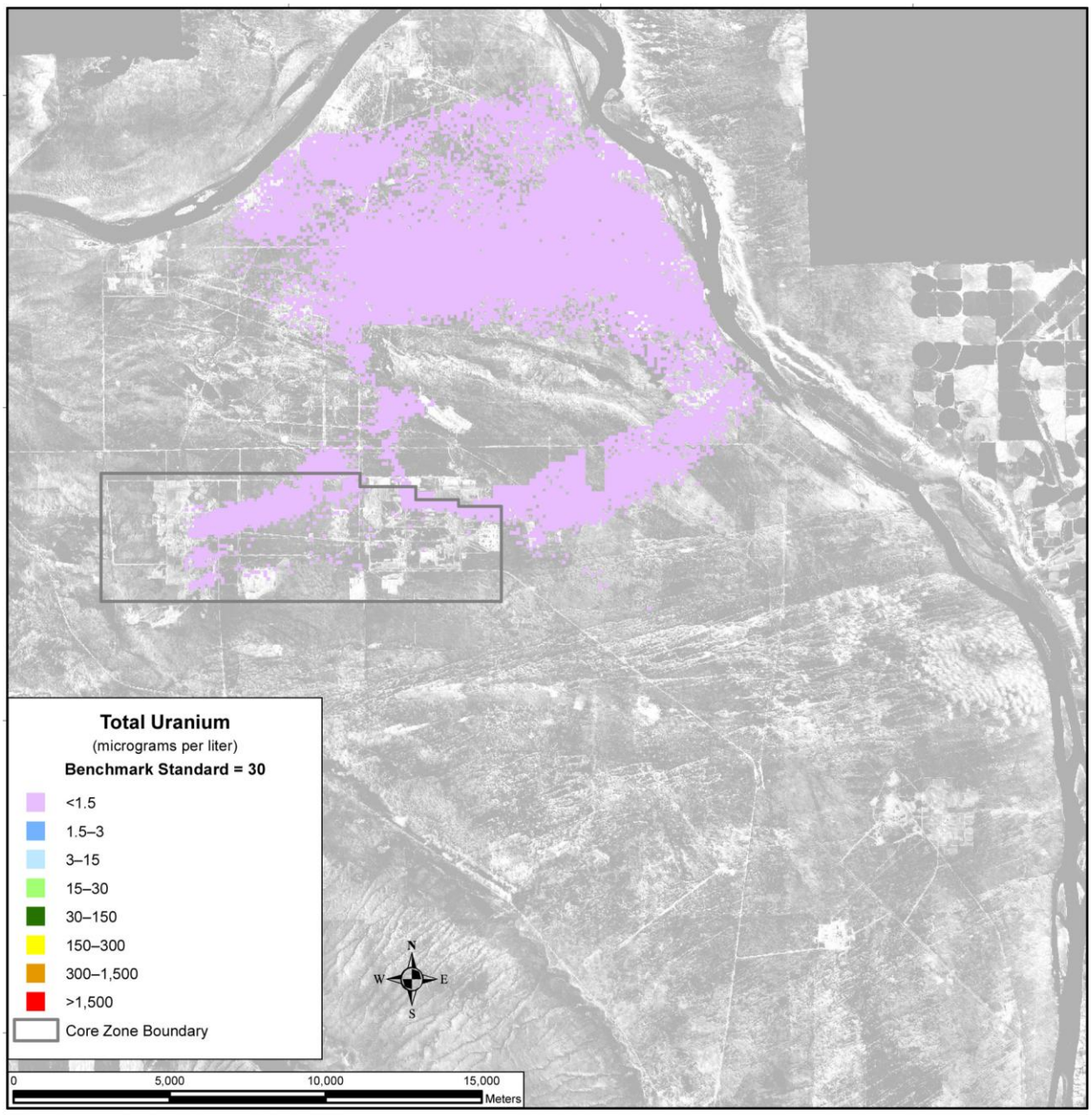


Figure 5–33. Tank Closure Alternative 1 Total Area of Groundwater Uranium-238 Concentration Exceeding the Benchmark Concentration as a Function of Time



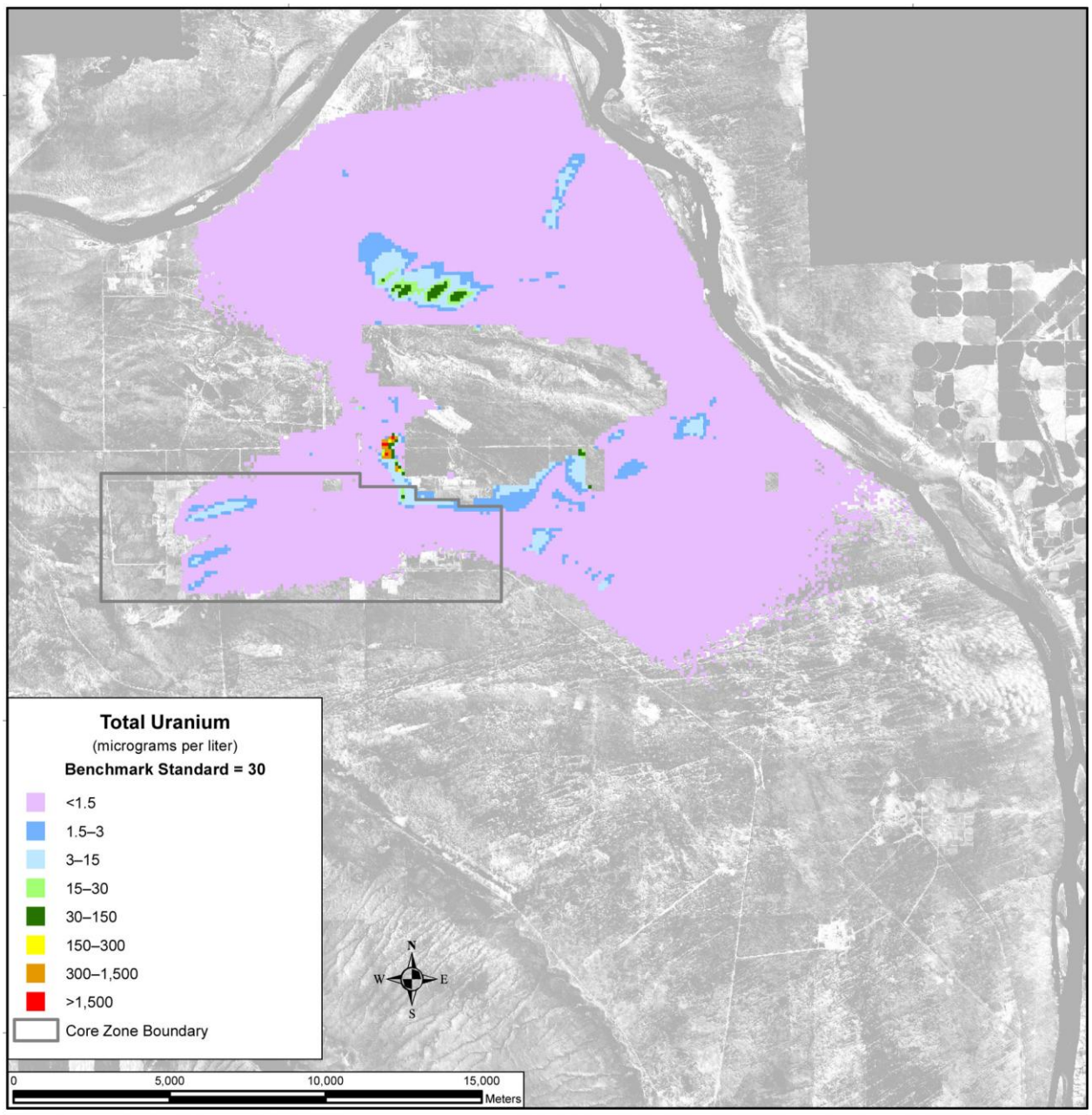
Note: To convert meters to feet, multiply by 3.281.

Figure 5–34. Tank Closure Alternative 1 Spatial Distribution of Groundwater Total Uranium Concentration, Calendar Year 2010



Note: To convert meters to feet, multiply by 3.281.

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



Note: To convert meters to feet, multiply by 3.281.

Figure 5–36. Tank Closure Alternative 1 Spatial Distribution of Groundwater Total Uranium Concentration, Calendar Year 11,940

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 secondary contributors.

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

Concentrations of tritium at the Core Zone Boundary exceed the benchmark by about two orders of magnitude during the first 100 years of the period of analysis. Tritium concentrations at the Columbia River nearshore 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 after CY 11,000 and are still one to two orders of magnitude below the benchmark at the Columbia River nearshore by CY 11,940. The intensity is highest and the area of the contamination plume 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 impacts 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 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 2193. This period includes retrieval, WTP pretreatment and treatment, and 100 years of administrative and institutional control. Waste treatment operations were assumed to be complete for immobilized high-level radioactive waste (IHLW) and immobilized low-activity waste (ILAW) in CY 2093; starting in CY 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 and to occur over a period of 1 year (see Appendix M, Section M.5.1, for a discussion of the effect of variation of duration of leaks). 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, but this discussion 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 contributions 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 the total amount of COPCs released to the vadose zone, groundwater, and the Columbia River during the 10,000-year period of analysis. Releases of radionuclides are totaled in curies; chemicals, in kilograms (see Figures 5–37 through 5–42). Three subtotals are plotted, representing releases from cribs and trenches (ditches), past leaks, and other tank farm sources (e.g., tank residuals, ancillary equipment). 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 of the radiological risk drivers and Figure 5–38, the chemical hazard drivers. The predominant sources of 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 of 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.

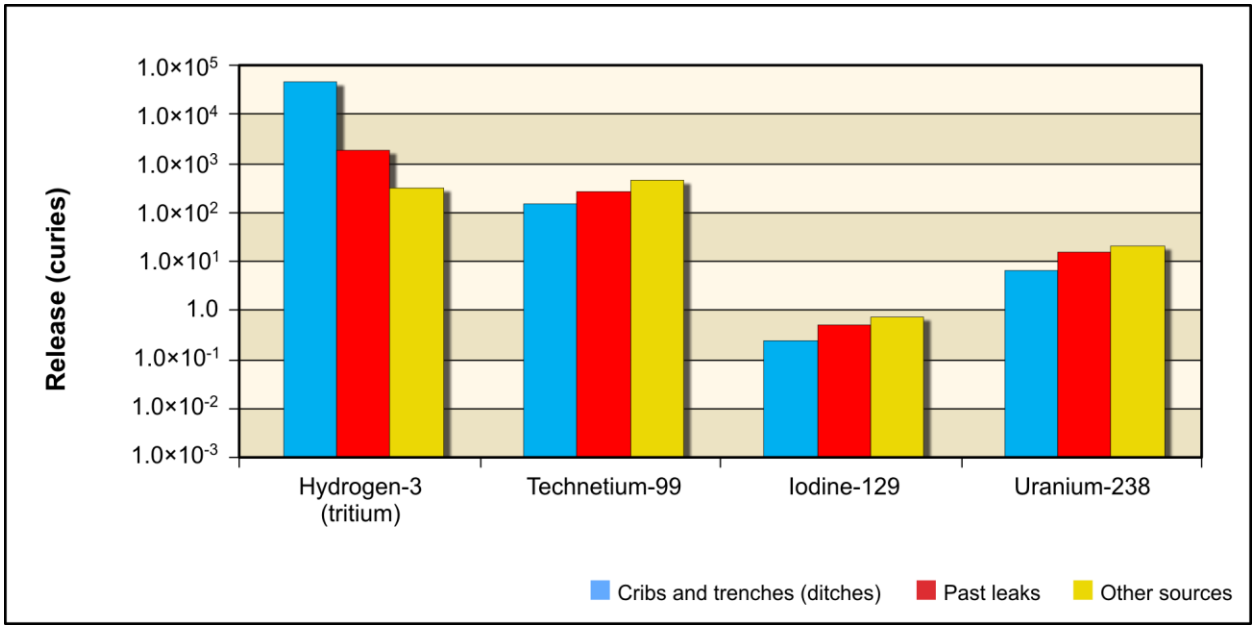


Figure 5–37. Tank Closure Alternative 2A Releases of Radioactive Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

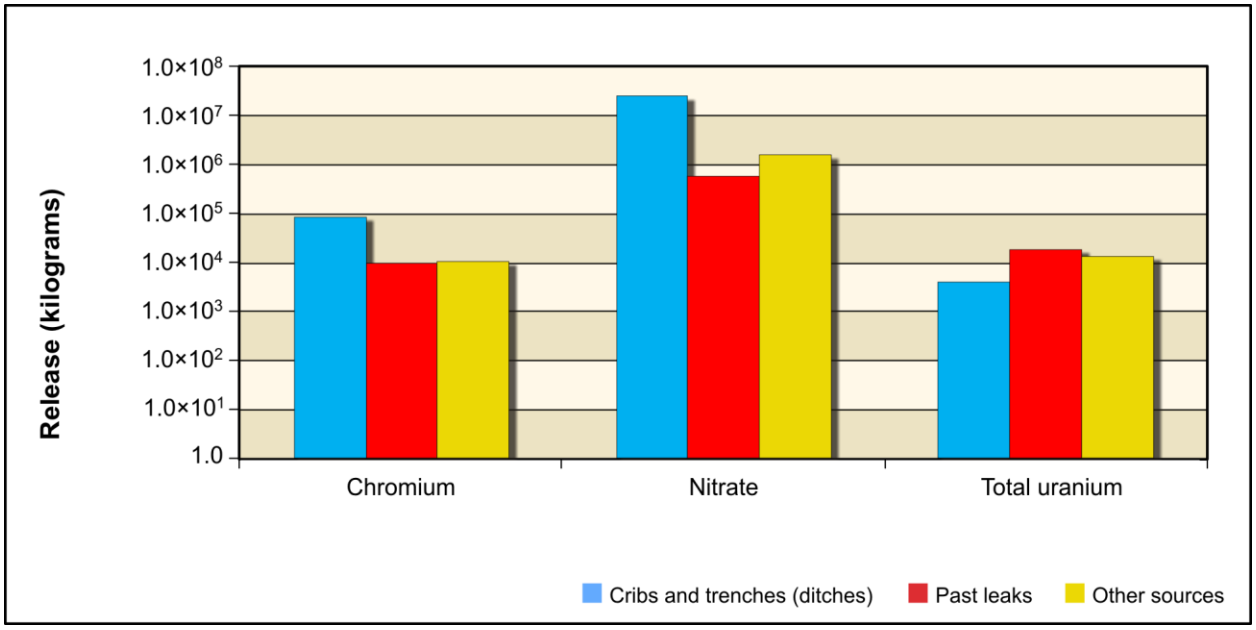


Figure 5–38. Tank Closure Alternative 2A Releases of Chemical Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

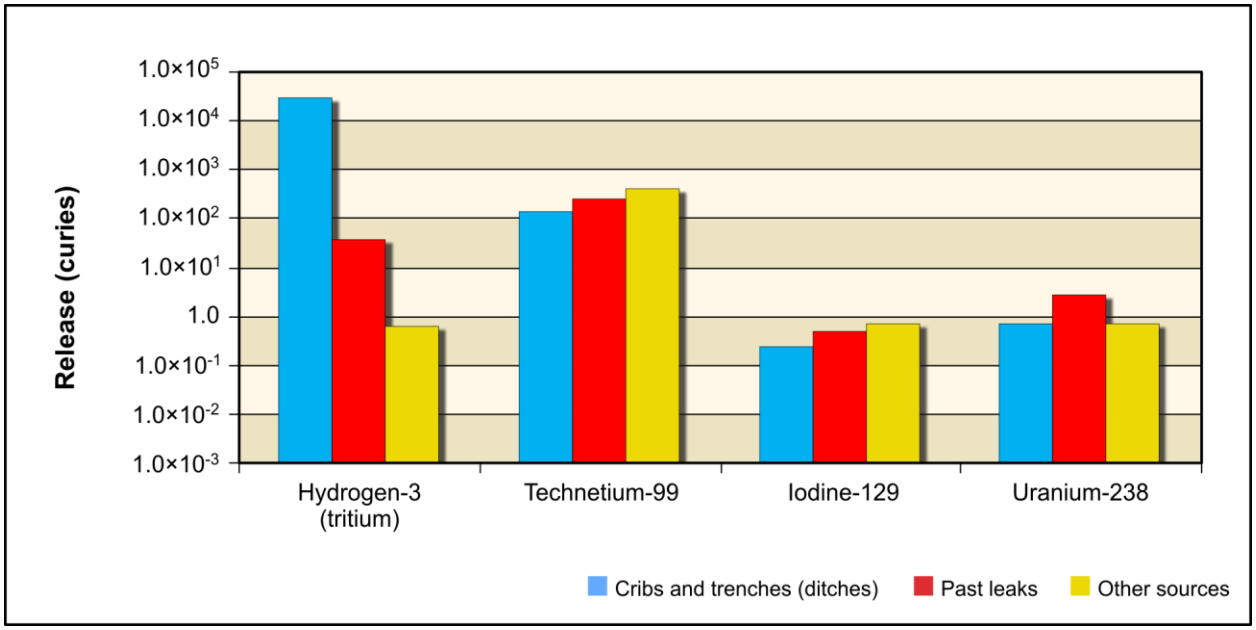


Figure 5–39. Tank Closure Alternative 2A Releases of Radioactive Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

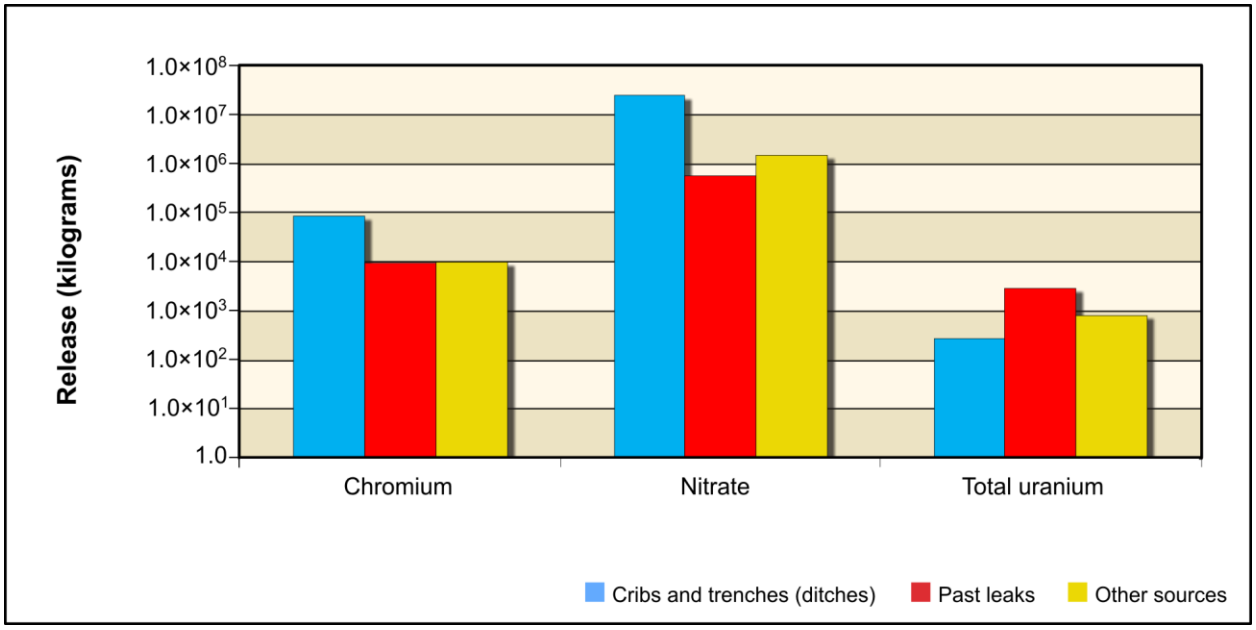


Figure 5–40. Tank Closure Alternative 2A Releases of Chemical Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

For tritium, the amount released to groundwater is attenuated by radioactive decay in the vadose zone. For releases from cribs and trenches (ditches), about 71 percent of the total inventory of tritium reaches groundwater in the analysis; for past leaks, only 2 percent; and for other tank farm sources, only one-fifth of 1 percent reaches 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 released 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 releases from 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 11 percent of the uranium-238 inventory and 7 percent of the total uranium inventory reach groundwater during the period of analysis. For past leaks, about 19 percent of the uranium-238 inventory and 16 percent of the total uranium inventory reach groundwater during the period of analysis. For other tank farm sources, about 4 percent of the uranium-238 inventory and 6 percent of the total uranium inventory reach groundwater during the period of analysis. These results also suggest that uranium-238 and total uranium impacts on groundwater 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 of 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 1 percent of the tritium released to groundwater reaches 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 released to groundwater because of retardation. Overall, about 39 percent of the uranium-238 and about 37 percent of the total uranium released to groundwater reach 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.

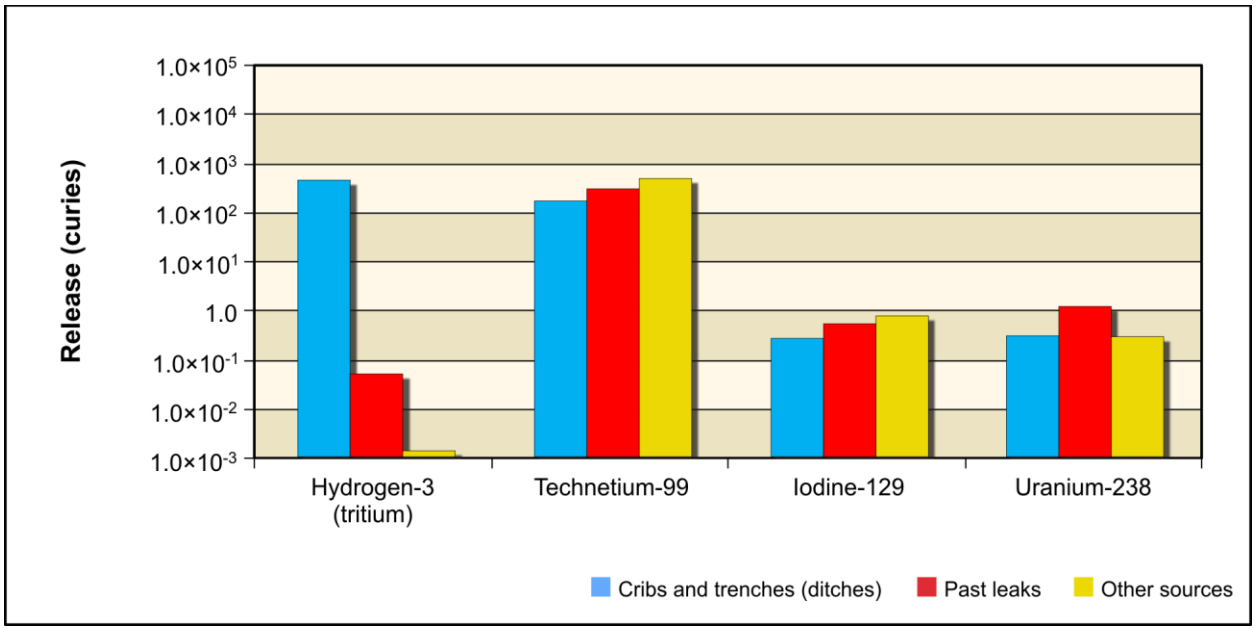


Figure 5–41. Tank Closure Alternative 2A Releases of Radioactive Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

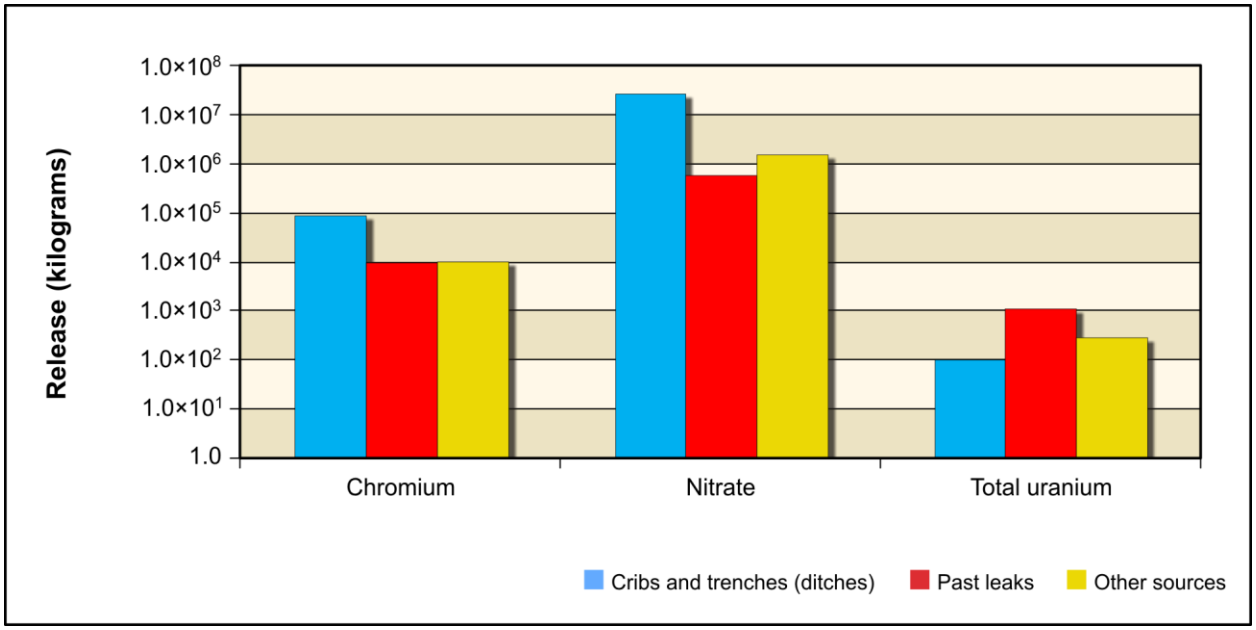


Figure 5–42. Tank Closure Alternative 2A Releases of Chemical Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

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 nearshore. 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 of each radionuclide and chemical is also shown. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over 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. Tank Closure Alternative 2A results in significant reductions in maximum concentrations at the tank farm barriers, Core Zone Boundary, and Columbia River nearshore relative to Tank Closure Alternative 1 (the No Action Alternative) primarily because 99 percent of the waste volume of the SSTs would be retrieved. Iodine-129 is the only constituent that reaches or exceeds the benchmark concentration at all barriers and the Core Zone Boundary. Technetium-99 does not exceed the benchmark concentration at the U Barrier or the Columbia River nearshore as was the case under the No Action Alternative. In addition, neither uranium-238 nor total uranium exceeds their respective benchmark concentrations at any of the barriers, Core Zone Boundary, or Columbia River nearshore after CY 2050, whereas under the No Action Alternative, uranium-238 and total uranium exceed the benchmarks at the B Barrier and Core Zone Boundary.

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 (picocuries per liter)								
Hydrogen-3 (tritium)	7 (2058)	481 (2064)	32 (2050)	2,560 (2053)	15 (2050)	561 (2053)	494 (2050)	20,000
Technetium-99	**964** (2095)	**4,000** (2068)	**1,540** (2051)	**6,480** (2050)	508 (2100)	**4,000** (2068)	418 (2317)	900
Iodine-129	**1.8** (2105)	**5.8** (2069)	**2.8** (2050)	**12.7** (2051)	0.9 (2092)	**5.8** (2069)	0.8 (2303)	1
Uranium isotopes (includes U-233, -234, -235, -238)	1 (11,860)	5 (11,789)	0 (11,788)	3 (11,827)	0 (11,839)	5 (11,789)	0 (11,935)	15
Chemical (micrograms per liter)								
Chromium	**108** (2170)	**228** (2158)	**157** (2050)	**341** (2051)	15 (2092)	**228** (2158)	74 (2079)	100
Nitrate	22,100 (2170)	**192,000** (2068)	5,160 (2081)	**64,500** (2098)	5,690 (2099)	**192,000** (2068)	17,500 (2131)	45,000
Total uranium	1 (11,849)	7 (11,797)	0 (11,706)	1 (11,724)	0 (11,796)	7 (11,797)	0 (11,929)	30

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. Because Tank Closure Alternative 2A has no impact on discharges to cribs and trenches (ditches) that occurred during the past-practice period, these releases cause Core Zone Boundary groundwater concentrations to exceed benchmark concentrations by one to two orders of magnitude for a short period of time during the early part of the period of analysis. This time period is represented by the first series of sharp inflections in the curve for the Core Zone Boundary from approximately CY 1955 until CY 1980. 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 2020. Retrieval of SST waste under Tank Closure Alternative 2A further attenuates tritium concentrations relative to the No Action Alternative. Retrieval of 99 percent of the waste volume results in tritium concentrations at the Core Zone Boundary that are approximately two orders of magnitude lower from CY 2107 until the end of the 10,000-year period of analysis.

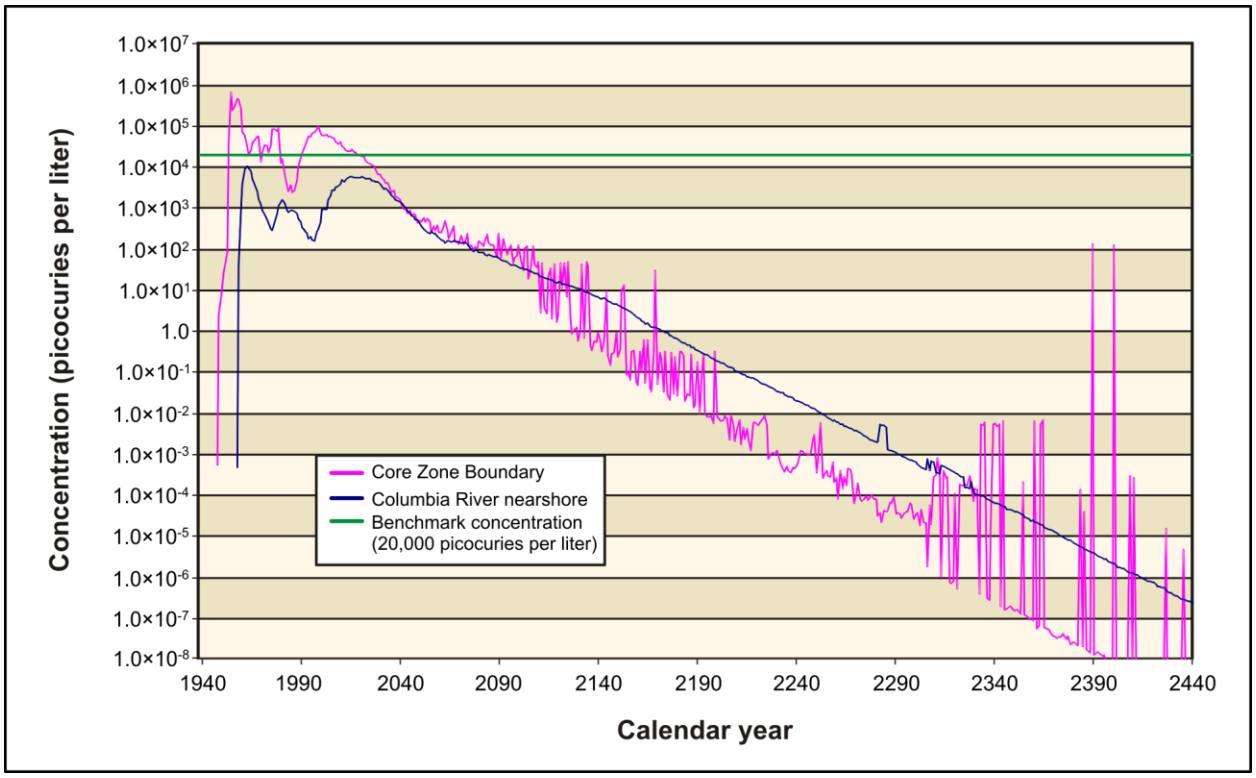


Figure 5–43. Tank Closure Alternative 2A Hydrogen-3 (Tritium) Concentration Versus Time

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 of iodine-129 at the Core Zone Boundary to exceed benchmark concentrations by about one to two orders of magnitude during the early part of the period of analysis. This early time period is represented by the multiple sharp inflections in the Core Zone Boundary curve that occur approximately between CYs 1955 and 1980. The iodine-129 signature also occurs at the Columbia River nearshore at a later time. By about CY 3000, the Core Zone Boundary groundwater concentrations return to levels below the benchmark. Groundwater concentrations at the Columbia River nearshore briefly reach the benchmark concentration early in the simulation and gradually decrease to around two to three orders of magnitude below the benchmark concentration near the end of the period of analysis. Technetium-99, chromium, and nitrate concentrations show similar curves, where concentrations are approximately equivalent to the benchmark during the time period of releases from cribs and trenches (ditches). Retrieval of 99 percent of the tank farm waste results in significant reductions in concentrations of all conservative tracers during the retrieval period and post–administrative control period. Mitigation of the COPC concentrations reduces the period of time in which benchmark concentrations are exceeded at the Core Zone Boundary and Columbia River nearshore.

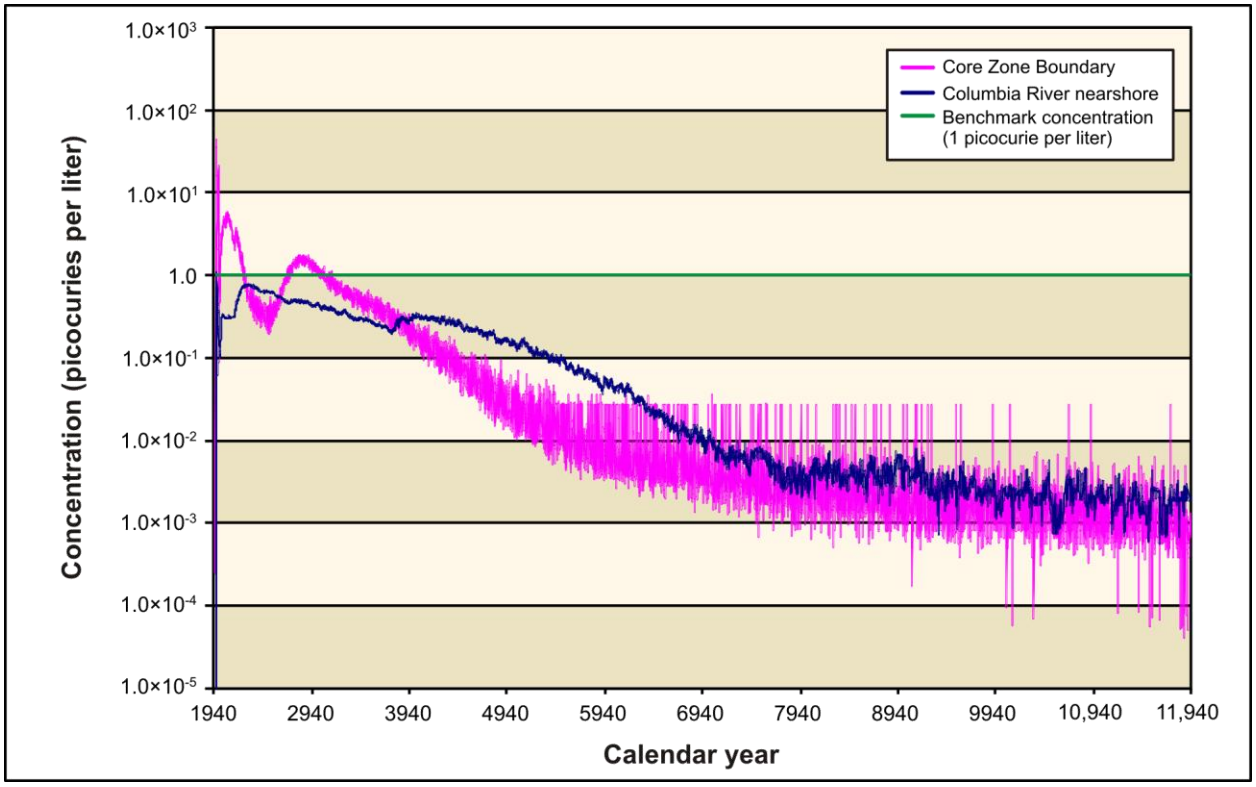


Figure 5–44. Tank Closure Alternative 2A Iodine-129 Concentration Versus Time

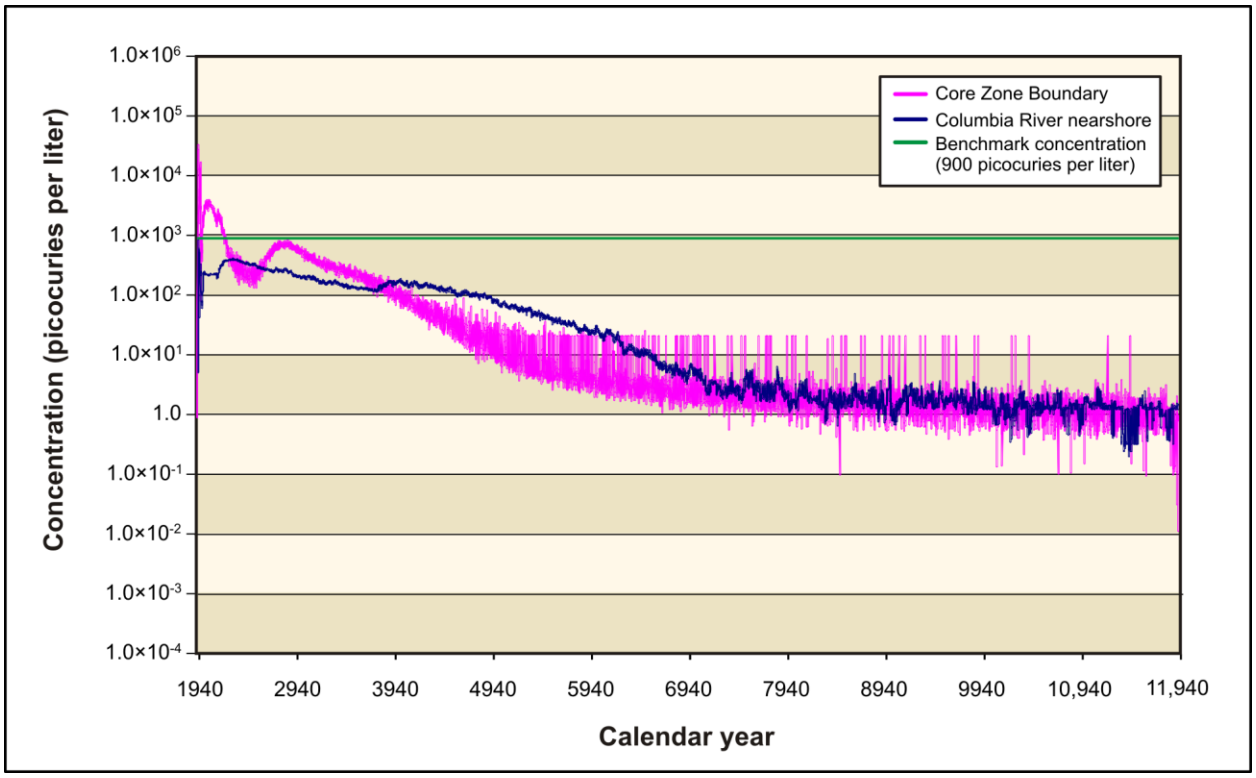


Figure 5–45. Tank Closure Alternative 2A Technetium-99 Concentration Versus Time

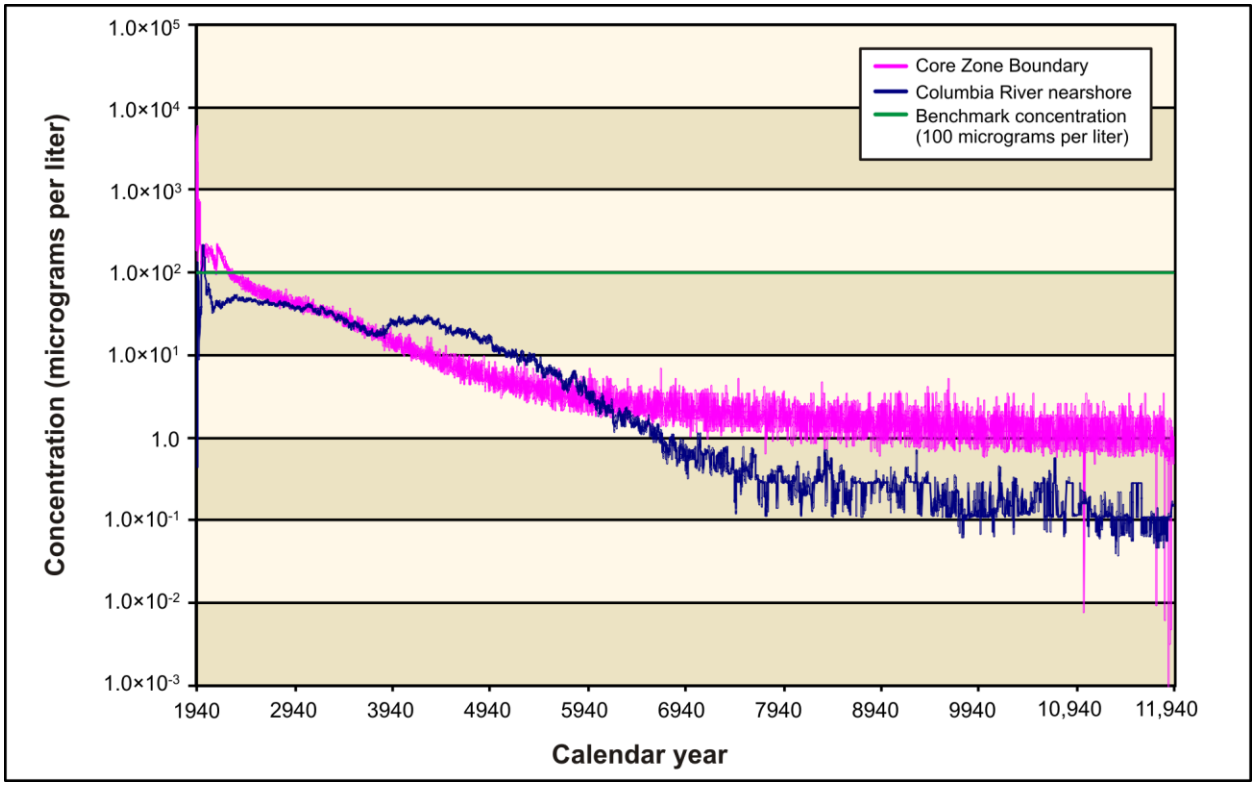


Figure 5–46. Tank Closure Alternative 2A Chromium Concentration Versus Time

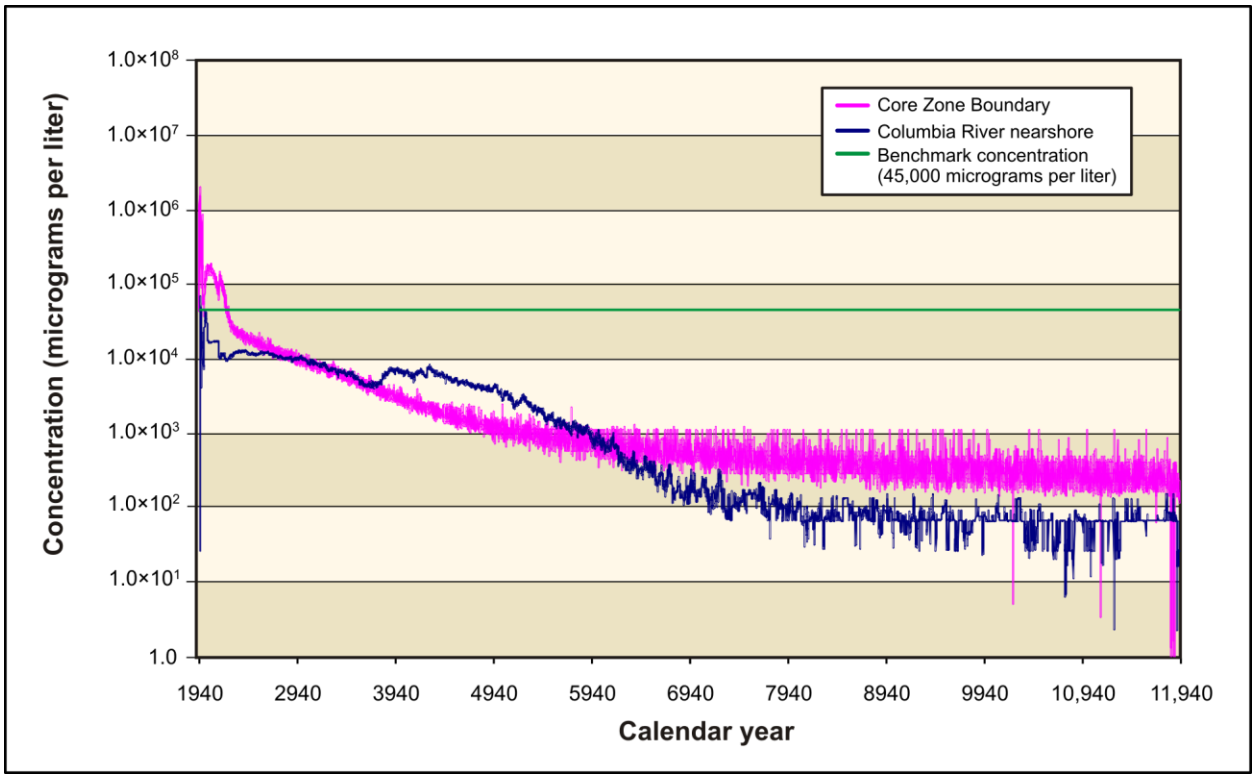


Figure 5–47. Tank Closure Alternative 2A Nitrate Concentration Versus Time

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 approximately two orders of magnitude lower than benchmark concentrations. Releases from other tank farm sources cause groundwater concentrations to rise throughout the duration of the period of analysis, approaching, but never surpassing, the benchmark concentration. The 99 percent retrieval of tank farm waste is the primary reason uranium concentrations never exceed the benchmarks during the 10,000-year period of analysis. Groundwater concentrations at the Columbia River nearshore also rise throughout the period of analysis, but remain about one to two orders of magnitude below the benchmark concentration.

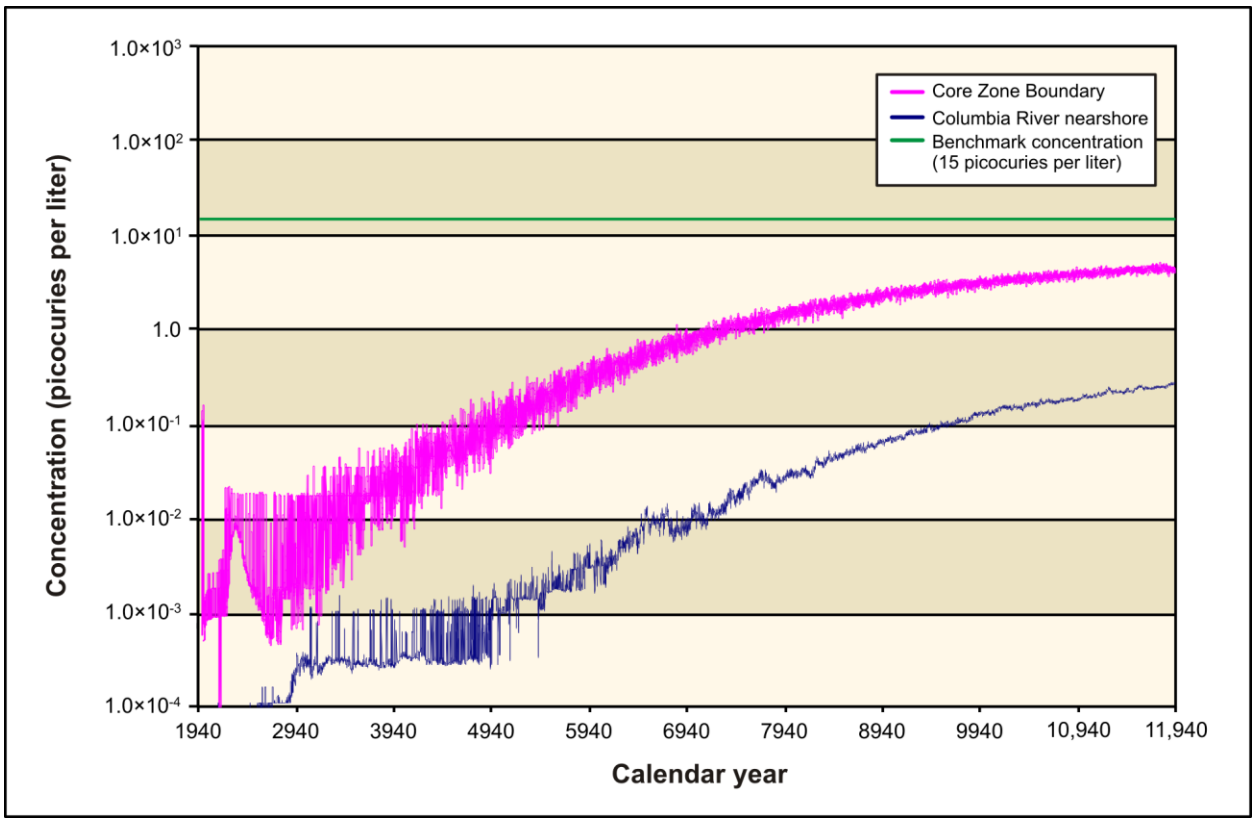


Figure 5–48. Tank Closure Alternative 2A Uranium-238 Concentration Versus Time

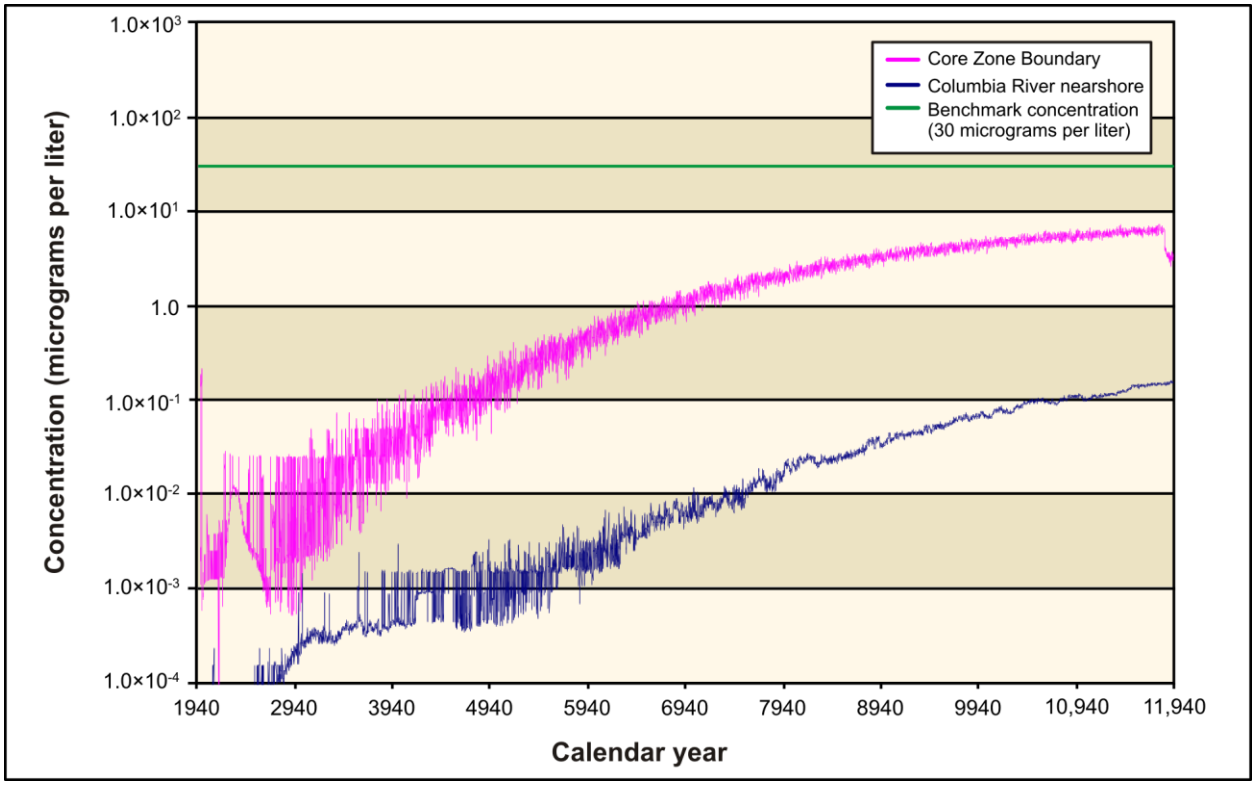
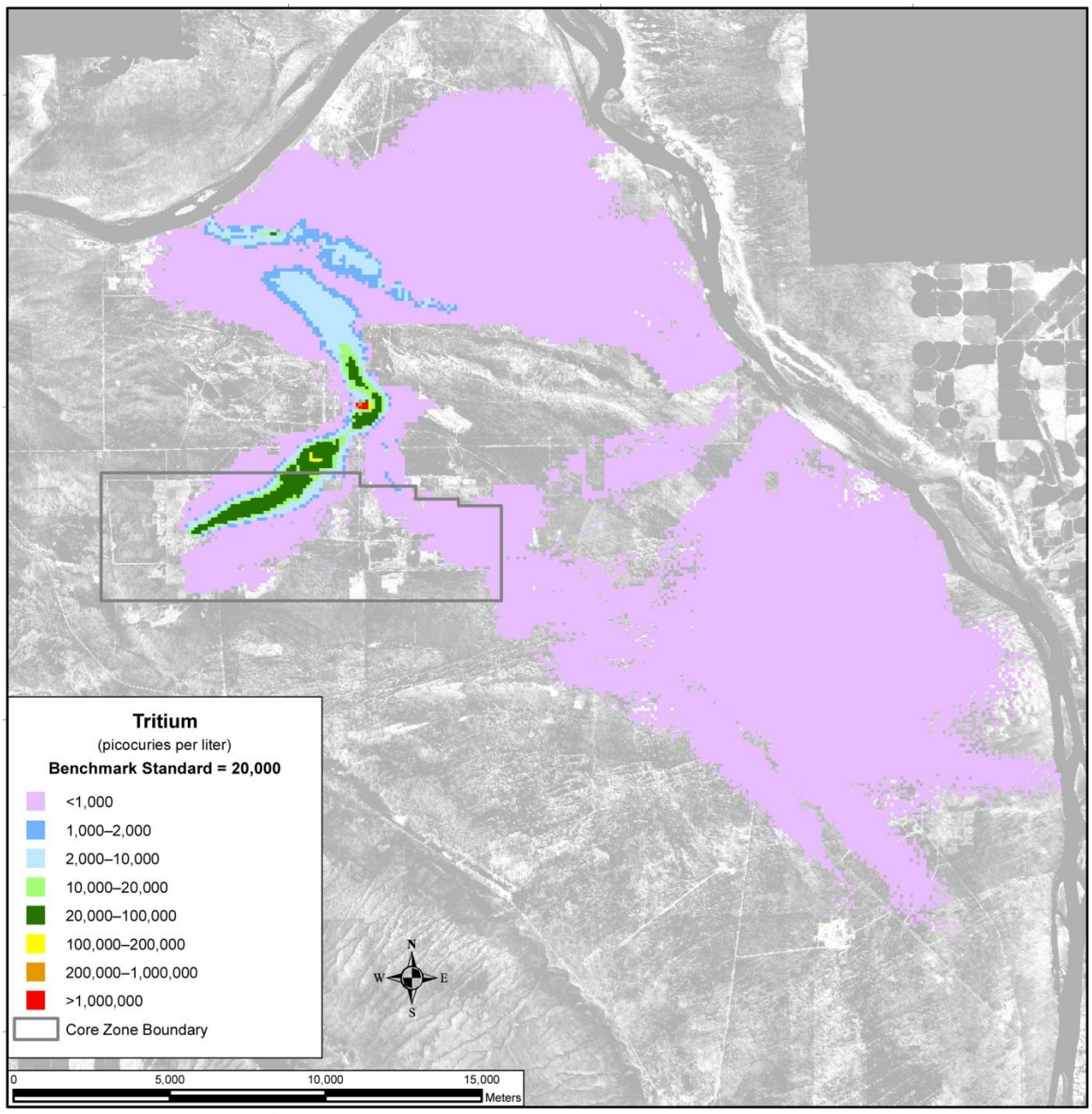


Figure 5–49. Tank Closure Alternative 2A Total Uranium Concentration Versus Time

5.1.1.2.5 Analysis of Spatial Distribution of Concentration

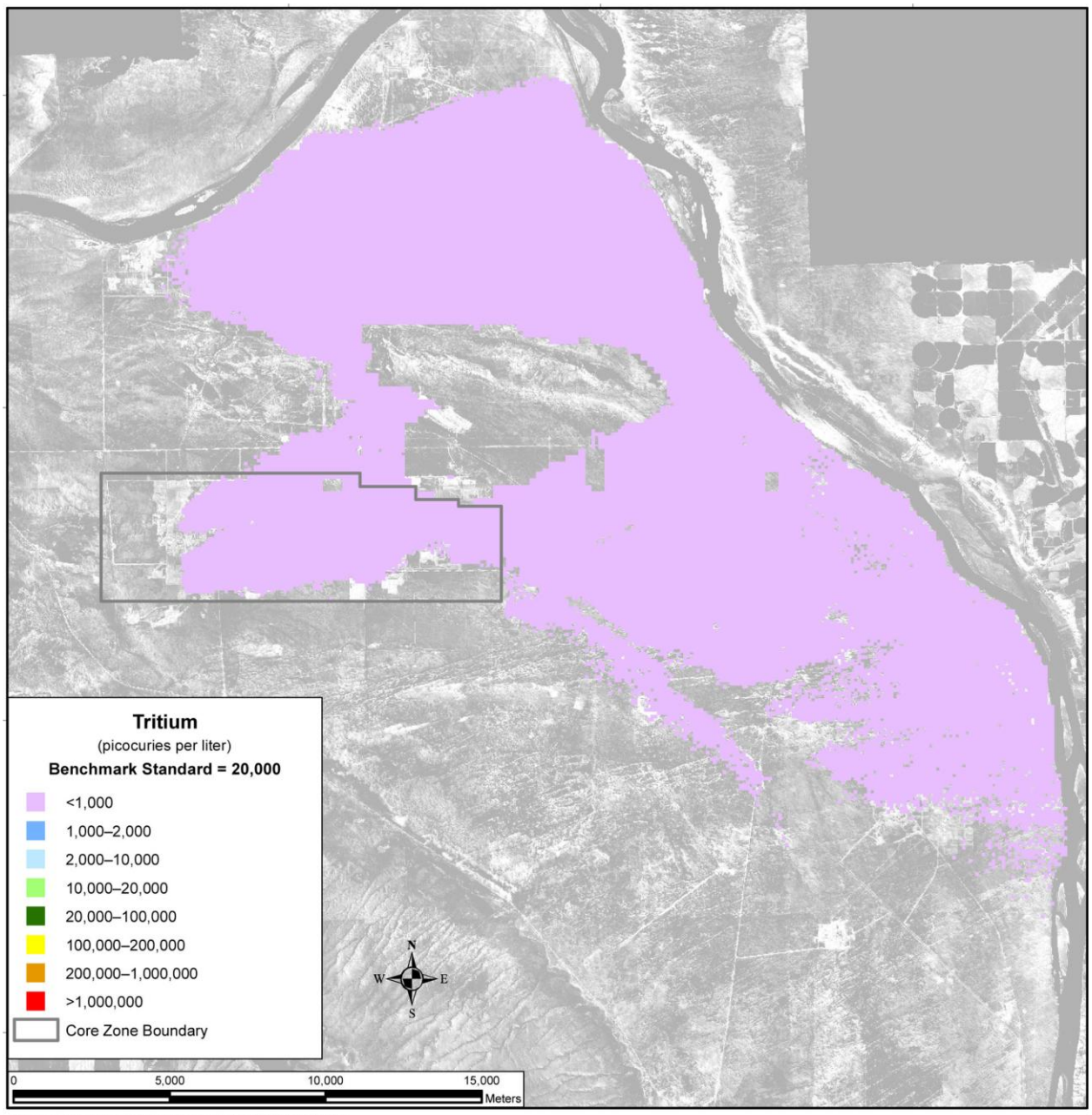
This section presents the impacts of Tank Closure Alternative 2A in terms of the spatial distribution of COPC driver concentrations in groundwater at selected times. Concentrations of radionuclides are in picocuries per liter; chemicals, in micrograms per liter. Concentrations of each radionuclide and 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 tritium concentrations in groundwater in CY 2010. 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, crosses the Core Zone Boundary, and continues toward Gable Gap. Peak concentrations in this plume are about 5 to 10 times greater than the benchmark and are 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, Calendar Year 2010

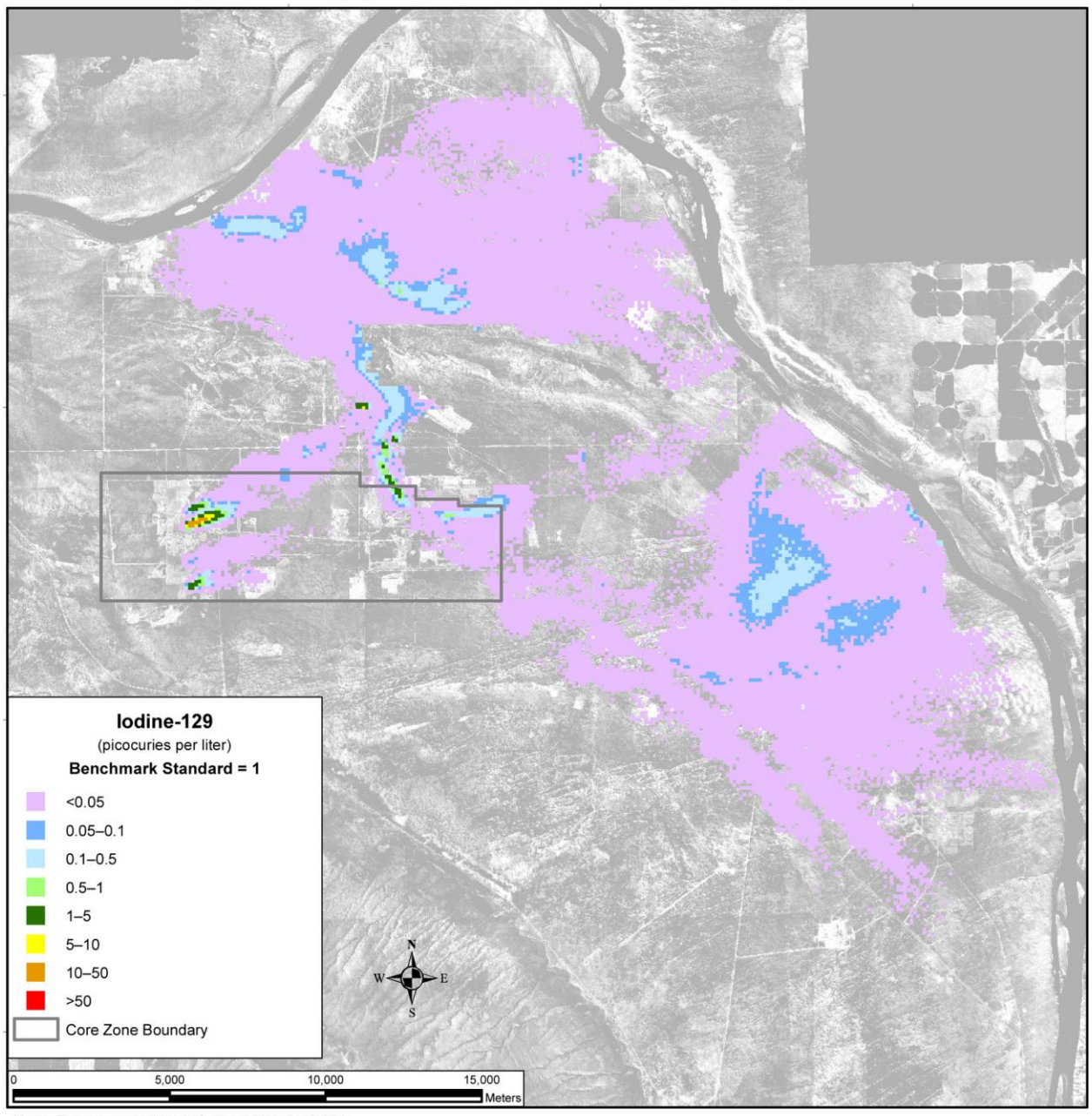


Note: To convert meters to feet, multiply by 3.281.

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

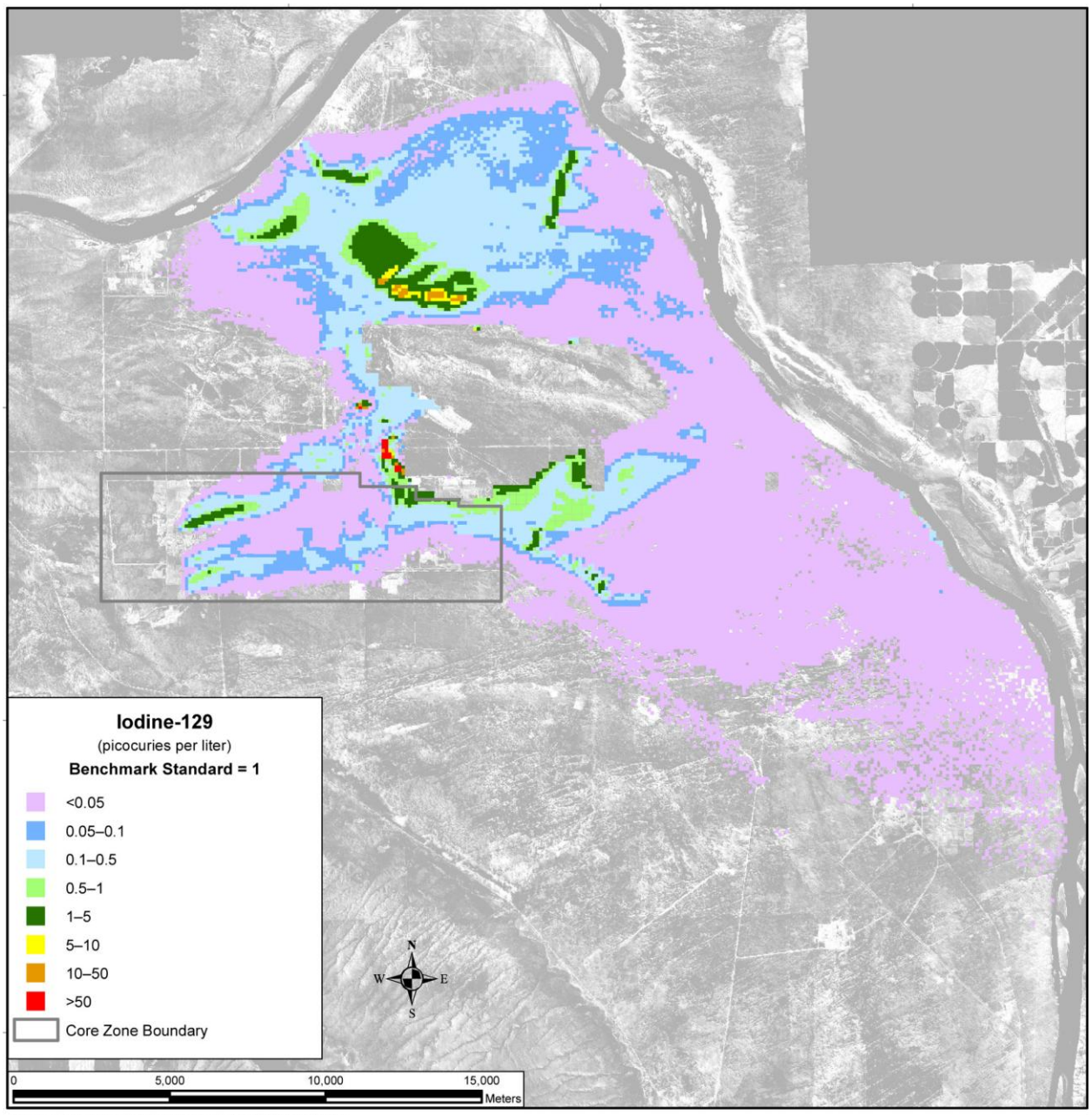
Figure 5–52 shows the spatial distribution of iodine-129 concentrations in groundwater in CY 2010. Releases from cribs and trenches (ditches) and past leaks result in groundwater concentration plumes that are at or exceed the benchmark concentration at the B, S, and T Barriers. Peak concentrations in these plumes are about 10 to 50 times greater than the benchmark and are mostly contained within the Core Zone Boundary. In CY 2135, the iodine-129 concentration continues to exceed the benchmark concentration in several areas. Peak groundwater concentrations, 10 to 50 times greater than the benchmark, are evident in the plume north of Gable Gap (see Figure 5–53). In CY 3890, the majority of the plume has concentrations below the benchmark concentration, although there are still several areas of groundwater with concentrations up to 5 times the benchmark concentration (see Figure 5–54). By CY 7140, most of the mass in the plume has reached the Columbia River, and the majority of the plume is

less than one-twentieth of the benchmark (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). The effect of 99 percent retrieval of tank waste results in a substantial lowering of groundwater concentrations during the retrieval and post–administrative control periods.



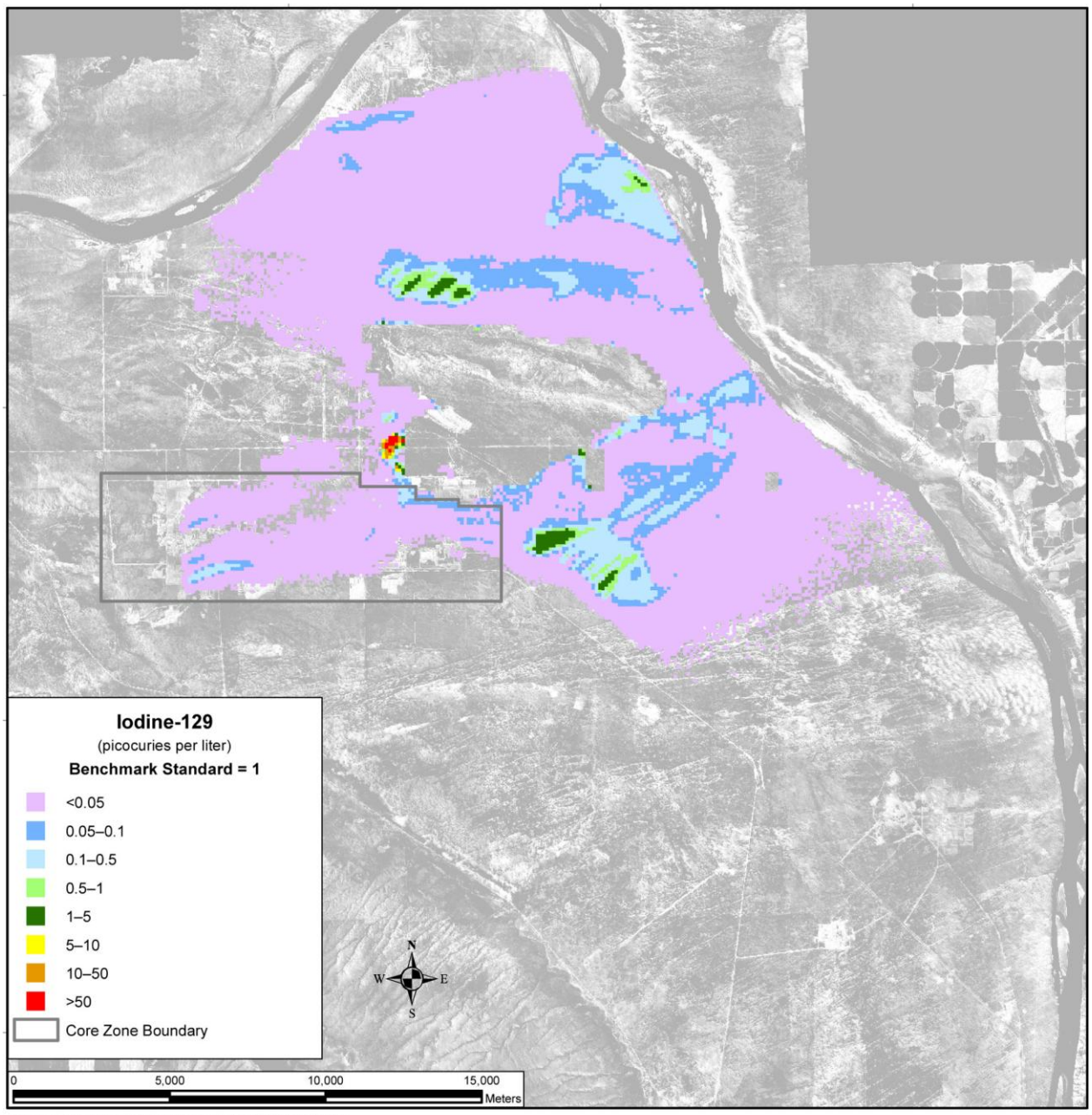
Note: To convert meters to feet, multiply by 3.281.

Figure 5–52. Tank Closure Alternative 2A Spatial Distribution of Groundwater Iodine-129 Concentration, Calendar Year 2010



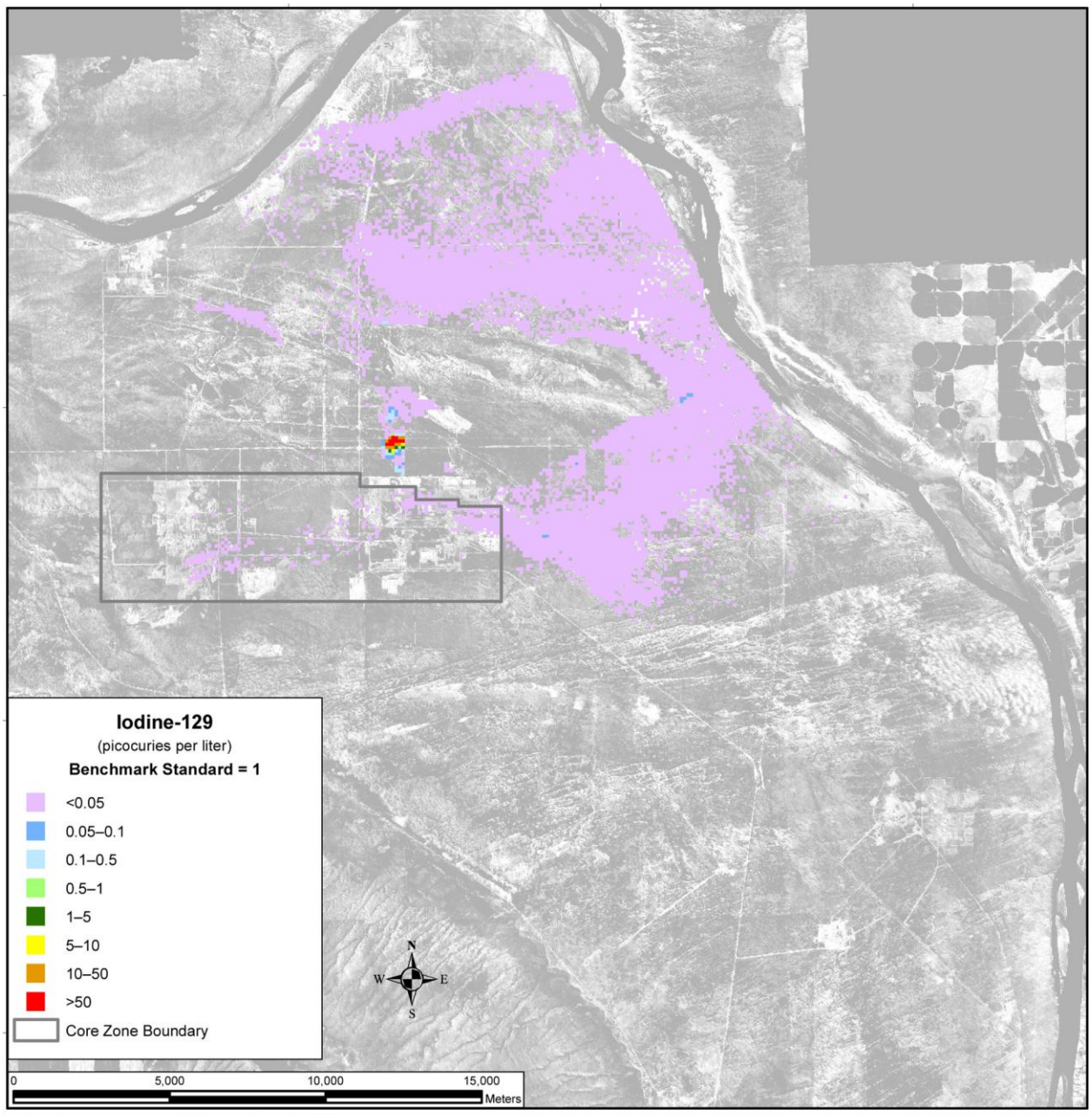
Note: To convert meters to feet, multiply by 3.281.

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



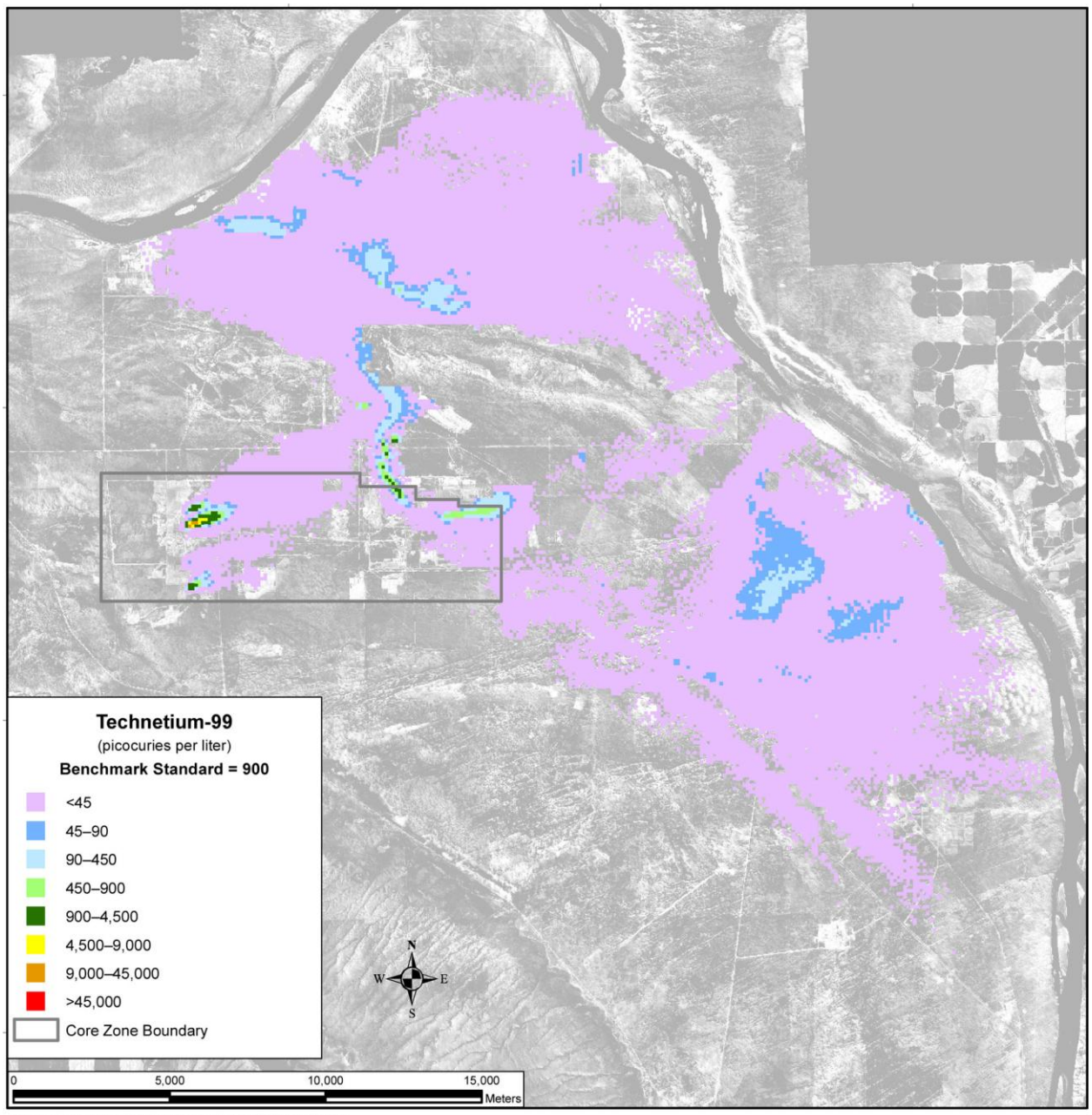
Note: To convert meters to feet, multiply by 3.281.

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



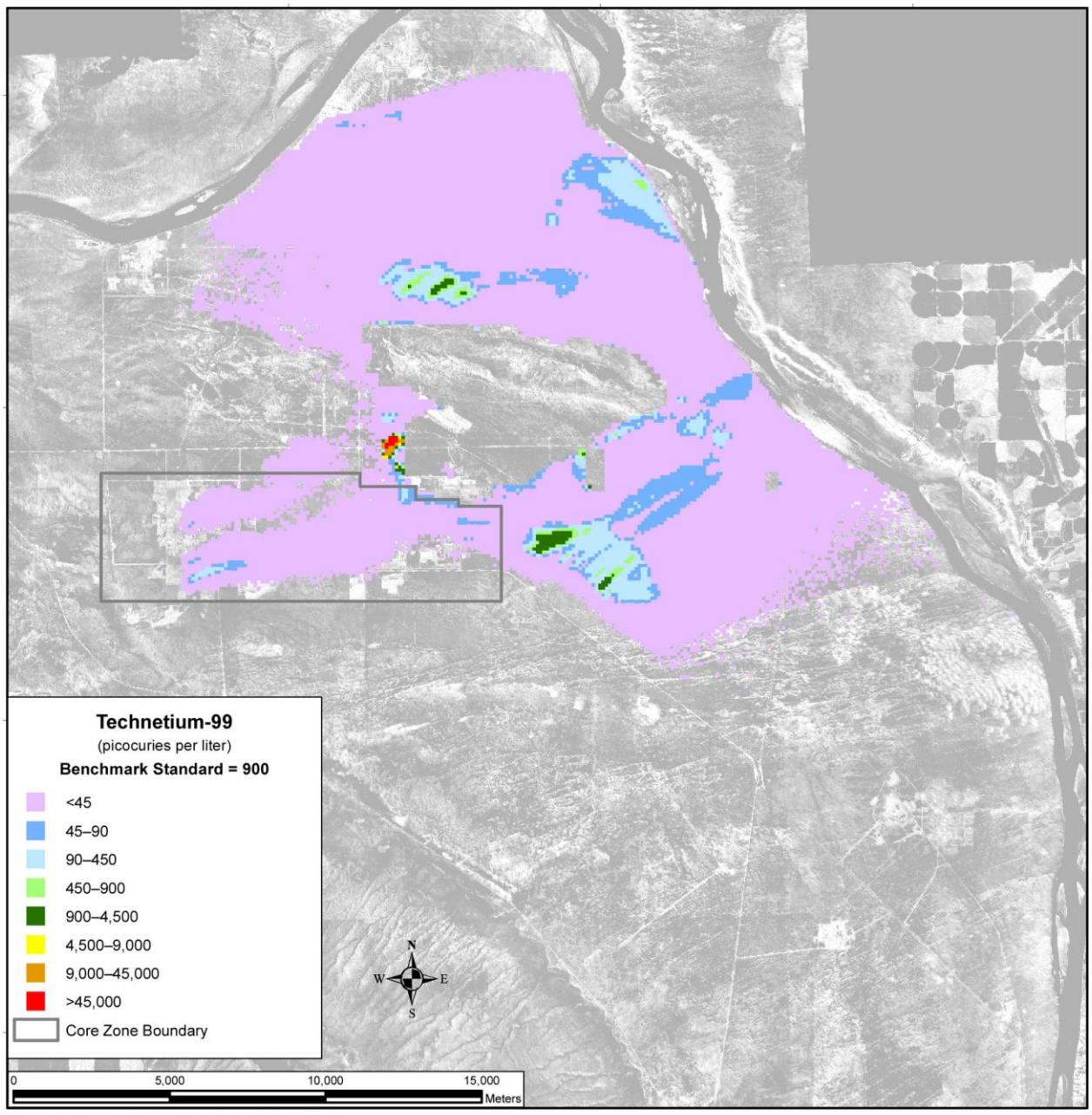
Note: To convert meters to feet, multiply by 3.281.

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



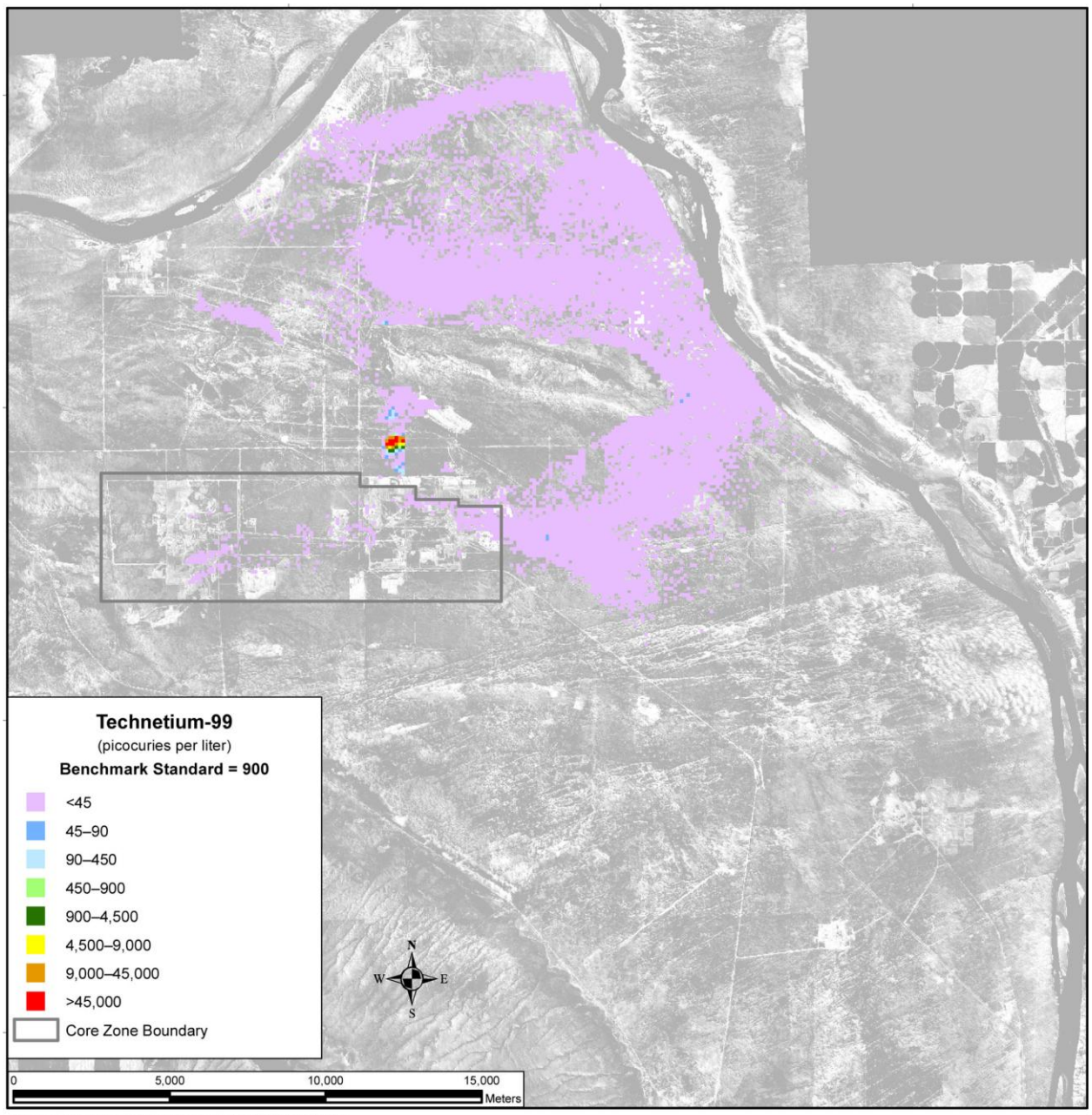
Note: To convert meters to feet, multiply by 3.281.

Figure 5–56. Tank Closure Alternative 2A Spatial Distribution of Groundwater Technetium-99 Concentration, Calendar Year 2010



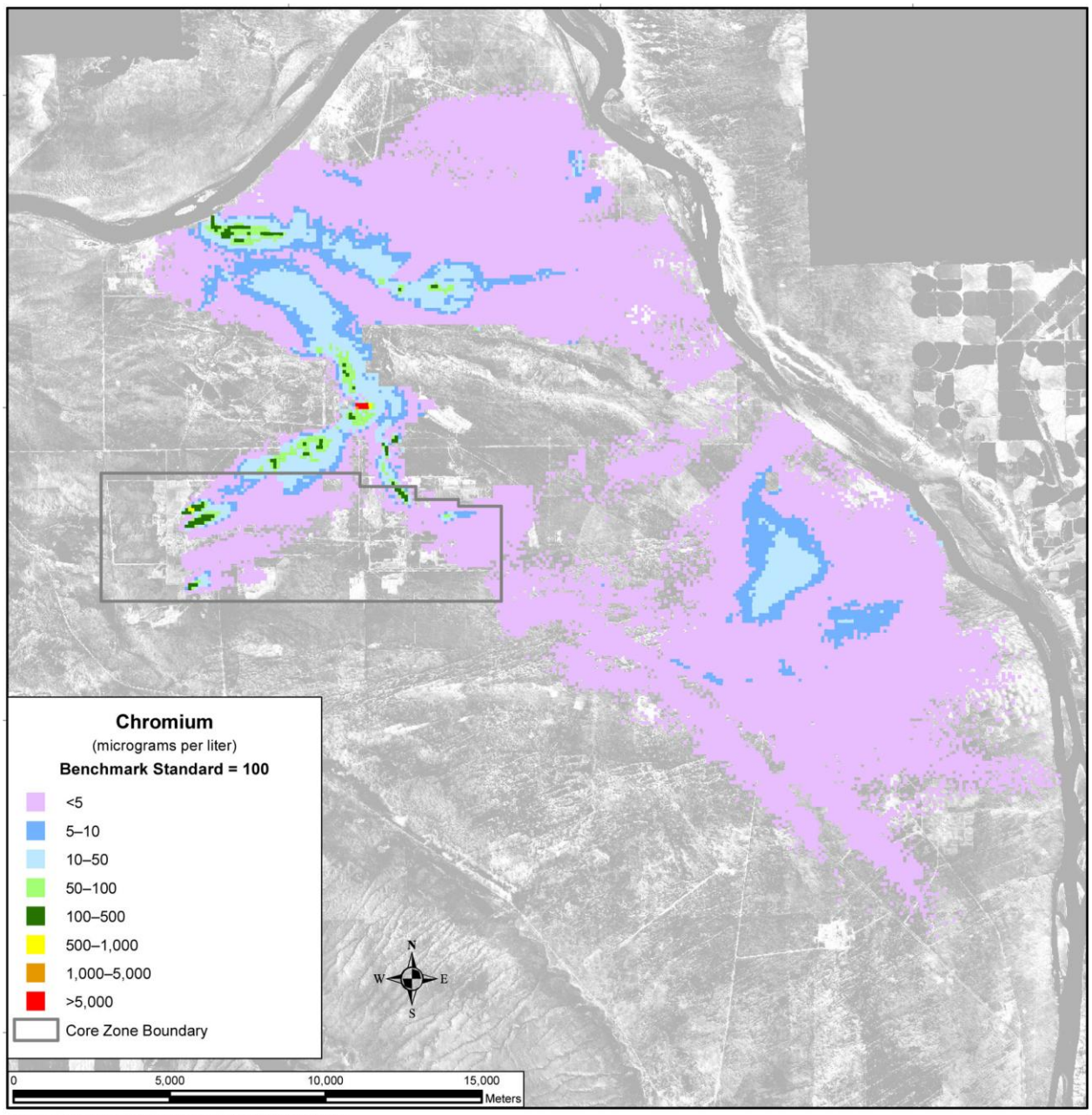
Note: To convert meters to feet, multiply by 3.281.

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



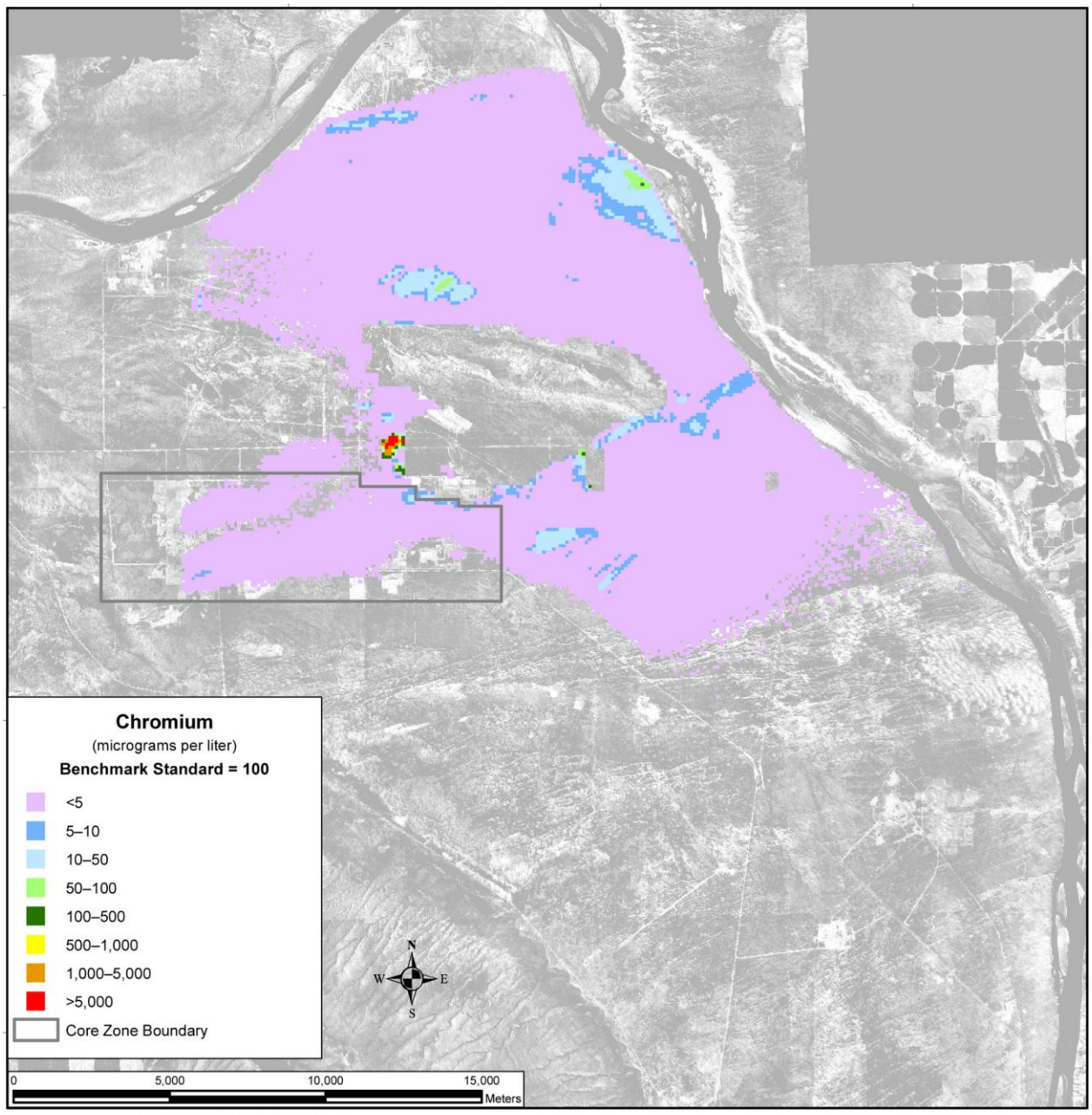
Note: To convert meters to feet, multiply by 3.281.

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



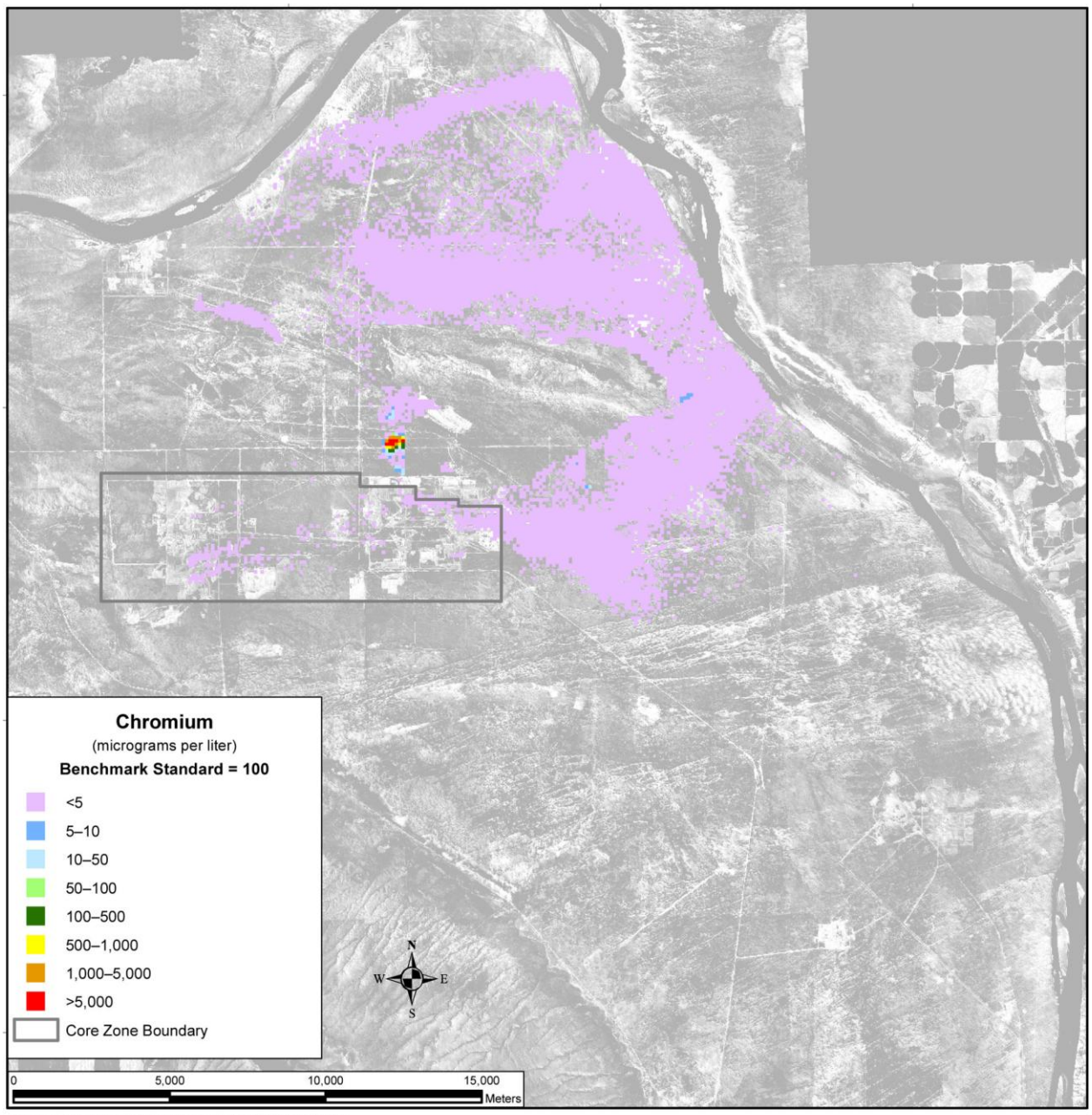
Note: To convert meters to feet, multiply by 3.281.

Figure 5–59. Tank Closure Alternative 2A Spatial Distribution of Groundwater Chromium Concentration, Calendar Year 2010



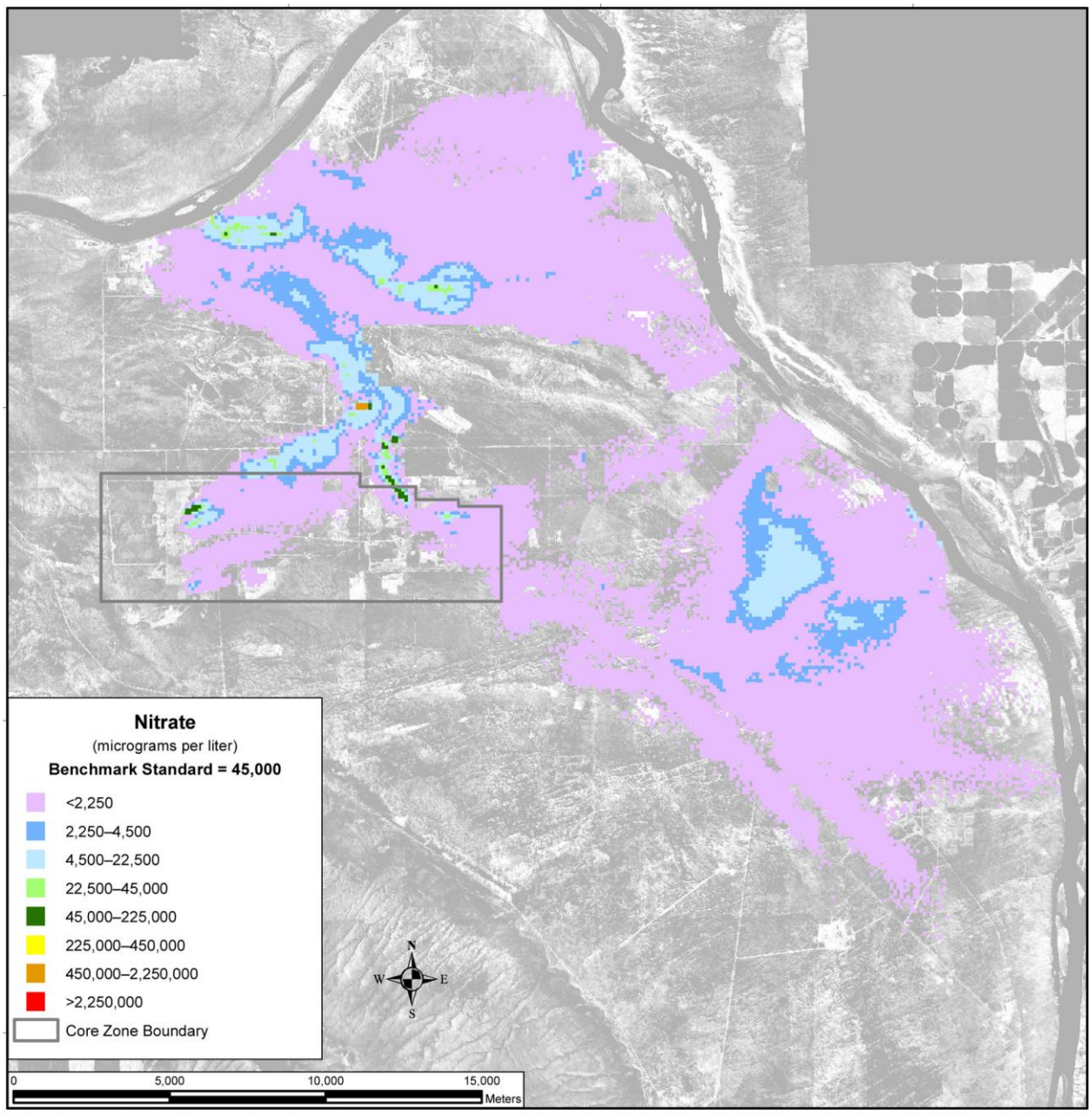
Note: To convert meters to feet, multiply by 3.281.

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



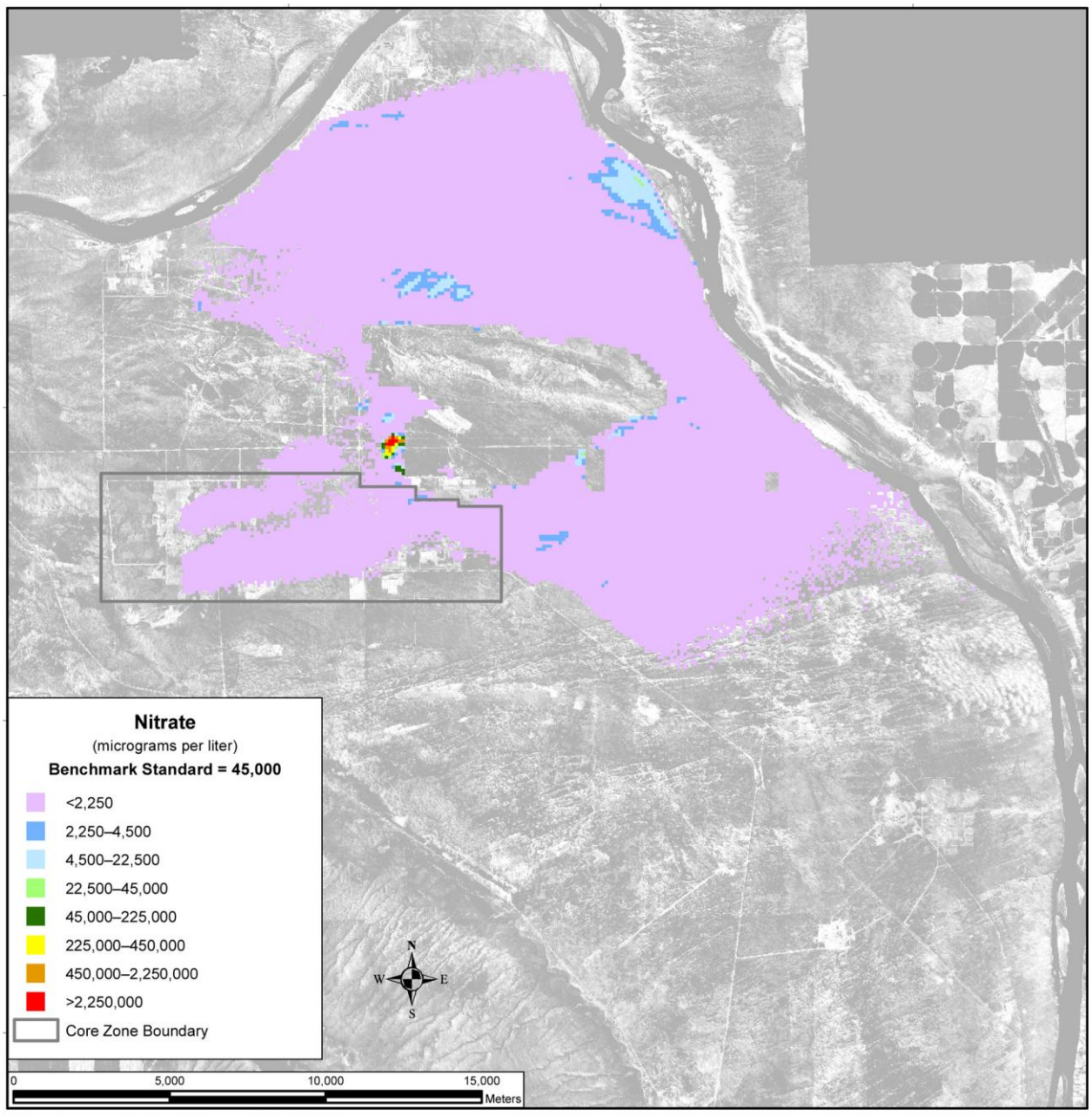
Note: To convert meters to feet, multiply by 3.281.

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



Note: To convert meters to feet, multiply by 3.281.

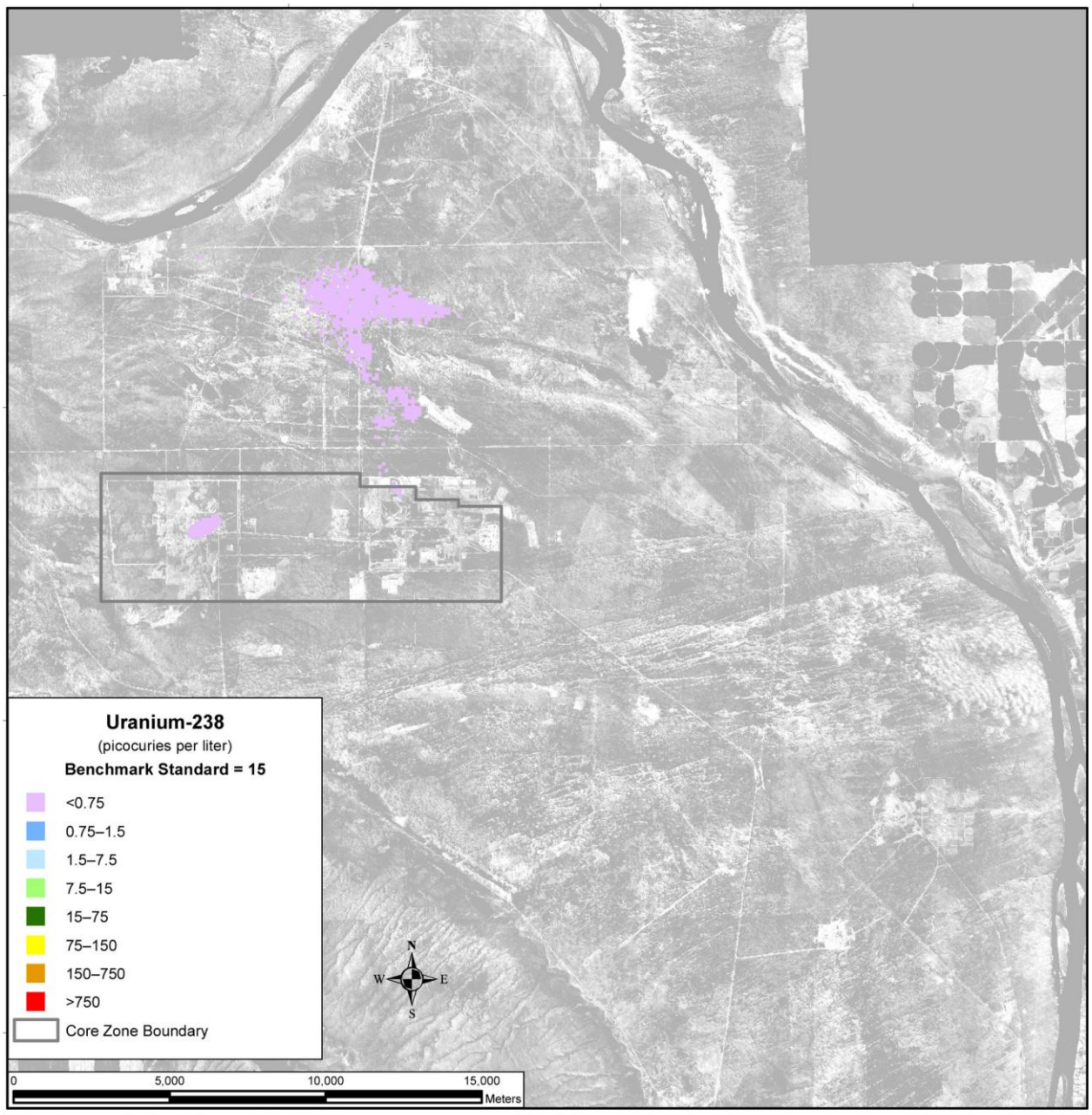
Figure 5–62. Tank Closure Alternative 2A Spatial Distribution of Groundwater Nitrate Concentration, Calendar Year 2010



Note: To convert meters to feet, multiply by 3.281.

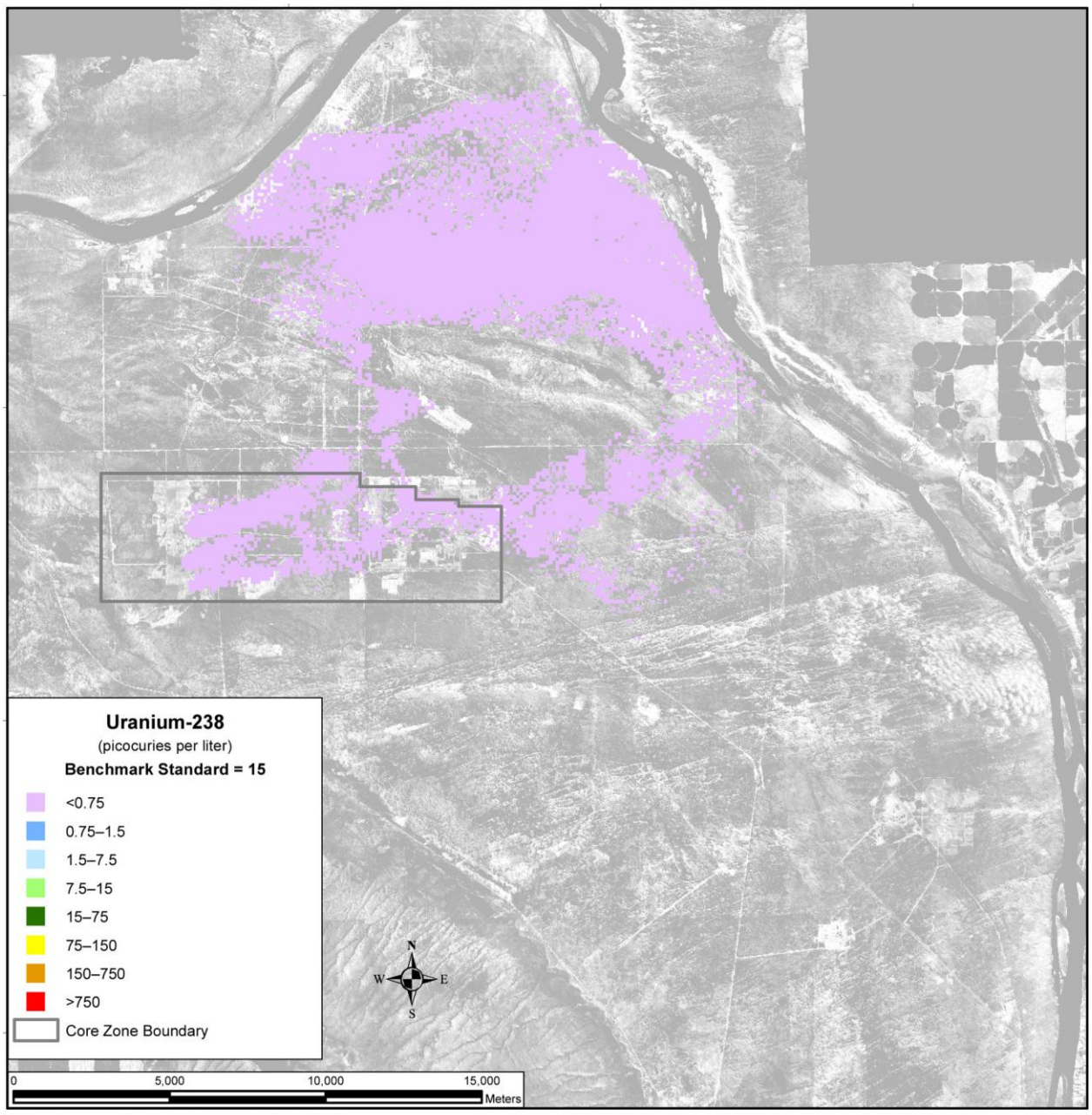
Figure 5–63. Tank Closure Alternative 2A Spatial Distribution of Groundwater Nitrate Concentration, Calendar Year 3890

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 more slowly 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 aqueous concentrations are also attenuated as a result of interaction of the dissolved uranium with the solids that make up the aquifer material. Figure 5–64 shows the distribution of uranium-238 in CY 2010. There is a small plume associated with releases from cribs and trenches (ditches) and past leaks at the T Barrier that is less than one-twentieth of the benchmark concentration. This plume also extends northeast up through Gable Gap. By CY 3890 (see Figure 5–65), the area of the plume has grown significantly, but there are no significant increases in peak concentration. In CY 11,940 (see Figure 5–66), the greatest development of the plume during the analysis period is seen, and the benchmark concentrations are exceeded only in a few isolated areas. Figures 5–67 through 5–69 show the corresponding results for total uranium, which shows similar spatial distributions at similarly selected times.



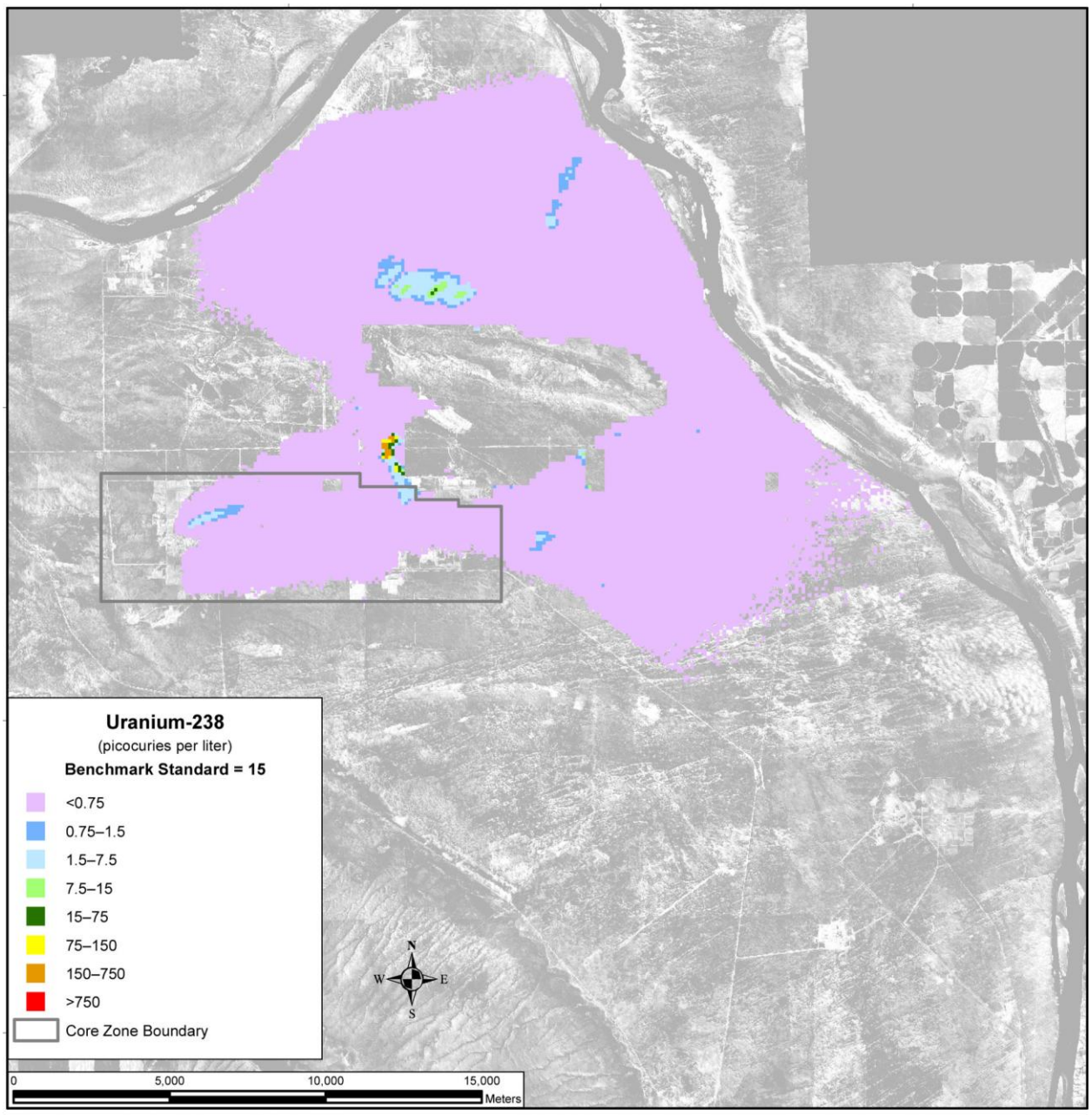
Note: To convert meters to feet, multiply by 3.281.

Figure 5–64. Tank Closure Alternative 2A Spatial Distribution of Groundwater Uranium-238 Concentration, Calendar Year 2010



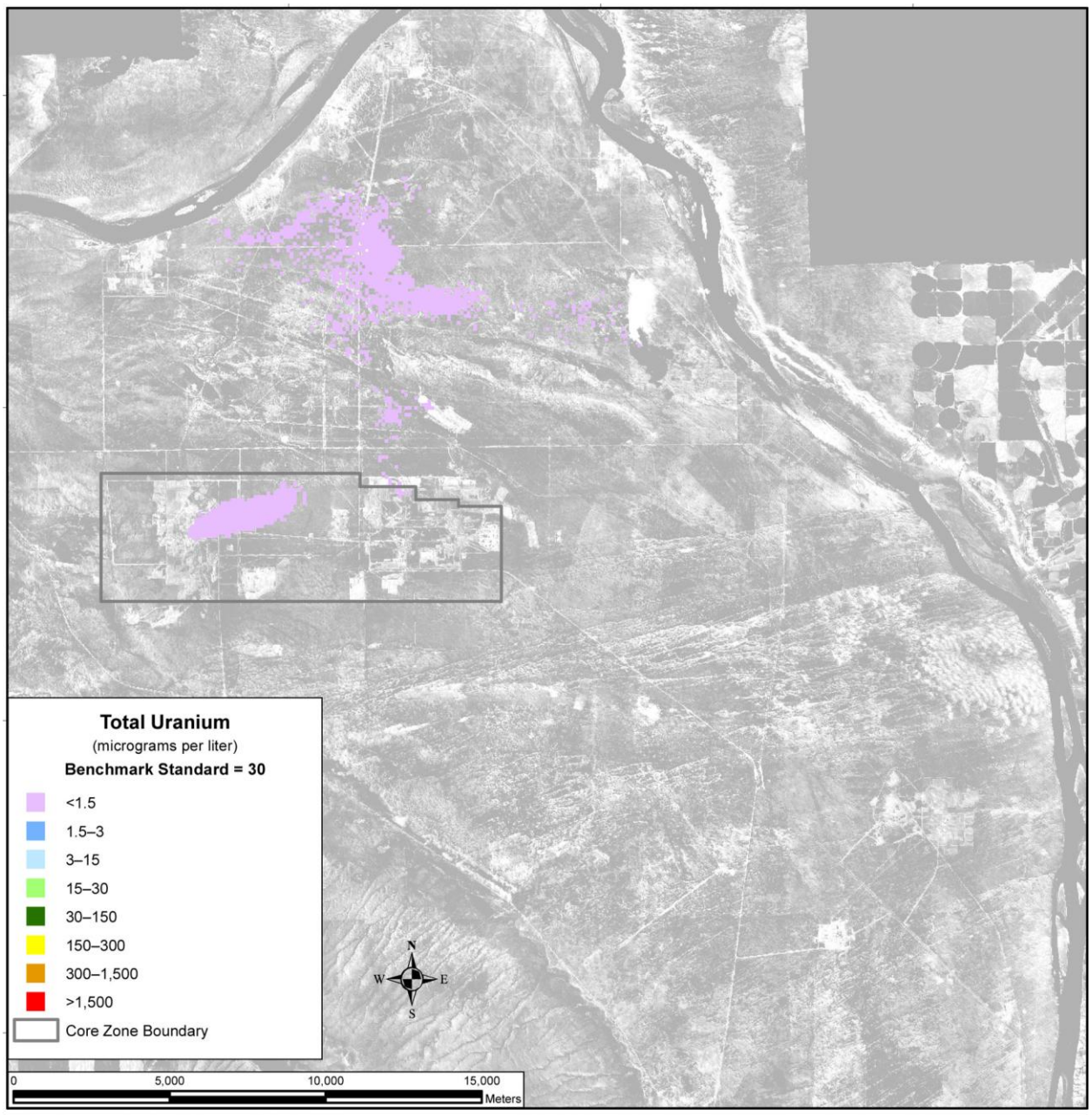
Note: To convert meters to feet, multiply by 3.281.

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



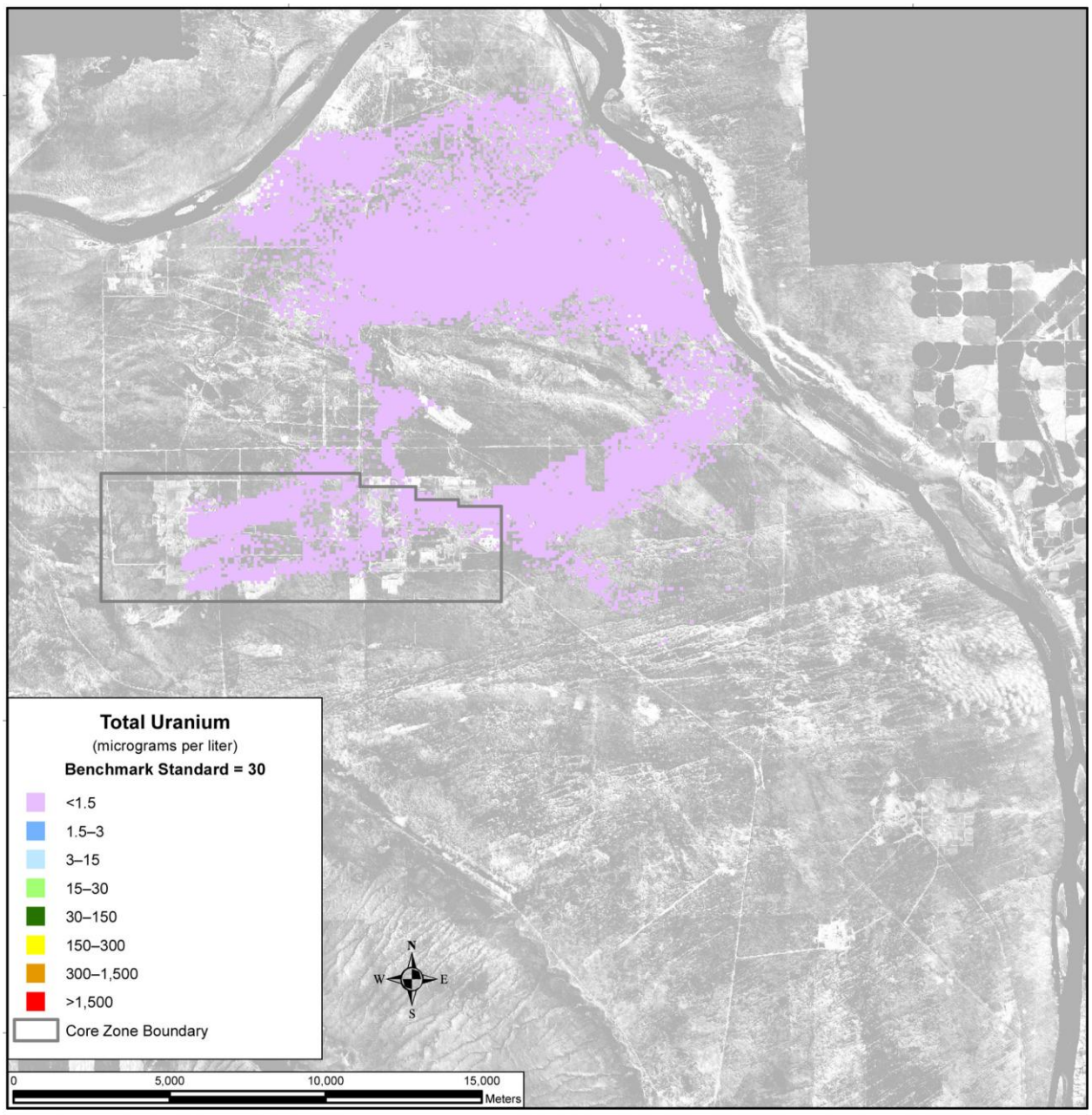
Note: To convert meters to feet, multiply by 3.281.

Figure 5–66. Tank Closure Alternative 2A Spatial Distribution of Groundwater Uranium-238 Concentration, Calendar Year 11,940



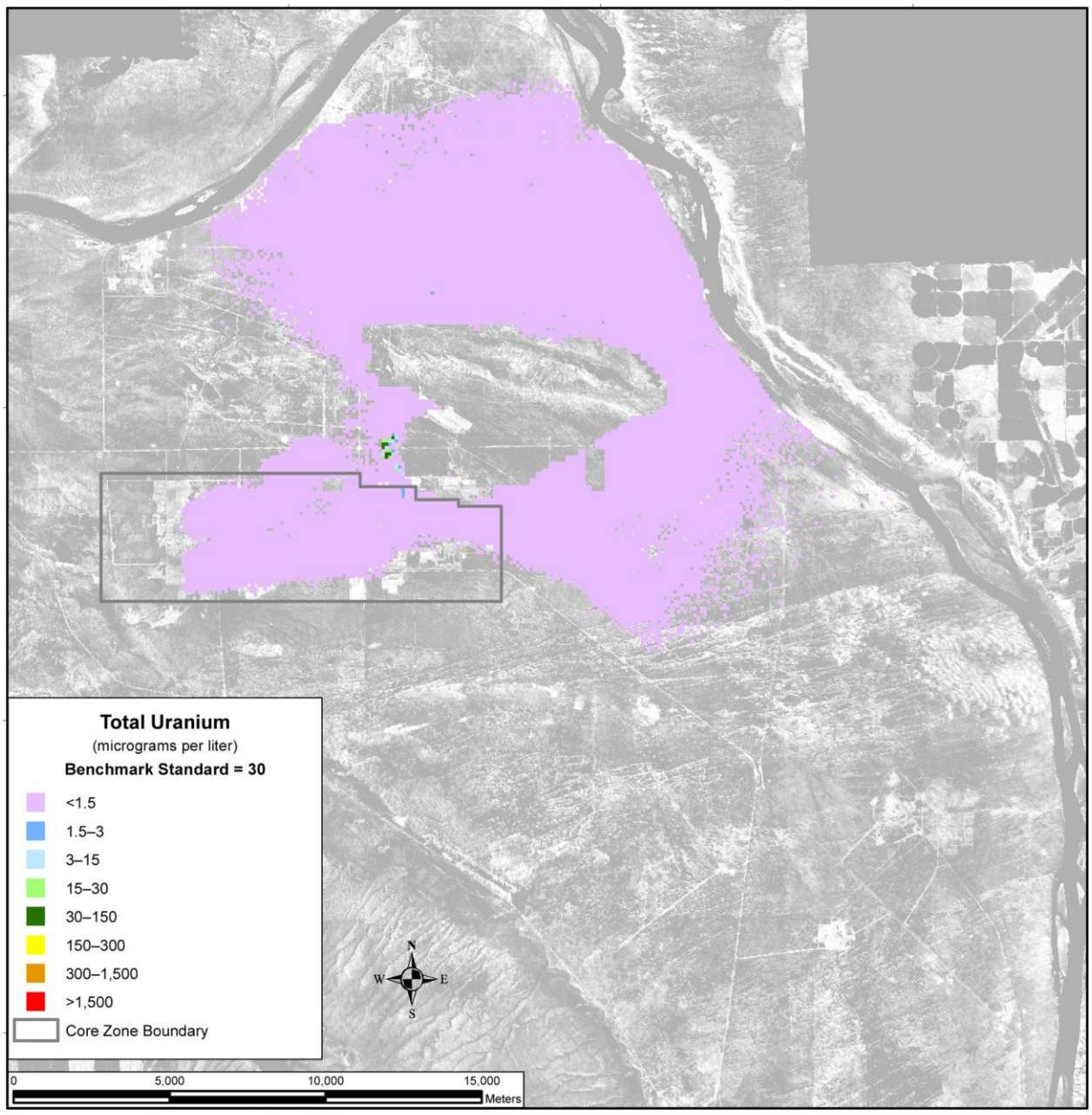
Note: To convert meters to feet, multiply by 3.281.

Figure 5–67. Tank Closure Alternative 2A Spatial Distribution of Groundwater Total Uranium Concentration, 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, Calendar Year 3890



Note: To convert meters to feet, multiply by 3.281.

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

Figures 5–70 through 5–72 show the area in which groundwater concentrations of iodine-129, technetium-99, and uranium-238 exceed their respective benchmark concentrations. Iodine-129 peaks early in the simulation, covering a peak area of just over 9 square kilometers (3.5 square miles) around CY 2140. This area decreases rapidly until CY 2790, when it begins to rise again, peaking at about 3.3 square kilometers (1.3 square miles) around CY 3340. Around CY 4190, this area drops below 1 square kilometer (0.38 square miles), continuing its decline to approximately 0.3 square kilometers (0.1 square miles) by CY 6500 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 2090 and reaching 0.25 square kilometers (0.1 square miles) in CY 6500. Uranium-238 shows a distinctly different pattern, without any area above the benchmark concentration until CY 5640. From

CY 5640 until the end of the simulation, areas in which uranium-238 concentrations exceed the benchmark slowly increase, never surpassing 0.36 square kilometers (0.14 square miles) during the simulation.

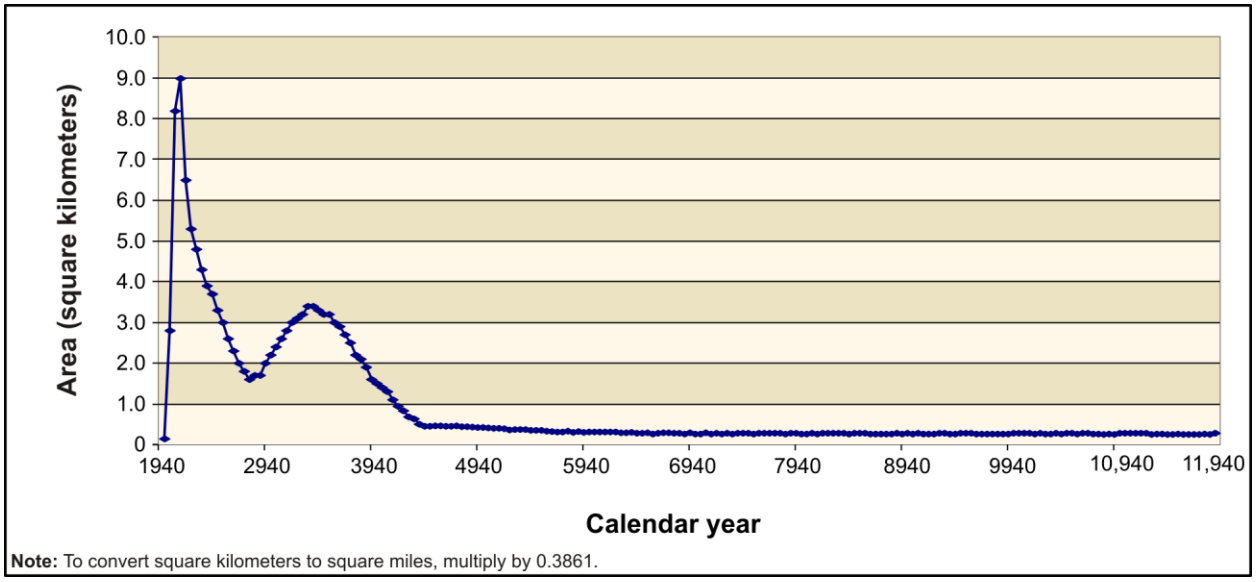


Figure 5–70. Tank Closure Alternative 2A Total Area of Groundwater Iodine-129 Concentration Exceeding the Benchmark Concentration as a Function of Time

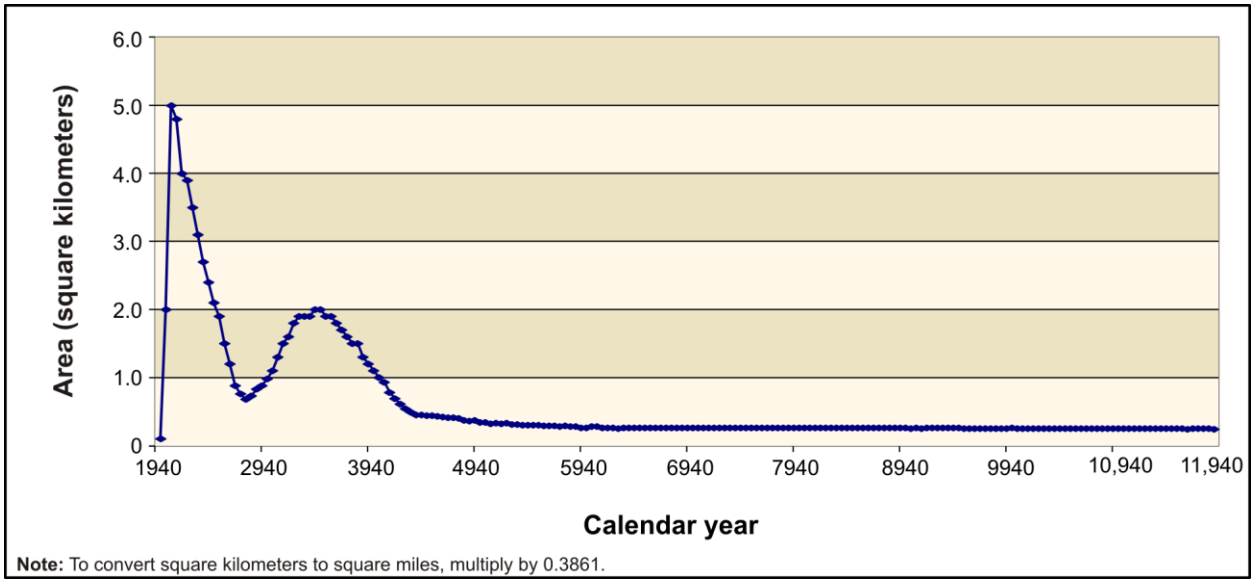


Figure 5–71. Tank Closure Alternative 2A Total Area of Groundwater Technetium-99 Concentration Exceeding the Benchmark Concentration as a Function of Time

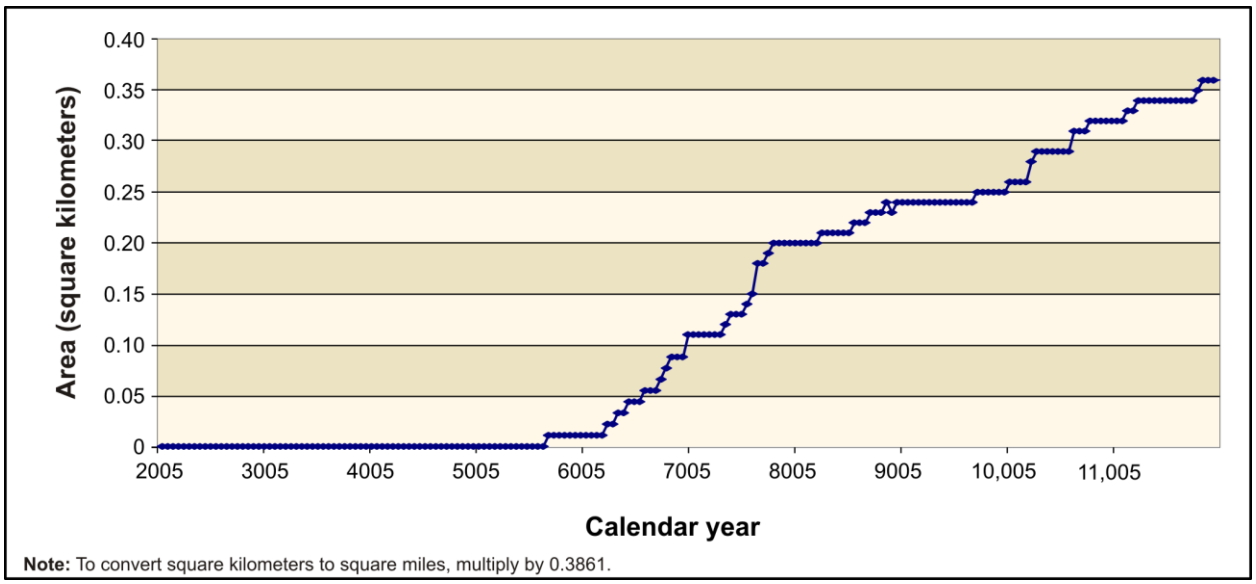


Figure 5–72. Tank Closure Alternative 2A Total Area of Groundwater Uranium-238 Concentration Exceeding the Benchmark Concentration as a Function of Time

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 CYs 1955 and 2200. These concentrations fall below the benchmark between CYs 2200 and 3100. Concentrations at the Columbia River nearshore exceed a few benchmark concentrations during the first 60 years simulated and then fall below the benchmark concentrations for the rest of the period of analysis.

Concentrations of tritium at the Core Zone Boundary exceed the benchmark by about one to two orders of magnitude during the first 100 years of the period of analysis. Tritium concentrations at the Columbia River nearshore 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. Although concentrations of these constituents continue to rise throughout the period of analysis, they never exceed benchmark concentrations at the Core Zone Boundary or the Columbia River nearshore.

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 at the tank farms 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 waste in tanks would be immobilized by grouting 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 impacts 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 presented in this section are 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 waste from other tank farm sources (e.g., tank residuals, 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, but this discussion 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 contributions 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 (e.g., tank residuals, ancillary equipment). For all three types of sources, the release to the vadose zone is controlled by the inventory (i.e., 100 percent of the inventory is 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 of the radiological risk drivers and Figure 5–74, the chemical hazard drivers. The predominant sources of 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 of 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.

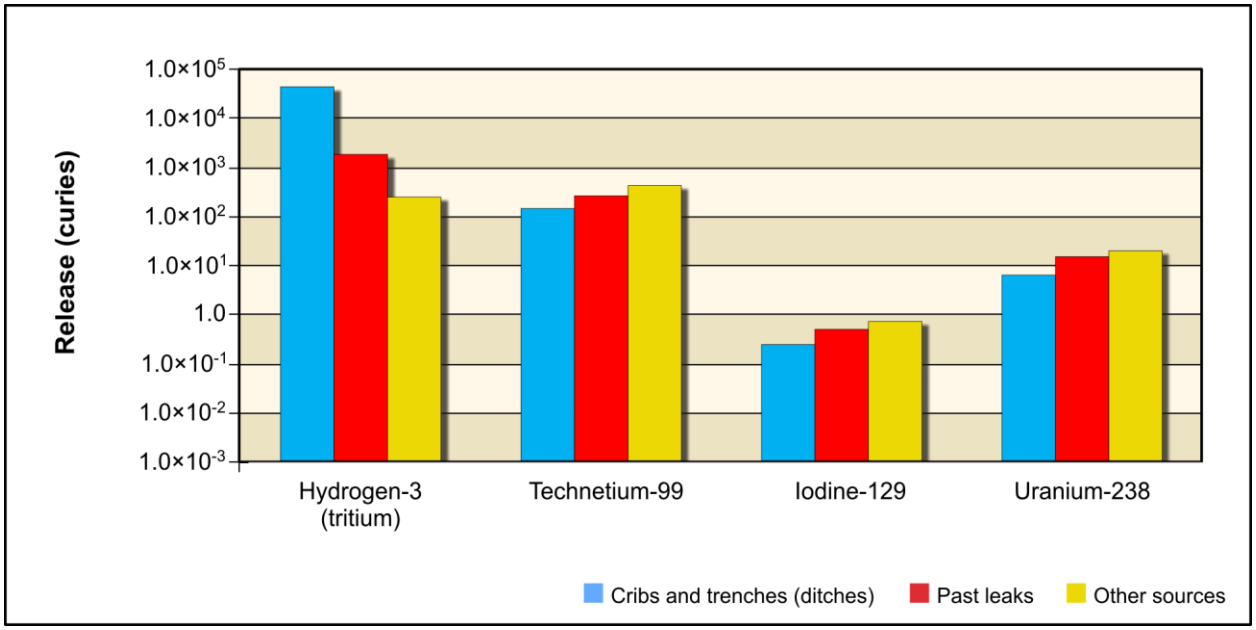


Figure 5–73. Tank Closure Alternative 2B Releases of Radioactive Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

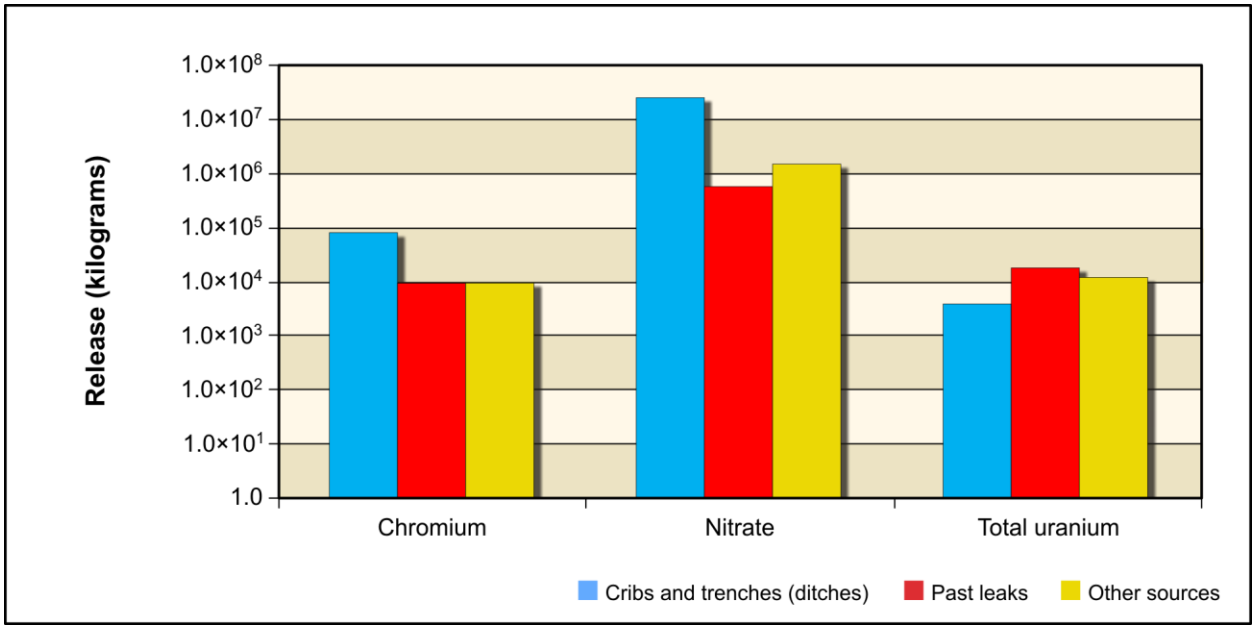


Figure 5–74. Tank Closure Alternative 2B Releases of Chemical Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

Figure 5–75 shows the estimated release to groundwater of 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.

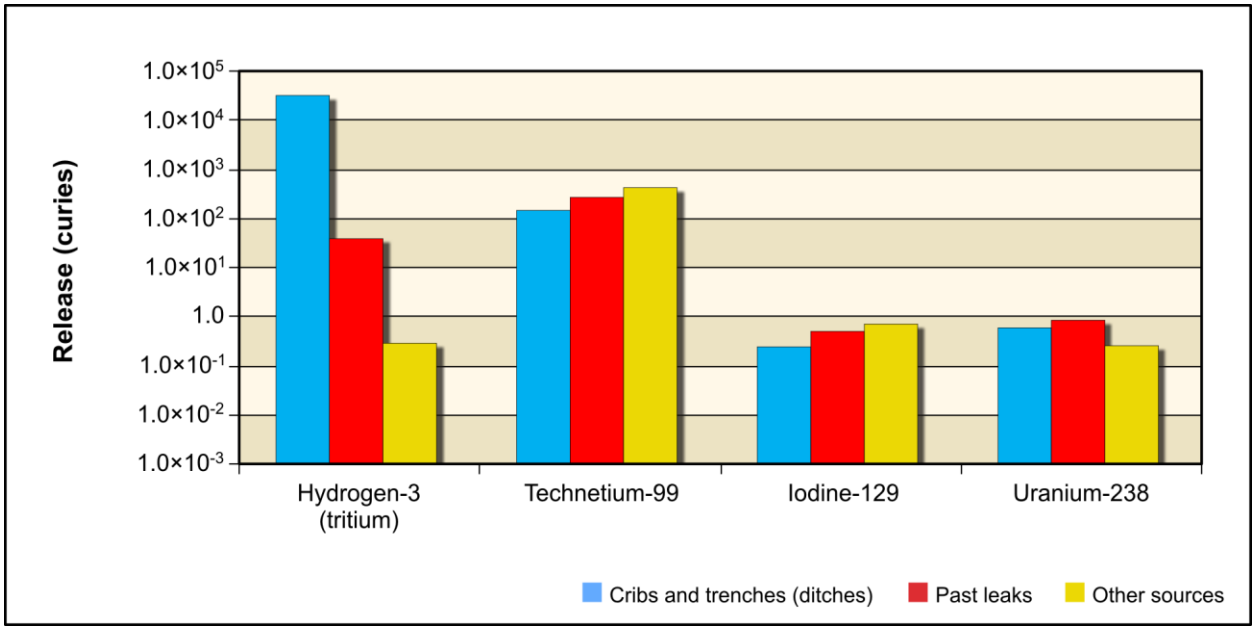


Figure 5–75. Tank Closure Alternative 2B Releases of Radioactive Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

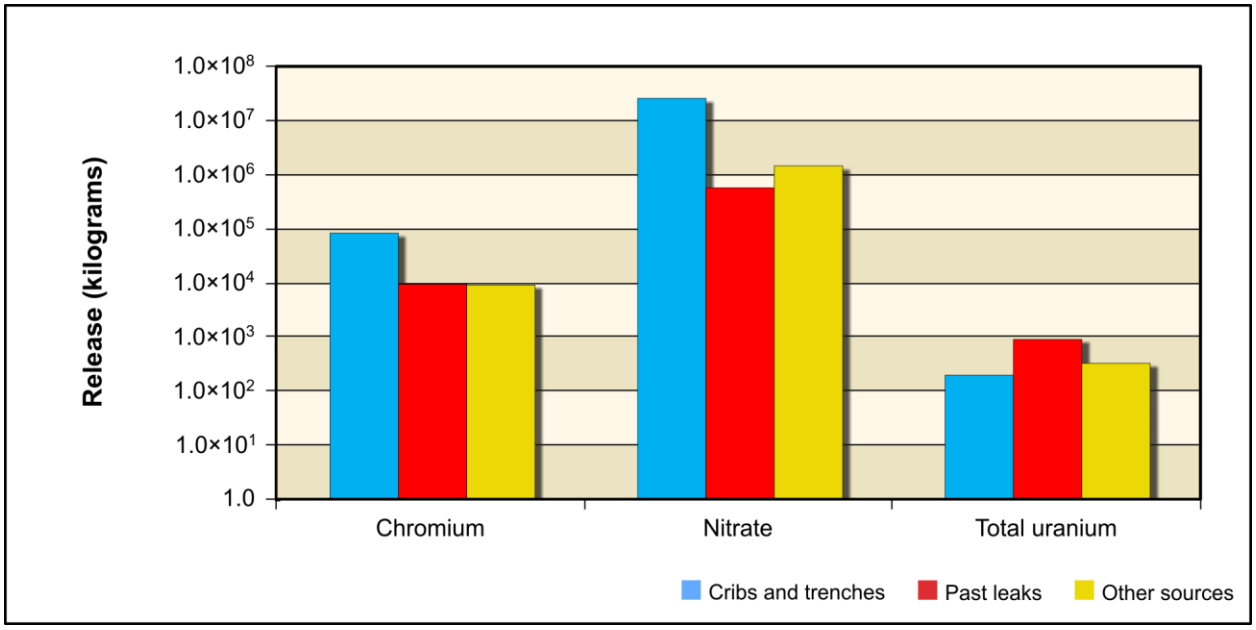


Figure 5–76. Tank Closure Alternative 2B Releases of Chemical Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

For uranium-238 and total uranium, the amount released to groundwater is less than that released 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 release from 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 5 percent of the total inventory of total uranium reaches groundwater during the period of analysis; for other tank farm sources, only about 3 percent of the total inventory reaches groundwater during the period of analysis. For releases from cribs and trenches (ditches), about 10 percent of the uranium-238 present in the vadose zone reaches groundwater; for past leaks, about 5 percent; and for other tank farm sources, only about

1 percent. These results suggest that uranium-238 and total uranium impacts on groundwater would occur later in the post–administrative control period because of the long travel times in the vadose zone for these COPCs.

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 2 percent; and for other tank farm sources, only about one-tenth of 1 percent reaches 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.

Figure 5–77 shows the estimated release to the Columbia River of 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 released to groundwater because of retardation. Overall, about 30 percent of the uranium-238 and about 26 percent of the total uranium released to groundwater during the period of analysis reach the Columbia River. For tritium, the amount released to the Columbia River is attenuated by radioactive decay. Overall, only about 1 percent of the tritium released to groundwater reaches 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.

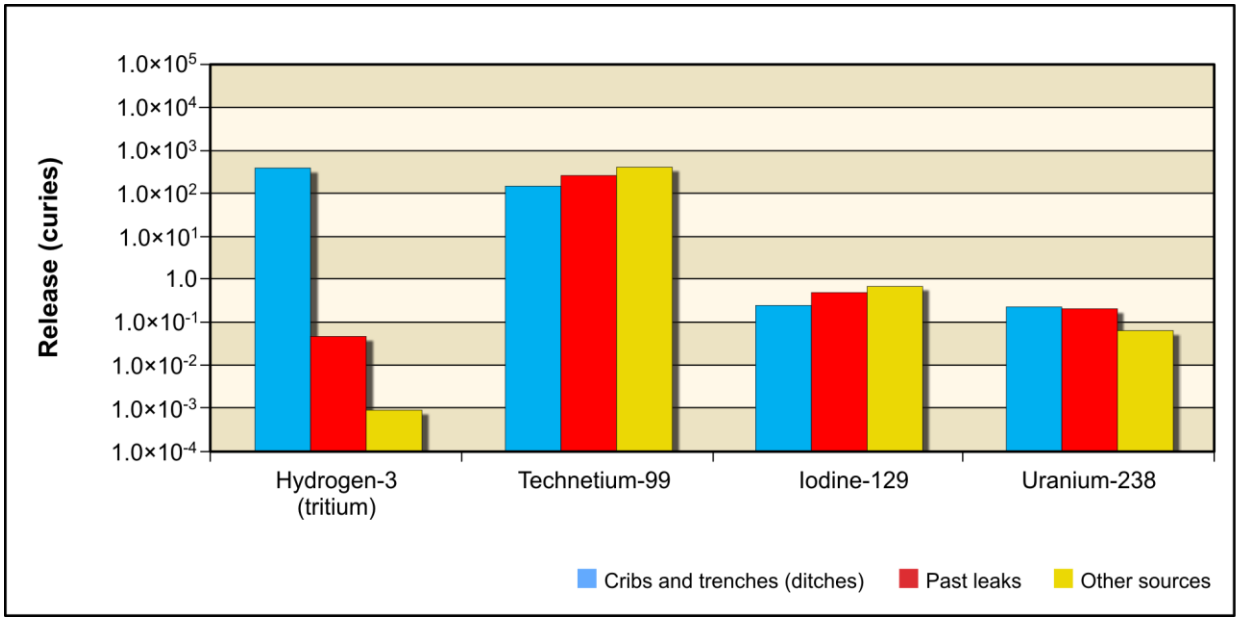


Figure 5–77. Tank Closure Alternative 2B Releases of Radioactive Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

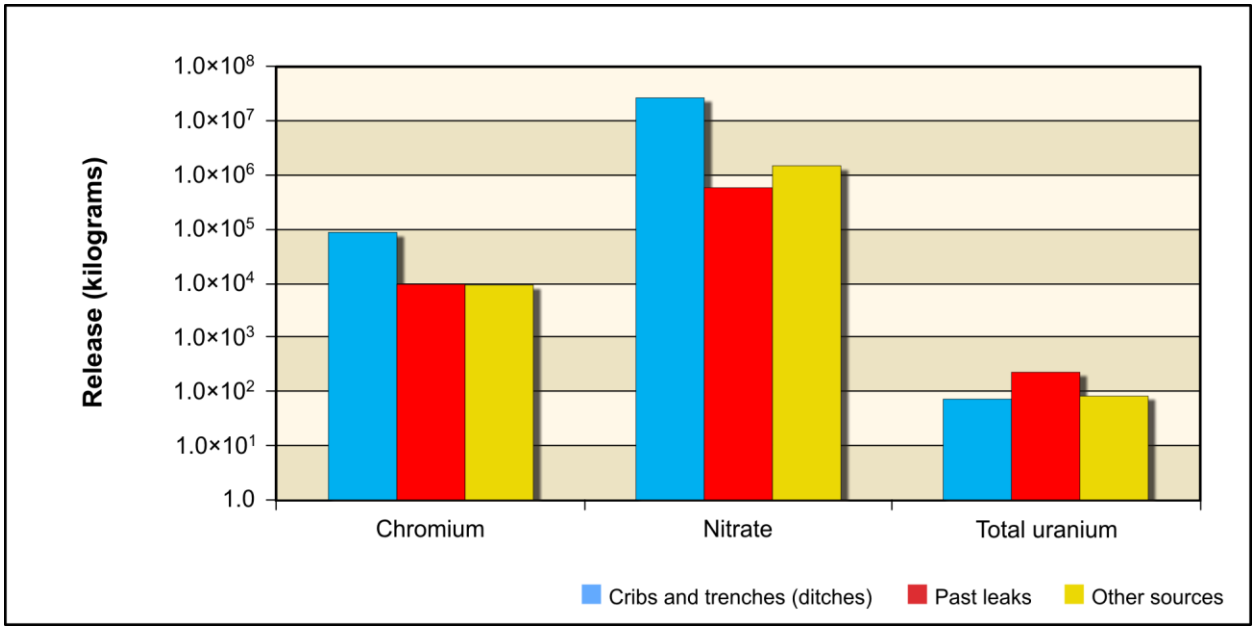


Figure 5–78. Tank Closure Alternative 2B Releases of Chemical Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

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 nearshore. 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 of each radionuclide and chemical is also shown. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over five orders of magnitude. Tables 5–3 through 5–8 list the contributions of individual releases to maximum concentrations of the COPCs in the peak year of arrival at the tank farm barriers, Core Zone Boundary, and Columbia River nearshore. Tank Closure Alternative 2B contains many of the features in DOE's Preferred Alternative. For clarity, additional breakdown tables for other tank farm sources are presented for this alternative. Note that for releases that occurred during the past-practice period from cribs and trenches (ditches) (see Table 5–3), past tank leaks (see Table 5–4), and unplanned releases (see Table 5–5), the year that the maximum concentrations were reported at each location occurs early in the period of analysis. For the releases that occur later during the retrieval or post–administrative control periods, including from tank residuals (see Table 5–6), retrieval leaks (see Table 5–7), and ancillary equipment (see Table 5–8), the values listed represent peak arrival concentrations after CY 2050. Table 5–9 lists the maximum concentrations of the COPCs from the contributions of all sources after CY 2050 at the tank farm barriers, Core Zone Boundary, and Columbia River nearshore. Tank Closure Alternative 2B has lower maximum COPC concentrations after CY 2050 than Tank Closure Alternative 2A. This difference is attributable to the closure activities that would occur under Tank Closure Alternative 2B.

Table 5–3. Tank Closure Alternative 2B Contribution of Releases from Cribs and Trenches (Ditches) to Maximum COPC Concentrations in the Peak Year at the Tank Farm Barriers, Core Zone Boundary, and Columbia River Nearshore

Contaminant	B Barrier	T Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclide (picocuries per liter)					
Hydrogen-3 (tritum)	**672,000** (1956)	**7,610,000** (1976)	**672,000** (1956)	10,700 (1964)	20,000
Technetium-99	**33,700** (1956)	278 (1969)	**33,700** (1956)	844 (1965)	900
Iodine-129	**42.3** (1956)	**2.3** (1968)	**42.3** (1956)	**1.1** (1964)	1
Uranium isotopes (includes U-233, -234, -235, -238)	0 (11,835)	1 (11,770)	0 (11,835)	0 (11,935)	15
Chemical (micrograms per liter)					
Chromium	**6,150** (1955)	**6,740** (1962)	**6,150** (1955)	**228** (2019)	100
Nitrate	**2,120,000** (1956)	**1,550,000** (1962)	**2,120,000** (1956)	**72,300** (1964)	45,000

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 5–4. Tank Closure Alternative 2B Contribution of Past Leaks to 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 (picocuries per liter)								
Hydrogen-3 (tritium)	191 (2002)	21 (2011)	247 (2021)	2,720 (2016)	36 (2016)	69 (2010)	1 (2072)	20,000
Technetium-99	**1,400** (2004)	**1,550** (2084)	**2,480** (2030)	**10,500** (2023)	129 (2050)	**1,550** (2084)	361 (2228)	900
Iodine-129	**1.5** (2104)	**2.8** (2085)	**4.6** (2026)	**20.2** (2024)	0.2 (2046)	**2.8** (2085)	0.6 (2275)	1
Uranium isotopes (includes U-233, -234, -235, -238)	0 (11,801)	3 (11,913)	0 (11,928)	1 (11,934)	0 (11,500)	3 (11,913)	0 (11,926)	15
Chemical (micrograms per liter)								
Chromium	66 (2104)	58 (2104)	**247** (2032)	**303** (2023)	6 (2032)	78 (2105)	7 (2253)	100
Nitrate	2,180 (2107)	3,030 (2095)	7,120 (2030)	24,100 (2023)	438 (2041)	3,030 (2095)	648 (2222)	45,000
Total uranium	0 (11,826)	4 (11,827)	0 (11,849)	0 (11,856)	0 (11,778)	4 (11,827)	0 (11,937)	30

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 5–5. Tank Closure Alternative 2B Contribution of Unplanned Releases to 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 (picocuries per liter)								
Hydrogen-3 (tritium)	17 (2004)	4 (2013)	0 (1940)	0 (2042)	0 (1940)	5 (2010)	0 (2002)	20,000
Technetium-99	58 (2004)	39 (2901)	0 (5396)	0 (2063)	0 (2698)	46 (2970)	1 (3196)	900
Iodine-129	0.2 (2794)	0.0 (2986)	0.0 (4392)	0.0 (2064)	0.0 (2724)	0.1 (2828)	0.0 (2910)	1
Chemical (micrograms per liter)								
Chromium	0 (2005)	1 (2032)	0 (1940)	0 (2062)	0 (2703)	1 (2032)	0 (2770)	100
Nitrate	56 (2004)	363 (2038)	0 (1940)	16 (2061)	0 (2697)	363 (2038)	6 (2781)	45,000

Note: Corresponding calendar years shown in parentheses.
Key: COPC=constituent of potential concern.

Table 5–6. Tank Closure Alternative 2B Contribution of Releases from Tank Residuals to 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 (picocuries per liter)								
Technetium-99	160 (3685)	617 (2965)	459 (3674)	362 (3329)	169 (3201)	617 (2965)	47 (4230)	900
Iodine-129	0.1 (3896)	0.7 (3533)	0.3 (4259)	0.4 (3719)	0.2 (3716)	0.7 (3533)	0.1 (4790)	1
Chemical (micrograms per liter)								
Chromium	5 (3451)	19 (2873)	14 (3620)	6 (3311)	4 (3194)	19 (2873)	1 (4025)	100
Nitrate	536 (3614)	1,700 (2966)	1,080 (3586)	1,320 (3354)	375 (3184)	1,700 (2966)	166 (4220)	45,000

Note: Corresponding calendar years shown in parentheses.
Key: COPC=constituent of potential concern.

Table 5–7. Tank Closure Alternative 2B Contribution of Retrieval Leaks to 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 (picocuries per liter)								
Hydrogen-3 (tritium)	2 (2053)	8 (2053)	5 (2061)	6 (2067)	2 (2061)	8 (2053)	0 (1940)	20,000
Technetium-99	94 (2063)	162 (2065)	99 (2082)	218 (2080)	49 (2085)	162 (2065)	15 (3276)	900
Iodine-129	0.2 (2063)	0.3 (2068)	0.2 (2082)	0.4 (2080)	0.1 (2082)	0.3 (2068)	0.0 (3170)	1
Chemical (micrograms per liter)								
Chromium	3 (2163)	6 (2064)	8 (2082)	4 (2080)	1 (2074)	6 (2064)	1 (2833)	100
Nitrate	3,190 (2062)	2,110 (2090)	986 (2082)	818 (2079)	712 (2082)	2,110 (2090)	134 (3174)	45,000

Note: Corresponding calendar years shown in parentheses.
Key: COPC=constituent of potential concern.

Table 5–8. Tank Closure Alternative 2B Contribution of Releases from Ancillary Equipment to 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 (picocuries per liter)								
Technetium-99	31 (3610)	191 (3113)	49 (3675)	94 (3469)	82 (3307)	191 (3113)	15 (4161)	900
Iodine-129	0.1 (3694)	0.3 (3342)	0.1 (3863)	0.2 (3616)	0.1 (3544)	0.3 (3342)	0.0 (4630)	1
Chemical (micrograms per liter)								
Chromium	1 (3647)	5 (3115)	2 (3724)	2 (3412)	2 (3273)	5 (3115)	0 (4217)	100
Nitrate	183 (3606)	490 (3045)	174 (3617)	337 (3414)	179 (3410)	490 (3045)	54 (4265)	45,000

Note: Corresponding calendar years shown in parentheses.
Key: COPC=constituent of potential concern.

Table 5–9. 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 (picocuries per liter)								
Hydrogen-3 (tritium)	7 (2051)	579 (2052)	32 (2050)	2,870 (2050)	15 (2050)	628 (2051)	477 (2051)	20,000
Technetium-99	774 (2102)	**3,570** (2056)	**1,510** (2051)	**6,600** (2051)	259 (3296)	**3,570** (2056)	396 (2254)	900
Iodine-129	**1.5** (2104)	**4.5** (2056)	**2.8** (2050)	**12.6** (2050)	0.3 (3593)	**4.5** (2056)	0.7 (2240)	1
Uranium isotopes (includes U-233, -234, -235, -238)	0 (11,865)	3 (11,913)	0 (11,928)	2 (11,909)	0 (11,910)	3 (11,913)	0 (11,937)	15
Chemical (micrograms per liter)								
Chromium	81 (2168)	**215** (2050)	**156** (2050)	**353** (2045)	6 (2050)	**215** (2050)	71 (2076)	100
Nitrate	17,900 (2172)	**171,000** (2055)	4,780 (2051)	**62,100** (2053)	909 (2071)	**171,000** (2055)	17,200 (2122)	45,000
Total uranium	0 (11,826)	4 (11,827)	0 (11,850)	1 (11,843)	0 (11,830)	4 (11,827)	0 (11,937)	30

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.

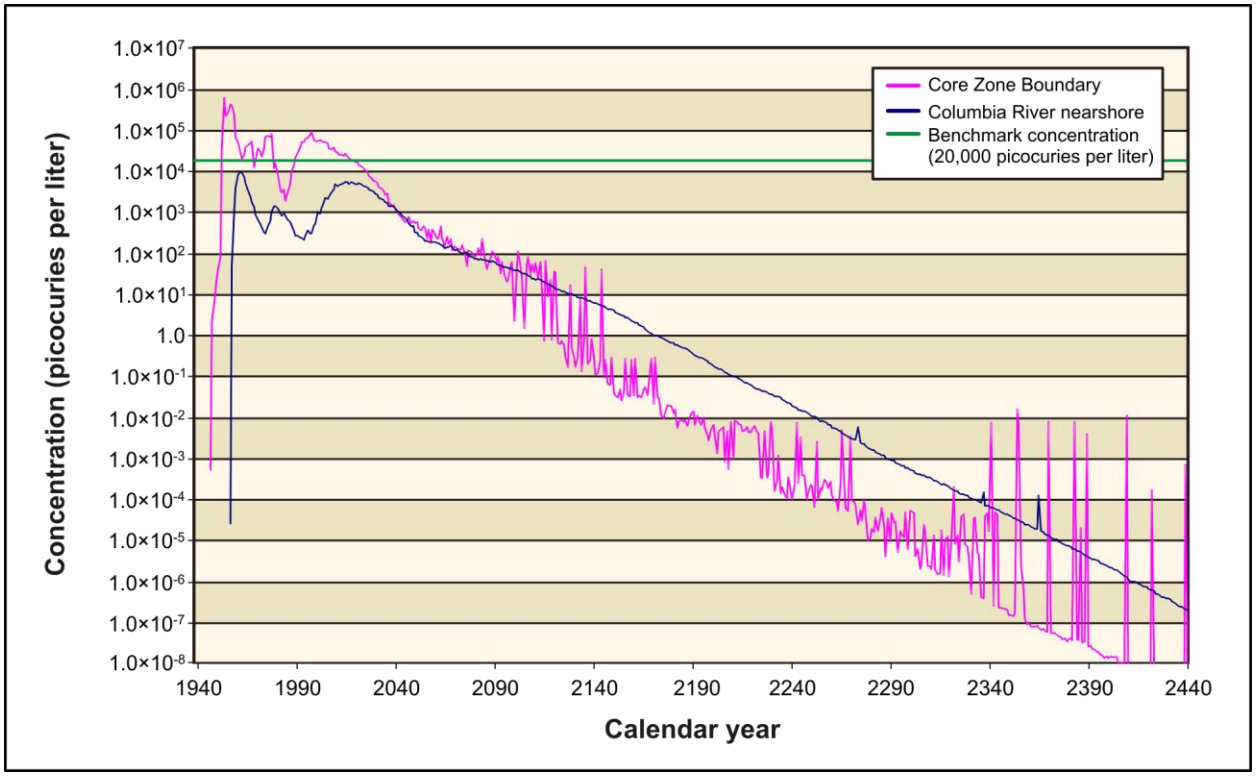


Figure 5–79. Tank Closure Alternative 2B, Case 1, Hydrogen-3 (Tritium) Concentration Versus Time

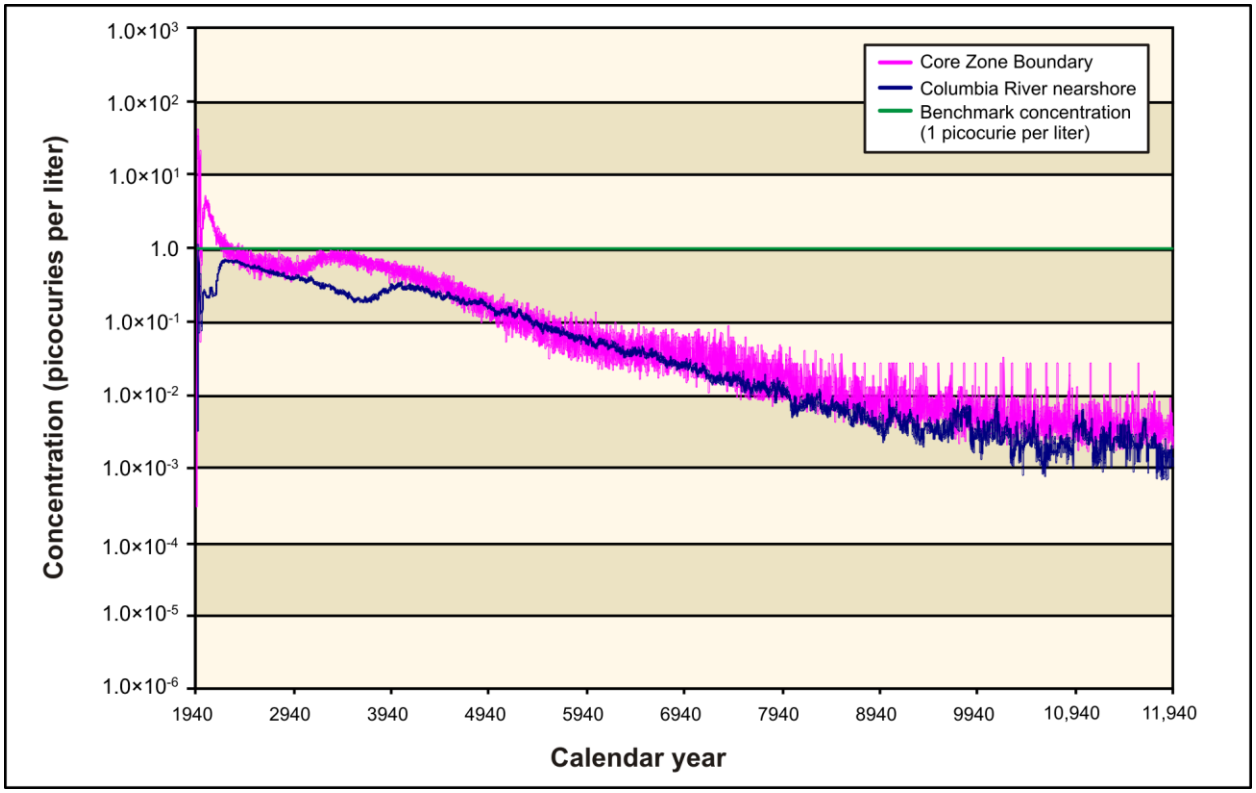


Figure 5–80. Tank Closure Alternative 2B, Case 1, Iodine-129 Concentration Versus Time

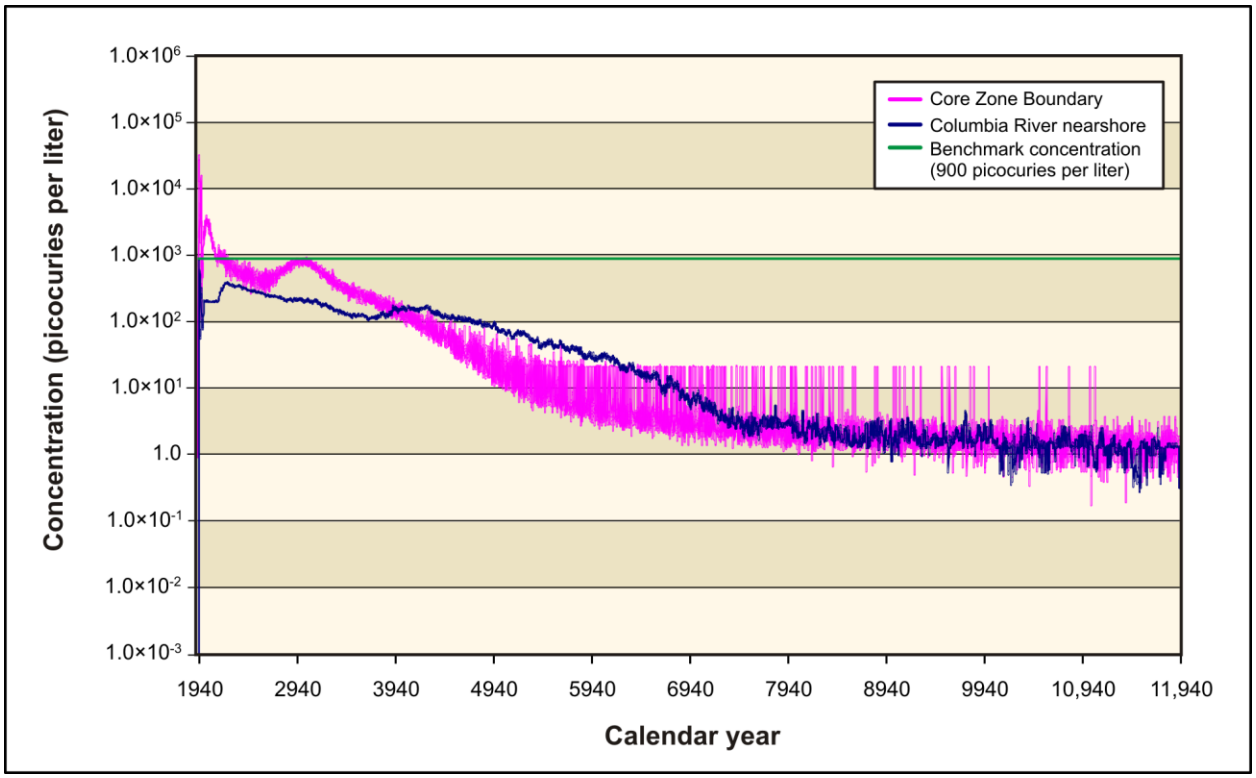


Figure 5–81. Tank Closure Alternative 2B, Case 1, Technetium-99 Concentration Versus Time

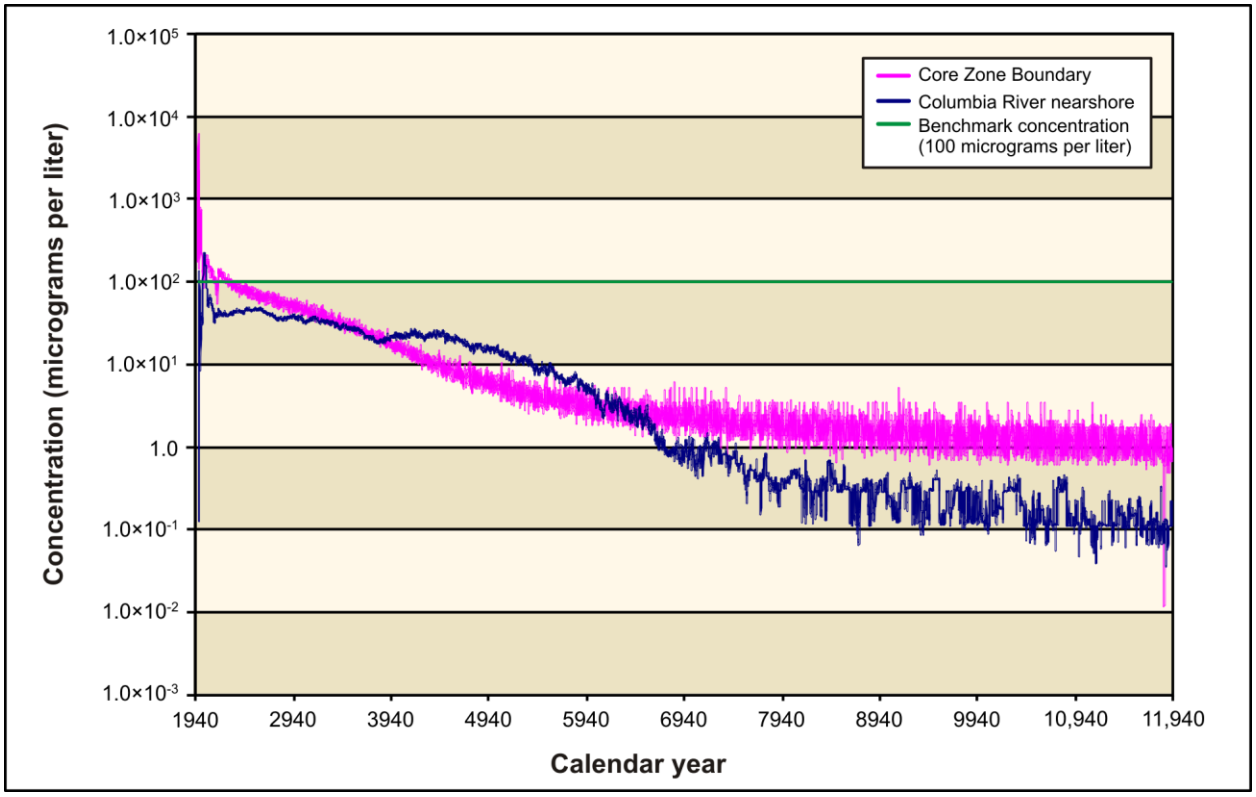


Figure 5–82. Tank Closure Alternative 2B, Case 1, Chromium Concentration Versus Time

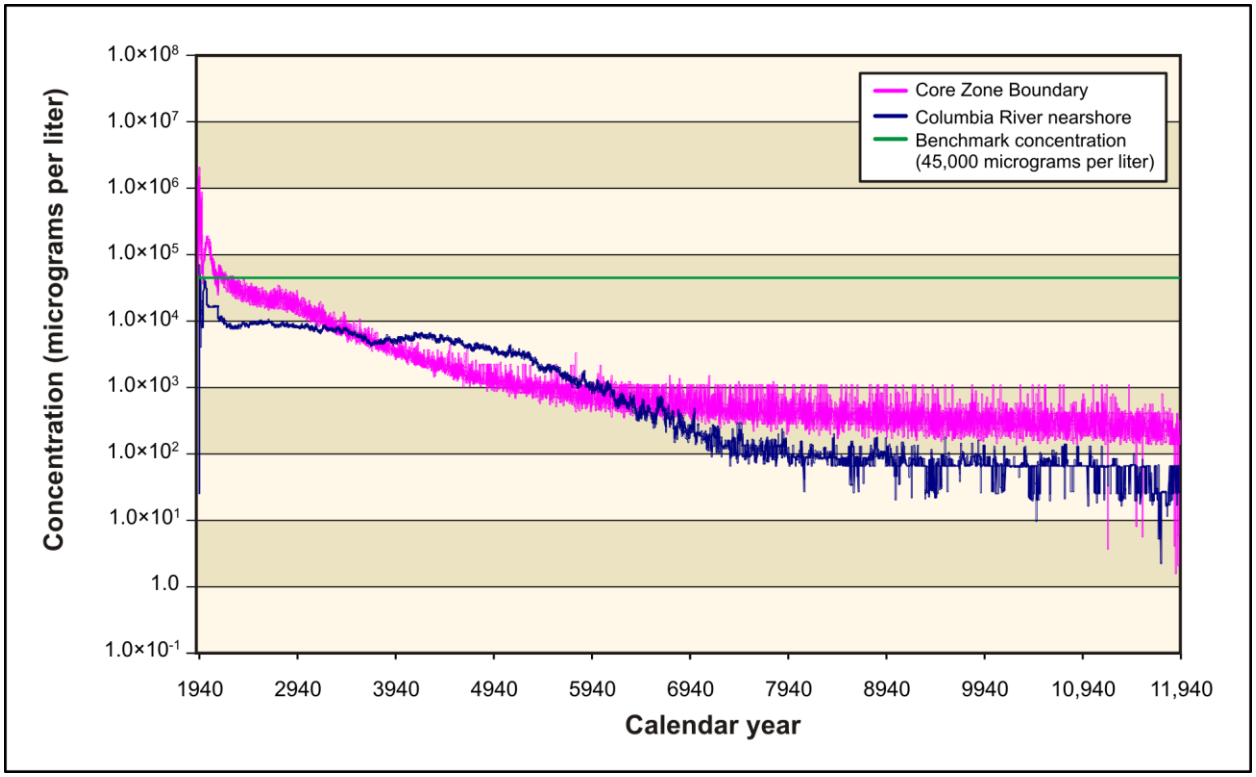


Figure 5–83. Tank Closure Alternative 2B, Case 1, Nitrate Concentration Versus Time

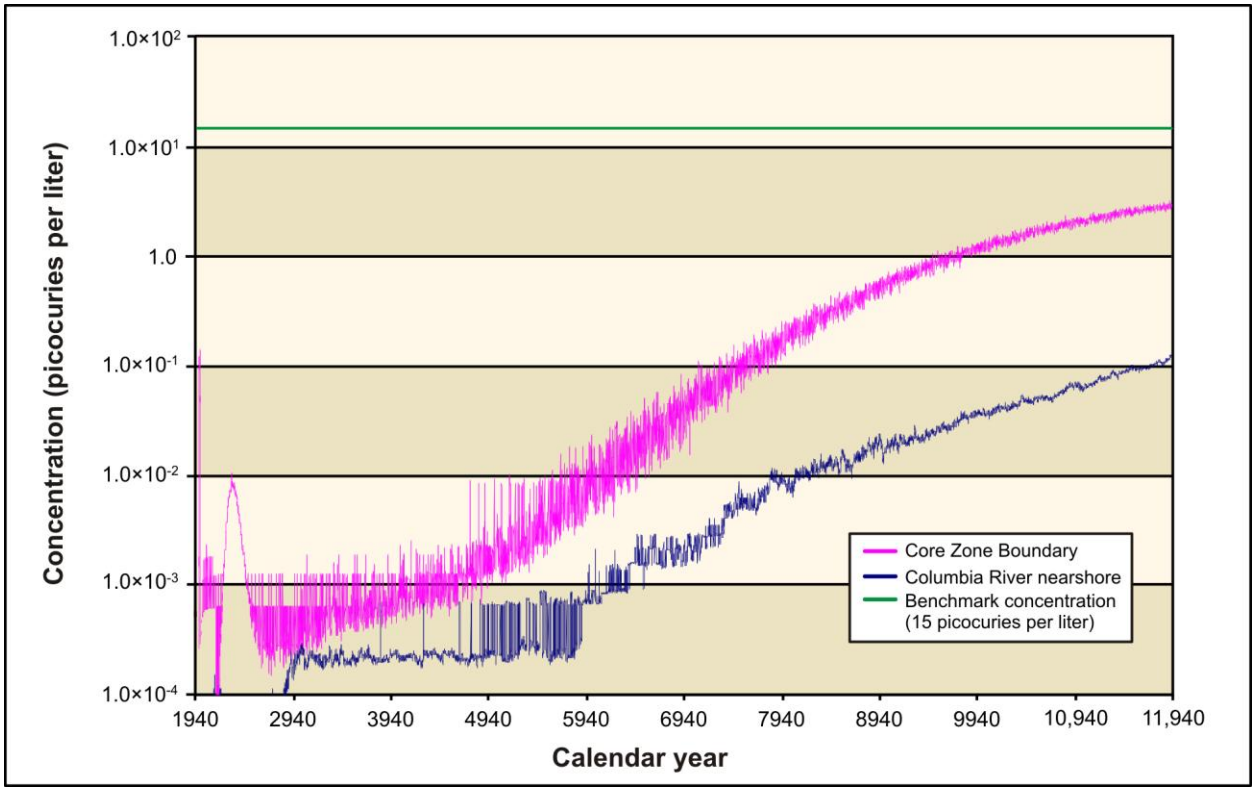


Figure 5–84. Tank Closure Alternative 2B, Case 1, Uranium-238 Concentration Versus Time

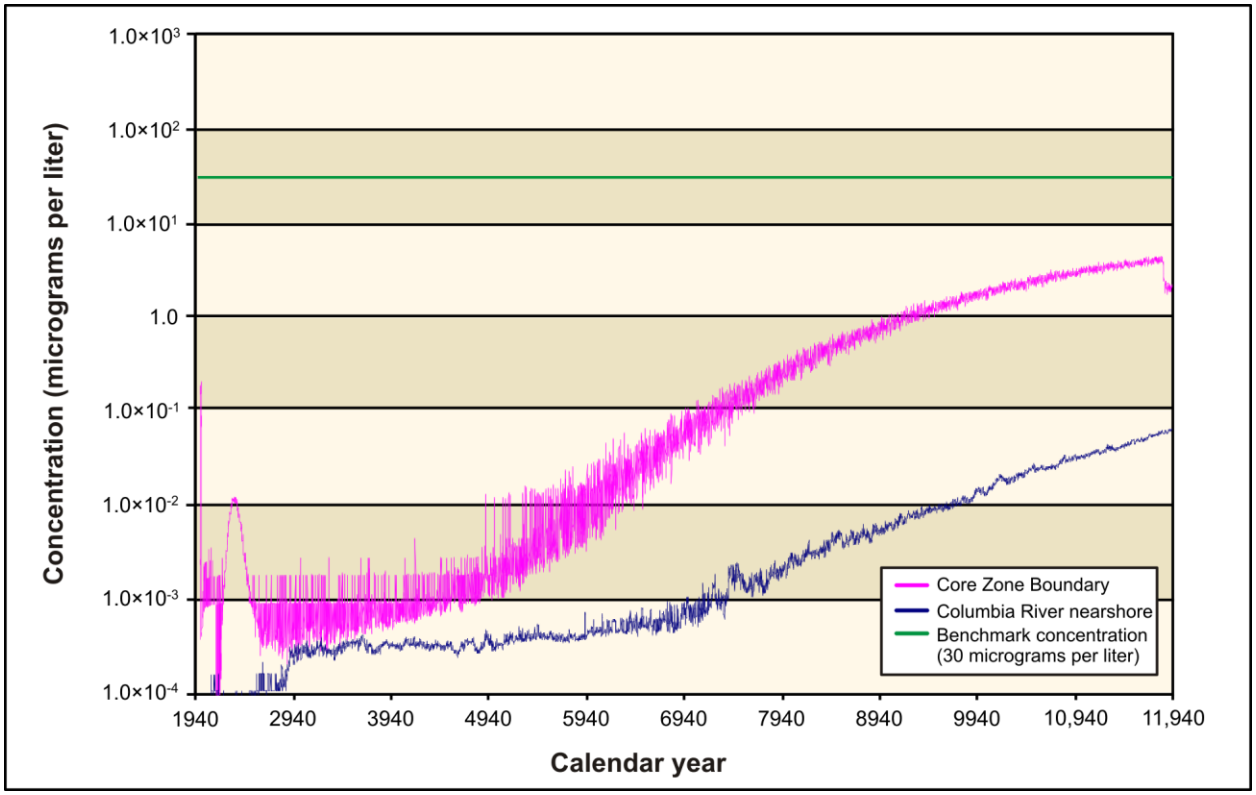


Figure 5–85. Tank Closure Alternative 2B, Case 1, Total Uranium Concentration Versus Time

In the analysis of concentration-versus-time graphs, three separate cases were modeled that differ in the types of releases that were considered to determine the sensitivity of the temporal distributions of the COPC concentrations for each case. Case 1 includes releases from all sources, including cribs and trenches (ditches), past leaks from the SST farms, retrieval leaks from SSTs (15,140 liters [4,000 gallons] per SST) during the retrieval period, and long-term releases of waste from other tank farm sources (e.g., residuals, ancillary equipment) that occur during the post–administrative control period. The all-sources Case 1 represents a scenario that is similar to the release scenarios modeled under Tank Closure Alternatives 1 and 2A.

Case 2 includes all of the releases included in Case 1 except the liquid loss from retrieval leaks (15,140 liters [4,000 gallons] per SST). This case can be viewed as representing mitigation measures during retrieval. More discussion on mitigation measures during retrieval and closure is presented in Chapter 7.

Case 3 includes all of the releases of Case 1 except discharges from cribs and trenches (ditches). This case is not intended to be a representative scenario for tank closure or mitigation and is provided here merely for reference. Eliminating the signature of the releases from cribs and trenches (ditches) makes the results of the all-sources Case 1 more amenable to interpretation.

Figure 5–79 shows concentration versus time for tritium for Case 1. Because Tank Closure Alternative 2B has no impact on discharges to cribs and trenches (ditches) that occurred during the past-practice period, these releases cause groundwater concentrations within the Core Zone Boundary to exceed benchmark concentrations by about one to two orders of magnitude for a short period of time during the early part of the period of analysis. This time period is represented by the first series of sharp inflections in the curve for the Core Zone Boundary from approximately CY 1955 until CY 1980. During this time, groundwater concentrations at the Columbia River nearshore approach but never exceed the benchmark concentration. Because the half-life of tritium is less than 13 years, radioactive decay rapidly attenuates groundwater concentrations and tritium remains below the benchmark concentration at the Core Zone Boundary after about CY 2020.

The tritium results for Tank Closure Alternative 2B, Case 1, are similar to those for Tank Closure Alternative 2A (cf., Figures 5–79 and 5–43), which indicate that including landfill closure as an option has no impact on tritium releases. The tritium results for Tank Closure Alternative 2B, Case 1, are also the same as those for Tank Closure Alternative 2B, Case 2 (cf., Figures 5–79 and 5–86), suggesting that mitigating the retrieval leak liquid loss has little impact on tritium attenuation. Figure 5–87 shows the tritium results for Tank Closure Alternative 2B, Case 3. Tritium concentrations peak at two to four orders of magnitude below the benchmark in this case, indicating that the primary contribution of tritium contamination originates from discharges to the cribs and trenches (ditches).

Figures 5–80 through 5–83 show concentration versus time for iodine-129, technetium-99, chromium, and nitrate (the conservative tracers) under Tank Closure Alternative 2B, Case 1. Releases from cribs and trenches (ditches) cause groundwater concentrations of iodine-129 at the Core Zone Boundary to exceed benchmark concentrations by about one to two orders of magnitude during the early part of the period of analysis. This early time period is represented by the multiple sharp inflections in the Core Zone Boundary curve that occur approximately between CY 1955 and CY 1980. By approximately CY 2300, the Core Zone Boundary groundwater concentrations return to levels below the benchmark. Groundwater concentrations at the Columbia River nearshore briefly reach the benchmark concentration during the early part of the period of analysis and gradually decrease to around two to three orders of magnitude below the benchmark by the end of the period of analysis. The other conservative tracers show similar curves.

The addition of landfill closure of the tank farms and associated cribs and trenches (ditches) under Tank Closure Alternative 2B has a noticeable, but minor, effect on the attenuation of the conservative tracers relative to Tank Closure Alternative 2A, which does not include landfill closure. Landfill closure results in some additional mitigation of the early part of the release of tank farm residuals in approximately CY 3000. Application of the landfill cover attenuates the concentrations of the conservative tracers at the Core Zone Boundary from about CY 2200 to the end of the 10,000-year analysis period. The use of an engineered barrier over the tank farms further reduces moisture movement through the vadose zone and subsequently delays downward transport of the conservative tracers. This behavior is most evident for iodine-129 under Tank Closure Alternative 2B, Case 1 (see Figure 5–80), in comparison with Tank Closure Alternative 2A (see Figure 5–44).

The results for iodine-129 under Tank Closure Alternative 2B, Case 1, are similar to those under Case 2 (cf., Figures 5–80 and 5–88). There is some reduction in concentrations at the Core Zone Boundary to levels at or just below the benchmark concentration beginning around CY 3500. Figure 5–89 shows the results for iodine-129 under Case 3. Figure 5–89 suggests that the past tank leaks and tank residuals are responsible for the exceedances of the benchmark concentrations at times beyond about CY 2050. The results for the other conservative tracers (technetium-99, chromium, and nitrate) exhibit similar behavior (see Figures 5–81 through 5–83 [Case 1 for each constituent] and 5–90 through 5–95 [Cases 2 and 3 for each constituent]).

Figures 5–84 and 5–85 show concentration versus time for uranium-238 and total uranium under Tank Closure Alternative 2B, Case 1. Early releases from cribs and trenches (ditches) result in groundwater concentrations that are approximately two to three orders of magnitude lower than benchmark concentrations. Releases from other tank farm sources cause Core Zone Boundary groundwater concentrations to rise to within one order of magnitude below the benchmark by the end of the period of analysis. Concentrations at the Columbia River nearshore continue to rise throughout the duration of the period of analysis, but remain two to three orders of magnitude below the benchmark by the end of the period of analysis (CY 11,940).

The addition of landfill closure of the tank farms and associated cribs and trenches (ditches) under Tank Closure Alternative 2B has a larger effect on the attenuation of uranium-238 and total uranium concentrations at the Core Zone Boundary than for the conservative tracers (iodine-129, technetium-99, chromium, and nitrate). Emplacement of an engineered barrier over the tank farms that reduces moisture movement in the vadose zone has a greater effect on uranium transport because uranium-238 and total uranium are retarded species. The uranium constituents move approximately seven times more slowly than the pore-water velocity in the saturated zone, and the retardation is enhanced in the unsaturated conditions of the vadose zone. The slower movement of the uranium species through the vadose zone with an engineered barrier in place causes additional delay in the arrival of the uranium constituents at the Core Zone Boundary. This behavior is evident when comparing Tank Closure Alternative 2B, Case 1, with Tank Closure Alternative 2A for uranium-238 (cf., Figures 5–84 and 5–48) or total uranium (cf., Figures 5–85 and 5–49).

The results for uranium-238 under Tank Closure Alternative 2B, Case 1, are similar to those under Case 2 (cf., Figures 5–84 and 5–96). Under both Case 1 and Case 2, uranium-238 concentrations continually rise during the simulation but stay about an order of magnitude below the benchmark concentration at the end of the 10,000-year period of analysis. There is some reduction in concentrations at the Core Zone Boundary to levels at or just below the benchmark concentration beginning around CY 3500. Figure 5–97 shows the results for uranium-238 under Case 3. Figure 5–97 suggests that the past tank leaks and tank residuals are responsible for the exceedances of the benchmark concentrations at times beyond about CY 2050. The results for the other conservative tracers (technetium-99, chromium, and nitrate) exhibit similar behavior (see Figures 5–81 through 5–83 [Case 1 for each constituent] and 5–90 through 5–95 [Cases 2 and 3 for each constituent]). The concentration results for total uranium are similar to those for uranium-238 because the retardation factors are identical, and they are not reproduced here for brevity.

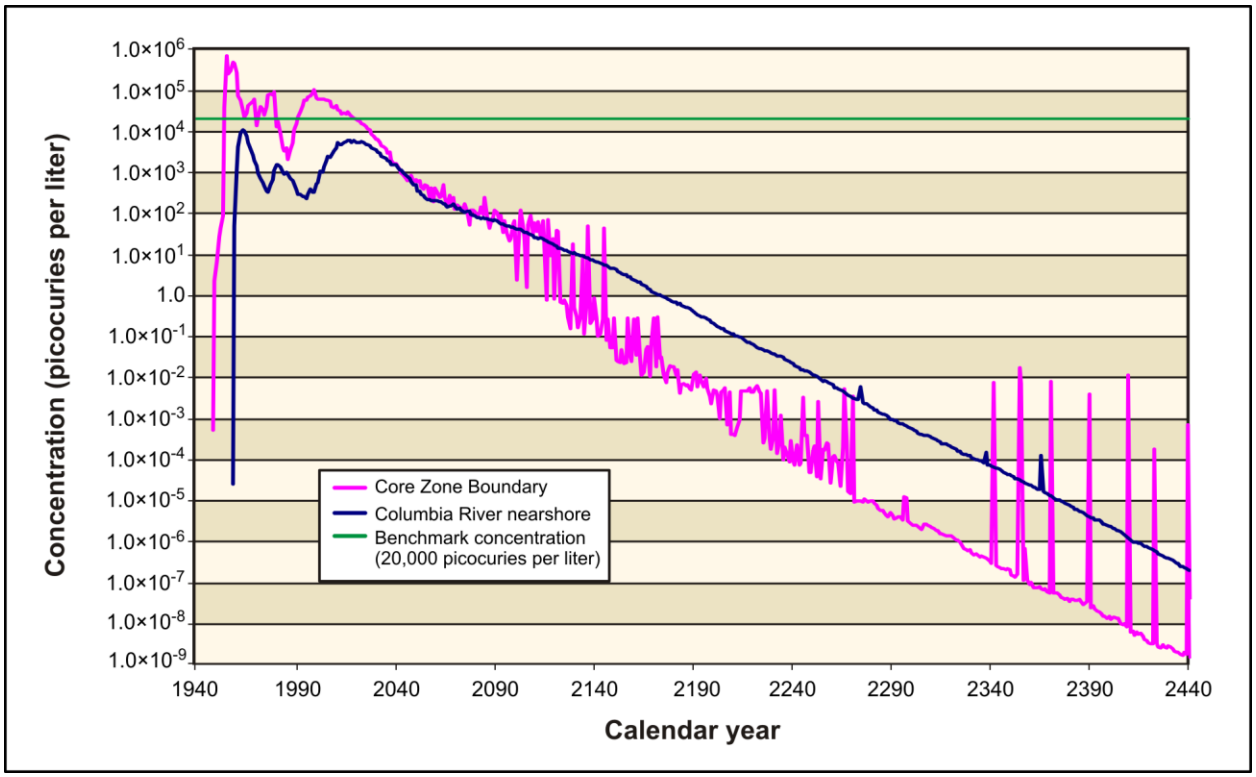


Figure 5–86. Tank Closure Alternative 2B, Case 2, Hydrogen-3 (Tritium) Concentration Versus Time

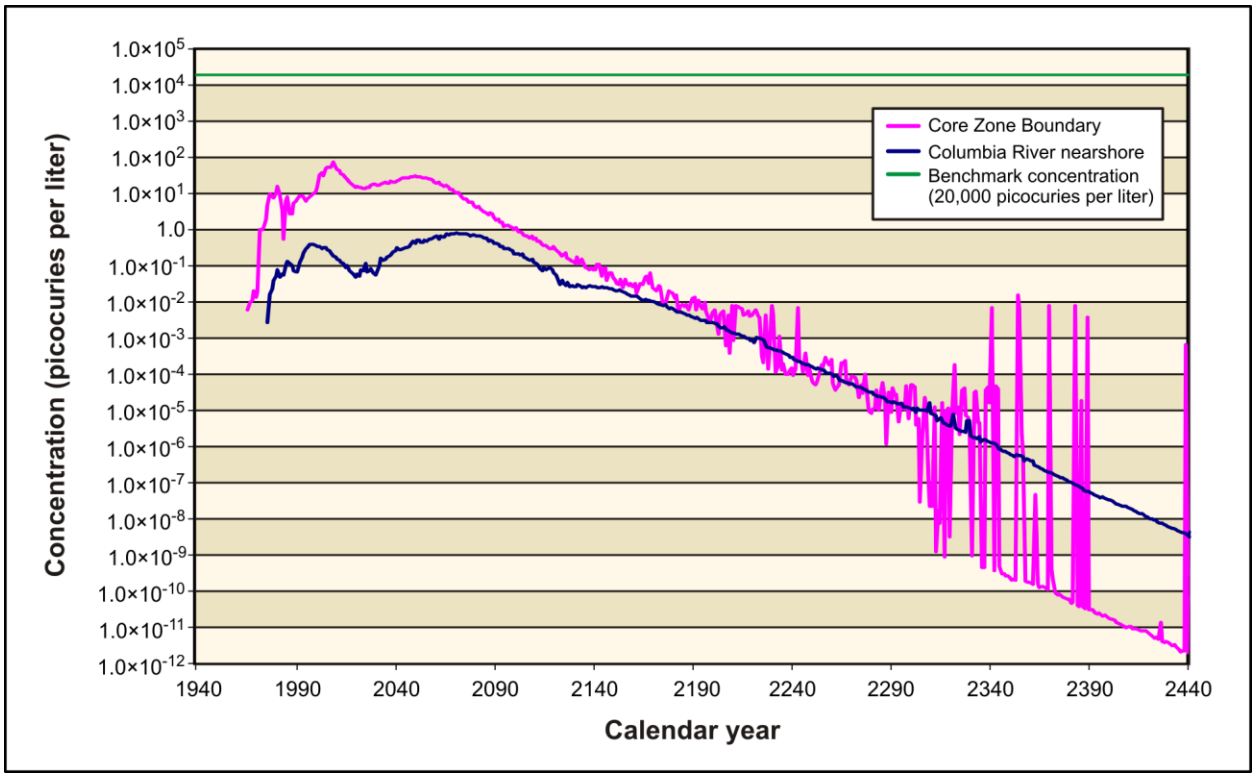


Figure 5–87. Tank Closure Alternative 2B, Case 3, Hydrogen-3 (Tritium) Concentration Versus Time

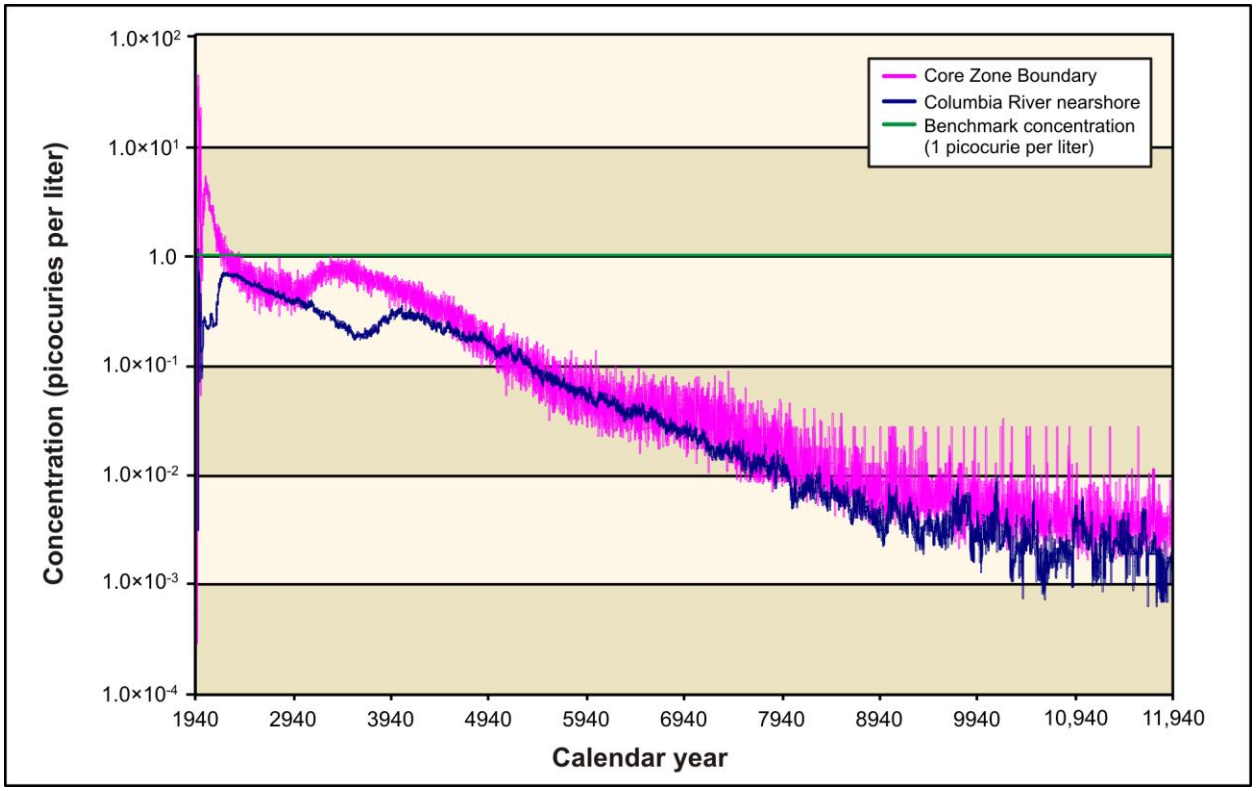


Figure 5–88. Tank Closure Alternative 2B, Case 2, Iodine-129 Concentration Versus Time

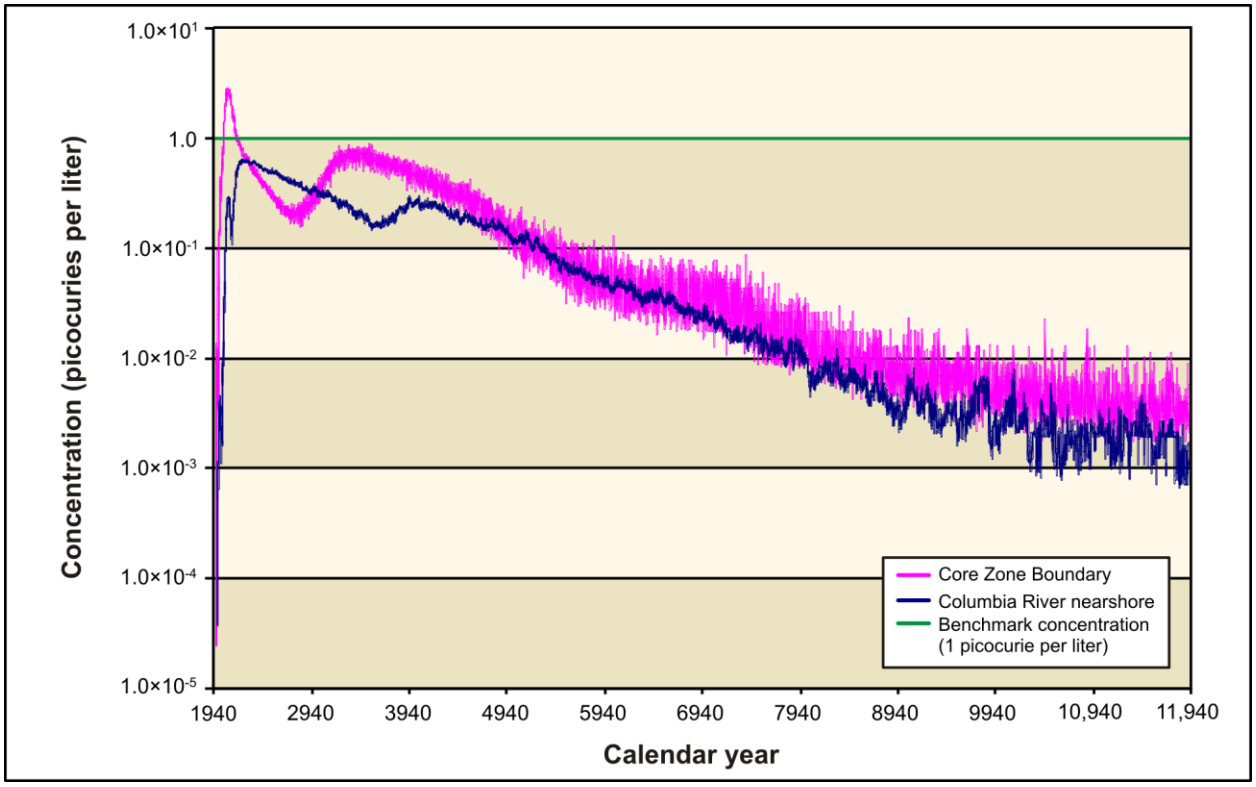


Figure 5–89. Tank Closure Alternative 2B, Case 3, Iodine-129 Concentration Versus Time

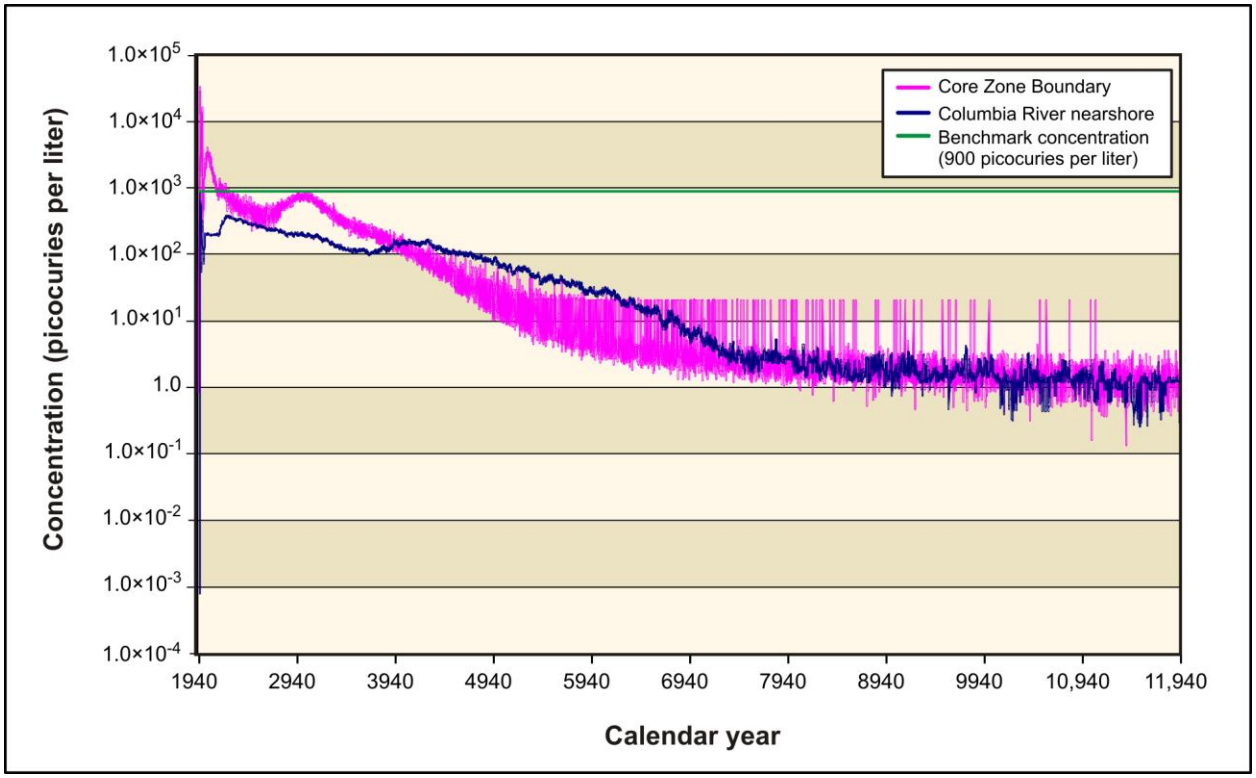


Figure 5–90. Tank Closure Alternative 2B, Case 2, Technetium-99 Concentration Versus Time

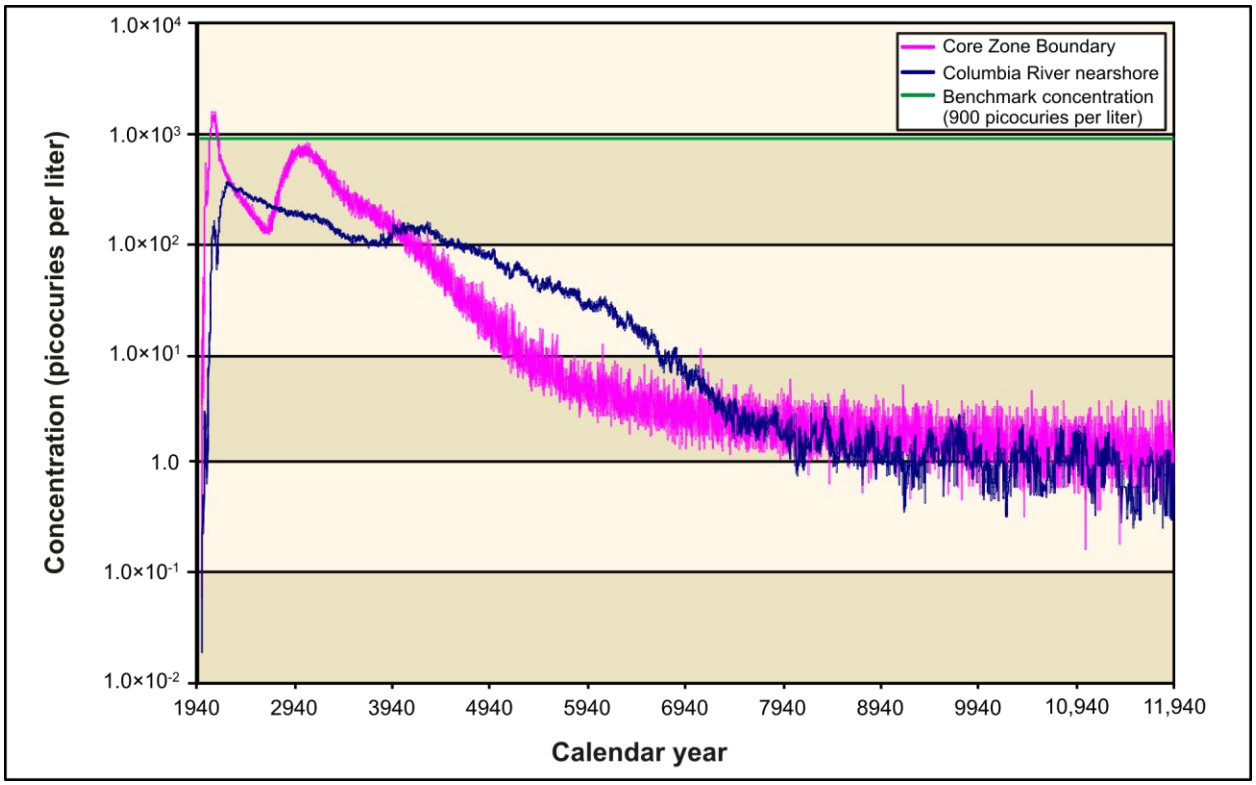


Figure 5–91. Tank Closure Alternative 2B, Case 3, Technetium-99 Concentration Versus Time

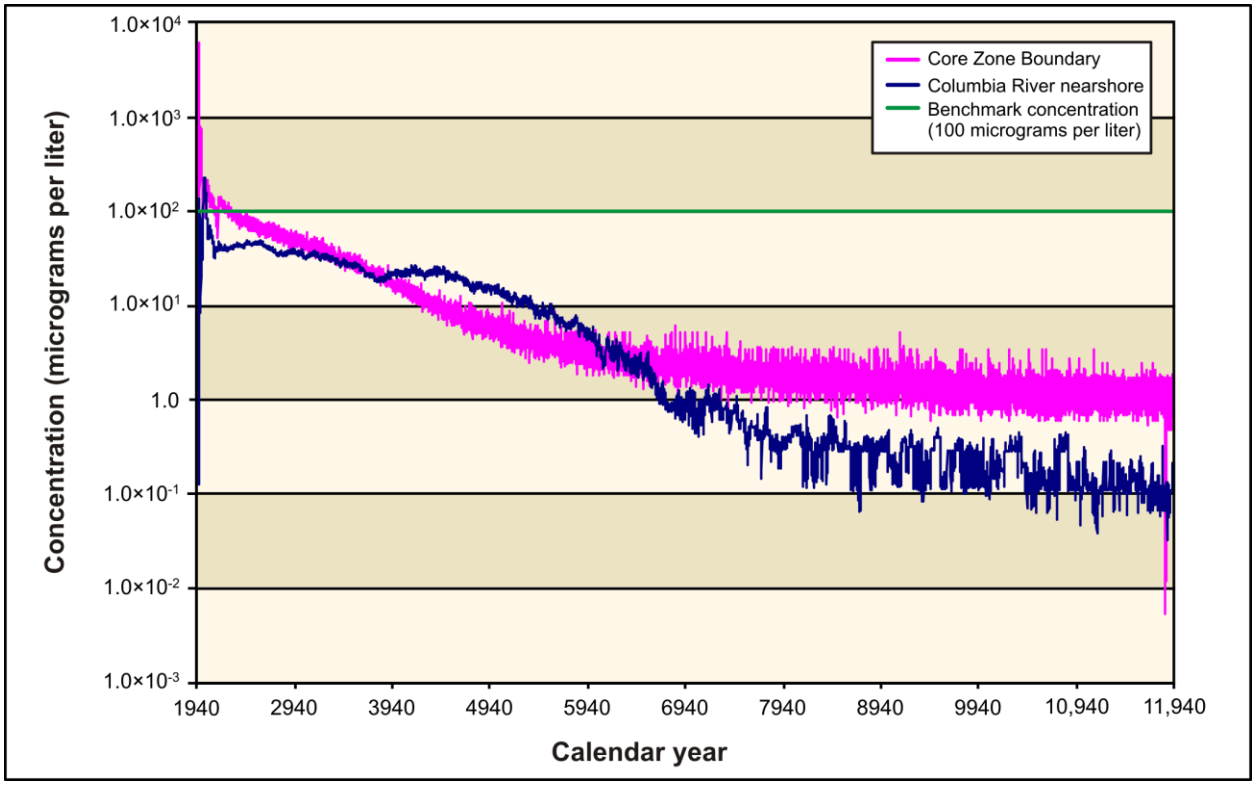


Figure 5–92. Tank Closure Alternative 2B, Case 2, Chromium Concentration Versus Time

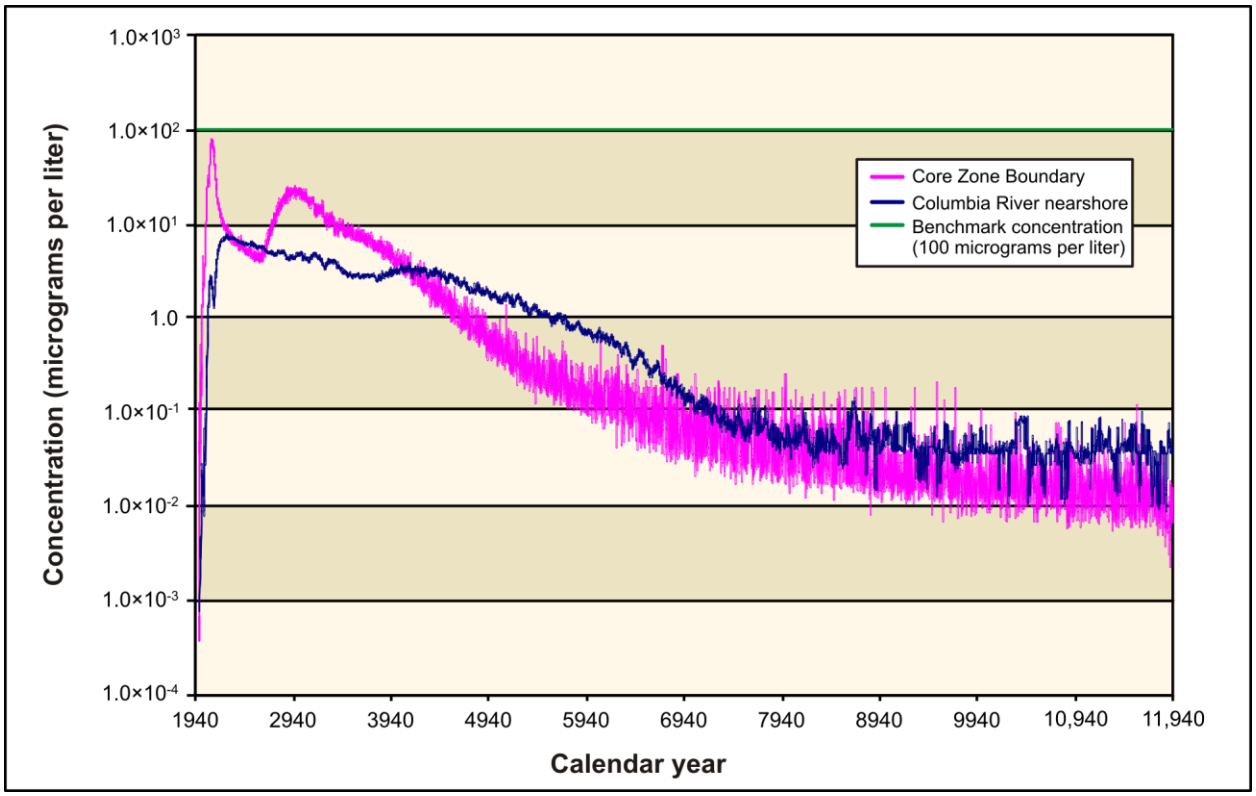


Figure 5–93. Tank Closure Alternative 2B, Case 3, Chromium Concentration Versus Time

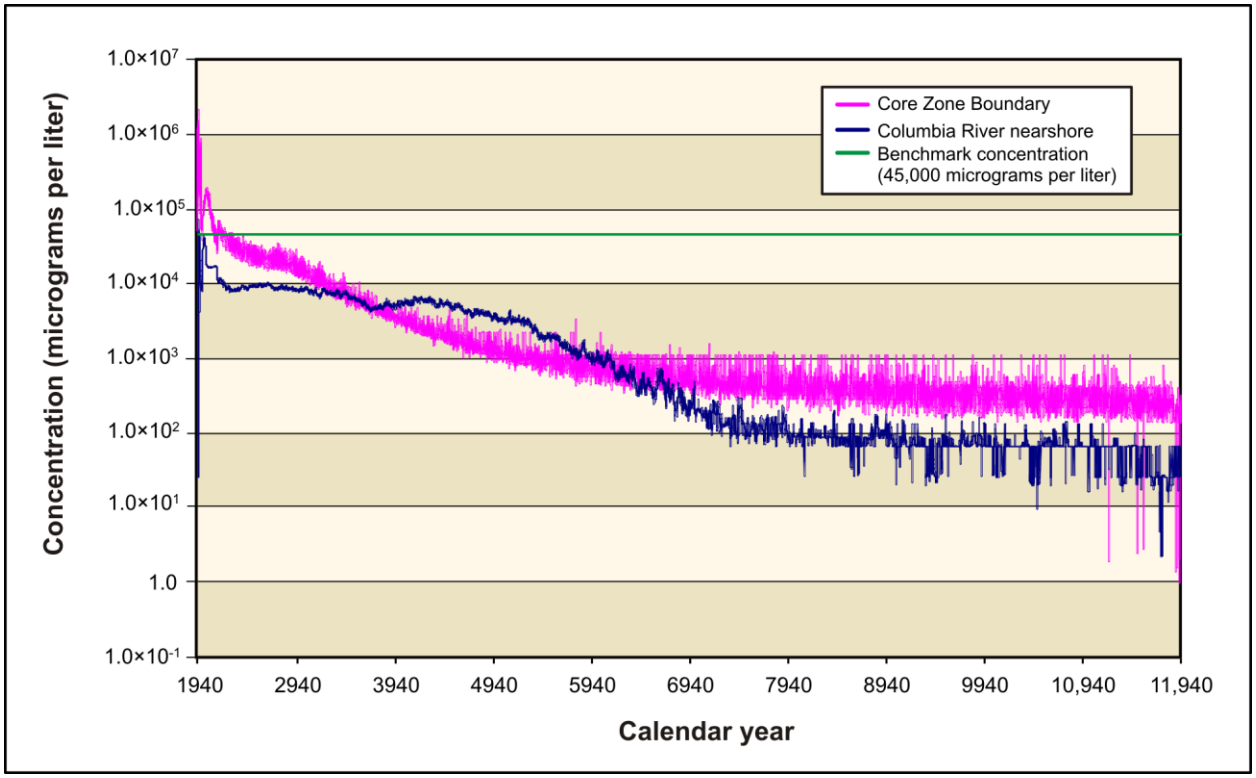


Figure 5–94. Tank Closure Alternative 2B, Case 2, Nitrate Concentration Versus Time

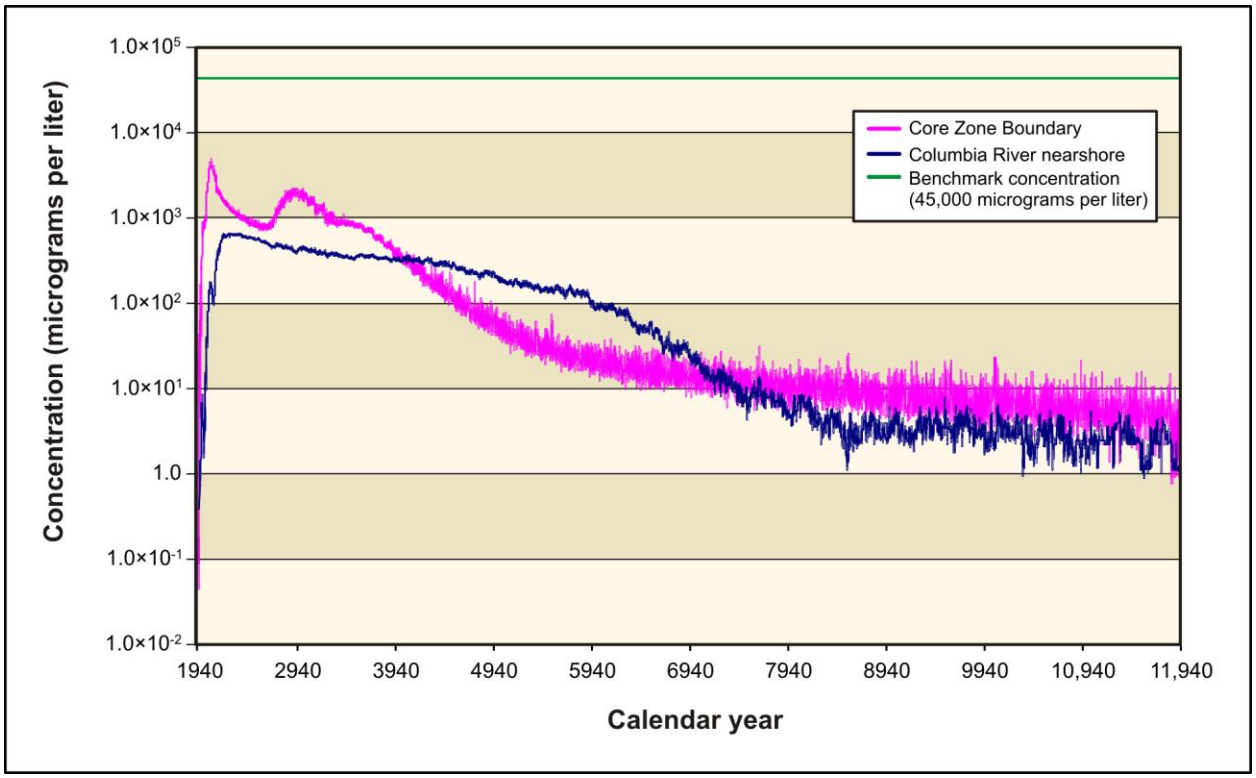


Figure 5–95. Tank Closure Alternative 2B, Case 3, Nitrate Concentration Versus Time

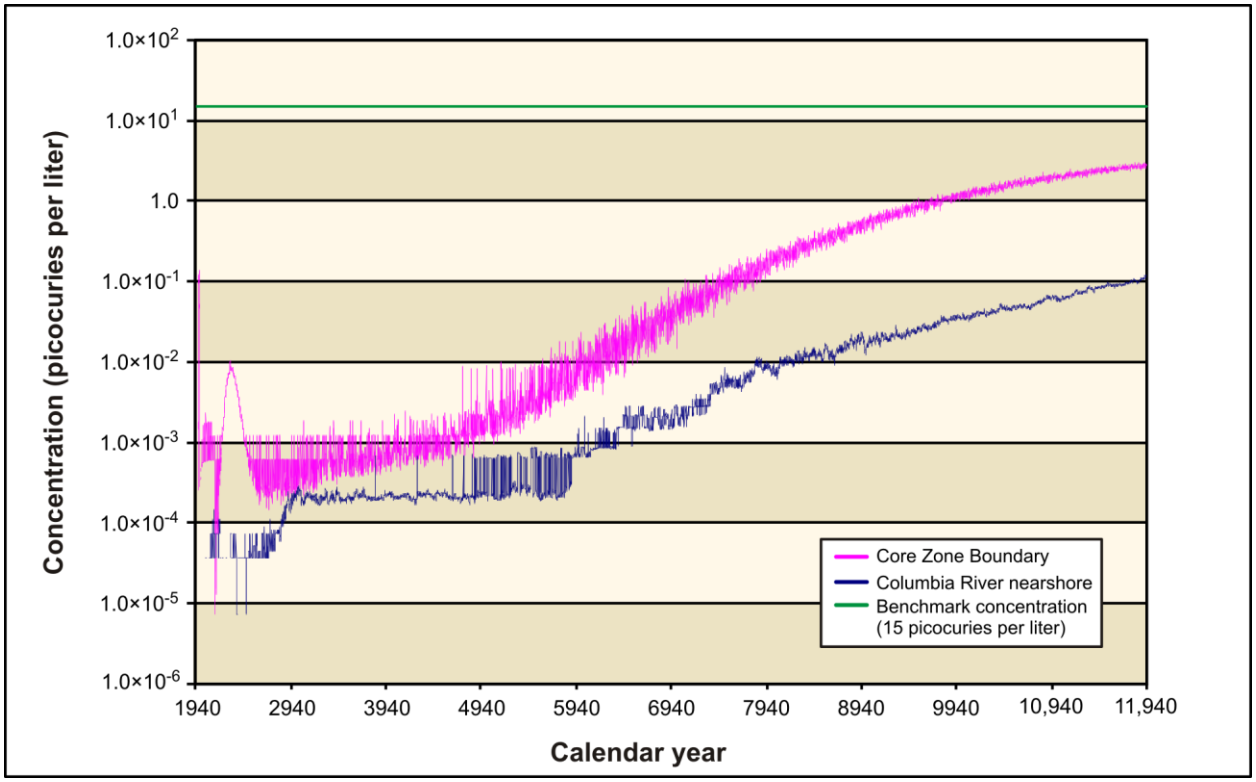


Figure 5–96. Tank Closure Alternative 2B, Case 2, Uranium-238 Concentration Versus Time

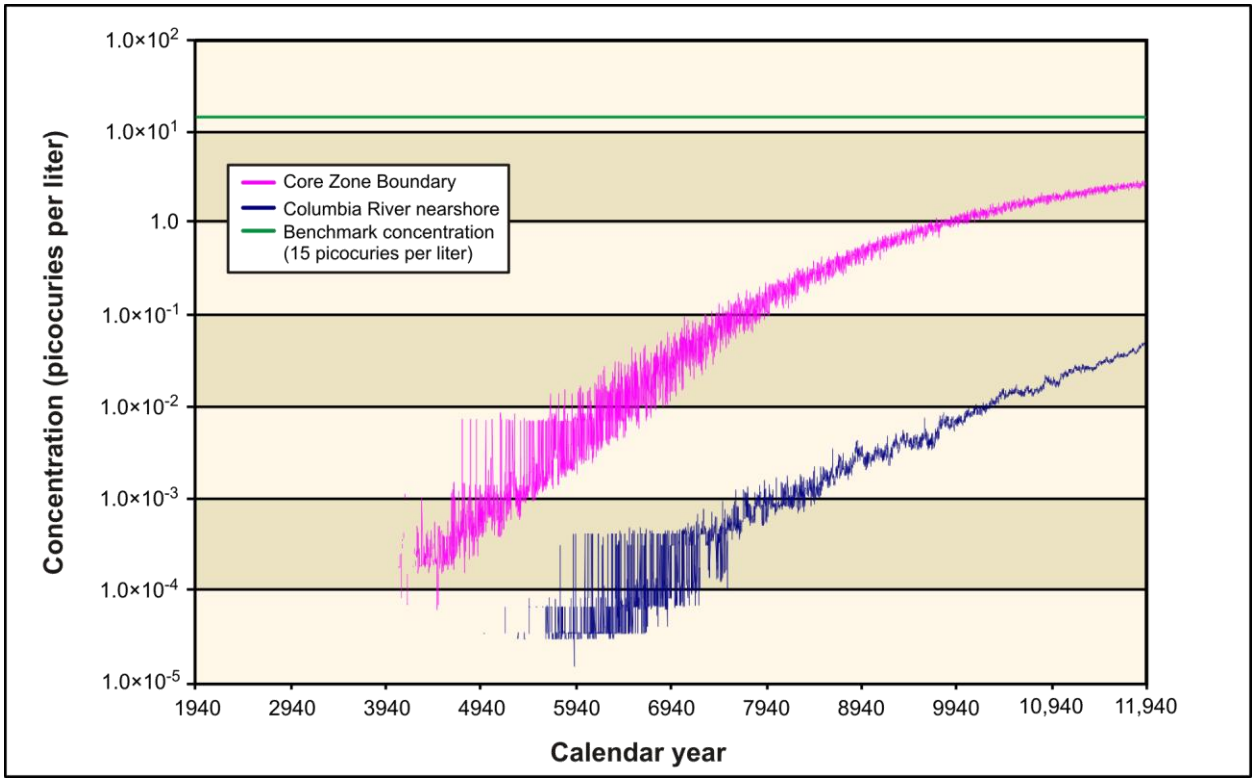
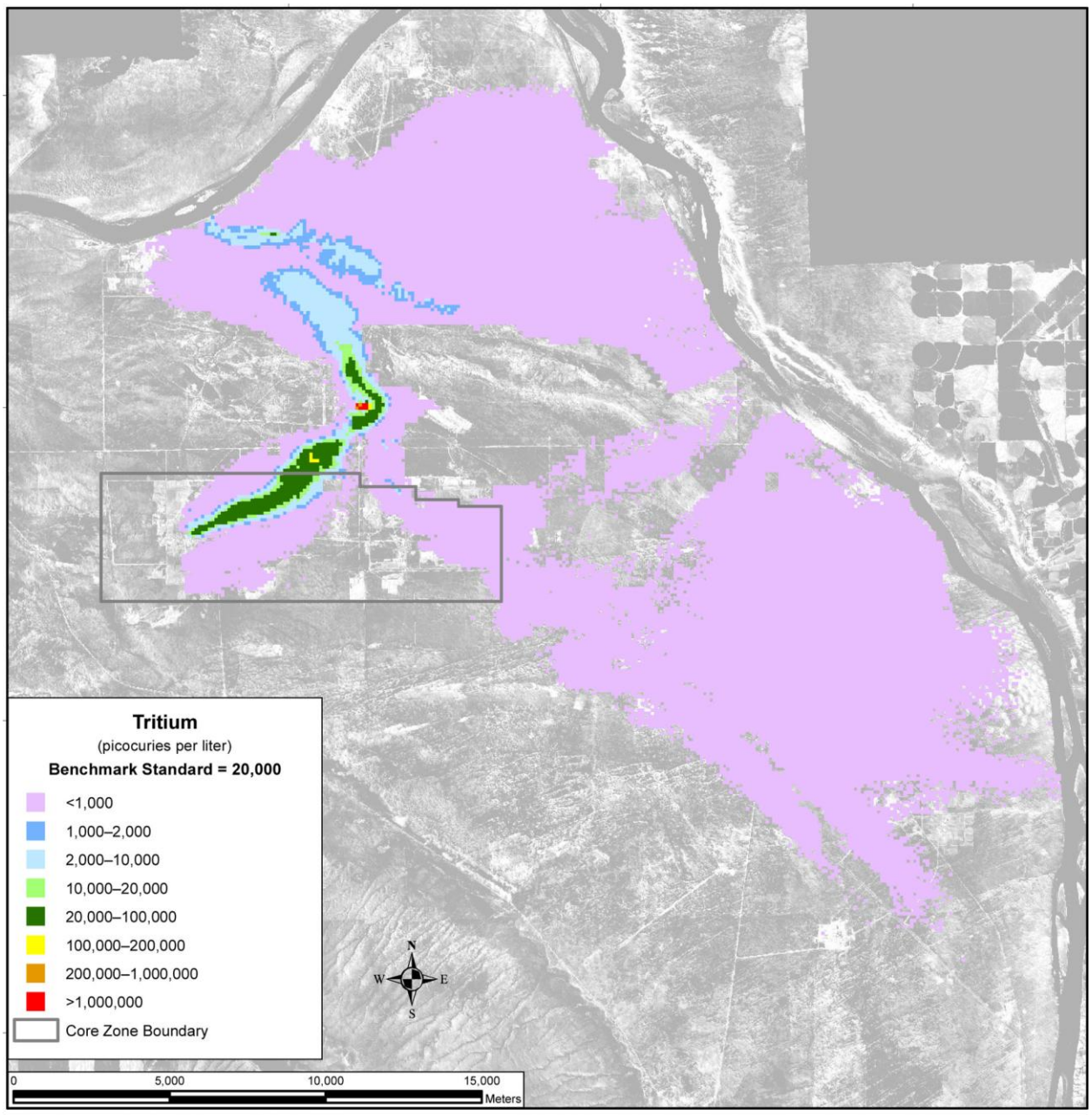


Figure 5–97. Tank Closure Alternative 2B, Case 3, Uranium-238 Concentration Versus Time

5.1.1.3.5 Analysis of Spatial Distribution of Concentration

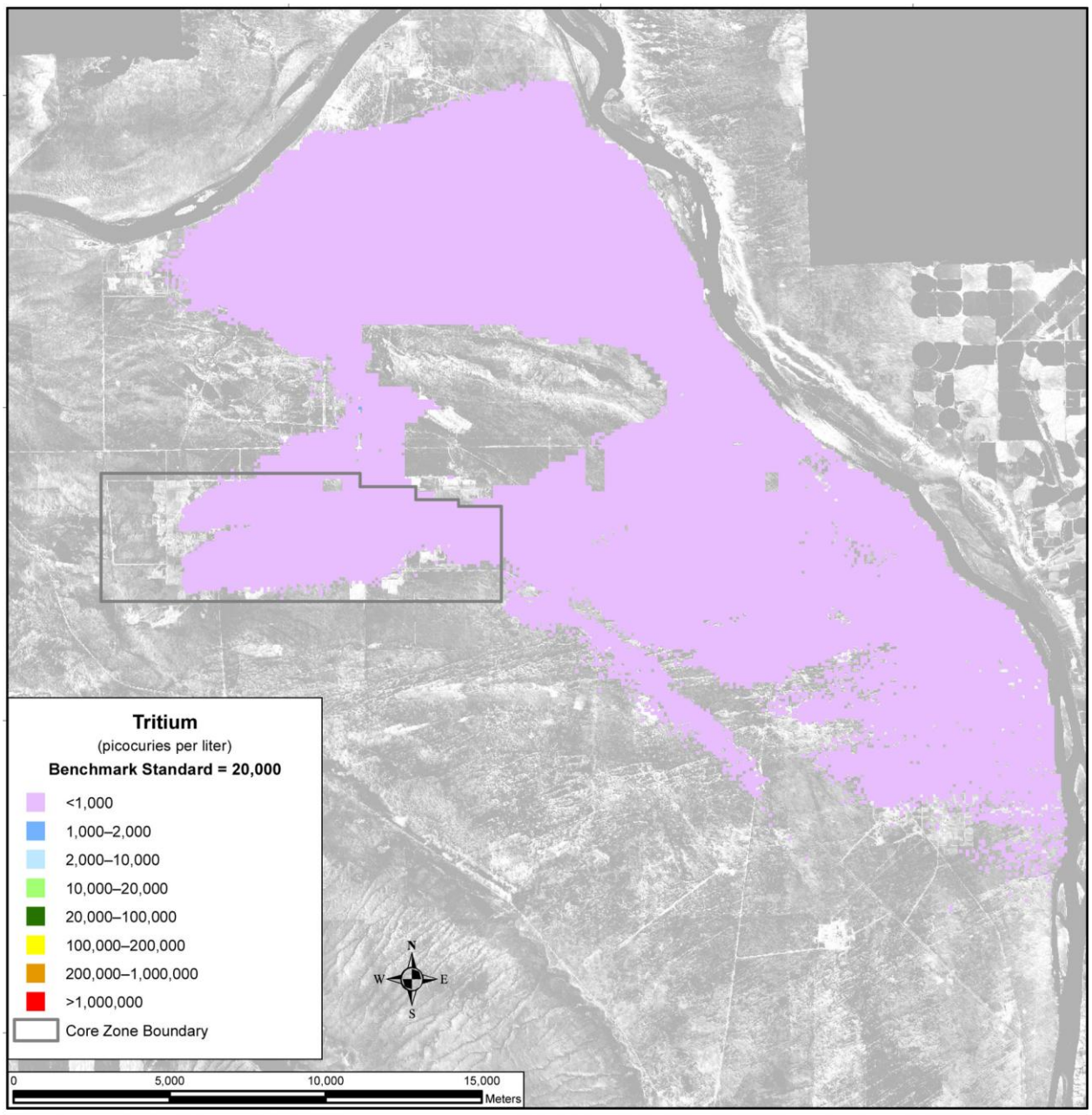
This section presents the impacts of Tank Closure Alternative 2B in terms of the spatial distribution of COPC driver concentrations in groundwater at selected times. Concentrations of radionuclides are in picocuries per liter; chemicals, in micrograms per liter. Concentrations of each radionuclide and 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 5–98 shows the spatial distribution of tritium concentrations in groundwater in CY 2010 resulting from releases from all sources. 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, crosses the Core Zone Boundary, and continues toward Gable Gap. Peak concentrations in this plume are about 5 to 10 times greater than the benchmark. By CY 2135, the tritium plume has diminished to levels less than one-twentieth of the benchmark concentration (see Figure 5–99).



Note: To convert meters to feet, multiply by 3.281.

Figure 5–98. Tank Closure Alternative 2B Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration, Calendar Year 2010

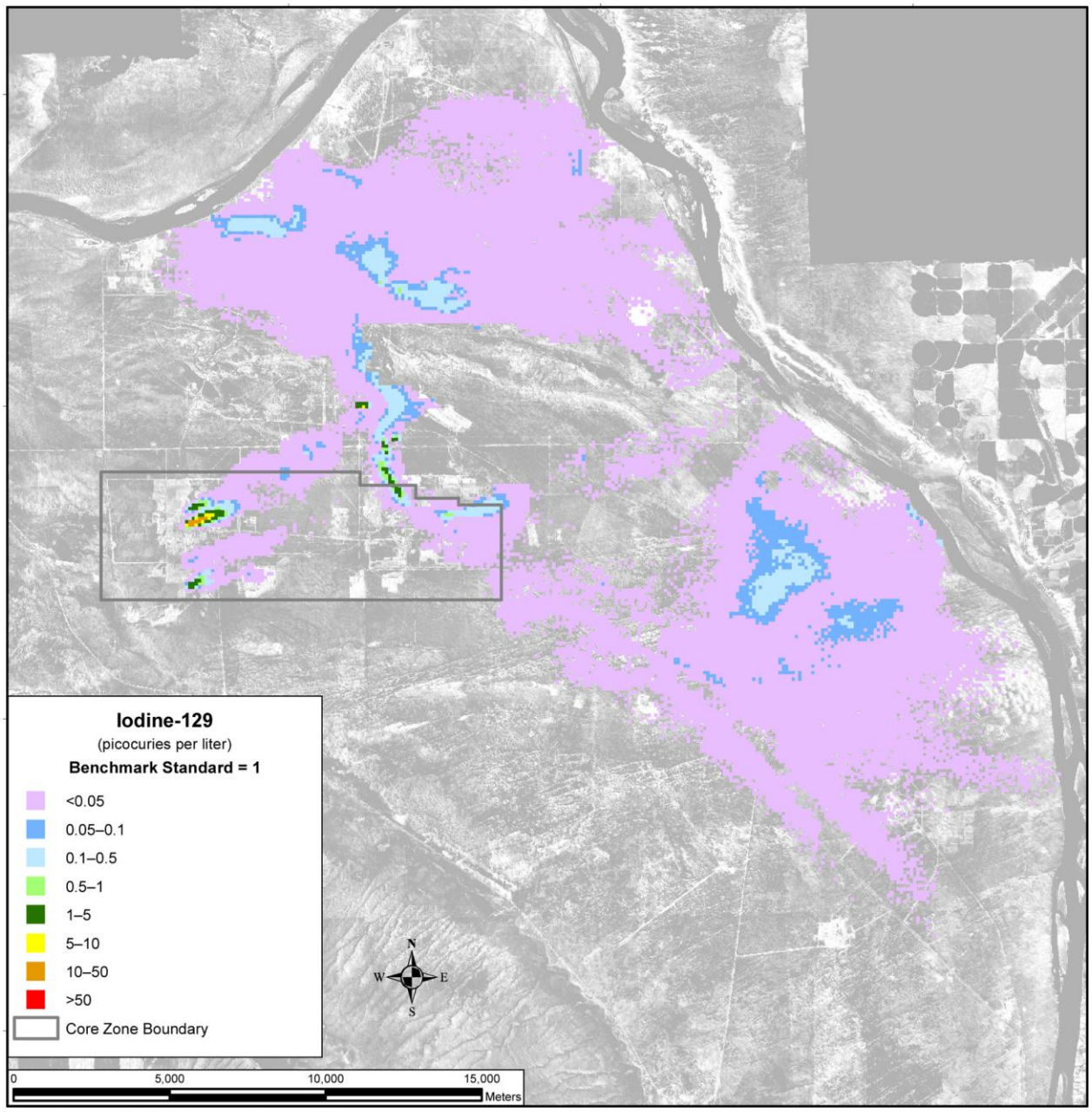


Note: To convert meters to feet, multiply by 3.281.

Figure 5–99. Tank Closure Alternative 2B Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration, Calendar Year 2135

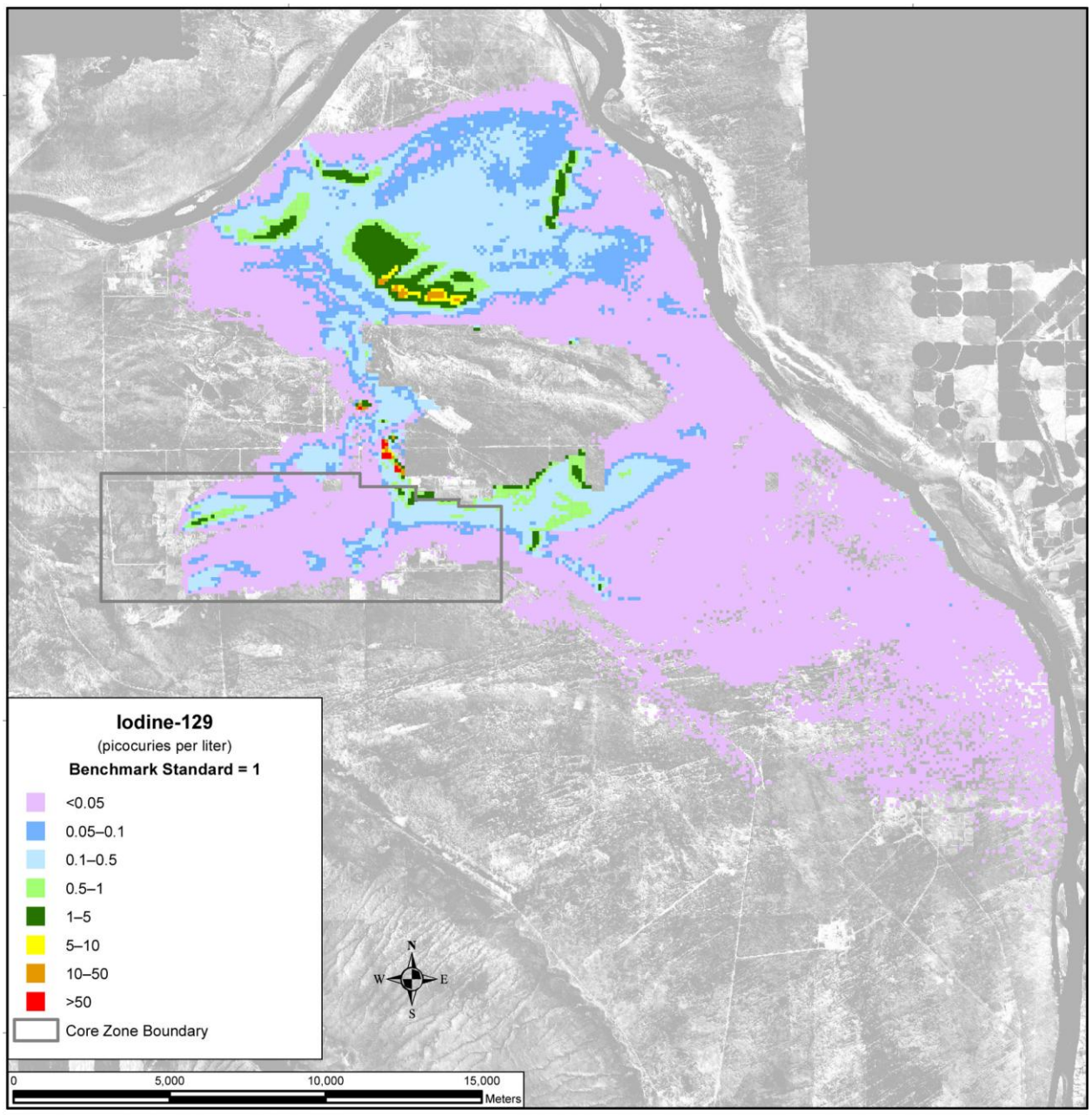
The conservative tracers (iodine-129, technetium-99, chromium, and nitrate) move at the rate of the pore-water velocity and are discussed as a group, as they show similar spatial distributions. Figure 5–100 shows the spatial distribution of iodine-129 concentrations in groundwater in CY 2010 under Case 1. Releases from cribs and trenches (ditches) and past leaks result in groundwater concentration plumes that exceed the benchmark concentration at the B, S, and T Barriers. Peak concentrations in these plumes are about 10 to 50 times greater than the benchmark and are mostly contained within the Core Zone Boundary. In CY 2135, releases from other tank farm sources create a more widespread plume north of Gable Mountain with peak concentrations 10–50 times the benchmark. Another less-intense plume (up to 5 to 10 times greater than the benchmark) is visible extending east from the A Barrier toward the Columbia River (see Figure 5–101). By CY 7140, most of the mass in the iodine-129 plume has reached

the Columbia River, with only isolated areas of high concentrations in Gable Gap (see Figure 5–102). Technetium-99, chromium, and nitrate show a similar spatial distribution at selected times (see Figures 5–103 through 5–111).



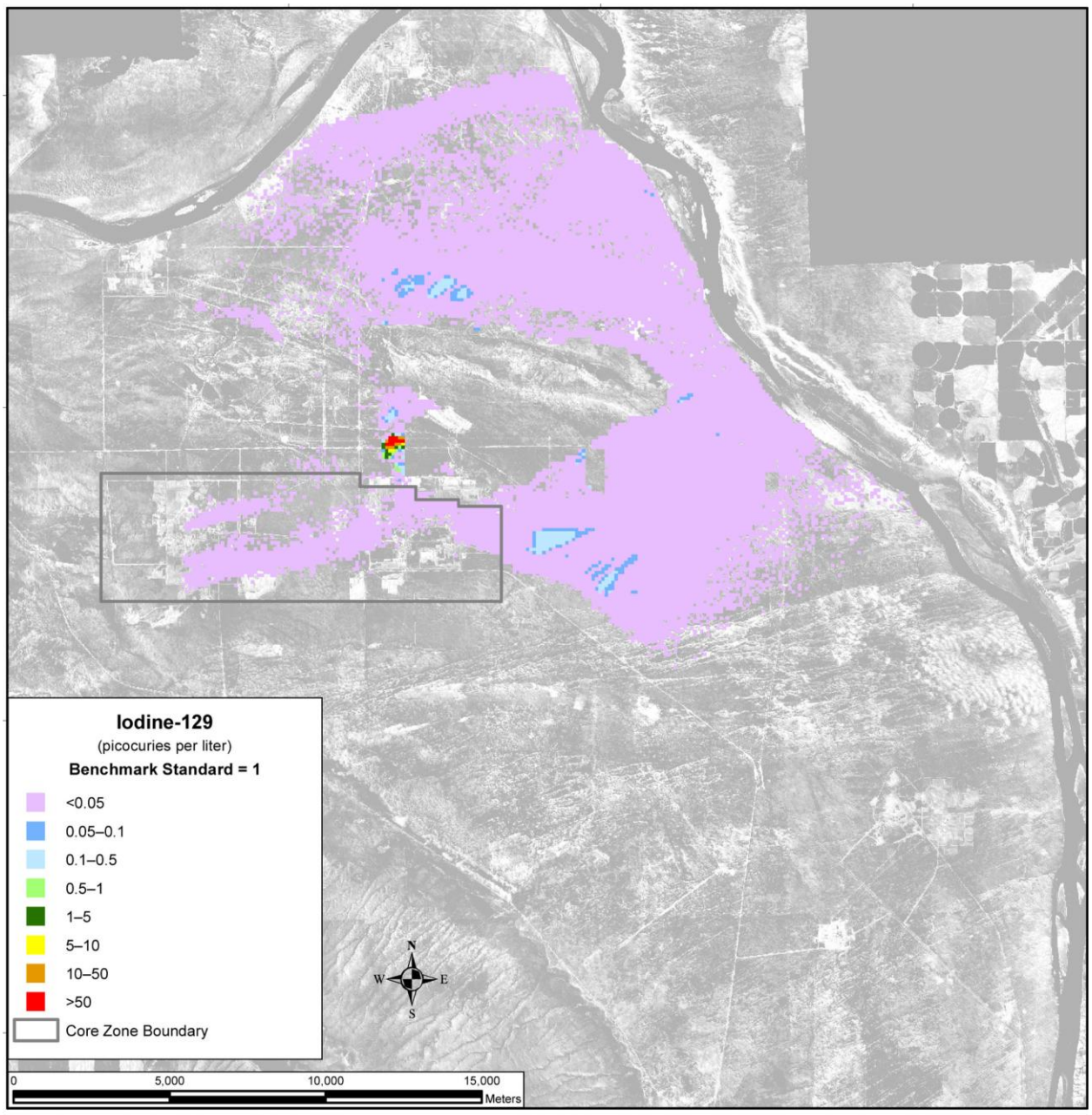
Note: To convert meters to feet, multiply by 3.281.

Figure 5–100. Tank Closure Alternative 2B Spatial Distribution of Groundwater Iodine-129 Concentration, Calendar Year 2010



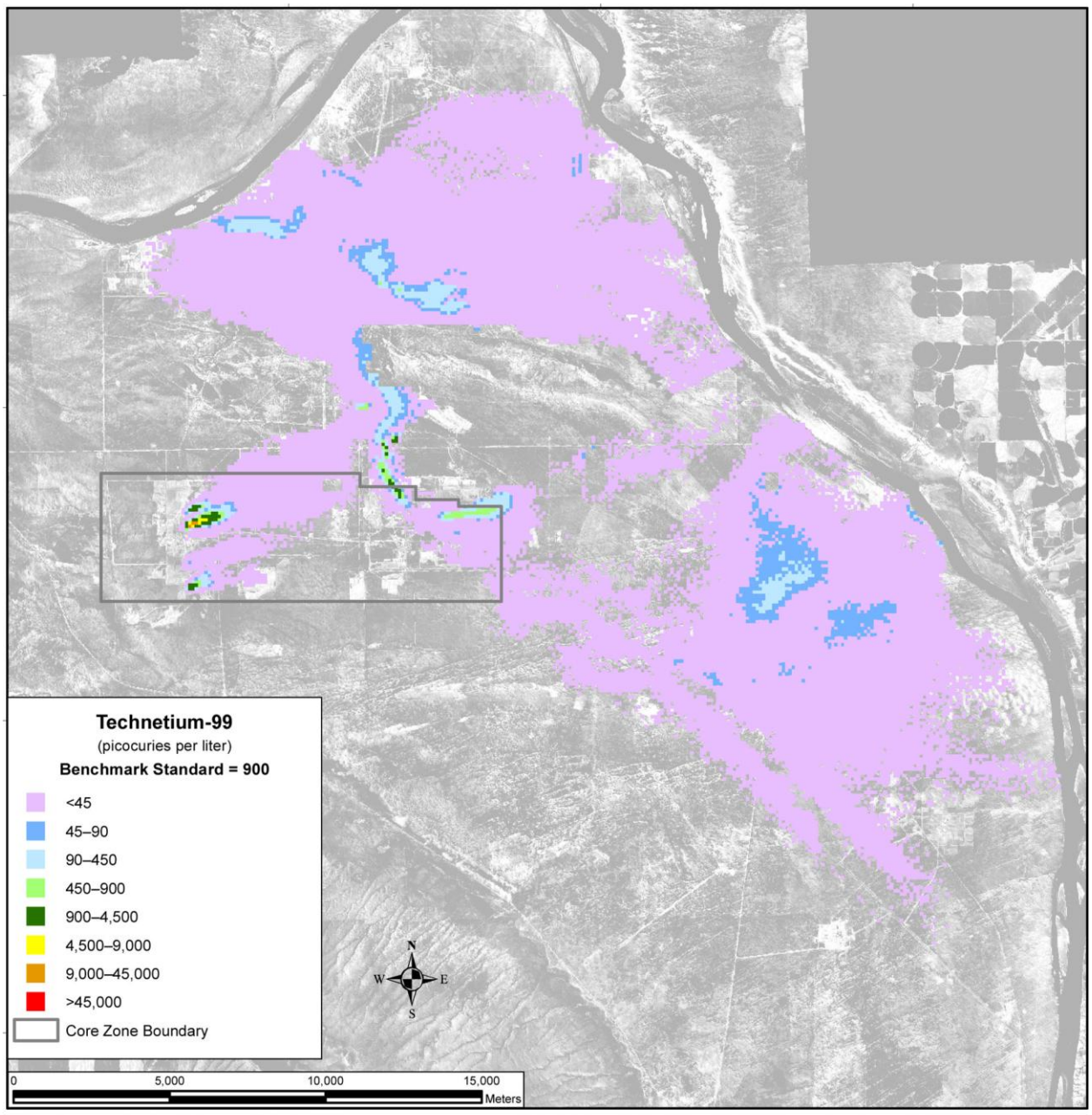
Note: To convert meters to feet, multiply by 3.281.

Figure 5–101. Tank Closure Alternative 2B Spatial Distribution of Groundwater Iodine-129 Concentration, Calendar Year 2135



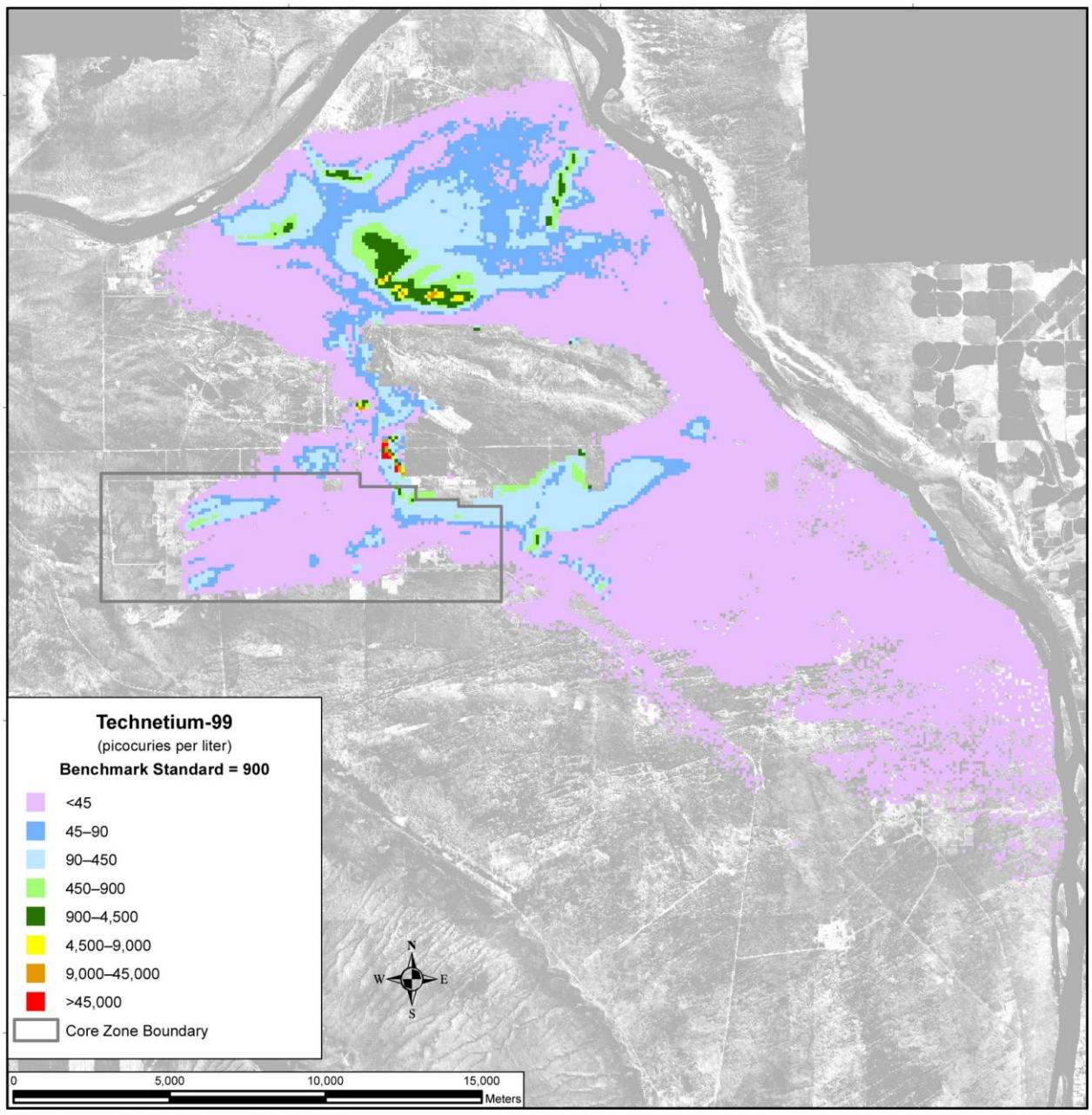
Note: To convert meters to feet, multiply by 3.281.

Figure 5–102. Tank Closure Alternative 2B Spatial Distribution of Groundwater Iodine-129 Concentration, Calendar Year 7140



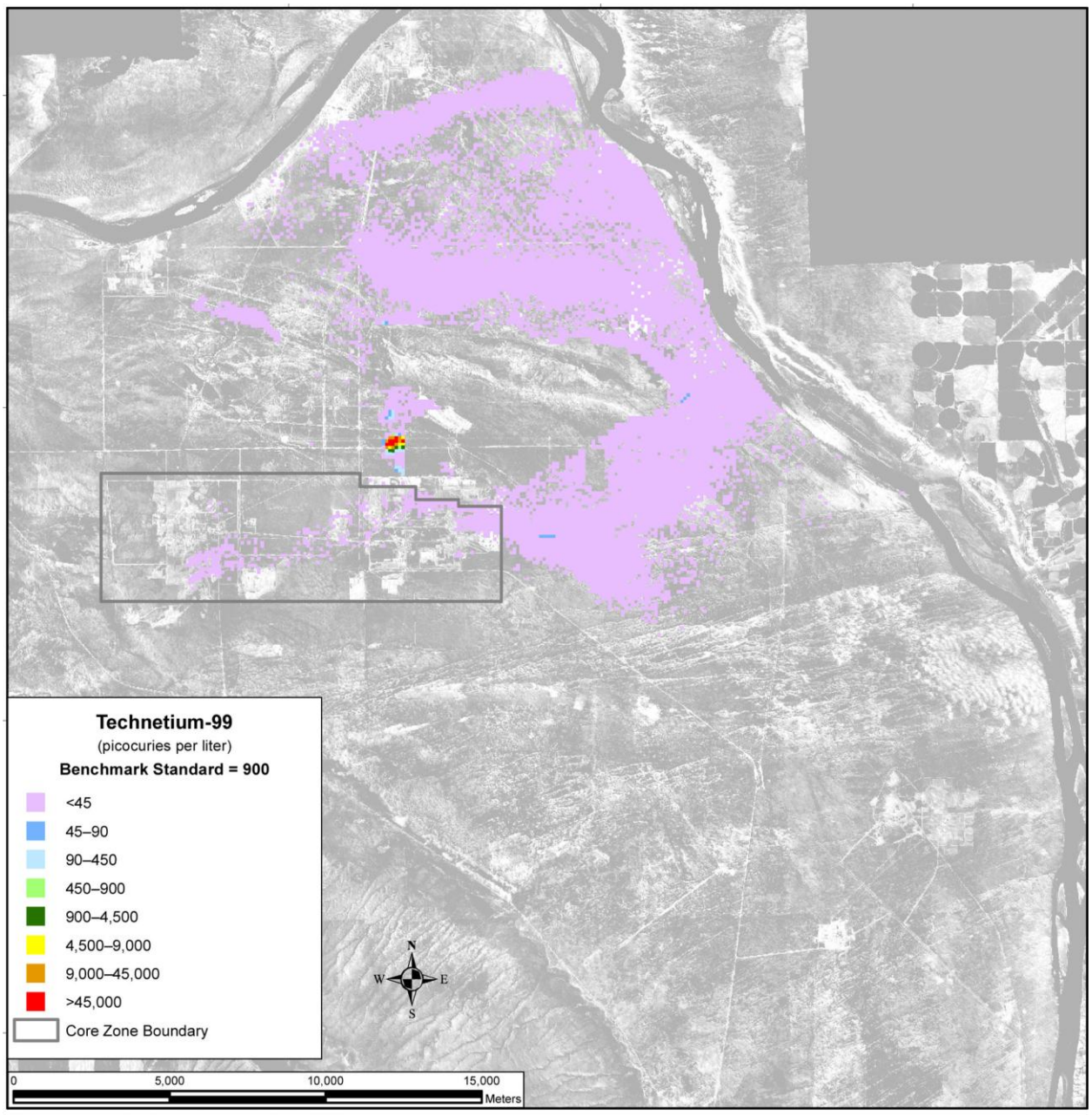
Note: To convert meters to feet, multiply by 3.281.

Figure 5–103. Tank Closure Alternative 2B Spatial Distribution of Groundwater Technetium-99 Concentration, Calendar Year 2010



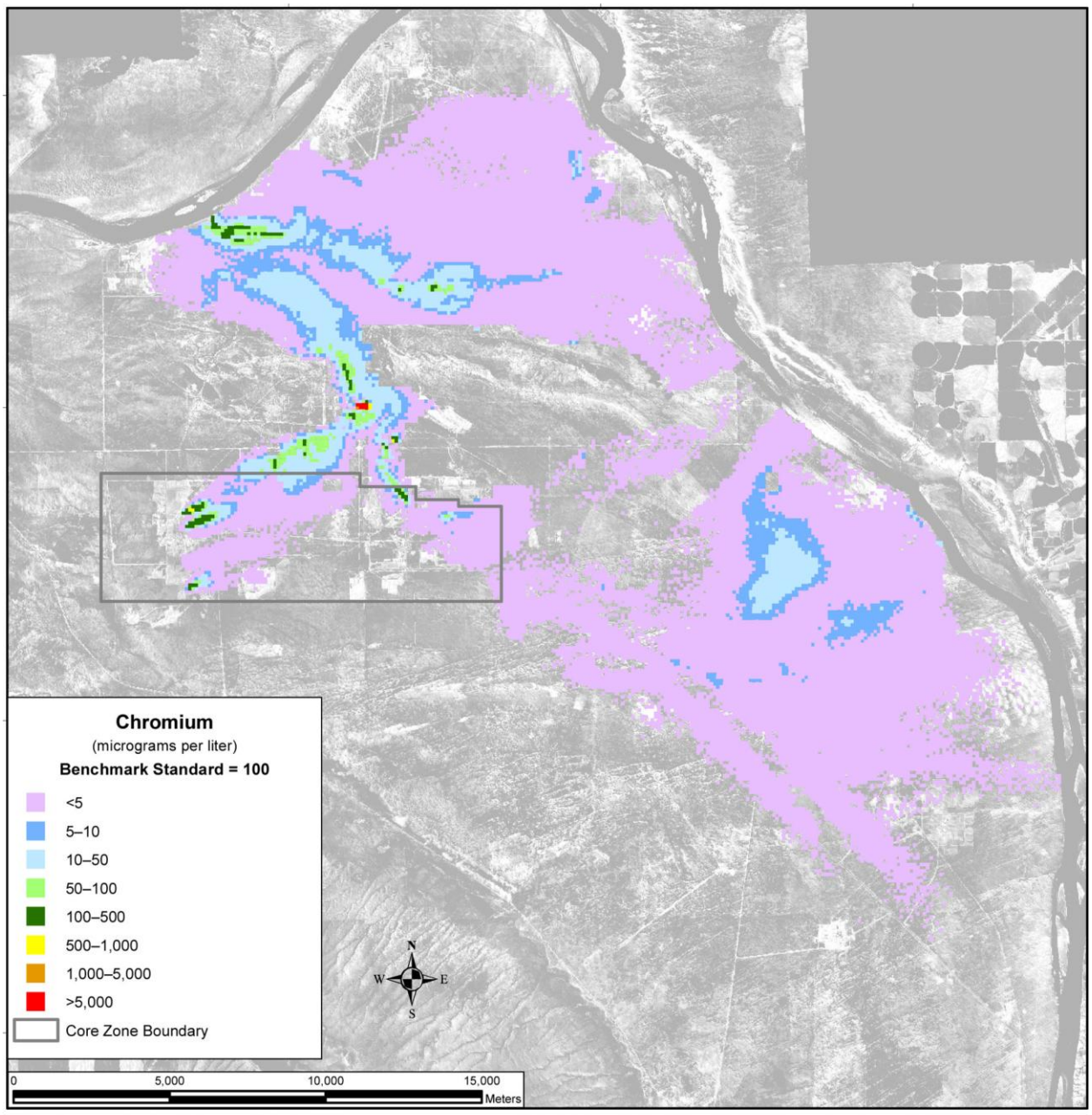
Note: To convert meters to feet, multiply by 3.281.

Figure 5–104. Tank Closure Alternative 2B Spatial Distribution of Groundwater Technetium-99 Concentration, Calendar Year 2135



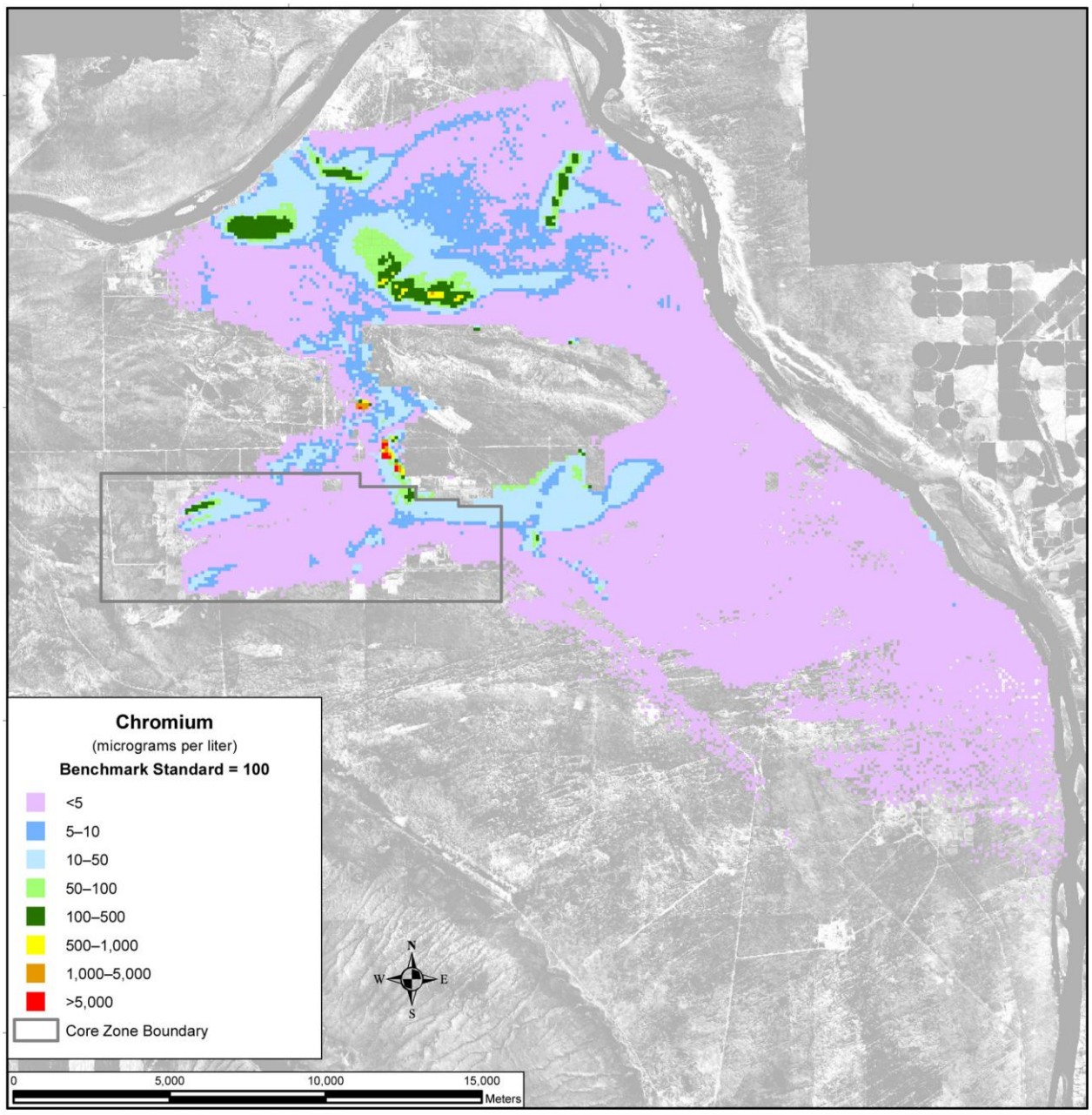
Note: To convert meters to feet, multiply by 3.281.

Figure 5–105. Tank Closure Alternative 2B Spatial Distribution of Groundwater Technetium-99 Concentration, Calendar Year 7140



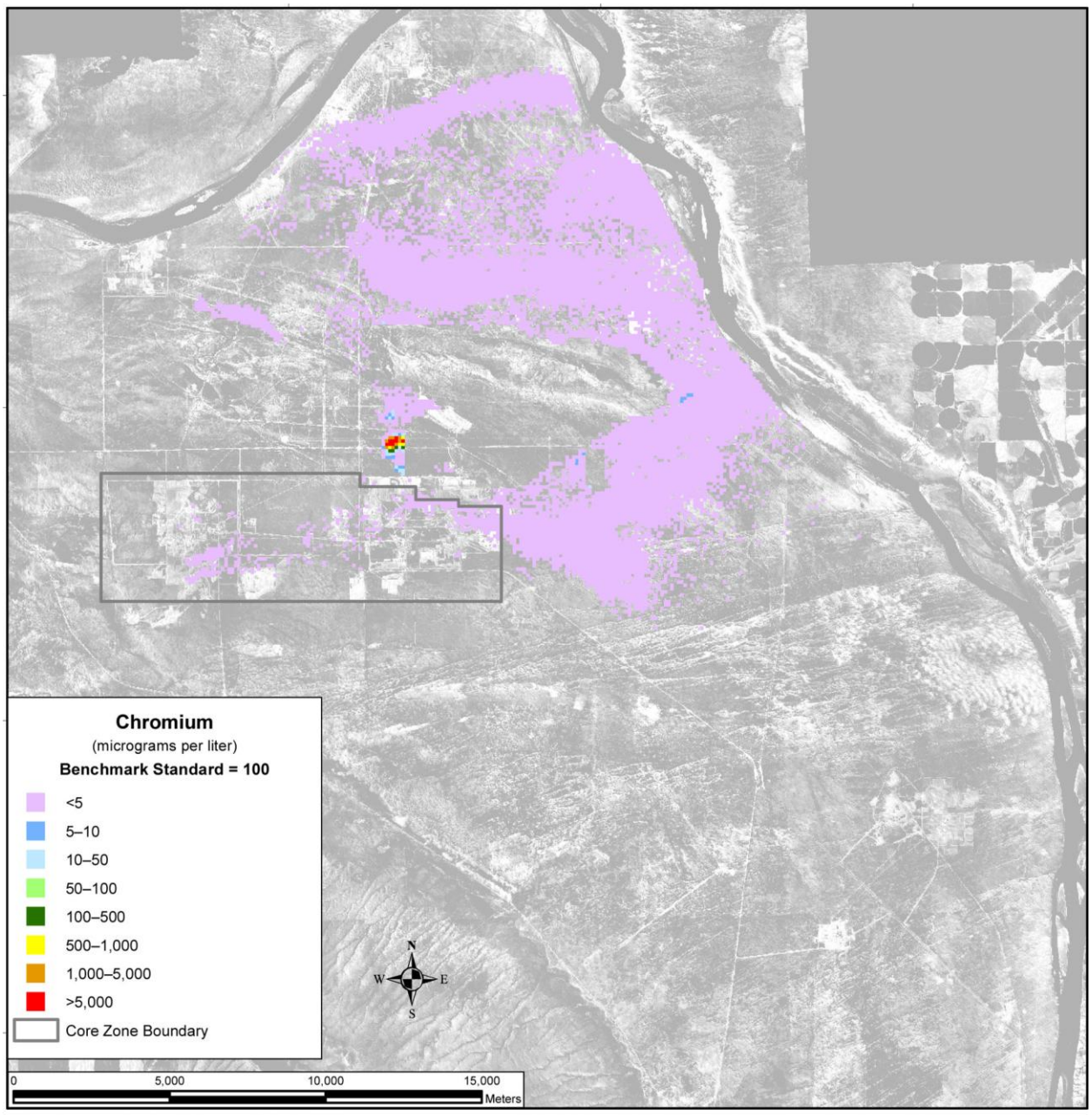
Note: To convert meters to feet, multiply by 3.281.

Figure 5–106. Tank Closure Alternative 2B Spatial Distribution of Groundwater Chromium Concentration, Calendar Year 2010



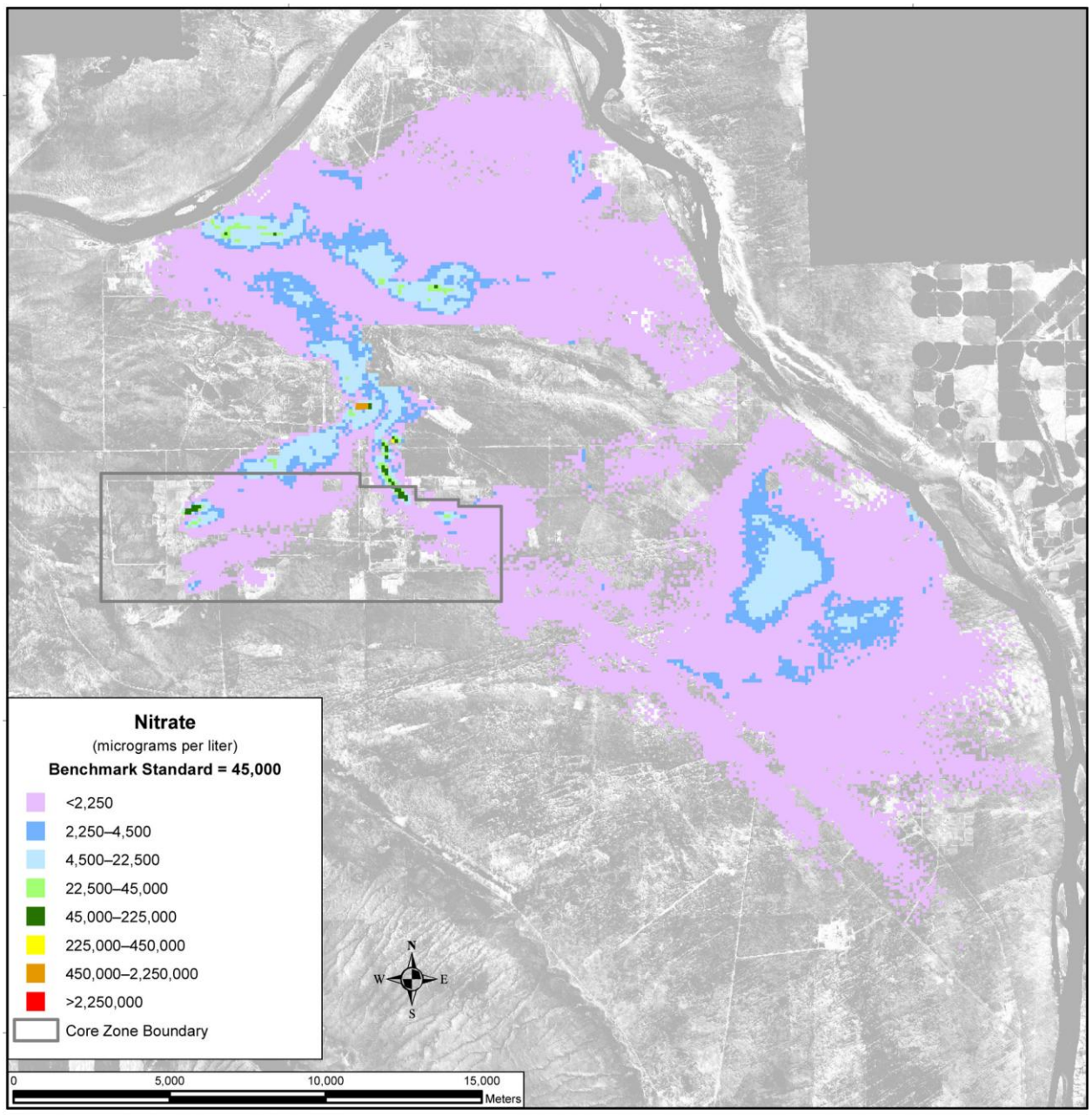
Note: To convert meters to feet, multiply by 3.281.

Figure 5–107. Tank Closure Alternative 2B Spatial Distribution of Groundwater Chromium Concentration, Calendar Year 2135



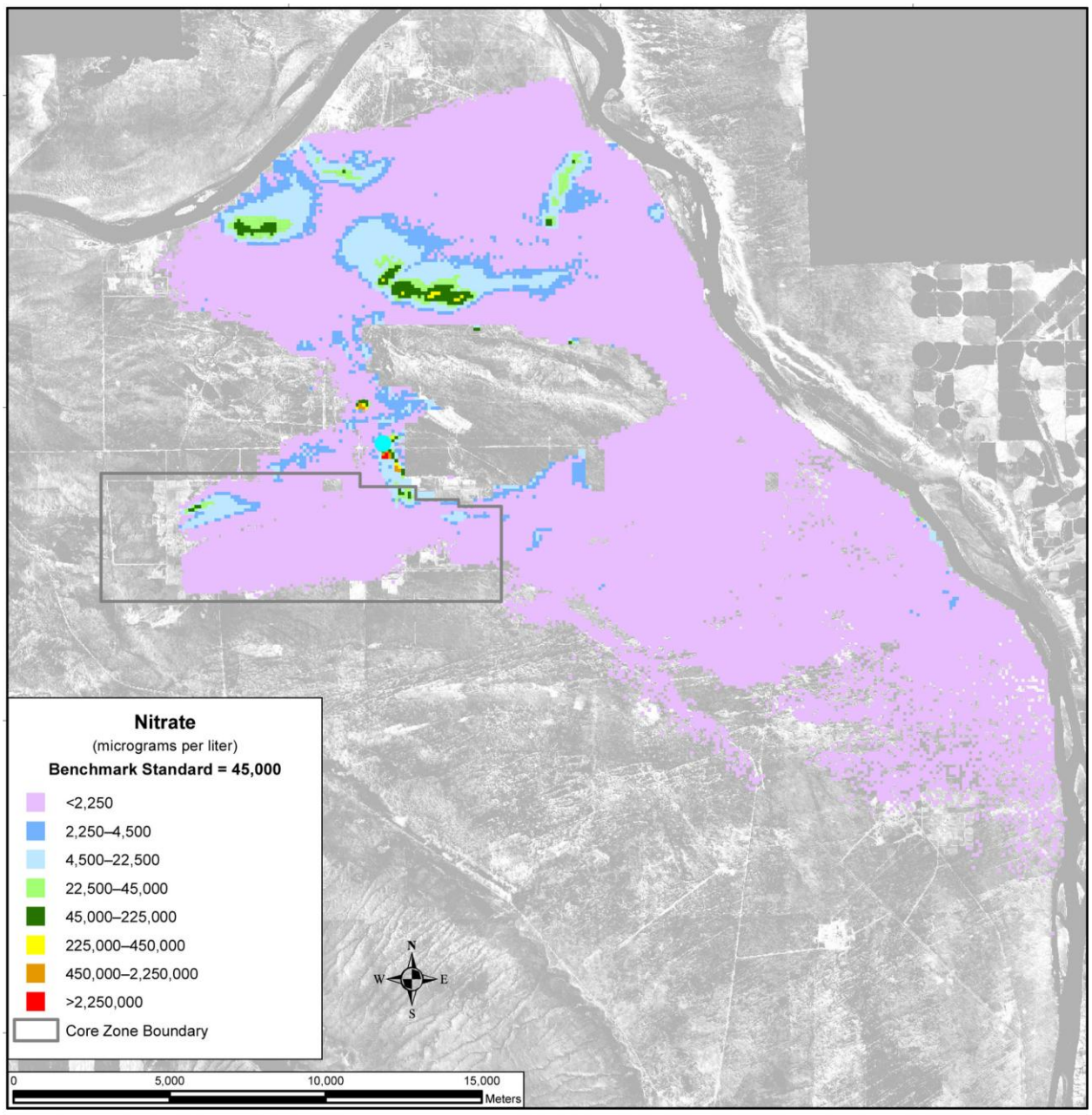
Note: To convert meters to feet, multiply by 3.281.

Figure 5–108. Tank Closure Alternative 2B Spatial Distribution of Groundwater Chromium Concentration, Calendar Year 7140



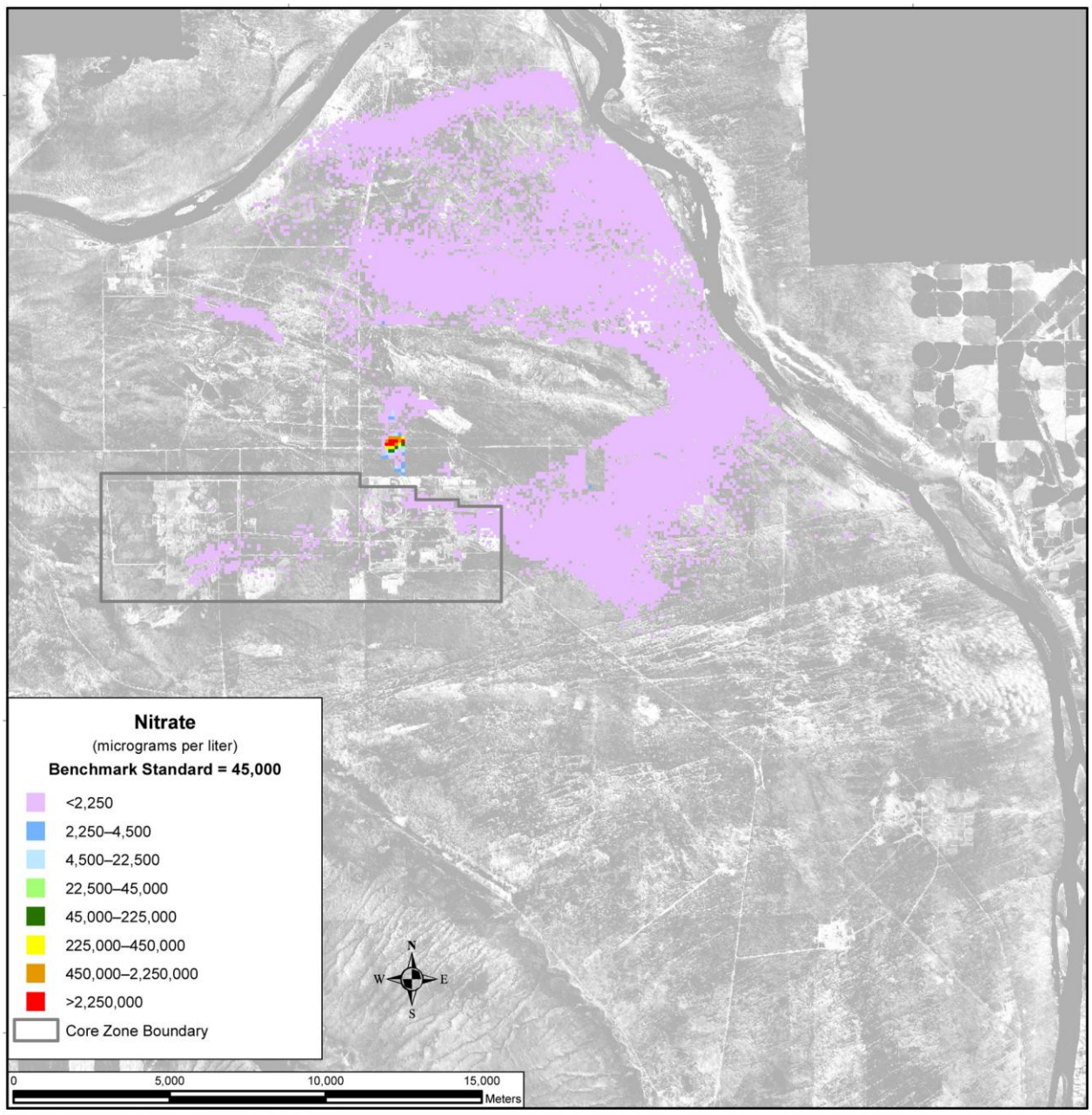
Note: To convert meters to feet, multiply by 3.281.

Figure 5–109. Tank Closure Alternative 2B Spatial Distribution of Groundwater Nitrate Concentration, Calendar Year 2010



Note: To convert meters to feet, multiply by 3.281.

Figure 5–110. Tank Closure Alternative 2B Spatial Distribution of Groundwater Nitrate Concentration, Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281.

Figure 5–111. Tank Closure Alternative 2B Spatial Distribution of Groundwater Nitrate Concentration, Calendar Year 7140

Figure 5–112 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 0.25 square kilometers (0.1 square miles). Iodine-129 shows a pattern similar to that of technetium-99, as both constituents are conservative tracers (see Figure 5–113).

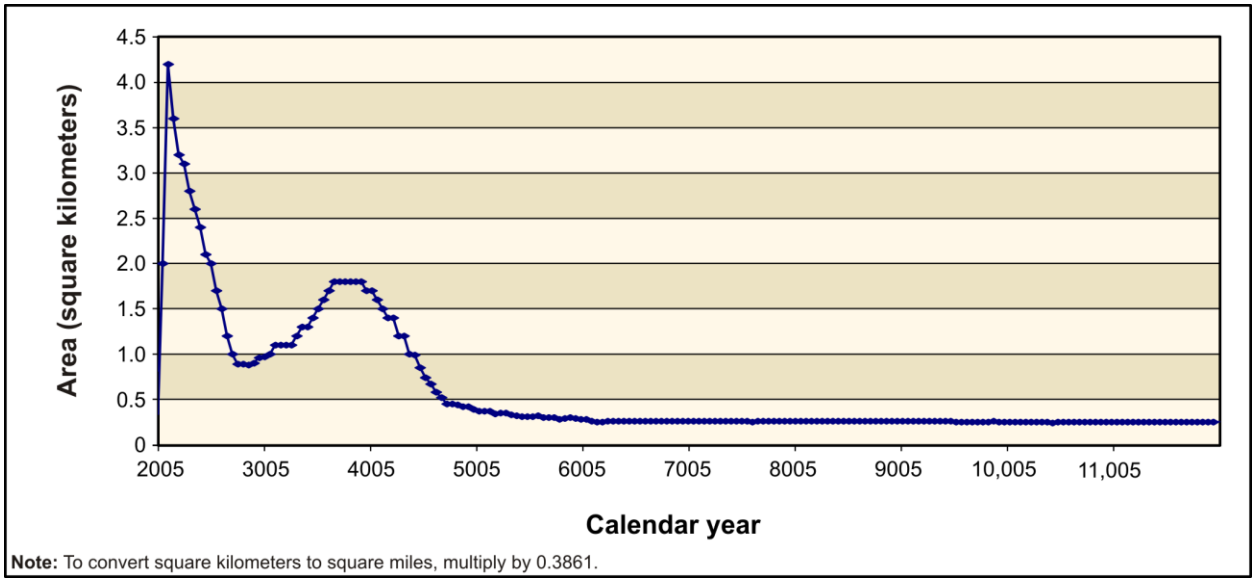


Figure 5–112. Tank Closure Alternative 2B Total Area of Groundwater Technetium-99 Concentration Exceeding the Benchmark Concentration as a Function of Time

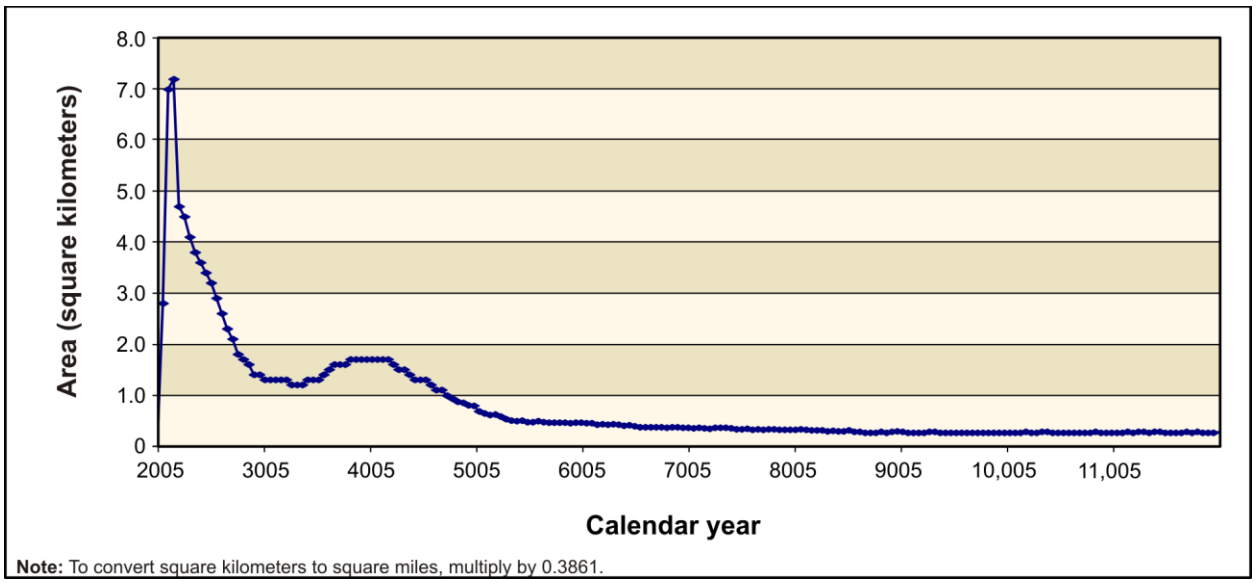
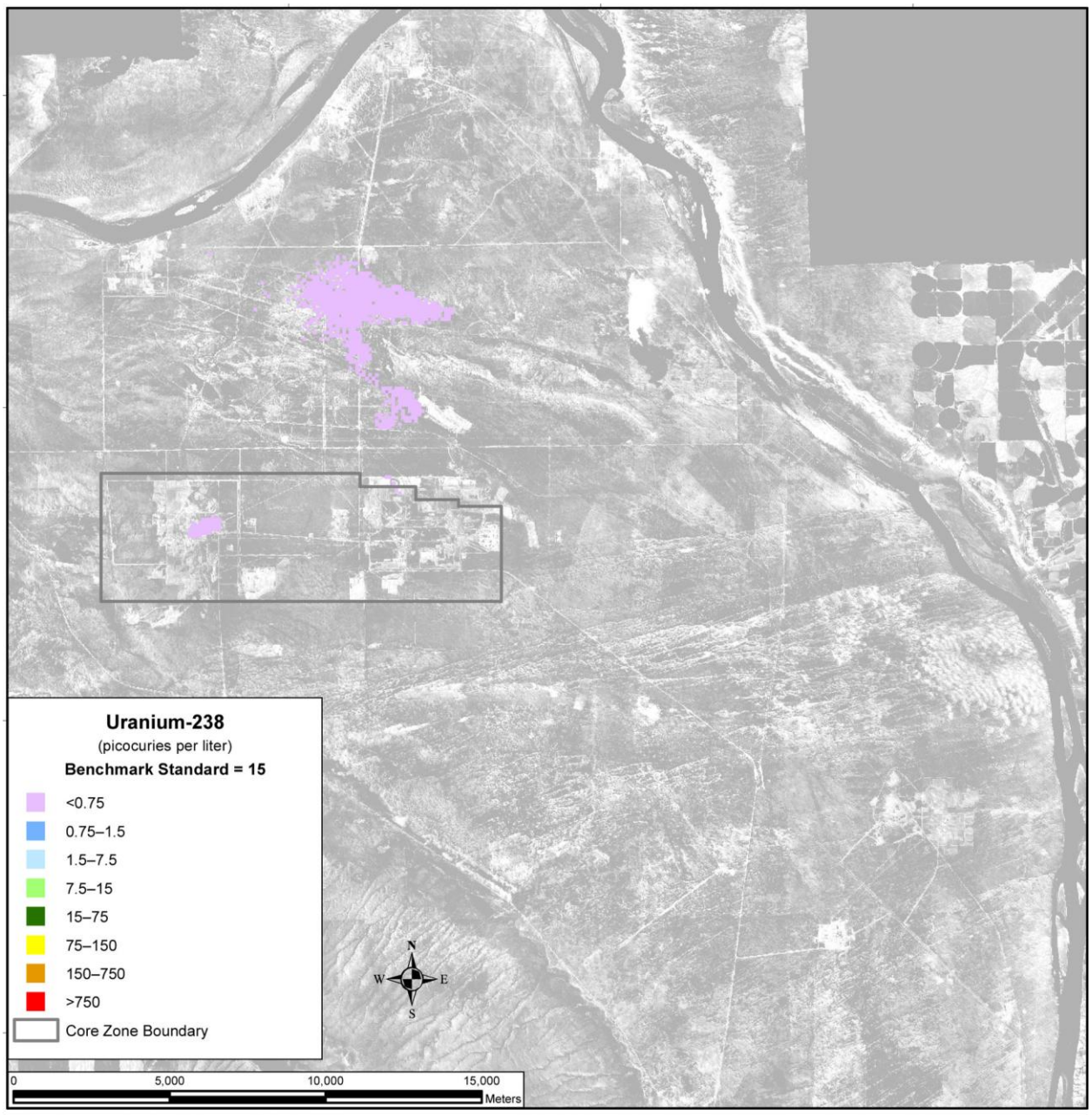


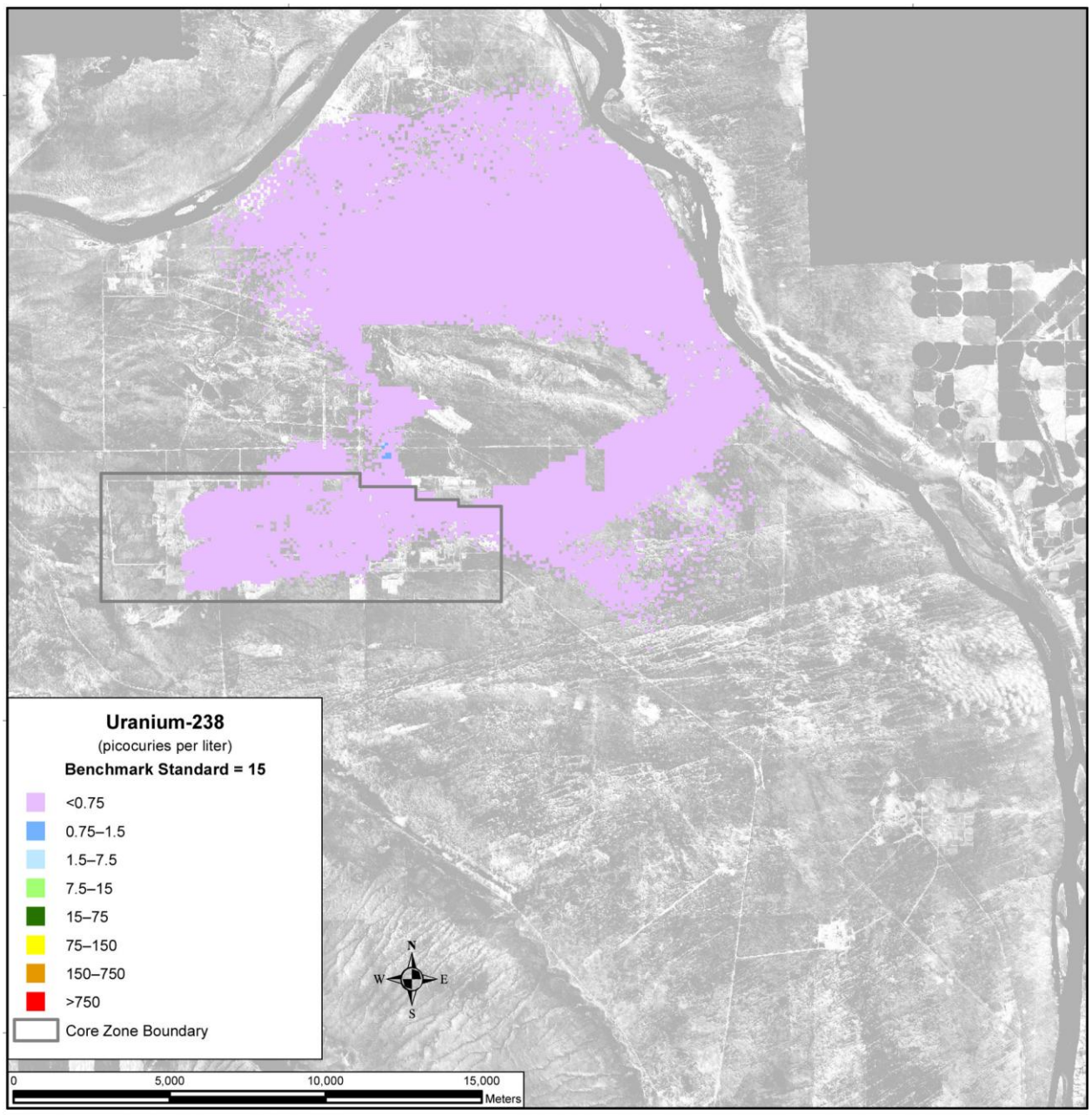
Figure 5–113. Tank Closure Alternative 2B Total Area of Groundwater Iodine-129 Concentration Exceeding the Benchmark Concentration as a Function of Time

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 more slowly 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 5–114 shows the distribution of uranium-238 in CY 2010 under Case 1. There is a small plume associated with releases from cribs and trenches (ditches) and past leaks at the T Barrier that is less than one-twentieth of the benchmark concentration. The plume extends northeast through Gable Gap. By CY 7140, the area of the plume has grown and extends to the Columbia River, but no significant increases in concentration are evident (see Figure 5–115). By CY 11,940 the greatest development of the plume during the analysis period has occurred, resulting primarily from past leaks and the release of other tank farm sources at the A and B Barriers (see Figure 5–116). Figures 5–117 through 5–119 show the corresponding results for total uranium.



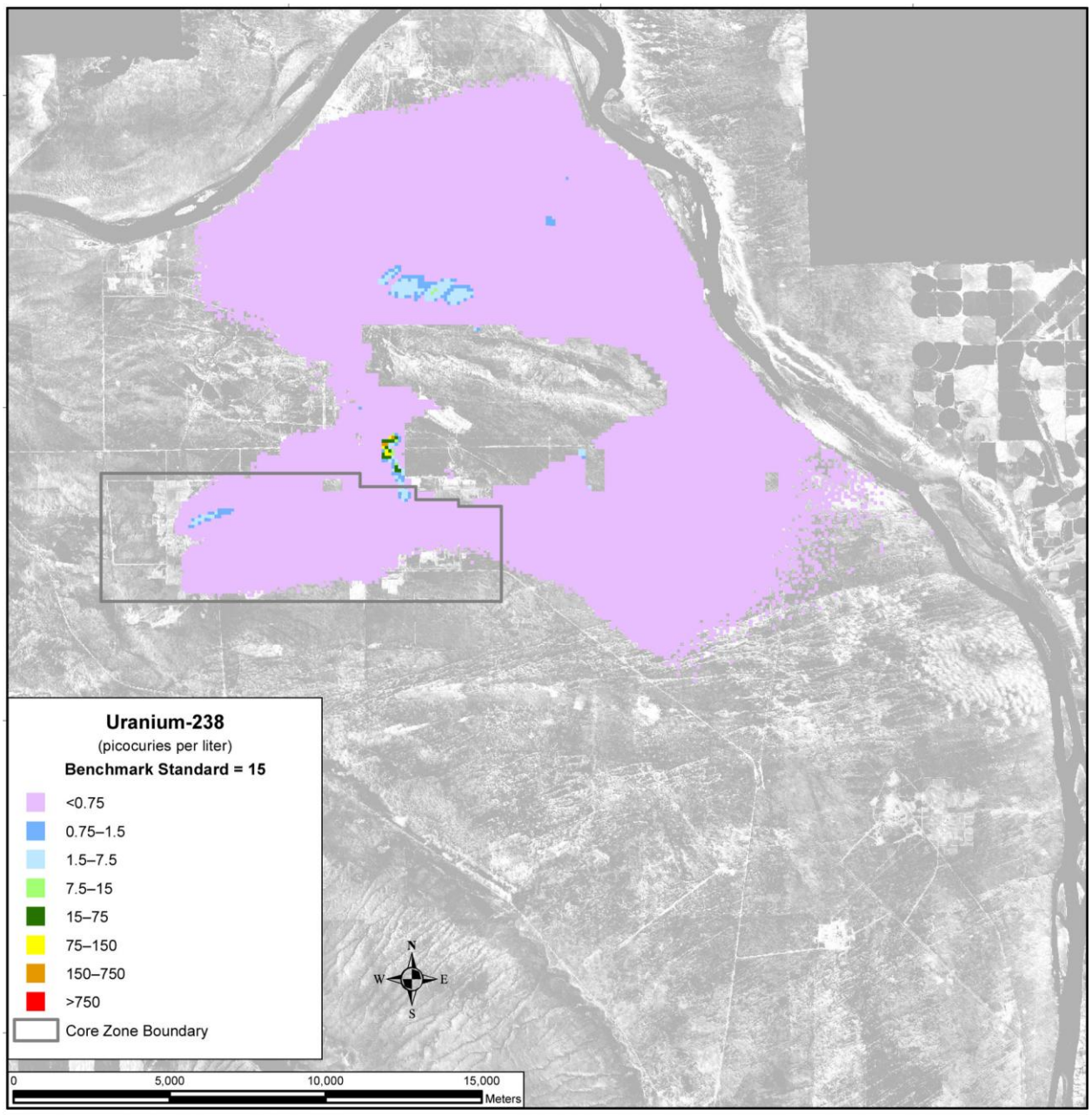
Note: To convert meters to feet, multiply by 3.281.

Figure 5–114. Tank Closure Alternative 2B Spatial Distribution of Groundwater Uranium-238 Concentration, Calendar Year 2010



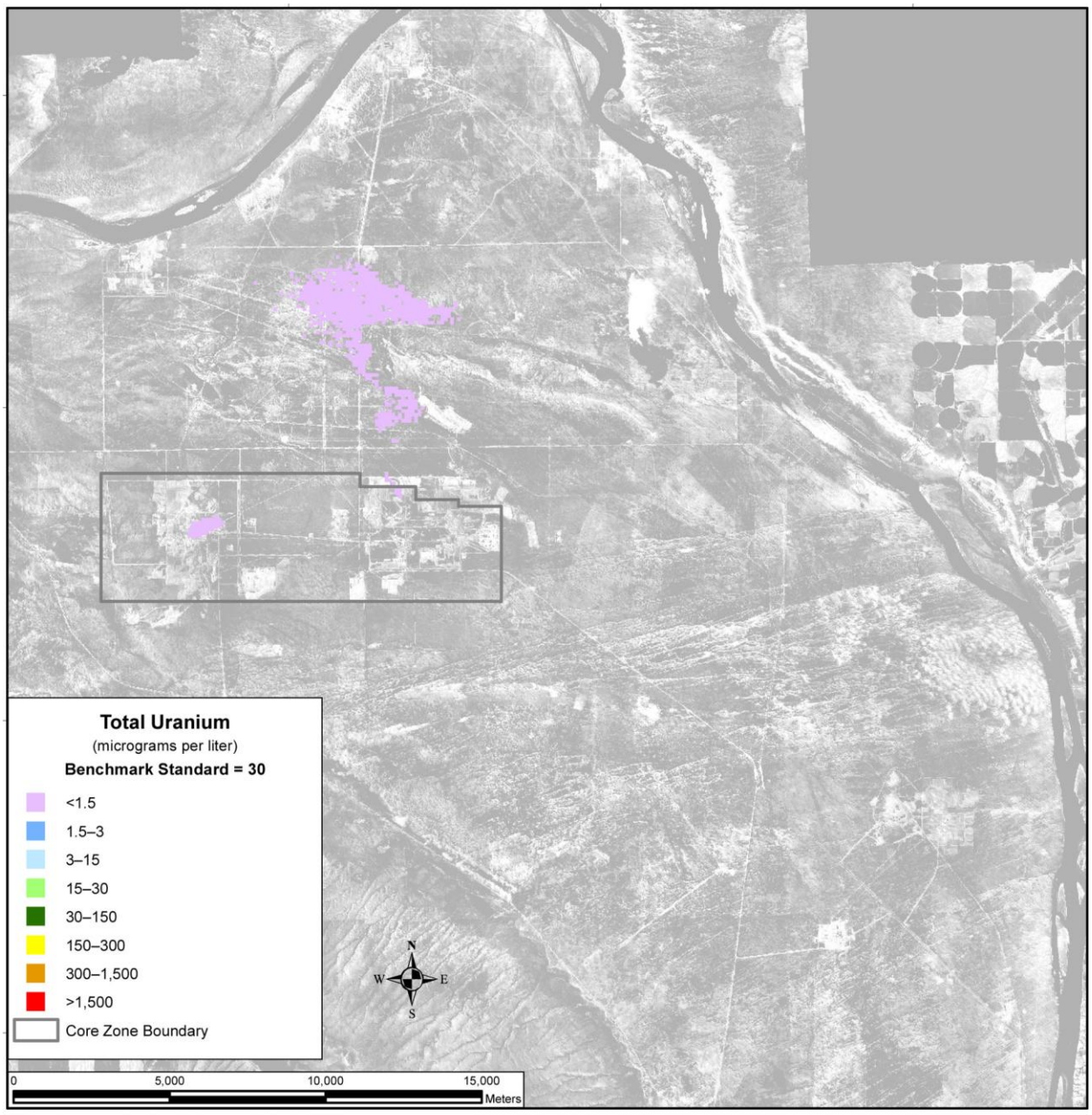
Note: To convert meters to feet, multiply by 3.281.

Figure 5–115. Tank Closure Alternative 2B Spatial Distribution of Groundwater Uranium-238 Concentration, Calendar Year 7140



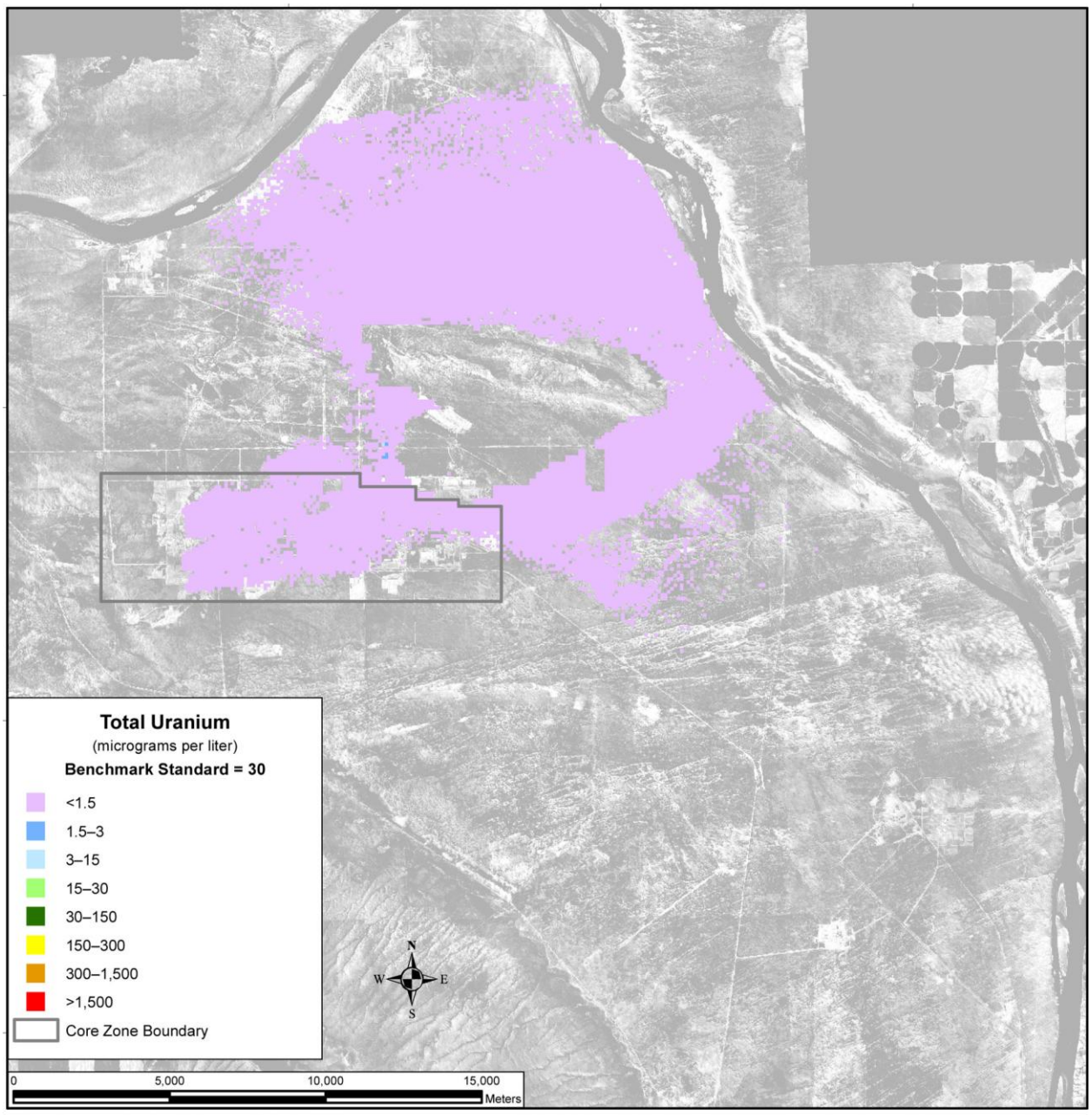
Note: To convert meters to feet, multiply by 3.281.

Figure 5–116. Tank Closure Alternative 2B Spatial Distribution of Groundwater Uranium-238 Concentration, Calendar Year 11,940



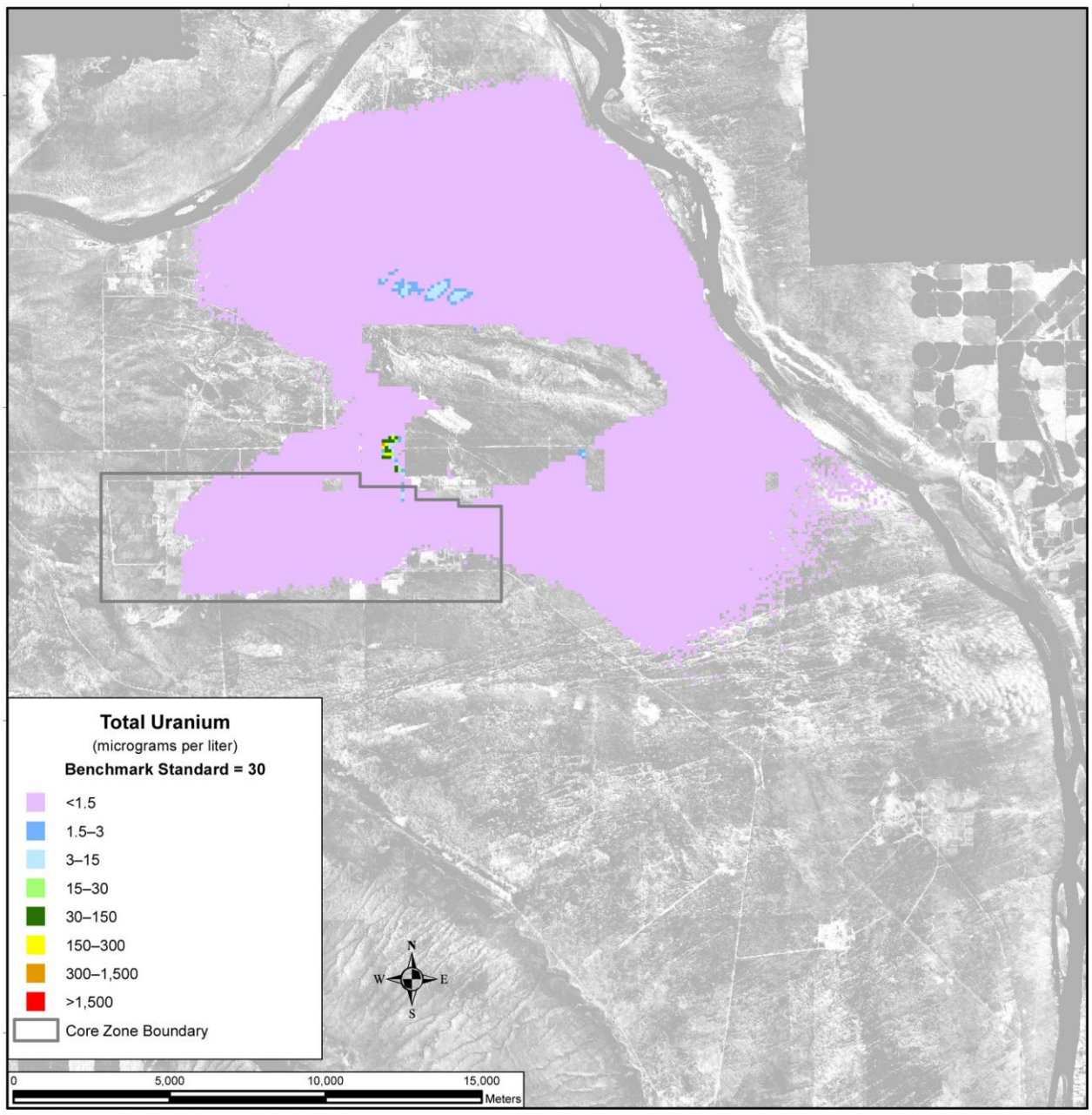
Note: To convert meters to feet, multiply by 3.281.

Figure 5–117. Tank Closure Alternative 2B Spatial Distribution of Groundwater Total Uranium Concentration, Calendar Year 2010



Note: To convert meters to feet, multiply by 3.281.

Figure 5–118. Tank Closure Alternative 2B Spatial Distribution of Groundwater Total Uranium Concentration, Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281.

Figure 5–119. Tank Closure Alternative 2B Spatial Distribution of Groundwater Total Uranium Concentration, Calendar Year 11,940

Uranium-238 does not exceed the benchmark concentration in any area until after CY 8100 (see Figure 5–120). A sharp increase in area with concentrations above the benchmark standard is seen after this time and continues to rise to about 0.24 square kilometers (0.1 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. The effect of landfill closure under Tank Closure Alternative 2B is to further delay the time uranium-238 exceeds the benchmark concentration in any area relative to Tank Closure Alternative 2A.

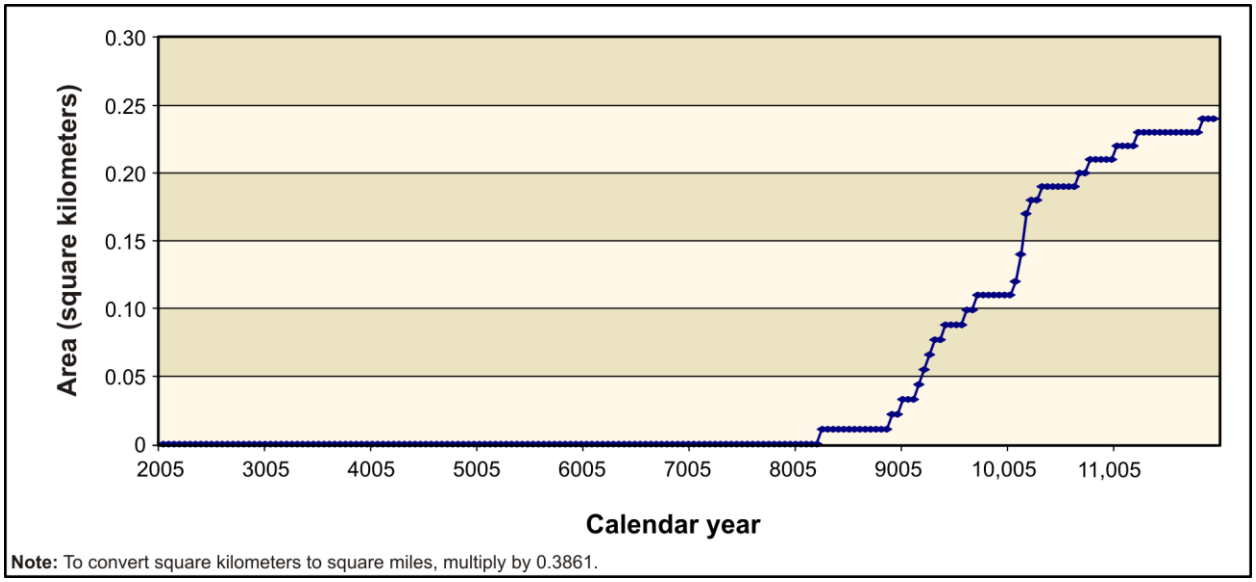


Figure 5–120. Tank Closure Alternative 2B Total Area of Groundwater Uranium-238 Concentration Exceeding the Benchmark Concentration as a Function of Time

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 one to 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 one to two orders of magnitude during the early part of the period of analysis and then gradually decline to around two to three orders of magnitude below the benchmark, where they remain throughout the period of analysis. Concentrations of conservative tracers at the Columbia River nearshore approach the benchmark during the early part of the period of analysis, but remain below the benchmark thereafter.

For uranium-238 and total uranium, limited mobility is an important factor governing the timeframes and scale of groundwater impacts. The concentrations of uranium-238 and total uranium at the Core Zone Boundary rise to about two to three orders of magnitude below the benchmark during the early period of analysis, then gradually rise to less than an order of magnitude below the benchmark by the end of the period of analysis. Concentrations of uranium-238 and total uranium at the Columbia River nearshore rise throughout the period of analysis but remain below the benchmark by around two to three orders of magnitude. The intensity is highest and the area of the contamination plume largest 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 waste in tanks would be grouted 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. See

Section 5.1.1.3 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, Case 1, which are identical to those for Tank Closure Alternative 3A.

5.1.1.4.1 Actions and Timeframes Influencing Groundwater Impacts

See Section 5.1.1.3.1 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, Case 1, which are identical to those for Tank Closure Alternative 3A.

5.1.1.4.2 COPC Drivers

See Section 5.1.1.3.2 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, Case 1, which are identical to those for Tank Closure Alternative 3A.

5.1.1.4.3 Analysis of Release and Mass Balance

See Section 5.1.1.3.3 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, Case 1, which are identical to those for Tank Closure Alternative 3A.

5.1.1.4.4 Analysis of Concentration Versus Time

See Section 5.1.1.3.4 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, Case 1, which are identical to those for Tank Closure Alternative 3A.

5.1.1.4.5 Analysis of Spatial Distribution of Concentration

See Section 5.1.1.3.5 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, Case 1, which are identical to those for Tank Closure Alternative 3A.

5.1.1.4.6 Summary of Impacts

See Section 5.1.1.3.6 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, Case 1, 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 waste in tanks would be grouted 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. See Section 5.1.1.3 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, Case 1, which are identical to those for Tank Closure Alternative 3B.

5.1.1.5.1 Actions and Timeframes Influencing Groundwater Impacts

See Section 5.1.1.3.1 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, Case 1, which are identical to those for Tank Closure Alternative 3B.

5.1.1.5.2 COPC Drivers

See Section 5.1.1.3.2 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, Case 1, which are identical to those for Tank Closure Alternative 3B.

5.1.1.5.3 Analysis of Release and Mass Balance

See Section 5.1.1.3.3 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, Case 1, which are identical to those for Tank Closure Alternative 3B.

5.1.1.5.4 Analysis of Concentration Versus Time

See Section 5.1.1.3.4 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, Case 1, which are identical to those for Tank Closure Alternative 3B.

5.1.1.5.5 Analysis of Spatial Distribution of Concentration

See Section 5.1.1.3.5 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, Case 1, which are identical to those for Tank Closure Alternative 3B.

5.1.1.5.6 Summary of Impacts

See Section 5.1.1.3.6 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, Case 1, 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 waste in tanks would be grouted 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. See Section 5.1.1.3 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, Case 1, which are identical to those for Tank Closure Alternative 3C.

5.1.1.6.1 Actions and Timeframes Influencing Groundwater Impacts

See Section 5.1.1.3.1 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, Case 1, which are identical to those for Tank Closure Alternative 3C.

5.1.1.6.2 COPC Drivers

See Section 5.1.1.3.2 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, Case 1, which are identical to those for Tank Closure Alternative 3C.

5.1.1.6.3 Analysis of Release and Mass Balance

See Section 5.1.1.3.3 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, Case 1, which are identical to those for Tank Closure Alternative 3C.

5.1.1.6.4 Analysis of Concentration Versus Time

See Section 5.1.1.3.4 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, Case 1, which are identical to those for Tank Closure Alternative 3C.

5.1.1.6.5 Analysis of Spatial Distribution of Concentration

See Section 5.1.1.3.5 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, Case 1, which are identical to those for Tank Closure Alternative 3C.

5.1.1.6.6 Summary of Impacts

See Section 5.1.1.3.6 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, Case 1, 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 impacts 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 are common to all of the Tank Closure alternatives.

- The retrieval period was assumed to start in 2008 and end in CY 2144. This includes retrieval, WTP pretreatment and treatment, landfill closure of most of the SST farm system, clean closure of BX and SX tank farms, and 100 years of postclosure care. 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 and was assumed to occur over a period of 1 year (see Appendix M, Section M.5.1, for a discussion of the effect of variation of duration of leaks). 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, but this discussion 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 contributions 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. No chemical risk is predicted. 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 the total amount of COPCs released to the vadose zone, groundwater, and the Columbia River during the 10,000-year period of analysis. Releases of radionuclides are totaled in curies; chemicals, in kilograms (see Figures 5–121 through 5–126). Three subtotals are plotted, representing releases from cribs and trenches (ditches), past leaks, and other tank farm sources (e.g., tank residuals, ancillary equipment). Note that the release amounts are plotted on a logarithmic scale to facilitate visual comparison of releases that vary over four orders of magnitude within the same series of figures.

Figure 5–121 shows the estimated release to the vadose zone of the radiological risk drivers and Figure 5–122, 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 is released during the period of analysis). The predominant sources of 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 5–123 shows the estimated release to groundwater of the radiological risk drivers and Figure 5–124, 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.

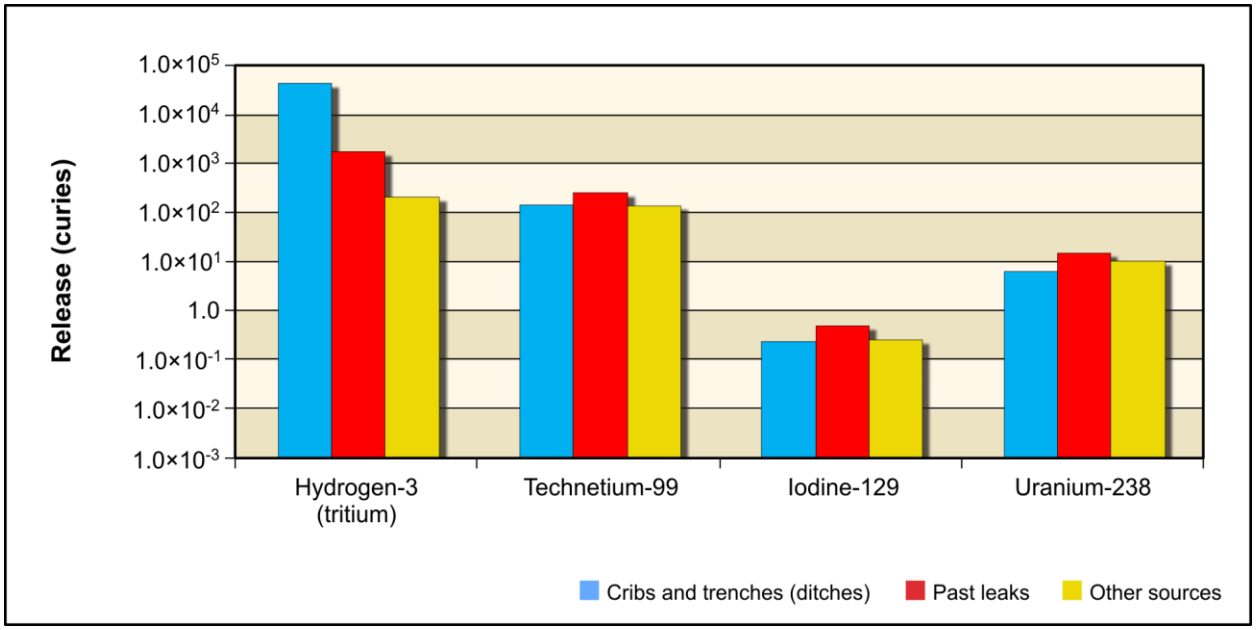


Figure 5–121. Tank Closure Alternative 4 Releases of Radioactive Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

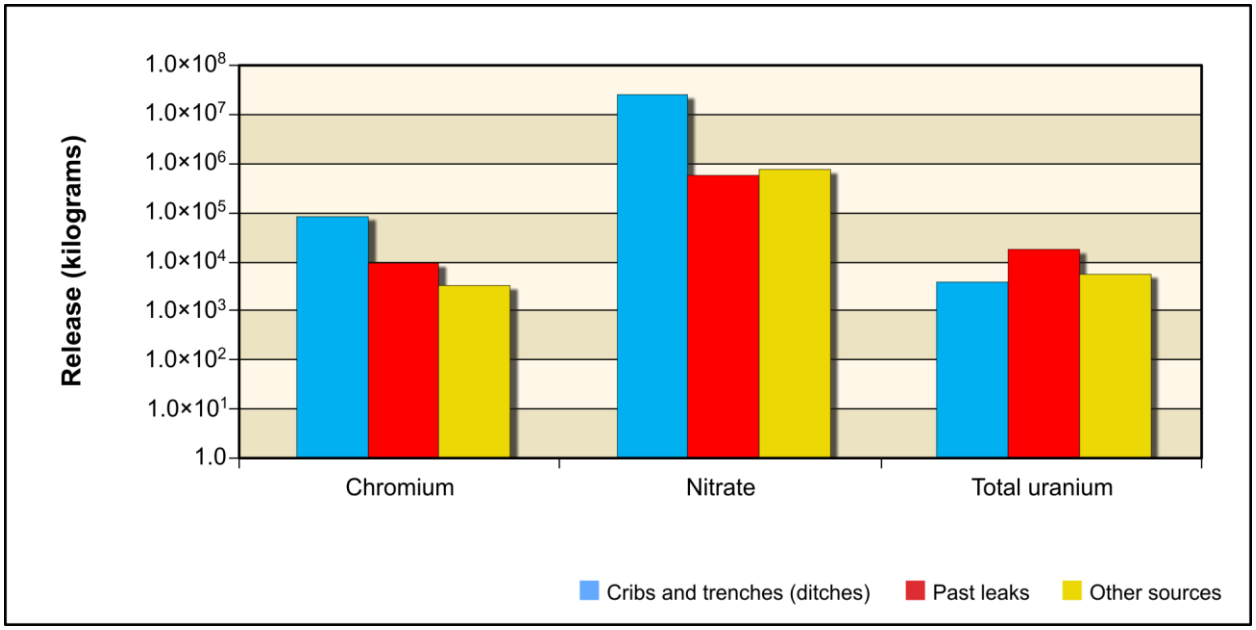


Figure 5–122. Tank Closure Alternative 4 Releases of Chemical Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

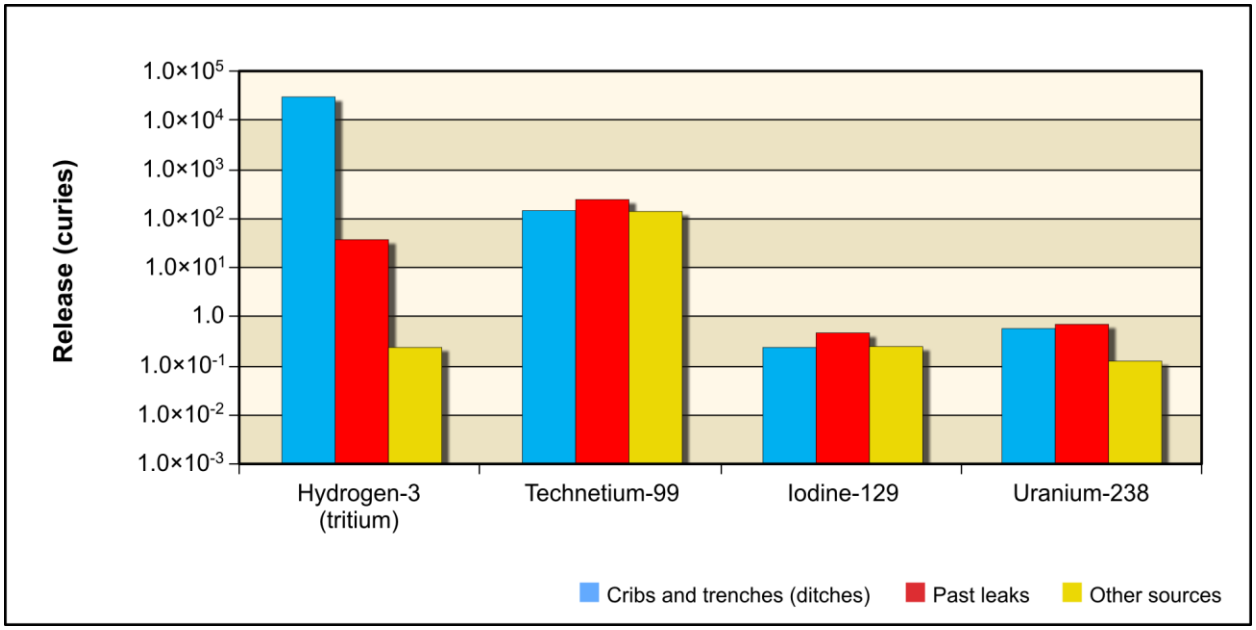


Figure 5–123. Tank Closure Alternative 4 Releases of Radioactive Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

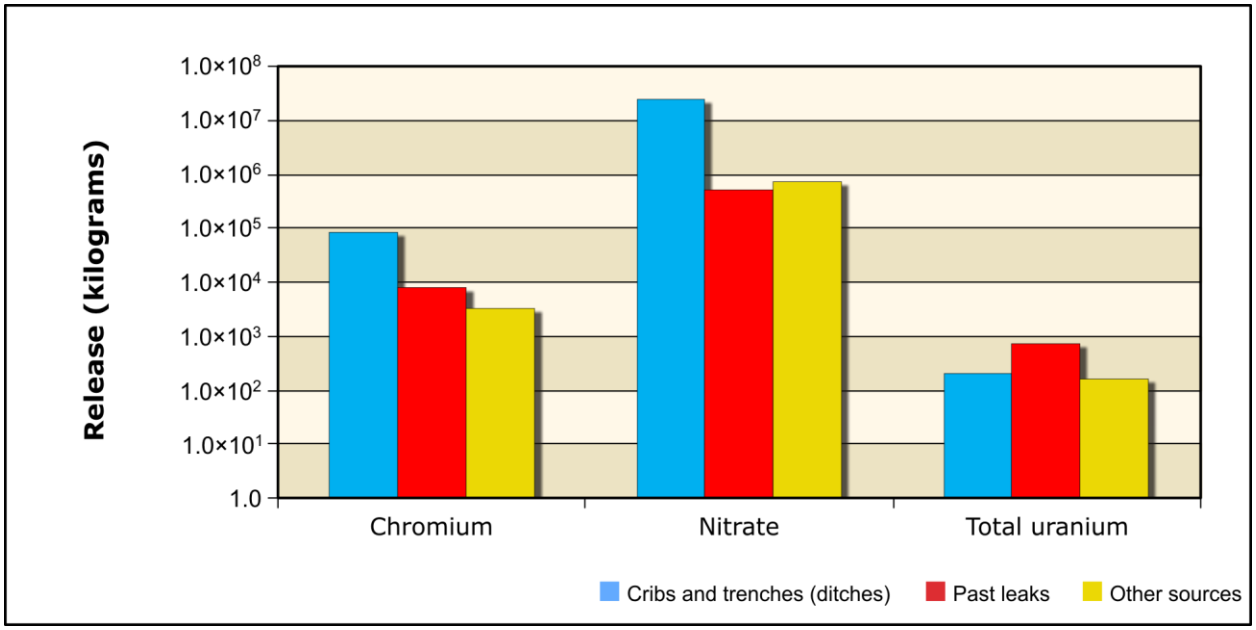


Figure 5–124. Tank Closure Alternative 4 Releases of Chemical Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

For uranium-238 and total uranium, the amount released to groundwater is less than that released 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 releases from 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 14 percent of the inventory of uranium-238 and 9 percent of the inventory of total uranium reach groundwater during the period of analysis; for other tank farm sources, only about 1 percent of the uranium-238 and 3 percent of the total uranium inventories reach groundwater during the period of analysis.

For tritium, the amount released to groundwater is attenuated by radioactive decay. For releases from cribs and trenches (ditches), about 70 percent of the total inventory reaches groundwater in the analysis; for past leaks, only 2 percent; and for other tank farm sources, only one-tenth of 1 percent reaches 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 on groundwater would occur later in the post–administrative control period because of the long travel times in the vadose zone for these COPCs.

Figure 5–125 shows the estimated release to the Columbia River of the radiological risk drivers and Figure 5–126, 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 released to groundwater because of retardation. Overall, about 30 percent of the uranium-238 and 27 percent of the total uranium released to groundwater during the period of analysis reach the Columbia River. For tritium, the amount released to the Columbia River is attenuated by radioactive decay. Overall, only about 1 percent of the tritium released to groundwater reaches 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.

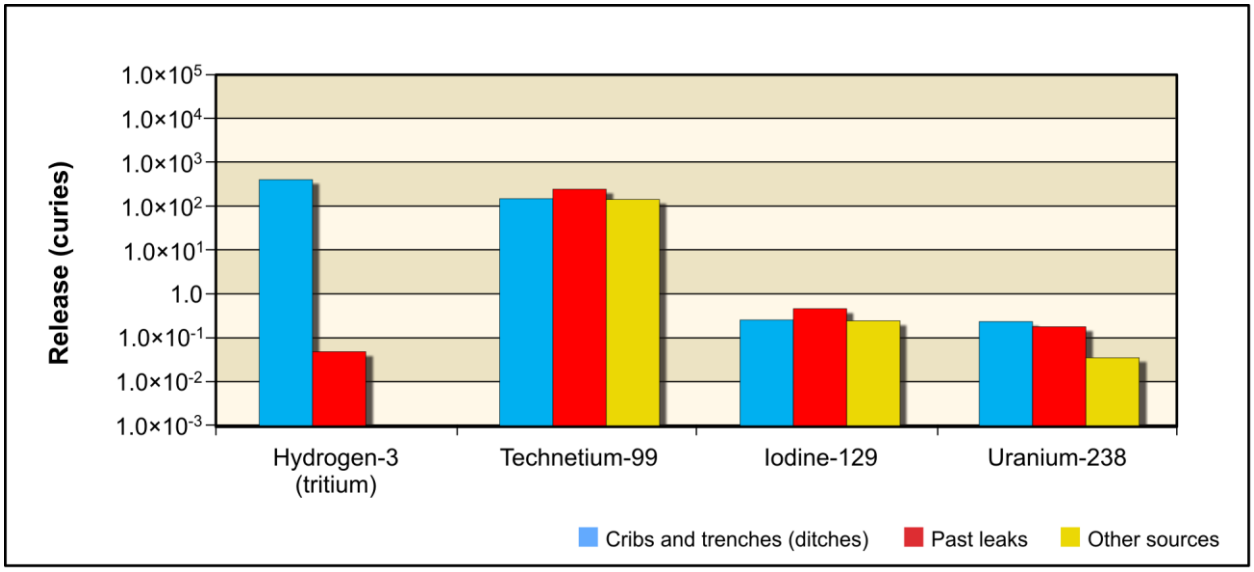


Figure 5–125. Tank Closure Alternative 4 Releases of Radioactive Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

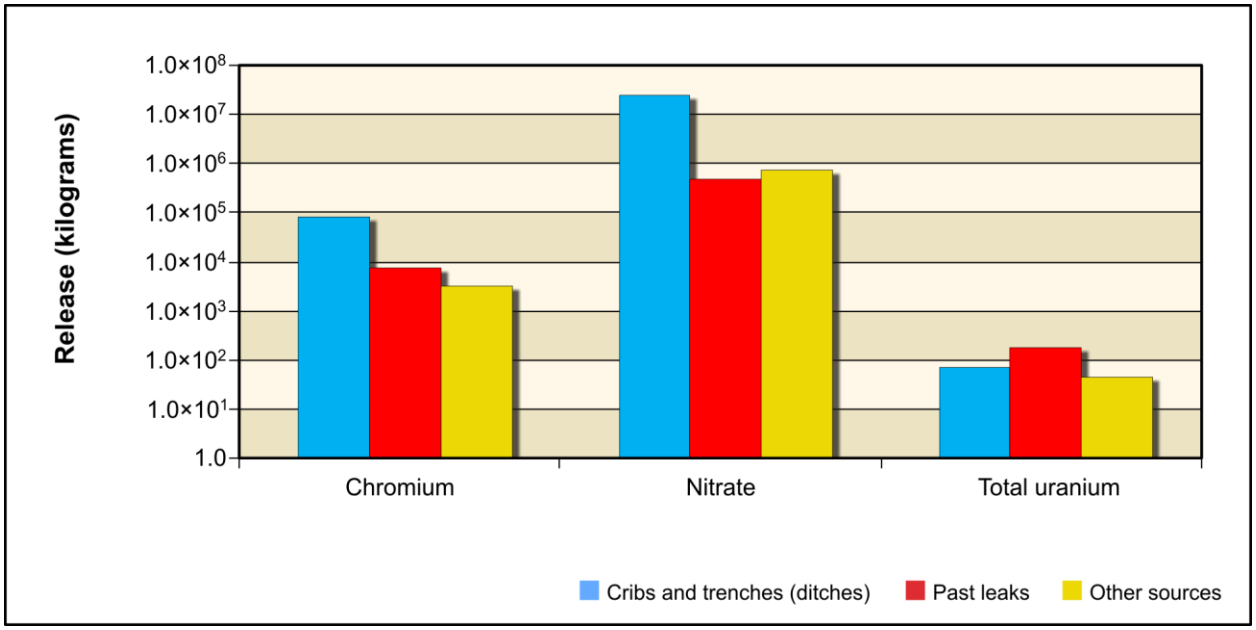


Figure 5–126. Tank Closure Alternative 4 Releases of Chemical Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

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 nearshore. Concentrations of radionuclides are in picocuries per liter; chemicals, in micrograms per liter (see Table 5–10 and Figures 5–127 through 5–133). The benchmark concentration of each radionuclide and chemical is also shown. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over five orders of magnitude. Table 5–10 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. Under Tank Closure Alternative 4, tritium, uranium-238, and total uranium never exceed their benchmark concentrations at any location beyond CY 2050. The highest impact occurs at the B and T Barriers and at the Core Zone Boundary, where concentrations of technetium-99, iodine-129, chromium, and nitrate peak above their benchmark concentration values. At the Columbia River nearshore, none of the COPCs peak above the benchmark concentration after CY 2050.

Figure 5–127 shows concentration versus time for tritium. Releases from cribs and trenches (ditches) cause Core Zone Boundary groundwater concentrations to exceed benchmark concentrations by one to two orders of magnitude for a short period of time during the early part of the period of analysis. This time period is represented by the first series of sharp inflections in the curve for the Core Zone Boundary from approximately CY 1955 until CY 1980. 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 2050.

Table 5–10. 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 (picocuries per liter)								
Hydrogen-3 (tritium)	7 (2051)	578 (2052)	4 (2050)	2,870 (2050)	15 (2050)	628 (2051)	477 (2051)	20,000
Technetium-99	790 (2100)	**3,500** (2056)	196 (2050)	**6,600** (2051)	147 (2058)	**3,500** (2056)	392 (2254)	900
Iodine-129	**1.4** (2102)	**4.3** (2056)	0.4 (2050)	**12.6** (2050)	0.2 (2072)	**4.3** (2056)	0.7 (2240)	1
Uranium isotopes (includes U-233, -234, -235, -238)	0 (11,865)	3 (11,913)	0 (11,932)	2 (11,909)	0 (11,923)	3 (11,913)	0 (11,937)	15
Chemical (micrograms per liter)								
Chromium	71 (2168)	**215** (2050)	27 (2059)	**353** (2045)	6 (2050)	**215** (2050)	71 (2076)	100
Nitrate	17,600 (2172)	**171,000** (2055)	965 (2070)	**62,100** (2053)	909 (2071)	**171,000** (2055)	17,200 (2122)	45,000
Total uranium	0 (11,826)	4 (11,827)	0 (11,810)	1 (11,843)	0 (11,814)	4 (11,827)	0 (11,937)	30

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.

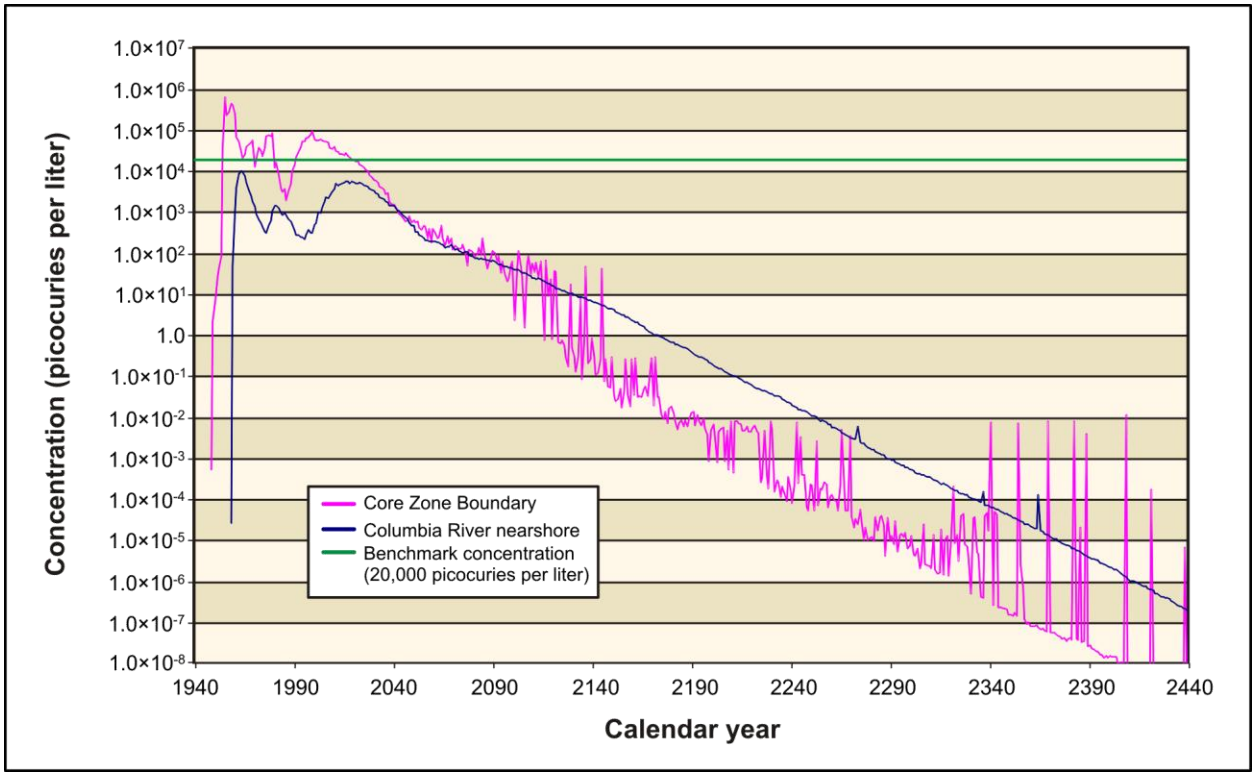


Figure 5–127. Tank Closure Alternative 4 Hydrogen-3 (Tritium) Concentration Versus Time

Figures 5–128 through 5–131 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 one to two orders of

magnitude during the early part of the period of analysis at the Core Zone Boundary. This early time period is represented by the multiple sharp inflections in the Core Zone Boundary curve that occur approximately between CY 1955 and CY 1980. The iodine-129 signature also occurs at the Columbia River nearshore at a later time. By about CY 2500, the iodine-129 Core Zone Boundary groundwater concentrations return to levels below the benchmark. Technetium-99, nitrate, and chromium concentrations fall below the benchmark concentration at the Core Zone Boundary around CY 2500. Concentrations of all of the conservative tracers decline over the remainder of the period of analysis.

Figures 5–132 and 5–133 show concentration versus time for uranium-238 and total uranium. Early releases from cribs and trenches (ditches) result in Core Zone Boundary groundwater concentrations that are about two orders of magnitude lower than benchmark concentrations. These concentrations continue to rise throughout the duration of the period of analysis. Uranium-238 and total uranium concentrations come to within an order of magnitude of the benchmark concentration at the Core Zone Boundary near the end of the period of analysis. Groundwater concentrations of uranium-238 and total uranium at the Columbia River nearshore rise throughout the period of analysis but remain over two orders of magnitude below the benchmark concentration for the duration of the simulation.

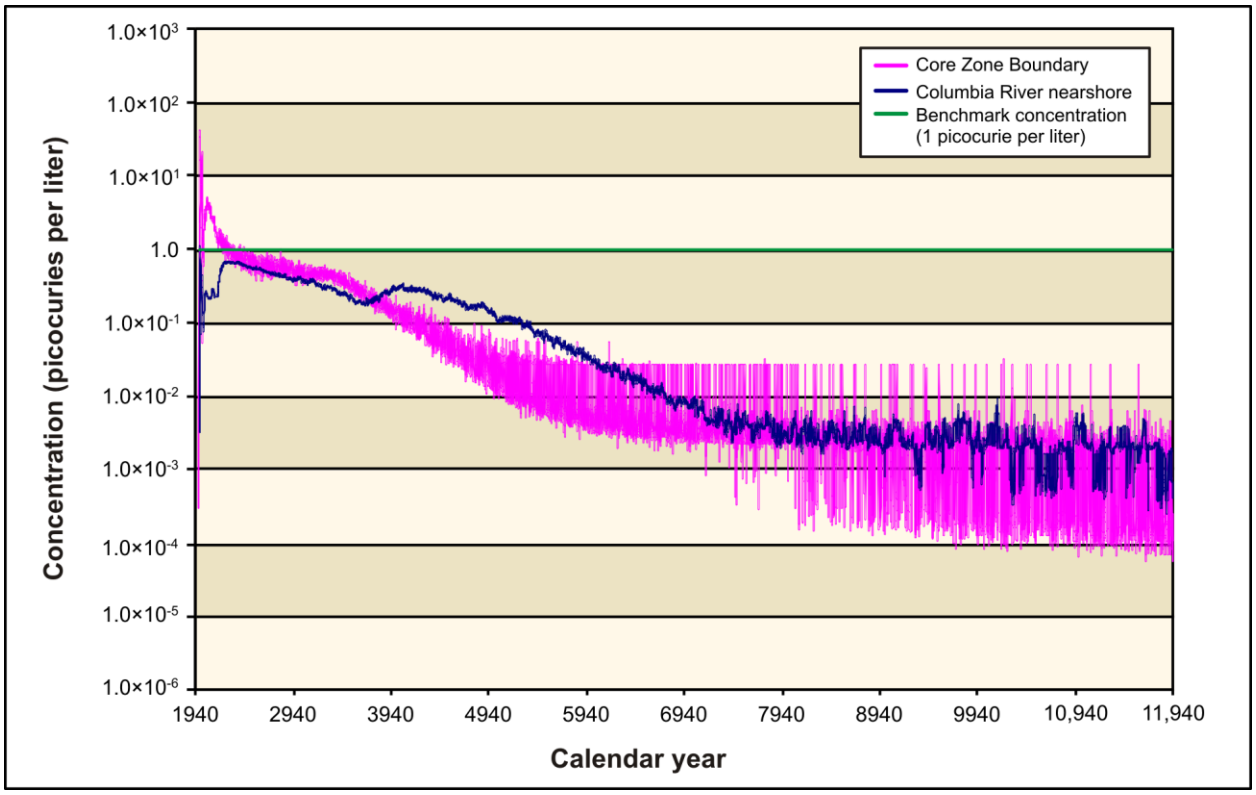


Figure 5–128. Tank Closure Alternative 4 Iodine-129 Concentration Versus Time

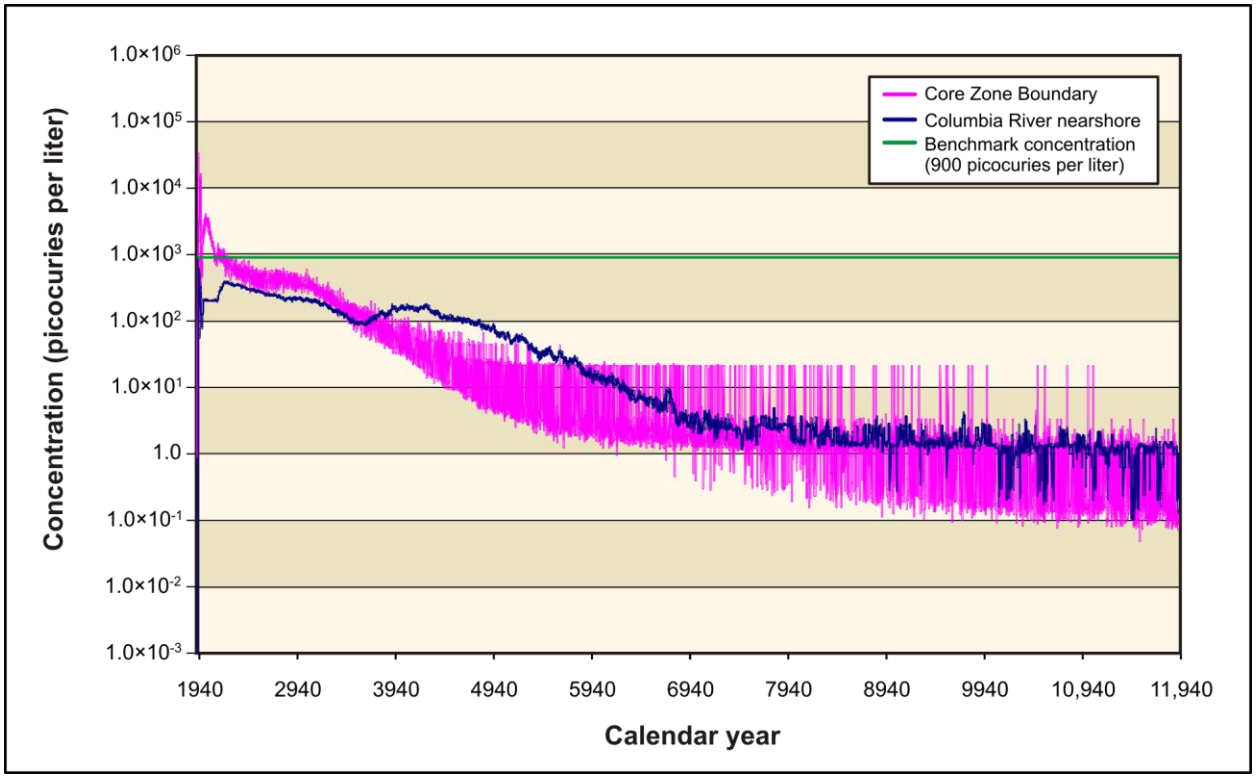


Figure 5–129. Tank Closure Alternative 4 Technetium-99 Concentration Versus Time

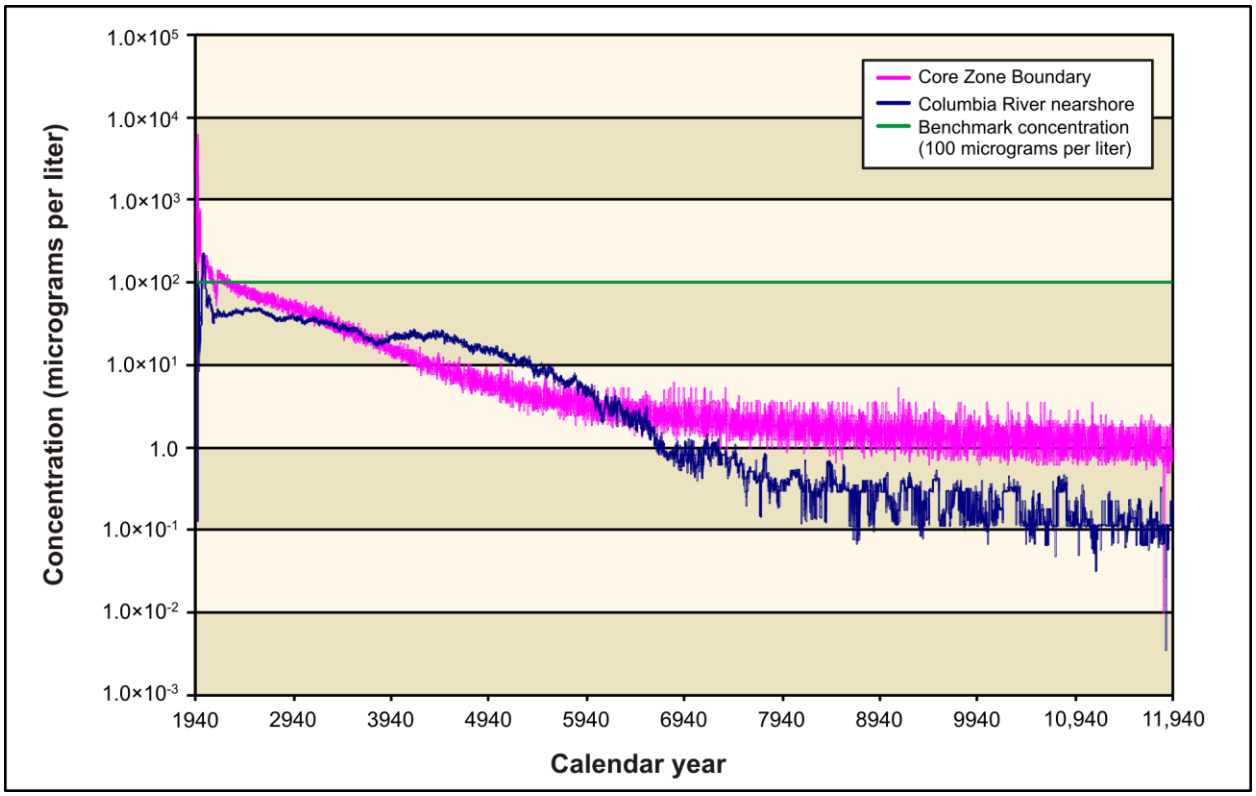


Figure 5–130. Tank Closure Alternative 4 Chromium Concentration Versus Time

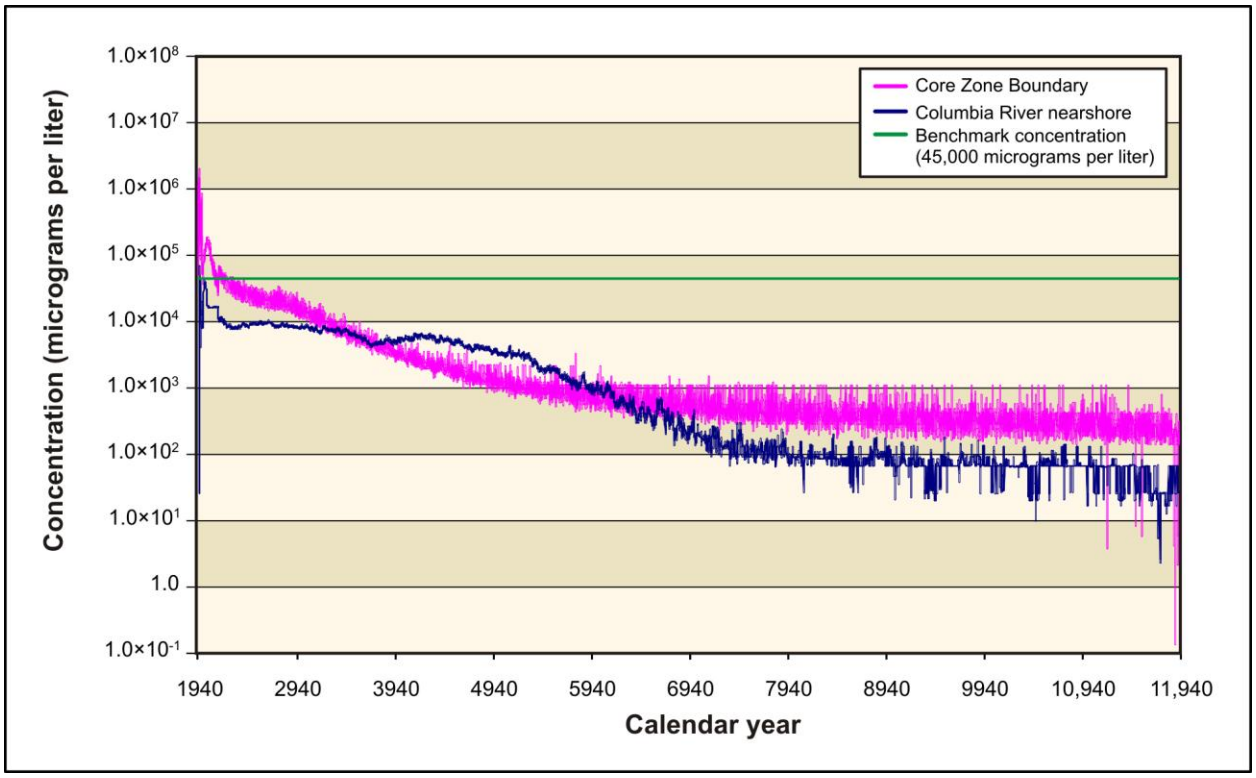


Figure 5–131. Tank Closure Alternative 4 Nitrate Concentration Versus Time

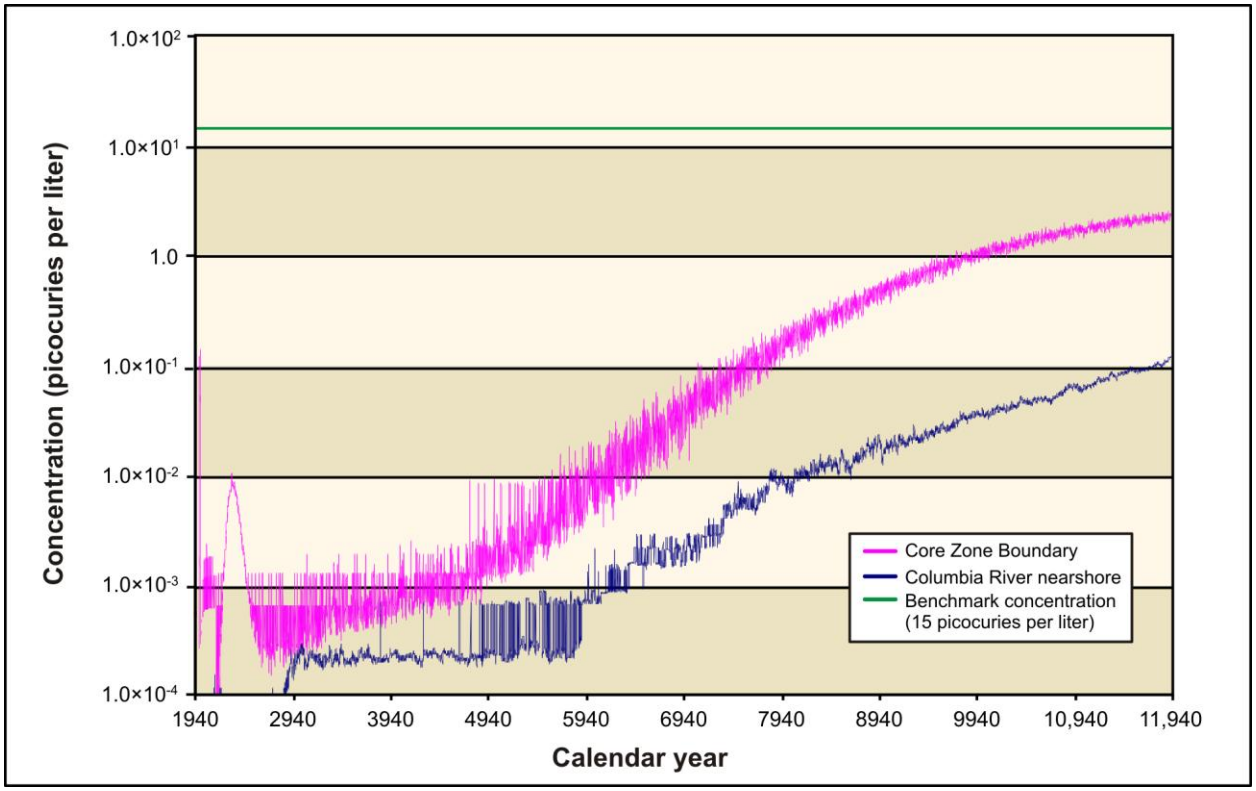


Figure 5–132. Tank Closure Alternative 4 Uranium-238 Concentration Versus Time

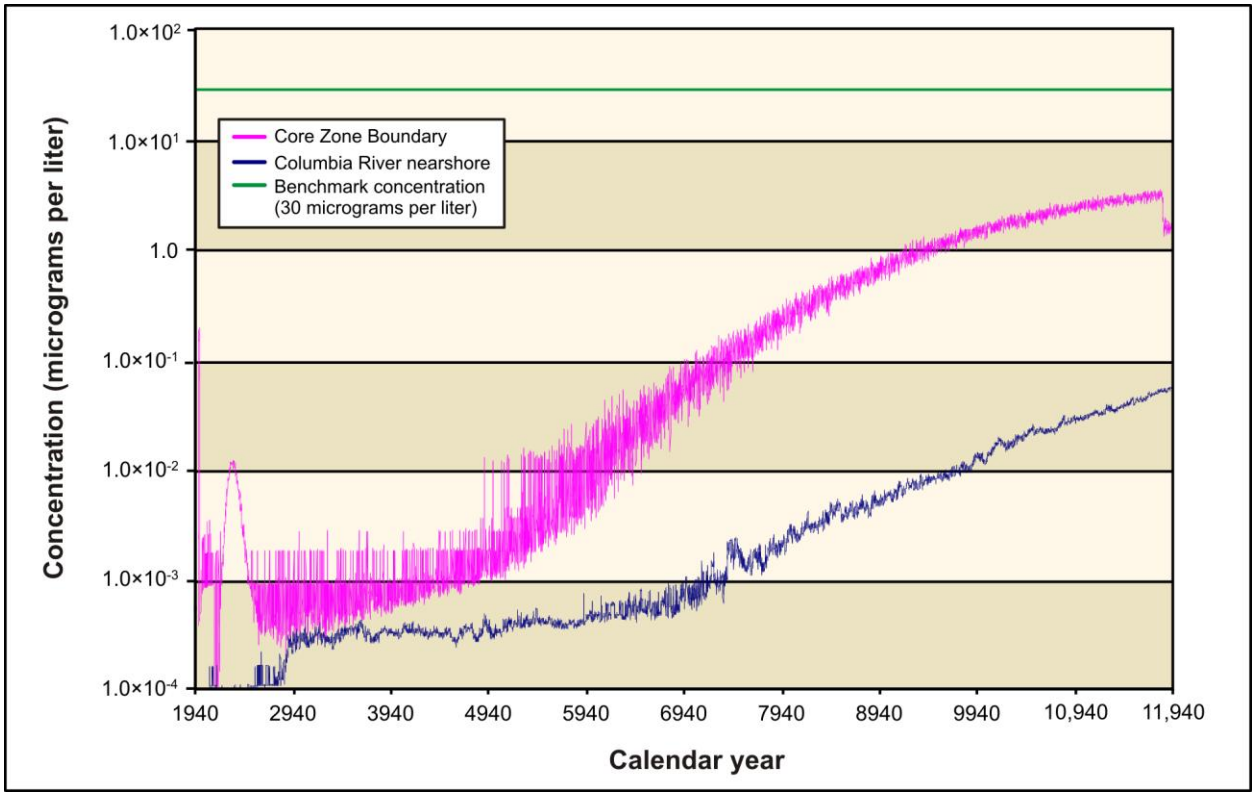
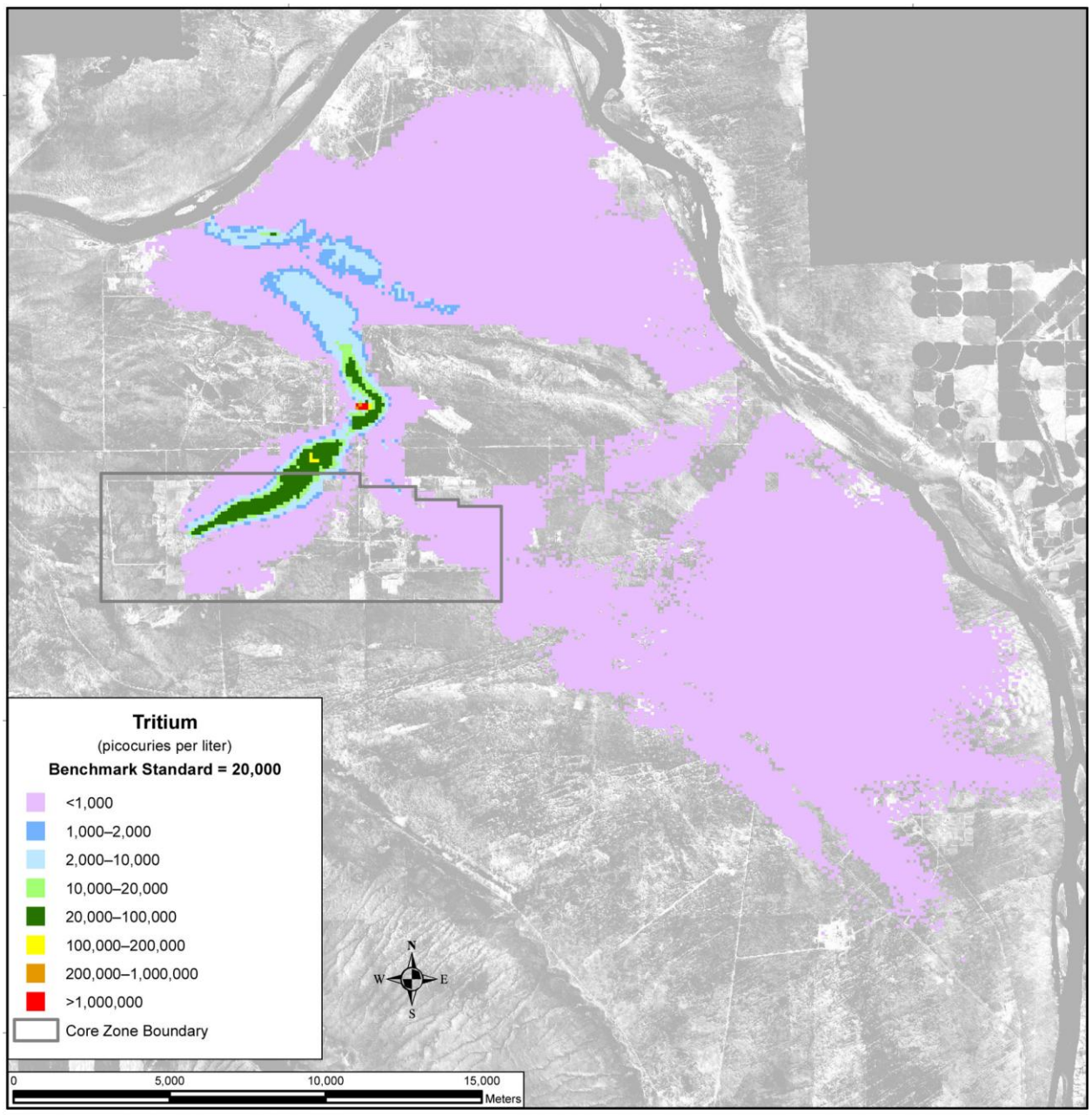


Figure 5–133. Tank Closure Alternative 4 Total Uranium Concentration Versus Time

5.1.1.7.5 Analysis of Spatial Distribution of Concentration

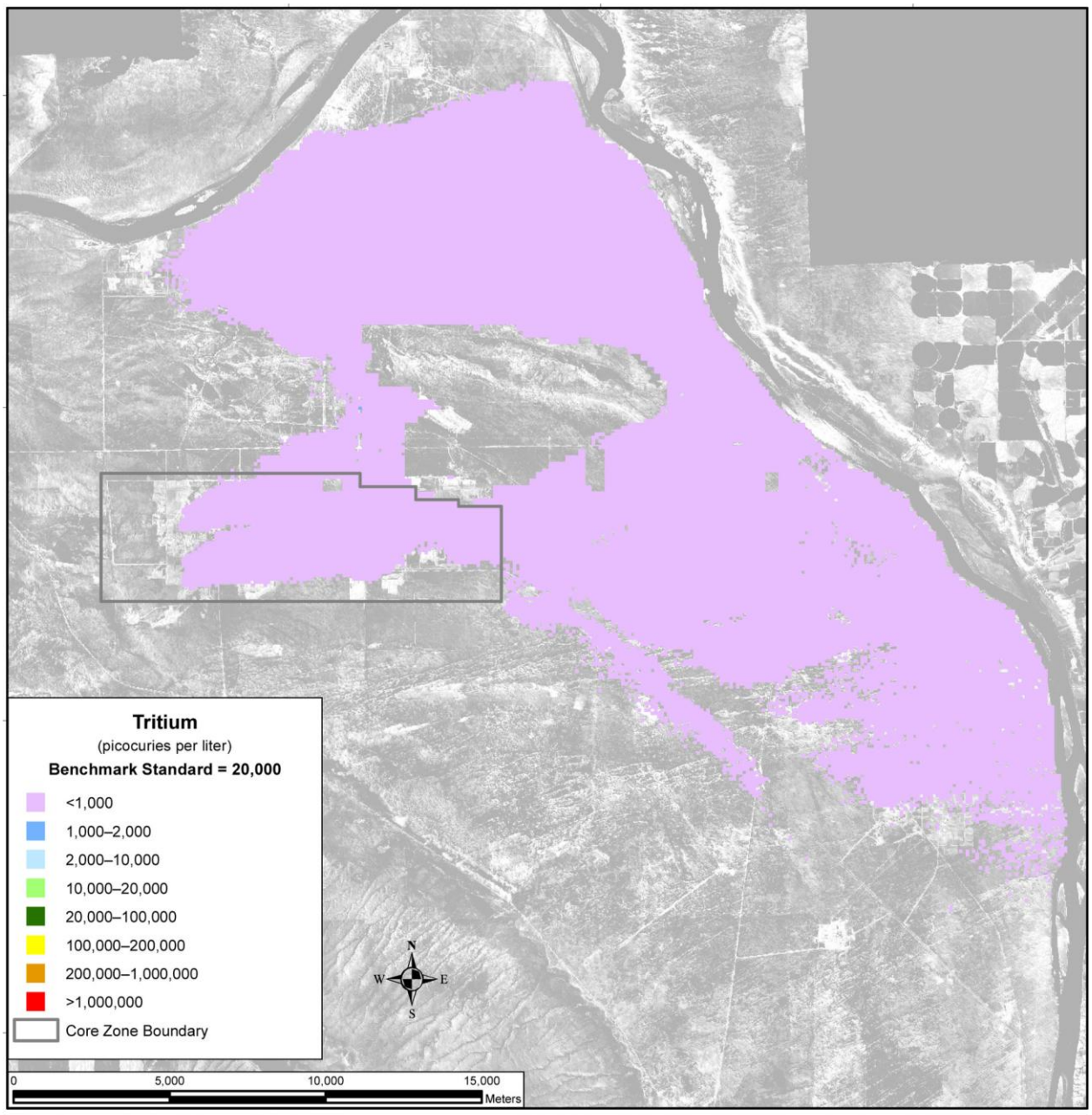
This section presents the impacts of Tank Closure Alternative 4 in terms of the spatial distribution of COPC driver concentrations in groundwater at selected times. Concentrations of radionuclides are in picocuries per liter; chemicals, in micrograms per liter (see Figures 5–134 through 5–155). Concentrations of 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 5–134 shows the spatial distribution of tritium concentrations in groundwater in CY 2010. 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, crosses the Core Zone Boundary, and continues toward Gable Gap. Peak concentrations in this plume are about 5 to 10 times greater than the benchmark. Tritium concentrations are attenuated by radioactive decay to levels less than one-twentieth of the benchmark concentration by CY 2135 (see Figure 5–135).



Note: To convert meters to feet, multiply by 3.281.

Figure 5–134. Tank Closure Alternative 4 Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration, Calendar Year 2010

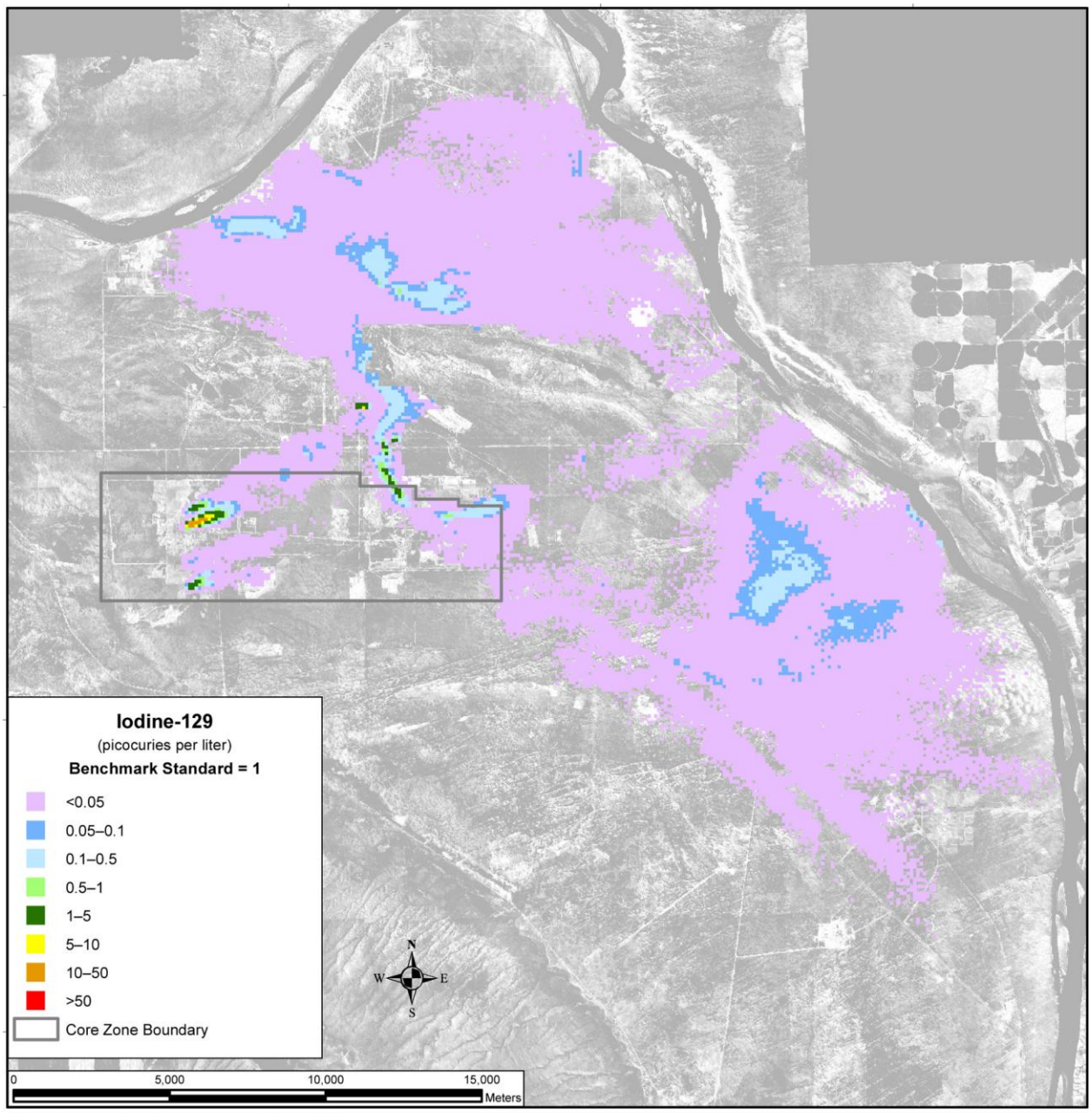


Note: To convert meters to feet, multiply by 3.281.

Figure 5–135. Tank Closure Alternative 4 Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration, Calendar Year 2135

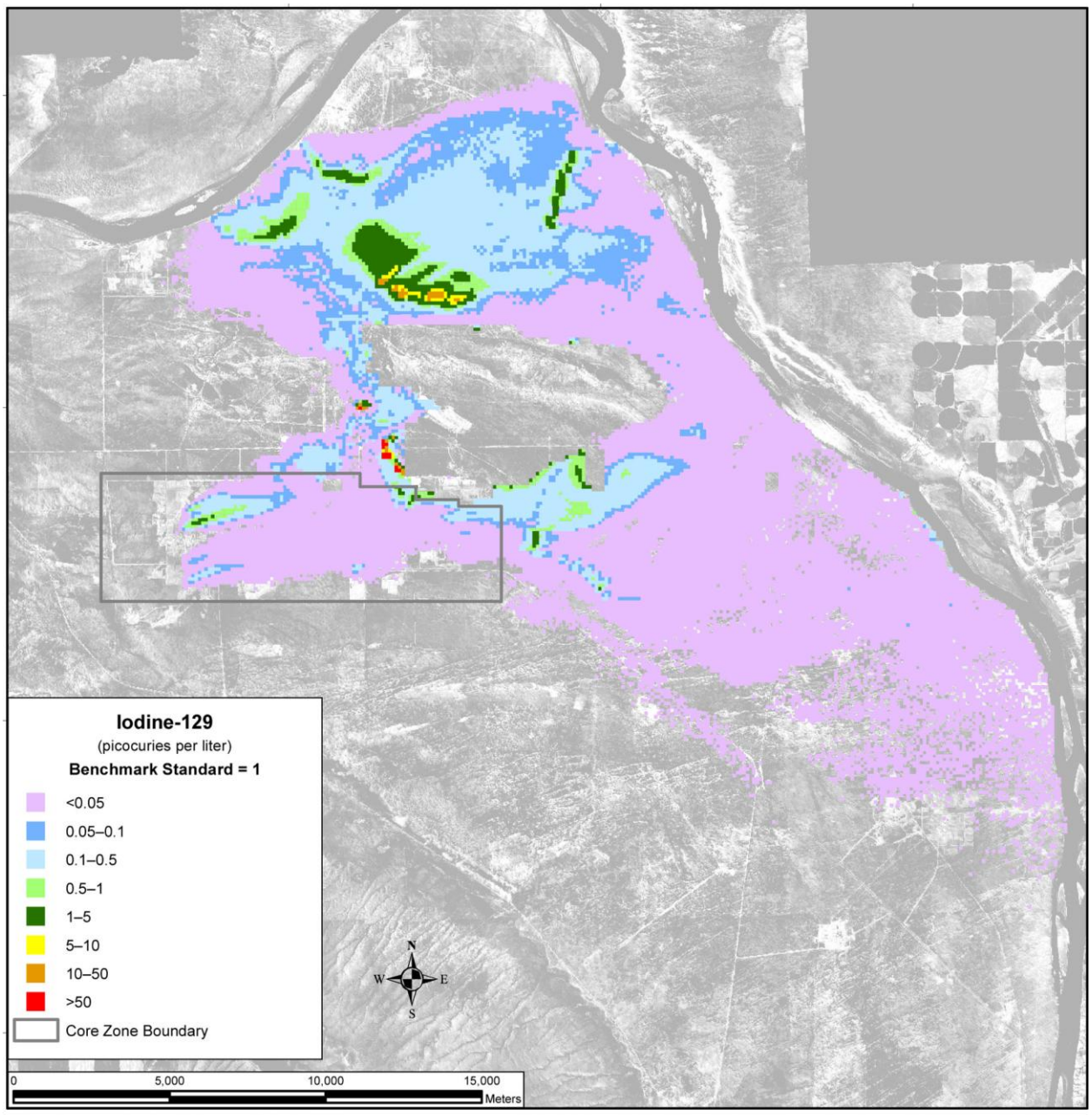
The spatial distribution of iodine-129 concentrations in groundwater in CY 2010 is shown in Figure 5–136. Releases from cribs and trenches (ditches) and past leaks result in groundwater concentration plumes that are at or exceed the benchmark concentration at the B, S, and T Barriers. Peak concentrations in these plumes are about 10 to 50 times greater than the benchmark. By CY 2135 (see Figure 5–137), areas in which groundwater iodine-129 concentrations exceed the benchmark exist mostly in the plume north of Gable Gap. Concentrations are as high as 10 to 50 times greater than the benchmark. By CY 7140, most of the mass in the plume, with concentrations less than one-twentieth of the benchmark, has reached the Columbia River (see Figure 5–138). Technetium-99 (see Figures 5–139 through 5–141), chromium (see Figures 5–142 through 5–144), and nitrate (see Figures 5–145 through

5–147) 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).



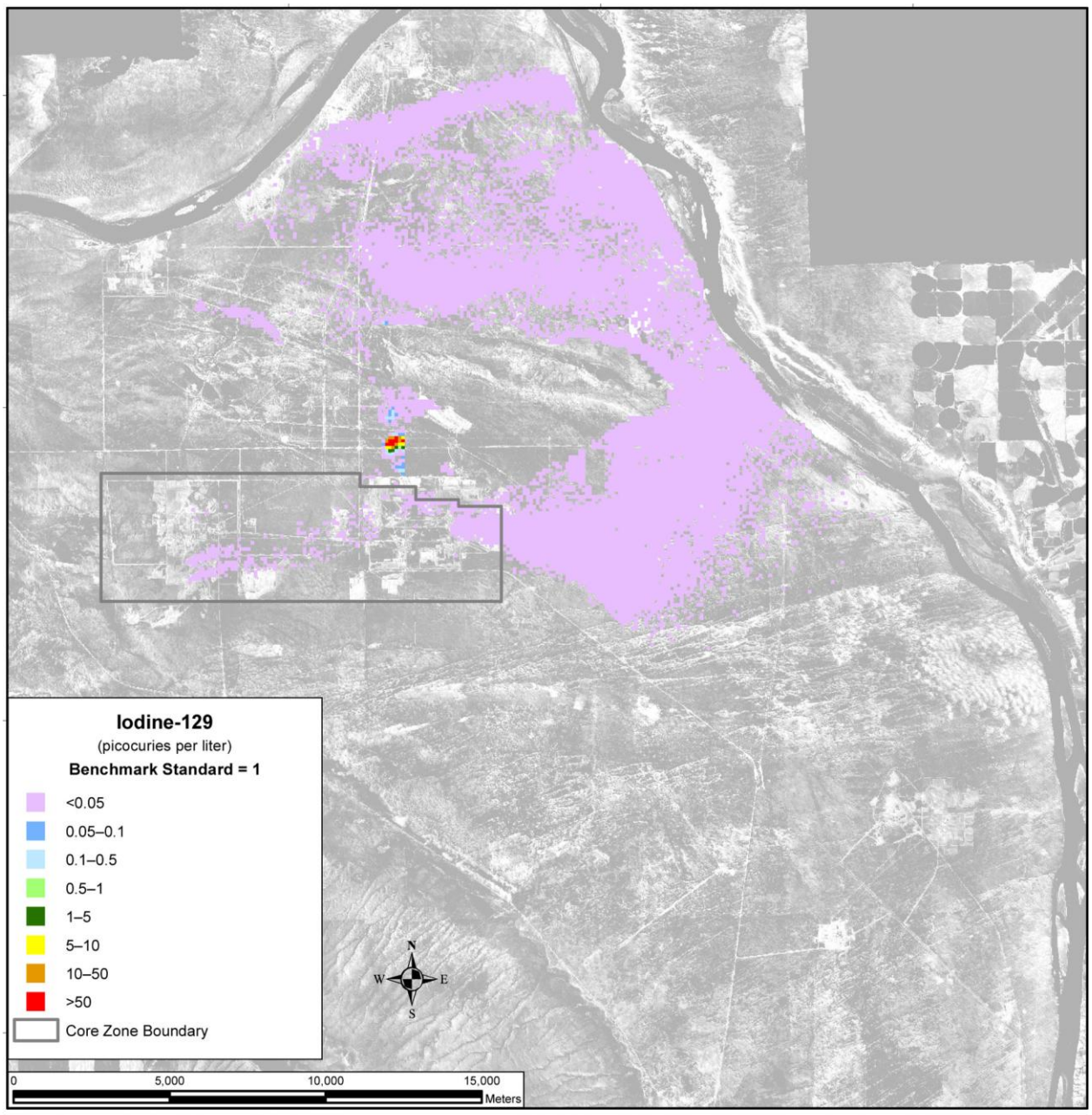
Note: To convert meters to feet, multiply by 3.281.

Figure 5–136. Tank Closure Alternative 4 Spatial Distribution of Groundwater Iodine-129 Concentration, Calendar Year 2010



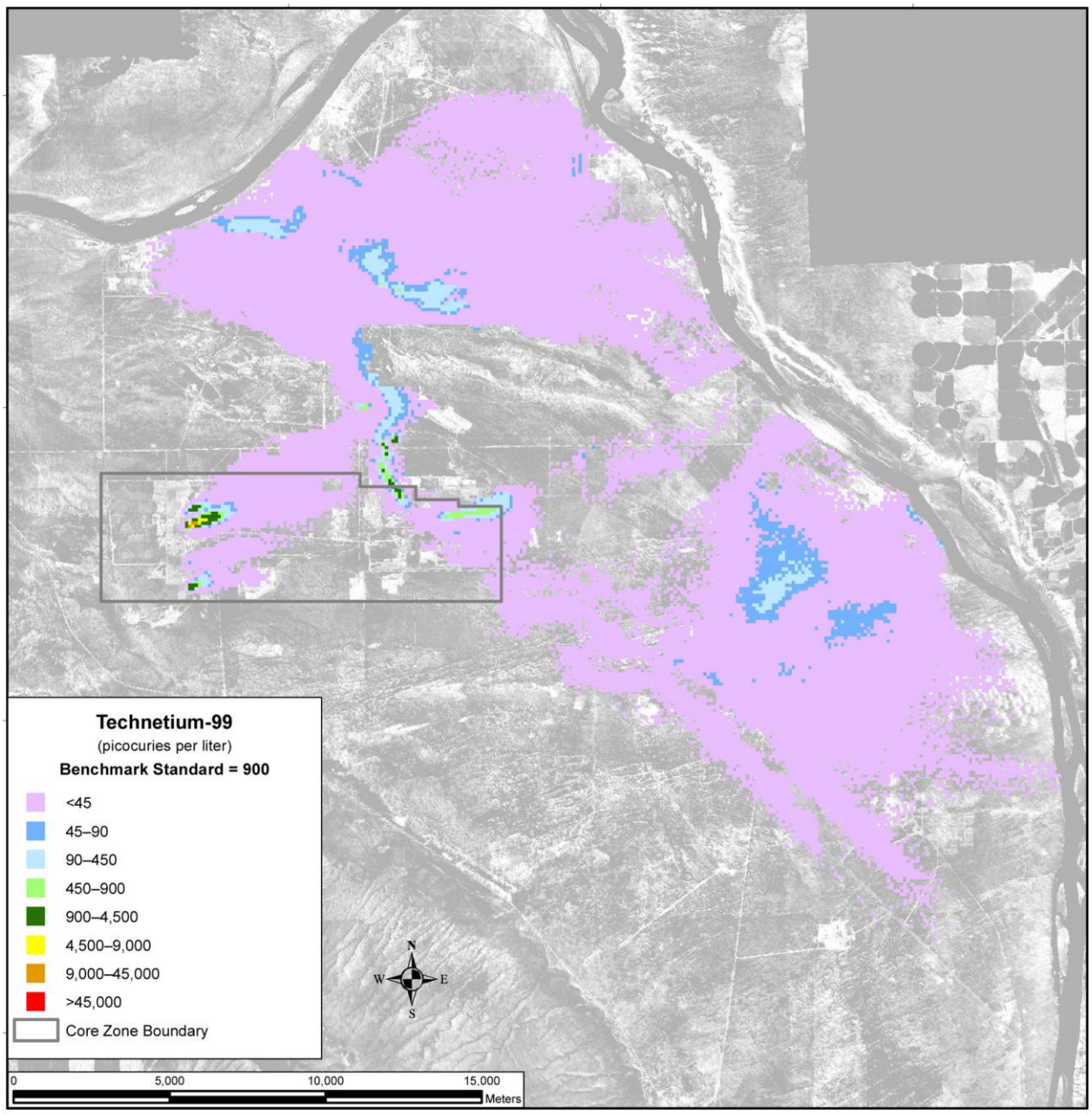
Note: To convert meters to feet, multiply by 3.281.

Figure 5–137. Tank Closure Alternative 4 Spatial Distribution of Groundwater Iodine-129 Concentration, Calendar Year 2135



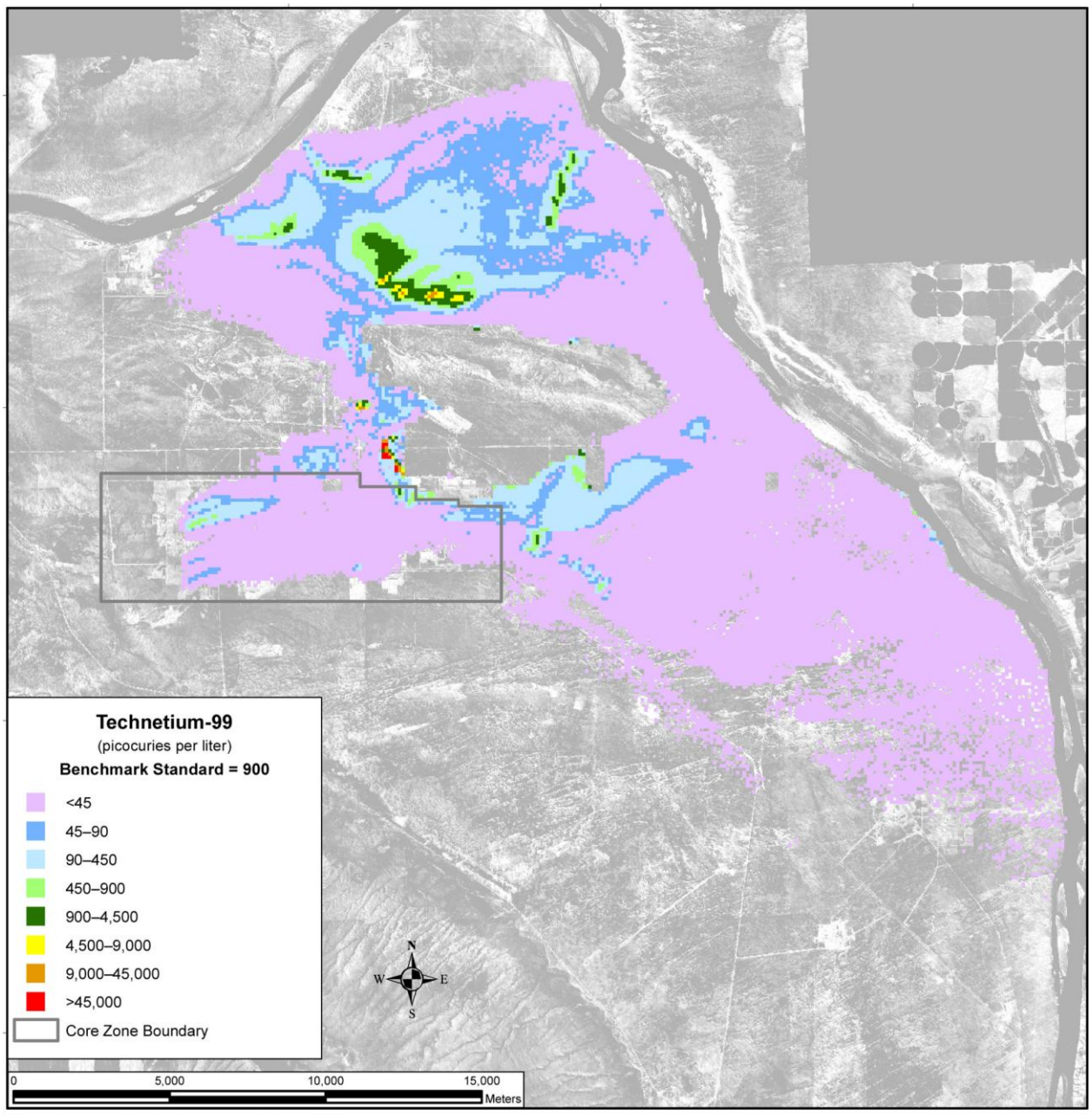
Note: To convert meters to feet, multiply by 3.281.

Figure 5–138. Tank Closure Alternative 4 Spatial Distribution of Groundwater Iodine-129 Concentration, Calendar Year 7140



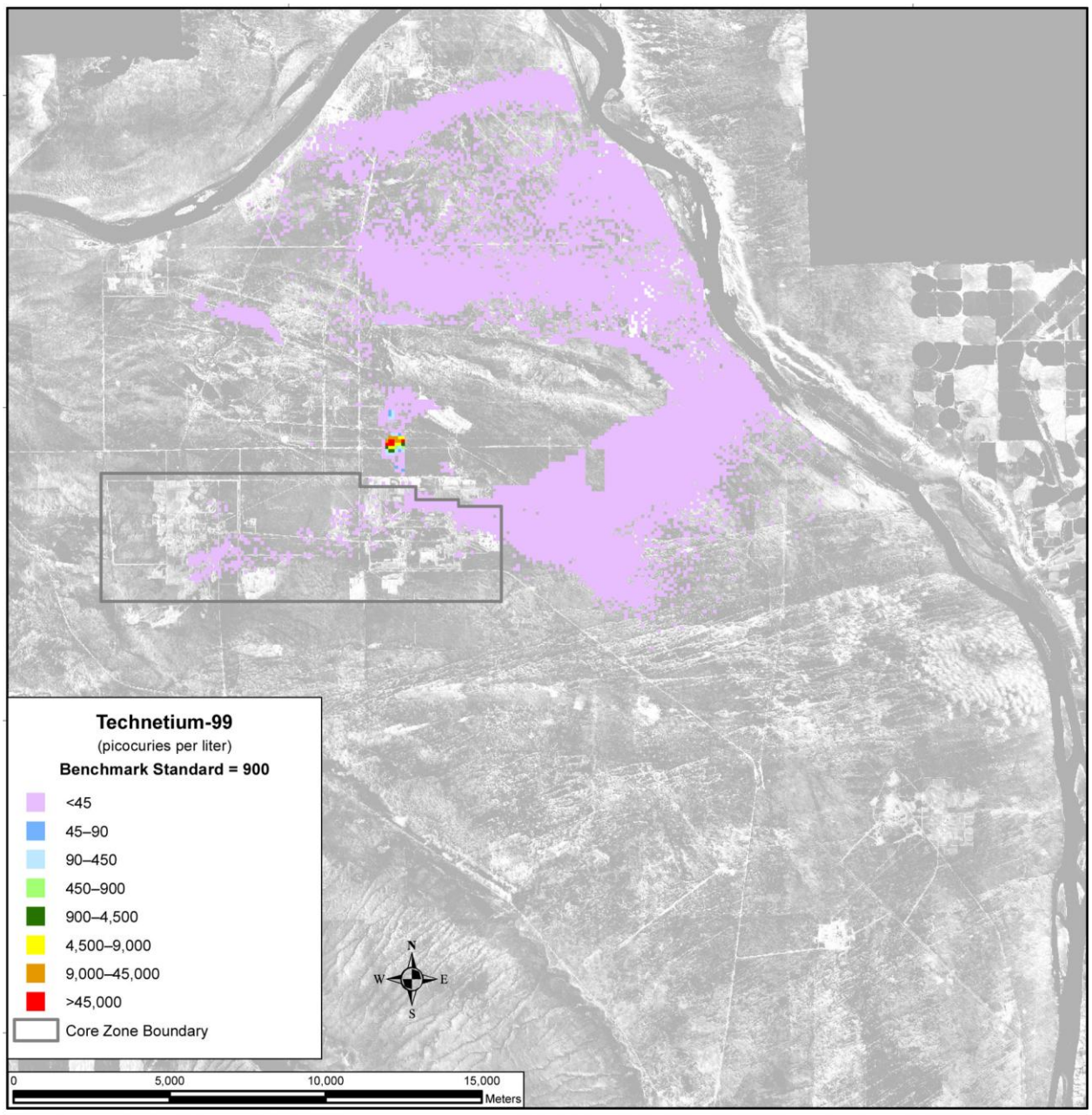
Note: To convert meters to feet, multiply by 3.281.

Figure 5–139. Tank Closure Alternative 4 Spatial Distribution of Groundwater Technetium-99 Concentration, Calendar Year 2010



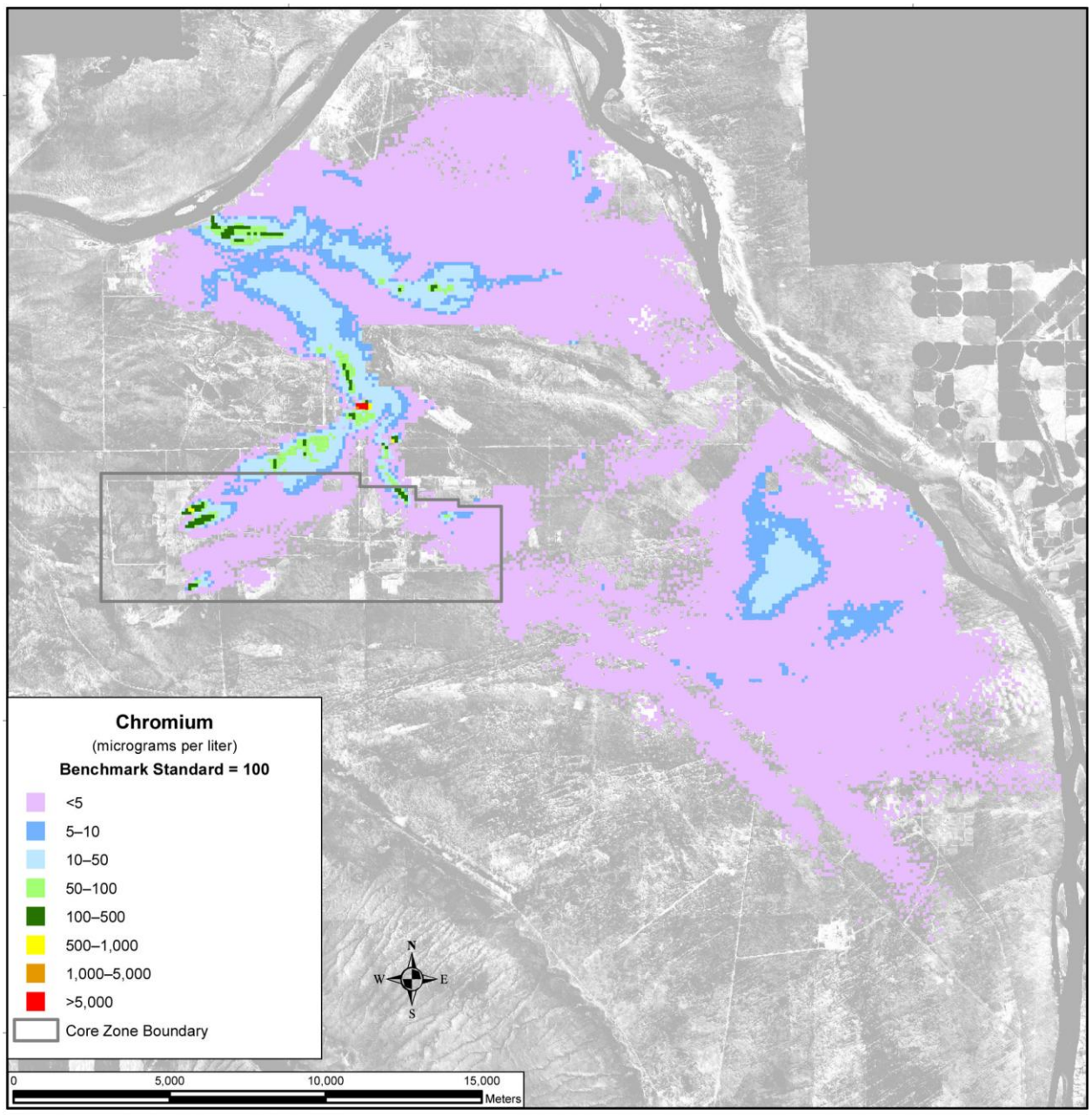
Note: To convert meters to feet, multiply by 3.281.

Figure 5–140. Tank Closure Alternative 4 Spatial Distribution of Groundwater Technetium-99 Concentration, Calendar Year 2135



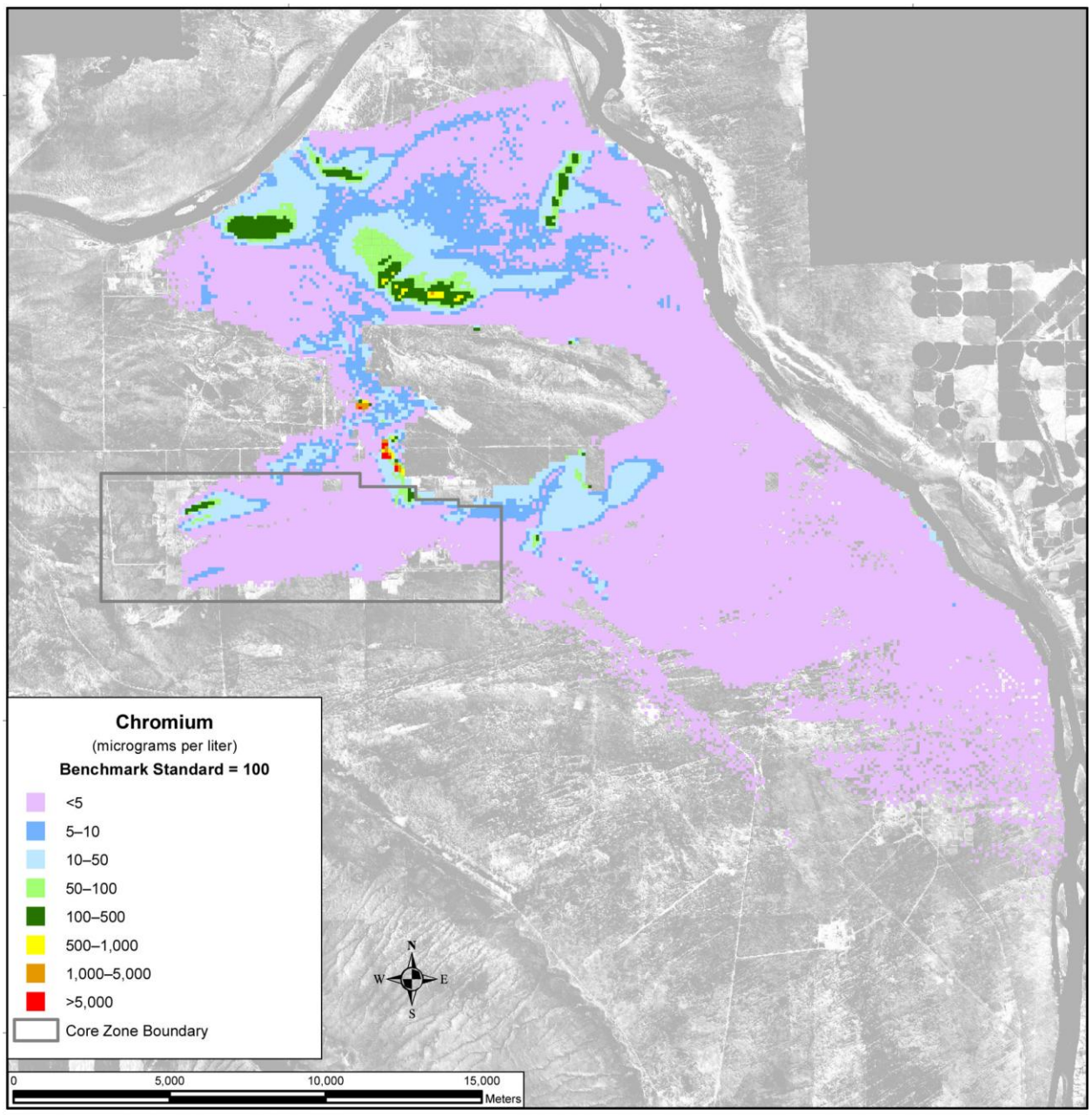
Note: To convert meters to feet, multiply by 3.281.

Figure 5–141. Tank Closure Alternative 4 Spatial Distribution of Groundwater Technetium-99 Concentration, Calendar Year 7140



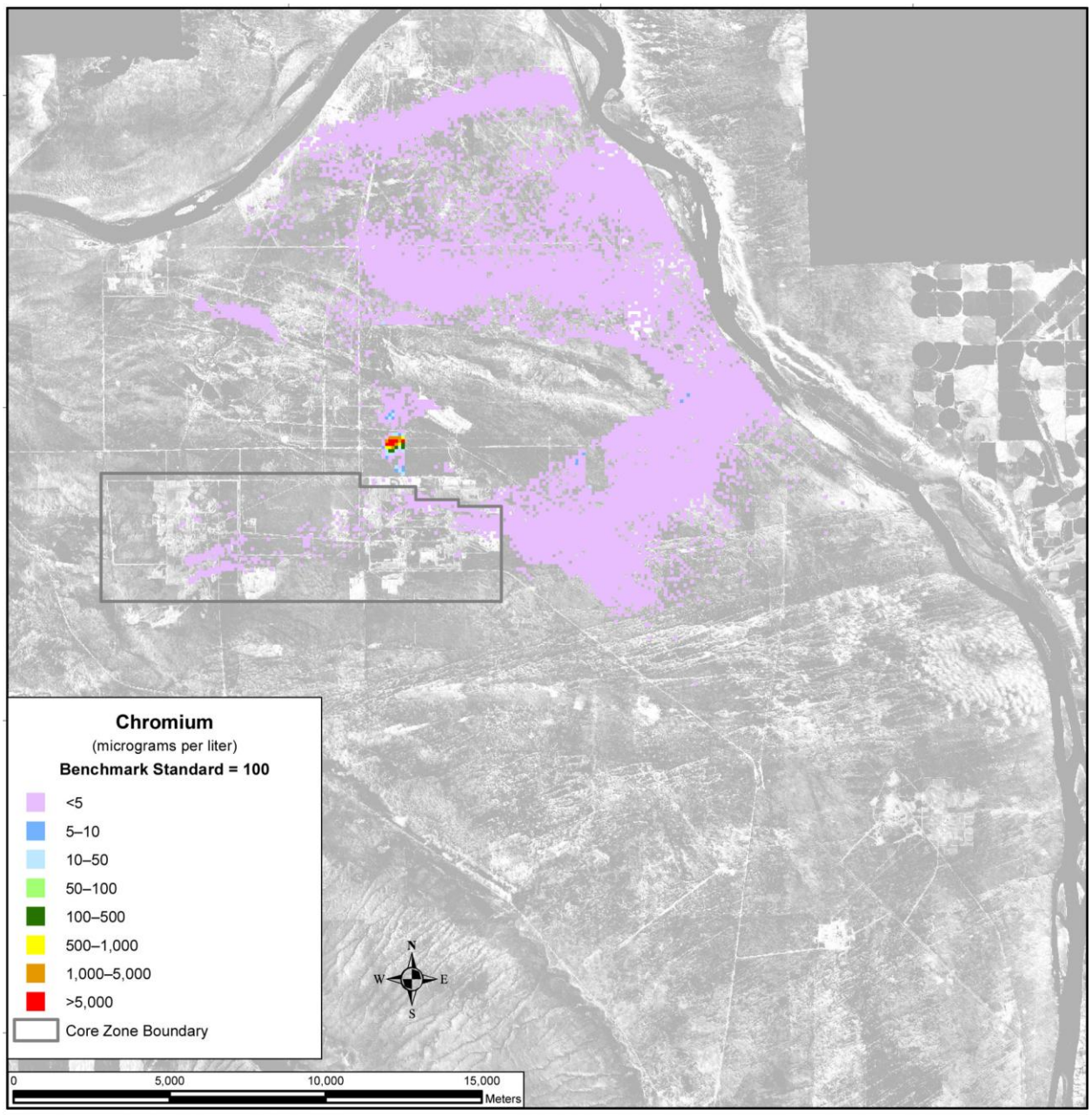
Note: To convert meters to feet, multiply by 3.281.

Figure 5–142. Tank Closure Alternative 4 Spatial Distribution of Groundwater Chromium Concentration, Calendar Year 2010



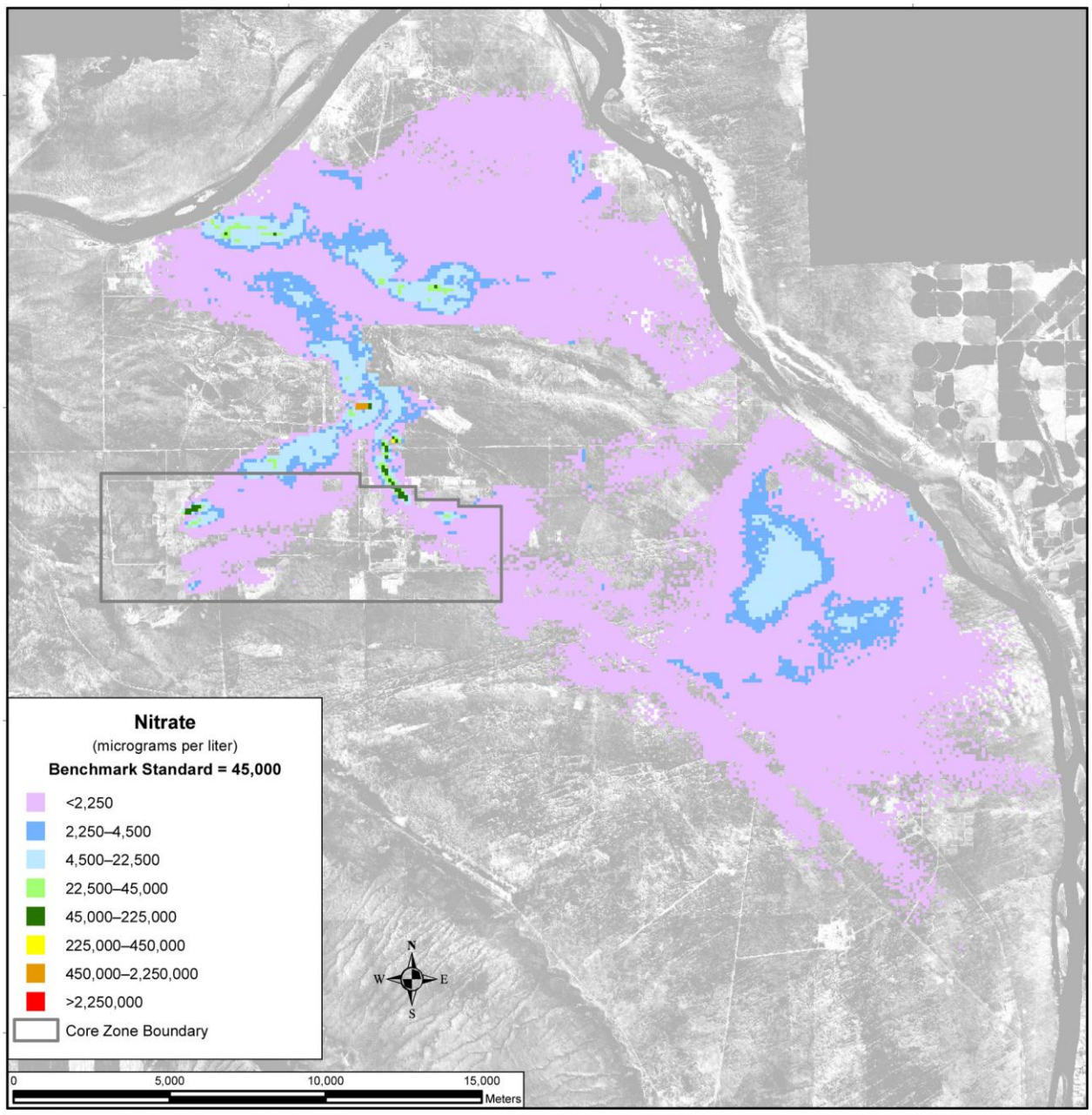
Note: To convert meters to feet, multiply by 3.281.

Figure 5–143. Tank Closure Alternative 4 Spatial Distribution of Groundwater Chromium Concentration, Calendar Year 2135



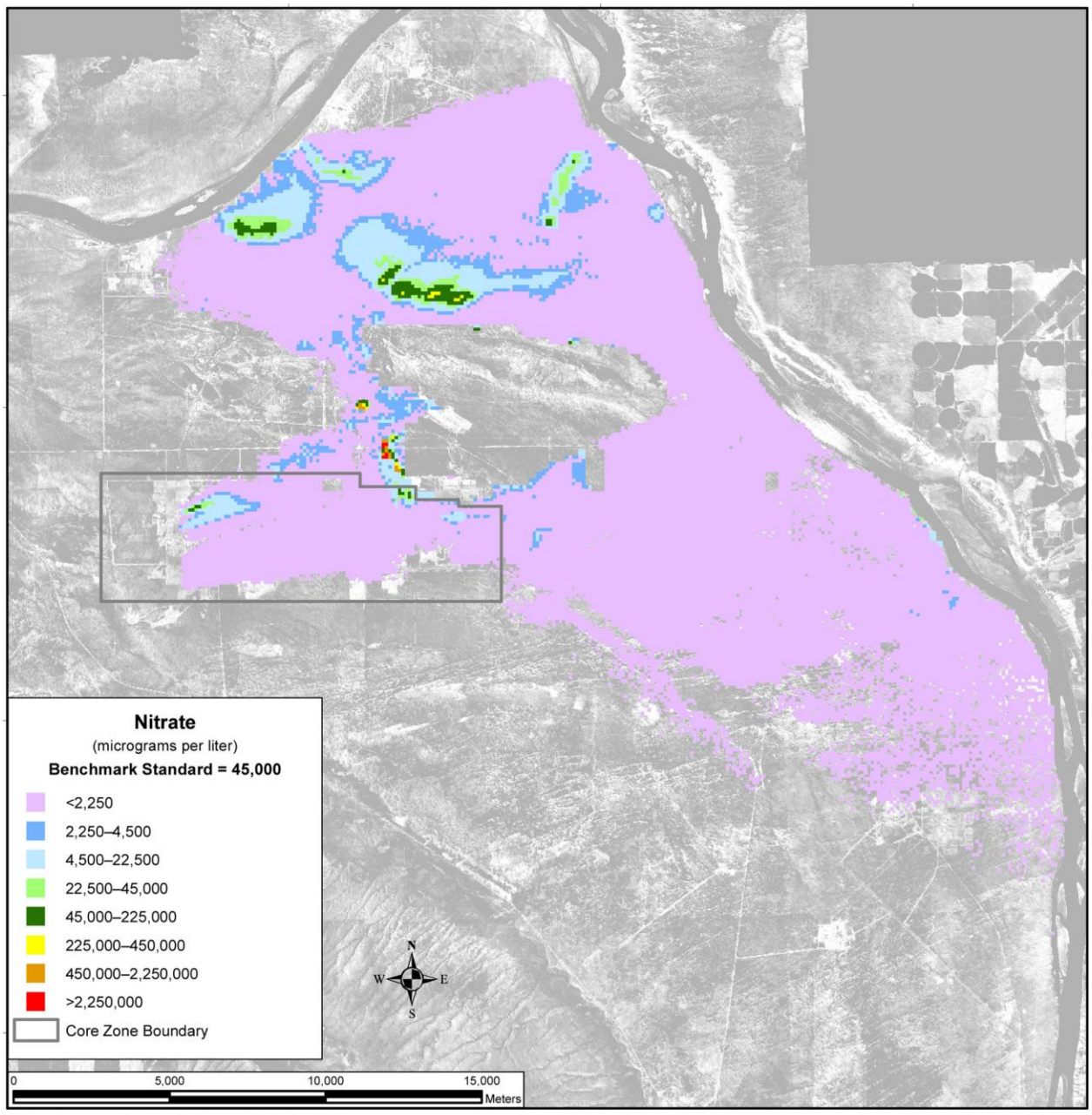
Note: To convert meters to feet, multiply by 3.281.

Figure 5–144. Tank Closure Alternative 4 Spatial Distribution of Groundwater Chromium Concentration, Calendar Year 7140



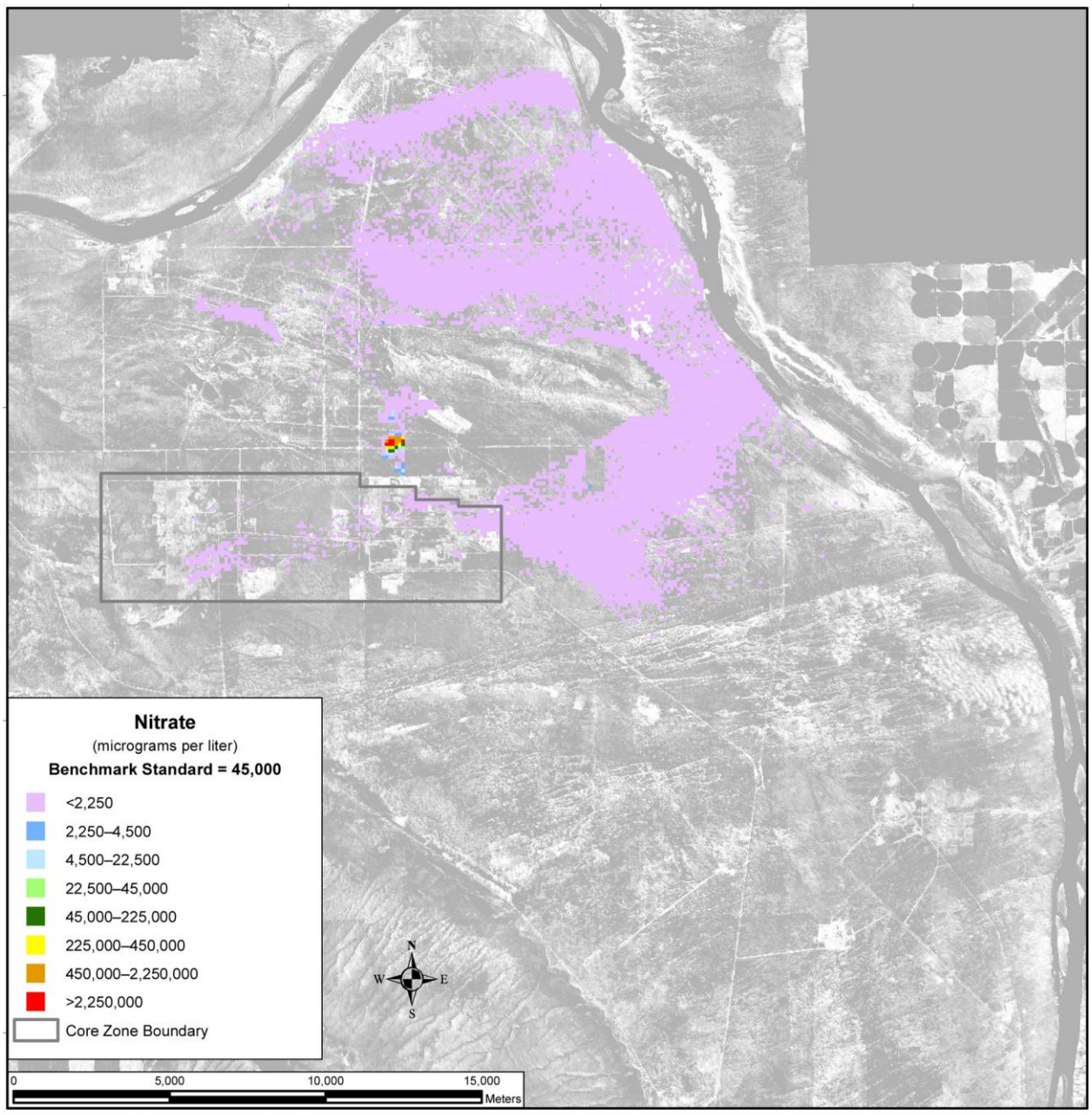
Note: To convert meters to feet, multiply by 3.281.

Figure 5–145. Tank Closure Alternative 4 Spatial Distribution of Groundwater Nitrate Concentration, Calendar Year 2010



Note: To convert meters to feet, multiply by 3.281.

Figure 5–146. Tank Closure Alternative 4 Spatial Distribution of Groundwater Nitrate Concentration, Calendar Year 2135

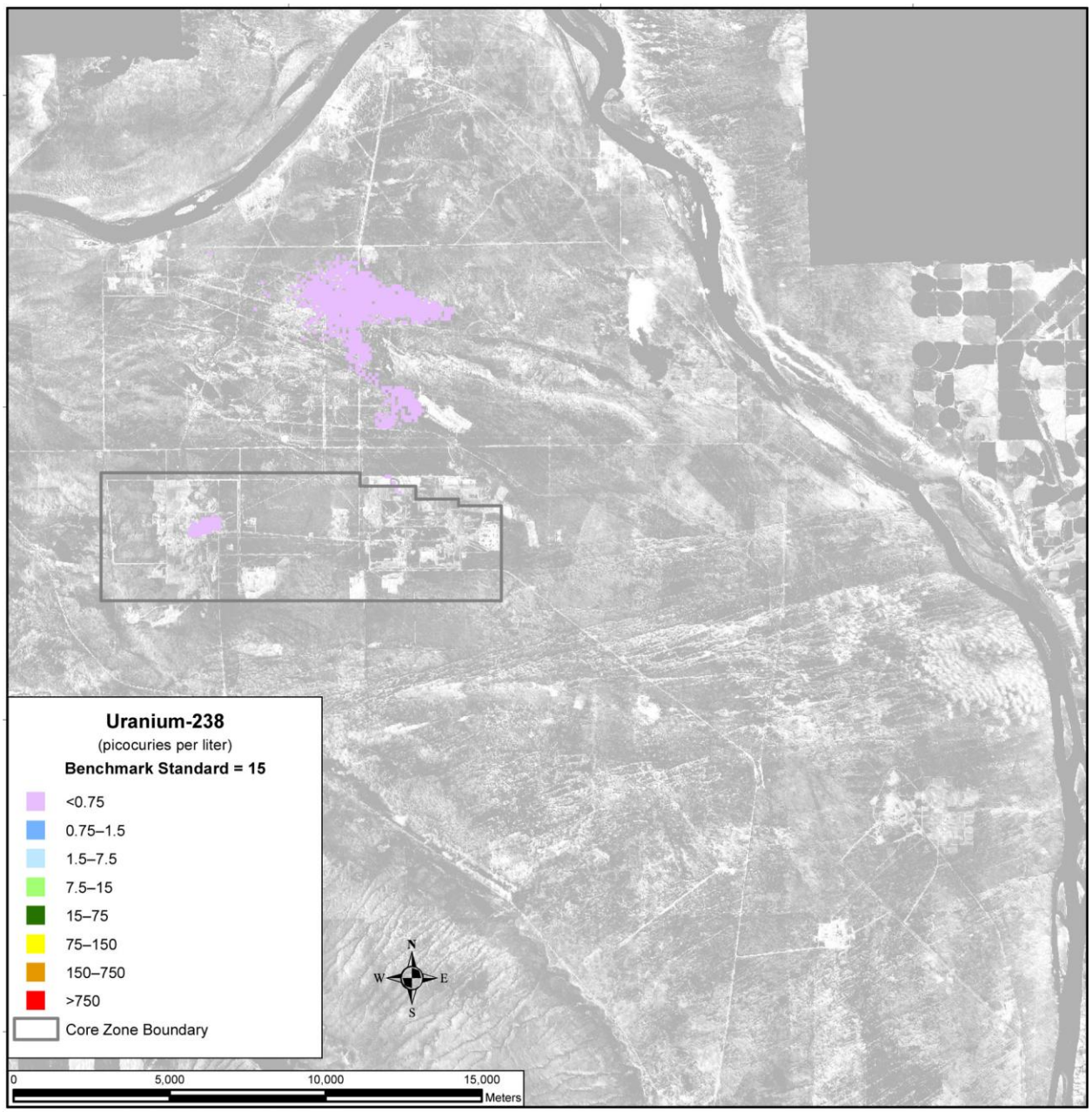


Note: To convert meters to feet, multiply by 3.281.

Figure 5–147. Tank Closure Alternative 4 Spatial Distribution of Groundwater Nitrate Concentration, Calendar Year 7140

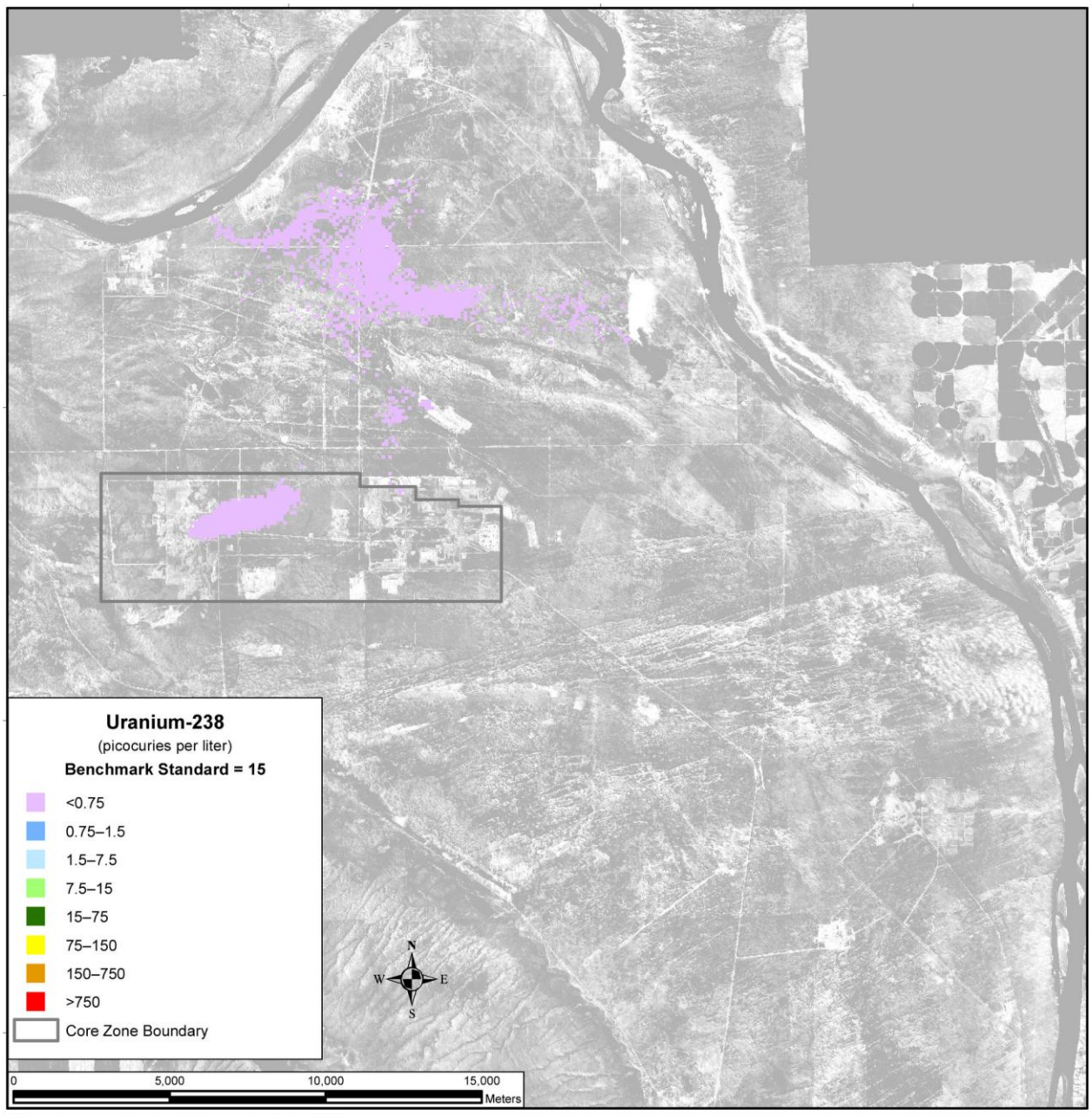
Uranium-238 and total uranium show a different spatial distribution in the analysis over time. These COPCs are not as mobile as those discussed above, moving about seven times more slowly than the pore-water velocity. As a result, travel times through the vadose zone are longer, release to the aquifer is delayed, and travel times through the aquifer to the Columbia River are longer. The distribution of uranium-238 in CY 2010 is shown in Figure 5–148. There is a small plume associated with releases from cribs and trenches (ditches) and past leaks at the T Barrier that is less than one-twentieth of the benchmark concentration. This plume extends northeast through Gable Gap. By CY 2135 (see Figure 5–149), the area of the plume has grown, but there are no significant increases in peak concentration. By CY 7140 (see Figure 5–150), the size of the plume has increased and 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. In CY 11,940 (see Figure 5–151), the greatest development of the plume during the analysis period is seen, resulting primarily from releases during the past-practice period. Figures 5–152 through 5–155 show the corresponding results for total uranium, which has a similar distribution.



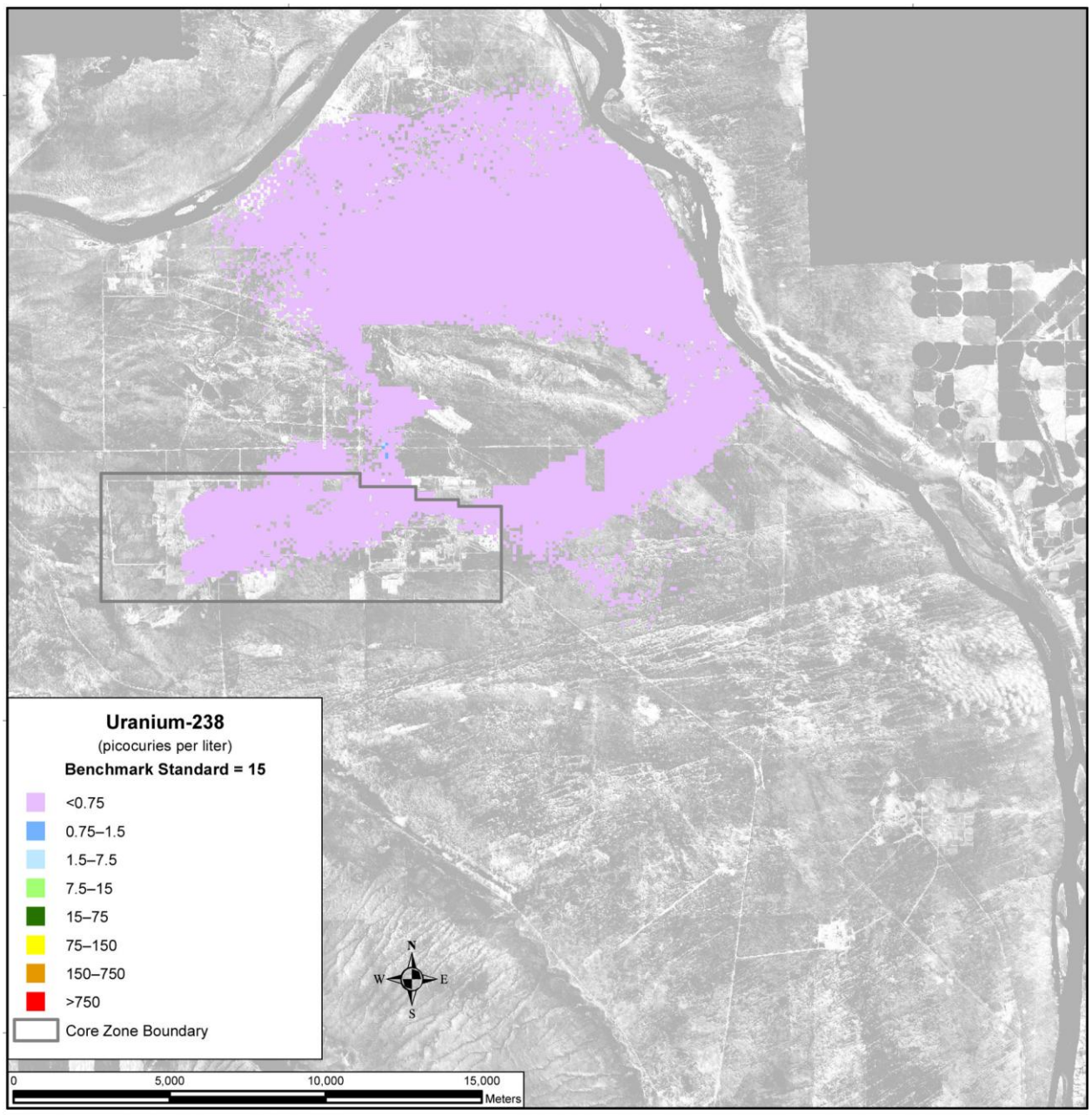
Note: To convert meters to feet, multiply by 3.281.

Figure 5–148. Tank Closure Alternative 4 Spatial Distribution of Groundwater Uranium-238 Concentration, Calendar Year 2010



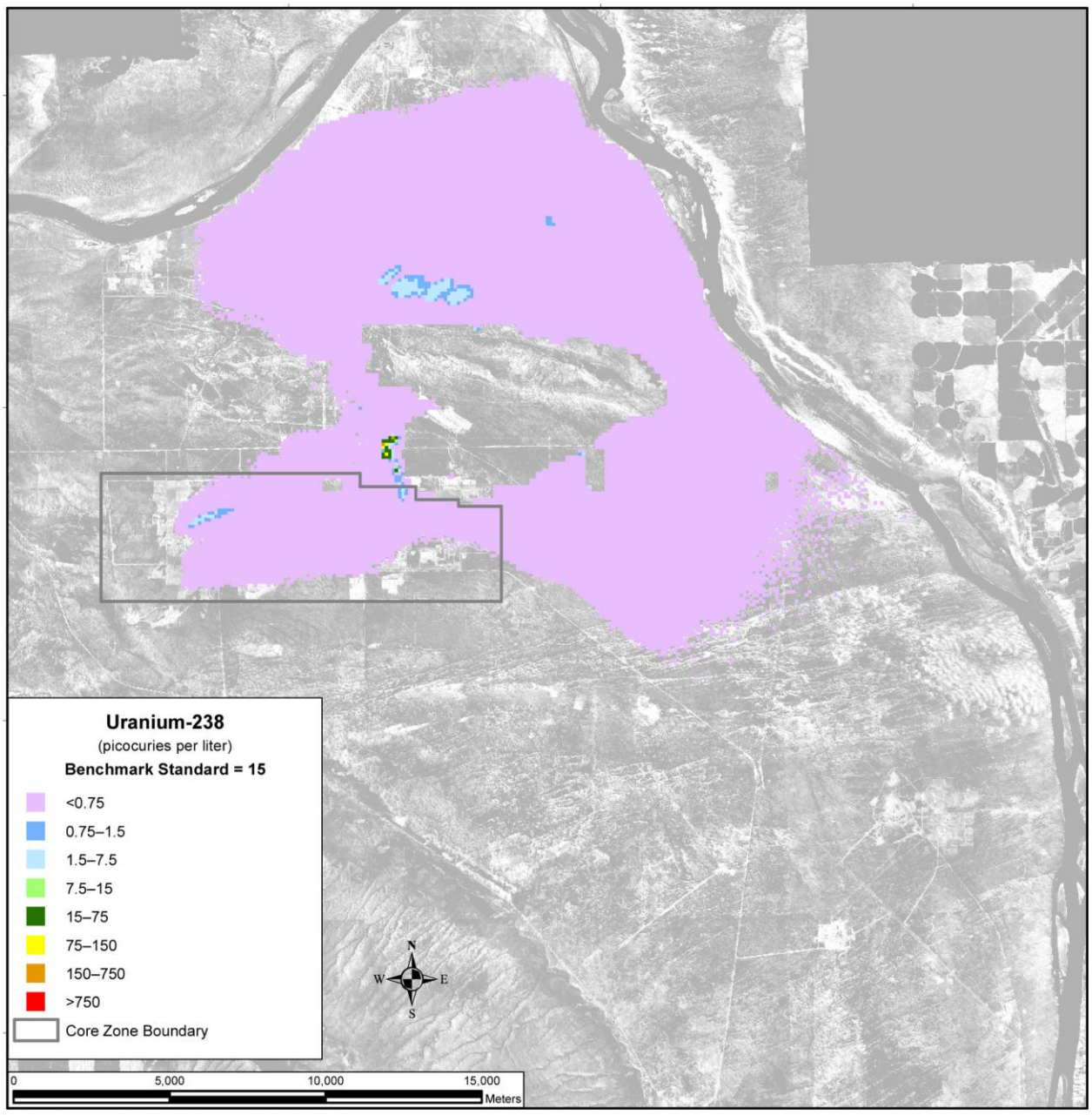
Note: To convert meters to feet, multiply by 3.281.

Figure 5–149. Tank Closure Alternative 4 Spatial Distribution of Groundwater Uranium-238 Concentration, Calendar Year 2135



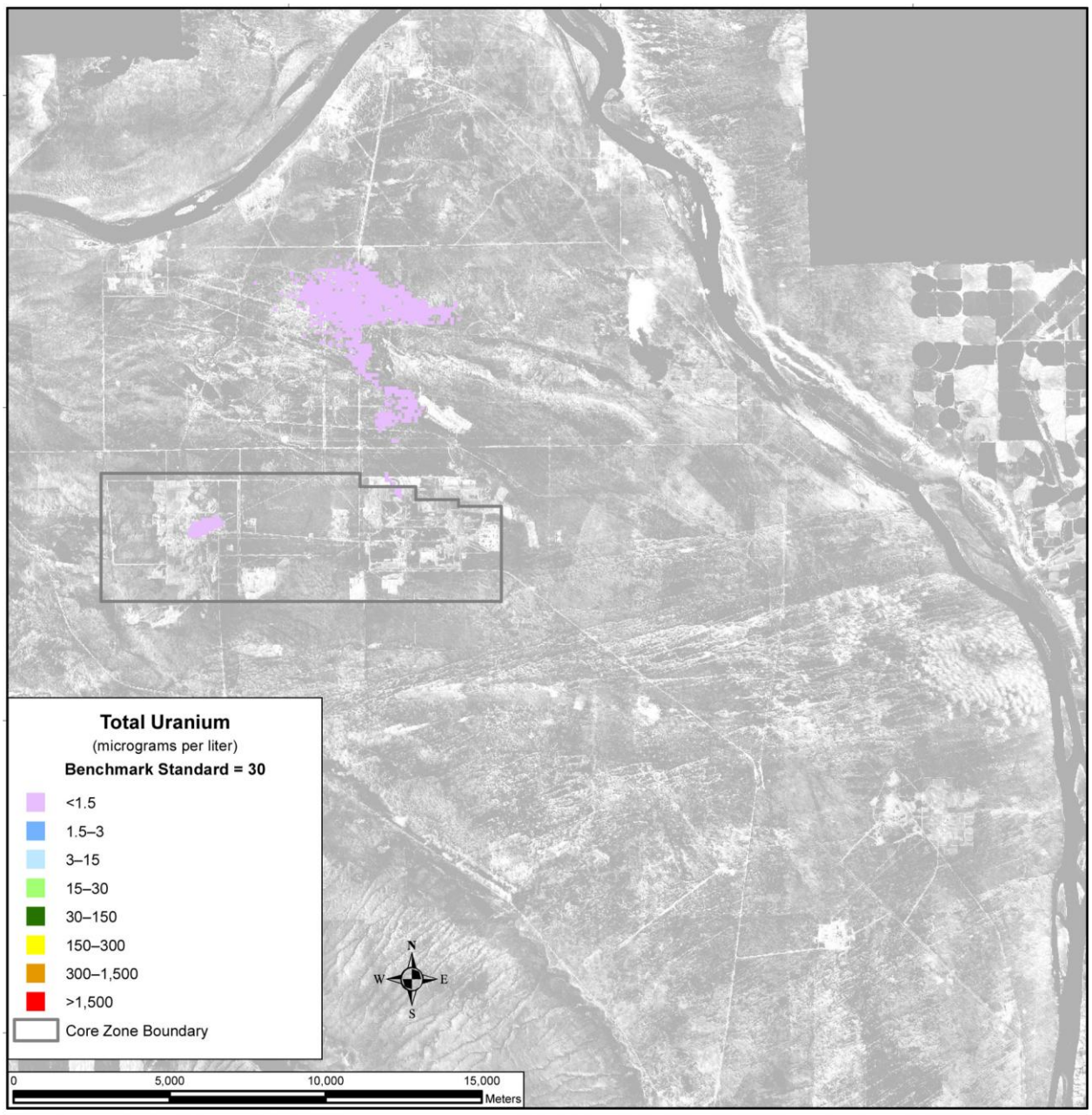
Note: To convert meters to feet, multiply by 3.281.

Figure 5–150. Tank Closure Alternative 4 Spatial Distribution of Groundwater Uranium-238 Concentration, Calendar Year 7140



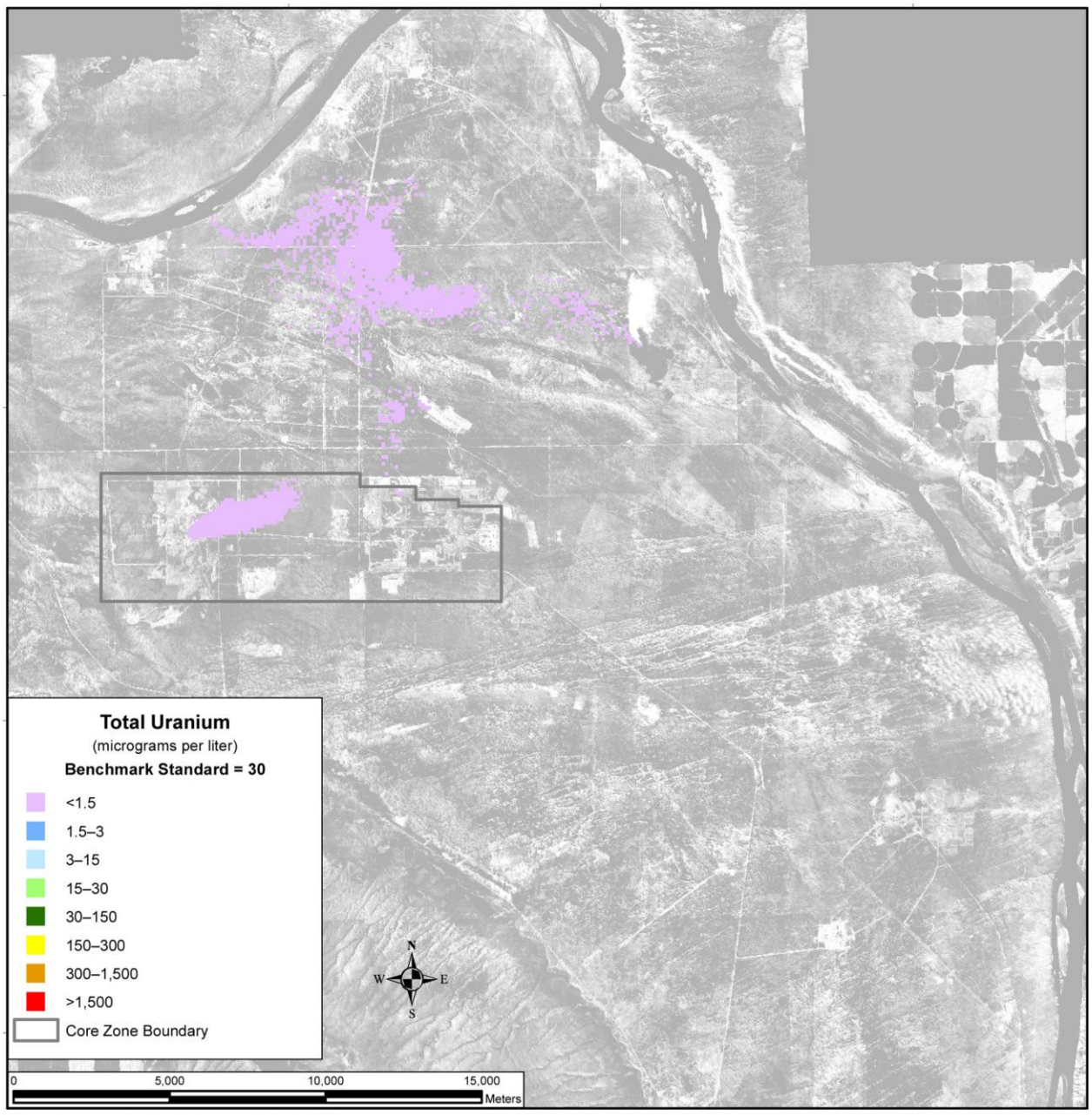
Note: To convert meters to feet, multiply by 3.281.

Figure 5–151. Tank Closure Alternative 4 Spatial Distribution of Groundwater Uranium-238 Concentration, Calendar Year 11,940



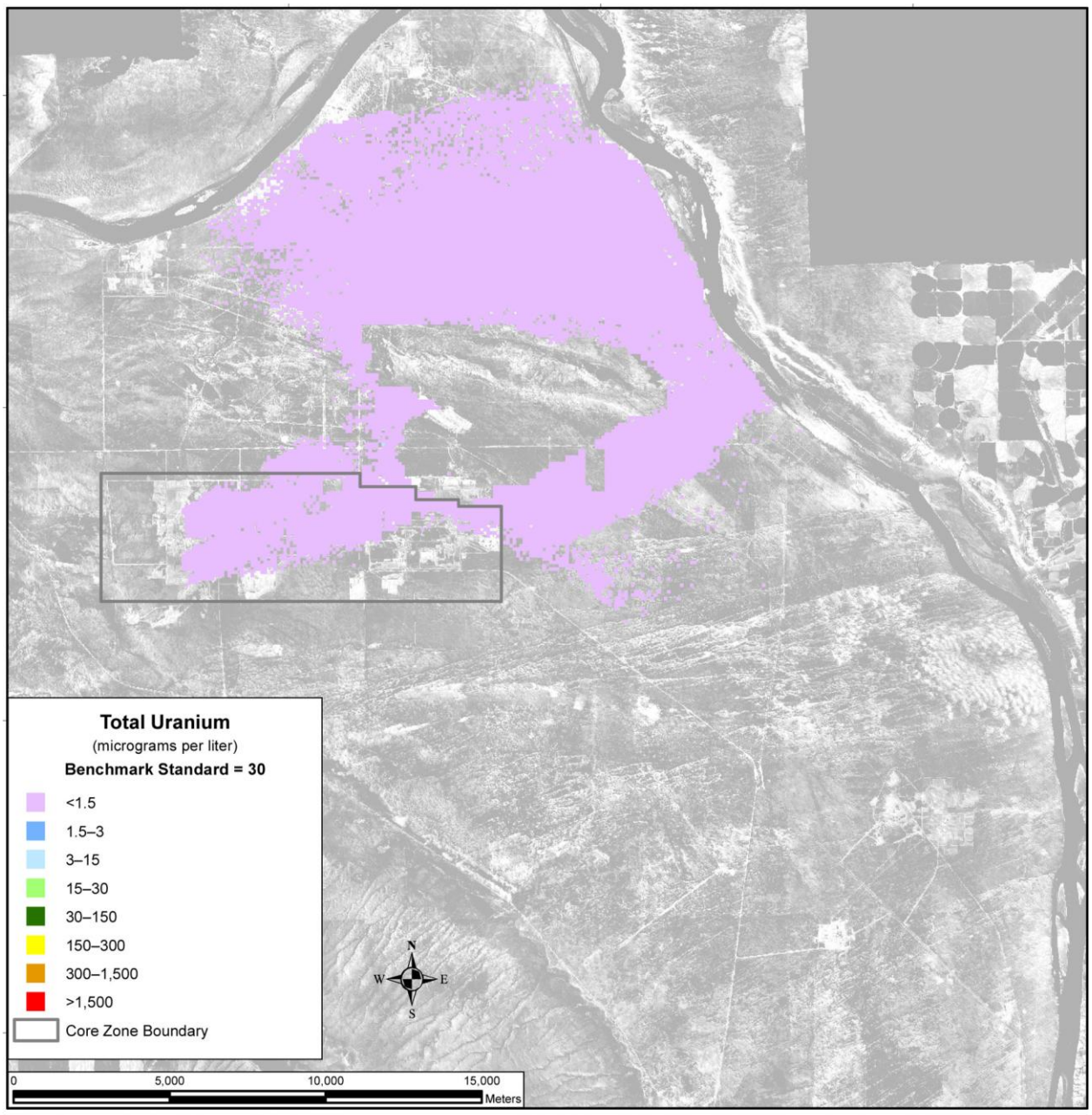
Note: To convert meters to feet, multiply by 3.281.

Figure 5–152. Tank Closure Alternative 4 Spatial Distribution of Groundwater Total Uranium Concentration, Calendar Year 2010



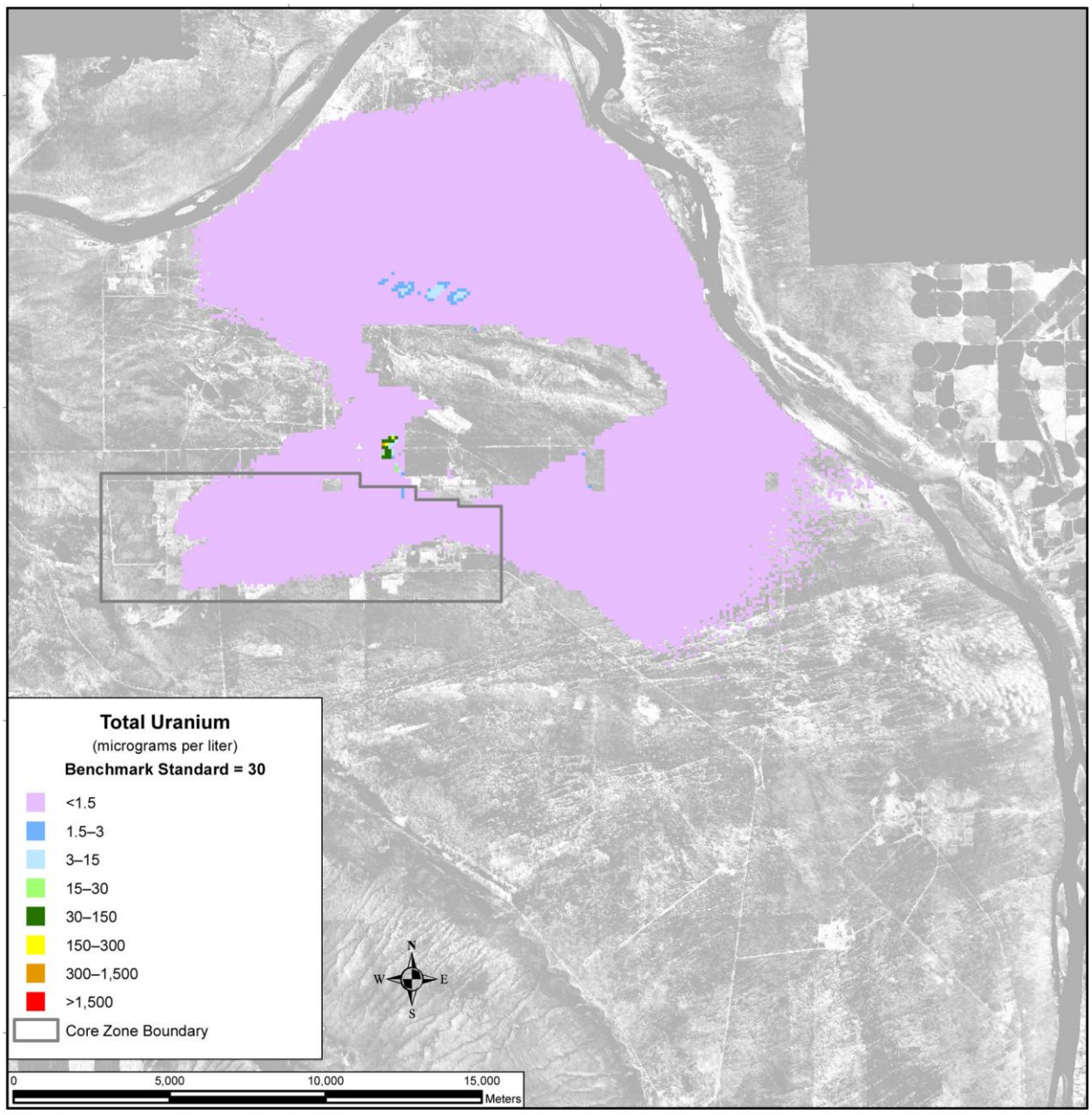
Note: To convert meters to feet, multiply by 3.281.

Figure 5–153. Tank Closure Alternative 4 Spatial Distribution of Groundwater Total Uranium Concentration, Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281.

Figure 5–154. Tank Closure Alternative 4 Spatial Distribution of Groundwater Total Uranium Concentration, Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281.

Figure 5–155. Tank Closure Alternative 4 Spatial Distribution of Groundwater Total Uranium Concentration, Calendar Year 11,940

Figures 5–156 through 5–158 show the area in which groundwater concentrations of iodine-129, technetium-99, and uranium-238 exceed their respective benchmark concentrations. Iodine-129 peaks early in the simulation, covering a peak area of 7 square kilometers (2.7 square miles) around CY 2100. This area drops below 0.76 square kilometers (0.3 square miles) around CY 3890, continuing its decline to 0.25 square kilometers (0.1 square miles) by CY 9740 and remaining near that level for the remainder of the simulation. Technetium-99 shows a similar trend, peaking at about 4.2 square kilometers (1.6 square miles) in CY 2070 and reaching 0.23 square kilometers (0.01 square miles) in CY 7790. Uranium-238 shows a distinctly different pattern, without any area above the benchmark concentration until CY 8340. From CY 8340 until the end of the simulation, areas in which uranium-238

concentrations exceed the benchmark concentration slowly increase, never surpassing 0.21 square kilometers (0.1 square miles).

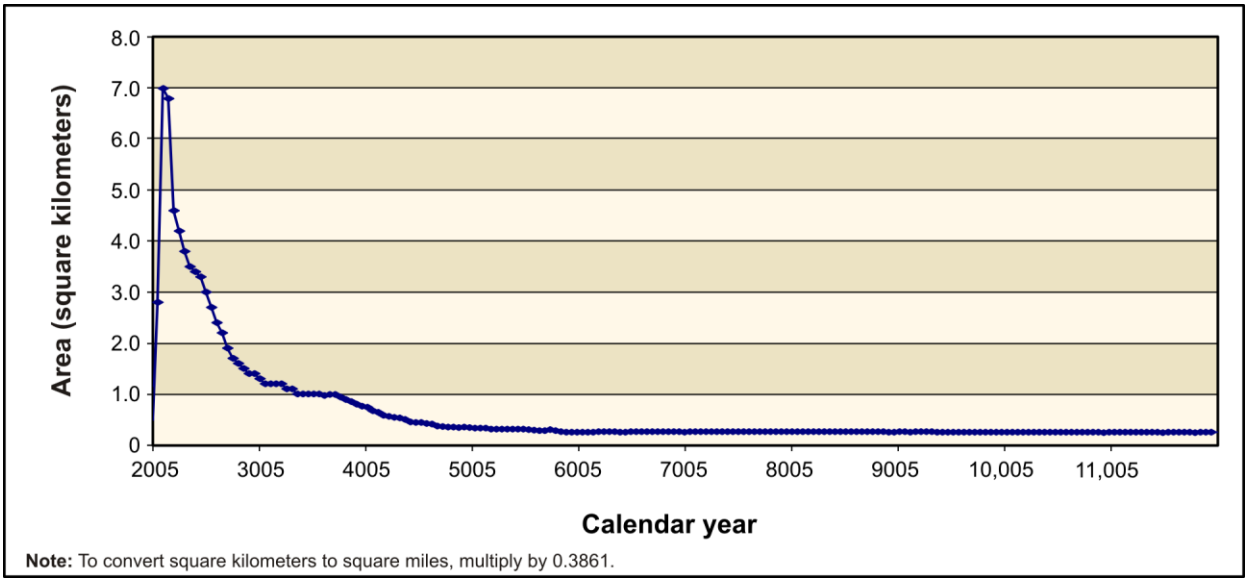


Figure 5–156. Tank Closure Alternative 4 Total Area of Groundwater Iodine-129 Concentration Exceeding the Benchmark Concentration as a Function of Time

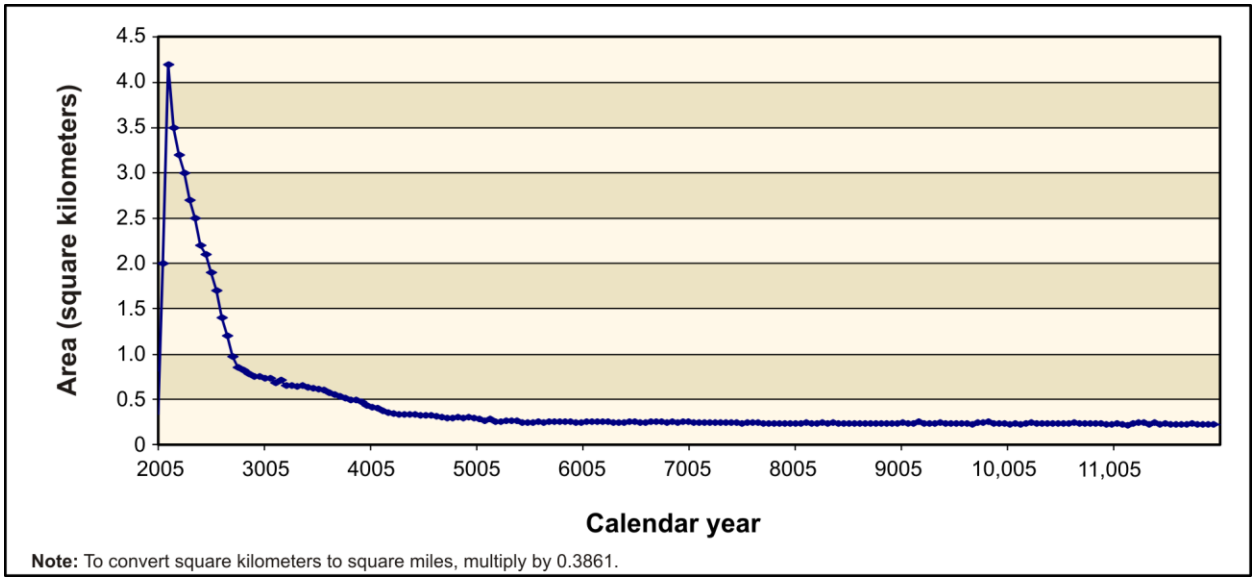


Figure 5–157. Tank Closure Alternative 4 Total Area of Groundwater Technetium-99 Concentration Exceeding the Benchmark Concentration as a Function of Time

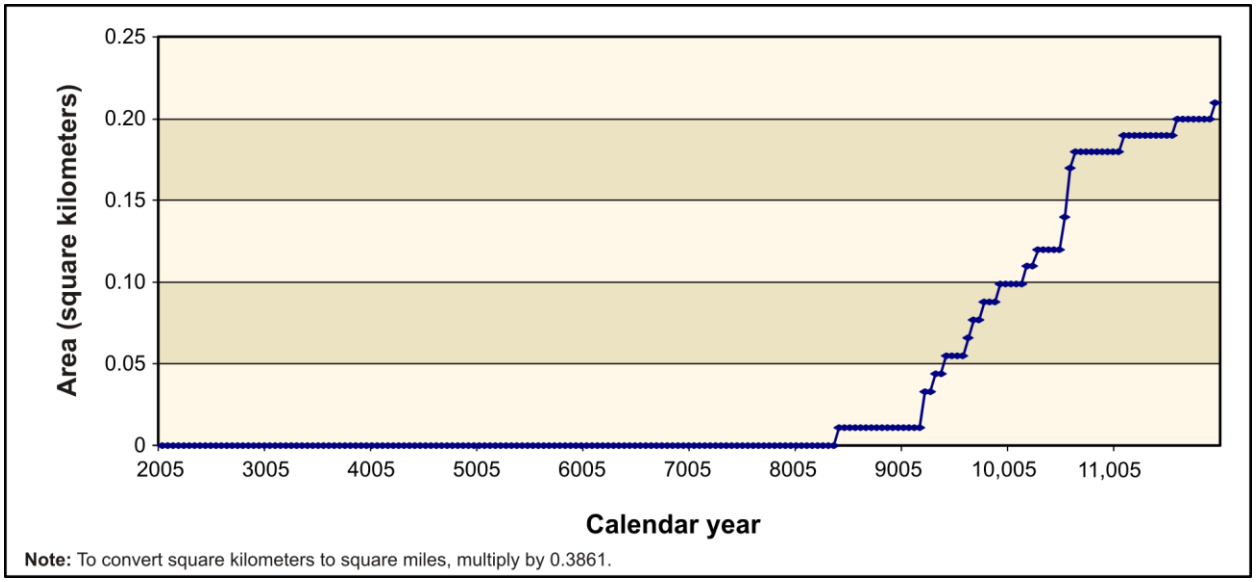


Figure 5–158. Tank Closure Alternative 4 Total Area of Groundwater Uranium-238 Concentration Exceeding the Benchmark Concentration as a Function of Time

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 during the post–administrative control period, are secondary contributors.

For the conservative tracers, concentrations at the Core Zone Boundary exceed benchmark standards by about one to two orders of magnitude during the early part of the period of analysis. Concentrations of conservative tracers at the Columbia River nearshore only exceed the benchmark for a short time during the past-practice period.

Concentrations of tritium at the Core Zone Boundary exceed the benchmark by about one to two orders of magnitude during the first 100 years of the period of analysis. Tritium concentrations at the Columbia River nearshore 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. Retention in the vadose zone during the operational period and subsequent removal of two tank farms (partial clean closure) reduce the impacts from past leaks and other tank farm sources. Concentrations of these retarded species never exceed the benchmark concentration at the Core Zone Boundary or at the Columbia River nearshore during the period of analysis. 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 impacts 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 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 5 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 2139. This period includes waste retrieval, WTP pretreatment and treatment, landfill closure of the SST farm system, and 100 years of postclosure care. 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. Retrieval leaks were assumed to occur over a period of 1 year (see Appendix M, Section M.5.1, for a discussion of the effect of variation of duration of leaks). The SST farm system would be landfill closed with the 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, but this discussion 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 contributions 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 the total amount of COPCs released to the vadose zone, groundwater, and the Columbia River during the 10,000-year period of analysis. Releases of radionuclides are totaled in curies; chemicals, in kilograms (see Figures 5–159 through 5–164). Three subtotals are plotted, representing releases from cribs and trenches (ditches), past leaks, and other tank farm sources (e.g., tank residuals, ancillary equipment). Note that the release amounts are plotted on a logarithmic scale to facilitate visual comparison of releases that vary over four orders of magnitude within the same series of figures.

Figure 5–159 shows the estimated release to the vadose zone of the radiological risk drivers and Figure 5–160, 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 is removed during the period of analysis by supplemental treatment technologies). The predominant sources of 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 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.

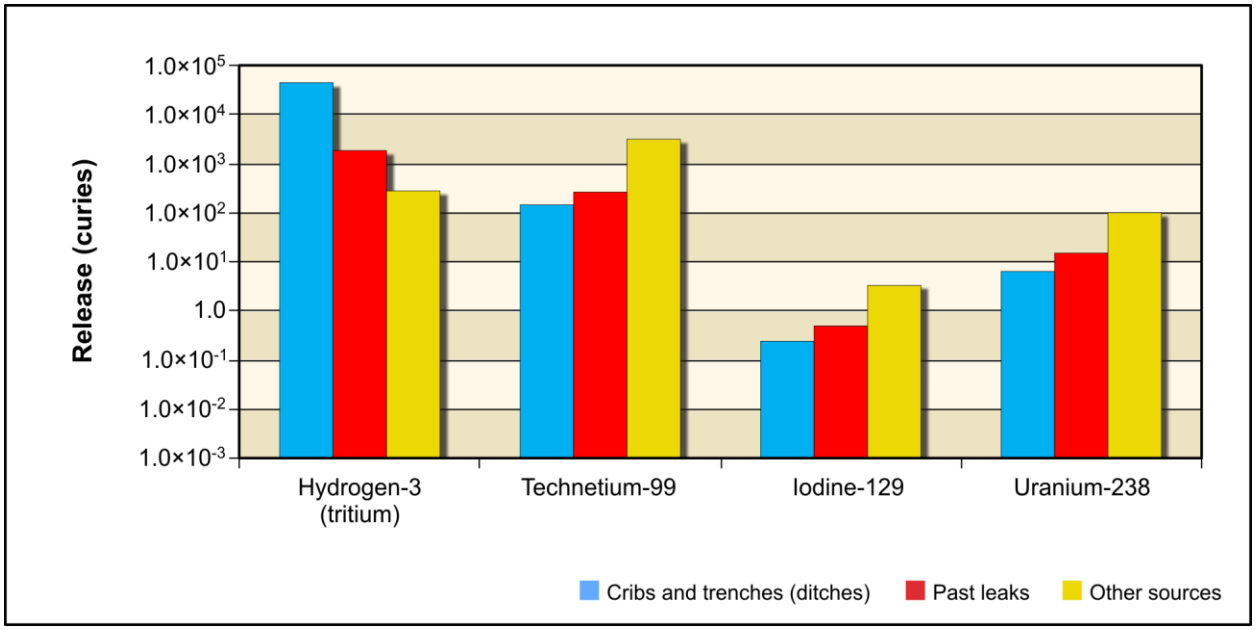


Figure 5–159. Tank Closure Alternative 5 Releases of Radioactive Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

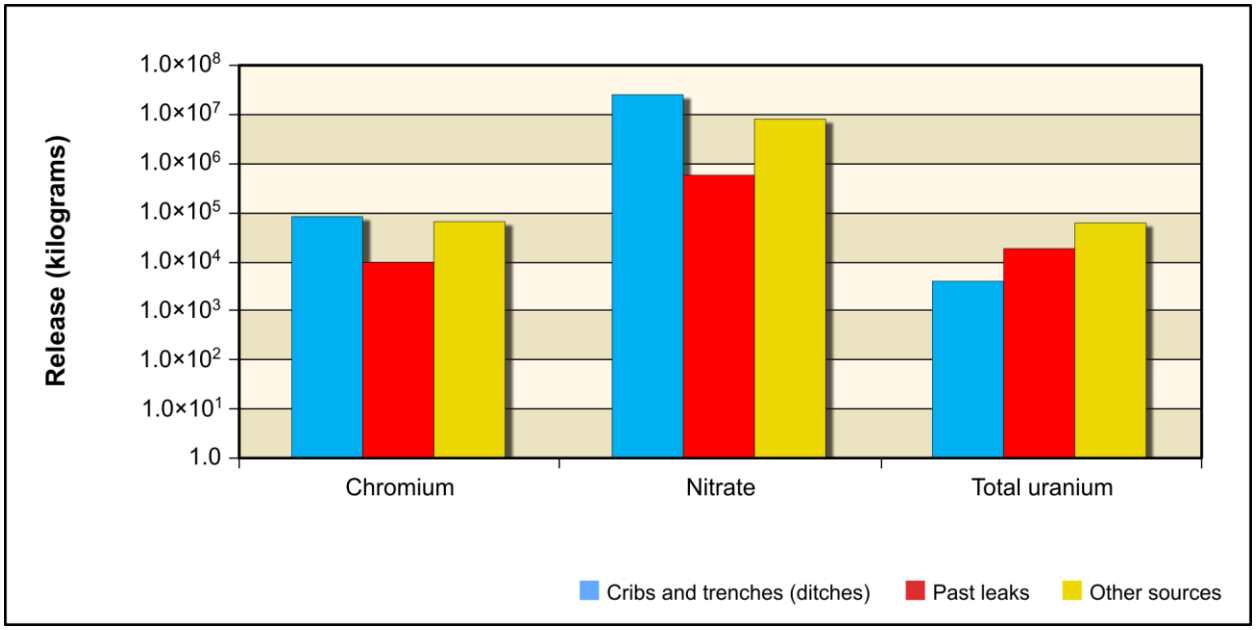


Figure 5–160. Tank Closure Alternative 5 Releases of Chemical Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

Figure 5–161 shows the estimated release to groundwater of the radiological risk drivers and Figure 5–162, 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.

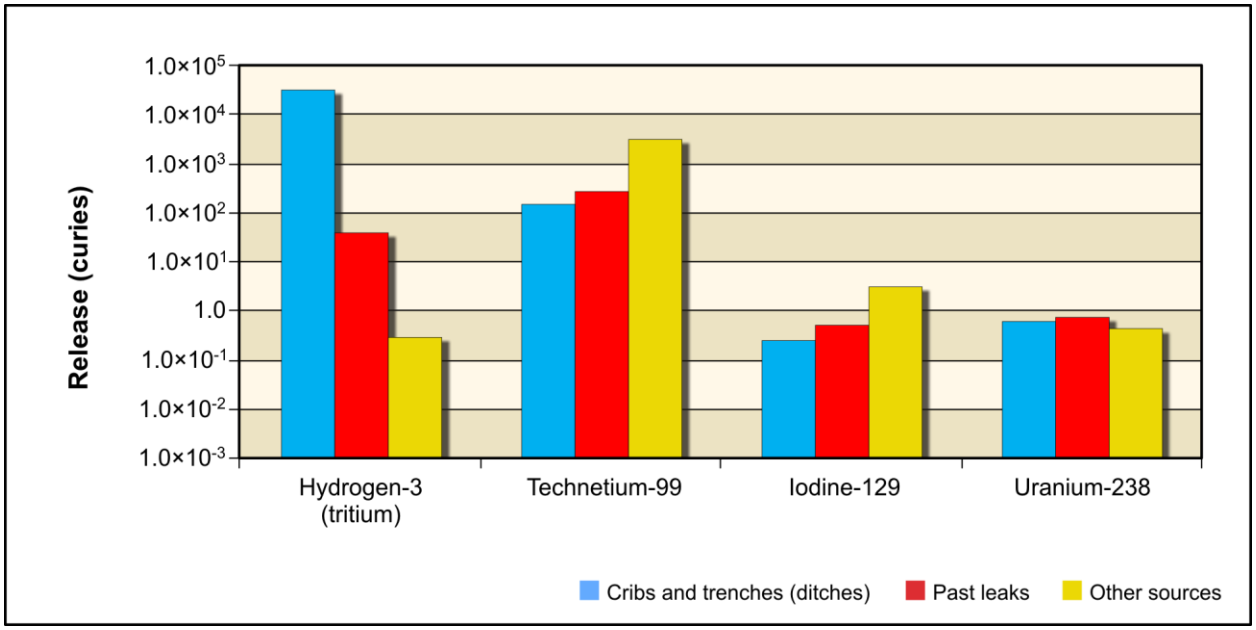


Figure 5–161. Tank Closure Alternative 5 Releases of Radioactive Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

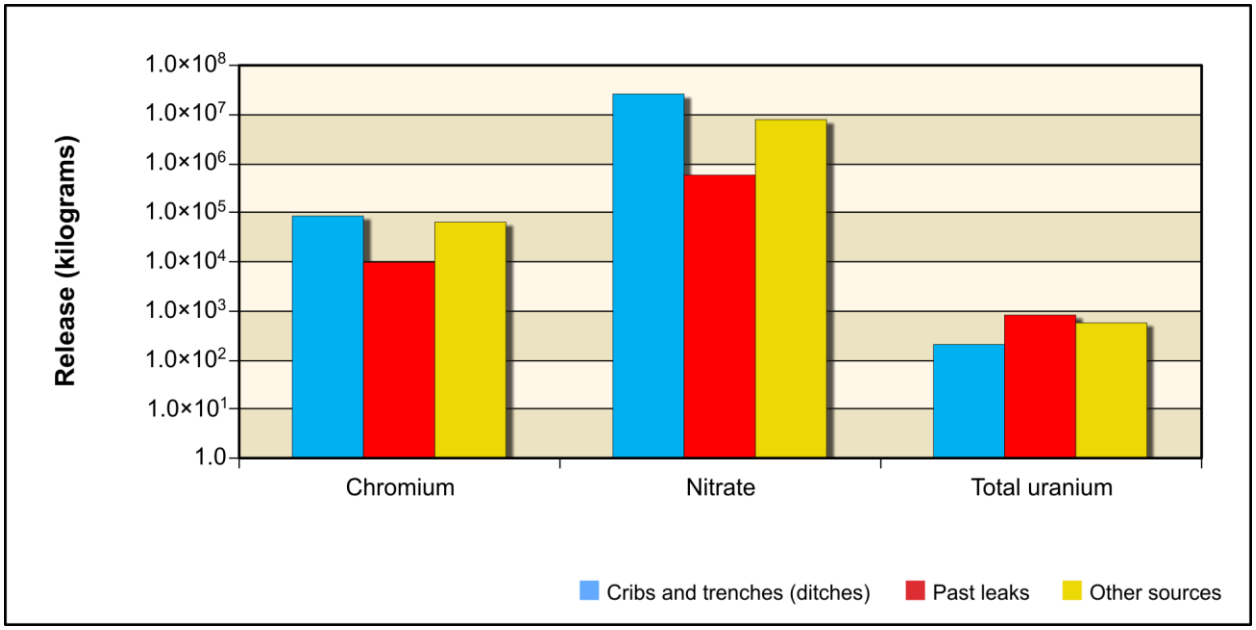


Figure 5–162. Tank Closure Alternative 5 Releases of Chemical Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

For uranium-238 and total uranium, the amount released to groundwater is less than that released 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 releases from 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 15 percent of the inventory of uranium-238 and 9 percent of the inventory of total uranium reach groundwater during the period of analysis; for other tank farm sources, less than 1 percent reaches groundwater.

For tritium, the amount released to groundwater is attenuated by radioactive decay. For releases from cribs and trenches (ditches), about 70 percent of the total inventory reaches groundwater in the analysis; for past leaks, only 2 percent; and for other tank farm sources, only one-tenth of 1 percent reaches 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 on groundwater would occur later in the post–administrative control period because of the long travel times in the vadose zone for these COPCs.

Figure 5–163 shows the estimated release to the Columbia River of the radiological risk drivers and Figure 5–164, 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 released to groundwater because of retardation. Overall, about 28 percent of the uranium-238 and 24 percent of the total uranium released to groundwater during the period of analysis reach the Columbia River. For tritium, the amount released to the Columbia River is attenuated by radioactive decay. Overall, only about 1 percent of the tritium released to groundwater reaches the Columbia River during the period of analysis. These results suggest that tritium impacts on the Columbia River are strongly attenuated by radioactive decay.

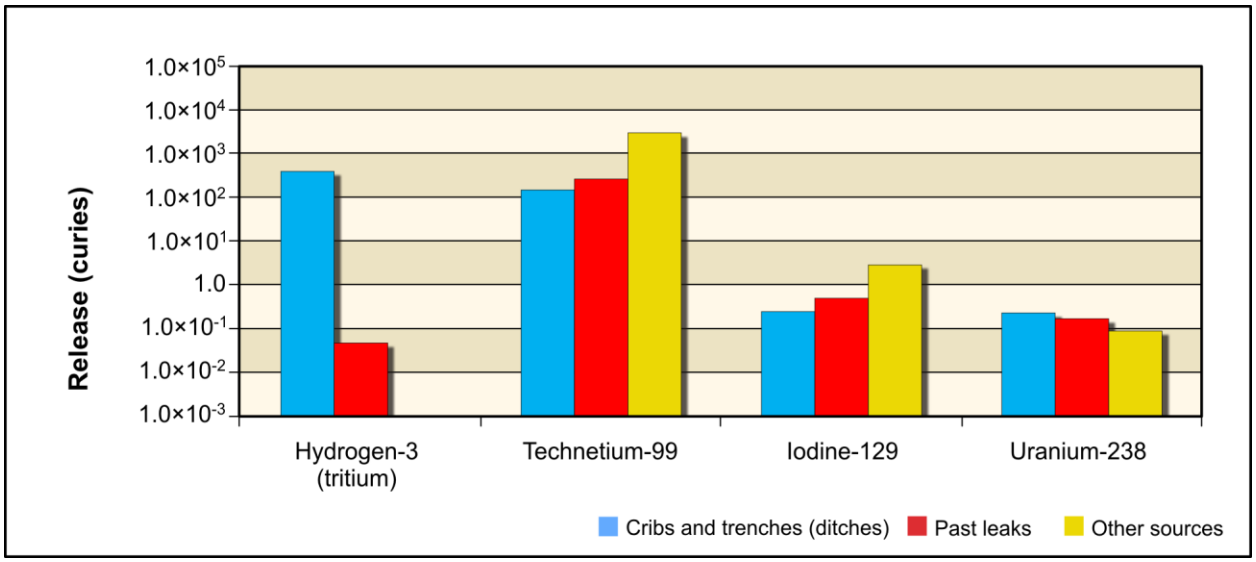


Figure 5–163. Tank Closure Alternative 5 Releases of Radioactive Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

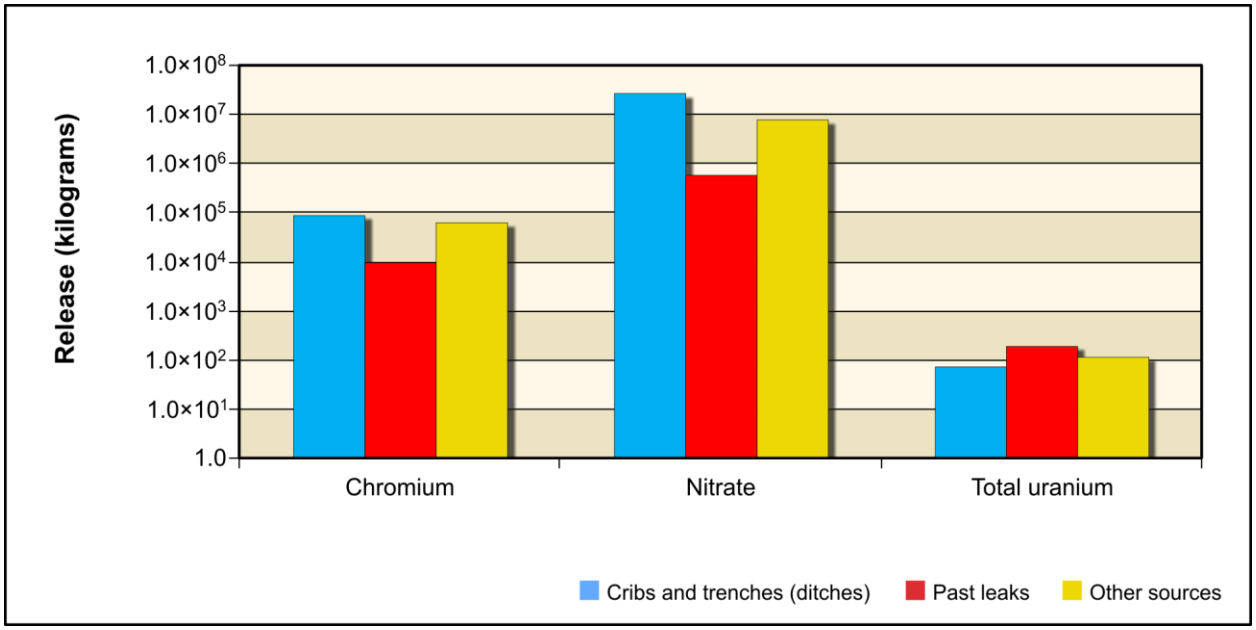


Figure 5–164. Tank Closure Alternative 5 Releases of Chemical Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

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 nearshore. Concentrations of radionuclides are in picocuries per liter; chemicals, in micrograms per liter (see Table 5–11 and Figures 5–165 through 5–171). The benchmark concentration of each radionuclide and chemical is also shown. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over five orders of magnitude. Table 5–11 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. Under Tank Closure Alternative 5, tritium, uranium-238, and total uranium never exceed their benchmark concentrations at any location beyond CY 2050. The highest impacts occur at the B and T Barriers and the Core Zone Boundary, where concentrations of iodine-129, technetium-99, chromium, and nitrate exceed their respective benchmark concentrations. None of the COPC drivers exceed the benchmark concentration at the Columbia River nearshore.

Figure 5–165 shows concentration versus time for tritium. Releases from cribs and trenches (ditches) cause Core Zone Boundary groundwater concentrations to exceed benchmark concentrations by one to two orders of magnitude for a short period of time during the early part of the period of analysis. This time period is represented by the first series of sharp inflections in the curve for the Core Zone Boundary from approximately CY 1955 until CY 1980. During this time, groundwater concentrations at the Columbia River nearshore approach but never exceed 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.

Figures 5–166 through 5–169 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 at the Core Zone Boundary during the early part of the period of analysis. This early time period is represented by the multiple sharp inflections in the Core Zone Boundary curve that occur between approximately CY 1955 and CY 1980. The iodine-129 signature also occurs at the Columbia

River nearshore at a later time. Tank farm residuals result in a broad concentration peak that hovers at or just below the benchmark concentration from about CY 3500 to the end of the period of analysis; this result indicates that the less effective (i.e., 90 percent) retrieval of the tank waste residuals under this alternative is not offset by the limitation of infiltration from the Hanford barriers over the tank farms. Under Tank Closure Alternative 4, in which 99.9 percent of the tank waste residuals would be retrieved, the iodine-129 concentrations resulting from releases from tank farm residuals drop below the benchmark after CY 2500. Under Tank Closure Alternative 5, groundwater iodine-129 concentrations at the Columbia River nearshore approach the benchmark concentration for a short time during the early period of analysis; thereafter, concentrations stay below the benchmark. Technetium-99, chromium, and nitrate concentrations show similar concentration-versus-time behavior.

Table 5–11. 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 (picocuries per liter)								
Hydrogen-3 (tritium)	7 (2051)	579 (2052)	32 (2050)	2,870 (2050)	15 (2050)	628 (2051)	477 (2051)	20,000
Technetium-99	**1,110** (4155)	**3,880** (3616)	**3,440** (4314)	**6,630** (2050)	**1,420** (3949)	**3,880** (3616)	479 (4918)	900
Iodine-129	**1.4** (2107)	**4.4** (2056)	**2.8** (2050)	**12.8** (2050)	0.5 (4371)	**4.4** (2056)	0.8 (2334)	1
Uranium isotopes (includes U-233, -234, -235, -238)	0 (11,832)	3 (11,938)	0 (11,918)	2 (11,895)	0 (11,904)	3 (11,938)	0 (11,935)	15
Chemical (micrograms per liter)								
Chromium	79 (2168)	**215** (2050)	**158** (2050)	**354** (2051)	30 (3565)	**215** (2050)	71 (2076)	100
Nitrate	17,800 (2172)	**171,000** (2055)	10,100 (4088)	**62,000** (2053)	3,440 (3568)	**171,000** (2055)	17,200 (2122)	45,000
Total uranium	0 (11,854)	5 (11,793)	0 (11,829)	1 (11,810)	0 (11,828)	5 (11,793)	0 (11,938)	30

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.

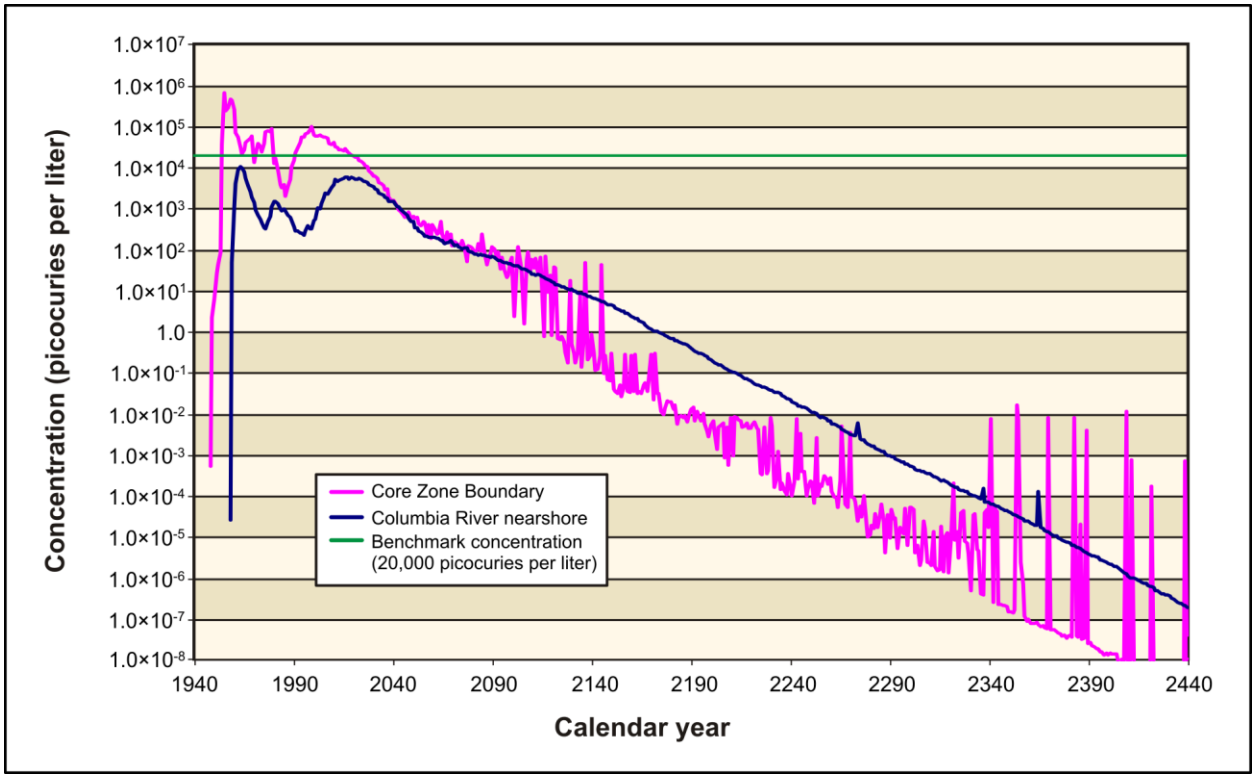


Figure 5–165. Tank Closure Alternative 5 Hydrogen-3 (Tritium) Concentration Versus Time

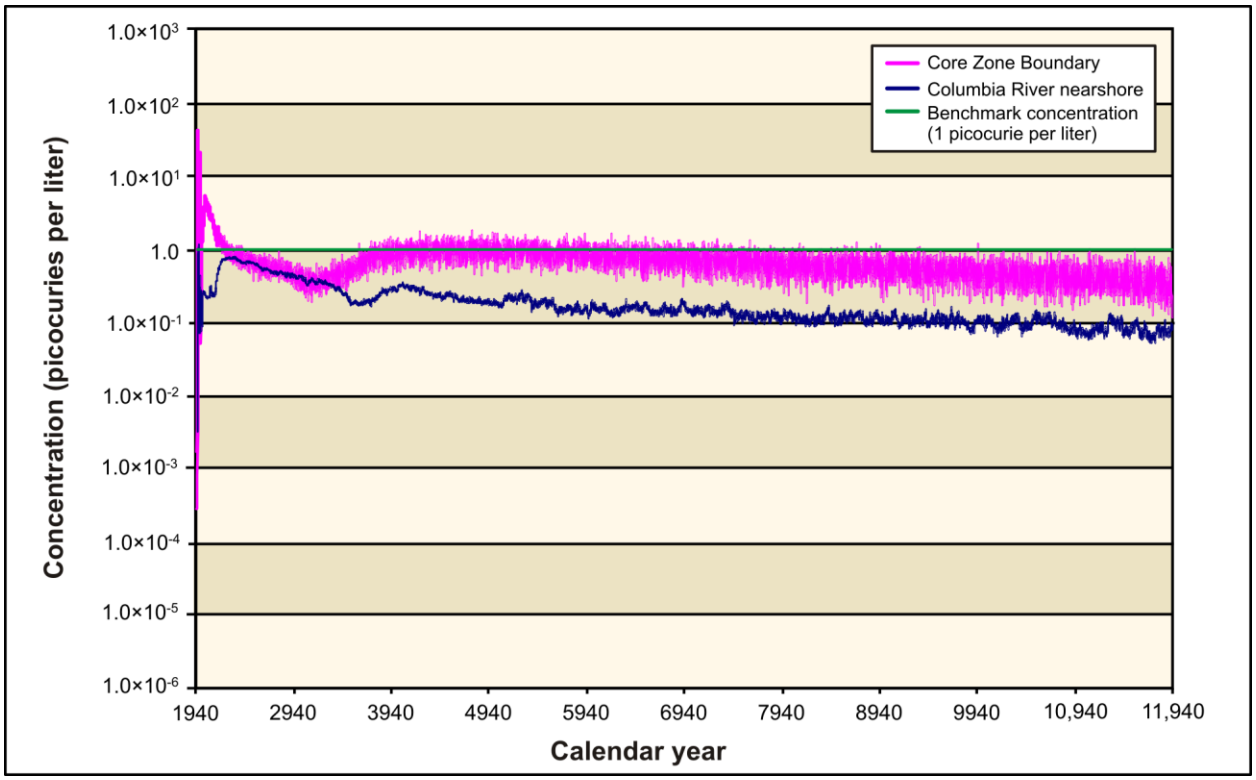


Figure 5–166. Tank Closure Alternative 5 Iodine-129 Concentration Versus Time

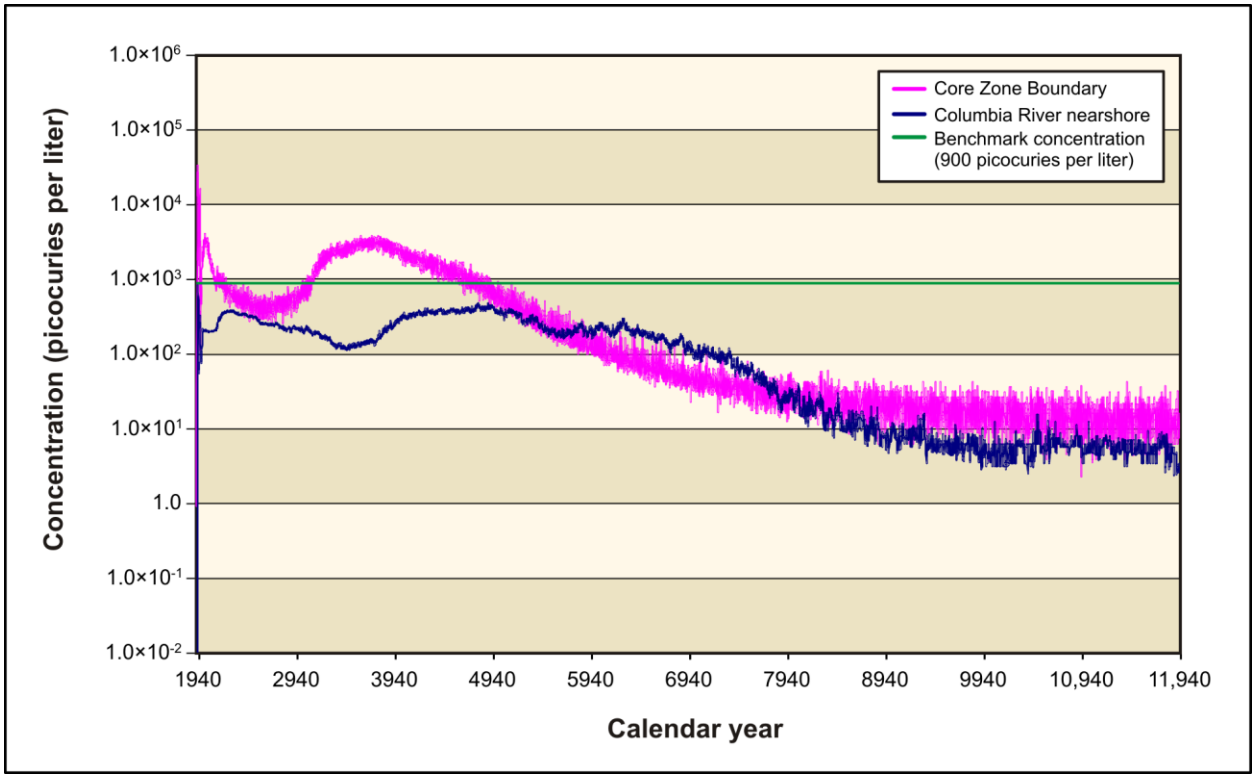


Figure 5–167. Tank Closure Alternative 5 Technetium-99 Concentration Versus Time

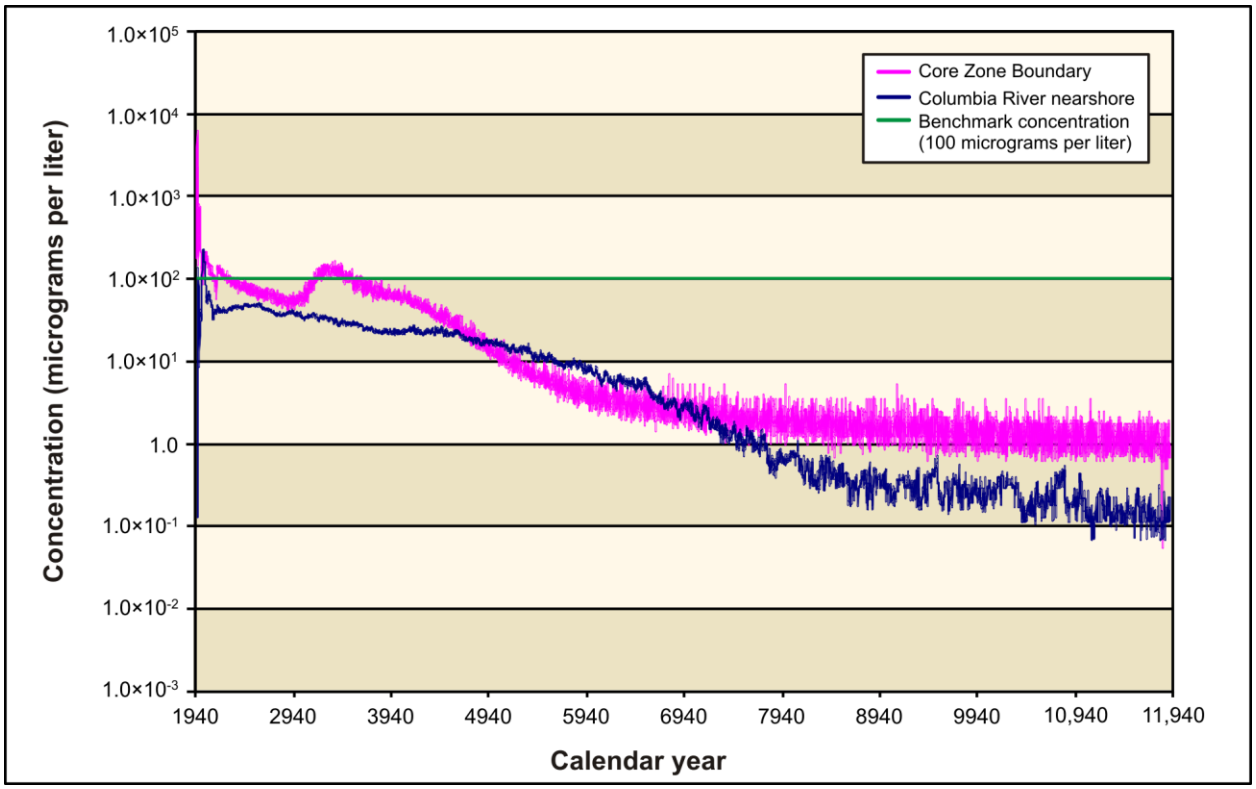


Figure 5–168. Tank Closure Alternative 5 Chromium Concentration Versus Time

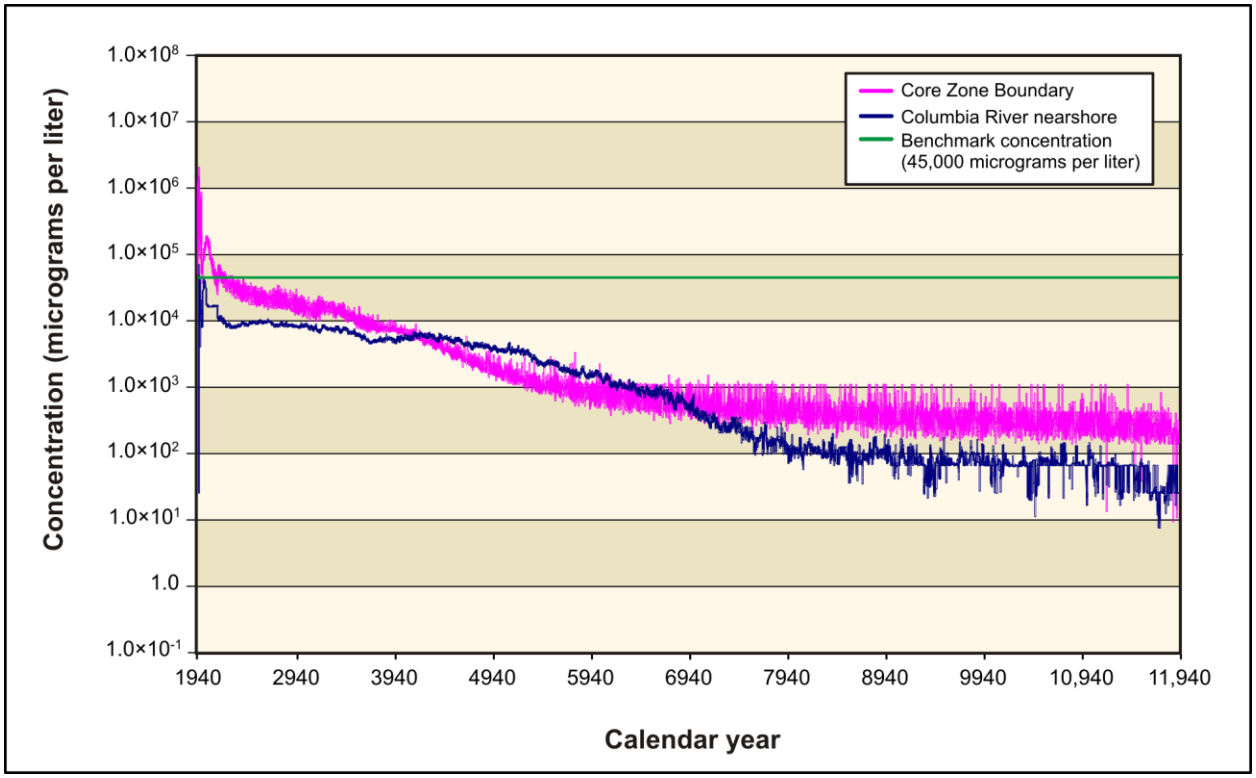


Figure 5–169. Tank Closure Alternative 5 Nitrate Concentration Versus Time

Figures 5–170 and 5–171 show concentration versus time for uranium-238 and total uranium. Early releases from cribs and trenches (ditches) result in groundwater concentrations that are about two orders of magnitude lower than benchmark concentrations. Releases from other tank farm sources cause groundwater concentrations to rise throughout the period of analysis. Groundwater concentrations at the Core Zone Boundary and Columbia River nearshore never exceed the benchmark concentration during the period of analysis.

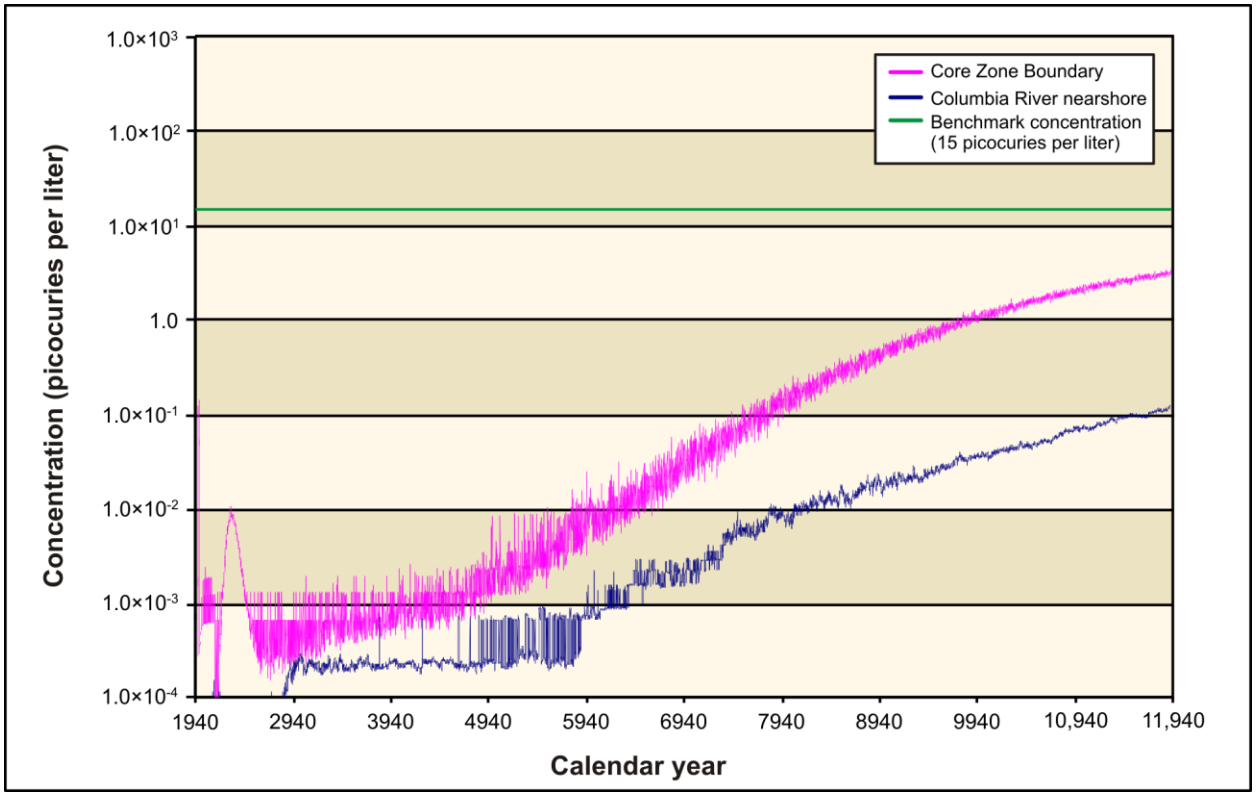


Figure 5–170. Tank Closure Alternative 5 Uranium-238 Concentration Versus Time

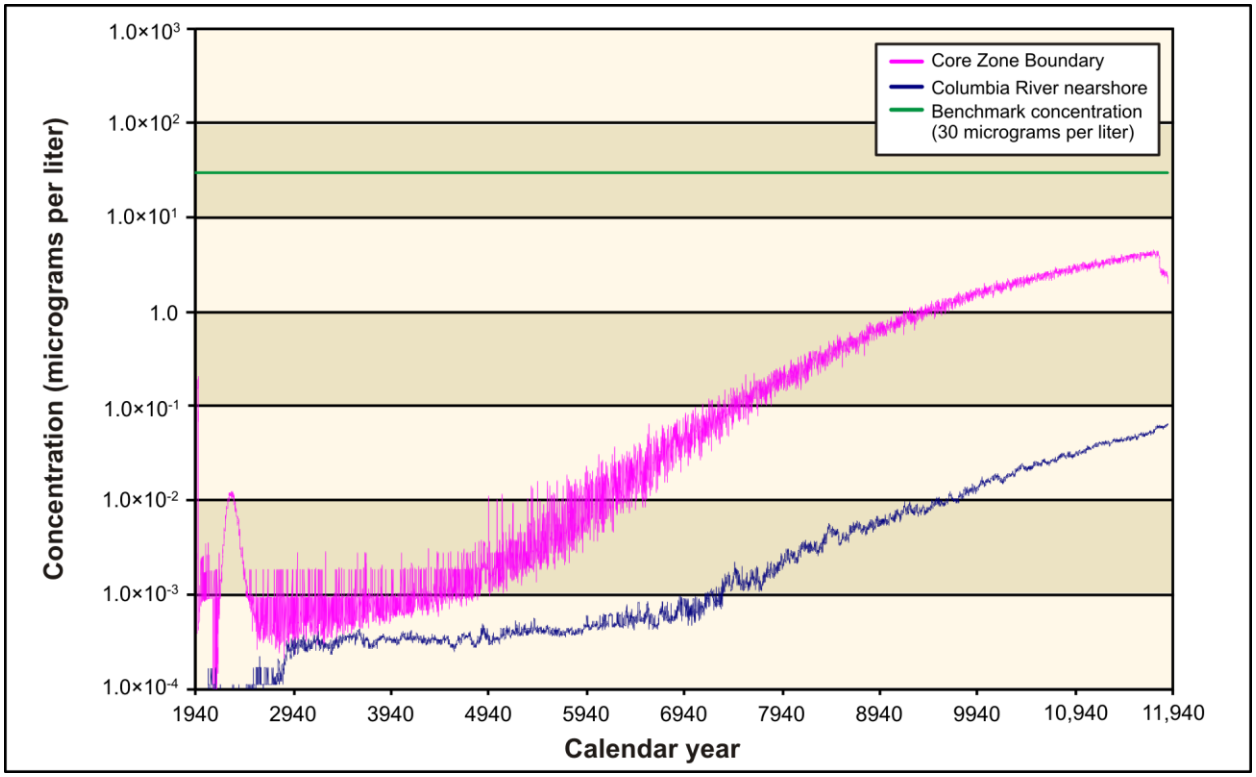
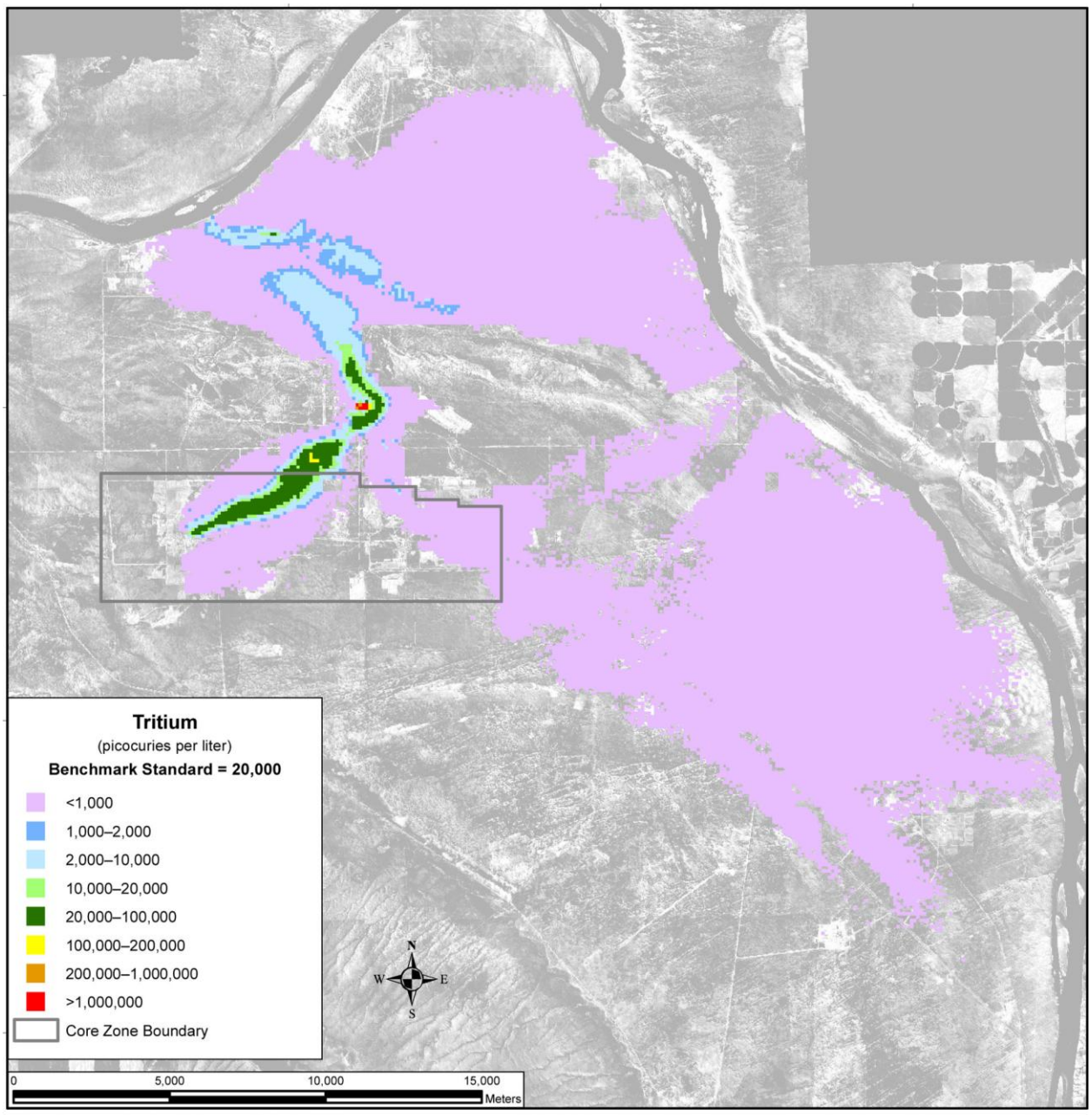


Figure 5–171. Tank Closure Alternative 5 Total Uranium Concentration Versus Time

5.1.1.8.5 Analysis of Spatial Distribution of Concentration

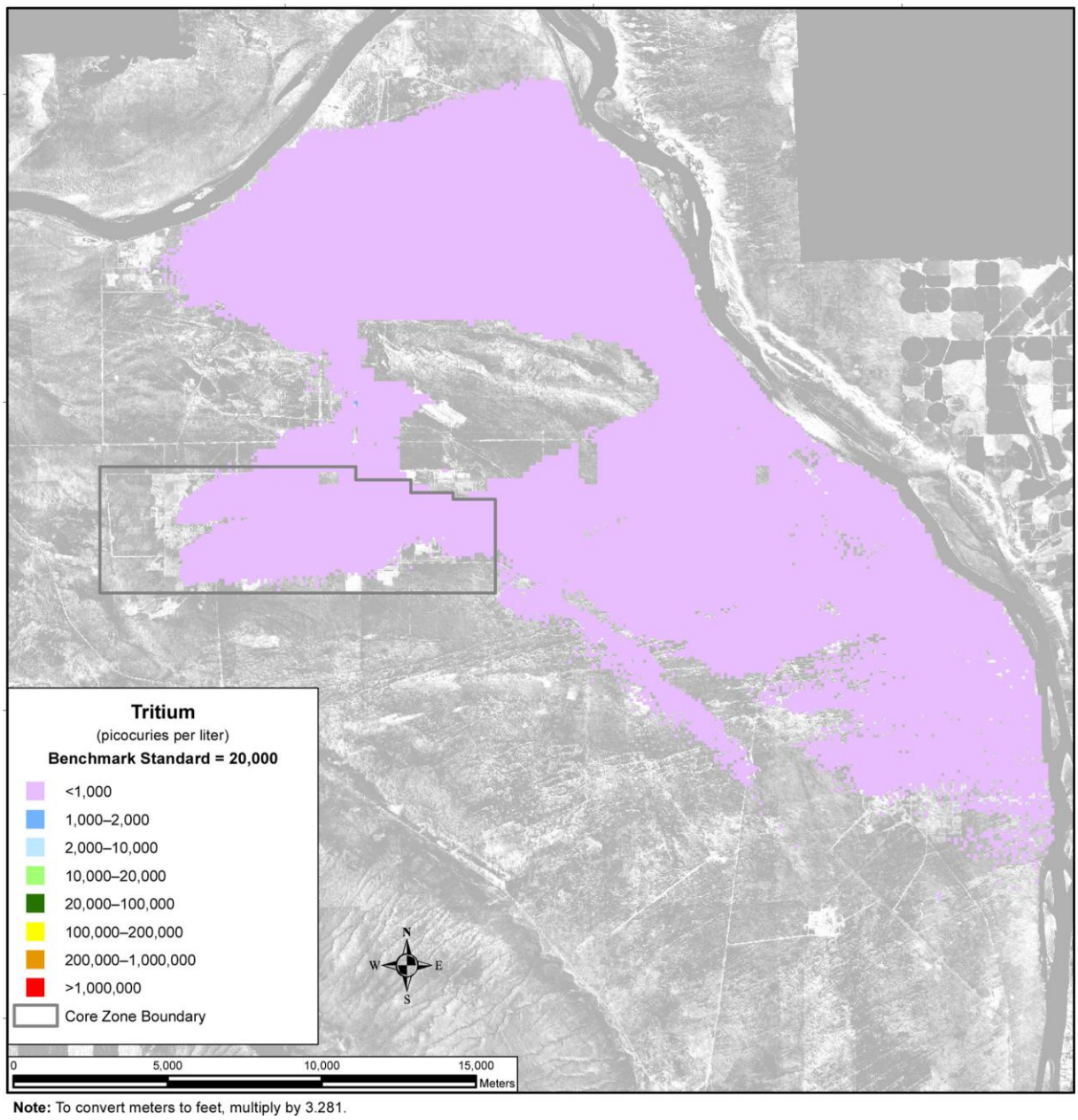
This section presents the impacts of Tank Closure Alternative 5 in terms of the spatial distribution of COPC driver concentrations in groundwater at selected times. Concentrations of radionuclides are in picocuries per liter; chemicals, in micrograms per liter (see Figures 5–172 through 5–194). Concentrations of 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 5–172 shows the spatial distribution of tritium concentrations in groundwater in CY 2010. 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, crosses the Core Zone Boundary, and continues toward Gable Gap. Peak concentrations in this plume are about 5 to 10 times greater than the benchmark. Tritium concentrations are attenuated by radioactive decay to levels less than one-twentieth of the benchmark concentration by CY 2135 (see Figure 5–173).



Note: To convert meters to feet, multiply by 3.281.

Figure 5–172. Tank Closure Alternative 5 Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration, Calendar Year 2010

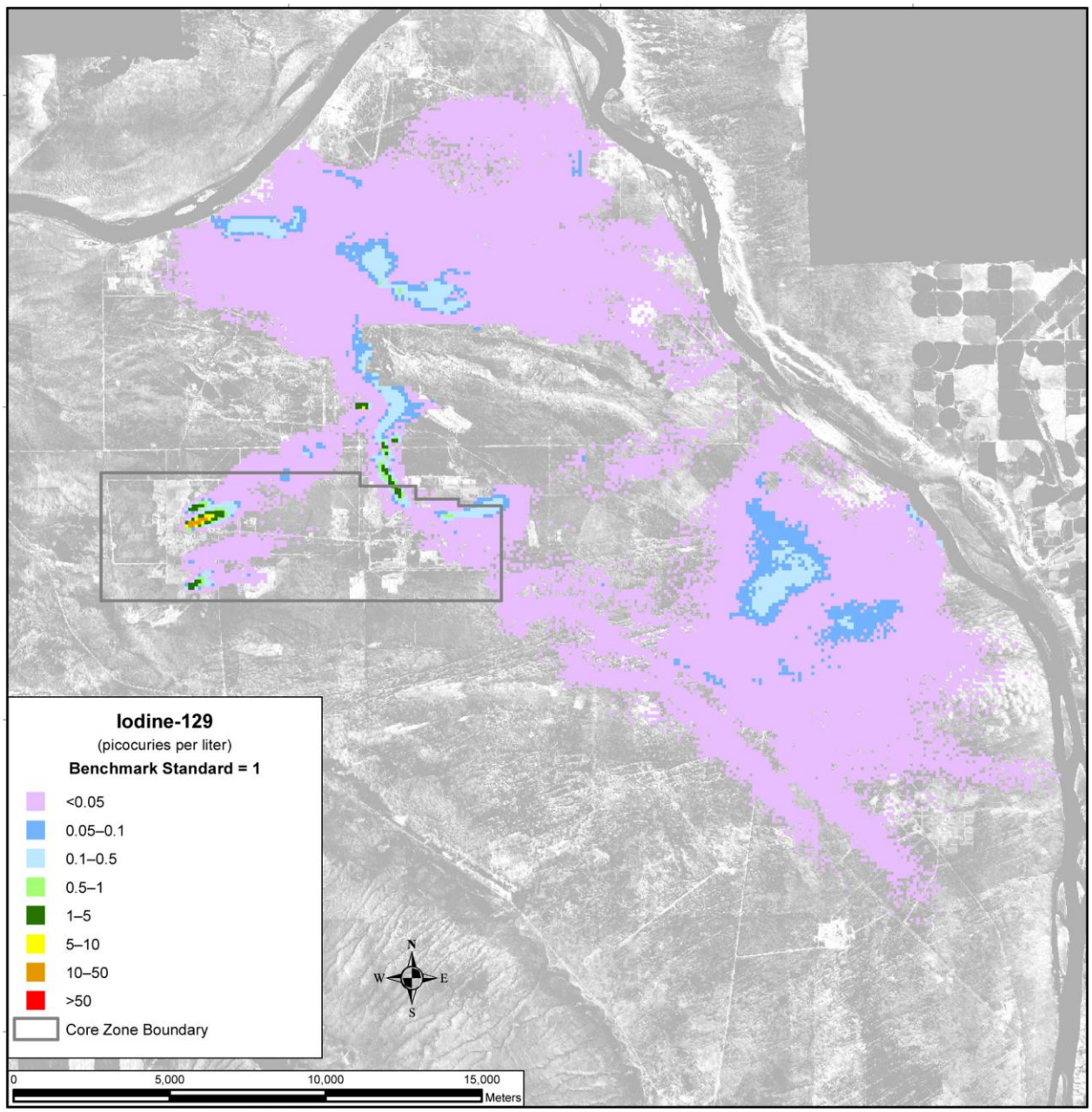


Note: To convert meters to feet, multiply by 3.281.

Figure 5–173. Tank Closure Alternative 5 Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration, Calendar Year 2135

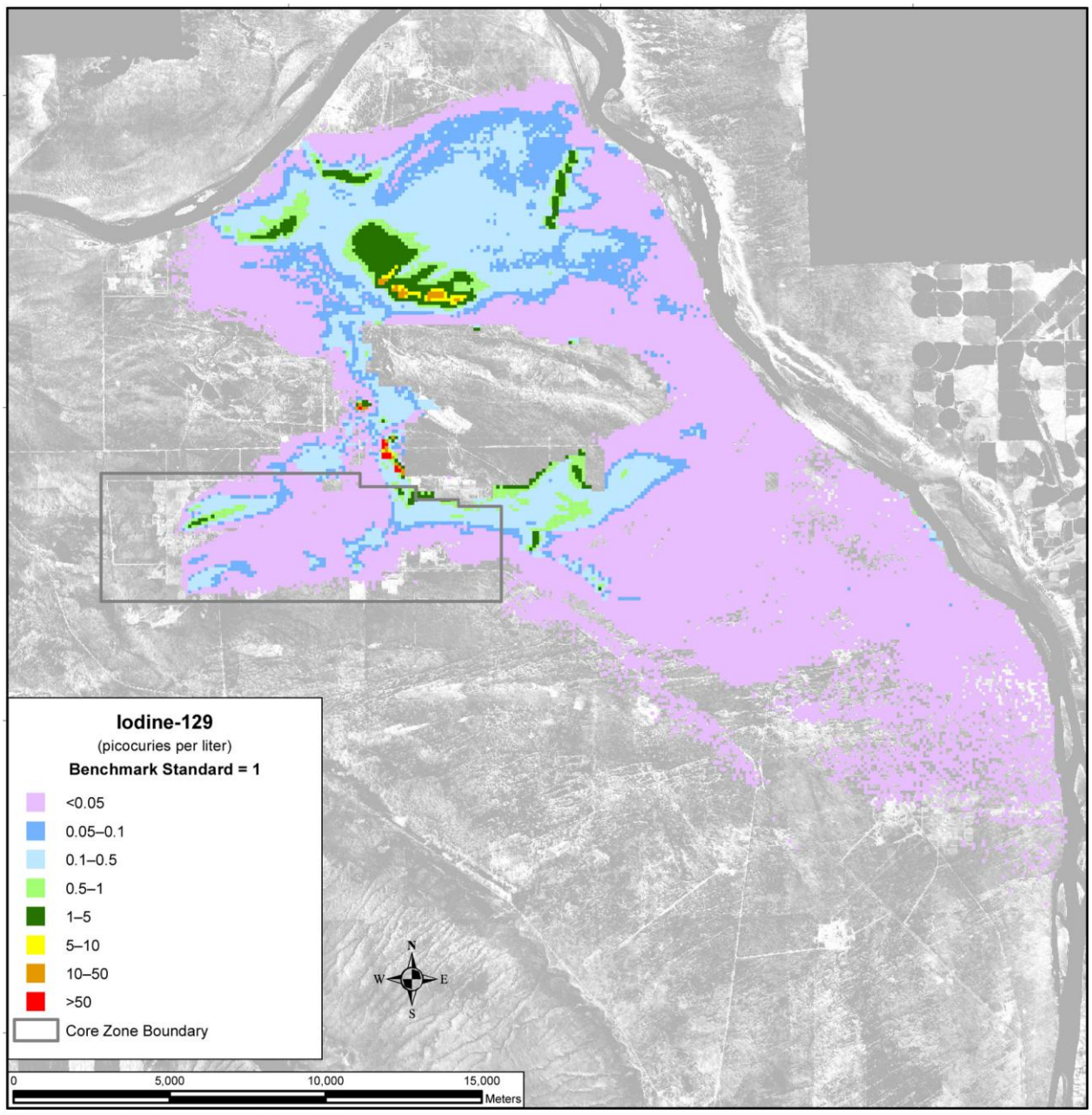
Figure 5–174 shows the spatial distribution of iodine-129 concentrations in groundwater in CY 2010. Releases from cribs and trenches (ditches) and past leaks result in groundwater concentration plumes that are at or exceed the benchmark concentration at the B, S, and T Barriers. Peak concentrations in this plume are about 10 to 50 times greater than the benchmark and are mostly contained within the Core Zone Boundary. In CY 2135, releases from other tank farm sources create a larger plume exceeding the benchmark concentration, extending north through Gable Gap and east from the A Barrier to the Columbia River (see Figure 5–175). By CY 7140, most of the mass in the plume has reached the Columbia River, with only isolated areas of high concentration, up to five times the benchmark, where the groundwater flow velocities are extremely small (see Figure 5–176). Technetium-99 (see Figures 5–177 through 5–179), chromium (see Figures 5–180 through 5–182), and nitrate (see Figure 5–183 through

5–185) 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).



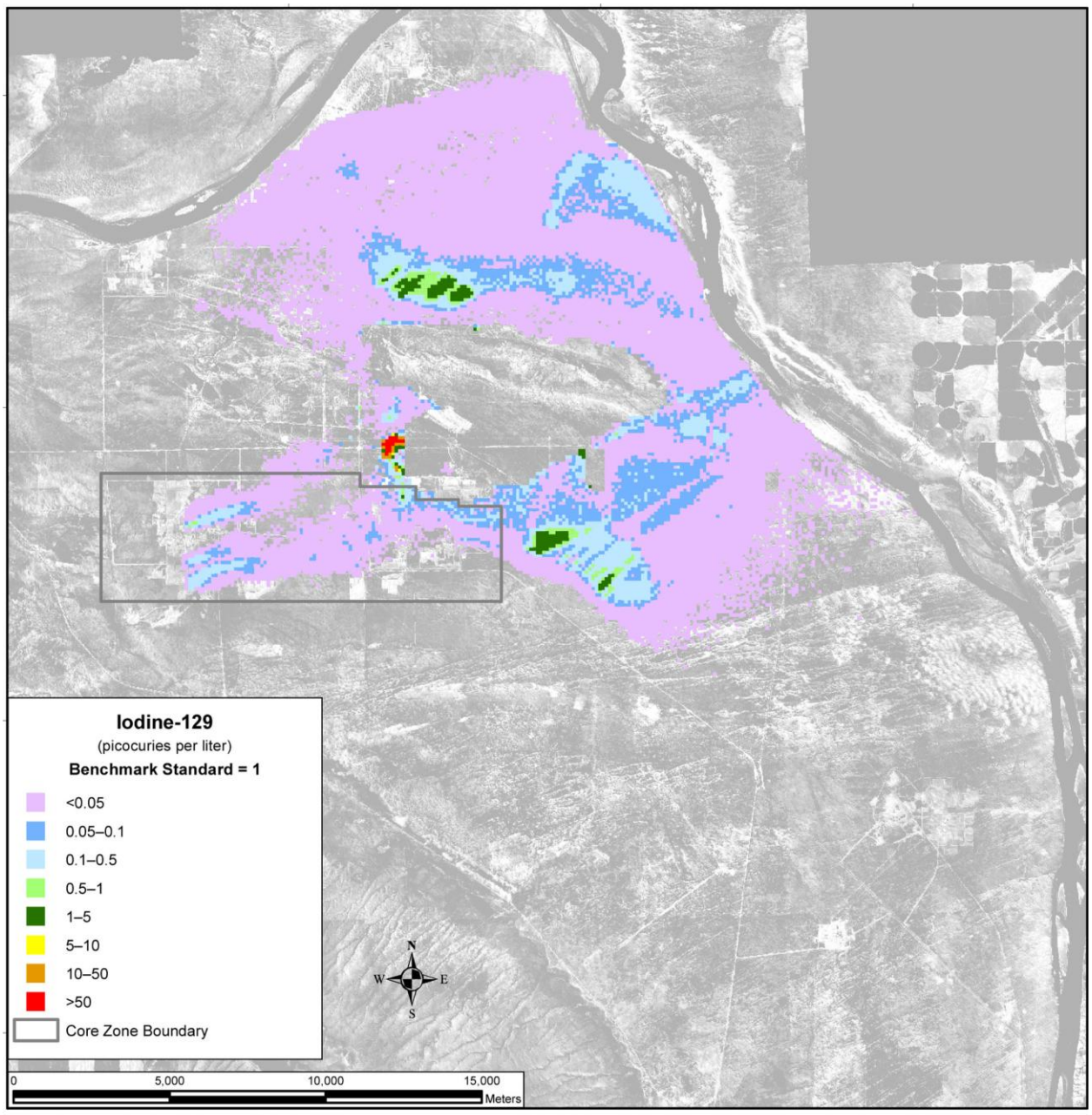
Note: To convert meters to feet, multiply by 3.281.

Figure 5–174. Tank Closure Alternative 5 Spatial Distribution of Groundwater Iodine-129 Concentration, Calendar Year 2010



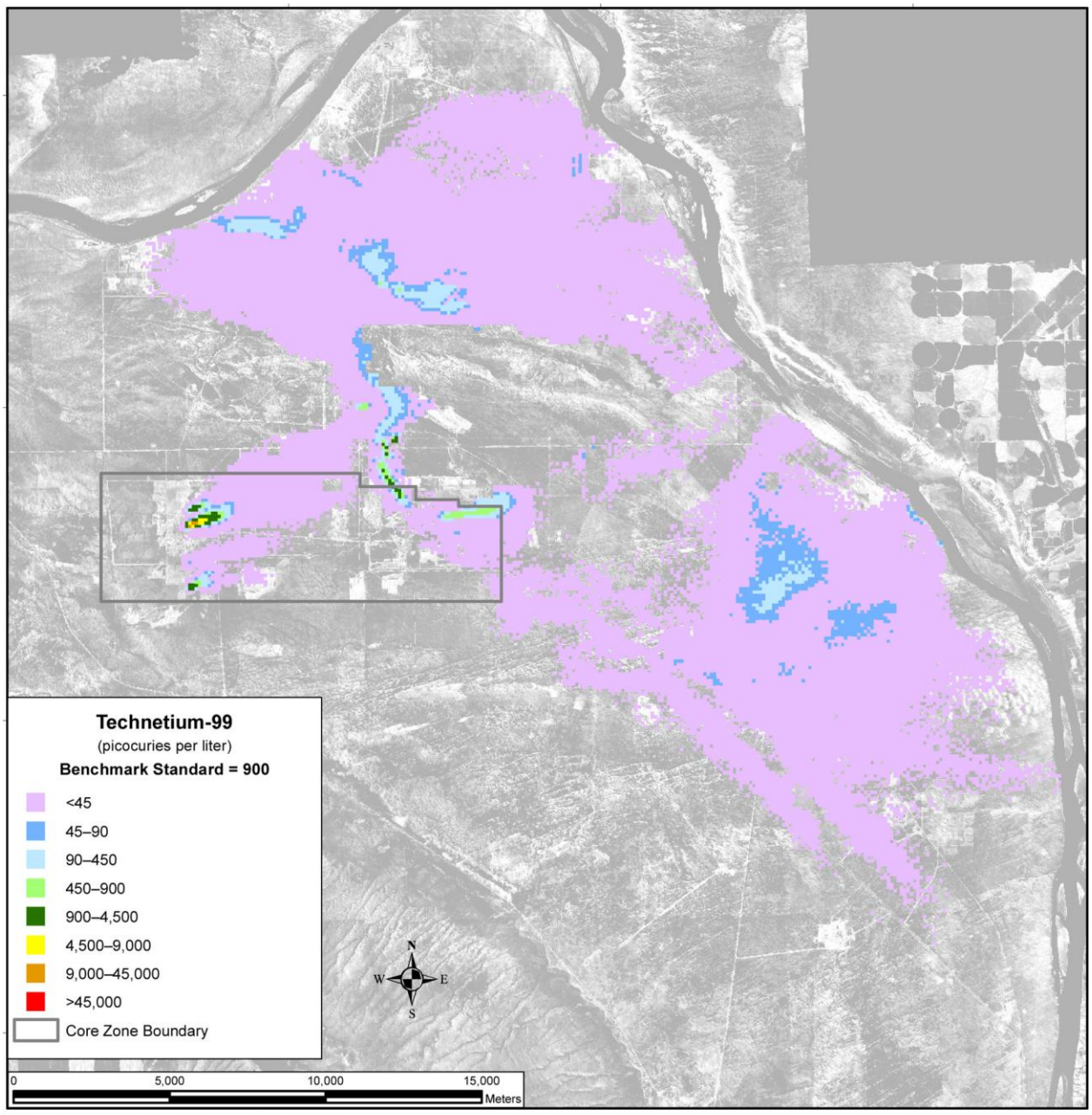
Note: To convert meters to feet, multiply by 3.281.

Figure 5–175. Tank Closure Alternative 5 Spatial Distribution of Groundwater Iodine-129 Concentration, Calendar Year 2135



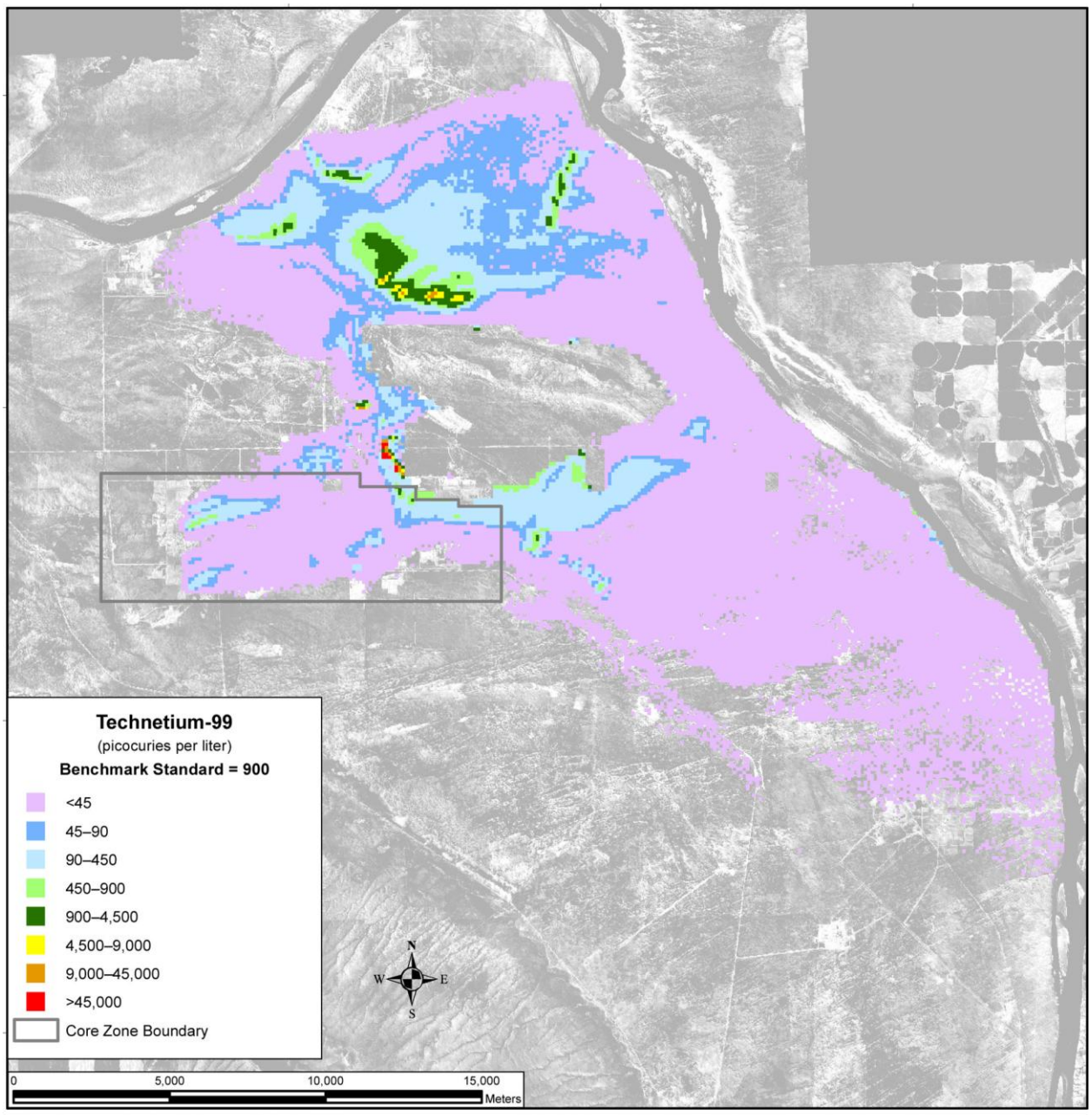
Note: To convert meters to feet, multiply by 3.281.

Figure 5–176. Tank Closure Alternative 5 Spatial Distribution of Groundwater Iodine-129 Concentration, Calendar Year 7140



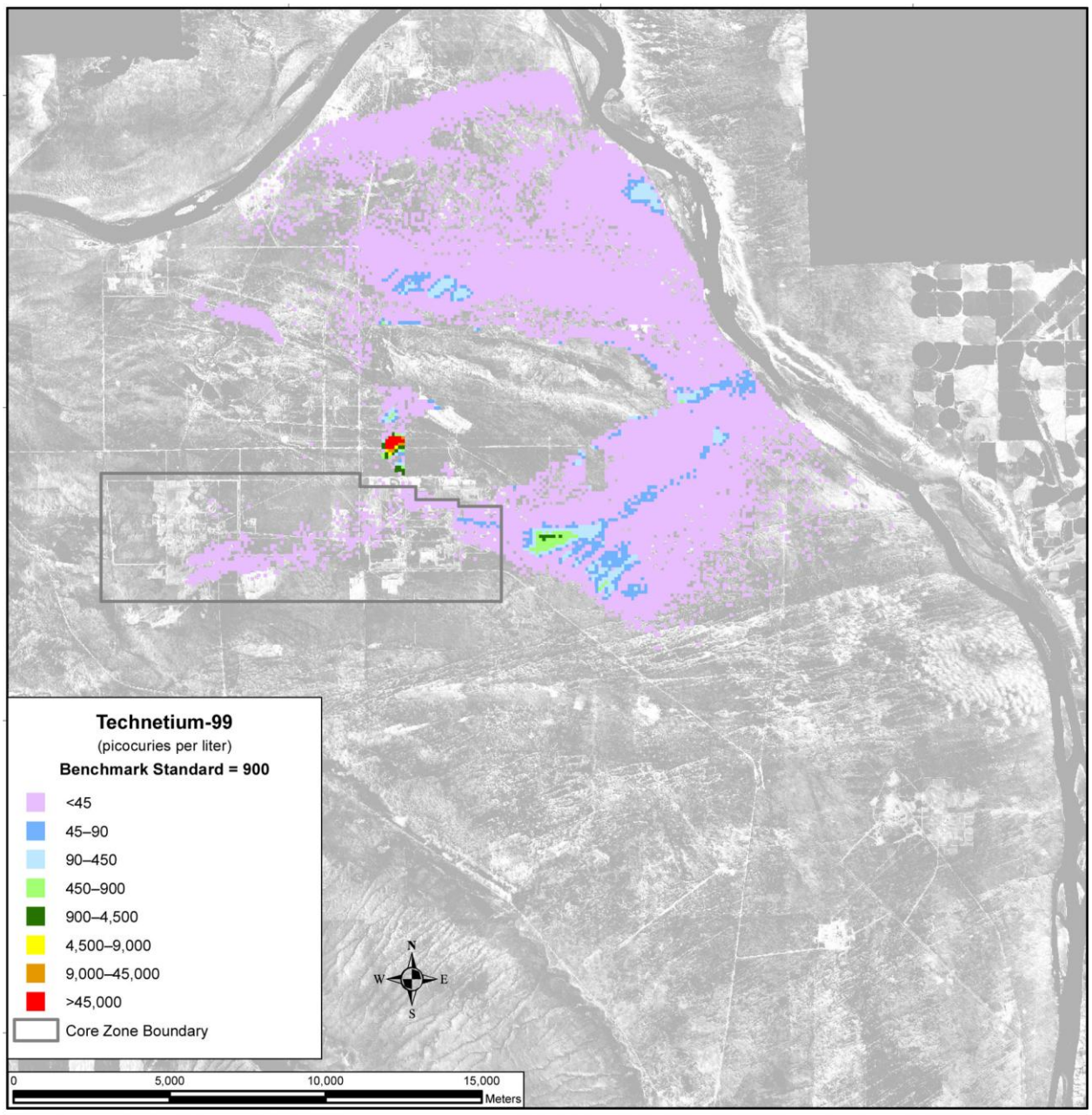
Note: To convert meters to feet, multiply by 3.281.

Figure 5–177. Tank Closure Alternative 5 Spatial Distribution of Groundwater Technetium-99 Concentration, Calendar Year 2010



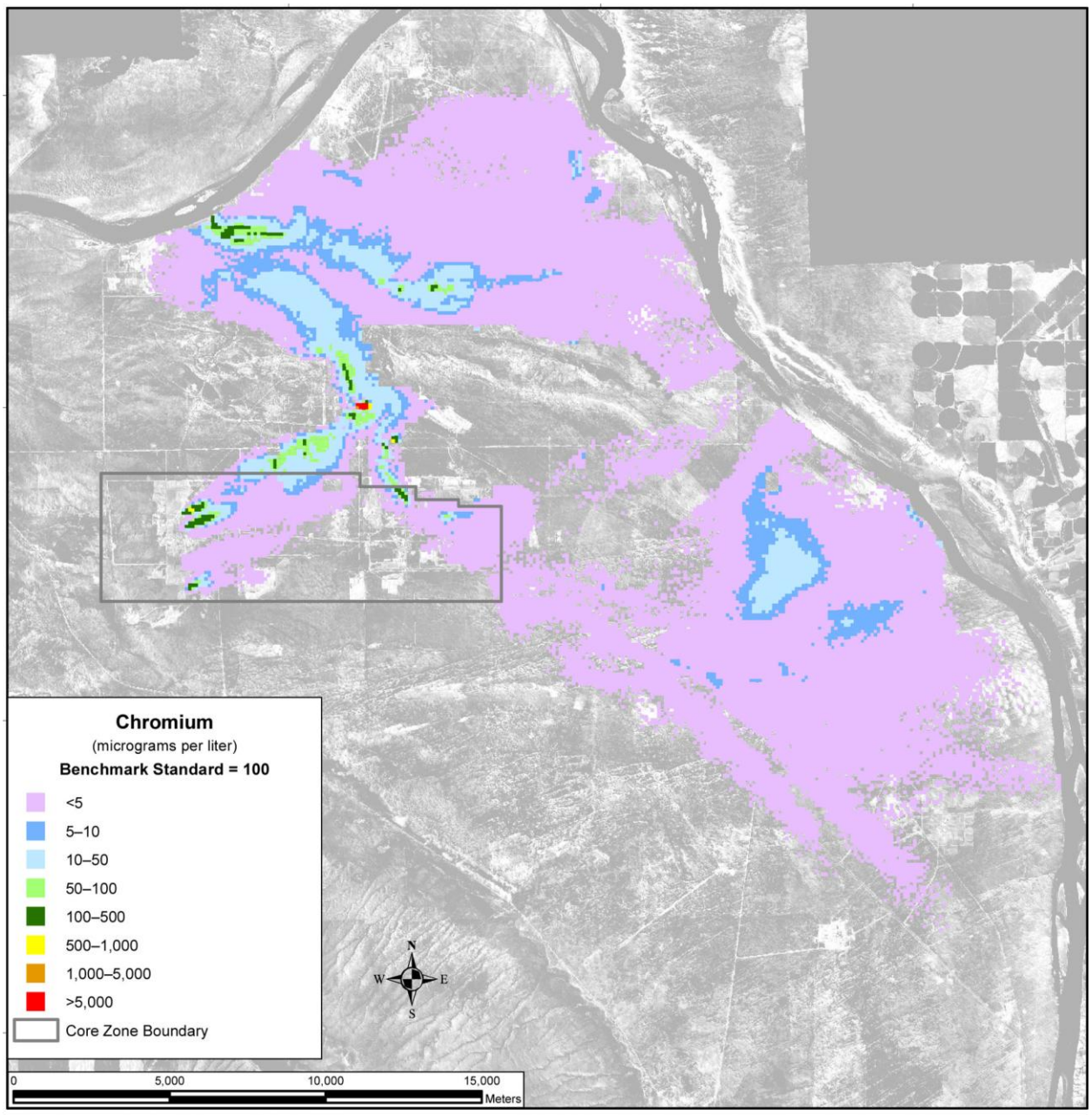
Note: To convert meters to feet, multiply by 3.281.

Figure 5–178. Tank Closure Alternative 5 Spatial Distribution of Groundwater Technetium-99 Concentration, Calendar Year 2135



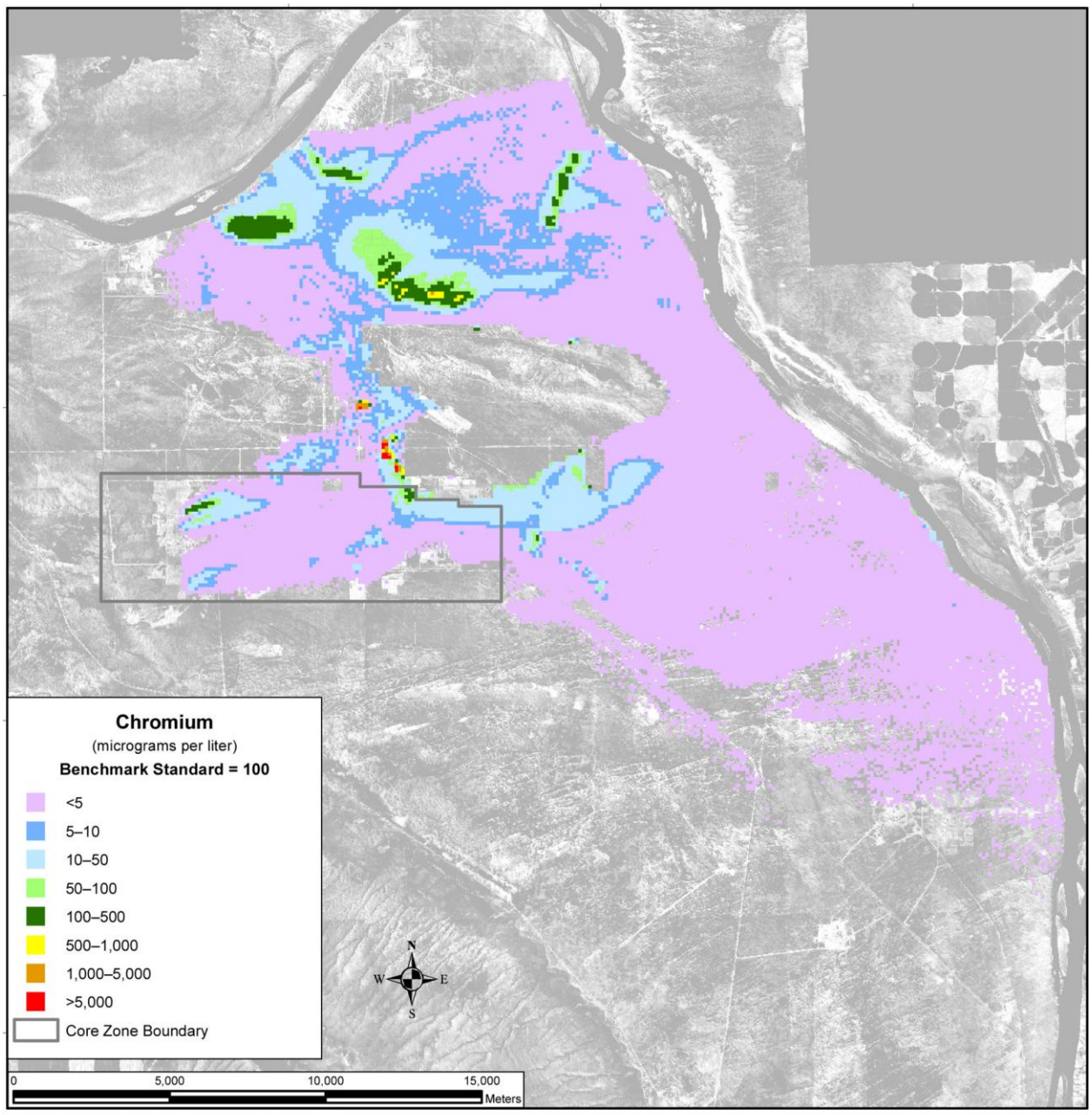
Note: To convert meters to feet, multiply by 3.281.

Figure 5–179. Tank Closure Alternative 5 Spatial Distribution of Groundwater Technetium-99 Concentration, Calendar Year 7140



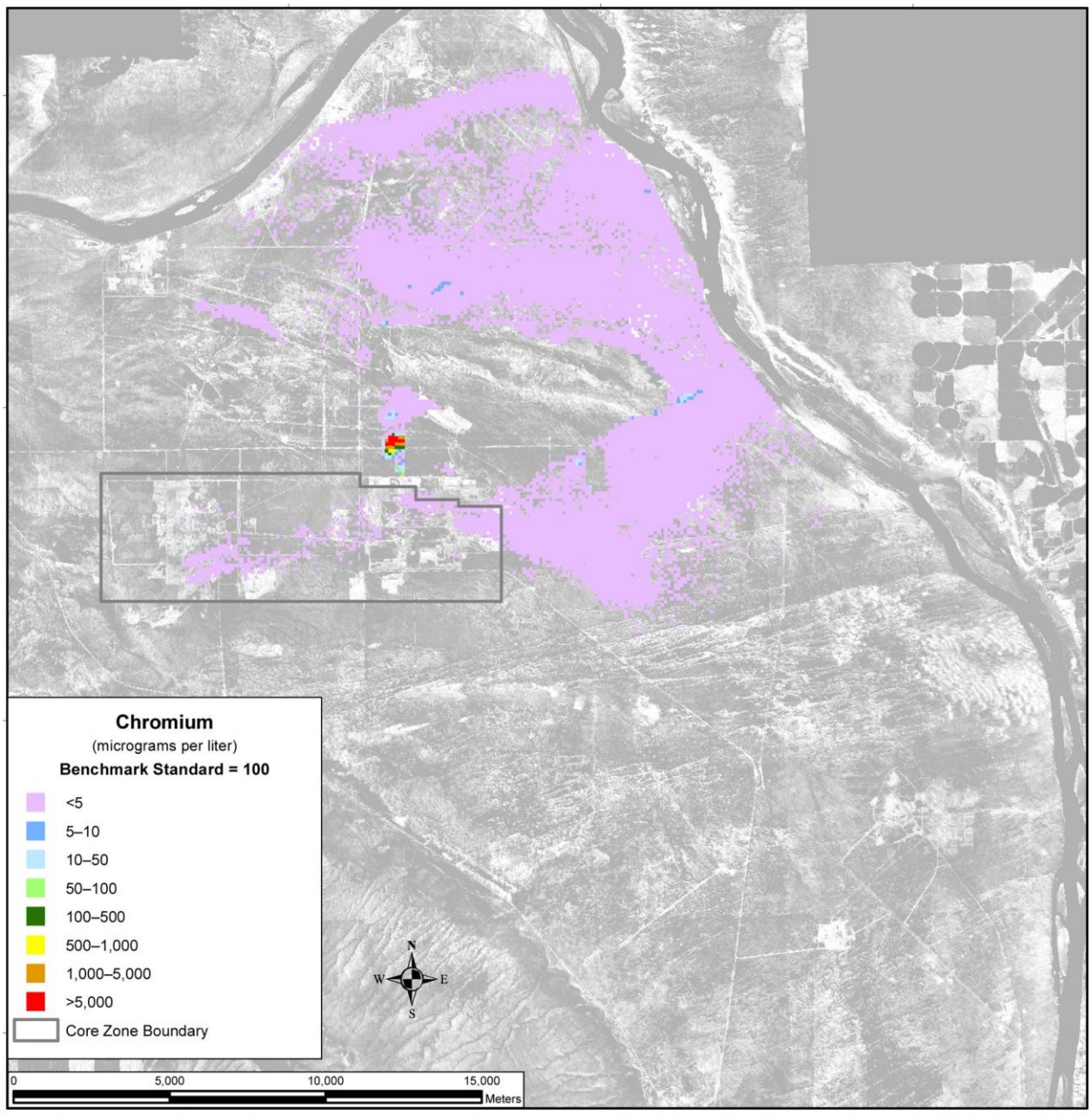
Note: To convert meters to feet, multiply by 3.281.

Figure 5–180. Tank Closure Alternative 5 Spatial Distribution of Groundwater Chromium Concentration, Calendar Year 2010



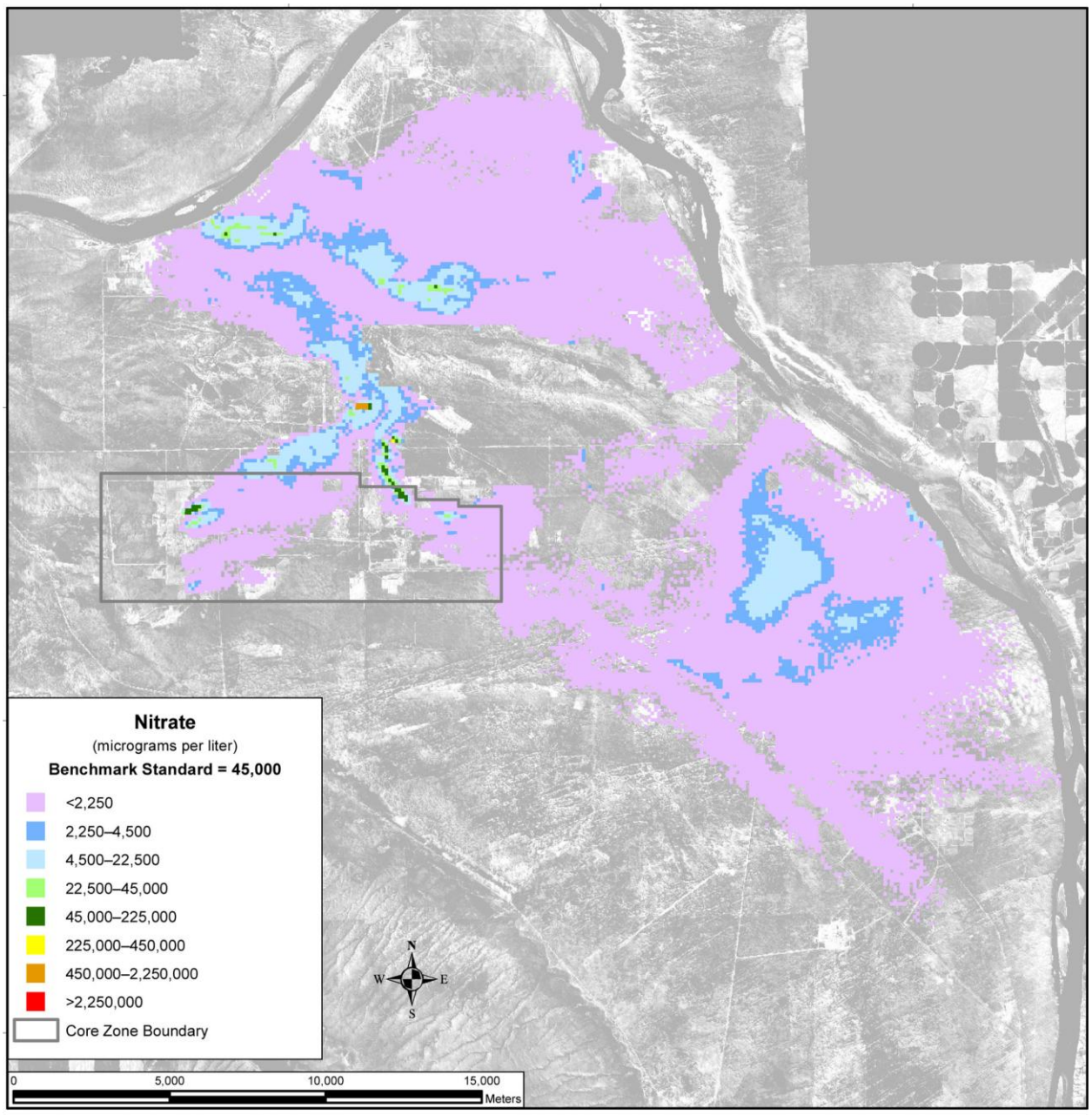
Note: To convert meters to feet, multiply by 3.281.

Figure 5–181. Tank Closure Alternative 5 Spatial Distribution of Groundwater Chromium Concentration, Calendar Year 2135



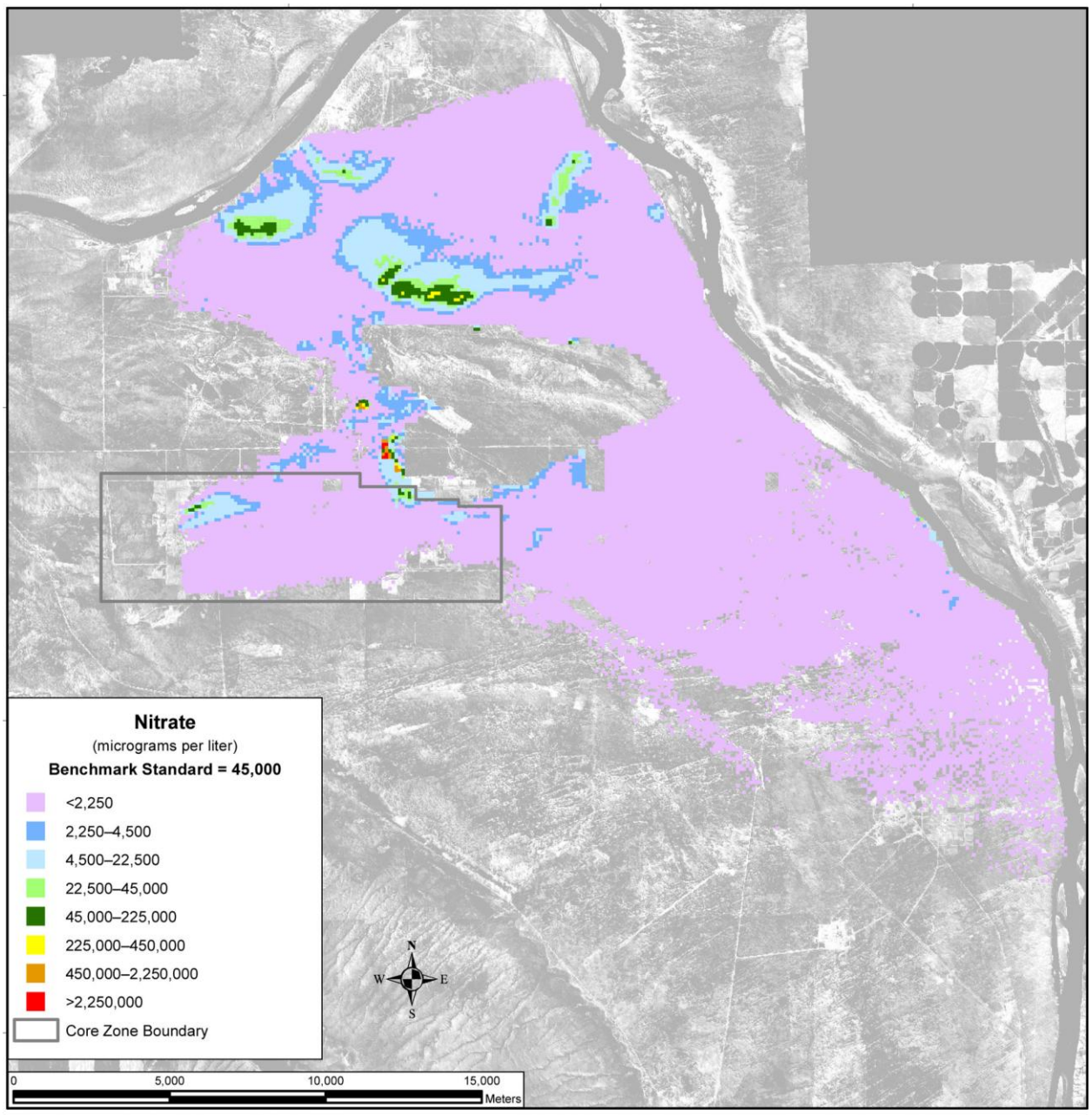
Note: To convert meters to feet, multiply by 3.281.

Figure 5–182. Tank Closure Alternative 5 Spatial Distribution of Groundwater Chromium Concentration, Calendar Year 7140



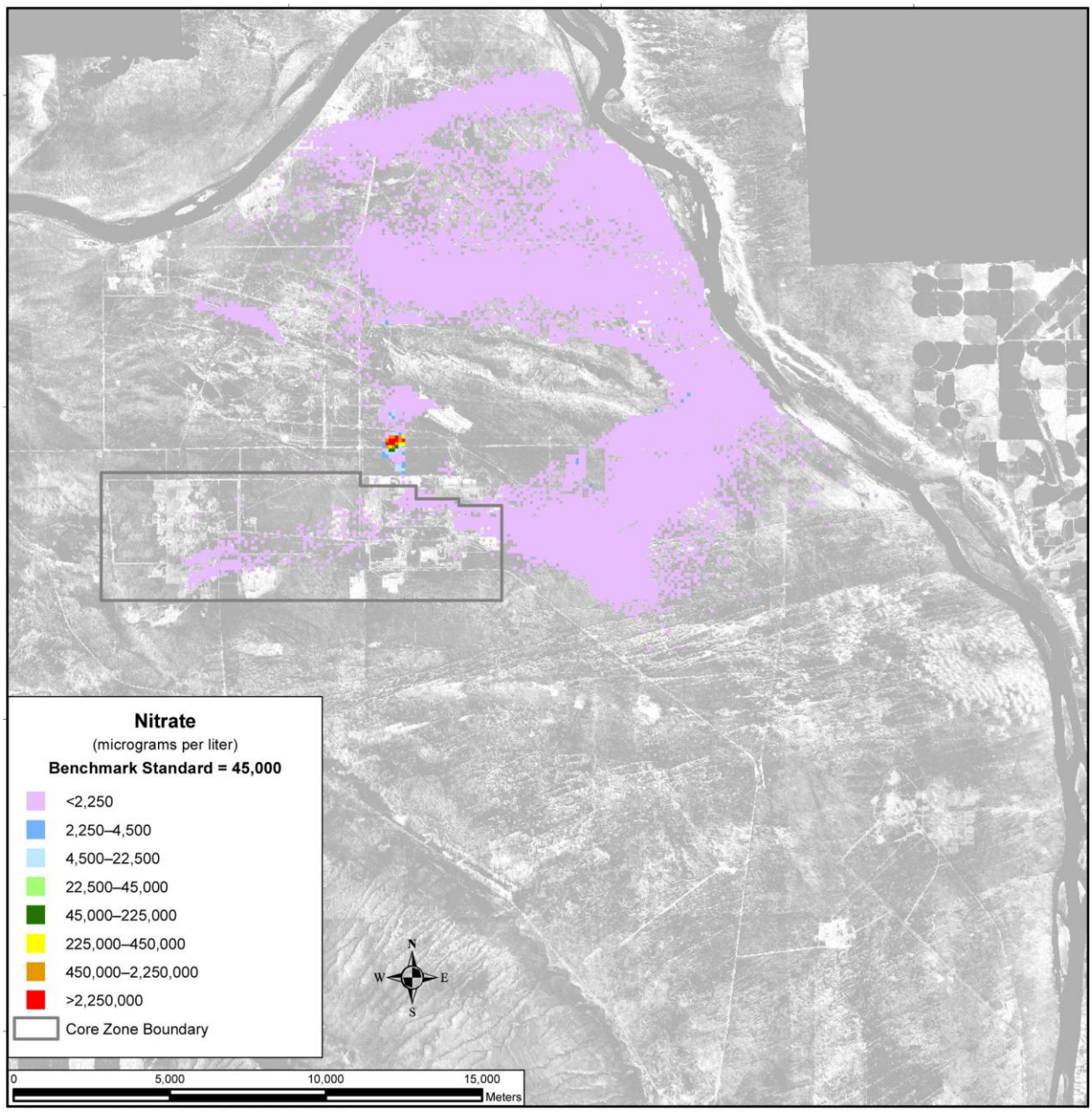
Note: To convert meters to feet, multiply by 3.281.

Figure 5–183. Tank Closure Alternative 5 Spatial Distribution of Groundwater Nitrate Concentration, Calendar Year 2010



Note: To convert meters to feet, multiply by 3.281.

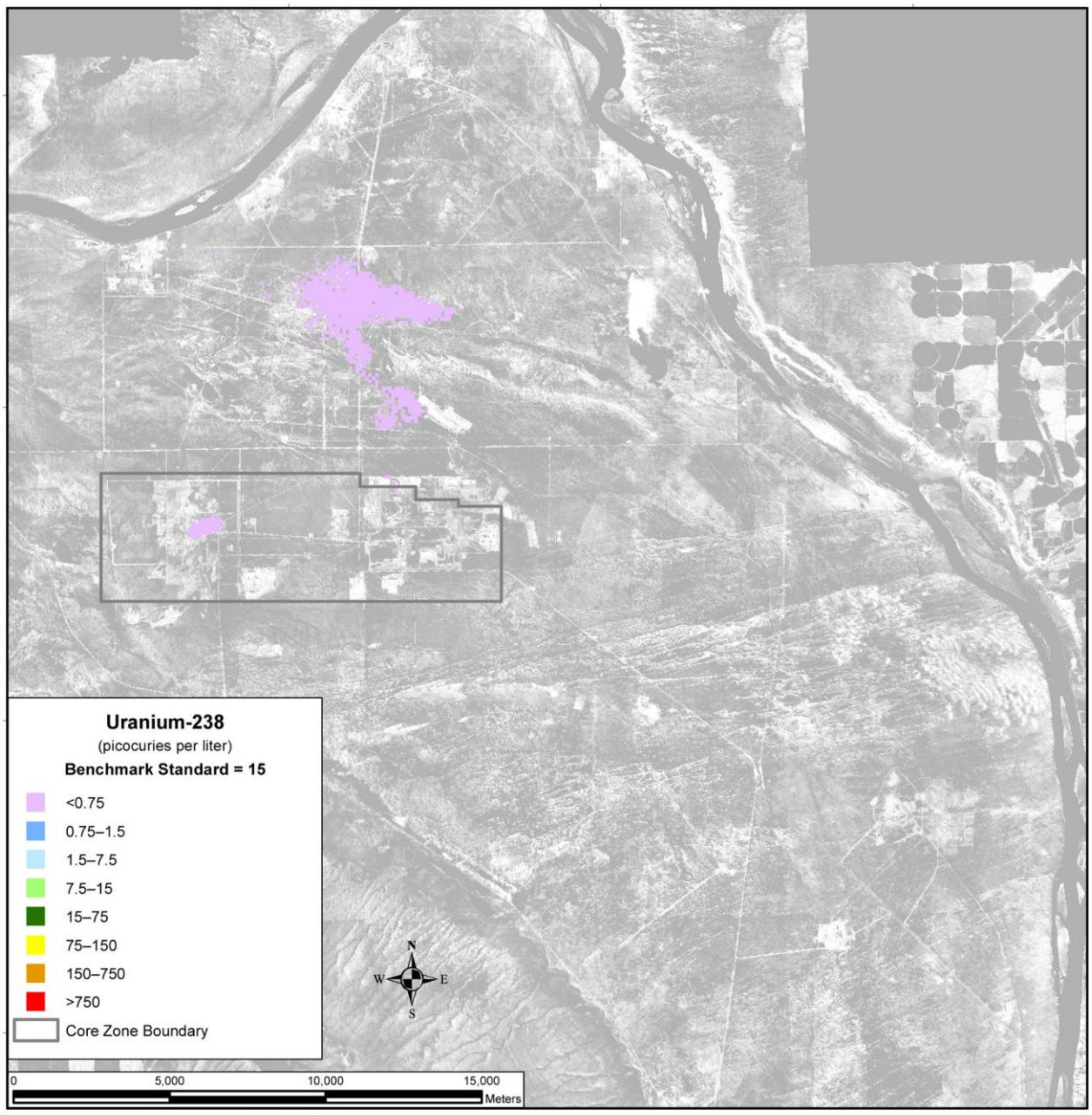
Figure 5–184. Tank Closure Alternative 5 Spatial Distribution of Groundwater Nitrate Concentration, Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281.

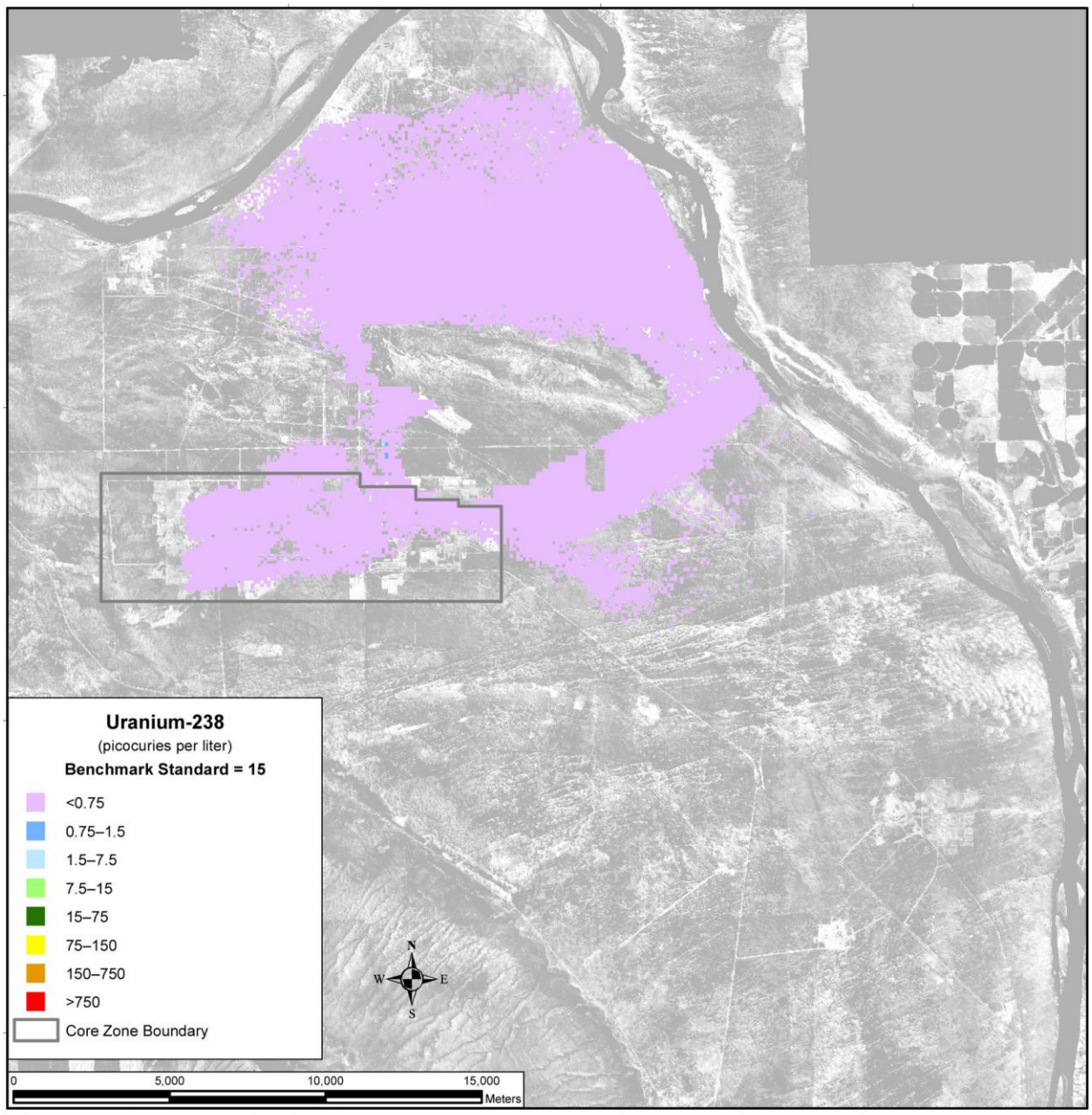
Figure 5–185. Tank Closure Alternative 5 Spatial Distribution of Groundwater Nitrate Concentration, Calendar Year 7140

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 more slowly 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 5–186 shows the distribution of uranium-238 in CY 2010. There is a small plume associated with releases from cribs and trenches (ditches) and past leaks at the T Barrier that is less than one-twentieth of the benchmark concentration. The plume extends northeast through Gable Gap. By CY 7140 (see Figure 5–187), the area of the plume has grown, but there are no significant increases in peak concentration. In CY 11,940 (see Figure 5–188), 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 5–189 through 5–191 show the corresponding results for total uranium.



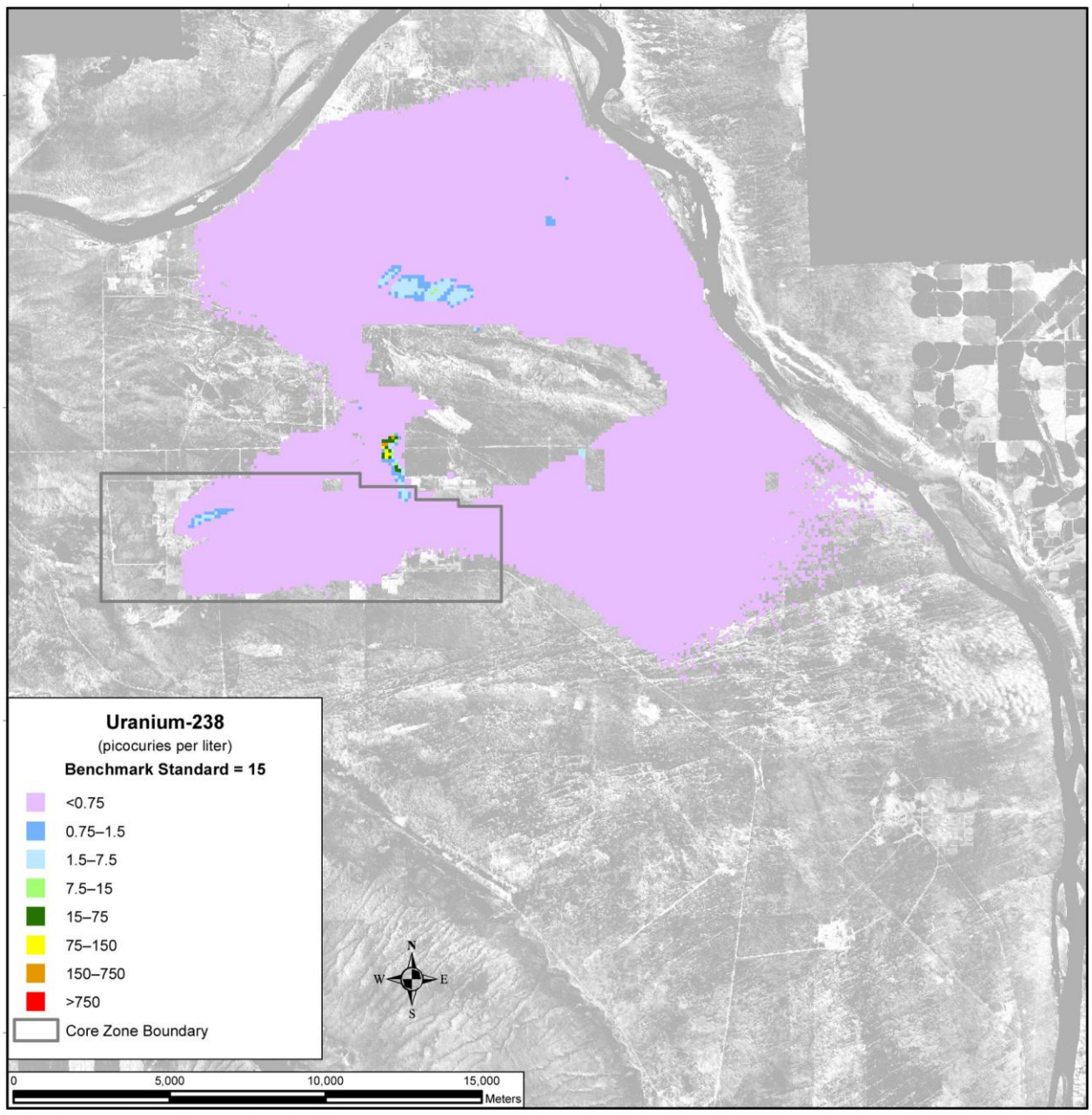
Note: To convert meters to feet, multiply by 3.281.

Figure 5–186. Tank Closure Alternative 5 Spatial Distribution of Groundwater Uranium-238 Concentration, Calendar Year 2010



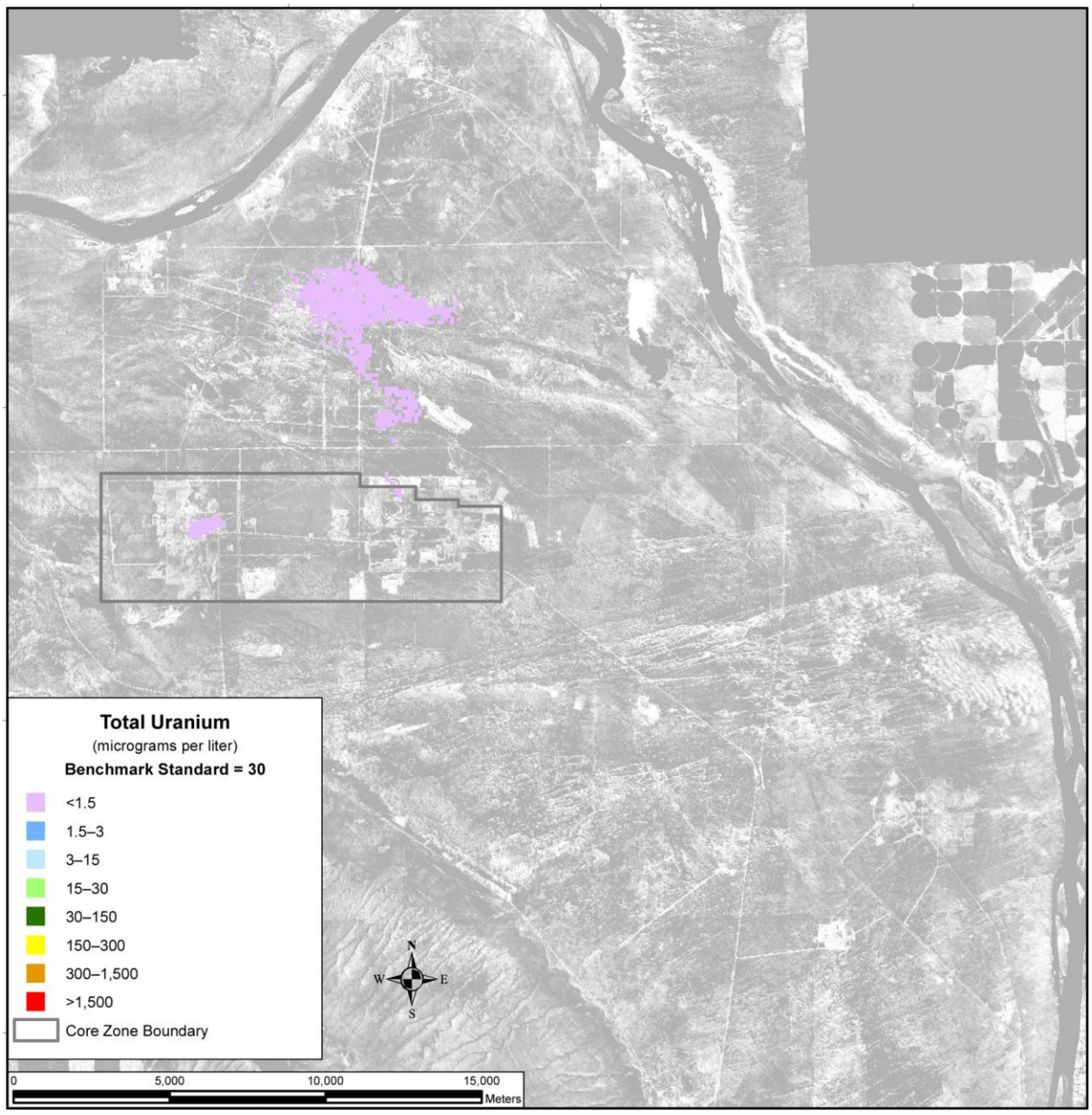
Note: To convert meters to feet, multiply by 3.281.

Figure 5–187. Tank Closure Alternative 5 Spatial Distribution of Groundwater Uranium-238 Concentration, Calendar Year 7140



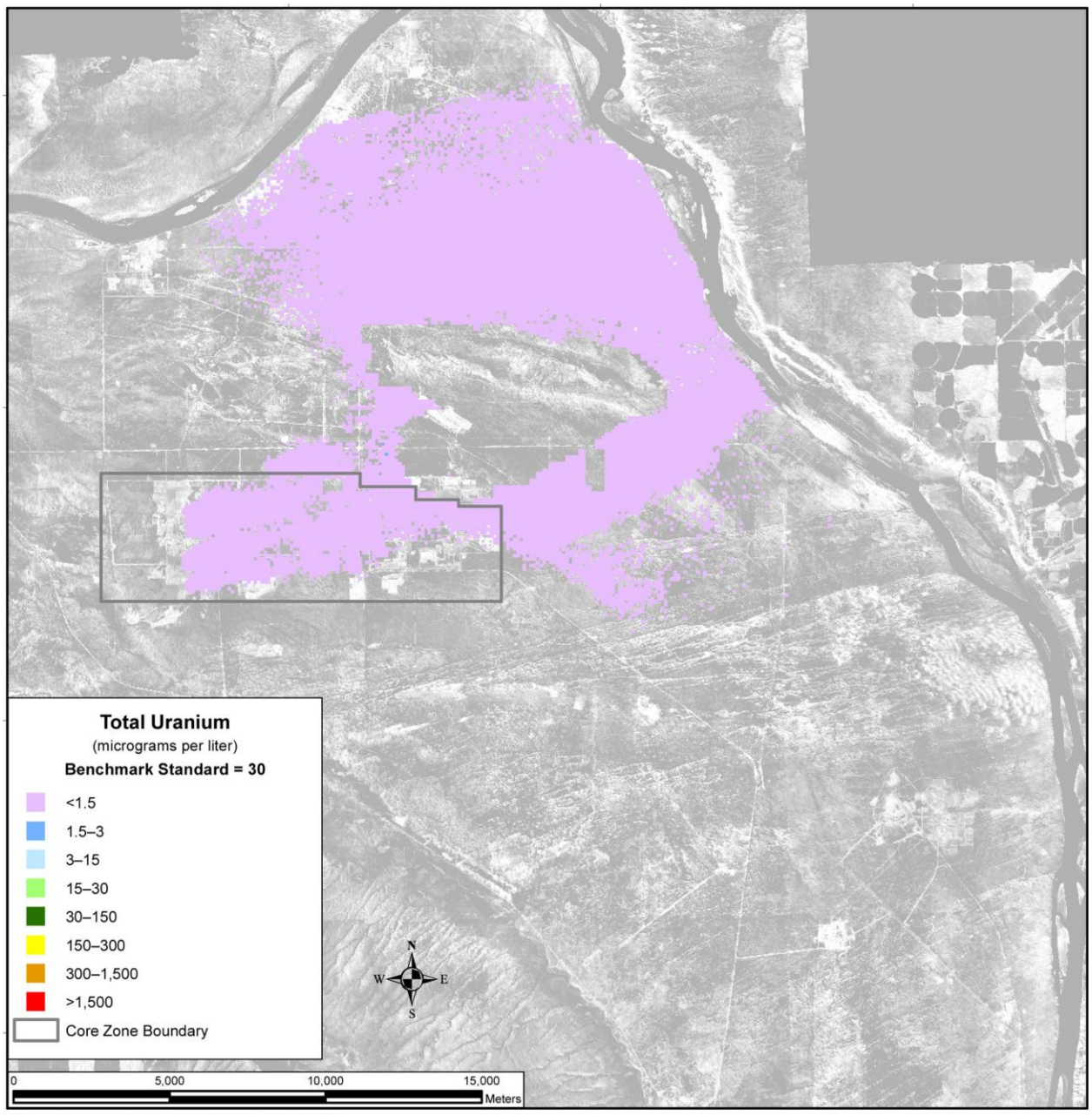
Note: To convert meters to feet, multiply by 3.281.

Figure 5–188. Tank Closure Alternative 5 Spatial Distribution of Groundwater Uranium-238 Concentration, Calendar Year 11,940



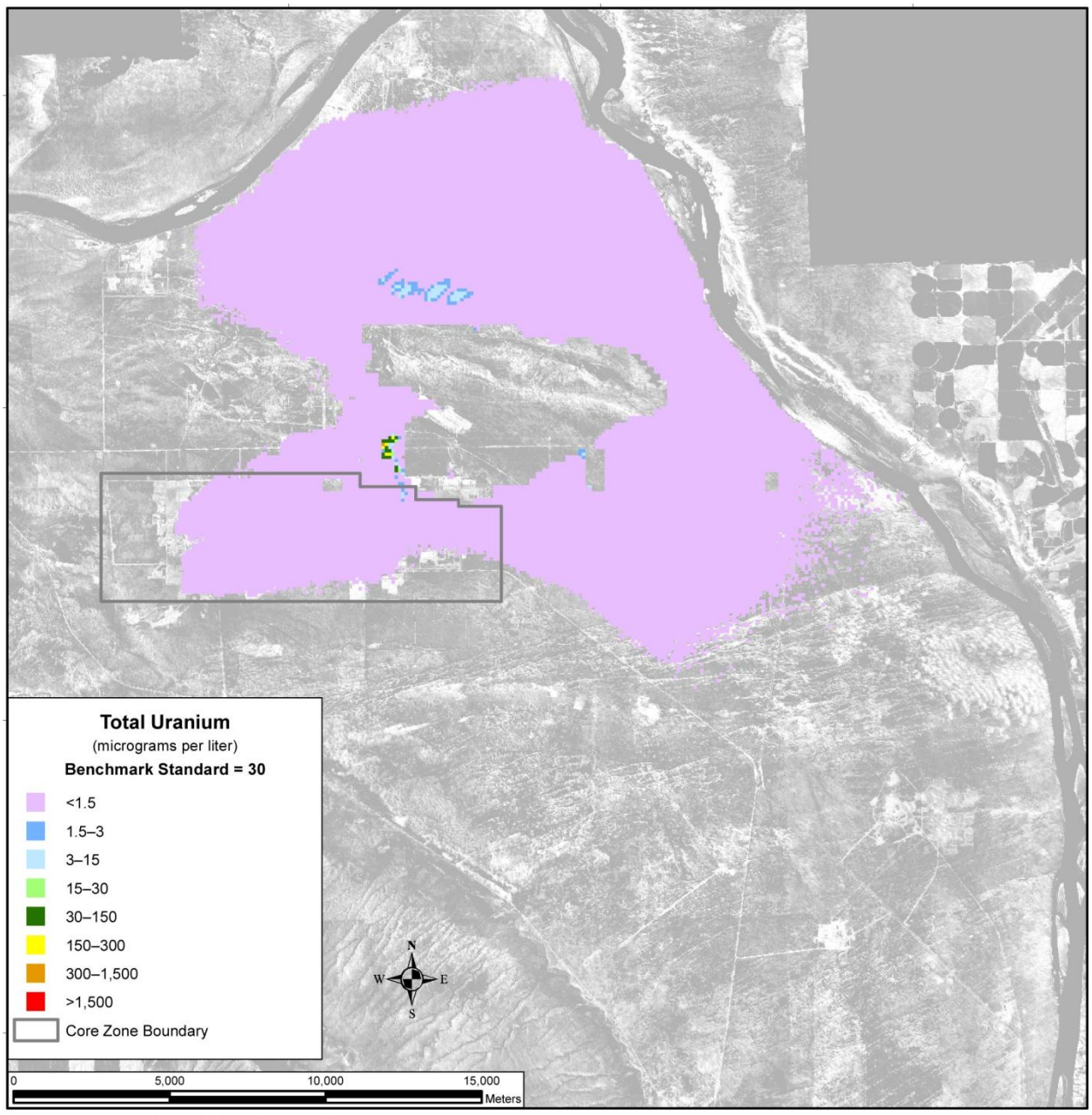
Note: To convert meters to feet, multiply by 3.281.

Figure 5–189. Tank Closure Alternative 5 Spatial Distribution of Groundwater Total Uranium Concentration, Calendar Year 2010



Note: To convert meters to feet, multiply by 3.281.

Figure 5–190. Tank Closure Alternative 5 Spatial Distribution of Groundwater Total Uranium Concentration, Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281.

Figure 5–191. Tank Closure Alternative 5 Spatial Distribution of Groundwater Total Uranium Concentration, Calendar Year 11,940

Figures 5–192 through 5–194 show the area in which groundwater iodine-129, technetium-99, and uranium-238 concentrations exceed their respective benchmark concentrations. Iodine-129 peaks early in the simulation, covering a peak area of just over 7 square kilometers (2.7 square miles) around CY 2100. This area drops below 1 square kilometer (0.4 square miles) by CY 3490. The plume then rises to about 3 square kilometers (1.2 square miles) in CY 4740, after which it declines to around 1 square kilometer (0.4 square miles) by CY 11,890. Technetium-99 shows a similar, more gradual trend, peaking at over 4 square kilometers (1.5 square miles) in CY 2100 and decreasing to less than 1 square kilometer (0.4 square miles) in CY 2890. The plume then increases to greater than 9 square kilometers (3.5 square miles) in CY 4440, declines rapidly to around 2 square kilometers (0.77 square miles), and finally levels off to around 0.3 square kilometers (0.001 square miles) by CY 11,890. Uranium-238 shows a distinctly

different pattern, without any area above the benchmark concentration until CY 8390. From CY 8390 until the end of the simulation, areas in which uranium-238 concentrations exceed the benchmark concentration slowly increase to about 0.24 square kilometers (0.1 square miles).

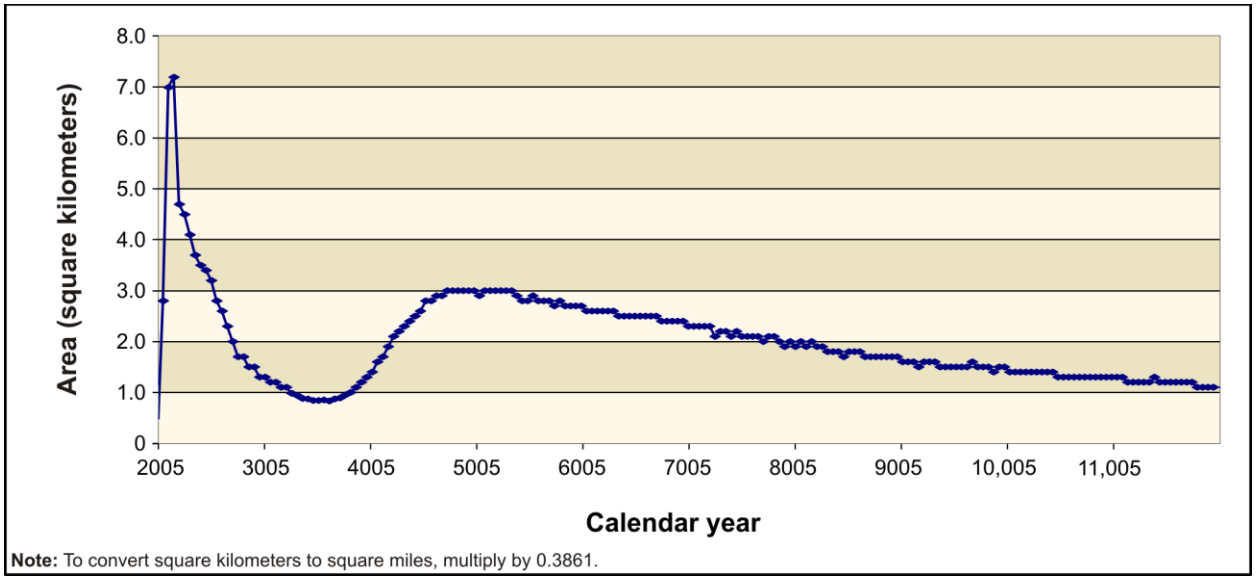


Figure 5–192. Tank Closure Alternative 5 Total Area of Groundwater Iodine-129 Concentration Exceeding the Benchmark Concentration as a Function of Time

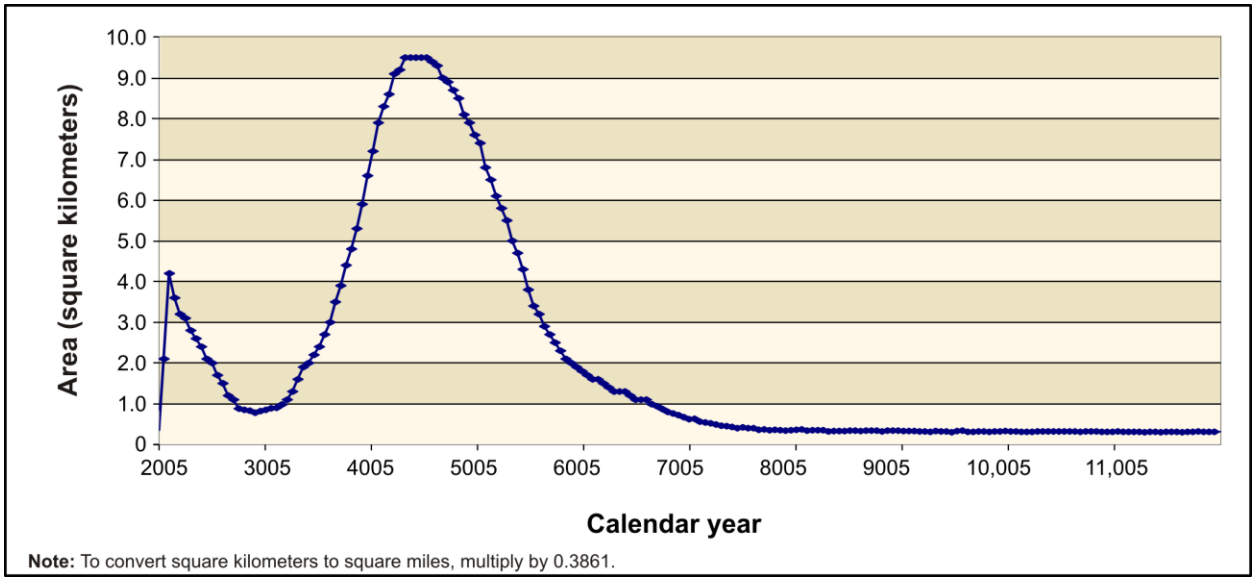


Figure 5–193. Tank Closure Alternative 5 Total Area of Groundwater Technetium-99 Concentration Exceeding the Benchmark Concentration as a Function of Time

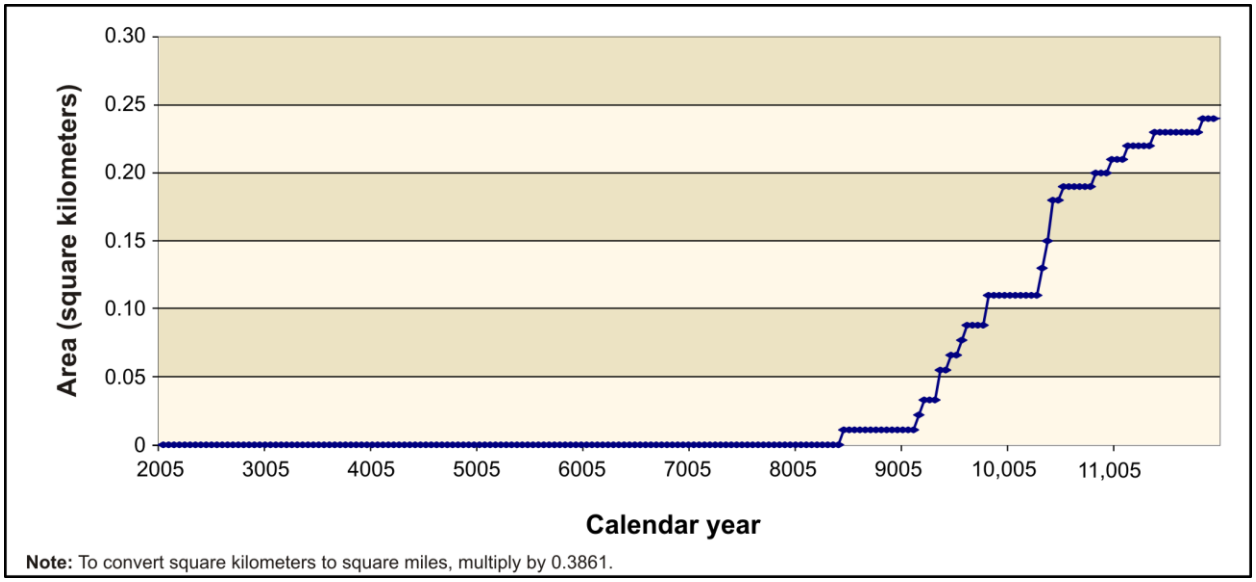


Figure 5–194. Tank Closure Alternative 5 Total Area of Groundwater Uranium-238 Concentration Exceeding the Benchmark Concentration as a Function of Time

5.1.1.8.6 Summary of Impacts

Under Tank Closure Alternative 5, concentrations of the conservative tracers at the Core Zone Boundary exceed benchmark standards by two to three orders of magnitude during the early part of the period of analysis. Tank farm residuals result in concentration peaks that exceed the benchmark concentrations early in the post–administrative control period and then continuously decline until the end of the 10,000-year analysis period. Concentrations of conservative tracers at the Columbia River nearshore approach the benchmark for a short time during the early period of analysis, but fall below the benchmark for the remainder of the period of analysis. The intensities and areas of these groundwater plumes peak around CY 2100 for iodine-129 and around CY 4440 for technetium-99.

Concentrations of tritium at the Core Zone Boundary exceed the benchmark by about one to two orders of magnitude during the first 100 years of the period of analysis. Tritium concentrations at the Columbia River nearshore 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 never exceed the benchmark concentration at the Core Zone Boundary or the Columbia River nearshore. The intensity is highest and the area of the contamination plume 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 of 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 impacts 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 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 2250. This period includes waste retrieval, WTP pretreatment and treatment, clean closure of the SST farm system, and 100 years of postclosure care. During this period, 99.9 percent of the waste would be retrieved from the tanks and all tank farms would be clean closed. Under Tank Closure Alternative 6A, Base Case, the adjacent cribs and trenches (ditches) would be covered with an engineered, modified RCRA Subtitle C barrier; under Alternative 6A, Option Case, they would be clean closed. In both cases, the highly contaminated soil would be treated at the Preprocessing Facility (PPF) and the washed soil would be disposed of in the RPPDF.

- 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, but this discussion 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 contributions 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 (Base and Option Cases) in terms of the total amount of COPCs released to the vadose zone, groundwater, and the Columbia River during the 10,000-year period of analysis. Releases of radionuclides are totaled in curies; chemicals, in kilograms (see Figures 5–195 through 5–206). Three subtotals are plotted, representing releases from cribs and trenches (ditches), past leaks, and other tank farm sources (e.g., tank residuals, ancillary equipment). Note that the release amounts are plotted on a logarithmic scale to facilitate visual comparison of releases that vary over four orders of magnitude within the same series of figures.

Figure 5–195 shows the estimated release to the vadose zone of the radiological risk drivers under the Base Case, which would include use of a modified RCRA Subtitle C barrier, and Figure 5–196, the chemical hazard drivers. The predominant sources of 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 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.

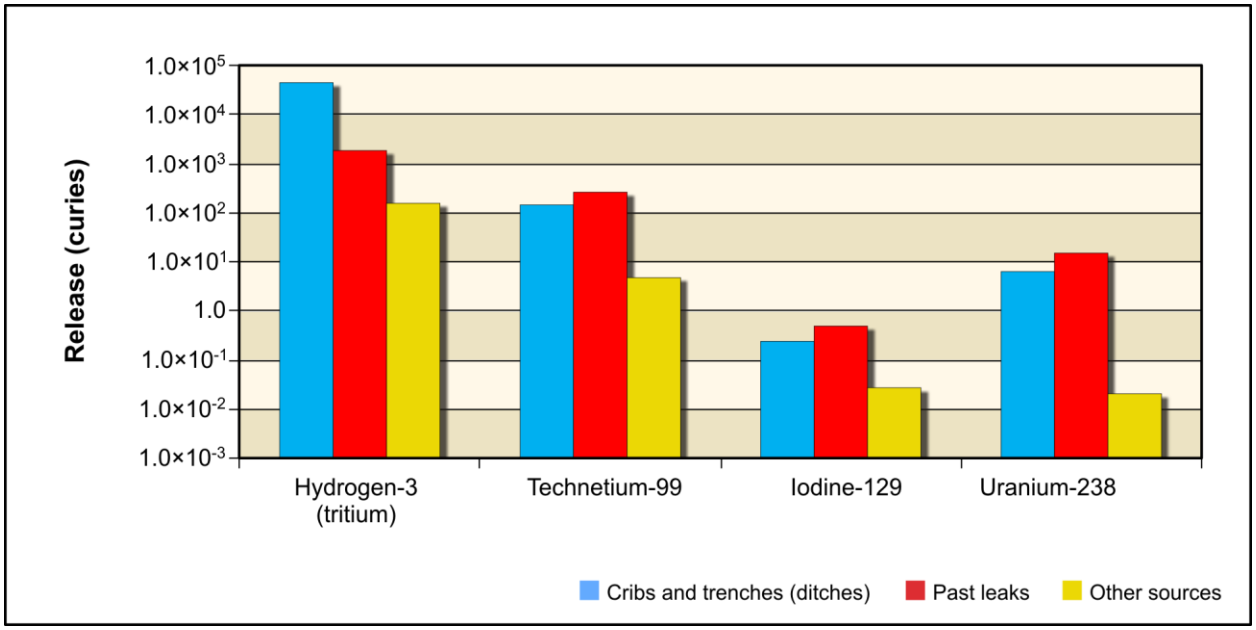


Figure 5–195. Tank Closure Alternative 6A, Base Case, Releases of Radioactive Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

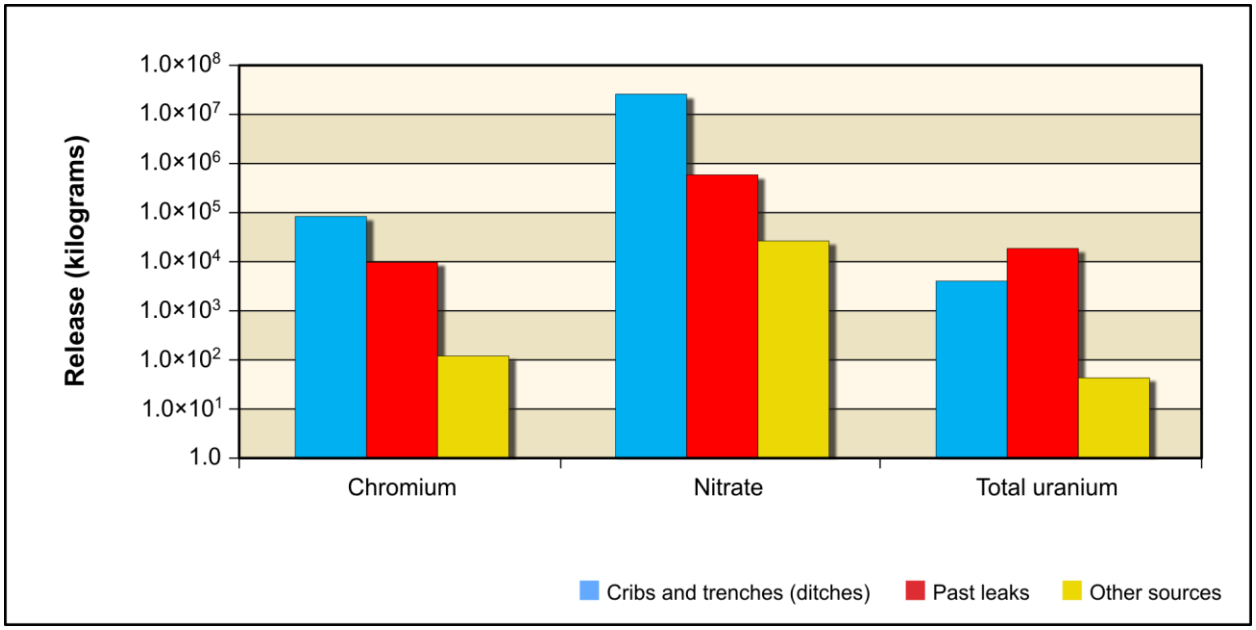


Figure 5–196. Tank Closure Alternative 6A, Base Case, Releases of Chemical Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

Figure 5–197 shows the estimated release to the vadose zone of the radiological risk drivers under the Option Case, which would include clean closure of cribs and trenches (ditches), and Figure 5–198, the chemical hazard drivers. The predominant sources of 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.

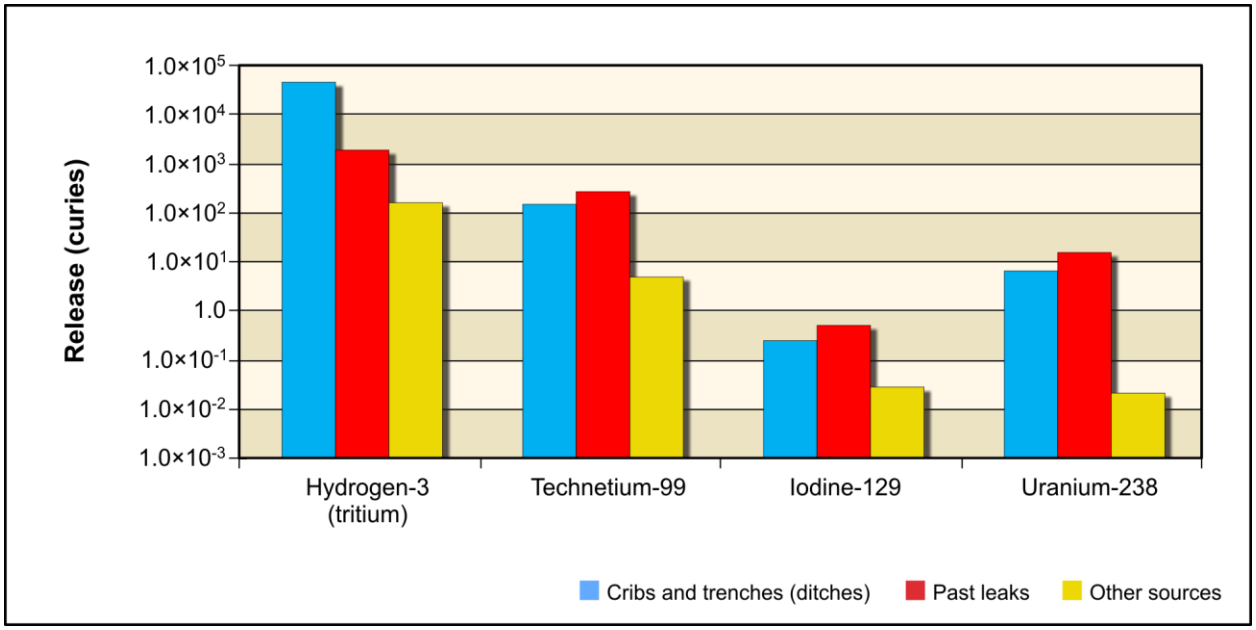


Figure 5–197. Tank Closure Alternative 6A, Option Case, Releases of Radioactive Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

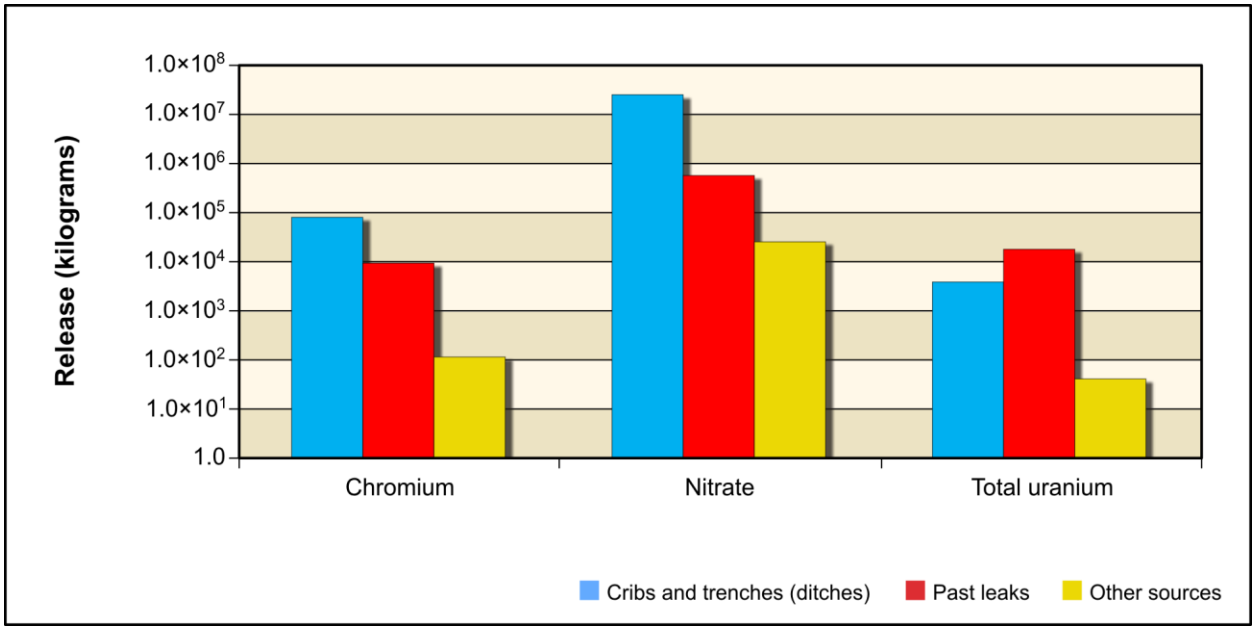


Figure 5–198. Tank Closure Alternative 6A, Option Case, Releases of Chemical Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

Figure 5–199 shows the estimated release to groundwater of the radiological risk drivers under the Base Case and Figure 5–200, 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 for cribs and trenches (ditches) and past leaks. For other tank farm sources, only about 40 percent, at most, is released to groundwater.

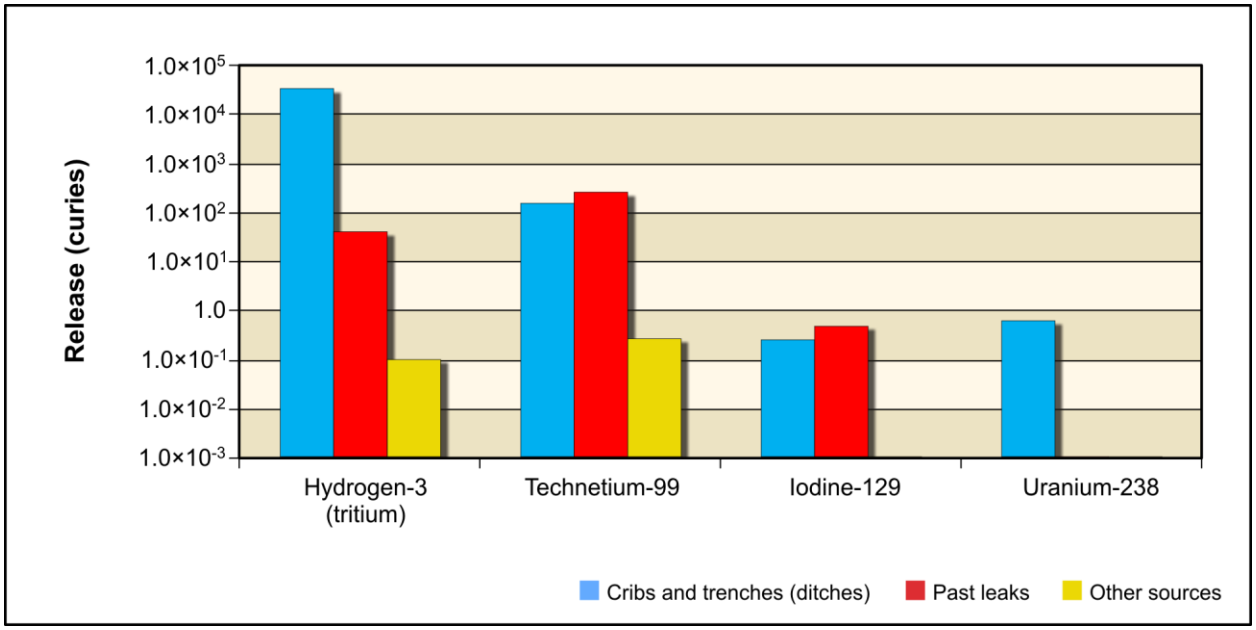


Figure 5–199. Tank Closure Alternative 6A, Base Case, Releases of Radioactive Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

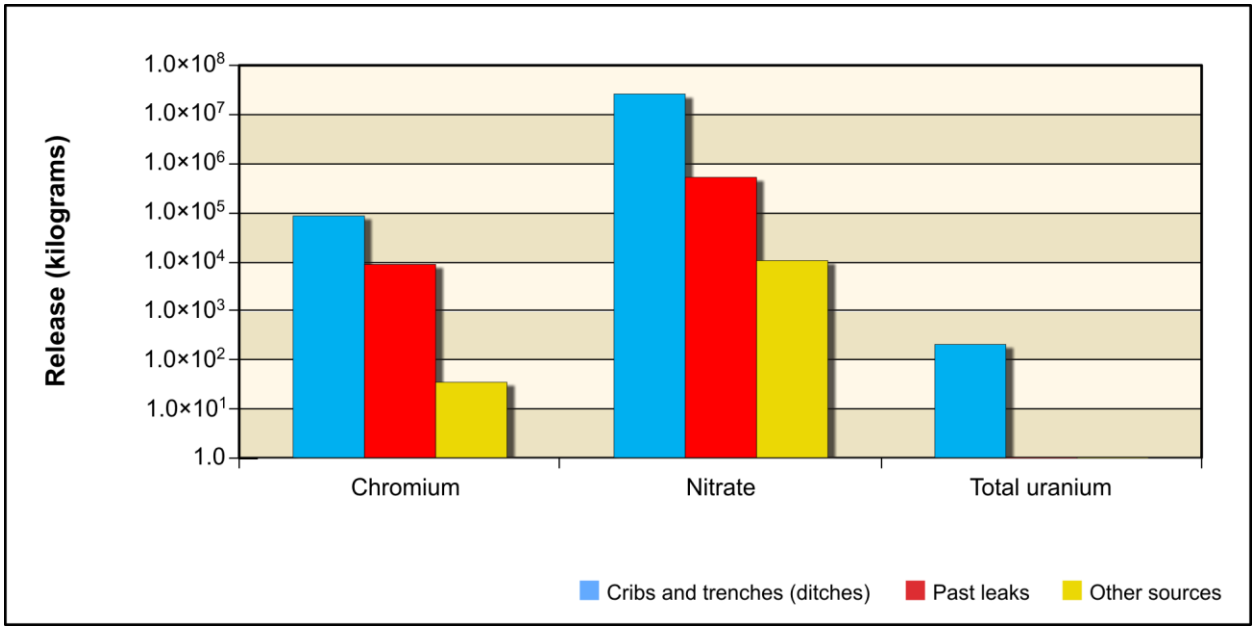


Figure 5–200. Tank Closure Alternative 6A, Base Case, Releases of Chemical Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

For uranium-238 and total uranium under the Base Case, the amount released to groundwater is less than that released to the vadose zone because of retardation. The amount of attenuation depends on the rate of moisture movement through the vadose zone. For releases from 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 uranium-238 and 5 percent of the total uranium reach groundwater during the period of analysis; for past leaks and other sources, essentially none of the total inventory reaches groundwater during the period of analysis.

For tritium under the Base Case, the amount released to groundwater is attenuated by radioactive decay. For cribs and trenches (ditches), about 71 percent of the total inventory reaches groundwater in the analysis; for past leaks, only 2 percent reaches groundwater; and for other sources, less than one-tenth of 1 percent reaches 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 on groundwater would occur later in the post–administrative control period because of the long travel times in the vadose zone for these COPCs.

Figure 5–201 shows the estimated release to groundwater of the radiological risk drivers under the Option Case and Figure 5–202, 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 13 to 30 percent less than the amount released to the vadose zone.

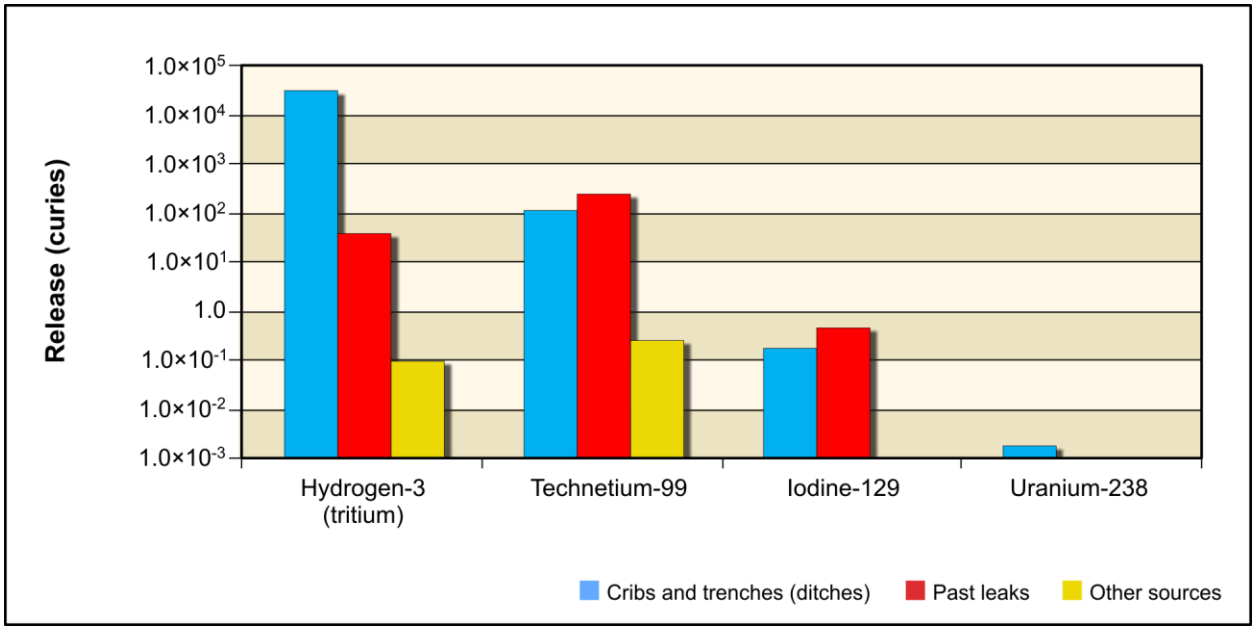


Figure 5–201. Tank Closure Alternative 6A, Option Case, Releases of Radioactive Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

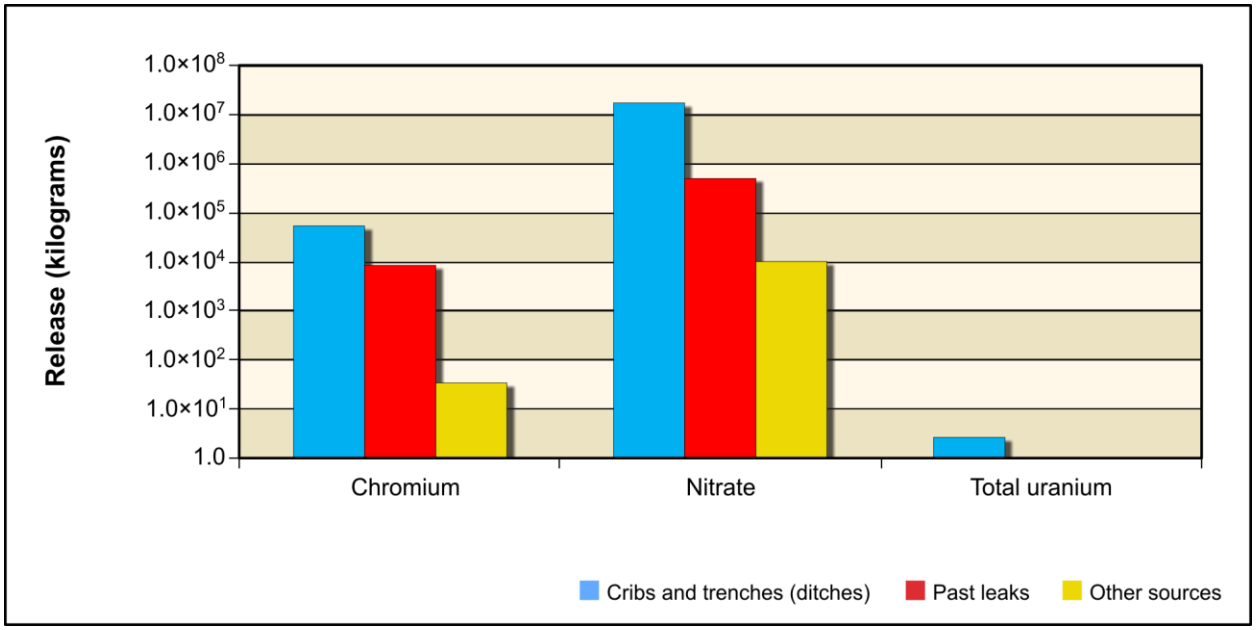


Figure 5–202. Tank Closure Alternative 6A, Option Case, Releases of Chemical Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

For uranium-238 and total uranium under the Option Case, the amount released to groundwater is less than that released 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 releases from cribs and trenches (ditches), where moisture movement through the vadose zone is relatively rapid (because of the volume of water associated with the source), less than one-tenth of 1 percent of the total inventory reaches groundwater during the period of analysis. For past leaks and other tank farm sources, essentially none of the total inventory reaches groundwater during the period of analysis.

For tritium under the Option Case, the amount released to groundwater is attenuated by radioactive decay. For cribs and trenches (ditches), about 71 percent of the total inventory reaches groundwater in the analysis; for past leaks, only 2 percent reaches groundwater; and for other sources, essentially no tritium reaches 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 on groundwater 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 5–203 shows the estimated release to the Columbia River of the radiological risk drivers under the Base Case and Figure 5–204, 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.

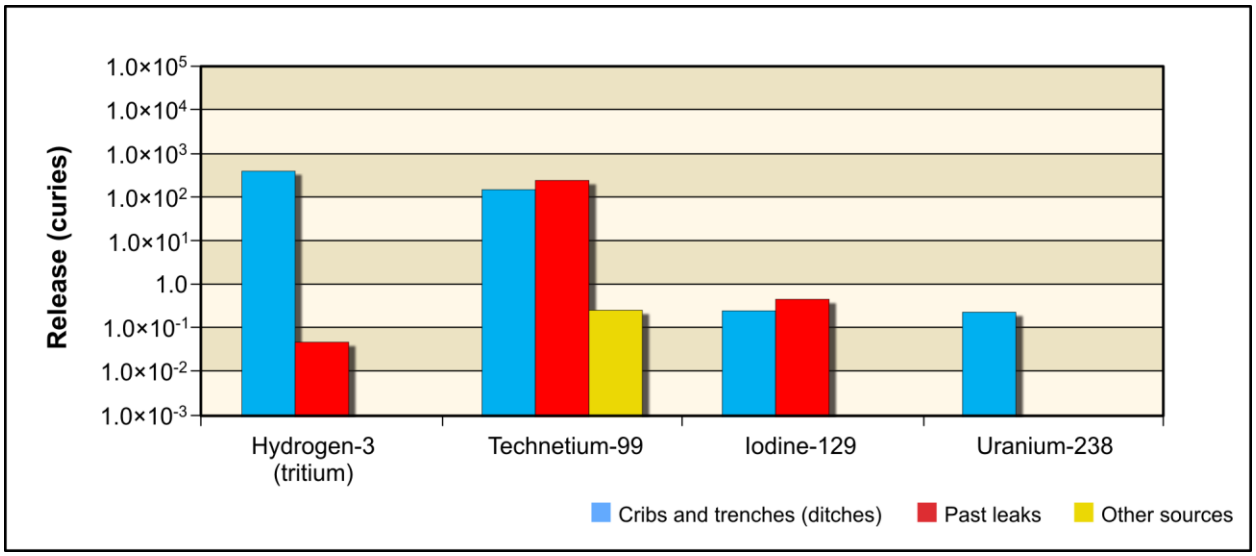


Figure 5–203. Tank Closure Alternative 6A, Base Case, Releases of Radioactive Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

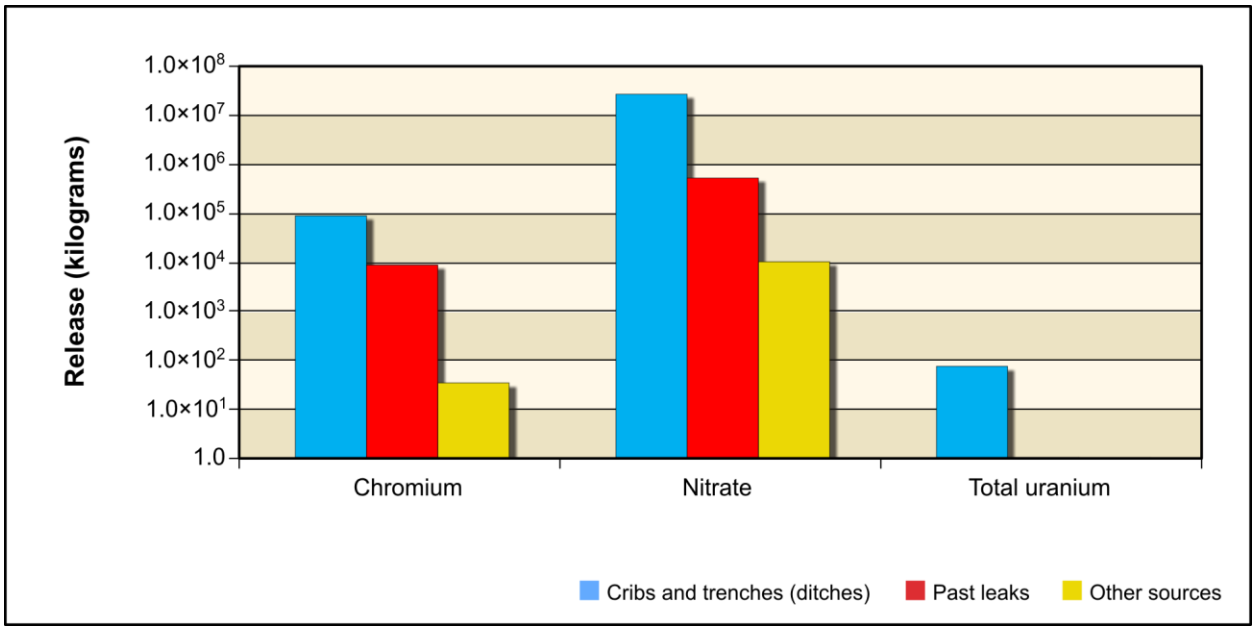


Figure 5–204. Tank Closure Alternative 6A, Base Case, Releases of Chemical Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

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

For tritium under the Base Case, the amount released to the Columbia River is attenuated by radioactive decay. For cribs and trenches (ditches), only about 1 percent of the tritium released to groundwater reaches the Columbia River. For past leaks and other sources, less than 1 percent of the tritium released to groundwater reaches 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 5–205 shows the estimated release to the Columbia River of the radiological risk drivers under the Option Case and Figure 5–206, 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 groundwater is effectively zero, as essentially no uranium reaches 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 1 percent of the tritium released to groundwater reaches the Columbia River in the analysis. For past leaks and other sources, less than 1 percent of the tritium released to groundwater reaches 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.

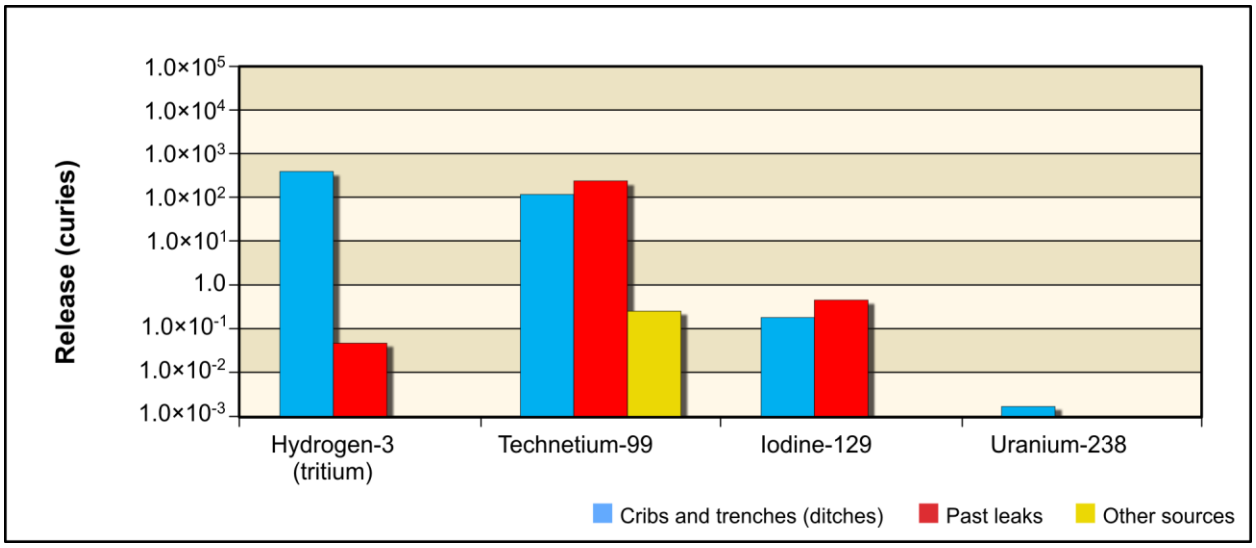


Figure 5–205. Tank Closure Alternative 6A, Option Case, Releases of Radioactive Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

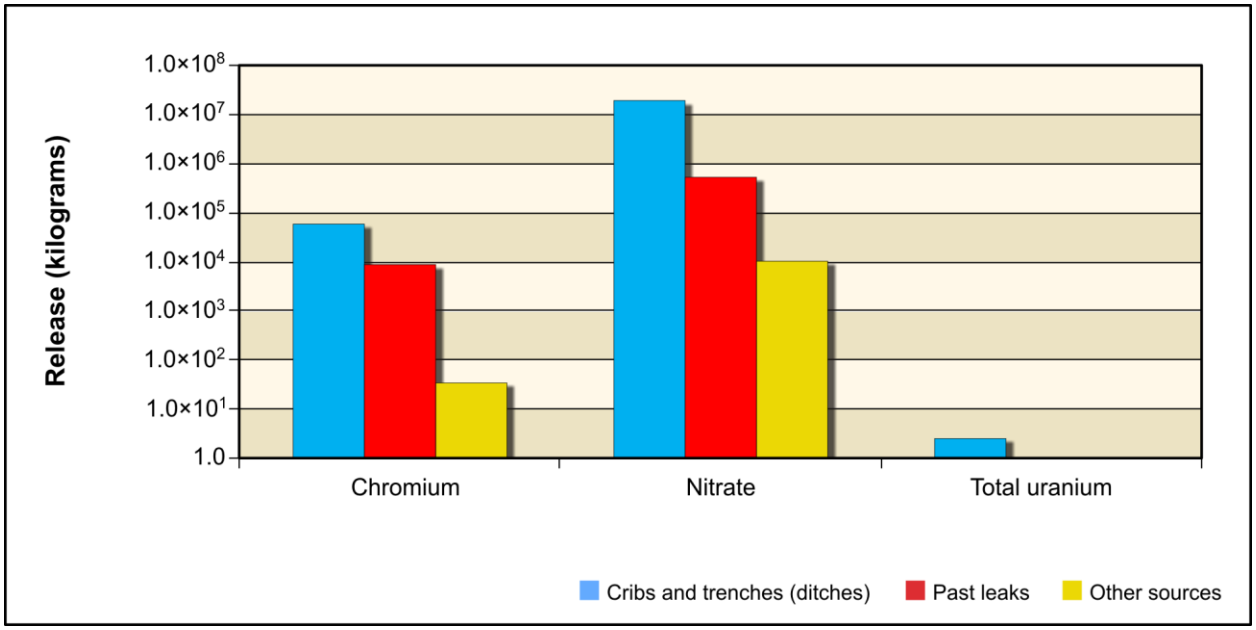


Figure 5–206. Tank Closure Alternative 6A, Option Case, Releases of Chemical Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

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 nearshore. Concentrations of radionuclides are in picocuries per liter; chemicals, in micrograms per liter (see Tables 5–12 and 5–13 and Figures 5–207 through 5–220). The benchmark concentration of each radionuclide and chemical is also shown. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over five orders of magnitude. Tables 5–12 and 5–13 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. Under Tank Closure Alternative 6A, Base Case, tritium, uranium-238, and total uranium never exceed their benchmark concentrations at any location beyond CY 2050. The highest impact areas are the B, S, and T Barriers and the Core Zone Boundary, where concentrations of technetium-99, iodine-129, chromium, and nitrate peak above their benchmark concentration values. At the Columbia River nearshore, iodine-129 approaches, but does not peak above the benchmark concentration after CY 2050. The maximum concentrations at the tank farm barriers, Core Zone Boundary, and Columbia River nearshore under the Option Case are similar to those under the Base Case.

Figure 5–207 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 one to two orders of magnitude for a short period of time during the early part of the period of analysis. This time period is represented by the first series of sharp inflections in the curve for the Core Zone Boundary from approximately CY 1955 until CY 1980. During the same period of time, the Columbia River nearshore concentrations approach but never reach the benchmark concentration. Because the half-life of tritium is less than 13 years, radioactive decay rapidly attenuates groundwater concentration.

The concentration versus time for tritium under the Option Case is essentially identical to that under the Base Case (see Figure 5–208).

Table 5–12. 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 (picocuries per liter)								
Hydrogen-3 (tritium)	7 (2050)	572 (2052)	31 (2050)	2,870 (2050)	14 (2050)	628 (2051)	477 (2051)	20,000
Technetium-99	**963** (2103)	**3,480** (2056)	**1,480** (2052)	**6,530** (2050)	138 (2067)	**3,480** (2056)	382 (2251)	900
Iodine-129	**1.9** (2100)	**4.8** (2092)	**2.9** (2050)	**12.6** (2050)	0.2 (2071)	**4.8** (2092)	0.7 (2265)	1
Chemical (micrograms per liter)								
Chromium	83 (2168)	**214** (2050)	**156** (2050)	**354** (2045)	6 (2050)	**214** (2050)	71 (2076)	100
Nitrate	16,800 (2172)	**171,000** (2055)	4,630 (2051)	**62,000** (2053)	413 (2050)	**171,000** (2055)	17,200 (2122)	45,000

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 5–13. 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 (picocuries per liter)								
Hydrogen-3 (tritium)	8 (2050)	455 (2057)	31 (2050)	2,390 (2043)	14 (2050)	660 (2050)	501 (2050)	20,000
Technetium-99	**963** (2103)	**3,650** (2066)	**1,480** (2052)	**6,530** (2050)	138 (2067)	**3,650** (2066)	396 (2239)	900
Iodine-129	**1.9** (2100)	**4.8** (2092)	**2.9** (2050)	**12.6** (2050)	0.2 (2071)	**4.8** (2092)	0.8 (2265)	1
Chemical (micrograms per liter)								
Chromium	80 (2164)	**208** (2050)	**156** (2050)	**339** (2050)	6 (2050)	**208** (2050)	64 (2076)	100
Nitrate	17,400 (2164)	**188,000** (2051)	4,630 (2051)	**63,000** (2050)	413 (2050)	**188,000** (2051)	17,400 (2146)	45,000

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.

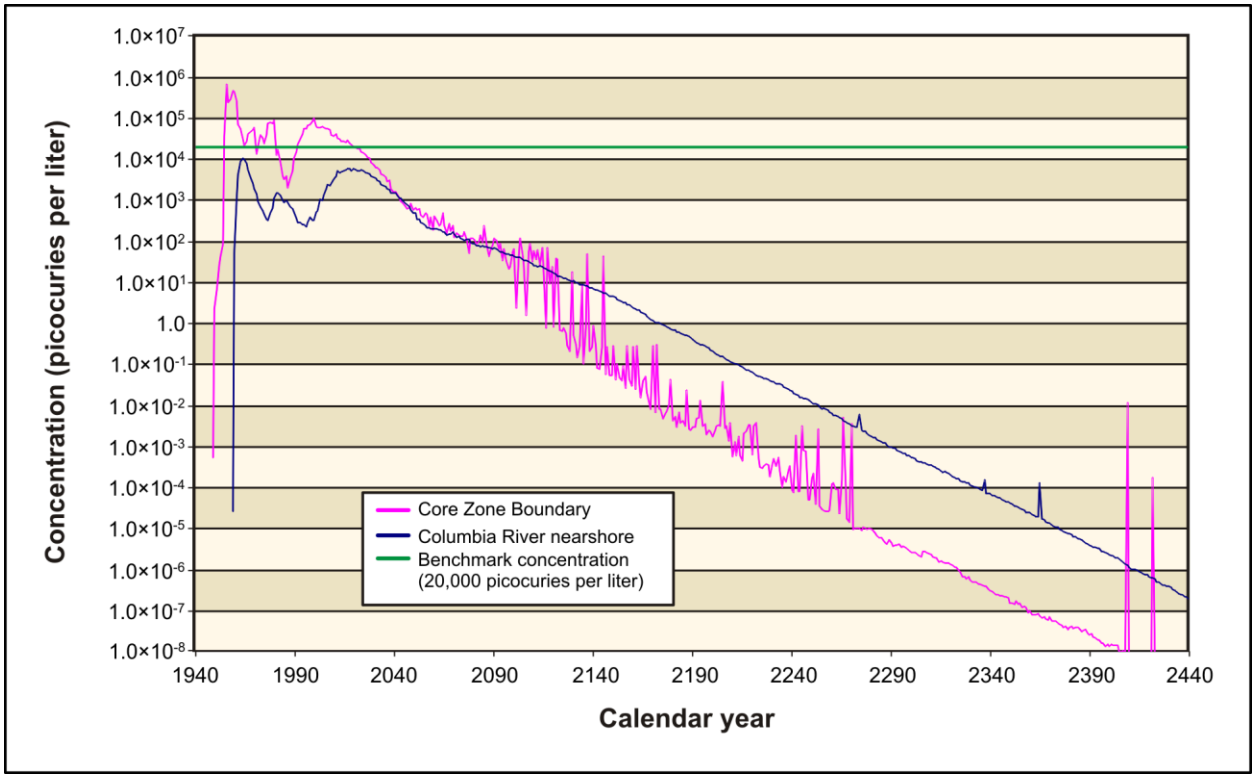


Figure 5–207. Tank Closure Alternative 6A, Base Case, Hydrogen-3 (Tritium) Concentration Versus Time

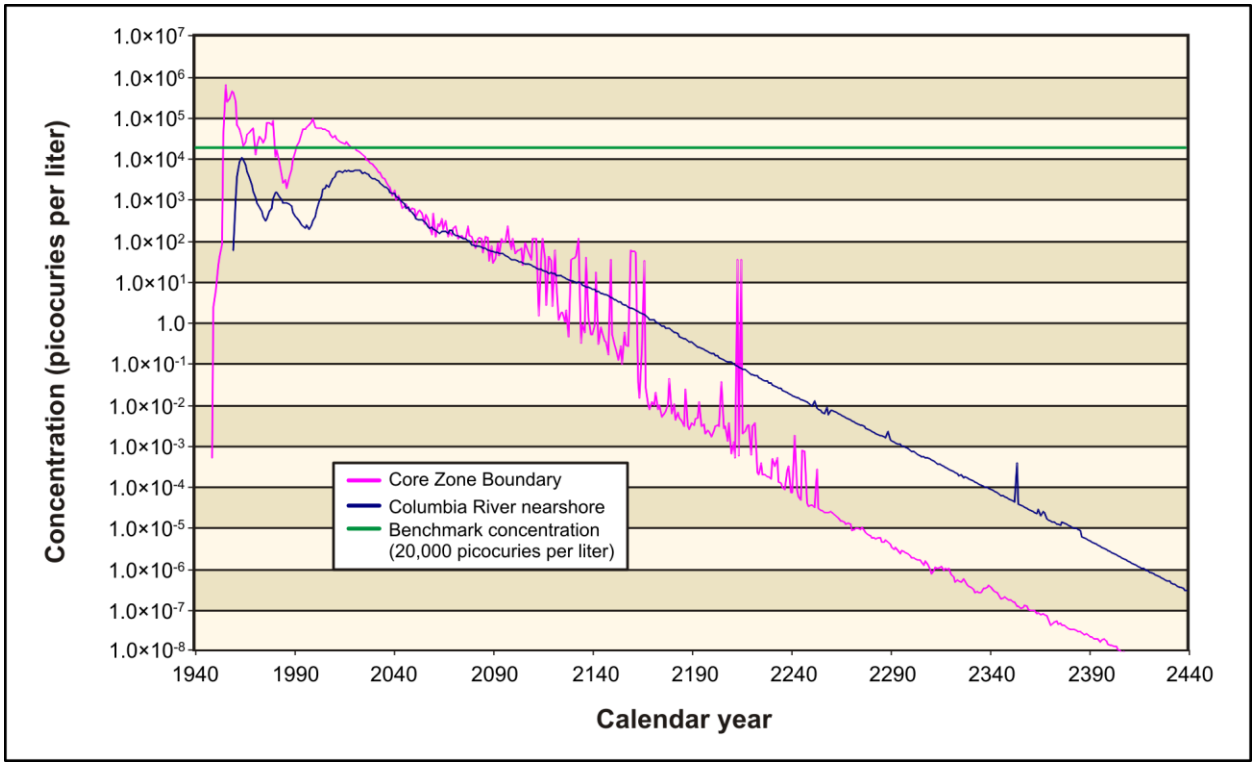


Figure 5–208. Tank Closure Alternative 6A, Option Case, Hydrogen-3 (Tritium) Concentration Versus Time

Figures 5–209 through 5–212 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 at the Core Zone Boundary to exceed benchmark concentrations by one to two orders of magnitude during the early part of the period of analysis, around CY 1956. The concentrations at the Columbia River nearshore approach the benchmark for a brief time during the early period of analysis but decrease to about two to three orders of magnitude below the benchmark by the end of the period of analysis.

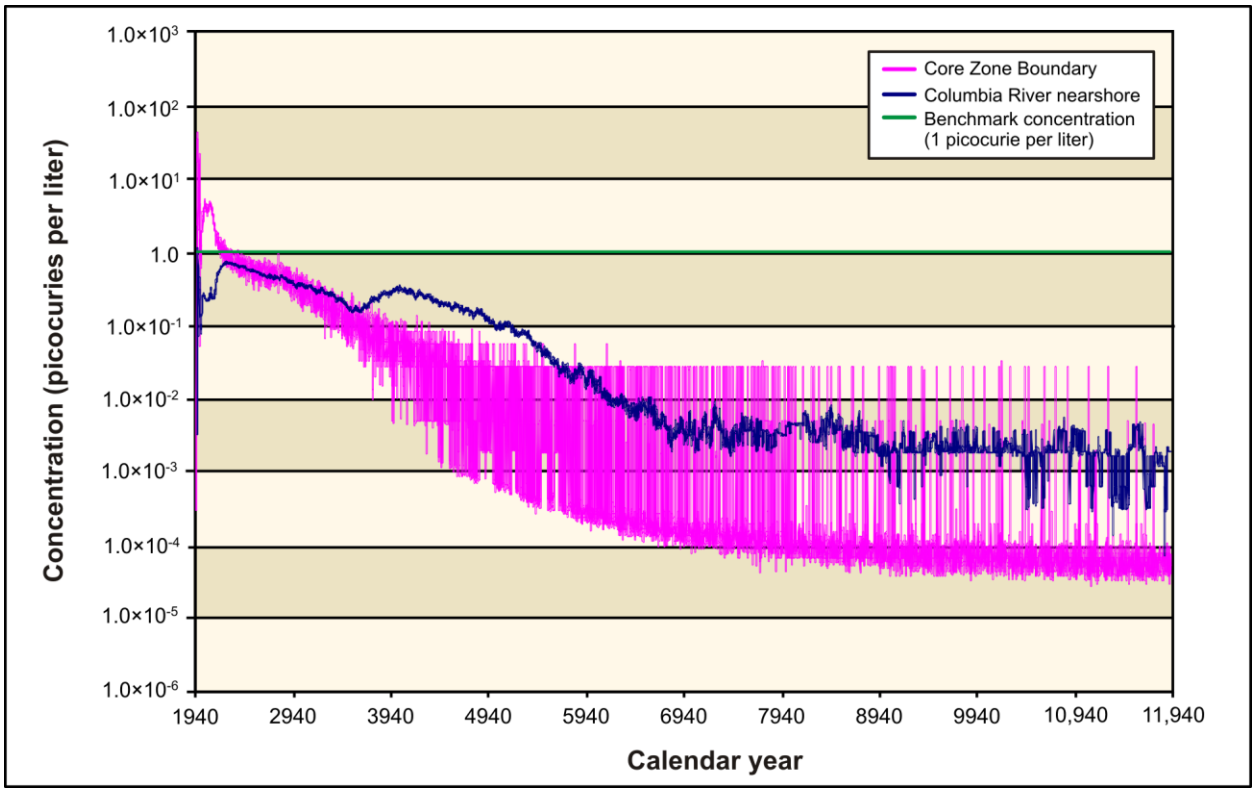


Figure 5–209. Tank Closure Alternative 6A, Base Case, Iodine-129 Concentration Versus Time

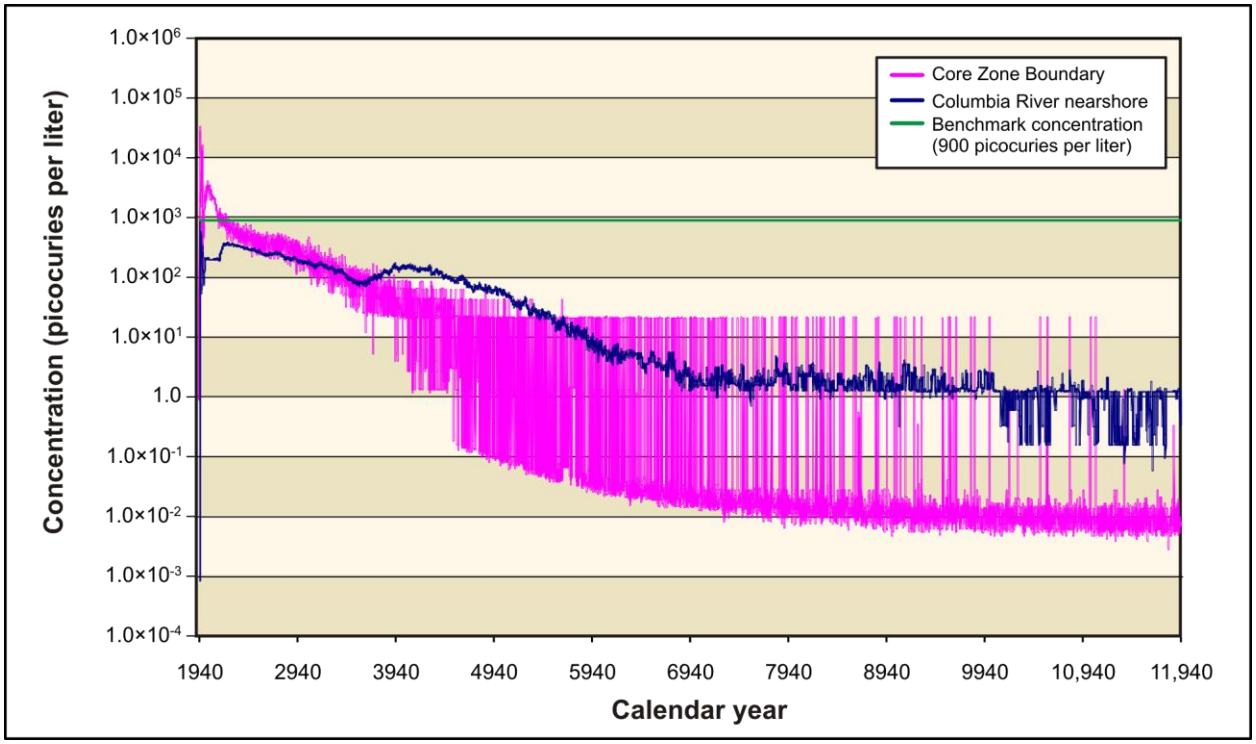


Figure 5–210. Tank Closure Alternative 6A, Base Case, Technetium-99 Concentration Versus Time

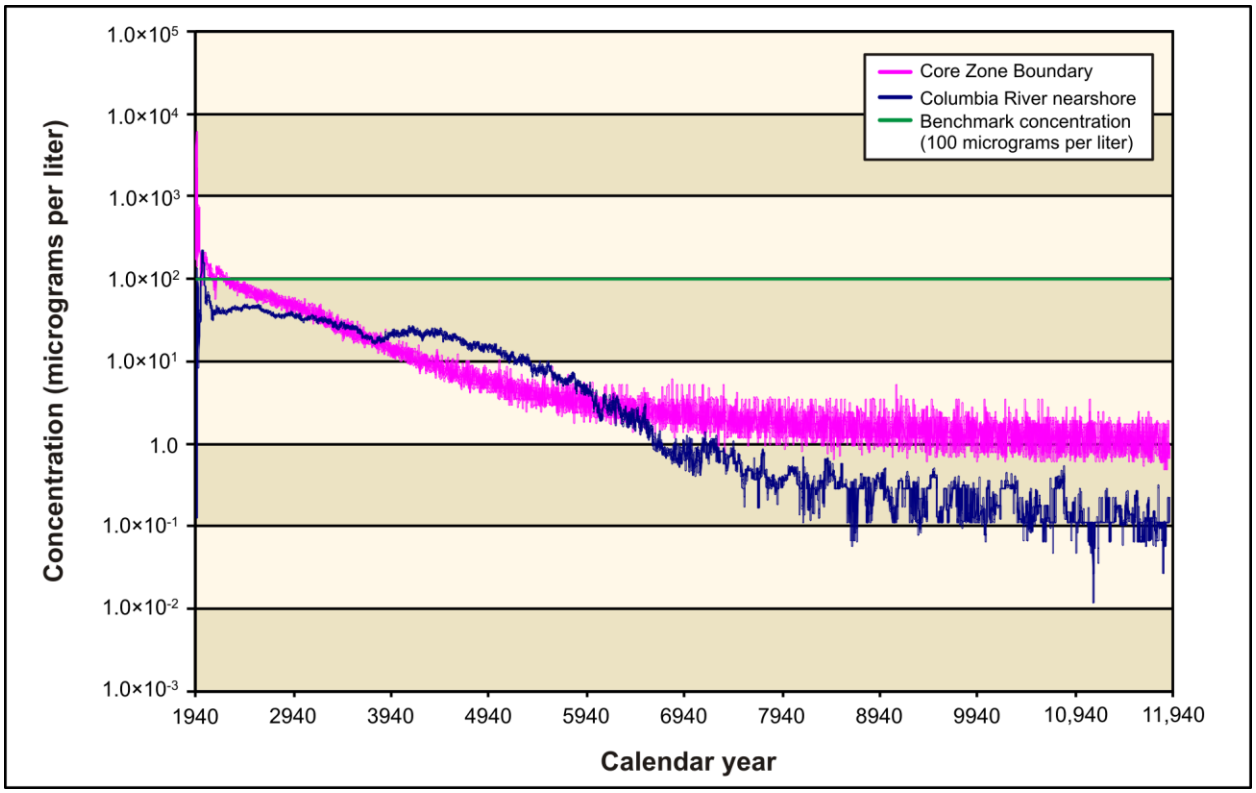


Figure 5–211. Tank Closure Alternative 6A, Base Case, Chromium Concentration Versus Time

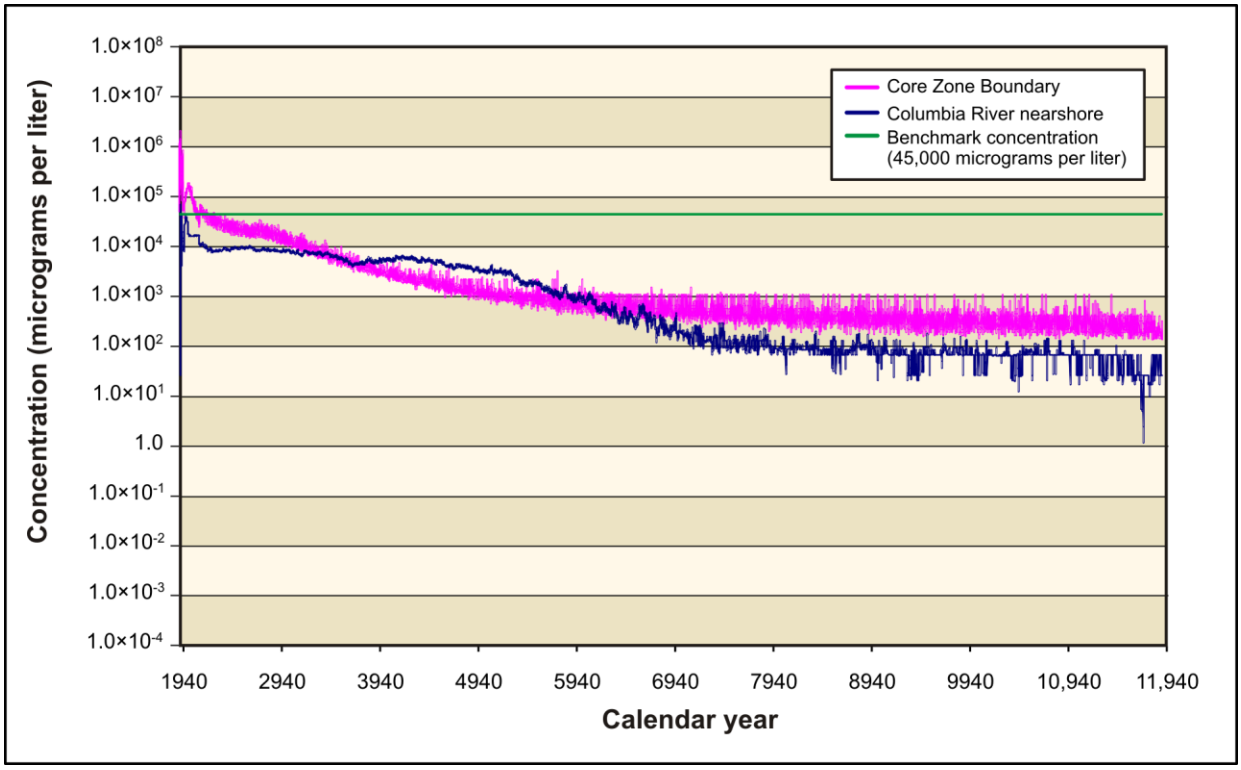


Figure 5–212. Tank Closure Alternative 6A, Base Case, Nitrate Concentration Versus Time

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 during the early part of the period of analysis. Differences arise around CY 3000 when, as a result of clean closure of the cribs and trenches (ditches), the concentrations at the Core Zone Boundary begin to decrease at a much faster rate than under the Base Case. Concentrations range over seven orders of magnitude below the benchmark by the end of the period of analysis (see Figures 5–213 through 5–216).

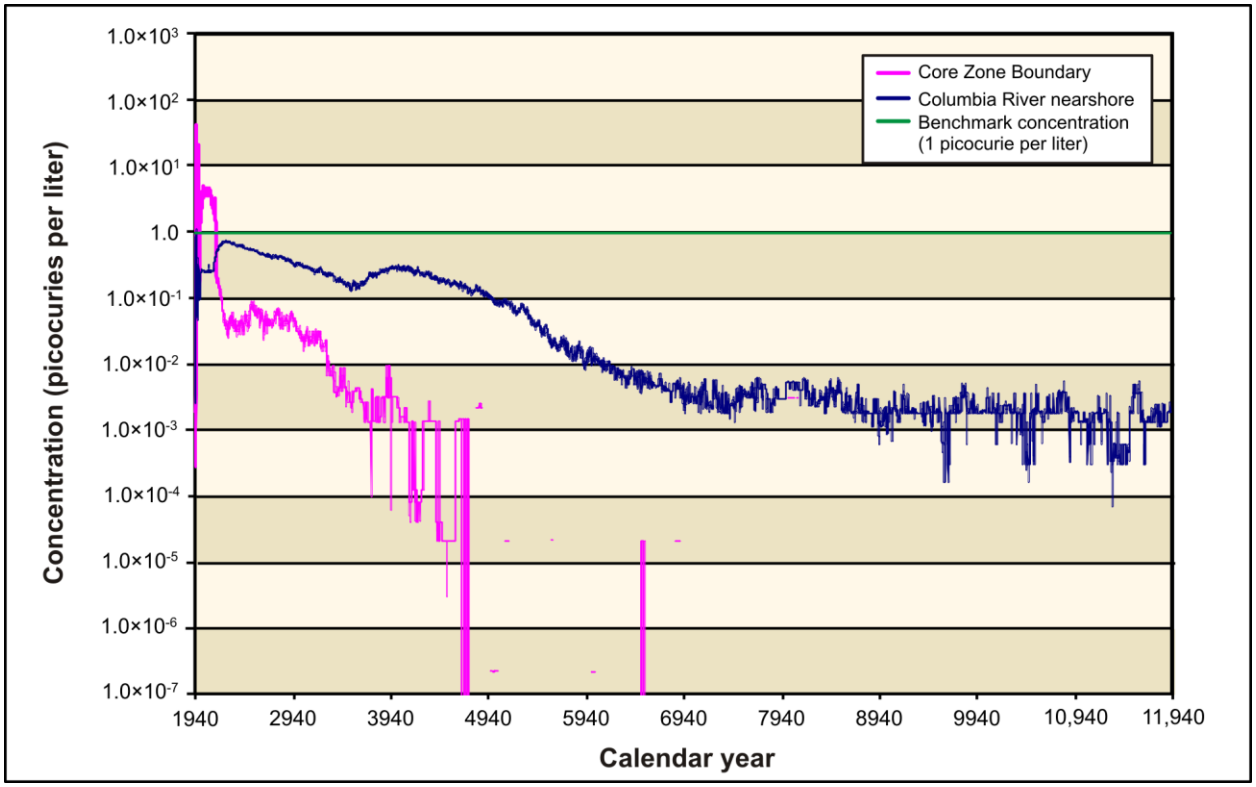


Figure 5–213. Tank Closure Alternative 6A, Option Case, Iodine-129 Concentration Versus Time

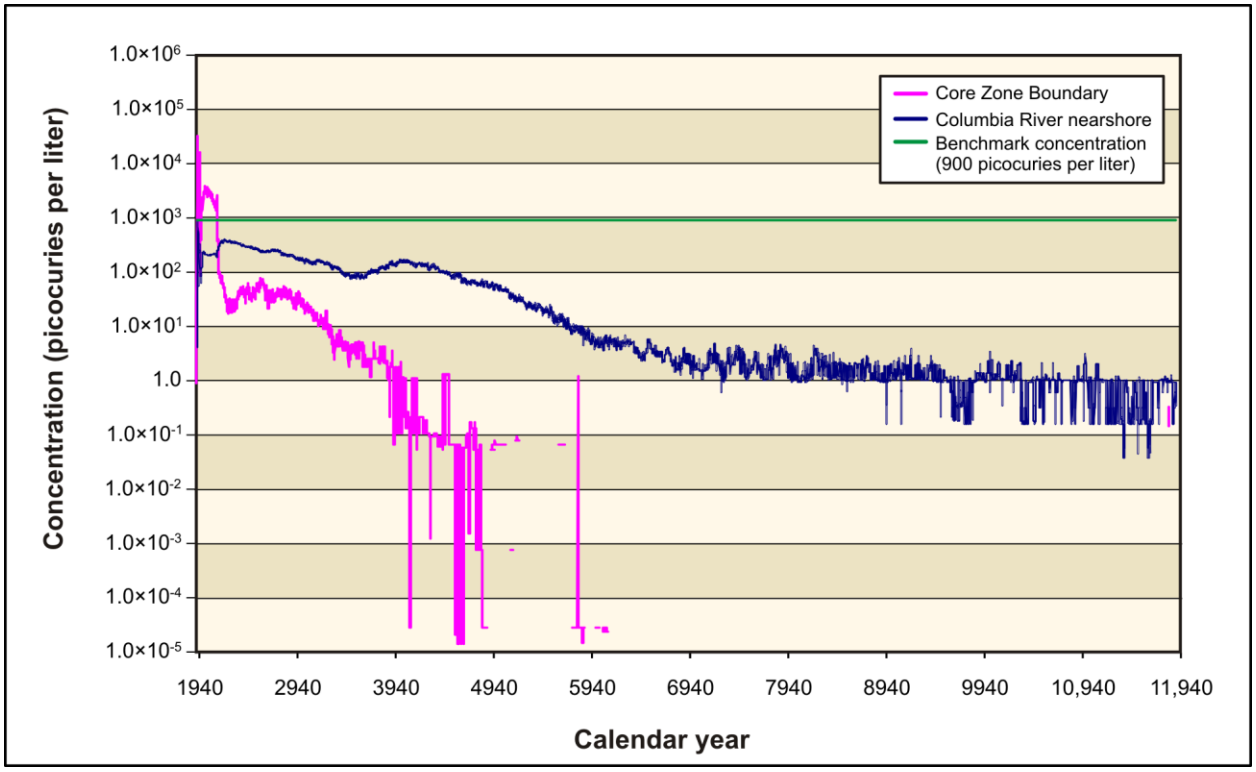


Figure 5–214. Tank Closure Alternative 6A, Option Case, Technetium-99 Concentration Versus Time

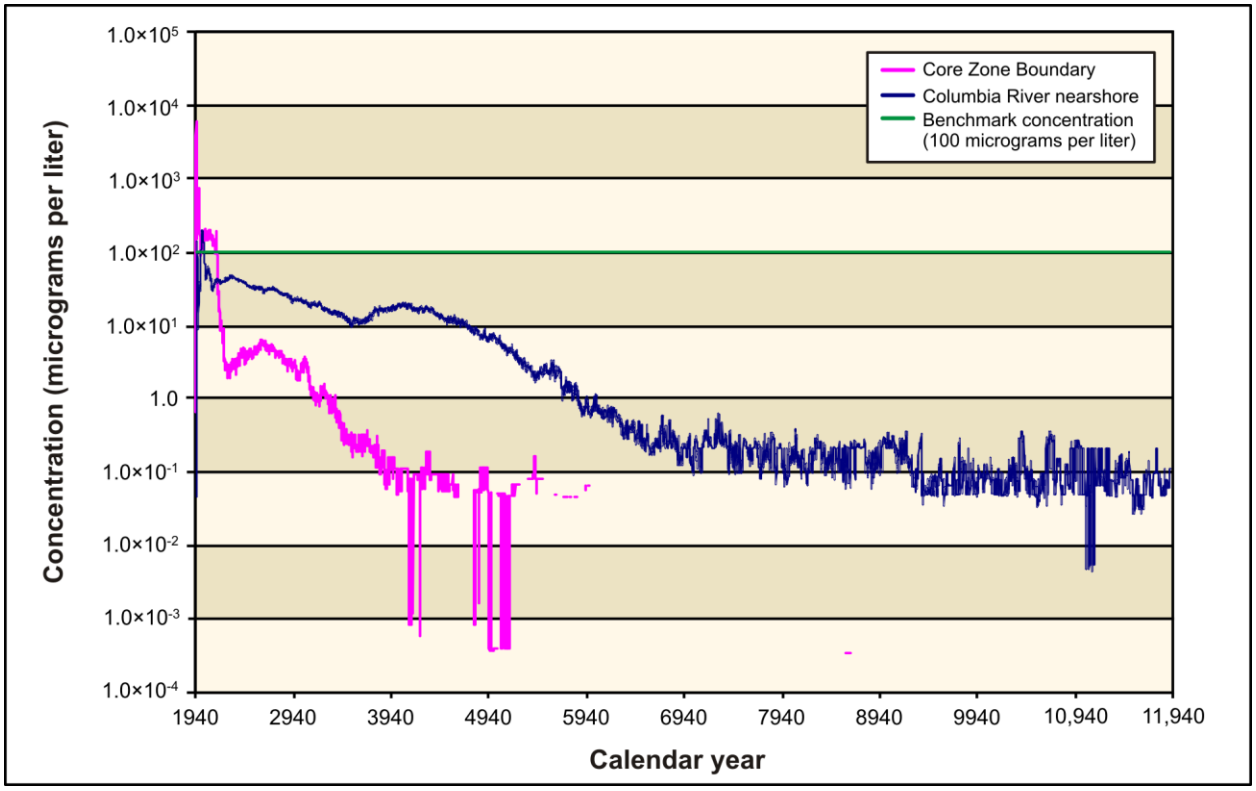


Figure 5–215. Tank Closure Alternative 6A, Option Case, Chromium Concentration Versus Time

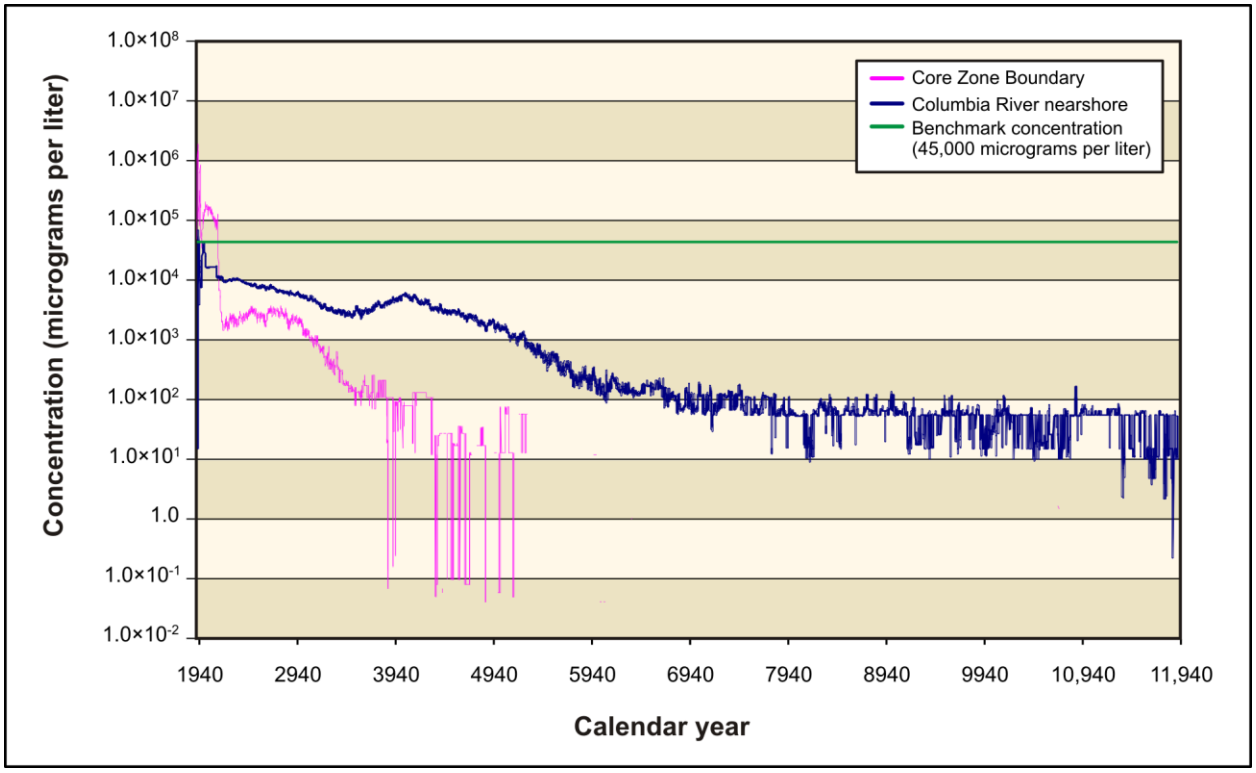


Figure 5–216. Tank Closure Alternative 6A, Option Case, Nitrate Concentration Versus Time

Figures 5–217 and 5–218 show concentration versus time for uranium-238 and total uranium under the Base Case. Although uranium-238 concentrations at the Core Zone Boundary begin to approach the benchmark concentration toward the latter part of the period of analysis, they never reach it. Total uranium concentrations at the Core Zone Boundary also begin to increase toward the end of the period of analysis but never come to within one order of magnitude of the benchmark. The concentration levels of uranium-238 and total uranium at the Columbia River nearshore never come to within about two orders of magnitude below the benchmark.

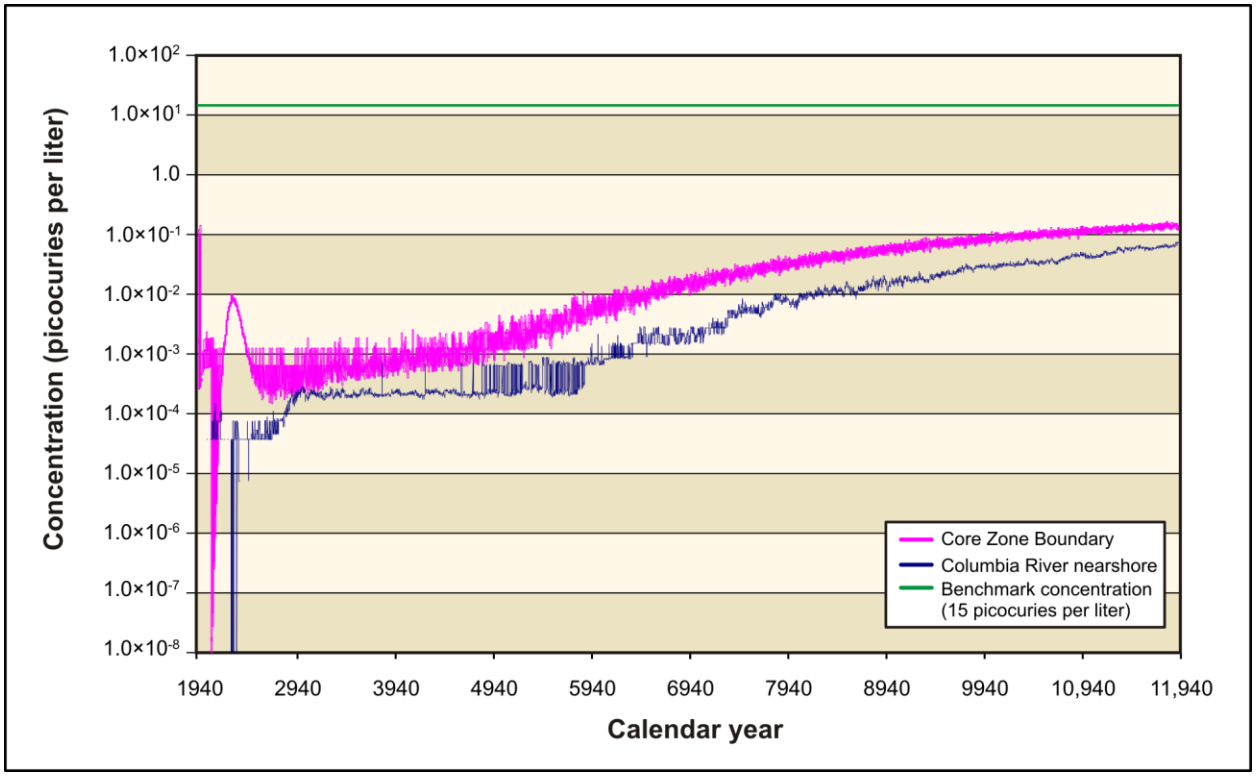


Figure 5–217. Tank Closure Alternative 6A, Base Case, Uranium-238 Concentration Versus Time

Under the Option Case, uranium-238 concentrations at the Core Zone Boundary peak at about two orders of magnitude below the benchmark at the beginning of the period of analysis (see Figure 5–219). Around CY 3000, the uranium-238 concentrations at the Core Zone Boundary drastically fall to over nine orders of magnitude below the benchmark, while the Columbia River nearshore concentrations of uranium-238 stay fairly constant at about five orders of magnitude below the benchmark. Total uranium concentrations are essentially identical to uranium-238 concentrations (see Figure 5–220).

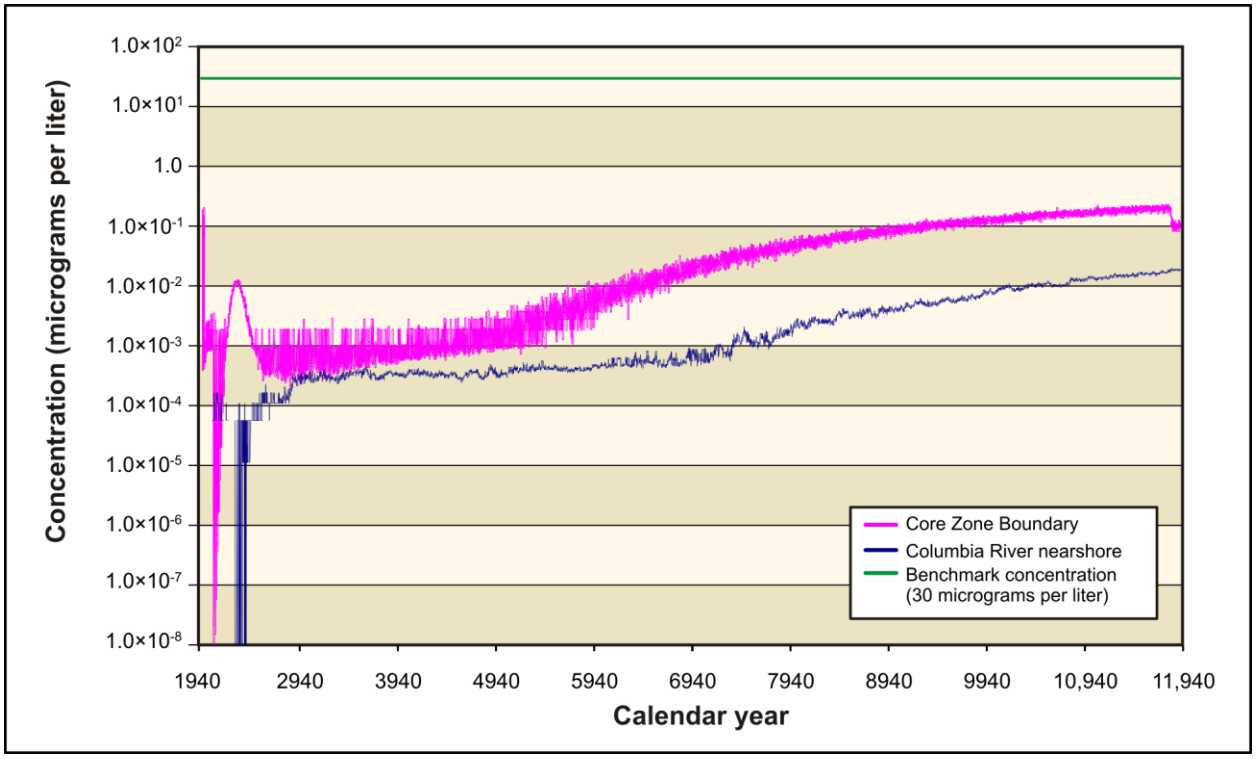


Figure 5–218. Tank Closure Alternative 6A, Base Case, Total Uranium Concentration Versus Time

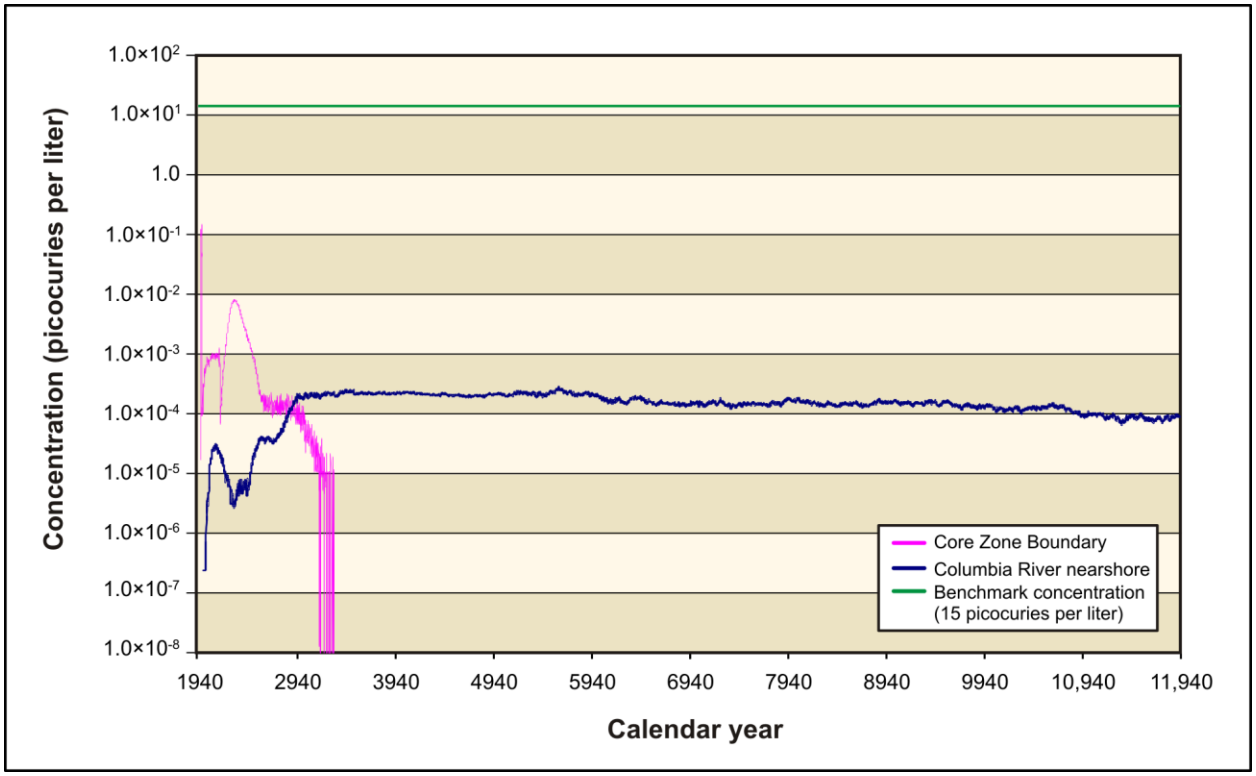


Figure 5–219. Tank Closure Alternative 6A, Option Case, Uranium-238 Concentration Versus Time

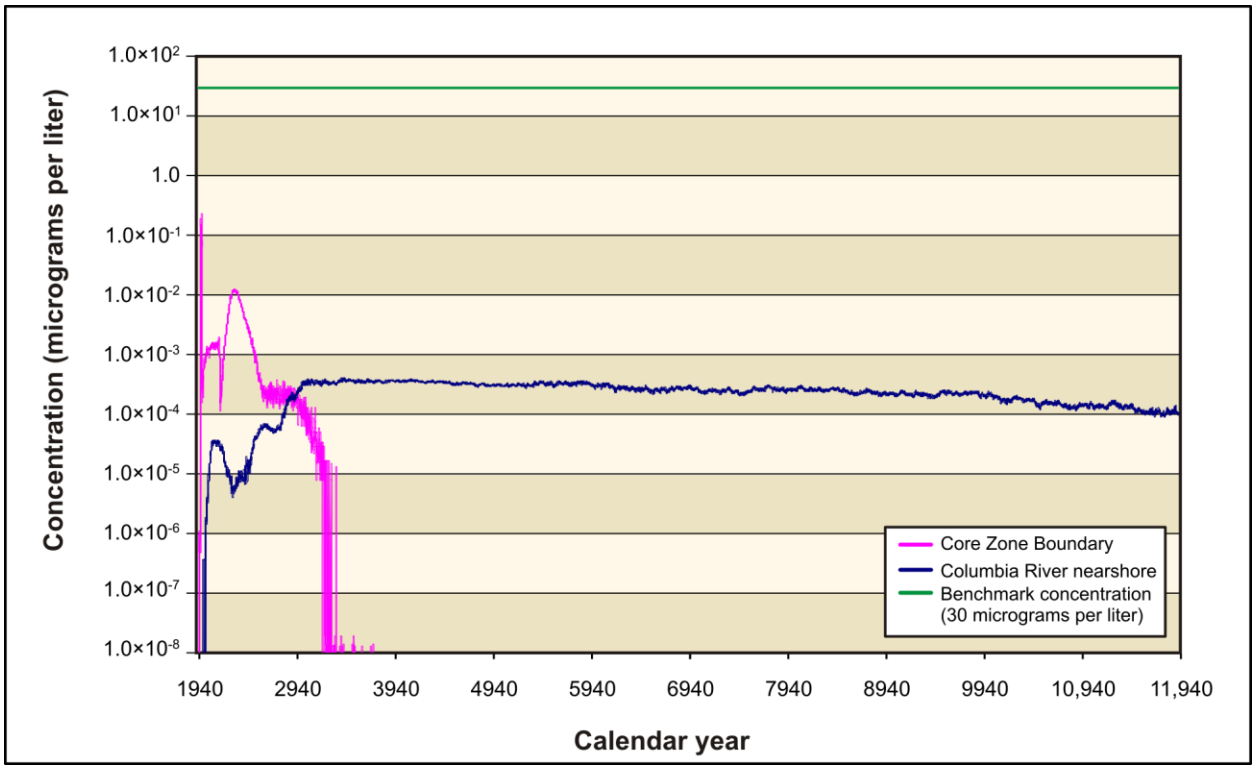


Figure 5–220. Tank Closure Alternative 6A, Option Case, Total Uranium Concentration Versus Time

5.1.1.9.5 Analysis of Spatial Distribution of Concentration

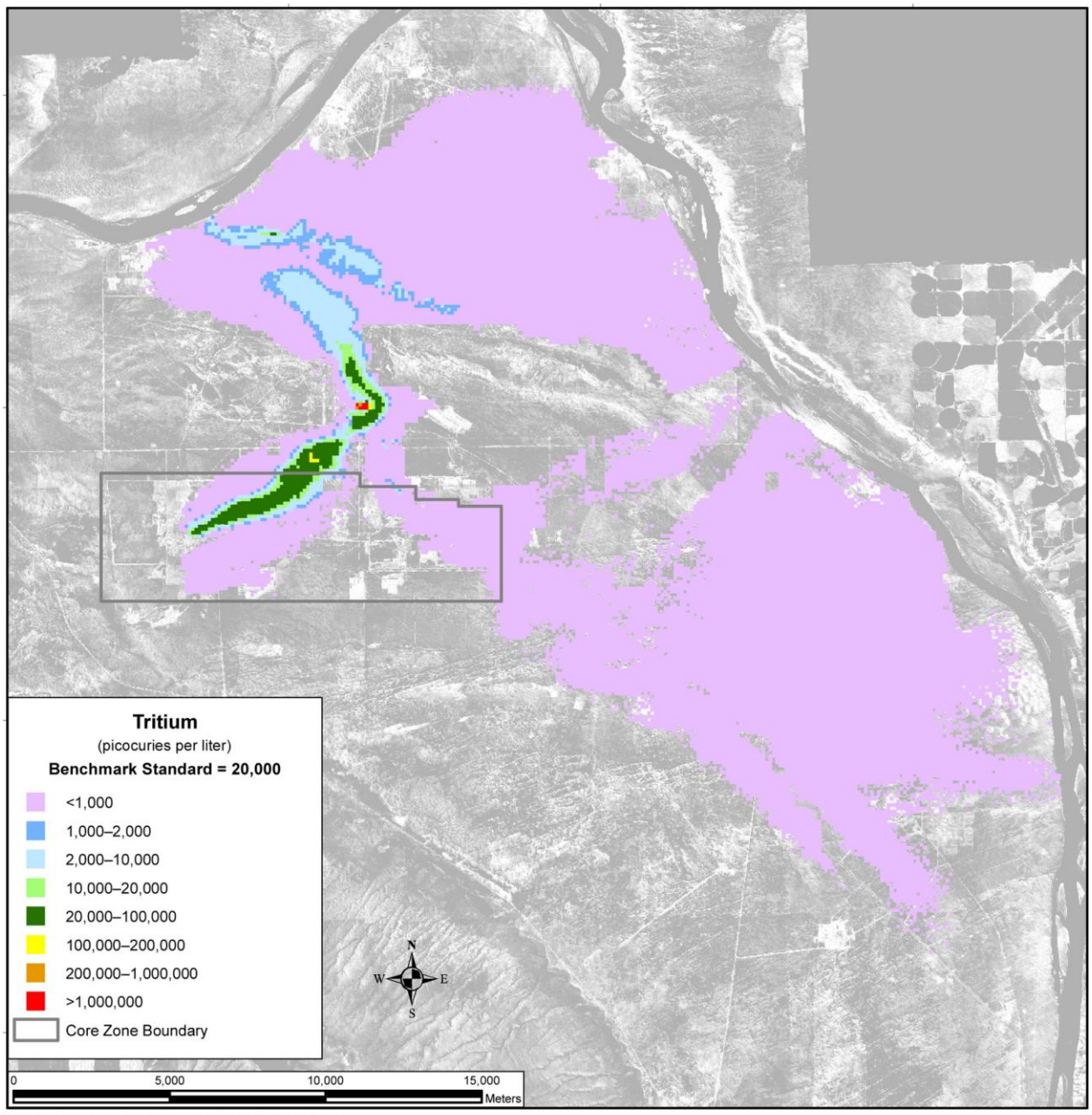
This section presents the impacts of Tank Closure Alternative 6A in terms of the spatial distribution of COPC driver concentrations in groundwater at selected times. Concentrations of radionuclides are in picocuries per liter; chemicals, in micrograms per liter (see Figures 5–221 through 5–262). Concentrations of 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 5–221 shows the spatial distribution of tritium concentrations in groundwater in CY 2010 under the Base Case, which would include use of a modified RCRA Subtitle C barrier. 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, crosses the Core Zone Boundary, and continues toward Gable Gap. Peak concentrations in this plume are about 5 to 10 times greater than the benchmark concentration. The overall tritium concentrations are attenuated by radioactive decay to levels less than one-twentieth of the benchmark concentration by CY 2135 (see Figure 5–222).

The spatial distribution of tritium concentrations in groundwater in CY 2010 and CY 2135 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 5–223 and 5–224).

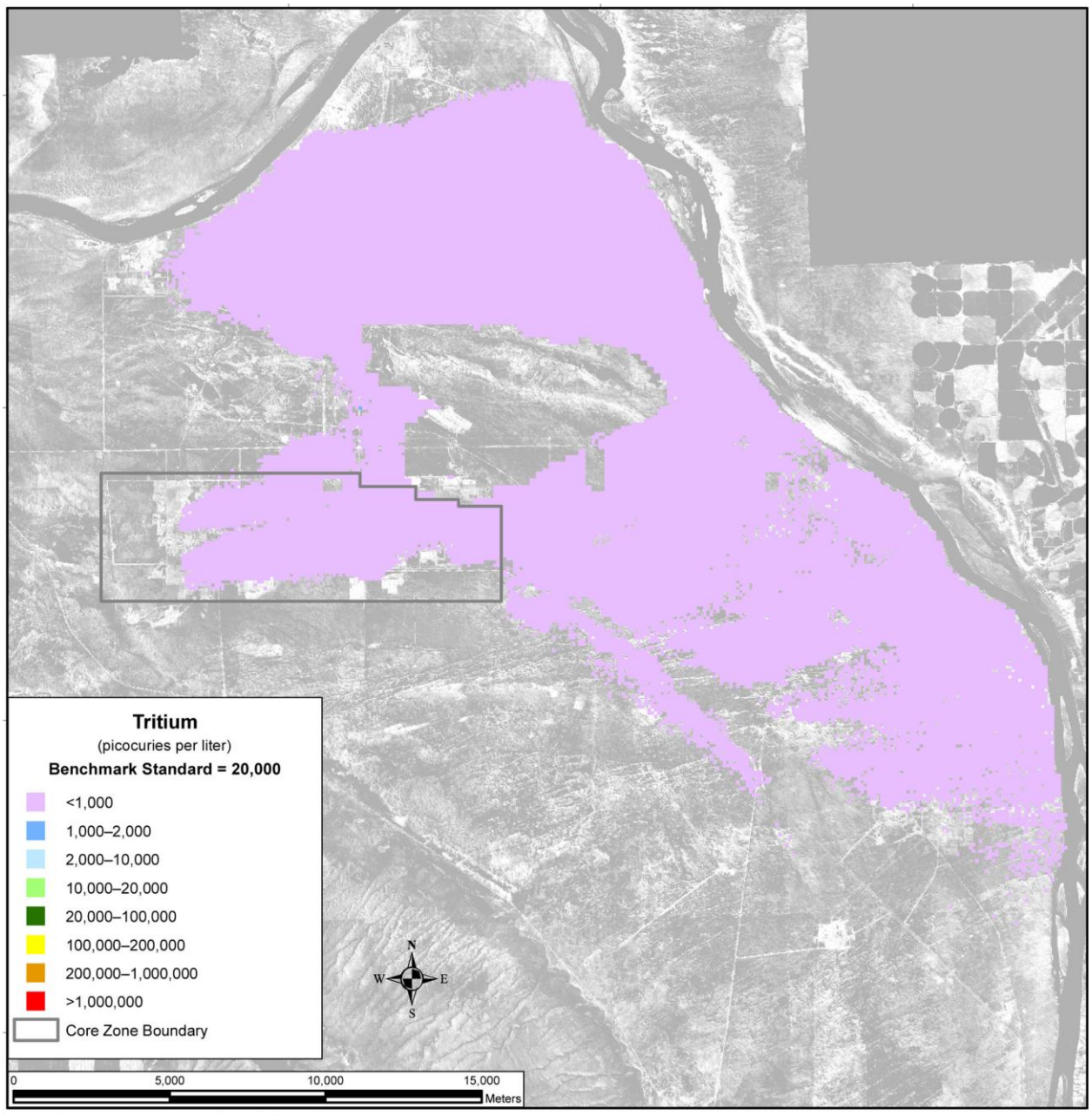
Figure 5–225 shows the spatial distribution of iodine-129 concentrations in groundwater in CY 2010 under the Base Case. Releases from cribs and trenches (ditches) and past leaks result in groundwater concentration plumes that are at or exceed the benchmark concentration at the B, S, and T Barriers. Peak concentrations in this plume are about 10 to 50 times greater than the benchmark and are 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 5–226). In the plume north of Gable Gap, contaminant levels are 10 to 50 times greater than the benchmark concentration. In the east, just outside of the Core Zone Boundary, peak concentration levels are up to 5 times greater than the benchmark. By CY 7140, most of the mass in the plume has reached the Columbia River, with concentrations less than one-twentieth of the benchmark (see Figure 5–227). Technetium-99 (see Figures 5–228 through 5–230), chromium (see Figures 5–231 through 5–233), and nitrate (see Figures 5–234 through 5–236) 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) 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 5–237 through 5–248).



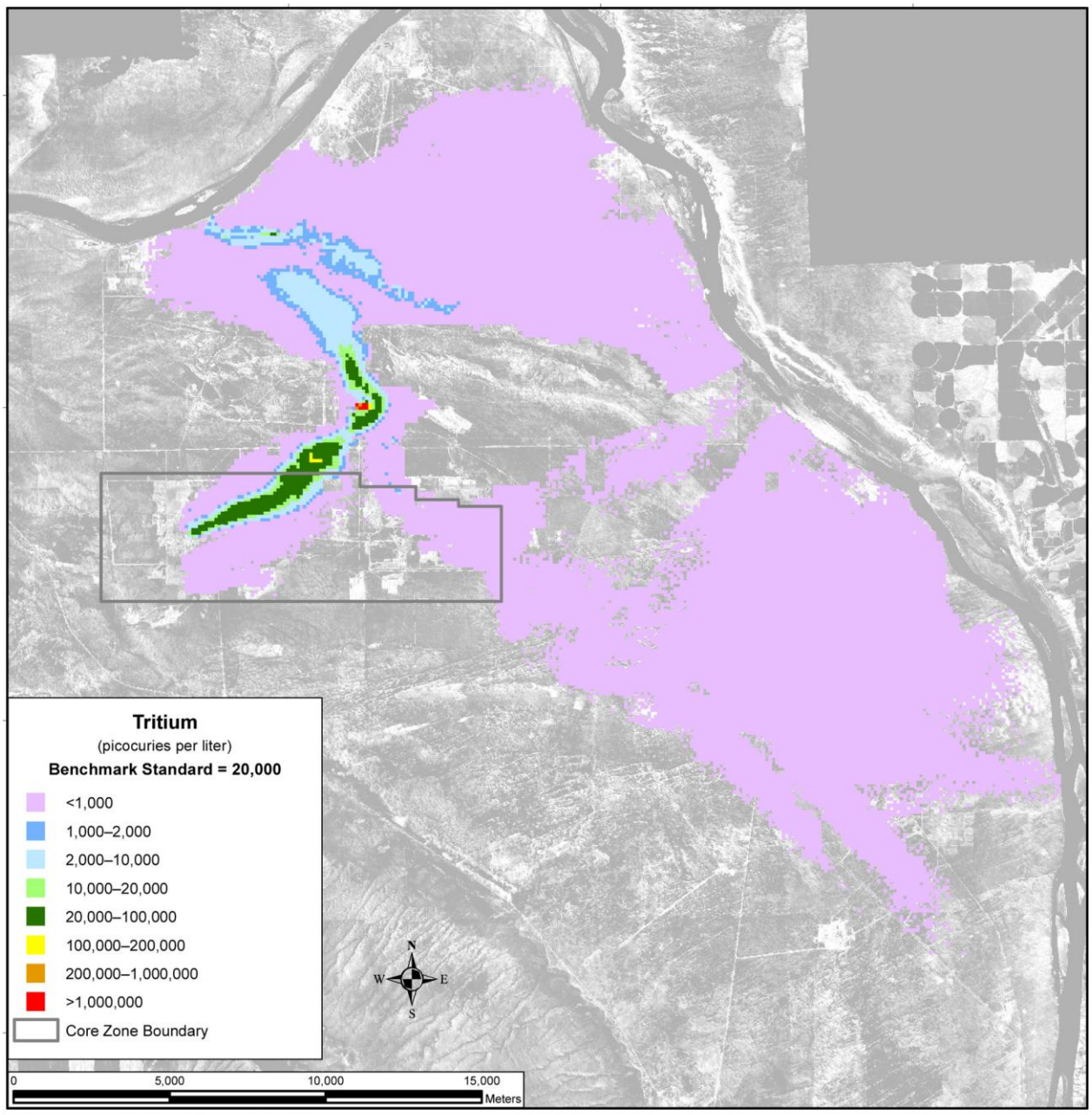
Note: To convert meters to feet, multiply by 3.281.

Figure 5–221. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration, Calendar Year 2010



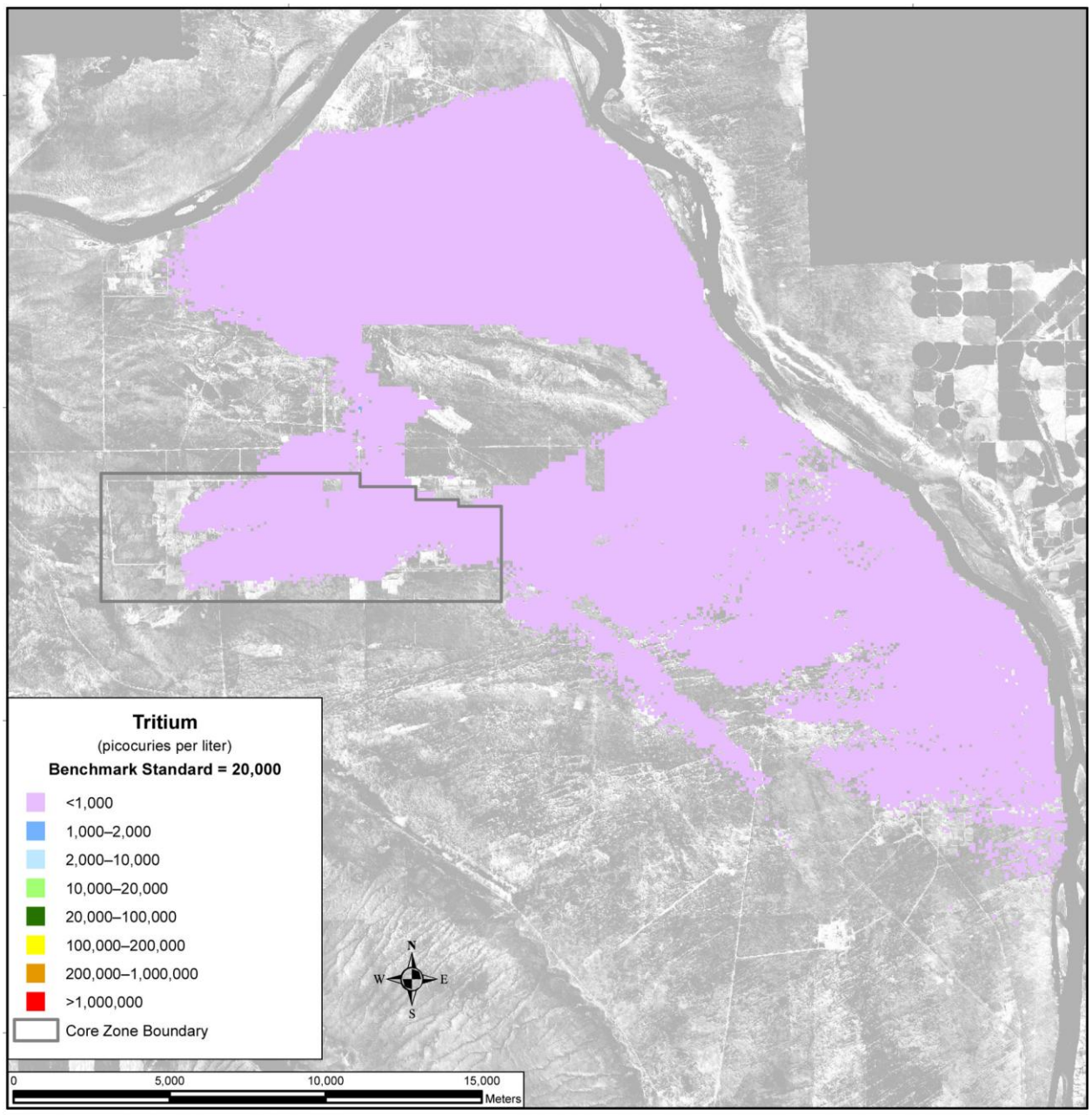
Note: To convert meters to feet, multiply by 3.281.

Figure 5–222. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Hydrogen-3 (Tritium), Concentration, Calendar Year 2135



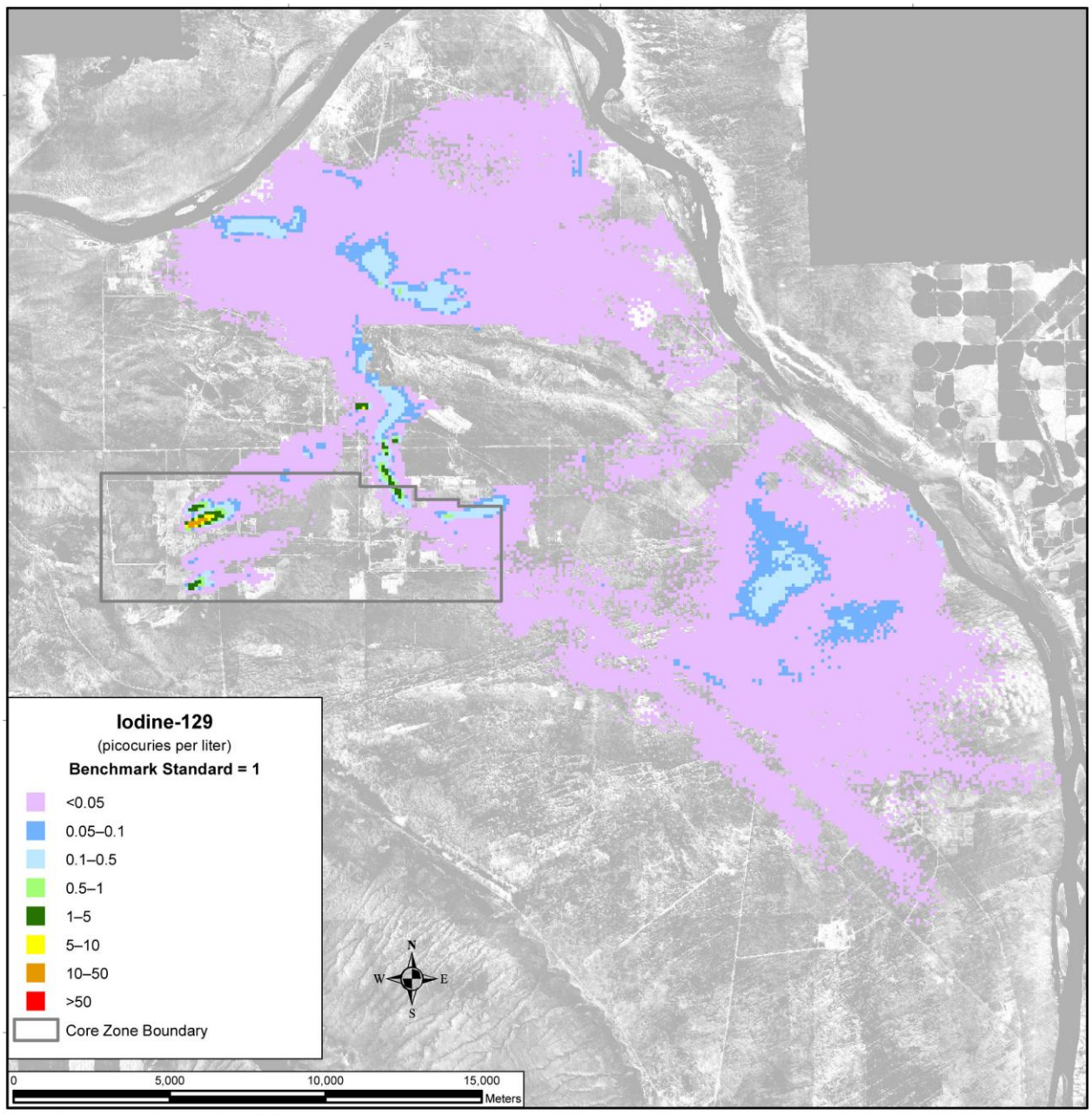
Note: To convert meters to feet, multiply by 3.281.

Figure 5–223. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration, Calendar Year 2010



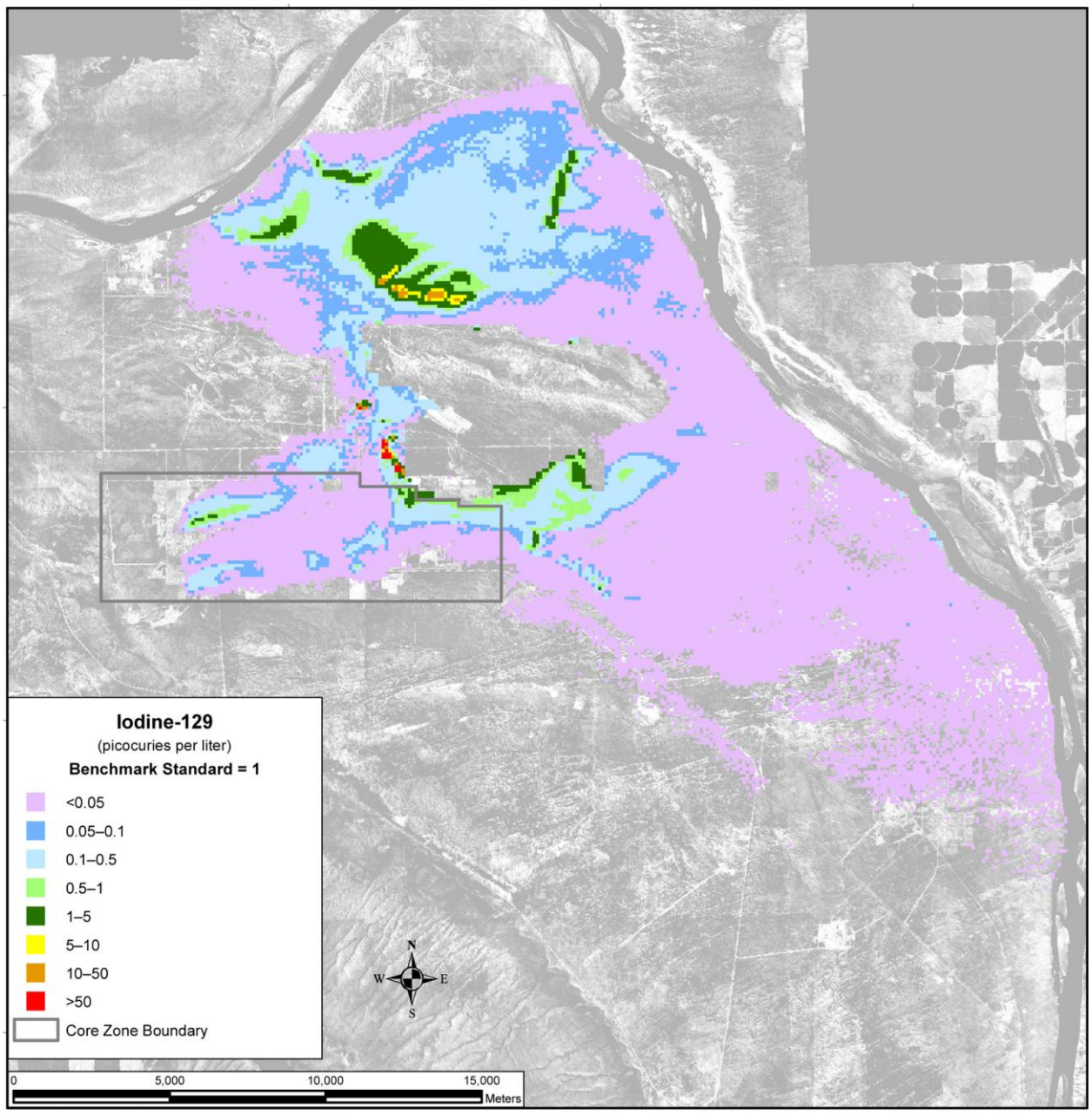
Note: To convert meters to feet, multiply by 3.281.

Figure 5–224. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration, Calendar Year 2135



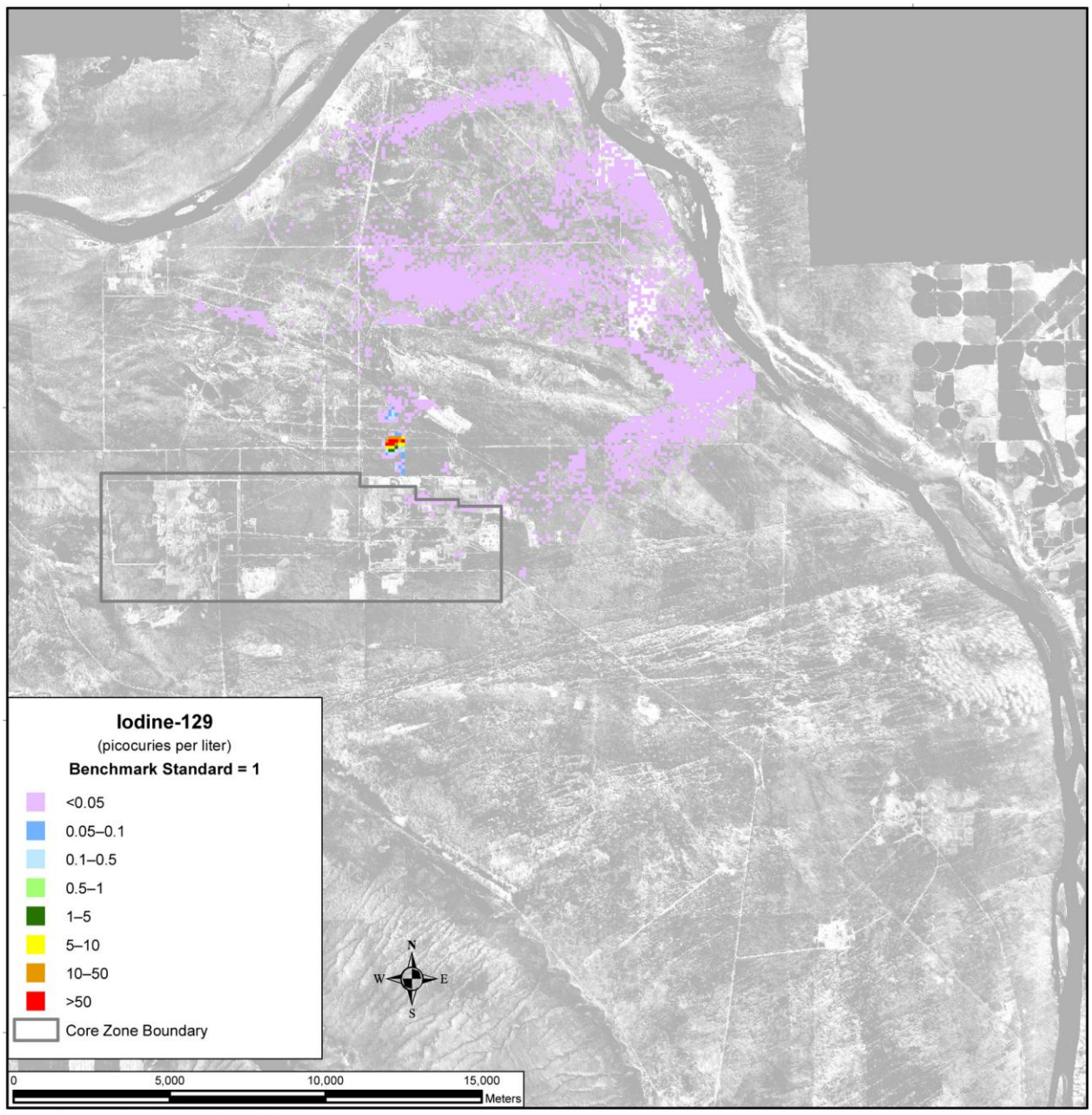
Note: To convert meters to feet, multiply by 3.281.

Figure 5–225. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Iodine-129 Concentration, Calendar Year 2010



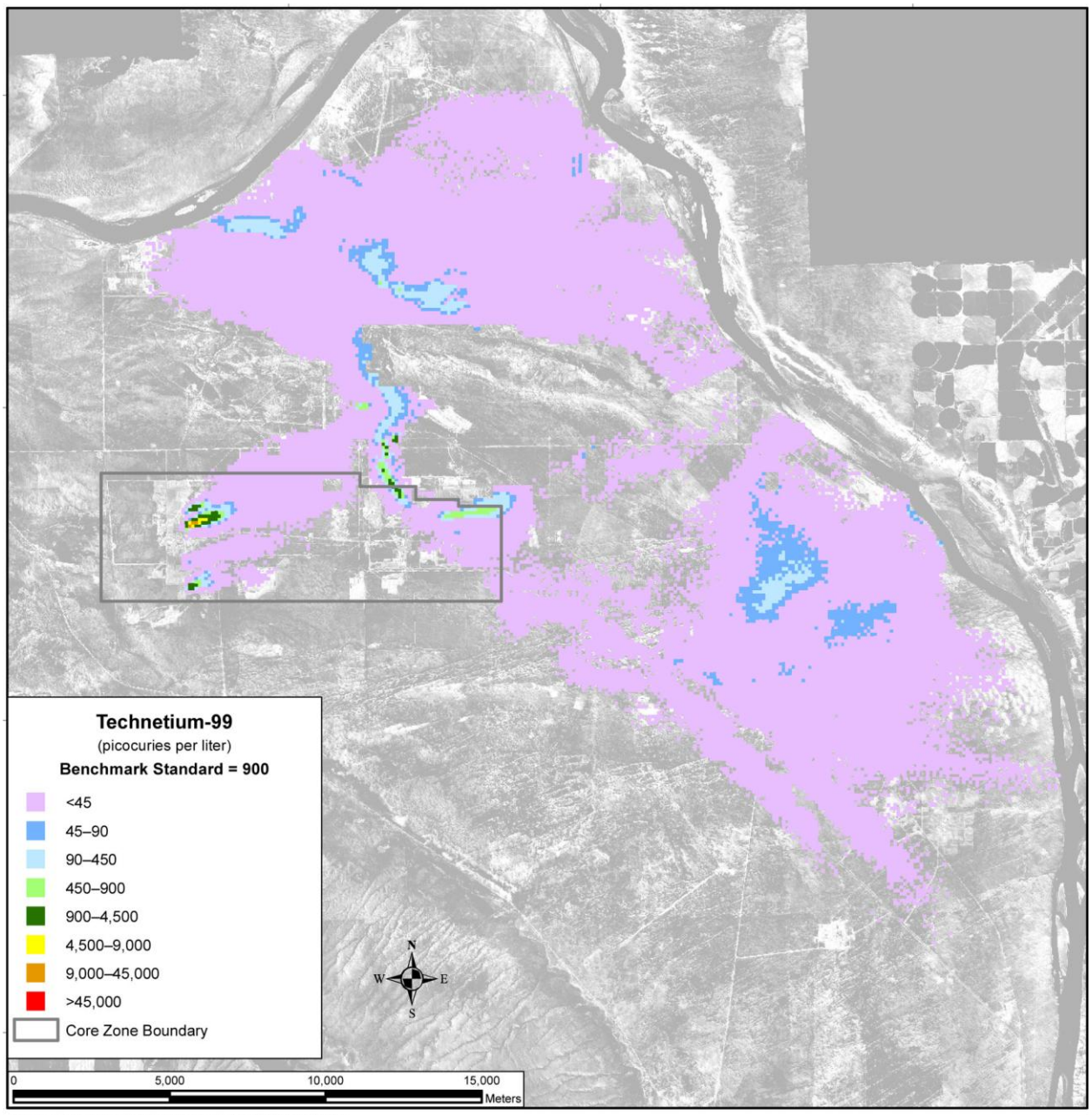
Note: To convert meters to feet, multiply by 3.281.

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



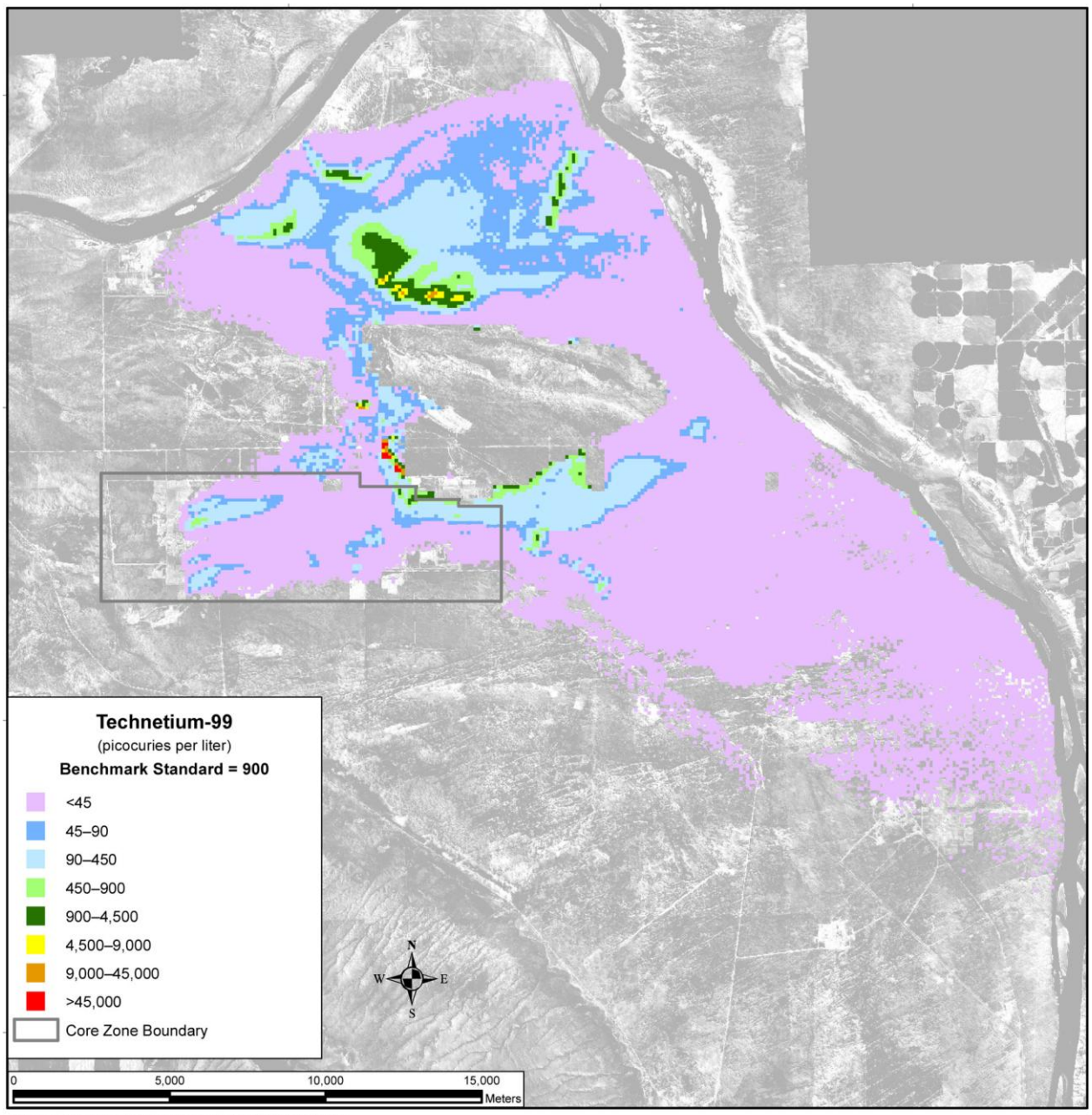
Note: To convert meters to feet, multiply by 3.281.

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



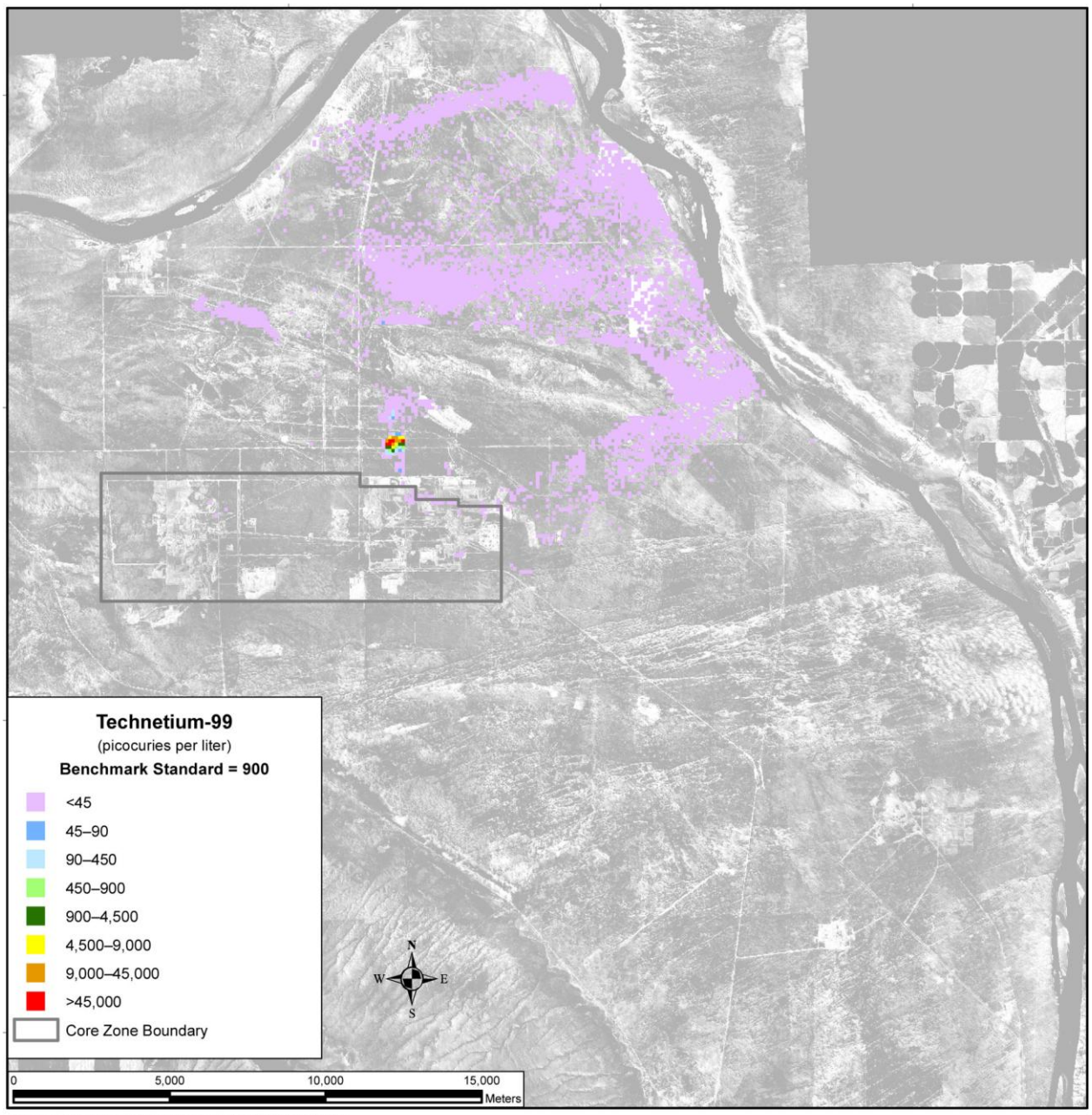
Note: To convert meters to feet, multiply by 3.281.

Figure 5–228. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Technetium-99 Concentration, Calendar Year 2010



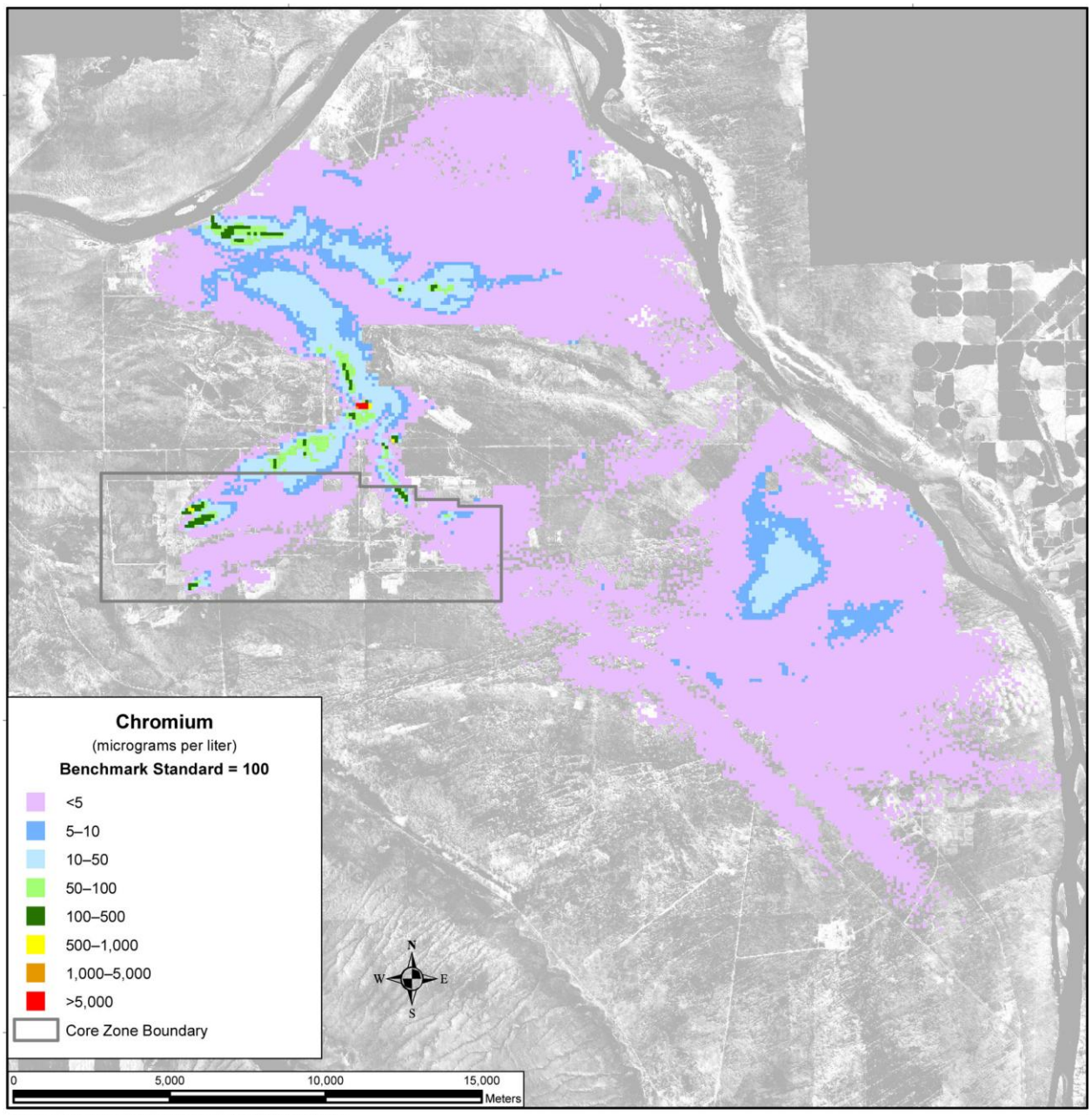
Note: To convert meters to feet, multiply by 3.281.

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



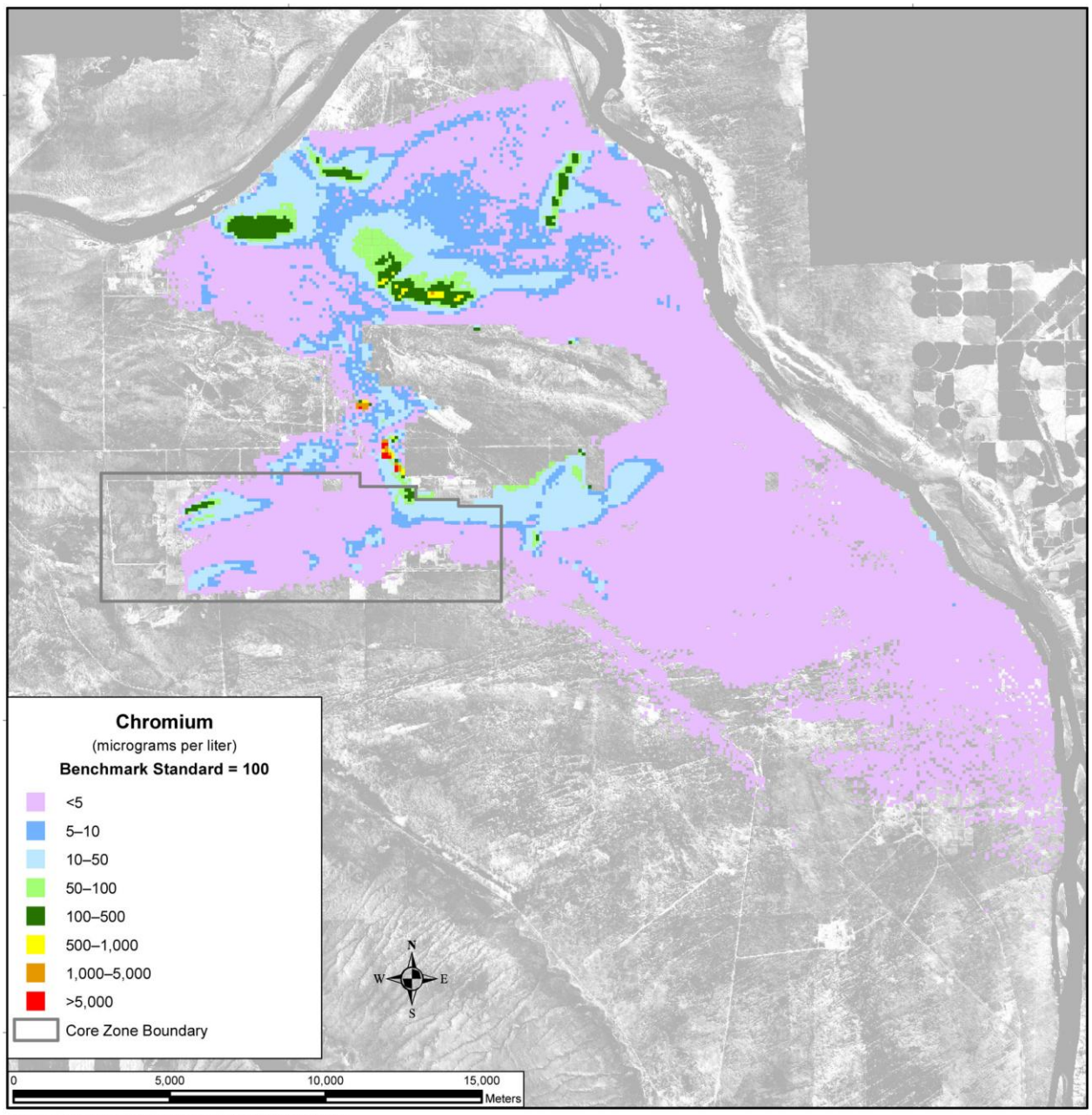
Note: To convert meters to feet, multiply by 3.281.

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



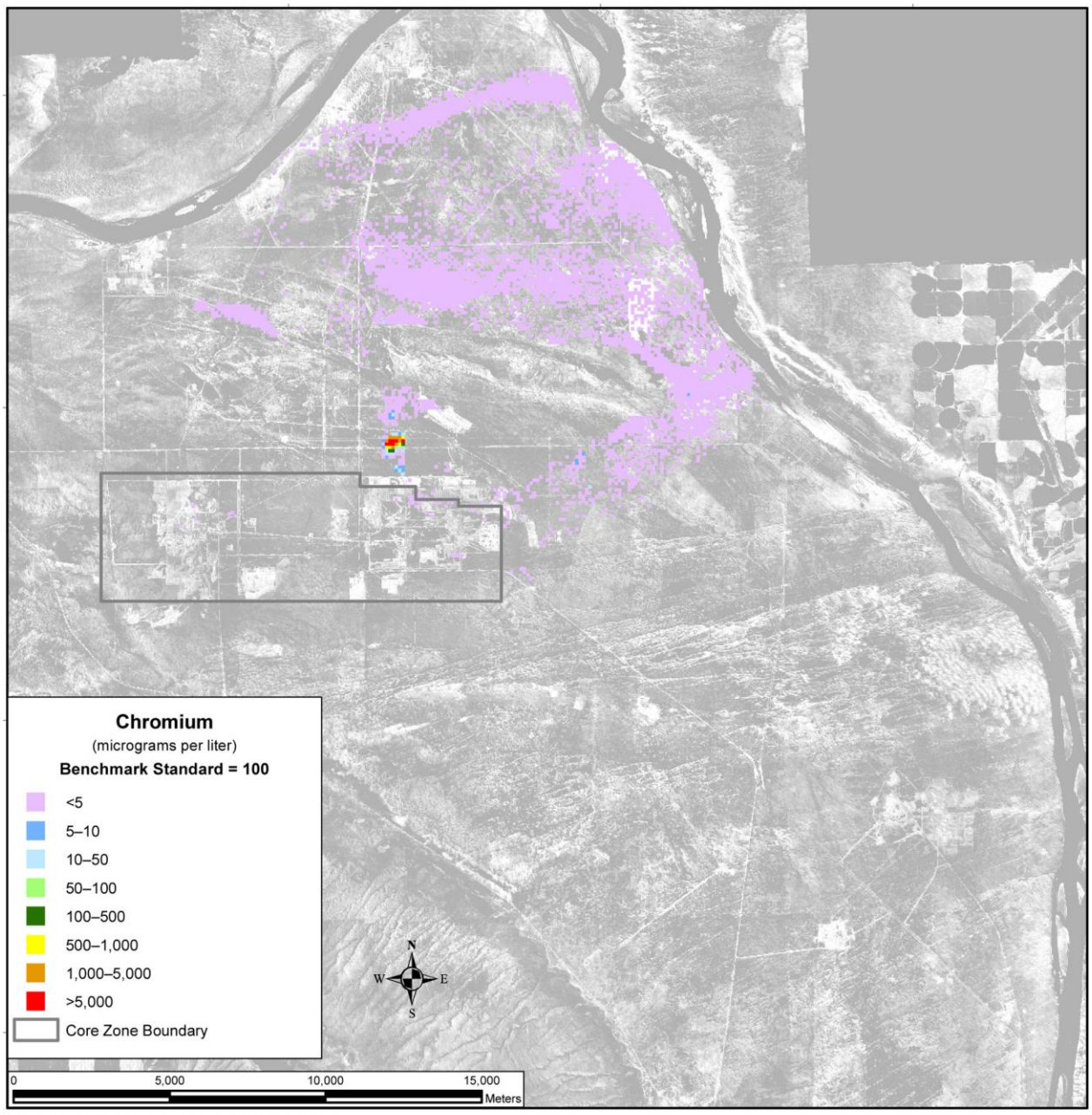
Note: To convert meters to feet, multiply by 3.281.

Figure 5–231. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Chromium Concentration, Calendar Year 2010



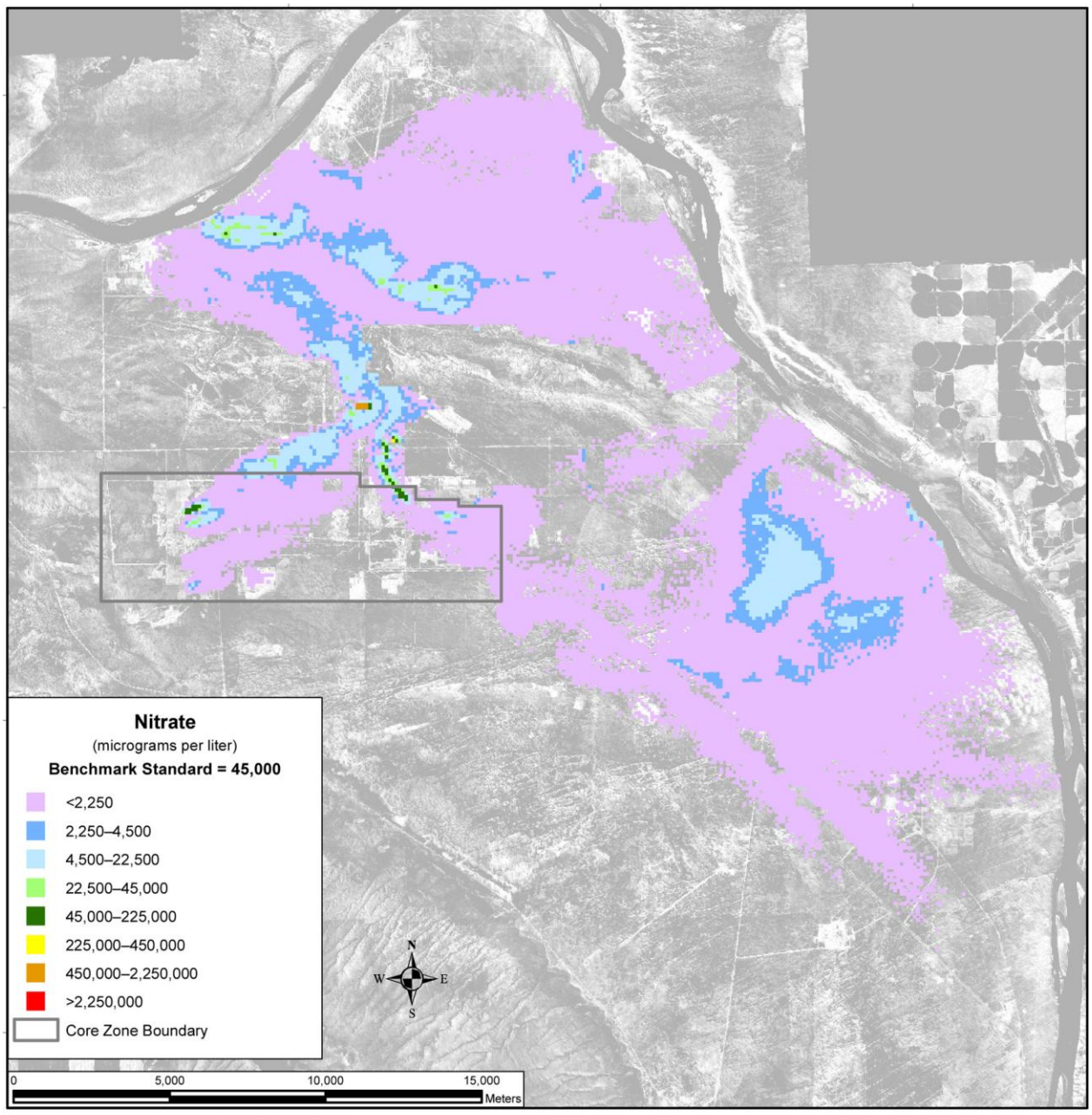
Note: To convert meters to feet, multiply by 3.281.

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



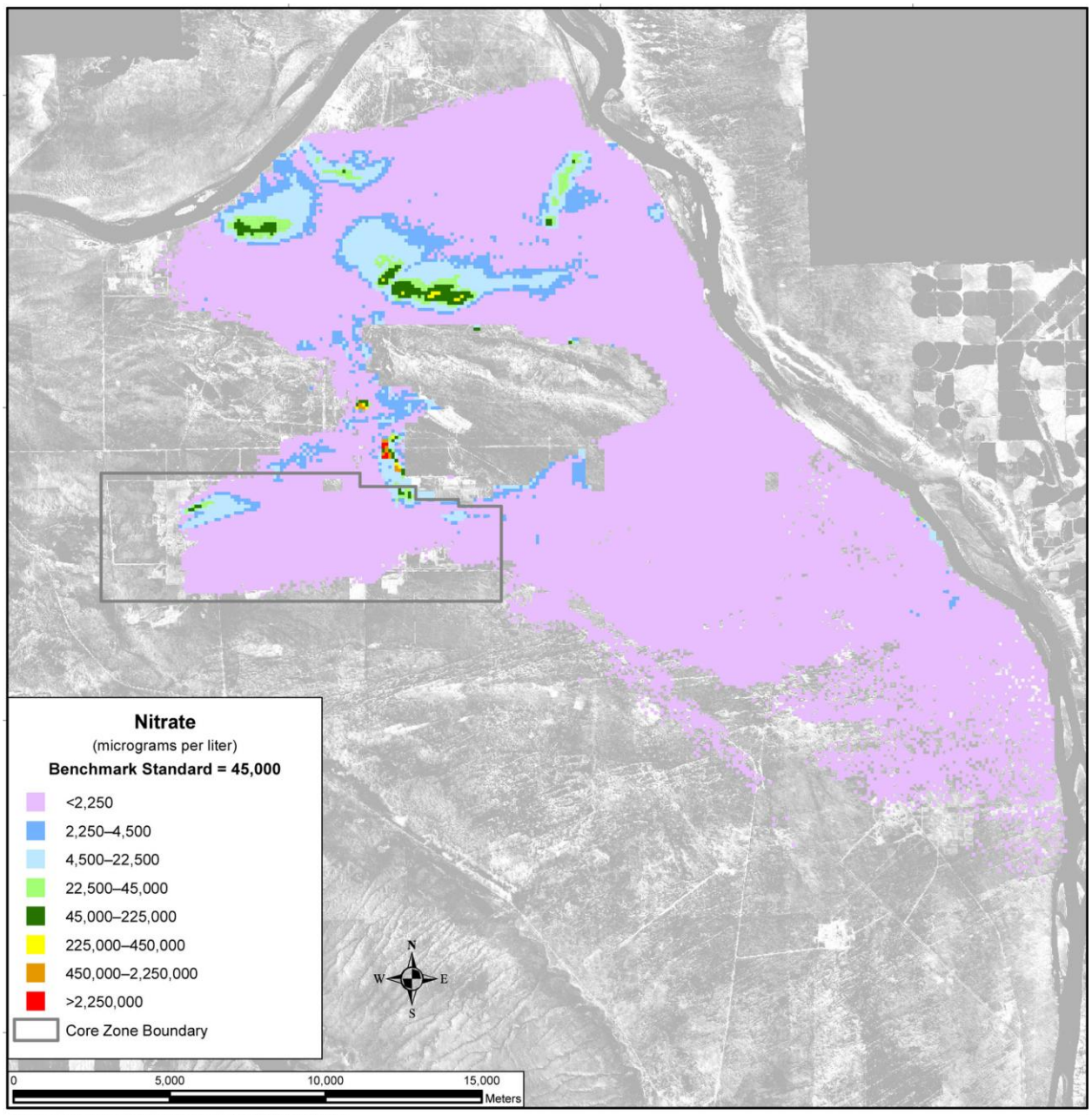
Note: To convert meters to feet, multiply by 3.281.

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



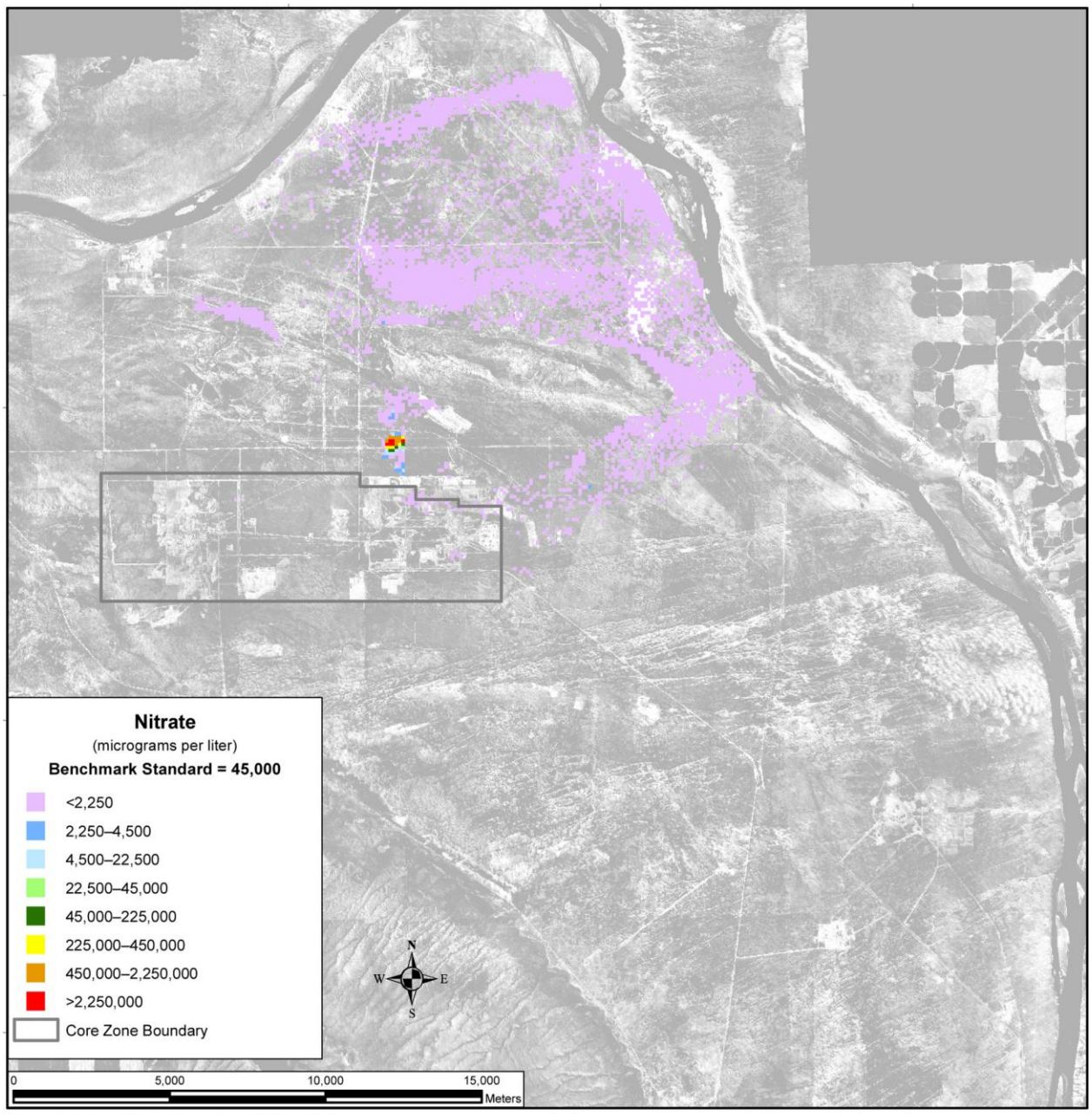
Note: To convert meters to feet, multiply by 3.281.

Figure 5–234. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Nitrate Concentration, Calendar Year 2010



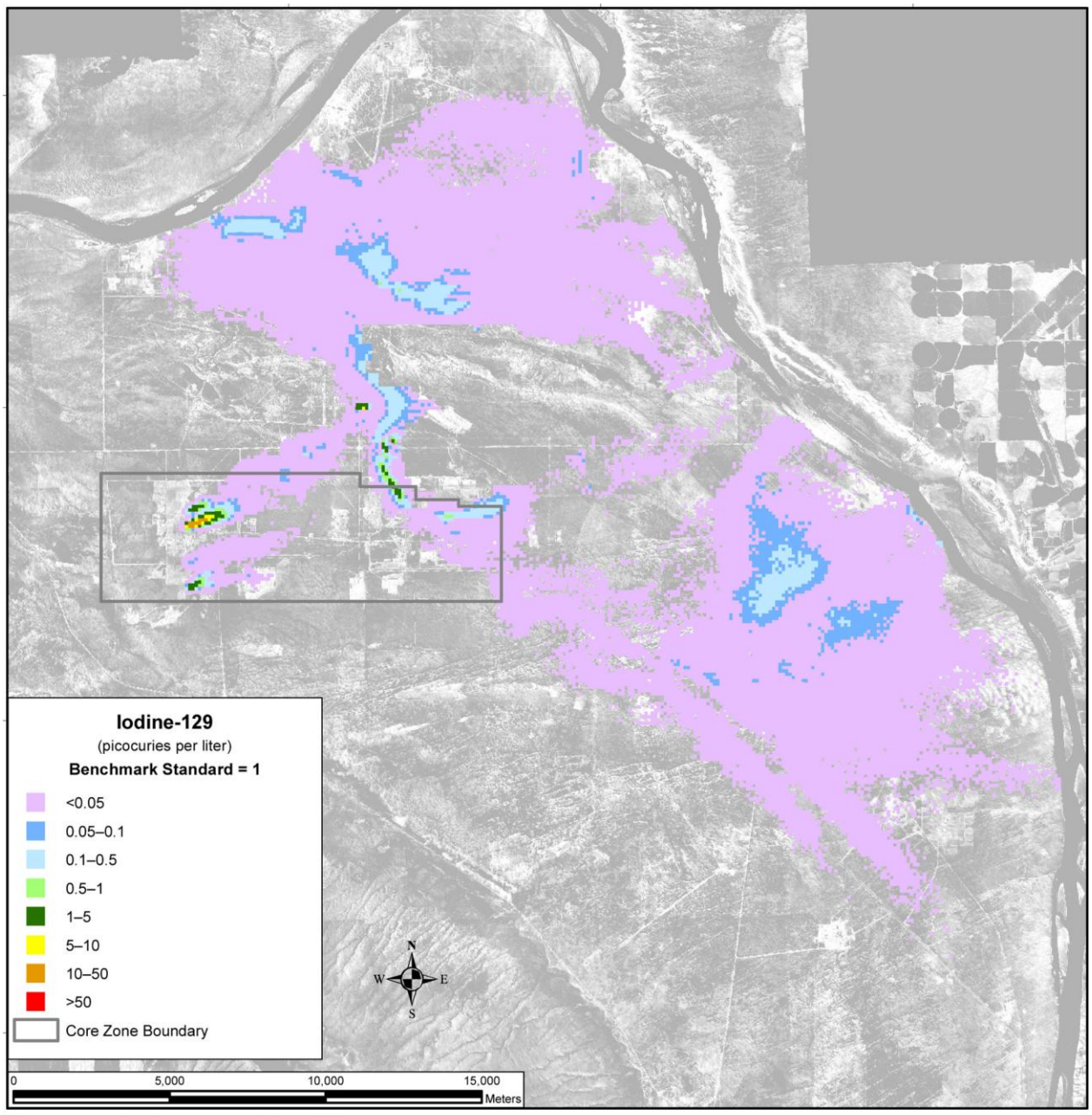
Note: To convert meters to feet, multiply by 3.281.

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



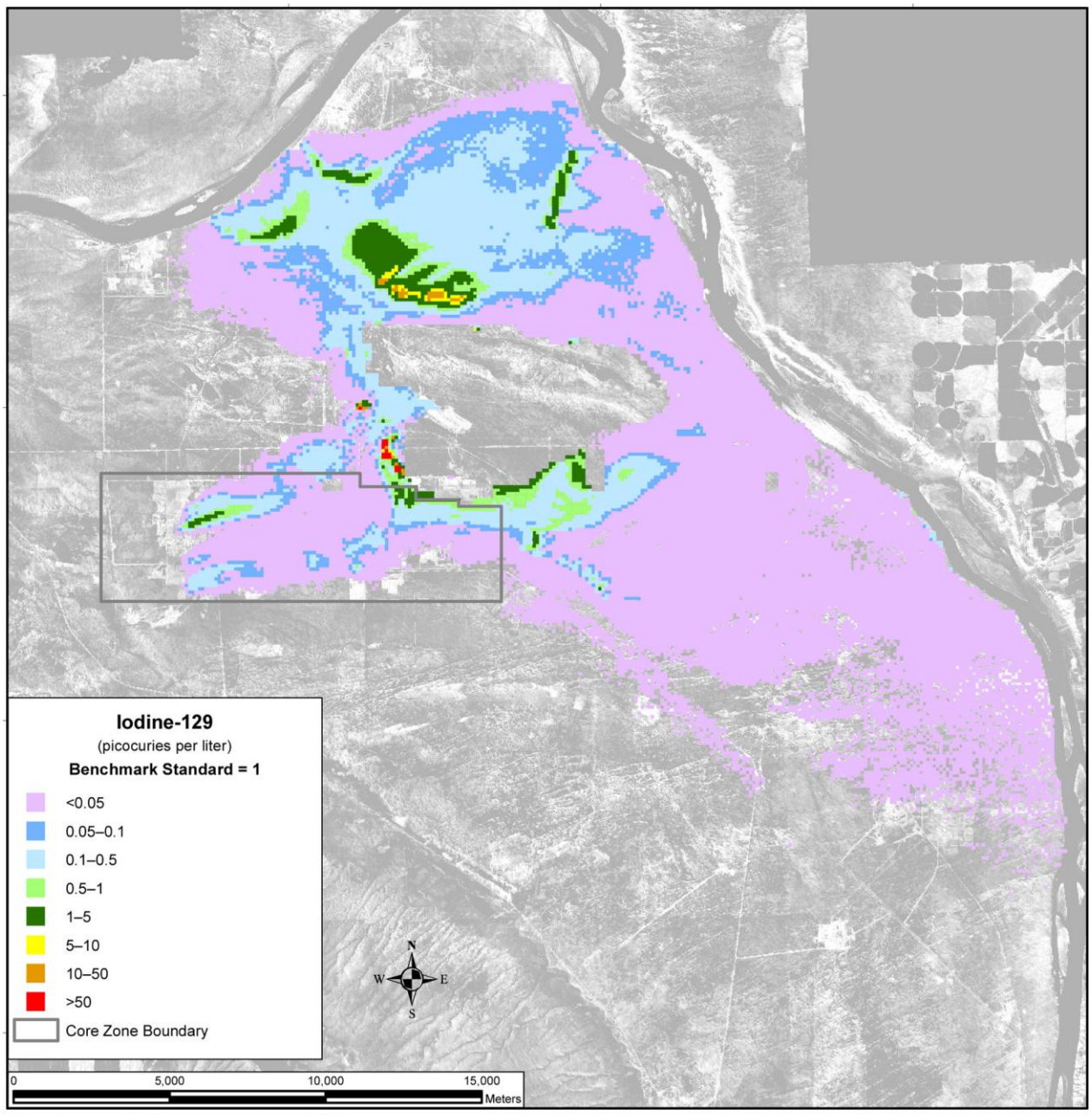
Note: To convert meters to feet, multiply by 3.281.

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



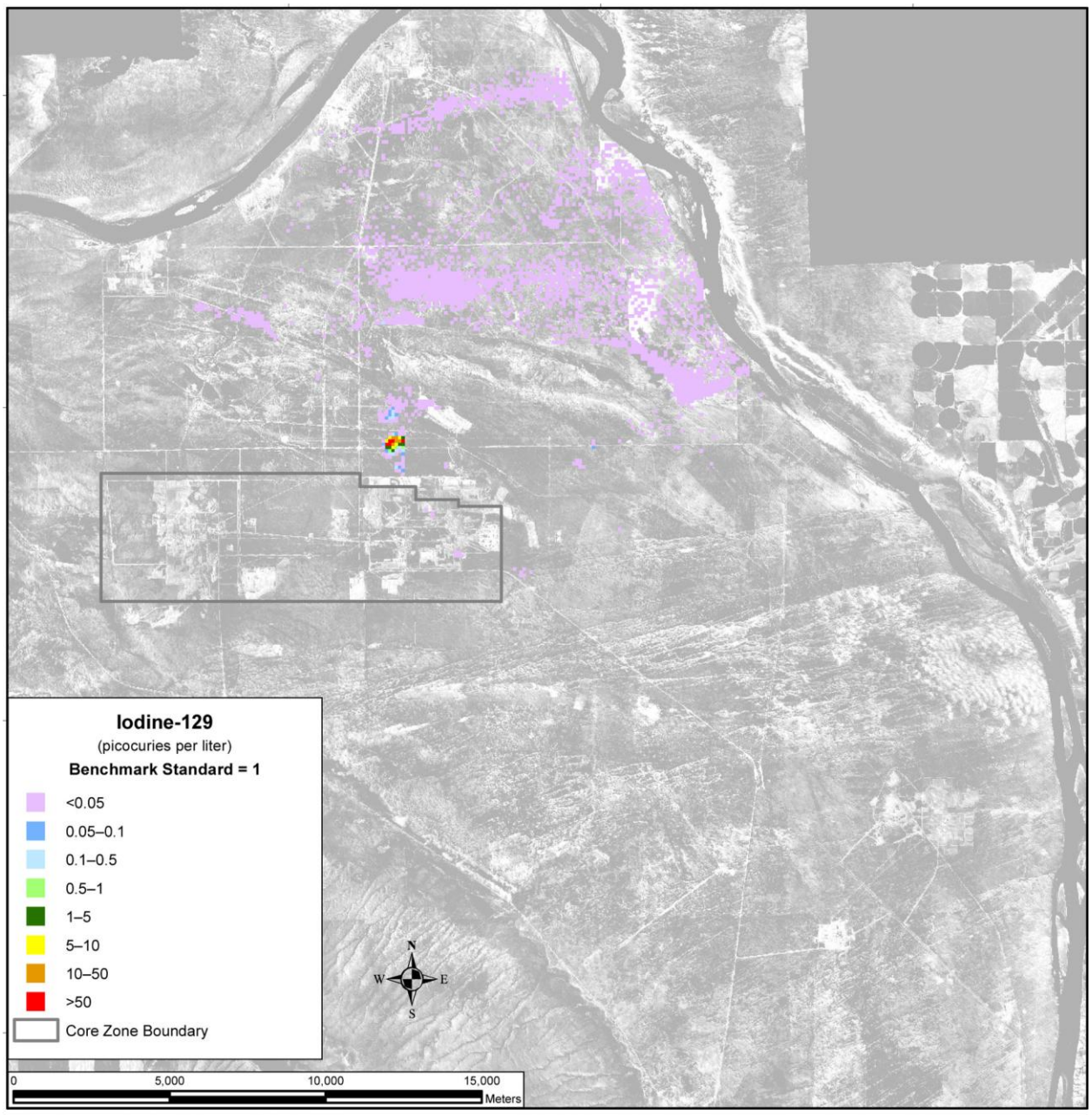
Note: To convert meters to feet, multiply by 3.281.

Figure 5–237. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Iodine-129 Concentration, Calendar Year 2010



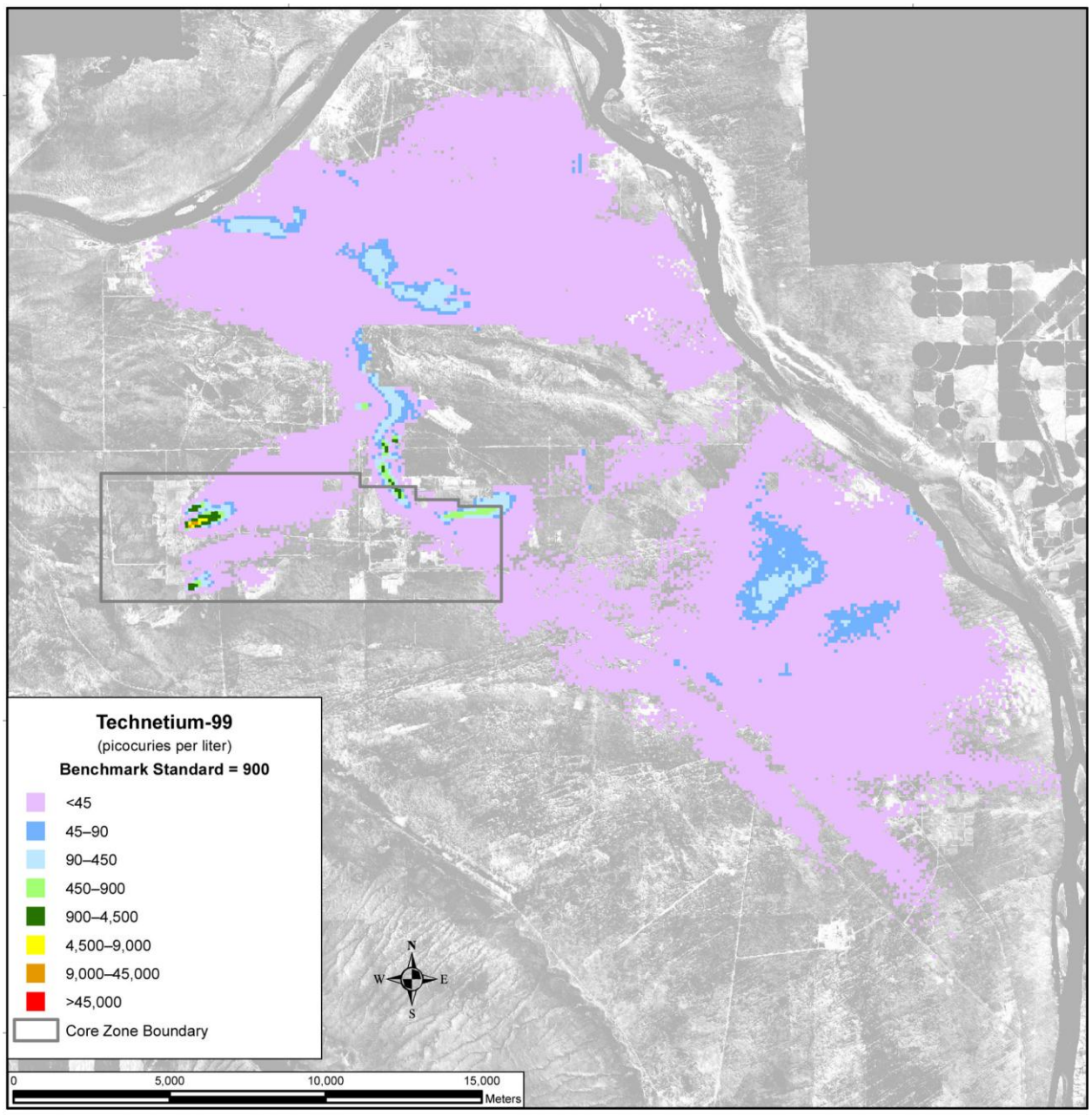
Note: To convert meters to feet, multiply by 3.281.

Figure 5–238. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Iodine-129 Concentration, Calendar Year 2135



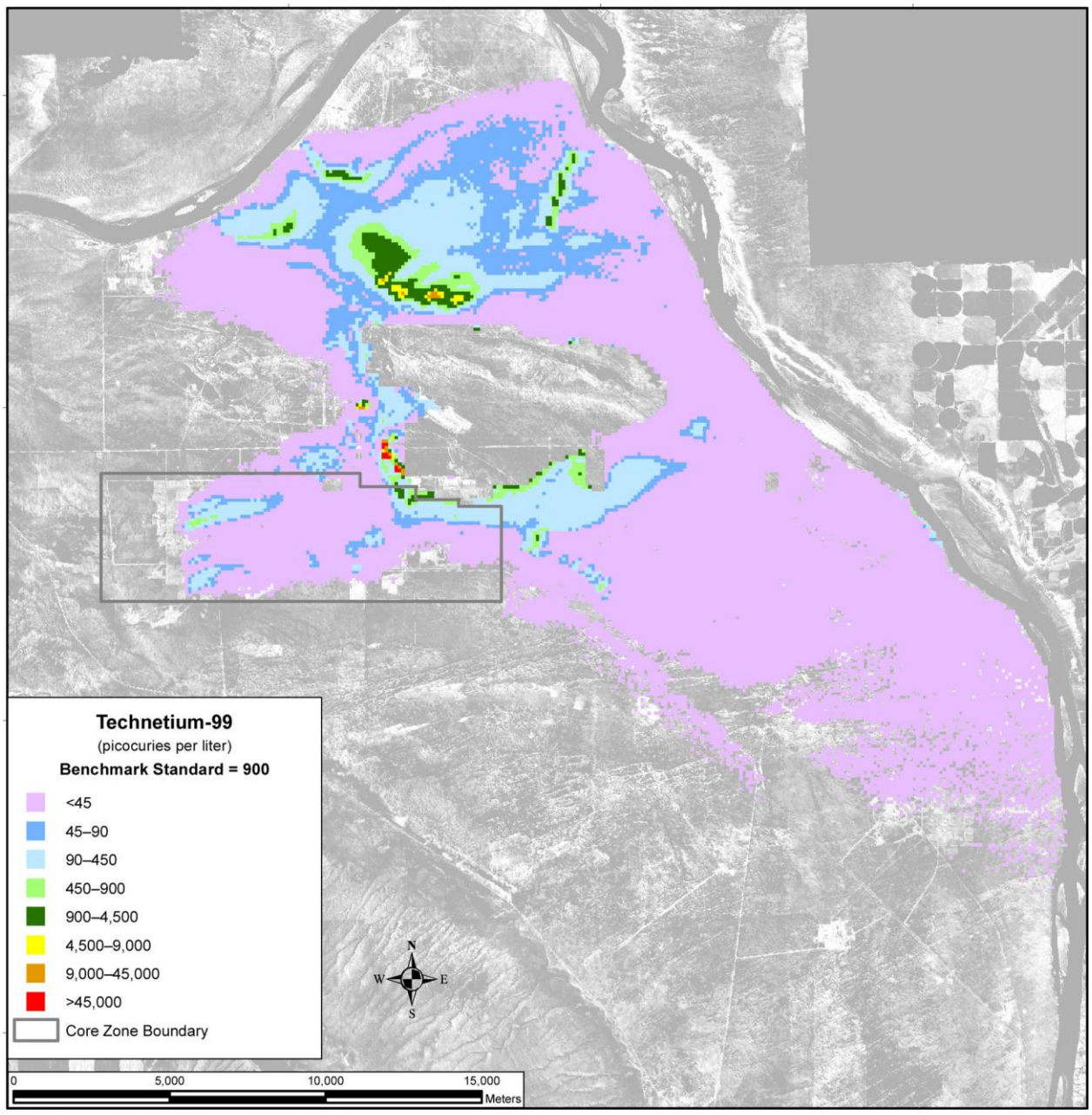
Note: To convert meters to feet, multiply by 3.281.

Figure 5–239. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Iodine-129 Concentration, Calendar Year 7140



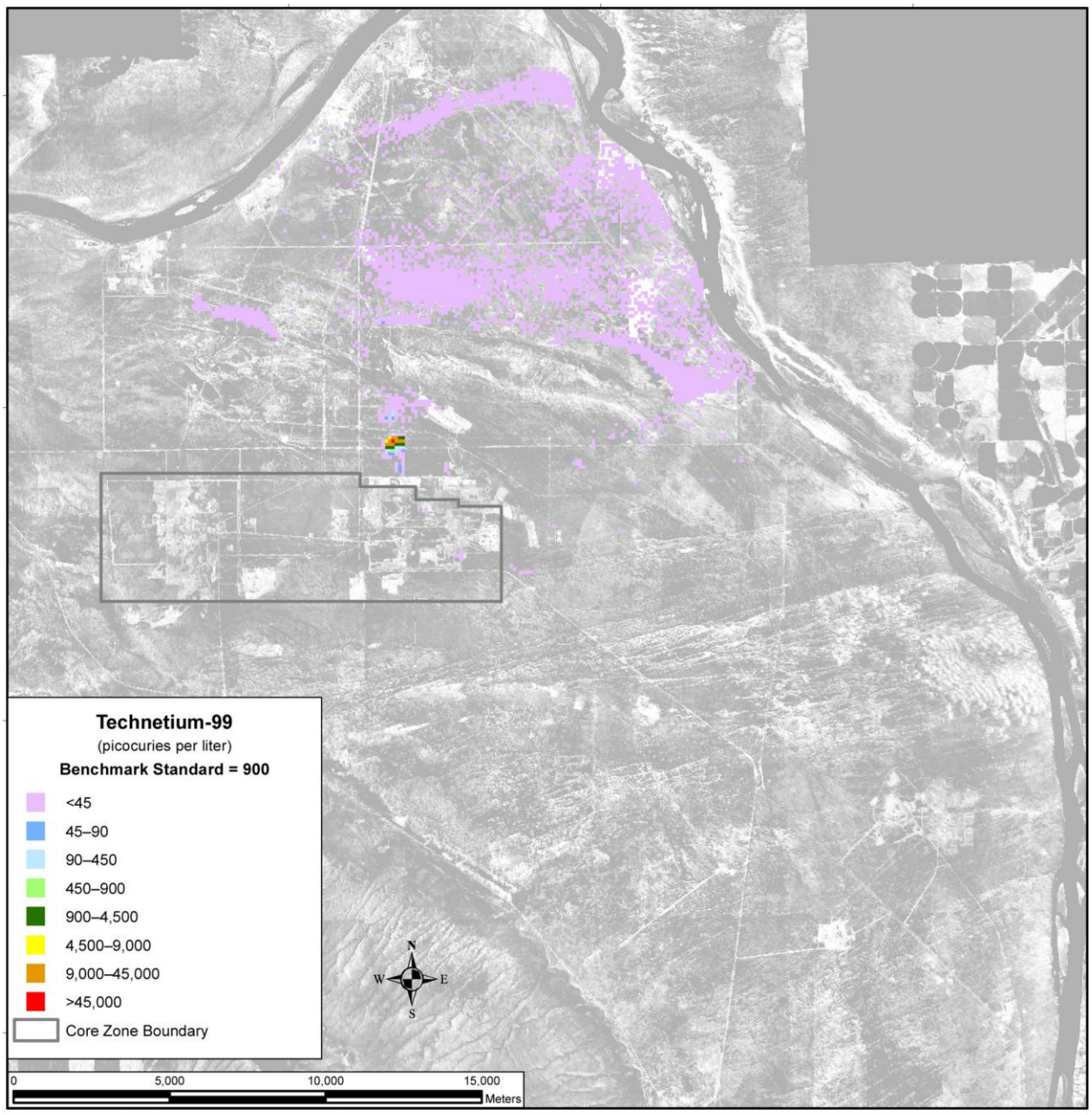
Note: To convert meters to feet, multiply by 3.281.

Figure 5–240. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Technetium-99 Concentration, Calendar Year 2010



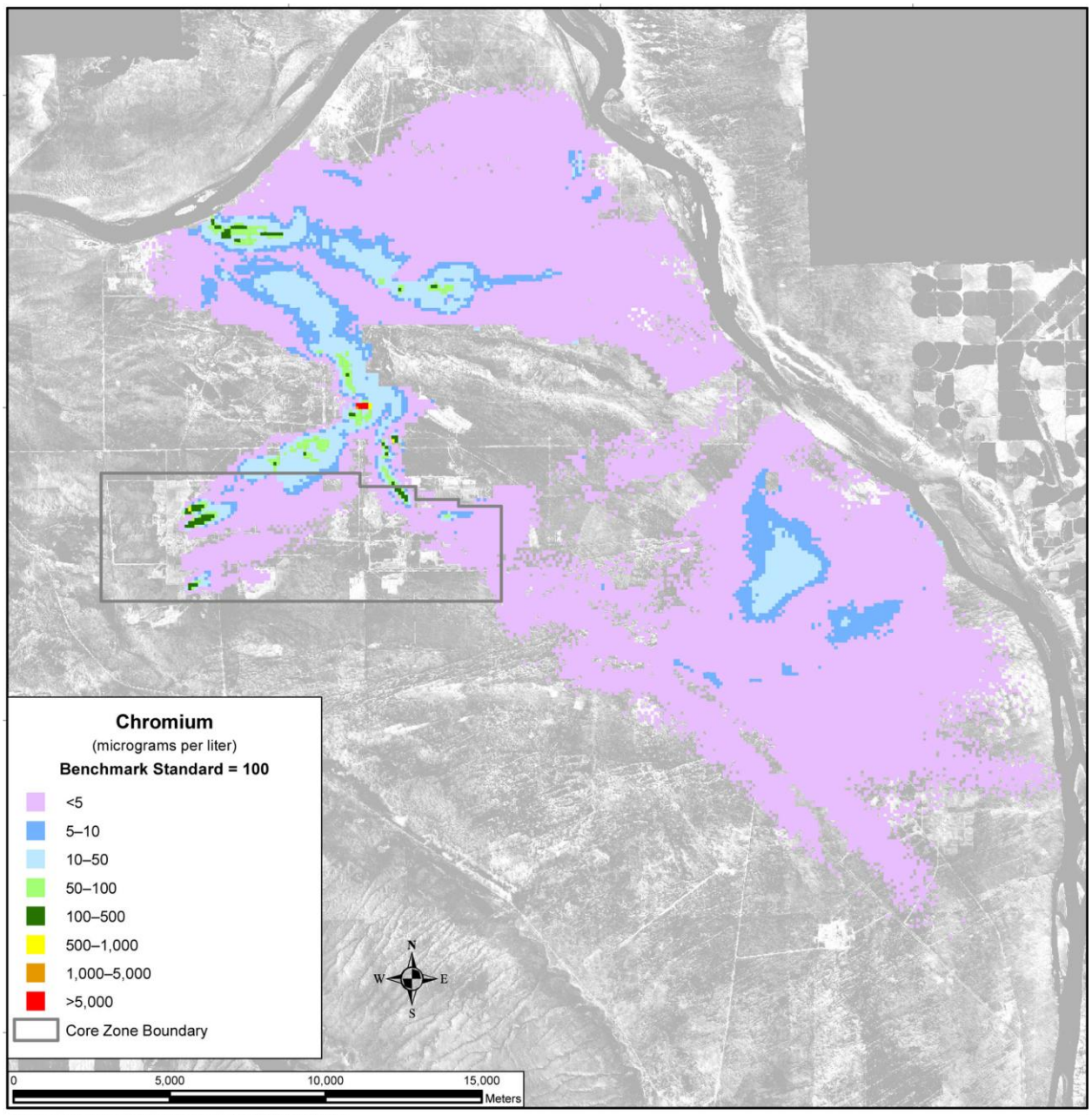
Note: To convert meters to feet, multiply by 3.281.

Figure 5–241. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Technetium-99 Concentration, Calendar Year 2135



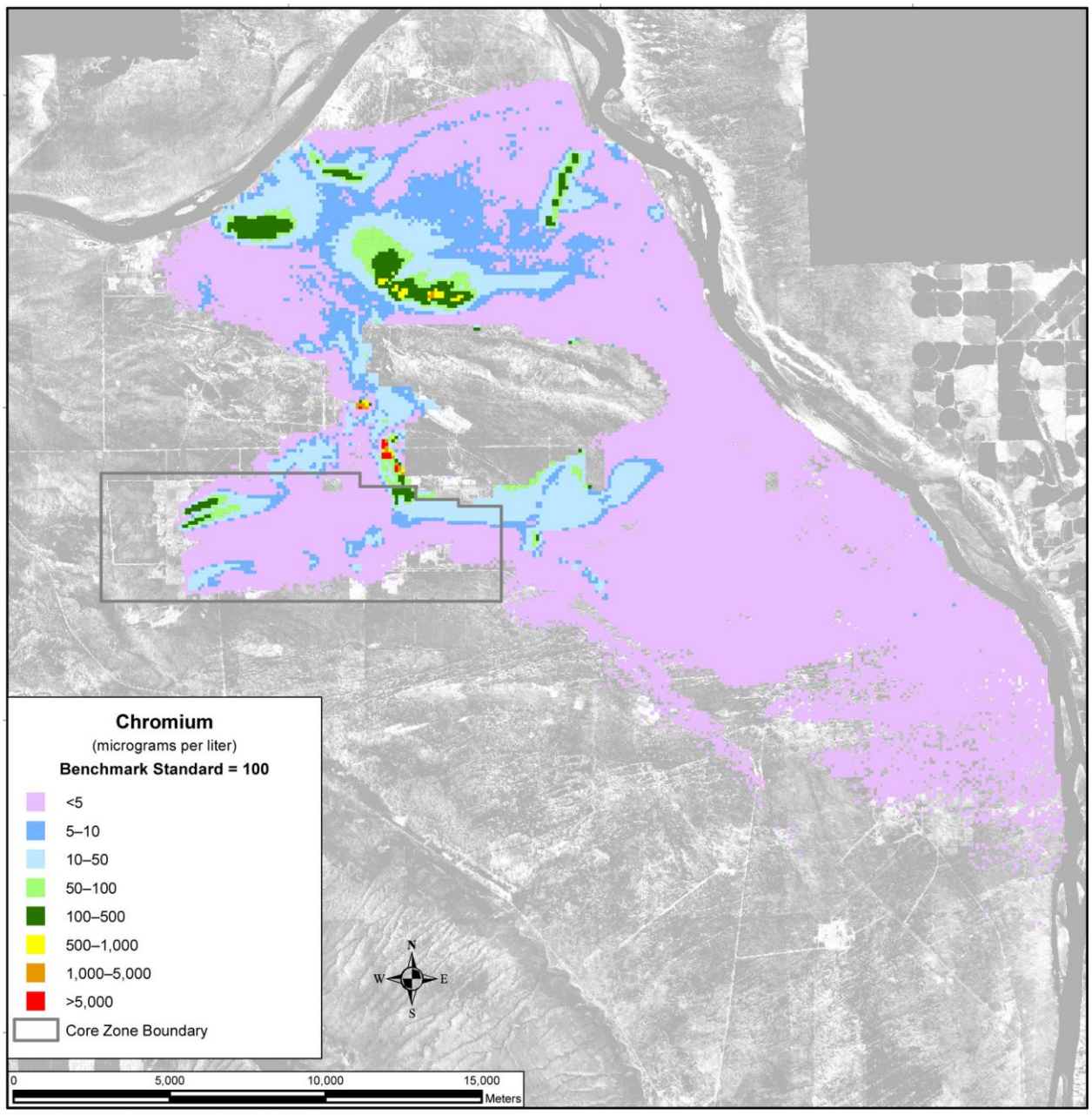
Note: To convert meters to feet, multiply by 3.281.

Figure 5–242. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Technetium-99 Concentration, Calendar Year 7140



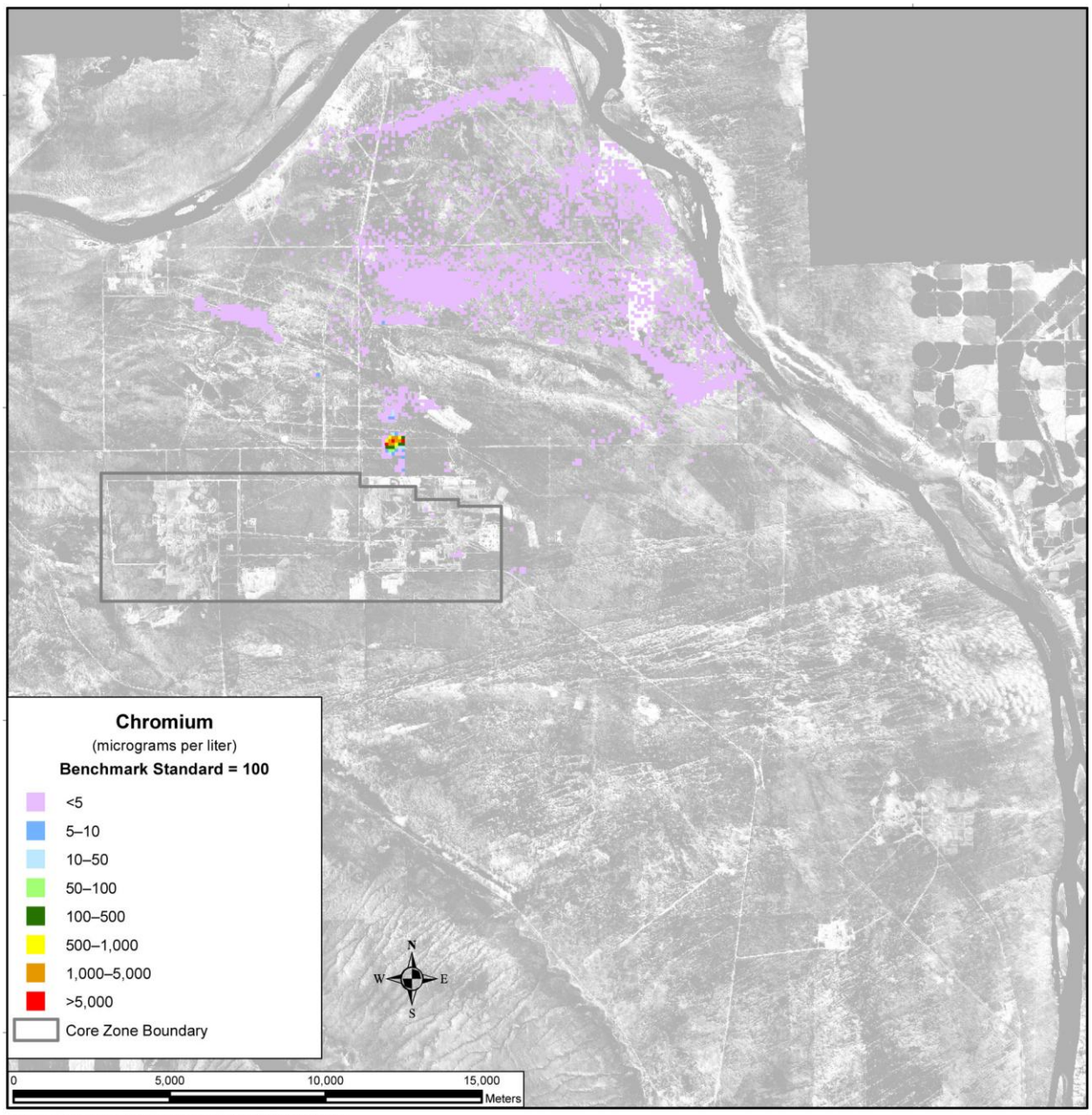
Note: To convert meters to feet, multiply by 3.281.

Figure 5–243. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Chromium Concentration, Calendar Year 2010



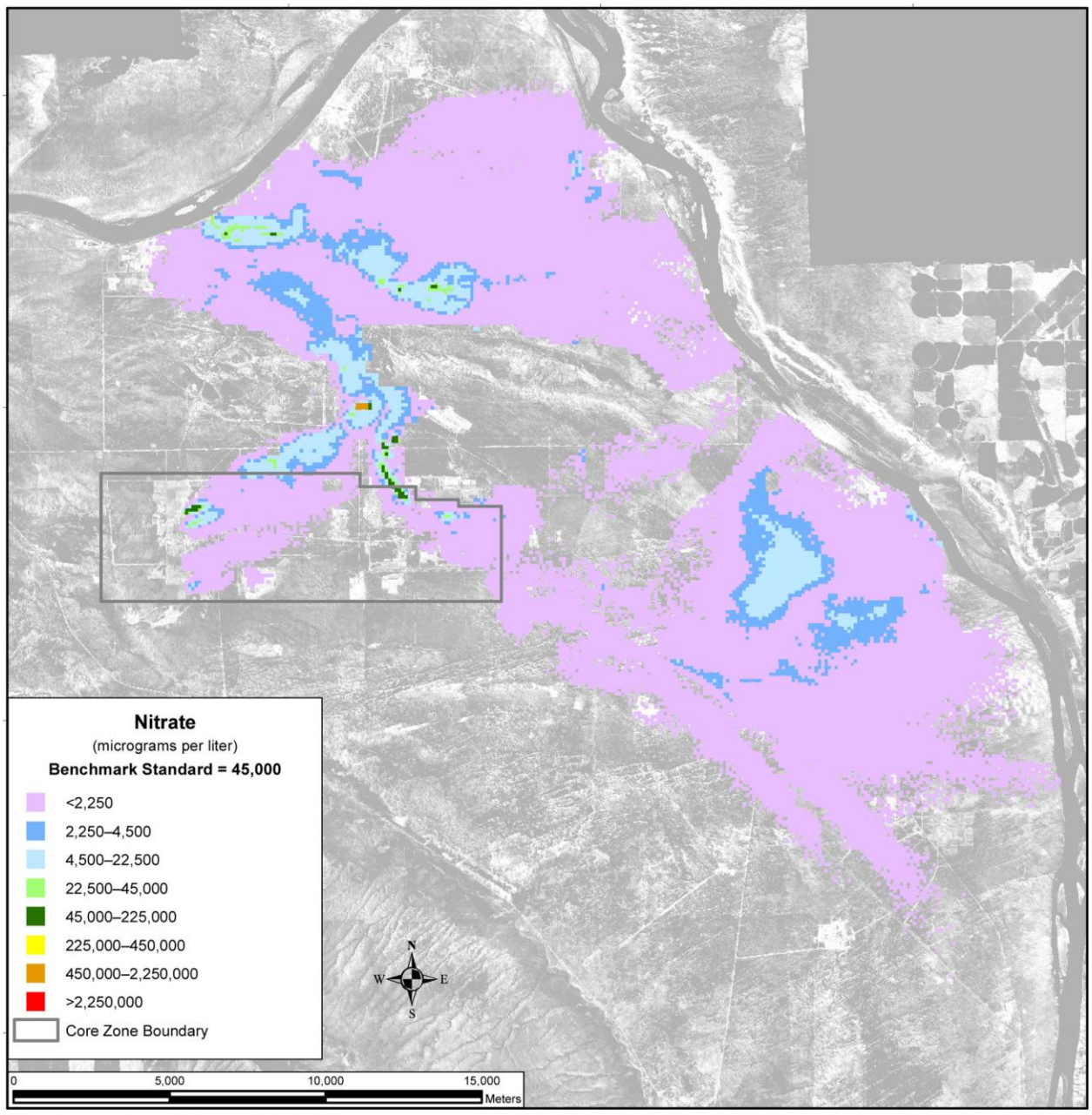
Note: To convert meters to feet, multiply by 3.281.

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



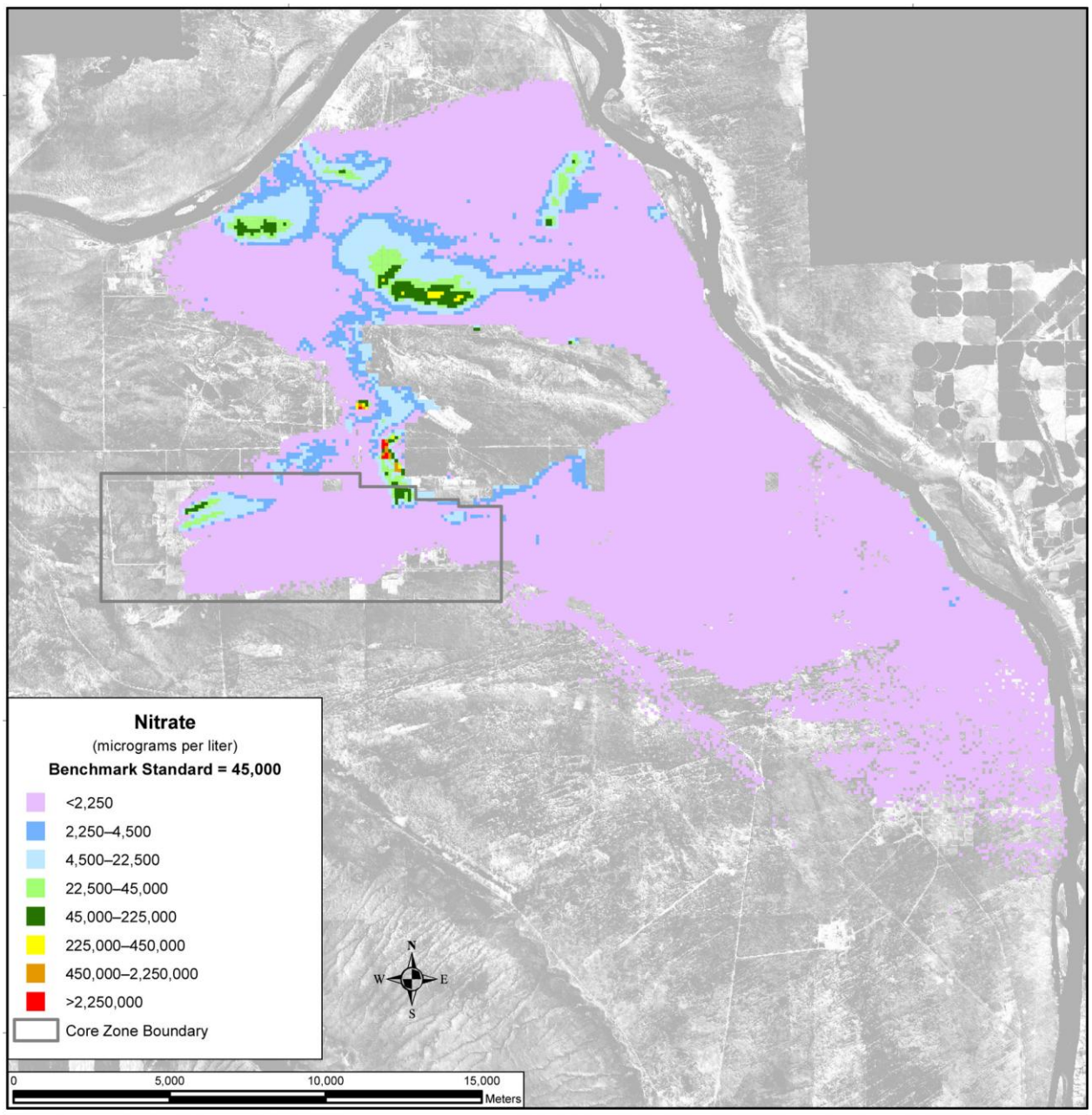
Note: To convert meters to feet, multiply by 3.281.

Figure 5–245. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Chromium Concentration, Calendar Year 7140



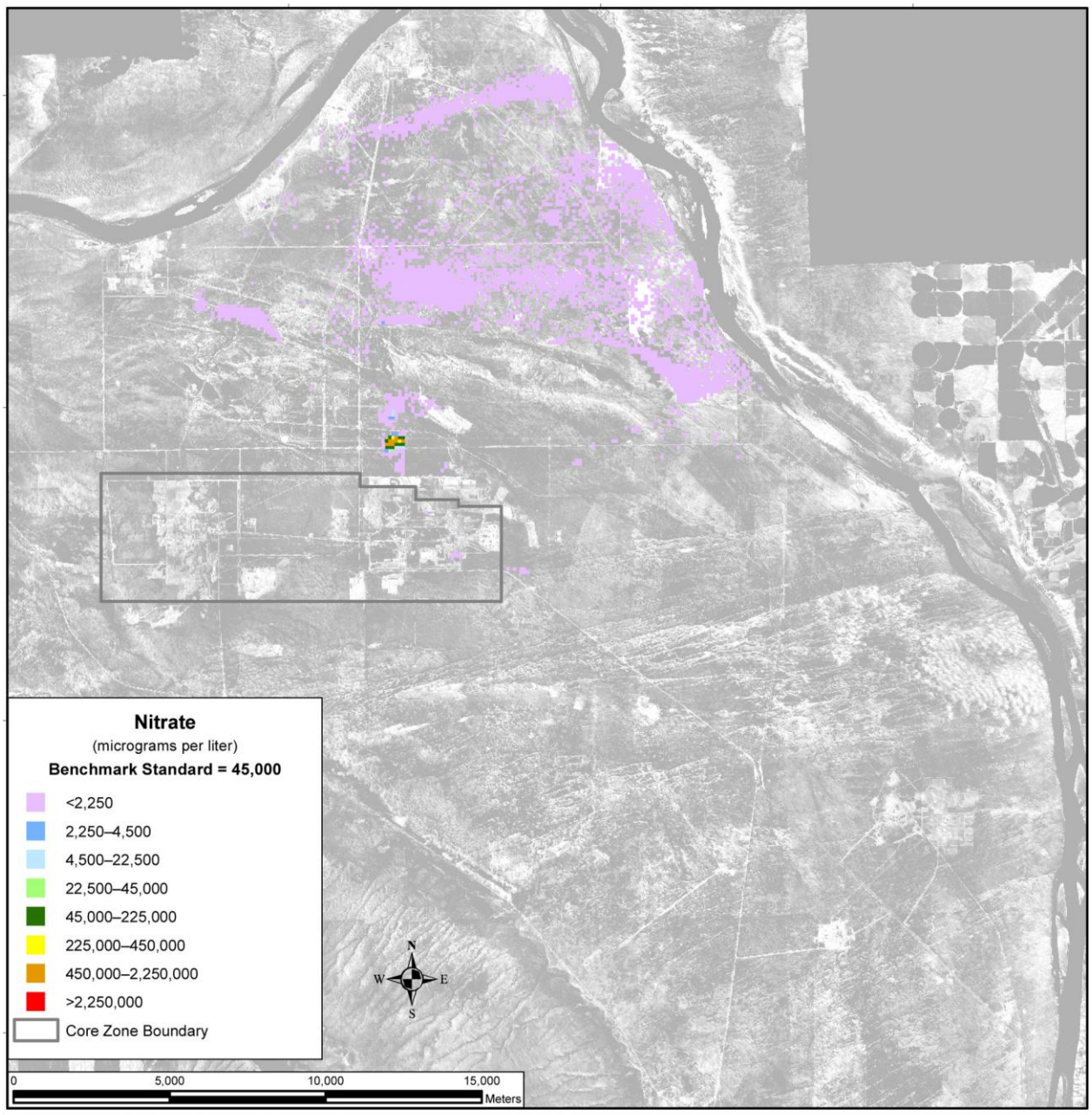
Note: To convert meters to feet, multiply by 3.281.

Figure 5–246. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Nitrate Concentration, Calendar Year 2010



Note: To convert meters to feet, multiply by 3.281.

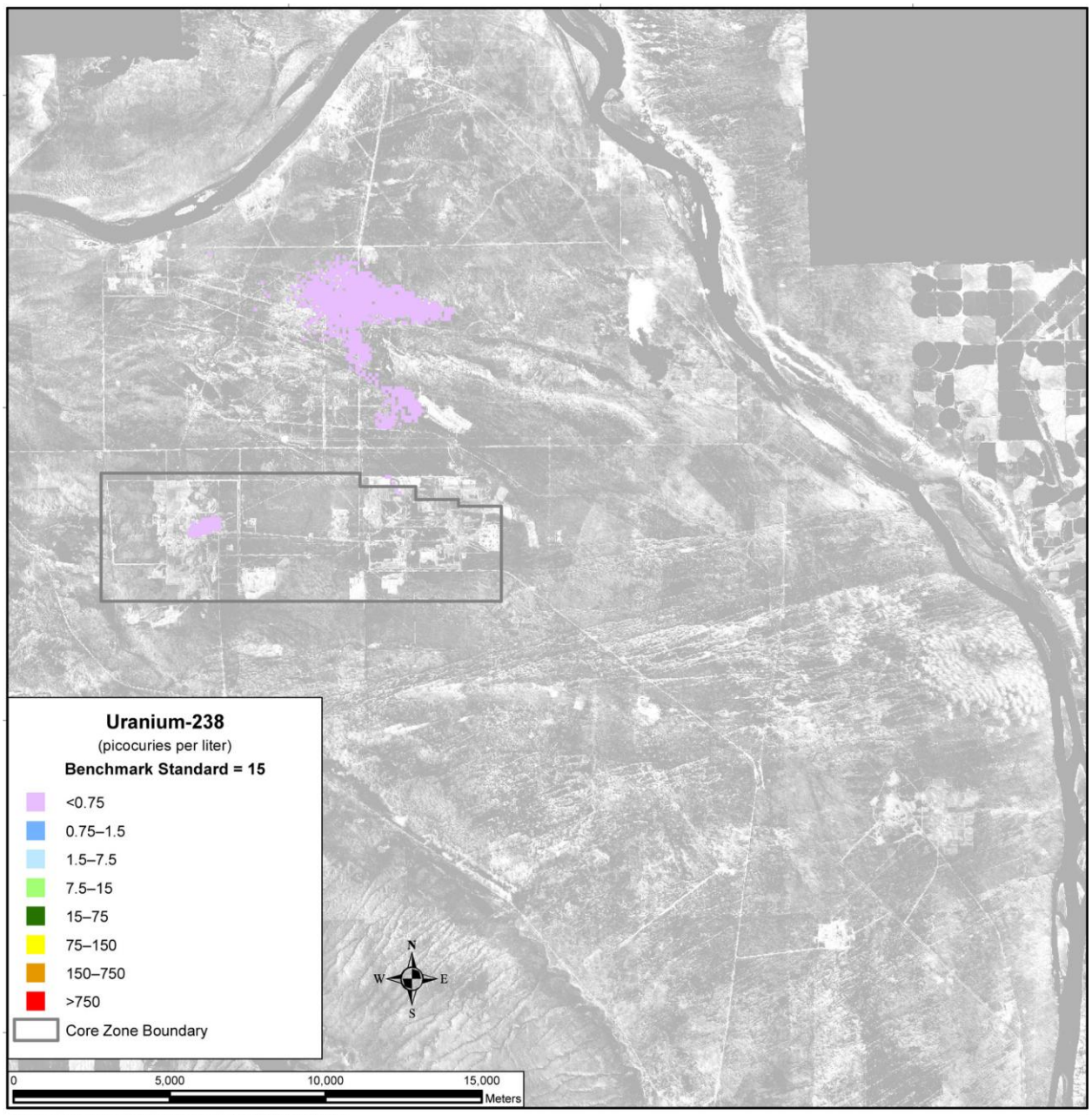
Figure 5–247. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Nitrate Concentration, Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281.

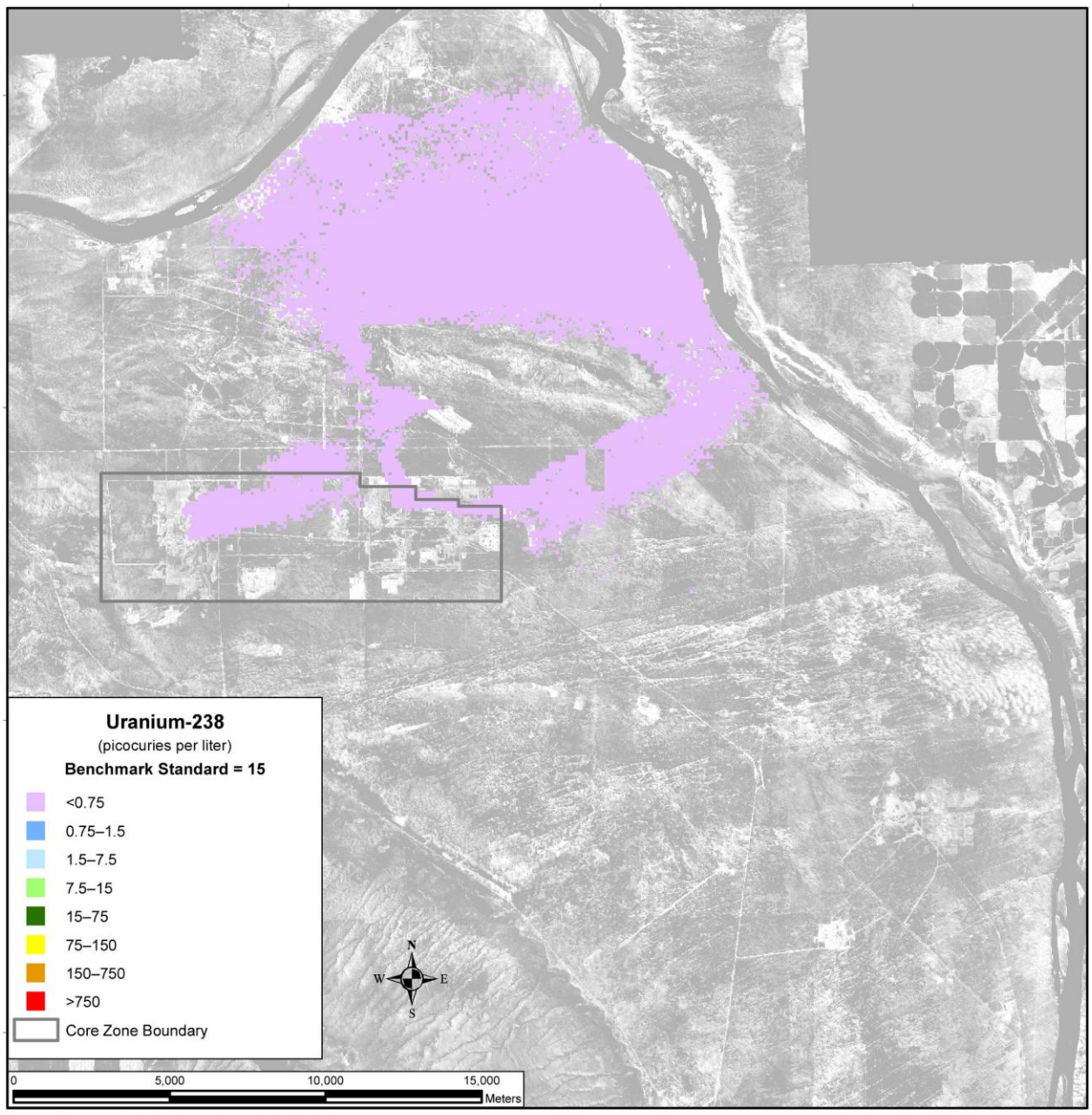
Figure 5–248. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Nitrate Concentration, Calendar Year 7140

Uranium-238 and total uranium under the Base Case are not as mobile as those COPCs discussed above, moving about seven times more slowly 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 5–249 shows the distribution of uranium-238 in CY 2010. There is a small plume associated with releases from cribs and trenches (ditches) and past leaks at the T Barrier that is less than one-twentieth of the benchmark concentration. This plume is seen extending northeast through Gable Gap. By CY 7140, the area of the plume has grown and extended to the Columbia River, but the plume is still significantly below the benchmark (see Figure 5–250). In CY 11,940, the greatest development of the plume during the analysis period is seen, although no areas exceed benchmark concentrations (see Figure 5–251).



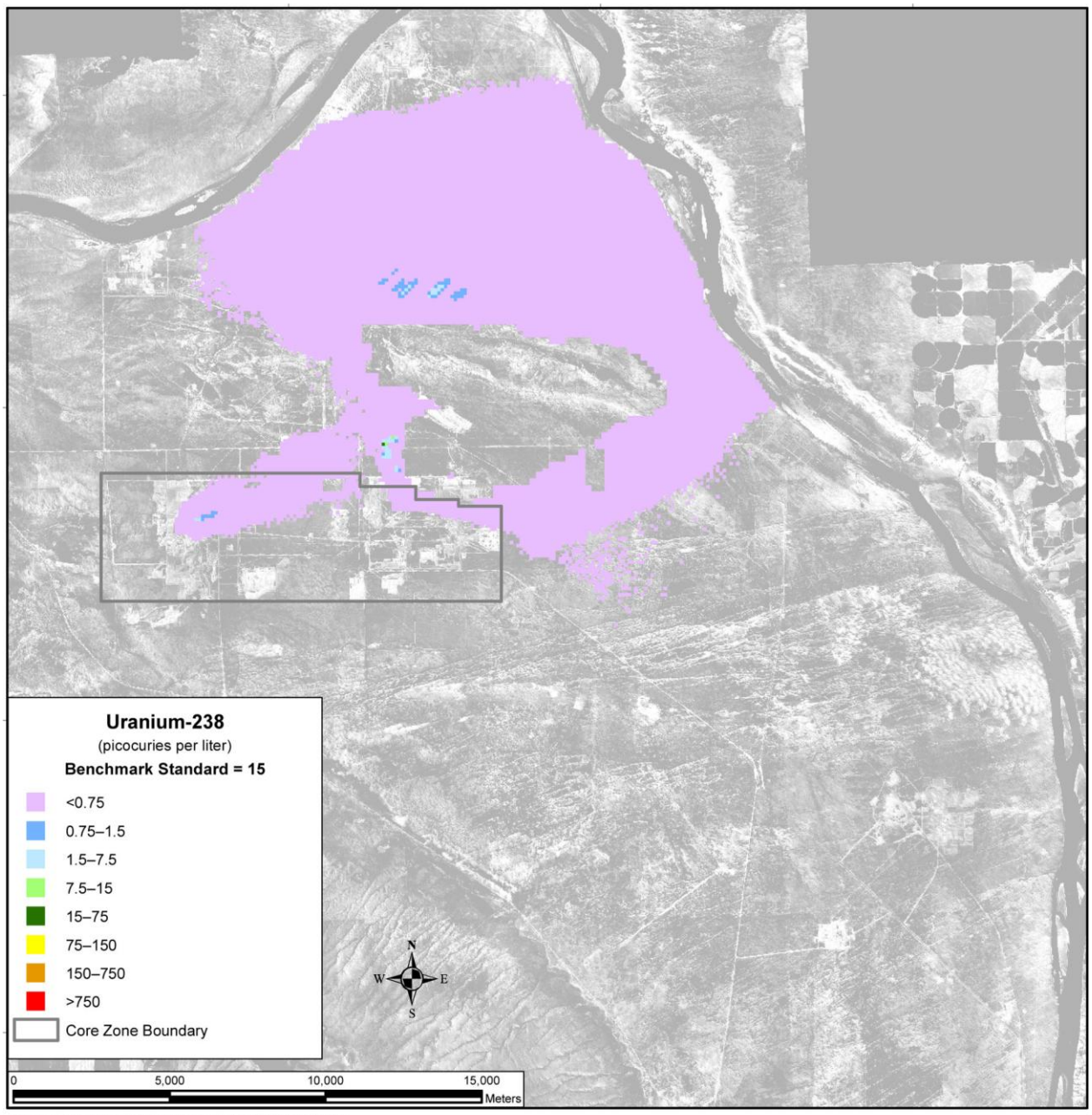
Note: To convert meters to feet, multiply by 3.281.

Figure 5–249. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Uranium-238 Concentration, Calendar Year 2010



Note: To convert meters to feet, multiply by 3.281.

Figure 5–250. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Uranium-238 Concentration, Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281.

Figure 5–251. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Uranium-238 Concentration, Calendar Year 11,940

Figure 5–252 shows the distribution of uranium-238 in CY 2010 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 larger than those under the Base Case. By CY 2135, the contaminant plumes have grown, but there are still no significant peaks in concentration levels (see Figure 5–253). By CY 11,940, the year in which the greatest development of the plumes occurs under the Base Case, the contaminant plumes under the Option Case have begun to recede (see Figure 5–254). This recession is due to the removal of the six sets of cribs and trenches (ditches) and the remediation of their contaminant plumes. Figures 5–255 through 5–257 show similar results for total uranium.