

CHAPTER 6

CUMULATIVE IMPACTS

This chapter presents the cumulative impact analyses for this *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*. The cumulative impact analyses build on the impacts of the three alternative combinations presented in Chapters 4 and 5. Generally, short-term cumulative impacts would be highest under Alternative Combination 3 and lowest under Alternative Combination 1. This is because Alternative Combination 3 generally would require the most resources and produce the most effluents and wastes, while Alternative Combination 1 would require the least resources and produce the least effluents and wastes. By contrast, long-term cumulative impacts on groundwater would generally be highest under Alternative Combination 1 and lowest under Alternative Combination 3. This is largely because Alternative Combination 1 would leave the most untreated waste and contaminants in the ground, while Alternative Combination 3 would leave the least.

6.1 METHODOLOGY

The methodology used in this *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington (TC & WM EIS)* to estimate cumulative impacts was divided into four phases: (1) identification of resource areas and appropriate regions of influence (ROIs); (2) identification of reasonably foreseeable future actions; (3) estimation of cumulative impacts; and (4) identification of monitoring and mitigation requirements. The detailed cumulative impacts methodology and a flowchart showing the four phases are presented in Appendix R of this environmental impact statement (EIS).

Cumulative Impact

Impact on the environment that results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions, regardless of what agency or person undertakes such other actions (40 CFR 1508.7).

Phase 1 - Identification of Resource Areas and Appropriate ROIs. This phase involved selecting the resource areas for the cumulative impact analyses. The resource areas selected were those considered most likely to have a potential for meaningful cumulative impacts. Steps in this process included the following:

Region of Influence

A site-specific geographic area in which the principal direct and indirect effects of the proposed actions are likely to occur.

- 1(a) Examining the resource areas evaluated in recent Hanford Site (Hanford) National Environmental Policy Act (NEPA) documents, resource areas evaluated in this *TC & WM EIS* (see Chapters 4 and 5), and resource areas where historically significant impacts have occurred to develop a list of resource areas that are likely to exhibit cumulative effects.
- 1(b) Identifying the ROI for each resource area to be evaluated. The ROIs determined the spatial limits of the cumulative impact analyses conducted for each resource area. These ROIs are described in the introduction to Appendix R, Table R-3, of this *TC & WM EIS*.

Phase 2 - Identification of Reasonably Foreseeable Future Actions. In this phase, reasonably foreseeable future actions were examined and screened to determine which needed to be included in the cumulative impact analyses. Steps in this process included the following:

Reasonably foreseeable actions are ongoing and will continue into the future, are funded for future implementation, or are included in firm near-term plans.

- 2(a) Identifying future Federal, non-Federal, or private actions planned in the ROIs. Information sources used for identification include (1) Records of Decision (RODs); (2) documents related to the Resource Conservation and Recovery Act (RCRA), the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), NEPA, and the Washington State Environmental Policy Act; (3) the Hanford Federal Facility Agreement and Consent Order, also

known as the Tri-Party Agreement (TPA); (4) permits and permit applications; (5) land use and development plans; and (6) other data sources.

- 2(b) Examining each future action to determine whether the action is reasonably foreseeable, would occur within the ROI, would occur within the same timeframe as the *TC & WM EIS* proposed actions, and was not already accounted for in the analyses of the baseline environmental conditions.
- 2(c) Retaining future actions that met the criteria listed in item 2(b) for analysis purposes. Future actions that did not meet all of the criteria were eliminated from further consideration.

Phase 3 - Estimation of Cumulative Impacts. During this phase, impact indicators for the alternative combinations (see Chapter 4, Section 4.4) were added to the baseline values and the values for the reasonably foreseeable future actions for the purpose of estimating the cumulative impacts. Steps in this process included the following:

- 3(a) Identifying and, to the extent possible, quantifying the baseline conditions. Baseline conditions reflect the effects of past and present actions (i.e., level of direct/indirect, beneficial/adverse, and short-term/long-term effects that a resource is currently experiencing). These conditions are described in Chapter 3, “Affected Environment,” of this *TC & WM EIS*. Current actions include both cleanup activities that could reduce the impacts of past actions and activities that could further degrade a resource. The importance of past actions to cumulative impacts is resource specific. For example, past air pollutant releases would not affect baseline (current) site air quality, whereas liquid releases to the ground could have a lasting effect and need to be considered as part of the baseline conditions. Therefore, only past actions that will continue to have impacts on a resource were considered in the cumulative impact analyses.
- 3(b) Identifying the impacts of the *TC & WM EIS* Preferred Alternatives and the *TC & WM EIS* alternative combinations (described in Chapters 4 and 5).
- 3(c) Identifying the impacts of reasonably foreseeable future actions from Phase 2 of the cumulative impacts analysis methodology. If quantitative data were available, those values were incorporated into quantitative or semiquantitative cumulative impact analyses. If quantitative data were not available, qualitative data were used.
- 3(d) Aggregating the effects on each resource of past, present, and reasonably foreseeable future actions, including the proposed actions. The aggregate effects were used to estimate the cumulative impacts on each resource area. The degree of the impacts was largely determined using the same impact measures described in Chapters 4 and 5 of this *TC & WM EIS*.

Phase 4 - Identification of Monitoring and Mitigation Requirements. In the fourth phase, the cumulative impact estimates developed in Phase 3 were examined to determine whether monitoring and/or mitigation activities would be needed. Steps in this process included the following:

- 4(a) Determining which resource areas would be affected by appreciable cumulative impacts.
- 4(b) Describing the measures that could be used to monitor and/or mitigate these potentially appreciable cumulative impacts. (See Chapter 7, Section 7.1, Mitigation, for information on mitigation measures that may be used to reduce impacts.)

In the *NEPA Recommendations for the Preparation of Environmental Assessments and Environmental Impact Statements* (known as the *Green Book*) (DOE 2004a), the U.S. Department of Energy (DOE) expands on Council on Environmental Quality instructions (40 CFR 1502.2) by stating that impacts

should be discussed in proportion to their significance, and that this sliding-scale approach applies to all recommendations in the *Green Book*. The *Green Book* specifically recommends the use of the sliding scale for impact identification and quantification (Chapter 6, Section 6.1, of the *Green Book*).

As described in Chapter 4, Section 4.4, several hundred impact scenarios could result from the potential combinations of the 11 Tank Closure, 3 FFTF Decommissioning, and 3 Waste Management alternatives when factored with their associated option cases and waste disposal groups. For purposes of cumulative impacts analysis, three combinations of alternatives were chosen to represent key points along the range of actions and associated overall impacts that could result from full implementation of the three sets of proposed actions. Alternative Combination 1 represents the potential short-term impacts resulting from minimal DOE action and the greatest long-term impacts with respect to groundwater. Alternative Combination 2 is a midrange case that represents DOE's Preferred Alternatives. Alternative Combination 3 represents a combination that would generally result in maximum potential short-term impacts, but would likely have the lowest long-term impacts on groundwater. (Note: For some resource areas, a combination that includes Tank Closure Alternative 6A, Option Case, would result in maximum impacts). These three alternative combinations were selected for cumulative impacts analysis in this EIS only to establish overall cumulative impact reference cases for stakeholders and decisionmakers to consider; selection of these combinations does not preclude the selection and implementation of different combinations of the various alternatives in support of final agency decisions.

Alternative Combinations Analyzed in This Environmental Impact Statement

Alternative Combination 1: All No Action Alternatives for tank closure, Fast Flux Test Facility (FFTF) decommissioning, and waste management

Alternative Combination 2: Tank Closure Alternative 2B, FFTF Decommissioning Alternative 2 with the Idaho Option for disposition of remote-handled special components (RH-SCs) and the Hanford Reuse Option for disposition of bulk sodium, and Waste Management Alternative 2 with Disposal Group 1

Alternative Combination 3: Tank Closure Alternative 6B, Base Case; FFTF Decommissioning Alternative 3 with the Idaho Option for disposition of RH-SCs and the Hanford Reuse Option for disposition of bulk sodium; and Waste Management Alternative 2 with Disposal Group 2

Analyses of cumulative impacts in this *TC & WM EIS* relied on a range of analytical methods based on the significance of the short- and long-term cumulative impacts on a given resource area, the available data, and the need to adequately address the impacts to provide information to decisionmakers and the public. Short-term cumulative impacts are discussed in Section 6.3. Long-term cumulative impacts are discussed in Section 6.4.

The short-term cumulative impacts were assumed to occur during the active project phase during which the construction, operations, deactivation, and closure activities described under the *TC & WM EIS* alternatives would take place. The following resource areas were selected for short-term cumulative impacts analysis: land resources (land use and visual resources); infrastructure; noise and vibration; air quality; geology and soils; water resources; ecological resources; cultural and paleontological resources; socioeconomics; public and occupational health and safety (during normal operations and transportation of radioactive materials); waste management; and industrial safety. The short-term cumulative impacts on these resource areas were analyzed based on semiquantitative data (i.e., simple addition of impact indicators) or qualitative information (i.e., non-numerical data). However, where data were not uniformly available or comparable across an ROI, some resource areas were addressed using a combination of semiquantitative and qualitative data.

The long-term cumulative impacts were assumed to occur following the active project phase of each *TC & WM EIS* alternative combination and were assessed out to approximately 10,000 years in the future. Resource areas selected for long-term cumulative impacts analysis comprise groundwater quality, public

health, ecological risk, and environmental justice. In general, the long-term cumulative impacts on these resource areas were evaluated quantitatively (i.e., they were modeled).

As described in Appendix R, there would be few short or long-term impacts that could substantially contribute to cumulative impacts at Idaho National Laboratory (INL) because (1) there would be no marked increase in the daily effluent emissions from, or waste generation by, the facilities; (2) sodium hydroxide, produced at INL, would be returned to Hanford for use in processing tank waste; (3) hazardous and radioactive wastes would not be disposed of at INL; and (4) impacts of the activities would be small. Therefore, cumulative impacts at INL were considered and found to be insignificant. Transportation of materials and waste to and from INL, however, was included in the cumulative impact analyses (see Section 6.3.11).

6.2 POTENTIAL CUMULATIVE ACTIONS

As stated under “Principles of Cumulative Effects Analysis” in the Council on Environmental Quality’s 1997 publication, *Considering Cumulative Effects Under the National Environmental Policy Act* (CEQ 1997), “cumulative effects are caused by the aggregate of past, present, and reasonably foreseeable future actions,” and “cumulative effects are the total effect...of all actions taken, no matter who (Federal, non-Federal, or private) has taken the action.” Therefore, it is important to identify past, present, and future actions that may appreciably degrade resources or add to the impacts on them.

For most resource areas, baseline conditions were taken from the information on the affected environment provided in Chapter 3 of this EIS. For example, as described in Chapter 3, current air quality in the ROI reflects both past and present activities. In contrast, for other resource areas, current resource use alone may not adequately account for past resource loss; thus, past use was also considered in developing baseline conditions for each resource.

Past, present, and reasonably foreseeable future actions that occur within the ROIs considered in this analysis may contribute to cumulative impacts. Examples of past Hanford activities include operation of the fuel fabrication plants, production reactors, PUREX [Plutonium-Uranium Extraction] Plant and other fuel reprocessing facilities, Plutonium Finishing Plant, and research facilities, as well as waste treatment and disposal activities. Current Hanford activities include site cleanup, waste disposal, and tank waste stabilization.

Non-DOE activities at Hanford include the following:

- Continued transport of U.S. Navy reactor compartments from the Columbia River and their disposal in trench 218-E-12B in the 200-East Area
- Continued operation of the Columbia Generating Station
- Continued operation of the US Ecology Commercial Low-Level Radioactive Waste Disposal Site (US Ecology), operated by US Ecology, Inc.
- Management of the Hanford Reach of the Columbia River as a national monument and a national wildlife refuge

Past, present, and reasonably foreseeable future offsite actions that occur in the ROIs considered in this analysis may also contribute to cumulative impacts; examples of such offsite activities include clearing land for agriculture and urban development, water diversion and irrigation projects, waste management, industrial and commercial development, mining, power generation, and development of transportation and utility networks. Activities in the region surrounding Hanford include the following:

- Future regional land use as described in local city and county comprehensive land use plans (see Chapter 3 for descriptions and locations of the cities and counties surrounding Hanford)
- Base realignment and closure and other U.S. Department of Defense activities
- Cleanup of toxic, hazardous, and dangerous waste disposal sites
- Columbia River and Yakima River water management
- Power generation and transmission line projects
- Wind energy projects
- Pipeline projects
- Transportation projects

Appendix R, Table R-4, shows the activities considered in the cumulative impact analyses.

In addition, under the American Recovery and Reinvestment Act (P.L. 111-5), DOE has accelerated its existing cleanup program at Hanford by undertaking projects to demolish nuclear facilities and support facilities, remediate contaminated groundwater, and retrieve solid waste from burial grounds. These projects are focused on cleaning up waste sites and other locations along the Columbia River to support DOE's goal of shrinking Hanford's active cleanup area from 1,518 to 194 square kilometers (586 to 75 square miles) or less by 2015. The projects are being conducted predominantly under CERCLA, with incorporation of NEPA values. However, additional NEPA reviews may be conducted, as appropriate.

6.3 SHORT-TERM CUMULATIVE IMPACTS

Short-term cumulative impacts are associated with the active project phase, during which the construction, operations, deactivation, and closure activities described under the *TC & WM EIS* alternatives would take place.

This section presents short-term cumulative impacts for the following resource areas: land resources (land use and visual resources); infrastructure; noise and vibration; air quality; geology and soils; water resources; ecological resources; cultural and paleontological resources; socioeconomics; public and occupational health and safety (during normal operations and transportation of radioactive materials); waste management; and industrial safety. Detailed tables supporting the short-term cumulative impact analyses are presented in Appendix T.

6.3.1 Land Resources

Cumulative impacts related to land use were evaluated in an ROI that includes the proposed *TC & WM EIS* action areas, Hanford, and areas up to 80 kilometers (50 miles) from Hanford. The land use analysis focuses on the area of land impacted by recent and future growth within the ROI. A general description of land resources at Hanford and within the region is presented in Chapter 3, Section 3.2.1.1. Additional detailed information is presented in Appendix T, Table T-1.

Because project descriptions obtained for this cumulative impacts analysis did not always identify existing land use, it was not always possible to determine specific future changes; however, in most cases, land use would change from agricultural or vacant land to a new use. In some cases, aerial photography viewed via Google Earth was used to determine current land use. It was assumed that, prior to the actual implementation of any offsite project within the ROI, issues such as conformance with existing land use plans and zoning would be resolved at the county or local level; thus, this issue was not addressed further.

For visual resources, the ROI includes the proposed *TC & WM EIS* action areas, Hanford, and nearby offsite areas. A qualitative analysis was performed to examine whether recently completed and reasonably foreseeable future actions would change the character of the viewshed. Factors considered include the overall area of land disturbed by the activities, the location of the activities relative to each other and public points of observation, and the proximity of the activities to the proposed *TC & WM EIS* action areas.

6.3.1.1 Land Use

To estimate the cumulative land area that would be disturbed within the ROI, the total area disturbed by the *TC & WM EIS* alternative combinations (see Chapter 4, Section 4.4.1) was added to the area disturbed by other DOE activities at Hanford and non-DOE activities within the ROI. Thirty-five activities within the ROI were analyzed in regard to the area of land they would disturb. These projects either were recently completed or are reasonably expected to be completed in the near future (see Appendix T, Table T-1). Note that the projects evaluated do not represent the only activities affecting land use within the ROI. For example, the addition of many smaller subdivisions and commercial developments within the region and the conversion of vacant land to agricultural use would have a direct, but unknown, additive effect on land use. Uncertainties also exist regarding implementation of a number of large projects within the ROI; information sufficient to project their impacts on land use was not available when this EIS was prepared. A number of these projects are addressed separately in the following text because they have the potential for cumulative impacts on future regional land use.

Certain activities occurring at Hanford and within the ROI may positively affect future land use. For example, remediation efforts at Hanford could facilitate potential reuse or restoration of land consistent with the land use designations described in the *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement (Hanford Comprehensive Land-Use Plan EIS)* (DOE 1999a). Reuse of land would negate the need to develop other, possibly undisturbed areas. Restoration of remediated sites would return some land to more-natural conditions (e.g., shrub-steppe habitat).

Table 6-1 presents the results of the cumulative land use analysis within the ROI. Cumulative actions may disturb from 25,000 to 25,800 hectares (61,800 to 63,800 acres) of land in the approximately 2.0-million-hectare (5.0-million-acre) area up to 80 kilometers (50 miles) from Hanford. The *TC & WM EIS* alternatives would use from 2 to 797 hectares (5 to 1,970 acres). To determine the contribution of the three alternative combinations to the cumulative land requirement, the area disturbed under each combination was divided by the total land requirement. Thus, Alternative Combination 1 represents 0.01 percent of the cumulative land requirement brought about by past, present, or reasonably foreseeable future actions within the ROI; Alternative Combination 2 represents 1.2 percent; and Alternative Combination 3 represents 3.1 percent. Although not one of the three alternative combinations selected for analysis, a combination of alternatives that includes Tank Closure Alternative 6A, Option Case; FFTF Decommissioning Alternative 3 (with all facilities to be built at Hanford); and Waste Management Alternative 3 (with Disposal Group 2 or 3) would require the greatest amount of land area. Such a combination would represent 4.0 percent of the cumulative land requirement within the ROI. As noted above, these are conservative estimates because actual land use changes in the region could be greater than those reported for the 35 analyzed activities, and some activities within the ROI could have a net positive impact on land use.

Table 6–1. Cumulative Land Area Disturbed

Actions/Activities	Land Area Disturbed (hectares)
TC & WM EIS Combined Impacts (see Chapter 4, Table 4–152)	
Alternative Combination 1	2
Alternative Combination 2	308
Alternative Combination 3	797
Other DOE Actions at the Hanford Site (see Appendix T, Table T–1)	752
Non-DOE Actions at the Hanford Site (see Appendix T, Table T–1)	449
Other Projects/Activities in the Region of Influence (see Appendix T, Table T–1)	23,800
Cumulative Totals^a	
Alternative Combination 1	25,000
Alternative Combination 2	25,300
Alternative Combination 3	25,800

^a The cumulative totals are the sums of the impacts under the *TC & WM EIS* alternative combinations, the other DOE and non-DOE actions at the Hanford Site, and other activities in the region of influence.

Note: To convert hectares to acres, multiply by 2.471. Totals may not equal the sum of the contributions due to rounding.

Key: DOE=U.S. Department of Energy; *TC & WM EIS*=*Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*.

Because the total area of developed land within the ROI is unknown, the change in the proportion of developed land within the region resulting from the 35 analyzed activities cannot be determined. However, considering the size of the ROI and the amount of past development, the additional disturbance of the land by the evaluated projects would be small. Because the extent of past development at Hanford—i.e., 6 percent, or 9,106 hectares (22,502 acres), of the total Hanford land area, which is 151,775 hectares (375,040 acres) (Neitzel 2005)—is known, it is possible to determine the effect that past, present, and reasonably foreseeable future development may have on the site. Thus, considering the land requirement of each of the three alternative combinations, as well as the other projects and activities occurring at the site, the total area of land disturbed at Hanford would increase to between 6.8 and 7.3 percent of the site under the three alternative combinations evaluated. Under the alternative combination that would have the maximum foreseeable environmental impacts (Tank Closure Alternative 6A, Option Case; FFTF Decommissioning Alternative 3 [with all facilities to be built at Hanford]; and Waste Management Alternative 3 [with Disposal Group 2 or 3]), which is not included in any cumulative impact tables, the total area of disturbed land would increase to 7.5 percent. As noted above, these are conservative estimates because future remediation and restoration efforts were not taken into account.

Additional actions that may impact land use within the ROI include decisions made in the ROD (64 FR 61615) and amended ROD (73 FR 55824) for the *Hanford Comprehensive Land-Use Plan EIS* (DOE 1999a), urban expansion, closure of the Umatilla Army Depot, the Columbia River Water Management Program, and a number of power-related projects.

The generalized land use plan established by the RODs for the *Hanford Comprehensive Land-Use Plan EIS* is shown in Chapter 3, Figure 3–1, of this *TC & WM EIS*. While there is minimal potential for development in certain areas of Hanford (e.g., the Hanford Reach National Monument, Gable Mountain, Gable Butte) due to the applicable land use designations described in the *Hanford Comprehensive*

Land-Use Plan EIS (DOE 1999a), other areas of the site could undergo future land use changes. For example, areas designated as Industrial-Exclusive are suitable for the treatment, storage, and disposal of various wastes, while those designated as Industrial are suitable for reactor operations, rail and barge transport facilities, mining, manufacturing, and distribution operations. In addition, areas designated as Conservation (Mining), while principally set aside for management and protection of cultural, ecological, and natural resources, may be utilized for mining operations. Other land use designations, including Research and Development and Recreation, would permit various levels of future development. Thus, the land use plan allows for as-yet-unspecified future changes at Hanford.

The 1990 Washington State Growth Management Act (RCW 36.70A) requires counties in the region around Hanford to have comprehensive land use plans. Cities and other government jurisdictions adopt such comprehensive plans to guide future activities within their jurisdictions. These plans project land development, housing, infrastructure, and community services needs 20 years into the future. Generally, the plans encourage growth in urban growth areas (lands set aside or designated as necessary for future population growth beyond those undeveloped lands already within city boundaries) and discourage growth outside these areas. As an example, the *City of Richland Comprehensive Land Use Plan* (Richland 2008:LU3-2) has designated urban growth areas that cover an area of 12,400 hectares (30,630 acres). While the designation of such areas helps planners with long-range planning efforts, specific details regarding future development are uncertain; thus, these county comprehensive land use plans cannot be used to project reasonably foreseeable future actions.

In May 2005, the U.S. Department of Defense announced its latest round of base realignment and closure actions (AFIS 2005; BRAC 2005). The 7,972-hectare (19,700-acre) Umatilla Army Depot, located about 48 kilometers (30 miles) to the south of Hanford, is the only major military facility in the ROI that would be affected. The Umatilla Army Depot Reuse Authority has recently developed the *U.S. Army Umatilla Chemical Depot Base Redevelopment Plan* (UMADRA 2010). This plan recommends specific redevelopment land use zones to accommodate the three overarching goals of economic development, environmental preservation, and military reuse and sets forth five alternatives for redevelopment of the Umatilla Army Depot. However, as the precise impacts of closure of the depot have not been evaluated and will be the subject of future NEPA documentation, impacts of redevelopment on land use are not addressed.

The Columbia River Basin Water Management Act (RCW 90.90) requires the Washington State Department of Ecology (Ecology) to “aggressively pursue the development of water supplies to benefit both in-stream and out-of-stream uses.” Ecology is currently in the process of developing the Columbia River Water Management Program to facilitate implementation of the legislation. Implementation of new storage or conservation projects would have clear implications for changes in future land use (Ecology 2007:1).

A number of power-related projects have been proposed for the ROI, but have been put on hold. These include the Plymouth Generation Facility (a 306-megawatt, natural-gas-fired turbine electricity-generating facility [Benton and BPA 2003; BPA 2009]) and the Wanapa Energy Center (a 1,200-megawatt gas and steam turbine electricity-generating facility [BIA 2004; BPA 2009]). If completed, these projects would result in additional changes in land use within the ROI.

6.3.1.2 Visual Resources

One measure of cumulative impacts is whether the visual character of the ROI would change as a result of implementation of past, present, and reasonably foreseeable future actions. Because of the limited size of many of the projects, their distance from Hanford, and their proximity to areas that are presently developed, the overall change to the viewshed within the ROI is likely to be minimal. Further, many activities at Hanford would not be visible from public viewpoints (e.g., nearby higher elevations,

highways, the Columbia River) and thus would contribute little to overall cumulative impacts on visual resources.

As noted above, the location of new facilities relative to public points of observation is an important consideration in determining cumulative visual impacts. One of the few locations that would permit a relatively unobstructed view of much of the ROI is the top of Rattlesnake Mountain. From this location, many activities at Hanford would be visible (see Chapter 4, Section 4.4.1.2), as would a number of offsite projects. For example, an observer atop Rattlesnake Mountain would be able to see Borrow Area C, some of the larger projects within the 200 Areas, and the Red Mountain American Viticultural Area near Benton City, Washington. These activities would replace existing views with ones that would be different from those currently observed. Implications of cumulative visual impacts on American Indians who consider Rattlesnake Mountain an important cultural property are addressed in Section 6.3.8.3.

The relative cumulative visual impacts of the three *TC & WM EIS* alternative combinations would be similar to the combined impacts addressed in Chapter 4, Section 4.4.1.2, because all other past, present, and reasonably foreseeable future non-DOE actions within the ROI would remain the same under all of the alternative combinations evaluated. Thus, development associated with Alternative Combination 1 would contribute the least to cumulative visual impacts, and Alternative Combination 3 would contribute the most. As noted in the discussion of combined visual impacts, a combination of alternatives involving Tank Closure Alternative 6A, Option Case; FFTF Decommissioning Alternative 3 (with all facilities to be built at Hanford); and Waste Management Alternative 3 (with Disposal Group 2 or 3) would disturb the greatest area and alter the existing viewshed to the greatest extent.

Completion of remediation and restoration activities at Hanford would positively impact the visual environment. These activities would include, for example, decommissioning of the reactors in the 100 Areas, closure of the canyon facilities in the 200 Areas, and restoration of the borrow areas following completion of mining activities. While remediated and restored areas would not precisely replicate past conditions, they would improve the viewshed overall and lessen the cumulative visual impacts. However, not all remediation actions would lead to the restoration of more-natural conditions because some facilities or sites are located within areas designated in the *Hanford Comprehensive Land-Use Plan EIS* (DOE 1999a) as Industrial-Exclusive or Industrial. These areas would continue to be available for further development, as noted in Section 6.3.1.1.

In most cases, activities within the ROI would not change the U.S. Bureau of Land Management visual resource management classifications because projects would be located in or adjacent to areas that are already developed. However, the visual resource management classification for Borrow Area C would change from Class II to Class III under Alternative Combination 1 and to Class IV under Alternative Combinations 2 and 3. In the latter case, mining activities would dominate an area that had previously undergone minimal development.

6.3.2 Infrastructure

For the purpose of providing the most meaningful analysis, electricity and water were selected as key resource indicators for assessing potential cumulative effects on utility infrastructure systems. For electric power, the ROI includes the electric power distribution and transmission system and associated power capacity that supplies the Hanford 100, 200, 300, and 400 Areas. For water, the affected ROI includes the Hanford Export Water System that supplies the Hanford 100 and 200 Areas and part of the 600 Area. Projected requirements for these utility resources under each of the *TC & WM EIS* alternative combinations (see Chapter 4, Section 4.4.2) were added to the demands of other DOE and non-DOE activities at Hanford, all of which have the potential to impact the associated utility system and utility resource consumption within the defined ROI. The ROIs for electric power and water supply were determined to provide the most meaningful analyses of potential cumulative effects on utility

infrastructure because the affected utility systems are relatively confined to Hanford and otherwise well defined, and projected demands can be quantified with the least amount of uncertainty.

Table 6–2 presents the results of the cumulative impacts analysis for utility infrastructure. The utility requirements presented in Table 6–2 represent the peak annualized utility resource demands under the three *TC & WM EIS* alternative combinations; baseline demands from Chapter 3; and projected utility demands for various DOE and non-DOE activities that have the potential to occur within the same timeframe. Appendix R, Table R–4, details the actions and activities that were evaluated to determine their possible contributions to cumulative impacts at Hanford. As specifically noted in that table, many of the listed actions are already either wholly or partially accounted for in the Hanford baseline in terms of their contribution to cumulative impacts.

Projected changes in cumulative utility resource demands over the period of analysis reflect operations activities, as well as finite actions (such as final closure actions) that may result in a spike and/or subsequent reduction in demands as activities are performed or final actions are completed. The potential for the cumulative demand to exceed the capacity of the utility system that supplies the resource within the Hanford utility infrastructure ROI was assessed. In short, the focus of this analysis was to forecast the potential maximum annual utility resource demand that could occur as a basis for assessing cumulative impacts on utility infrastructure. The totals presented represent upper limits of utility demands at Hanford.

As indicated in Table 6–2, neither the capacity of the Hanford electric transmission system (1.74 million megawatt-hours per year) nor the capacity of the Hanford Export Water System (18,500 million liters per year [4,881 million gallons per year]) would be exceeded on a cumulative basis. For electric power, peak cumulative demands would range from about 10 percent of capacity under Alternative Combination 1 to 81 percent under Alternative Combination 3. For water supply, peak cumulative demands would range from about 10 percent under Alternative Combination 1 to 24 percent under Alternative Combination 3. An alternative combination that would include Tank Closure Alternative 6A, Base or Option Case, would exceed the current Hanford electrical transmission capacity of 1.74 million megawatt-hours per year. These peak electricity requirements for Alternative 6A, Base and Option Cases, are presented in Chapter 4, Section 4.4.2.

Based on the analysis performed, only the electric power system would be substantially impacted by the cumulative effects of the *TC & WM EIS* alternative combinations and present and future actions; up to 90 percent of the cumulative effect on electric power capacity would be attributable to *TC & WM EIS* activities alone. Cumulative peak annual utility demands approaching the capacity of the utility system that supplies the resource would be indicative of the need for DOE and utility providers to consider project changes, resource conservation, augmentation of utility capacity, or some combination of measures to ensure that utility demands can be met at Hanford to support ongoing and future tank closure, waste treatment, and other related actions. As referenced in this chapter and in Appendix R, proposed wind energy projects could help alleviate any electric power shortages that could otherwise indirectly affect the Hanford electric power system in the future.

Historically, electric power consumption across Hanford and the capacity of the transmission and distribution systems were much greater, especially when the 100 Area reactors were in operation (see Chapter 3, Section 3.2.2.2). This is also true for the Hanford Export Water System, which withdraws water from the Columbia River and once supplied water to the 100 Areas, but has been reconfigured over time (see Chapter 3, Section 3.2.2.4). As indicated in Appendix R, decommissioning of the 100 Area reactor facilities is ongoing. Prior to 1990, the 200 Areas alone had annual water demands of more than 22,700 million liters (6,000 million gallons), which were supplied via the Hanford Export Water System.

Table 6–2. Potential Cumulative Utility Infrastructure Requirements

Actions/Activities ^a	Peak Annualized Requirement	
	Electricity (million megawatt-hours)	Water (million liters)
TC & WM EIS Combined Impacts (see Chapter 4, Table 4–158)		
Alternative Combination 1	0.04	1,120
Alternative Combination 2	1.20	3,690
Alternative Combination 3	1.27	3,830
Other DOE Actions at the Hanford Site		
Hanford Site baseline ^b	0.173	817
Cleanup and restoration activities (2006–2035)	No data	No data
Actions to empty the K Basins in the 100-K Area (2006–2036) (DOE 1996a)	–0.013	0.90
Deactivation of FFTF in the 400 Area (2006–2036) ^c	–0.020	–116
Excavation and use of geologic materials (2006–2013) (DOE 2001, 2003a)	No data	No data
Construction and operation of the ERDF (2006–2024) (DOE 1994)	No data	No data
Pacific Northwest National Laboratory Physical Sciences Facility (2006–2011) (DOE 2007a)	No data	No data
Construction, operation, and long-term management of GTCC LLW and GTCC-like waste (2019–2083) (DOE 2011a)	0.0060	8.5
Other DOE Actions Subtotal	0.146	710
Non-DOE Actions in the Region of Influence		
US Ecology Commercial Low-Level Radioactive Waste Disposal Site (2006–2056) (Ecology and WSDOH 2004:140)	0.00045	0.076
Hanford Reach National Monument (2006–2022) (USFWS 2008)	No data	No data
Non-DOE Actions Subtotal	0.00045	0.076
Cumulative Totals^d		
Alternative Combination 1	0.186	1,830
Alternative Combination 2	1.346	4,400
Alternative Combination 3	1.416	4,540
Utility System Capacity^e	1.74	18,500

^a Actions/activities as identified in Appendix R, Table R–4. Years in parentheses reflect the timeframe in which the resource demand may occur.

^b From Chapter 3, Table 3–2.

^c Assumes future decommissioning of FFTF and the 400 Area with the resulting cessation of pre-deactivation levels of utility consumption (based on fiscal year 2006 reporting).

^d The cumulative totals are the sums of the impacts under the *TC & WM EIS* alternative combinations and the other DOE and non-DOE activities. Subtotals and totals may not equal the sum of the contributions due to rounding.

^e Capacity of the electric power and water supply systems serving the Hanford Site from Chapter 3, Table 3–2.

Note: To convert liters to gallons, multiply by 0.26417.

Key: DOE=U.S. Department of Energy; ERDF=Environmental Restoration Disposal Facility; FFTF=Fast Flux Test Facility; GTCC=greater-than-Class C; LLW=low-level radioactive waste; *TC & WM EIS*=*Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*.

As indicated in Chapter 4, Section 4.4.2, the projected resource demands under the three *TC & WM EIS* alternative combinations would be very conservative because contributing peak utility demands are likely to occur in different timeframes and not overlap. In addition, the Hanford baseline already includes utility

impacts associated with existing and ongoing tank closure activities that cannot be separated out; therefore, their addition to the impacts of the *TC & WM EIS* alternative combinations unavoidably reflects some level of double counting. Future actions associated with sitewide waste cleanup and restoration activities, including proposed closure of the Central Plateau, are expected to cause a temporary increase in utility demands, followed by a decline and even cessation of resource consumption after specified cleanup actions are completed. The timing and duration of associated peaks in utility consumption and subsequent reduction in utility demands upon completion of activities are very speculative, and no data are available for calculating such estimates.

Similarly, utility resource requirements for cleanup of the balance of Hanford and decontamination and decommissioning (D&D) of individual facilities have not been well quantified in available documentation such as the *Draft Hanford Remedial Action Environmental Impact Statement and Comprehensive Land Use Plan* (DOE 1996b) or subsequent plans or studies. While there would likely be an incremental increase in utility demands in the short term to complete individual cleanup and facility D&D actions, the net effect over the longer term would be a sitewide reduction in utility demands once activities have ceased. While individual future cleanup and facility disposition and D&D actions were considered in this *TC & WM EIS* (see Appendix R, Table R-4), they are not specifically listed in Table 6-2, and their cumulative effect on utility infrastructure presents another point of uncertainty and possible conservatism in the analysis.

Some actions will undoubtedly also result in reduced resource consumption where existing facilities and infrastructure are upgraded and/or replaced with modern facilities that use resources more efficiently. Such is the case with the relocation of Pacific Northwest National Laboratory (PNNL) personnel and activities from the 300 Area to the new PNNL Physical Sciences Facility. Construction of the PNNL Physical Sciences Facility was completed in 2010. Net operational impacts on Hanford's utility infrastructure would decrease once the transition is complete (DOE 2007a:S-3, 15). Nevertheless, this reduction in utility resource demands has not been quantified. In any event, as the City of Richland, Washington, provides utility services to Hanford (DOE 2007a:5-13, 15), any operational impacts would not directly affect the utility systems serving Hanford facilities. Such circumstances further add to the conservative nature of this analysis.

Hanford is being considered for the development, operation, and long-term management of a facility for the greater-than-Class C (GTCC) low-level radioactive waste (LLW) and GTCC-like waste (DOE 2011a). Although a preferred alternative has not been identified, should Hanford be selected, small short-term incremental demand on water and electricity could result (DOE 2011a). Conservative estimates for peak annual water and electricity requirements are included in Table 6-2.

Excavation of geologic and soil resources for use across Hanford in support of ongoing activities necessarily entails some consumption of utility resources, including water to control dust and to aid crushing and sorting operations and liquid fuels to operate heavy equipment. While not separately quantified from available data, these demands were assumed to be at least partially captured in the Hanford baseline value presented in Table 6-2. Utility resource consumption would likely increase in proportion to the excavation and conveyance of greater volumes of material to support future actions (see Section 6.3.5); these utility requirements were already quantified to some extent within the requirements of the three *TC & WM EIS* alternative combinations.

As stated previously, the analysis also considered utility infrastructure impacts of non-DOE activities. Ongoing operations and utility resource consumption associated with US Ecology are included in the Hanford baseline. Future closure actions would result in additional, short-term demands, but are difficult both to quantify and to separate from operational demands already included in the Hanford baseline. Estimates for these incremental demands are included in Table 6-2, where available, and likely contribute further to the conservative nature and uncertainty of the analysis presented.

In addition, U.S. Fish and Wildlife Service personnel working at the Hanford Reach National Monument are using existing Hanford facilities that have been declared surplus to DOE needs, including maintenance shops, a pump house, and a reservoir, as well as sharing space with other entities such as the Bonneville Power Administration (USFWS 2008:3-145, 3-146). Utility demands associated with operation of these facilities were assumed to be part of the Hanford baseline. Nonetheless, the U.S. Fish and Wildlife Service's preferred alternative for management of the Hanford Reach National Monument would entail construction and maintenance of new facilities and other improvements, including interpretive sites, parking and boat access areas, trails, and a possible visitor center to enhance visitor use and access to areas within the Hanford Reach National Monument (USFWS 2008:4-225–4-227). While these activities would add to the cumulative demand for utility resources, the demand cannot be quantified at this time.

6.3.3 Noise and Vibration

Noise impacts of activities under the *TC & WM EIS* alternatives would result primarily from changes in vehicle traffic on access roads to Hanford, as discussed in Chapter 4, Sections 4.1.3, 4.2.3, and 4.3.3. Based on information provided in the NEPA documents that are available (see Appendix R, Table R-4), noise impacts on the public from other DOE activities are related primarily to vehicle traffic. Impacts on wildlife could occur from various construction activities, including remediation, closure, and operation of the various borrow areas.

Noise impacts of non-DOE construction and operations activities were also considered, including impacts on the public and wildlife from construction-related activities and future industrial operations in the 300 Area. Noise impacts from existing non-DOE activities at Hanford, such as traffic noise from the Columbia Generating Station and operation of the AREVA NP, Inc. (formerly Framatome ANP, Inc.), facility, the Perma-Fix Northwest (formerly known as Pacific EcoSolutions) waste treatment facility, and US Ecology, are part of the existing background sound environment near Hanford.

Future activities at Hanford and in the areas near the site, such as new industries, oil and gas development, agriculture, offices, schools, residential development, new roads, and other infrastructure improvements, could result in variations in the levels of traffic noise along access roads to the site and increased noise levels near these developments. Some of the proposed developments in the area that are expected to result in increased noise levels include various wind energy projects; the Columbia Ethanol Plant in Finley, Washington; the Southridge, Hansen Park, and Clearwater Park developments in Kennewick, Washington; and the new PNNL Physical Sciences Facility at Hanford.

As such, the cumulative impact on noise levels in the region from the activities described above is expected to result in some increase in traffic noise and localized changes in noise levels from new facilities and developments. Because of the distance to the site boundary, little or no change in overall offsite noise levels is expected due to construction, operations, and decommissioning activities at Hanford.

DOE activities, other activities at Hanford, traffic through Hanford, and roadwork at Hanford could result in ground vibration that could affect the operation of the Laser Interferometer Gravitational-Wave Observatory. Most activities that are expected to impact this facility are associated with the use of heavy vehicles and large construction equipment. It is expected that blasting during building and road construction and during mining could also have an impact on this facility. Although DOE would coordinate vibration-producing activities with the operators of the observatory, the cumulative impacts of these activities are expected to result in some interference with its operations.

6.3.4 Air Quality

Cumulative impacts of criteria air pollutants are shown in Table 6–3 for DOE actions at Hanford and non-DOE actions in the region for those pollutant concentrations that have been quantified. Cumulative impacts of radioactive air emissions on public and occupational health and safety are discussed in Section 6.3.10. The concentrations presented in Table 6–3 represent the maximum concentrations under the three *TC & WM EIS* alternative combinations, the baseline concentrations from Chapter 3, and the estimated maximum concentrations for various DOE and non-DOE activities that have been presented in NEPA documents.

Table 6–3 indicates that cumulative concentrations of carbon monoxide, nitrogen oxides, and sulfur oxides could be up to 499, 109, and 251 percent of applicable standards under Alternative Combination 3, respectively. Cumulative concentrations of particulate matter with an aerodynamic diameter less than or equal to 10 micrometers (PM₁₀) could be up to 157 times the applicable standard under Alternative Combination 3.

The carbon monoxide concentrations expected under Alternative Combination 2, 17,200 micrograms per cubic meter, and Alternative Combination 3, 49,900 micrograms per cubic meter, could exceed the 8-hour carbon monoxide standard of 10,000 micrograms per cubic meter. The nitrogen oxide concentration expected under Alternative Combination 3 could exceed the annual nitrogen oxide standard of 100 micrograms per cubic meter. The peak concentrations of carbon monoxide and nitrogen oxide expected under the *TC & WM EIS* alternatives would result primarily from fuel-burning activities. These concentrations could be reduced by applying appropriate administrative control measures and by converting to alternative fuels (see Chapter 7, Section 7.1.4).

Particulate matter (PM) concentrations expected under the *TC & WM EIS* alternative combinations could exceed the 24-hour standard for PM₁₀, 150 micrograms per cubic meter. Concentrations would range from 1,050 micrograms per cubic meter under Alternative Combination 1 to 23,500 under Alternative Combination 3. The peak concentration of PM expected under the *TC & WM EIS* alternatives would result primarily from construction and earthmoving activities. PM concentrations could be reduced by applying appropriate dust control measures (see Chapter 7, Section 7.1.4).

The cumulative impacts analysis is very conservative because many of the air pollutant releases would occur at different times, and the peak concentrations would occur at different locations and may not be additive. The estimates of air pollutant concentrations under the *TC & WM EIS* alternative combinations were based on conservative analyses that would be refined in future design documents. If the more refined future analyses still predict exceedances of air quality standards, additional measures (e.g., location changes, use of additional pollution control equipment, or administrative controls) would be instituted to reduce emissions to an acceptable level. Activities that would cause air quality standards to be exceeded would not be allowed.

Hanford facilities that are permitted under the Hanford Site Air Operating Permit were included in the estimate of the Hanford baseline concentrations (see Chapter 3, Section 3.2.4, of this *TC & WM EIS*) based on the annual emissions inventory.

Impacts of other onsite activities are discussed below based on the information provided in the environmental impact documents that are available.

Table 6–3. Cumulative Impacts of Criteria Air Pollutants

Actions/Activities	Maximum Average Concentration (micrograms per cubic meter)			
	Carbon Monoxide (8 hours)	Nitrogen Oxides (annual)	Particulate Matter (PM ₁₀) (24 hours)	Sulfur Oxides (1 hour)
TC & WM EIS Combined Impacts^a				
Alternative Combination 1	3,490	9.5	1,050	24.8
Alternative Combination 2	17,200	46.6	9,040	228
Alternative Combination 3	49,900	109	23,500	492
Other DOE Actions at the Hanford Site				
Hanford Site baseline ^b	39.5	0.237	0.926	2.19
Existing borrow areas (DOE 2001) ^c	NR	NR	4.03	NR
Cleanup and restoration activities	No data	No data	No data	No data
Construction and operation of the ERDF (2006–2024) (DOE 1994)	No data	No data	No data	No data
Other DOE Actions Subtotal	39.5	0.237	0.926	2.19
Non-DOE Actions in the Region of Influence				
Perma-Fix Northwest offsite thermal treatment of Hanford Site LLW (DOE 1999b)	0.24	0.0283	0.000442	0.0398
Perma-Fix Northwest nonthermal treatment of Hanford Site LLW (DOE 1998a)	NR	NR	0.0026	NR
Non-DOE Actions Subtotal^d	0.24	0.028	0.003	0.040
Cumulative Totals^e				
Alternative Combination 1	3,530	9.77	1,050	27.0
Alternative Combination 2	17,200	46.9	9,040	230
Alternative Combination 3	49,900	109	23,500	494
Most Stringent Standard	<i>10,000</i>	<i>100</i>	<i>150</i>	<i>197</i>

^a See Chapter 4, Table 4–159.

^b See Chapter 3, Table 3–3.

^c Particulate matter concentration at a borrow pit. Value is not representative of the concentration to which the public would be exposed; thus, it is not reflected in the subtotal presented.

^d The maximum from these non-DOE facilities is presented because the location of these estimated concentrations is not presented in the source documents.

^e The cumulative totals are the sums of the impacts under the *TC & WM EIS* alternative combinations and the other DOE and non-DOE activities.

Note: Values that exceed the standard value are shown in **bold** text. Subtotals and totals may not equal the sum of the contributions due to rounding.

Key: DOE=U.S. Department of Energy; ERDF=Environmental Restoration Disposal Facility; LLW=low-level radioactive waste; NR=not reported; PM₁₀=particulate matter with an aerodynamic diameter less than or equal to 10 micrometers; *TC & WM EIS*=*Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*.

In the 100 Areas, there would be continuing fugitive dust emissions and emissions from reactor decommissioning over the next 50 years or more (DOE 1999a:3-61, 5-45) and dust from waste site excavation (DOE 2006a). In the 200 Areas, there would be ongoing fugitive dust emissions and equipment emissions from various borrow area and construction sites (DOE 1999a:3-61, 5-45); dust and equipment emissions from ongoing construction and operation of the Environmental Restoration Disposal Facility (ERDF) (DOE 1994); emissions from canyon disposition (221-U closure) (DOE 2004b); emissions from facility demolition and remediation, including excavation, backfill, and capping (Fluor

Hanford 2004); and emissions from above-grade structure removal of the Plutonium Finishing Plant (DOE 2003a). In the 300 Area, there would be fugitive dust emissions and other emissions from closure and future uses of surplus facilities (DOE 1999a).

Other DOE activities at Hanford include activities at existing active borrow pits and quarries (DOE 2001), as well as reactivation of former borrow areas in the 100-F, 100-H, and 100-N Areas (DOE 2003b), which would produce emissions of fugitive dust and other pollutants from excavation equipment and trucks. Construction and operation of the PNNL Physical Sciences Facility, relocated from the 300 Area to the PNNL campus, likely resulted in some fugitive dust emissions and other construction emissions during the period from 2007 to 2008, as well as emissions of other criteria pollutants from boiler use and emergency generator operation. Maximum concentrations resulting from operation of this facility were estimated to be about 4 percent of the 8-hour carbon monoxide standard and 4 percent of the PM₁₀ 24-hour standard and are not included in Table 6-3 (DOE 2007a).

Non-DOE activities that would emit fugitive dust and other pollutants include AREVA NP facility operation, which would have nitrogen oxides emissions; Perma-Fix Northwest nonthermal and thermal treatment of mixed low-level radioactive waste (MLLW), which could have some combustion emissions (DOE 1998a, 1999b; Pacific EcoSolutions 2007); Volpentest Training and Education Center activities, which would have negligible emissions, except for vehicular emissions (DOE 2002a); and operation of US Ecology, which would have fugitive dust emissions (Ecology and WSDOH 2004). The proposed Wanapa Energy Center, if built, would be a major source of air pollutant emissions, but would not significantly deteriorate the quality of the air surrounding the proposed site or lead to deterioration of air quality in nearby pristine areas (BIA 2004:3.5-1, 3.5-2). The proposed Plymouth Generating Facility, if built, would not significantly deteriorate the quality of the air surrounding the proposed site (Benton and BPA 2003:II-4). The Wanapa Energy Center and Plymouth Generating Facility projects are currently on hold (BPA 2009).

Oil and gas development, including exploration and production activities, could result in fugitive dust emissions and other air pollutant emissions from drilling equipment, compressor stations, and other equipment. Maximum impacts of these activities generally occur close to the source; therefore, they are not expected to contribute substantially to impacts near Hanford. Facility conversion of waste to energy and biofuels could result in fugitive dust emissions from construction and other air pollutant emissions from operations. The Columbia Ethanol Plant in Finley, when completed, would have annual emissions of approximately 29 metric tons of nitrogen oxides; 19 of sulfur oxides; 64 of carbon monoxide; 89 of volatile organic compounds; and 63 of PM from vents, the stack, and roads (total PM and PM₁₀). Emission of ethanol and other organic compounds would be below the levels of concern for human health risk (Columbia Ethanol Plant Holdings, LLC 2006). Other proposed or recently permitted biofuels facilities in the region would emit similar air pollutants.

Mobile source emissions in Benton County account for about 68 percent of county annual emissions of carbon monoxide, 52 percent of nitrogen oxides, 69 percent of sulfur oxides, and 39 percent of volatile organic compounds (EPA 2011). In addition to the industrial sources of air pollutants discussed above, there are industries that produce asphalt paving material and block, nitrogen fertilizer, crushed stone, canned fruits and vegetables, frozen foods, and nonferrous metal sheet, as well as grain storage facilities and natural gas transmission facilities (EPA 2007).

Other development in the region could result in increases in air pollutant emissions from construction activities, vehicle traffic, and other sources related to new housing, businesses, and industries. For example, in Kennewick, the subarea plans for Southridge, Hansen Park, and Clearwater Park include the development of several thousand acres for housing, commercial and business use, and industrial use (see Section 6.3.1.1). In addition, increased mining activity and reclamation of mined areas could lead to increases in air pollutant emissions.

Cumulative impacts of worldwide emissions of greenhouse gases are projected to include a continued increase in the average temperature in the northwestern United States. See Section 6.5.2 for a discussion of global climate change. Many climate models indicate an increase in winter precipitation in the northwest and a decrease in summer precipitation. Changes in snowpack, earlier snowpack melting, and changes in stream flows are expected to continue. Higher temperatures during cooler months would result in more precipitation falling as rain and in earlier snowpack melting (GCRP 2009:135–138). Decreased energy use for heating could decrease emissions of air pollutants. Higher temperatures and changes in precipitation are expected to increase the risk of fires and the amount of windblown dust, thus increasing the frequency of natural windblown dust events. Increased electricity demands for cooling could increase emissions of air pollutants from electricity generation. Decreased availability of water could result in less irrigation and increased acreage susceptible to wind erosion.

6.3.5 Geology and Soils

Existing conditions in regard to geology and soils are presented in Chapter 3, Section 3.2.5. These existing conditions define the Hanford baseline that was considered for this cumulative impacts analysis. The Hanford baseline already reflects past actions that have directly impacted geology and soils. Therefore, past activities were not considered further; rather, this discussion focuses on the potential for cumulative impacts on geology and soils resulting from ongoing and future actions. As such, the ROI for geologic and soil resources encompasses all of Hanford, including the proposed *TC & WM EIS* action areas and any ongoing or future actions across Hanford that may require excavation of geologic and soil resources from Borrow Area C and additional materials from gravel pit No. 30.

Table 6–4 presents the results of the cumulative impacts analysis for geologic and soil resources. The resource requirements presented in Table 6–4 represent the total projected material demands under the three *TC & WM EIS* alternative combinations and the projected demands to support various DOE and non-DOE activities that could potentially occur within the same timeframe. The potential for the cumulative demand to exceed the available reserves of geologic and soil resources at Hanford was also assessed. Appendix R, Table R–4, details the actions and activities that were considered for their possible contribution to cumulative impacts at Hanford.

Projected cumulative impacts on geologic and soils resources over the period of analysis mainly reflect demands for sitewide cleanup and closure actions and facility D&D. Added to these demands are those associated with construction, operation, and future deactivation and closure of facilities under the three *TC & WM EIS* alternative combinations. Future closure actions, including cleanup and restoration of closed disposal facilities, as well as final capping of closed disposal facilities or facilities that have undergone D&D, but contain residual waste, represent the largest activity demands for geologic and soil resources (see Table 6–4).

As for the other DOE actions considered, construction of the new PNNL Physical Sciences Facility south of the 300 Area would require geologic and soil resources as part of site preparation, including crushed stone and structural fill, dense-graded aggregate, and other materials needed to meet geotechnical specifications (DOE 2007a:15). These requirements have not been quantified, as shown in Table 6–4, but the related demand would add to Hanford’s overall geologic and soil resource requirements. In addition, DOE has included Hanford as one of several possible locations to construct and operate a new facility for the disposal of GTCC LLW and GTCC-like waste. Disposal methods would include trenches, boreholes, and vaults. Of the three disposal methods, the vault method would require the most geologic material, including gravel, sand, clay, soil, and those raw geologic materials for concrete, because this method would involve the installation of interim and final cover systems (DOE 2011a:5-49, 6-81). Geologic resource requirements for the vault disposal method are included in Table 6–4.

Table 6–4. Potential Cumulative Geologic and Soil Resource Requirements

Actions/Activities ^a	Total Geologic and Soil Resource Requirements (cubic meters)
<i>TC & WM EIS Combined Impacts (see Chapter 4, Table 4–155)</i>	
Alternative Combination 1	99,000
Alternative Combination 2	6,480,000
Alternative Combination 3	18,700,000
Other DOE Actions at the Hanford Site	
Hanford Site baseline ^b	Not applicable
Excavation and use of geologic materials (2006–2050) (DOE 2001:2-2; 2003a:2-2)	1,170,000
Cleanup and restoration activities (2006–2146) (DOE 1996b:5-40, 5-93)	17,800,000
Final disposition of the canyons, PUREX Plant, PUREX tunnels, and other facilities (2006–2035) (Fluor Hanford 2004:2-13, 2-15)	30,900,000
Retrieval of retrievably stored transuranic waste (2017–2018) (based on SAIC 2007)	No data
Construction and operation of the ERDF (2006–2024) (DOE 1994:9T-6)	6,420,000
Pacific Northwest National Laboratory Physical Sciences Facility (2006–2010) (DOE 2007a)	No data
Closure of Nonradioactive Dangerous Waste Landfill and 600 Area Central Landfill ^c (2010–unknown date) (DOE 2011b)	11,500,000
Disposal of GTCC low-level radioactive waste and GTCC-like waste (2015–2039) (DOE 2011a:5-49)	576,000
Other DOE Actions Subtotal	68,400,000
Non-DOE Actions in the Region of Influence	
US Ecology Commercial Low-Level Radioactive Waste Disposal Site (2006–2056) (Ecology and WSDOH 2004:140)	552,000
Hanford Reach National Monument (2006–2022) (USFWS 2008)	No data
Non-DOE Actions Subtotal	552,000
Cumulative Totals^d	
Alternative Combination 1	69,000,000
Alternative Combination 2	75,400,000
Alternative Combination 3	87,700,000
<i>Site Resource Availability^e</i>	<i>49,600,000</i>

^a Actions/activities as identified in Appendix R, Table R–4. Years in parentheses reflect the timeframe in which the resource demand may occur.

^b Past and present geologic and soil resource consumption is not applicable to the analysis of cumulative impacts. The region of influence for this analysis consists of Borrow Area C, which has not been impacted to date, and gravel pit No. 30, from which Waste Treatment Plant construction materials have been extracted to date.

^c The 600 Area Central Landfill is referred to as the “Solid Waste Landfill” in the cited reference (DOE 2011b).

^d The cumulative totals are the sums of the impacts under the *TC & WM EIS* alternative combinations and the other DOE and non-DOE activities.

^e Combined resource reserves from Borrow Area C and gravel pit No. 30 (see Chapter 3, Section 3.2.5).

Note: Values that exceed the established resource capacity are shown in **bold** text. To convert cubic meters to cubic yards, multiply by 1.308. Subtotals and totals may not equal the sum of the contributions due to rounding.

Key: DOE=U.S. Department of Energy; ERDF=Environmental Restoration Disposal Facility; GTCC=greater-than-Class C; PUREX=Plutonium-Uranium Extraction; *TC & WM EIS*=*Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*.

Closure actions associated with non-DOE activities were also considered, including final closure of US Ecology (see Table 6–4). As noted in Section 6.3.2, implementation of the *Hanford Reach National Monument Final Comprehensive Conservation Plan and Environmental Impact Statement, Adams, Benton, Grant and Franklin Counties, Washington* (USFWS 2008) would entail construction and maintenance of new facilities and other improvements such as interpretive sites, parking and boat access areas, trails, and a possible visitor center. These proposed activities would consume geologic and soil resources. However, these needs, as well as the ongoing demand for maintenance of existing assets, cannot be quantified at this time.

As indicated in Table 6–4, projected demands for other DOE and non-DOE activities would exceed the 49.6 million cubic meters (64.9 million cubic yards) of established geologic and soil reserves from Borrow Area C and gravel pit No. 30 even without the additional requirements of the *TC & WM EIS* alternative combinations. Projected cumulative demands for geologic and soil resources would range from about 19 to 51 percent in excess of established reserves under Alternative Combinations 1, 2, and 3. Although the projected volumes of geologic and soil resources for the activities listed in Table 6–4 are believed to be conservative, the analysis does indicate that completion of all contemplated future actions could require use and development of additional borrow areas beyond Borrow Area C and gravel pit No. 30. Geologic and soil resources, including relatively large volumes of gravel, sand, and silt, are available from the suprabasalt sediments and associated soils across Hanford and elsewhere in the region. Rock in the form of basalt is also plentiful. Alternatively, any shortfall, if realized, could be fully or partially provided from offsite commercial quarries, but would result in additional transportation impacts due to increased truck transportation to and from Hanford, as well as additional costs for obtaining these materials from commercial sources.

6.3.6 Water Resources

This section addresses the potential cumulative impacts of past, present, and reasonably foreseeable future actions on water resources, including surface water (with a special focus on the Columbia River) and the Hanford groundwater system (including the vadose zone). Existing conditions in regard to water use and surface-water and groundwater quality are presented in Chapter 3, Sections 3.2.2.4, 3.2.6.1, and 3.2.6.3, respectively. These existing conditions define the Hanford baseline that was considered for this cumulative impacts analysis. The Hanford baseline already reflects past DOE and non-DOE actions that have directly impacted existing surface waters, such as alteration of Columbia River hydrology, as well as historical contaminant releases from DOE or other facilities that have impacted surface-water and groundwater quality. Therefore, past activities were not considered further; rather, this discussion is focused on the potential for ongoing and future actions to have short-term cumulative impacts on water resources.

Cumulative water resources impacts of ongoing and future DOE and non-DOE activities were considered, including individual future cleanup and facility disposition activities and D&D actions identified in Appendix R, Table R–4. Ongoing and future actions to clean up the Central Plateau, as well as individual facility D&D actions, combined with actions associated with the *TC & WM EIS* alternative combinations (see Chapter 4, Section 4.4.5), are not expected to contribute to direct cumulative impacts on water resources. This is because, other than the Columbia River, water courses are essentially nonexistent at Hanford; surface-water drainage patterns are poorly developed to convey potentially contaminated stormwater or other effluents; the depth to groundwater across much of the site is such that any effluents would be unlikely to affect groundwater; and the most intensive cleanup and D&D activities (on the Central Plateau) are located at some distance from the Columbia River. In addition, best management practices and other mitigation measures would be employed to ensure that stormwater runoff and infiltration does not convey soil, sediments, and other pollutants to any nearby surface water or groundwater. Furthermore, compliance with applicable permit provisions would help ensure that any generated effluents from ongoing and future actions are treated and disposed of so as to have no

additional impact on surface water, the vadose zone, or groundwater. Additionally, while not easily quantified, future non-DOE activities near Hanford (new industries, oil and gas development, agriculture, residential development, new road construction, and other infrastructure improvements) are likely to be the larger contributors to cumulative impacts on surface water and groundwater over the timeframe considered in this analysis.

As quantified in Section 6.3.2, projected water use from the Columbia River associated with the *TC & WM EIS* alternative combinations, coupled with other future actions at Hanford, is not expected to have a substantial cumulative impact on the availability of water for downstream users. This is because the projected cumulative demands by all DOE and non-DOE actions would be only about 20 percent of the pre-1990 water demands of the Hanford 200 Area facilities. While water use by communities that utilize the Columbia River as a water source is expected to rise commensurate with land use development and general population increases in the region, as discussed in Section 6.3.2, contemplated actions at Hanford would actually reduce the overall impact on surface-water and groundwater availability and quality.

Ongoing and future DOE actions, including many associated with the *TC & WM EIS* alternative combinations, would have positive short- and long-term effects on water resources. Sitewide cleanup and closure actions and facility D&D would remove and immobilize contaminants in the Hanford vadose zone and prevent or delay their entry into the groundwater and ultimately into the Columbia River. In addition, such remedial actions, coupled with DOE efforts across Hanford to significantly curtail wastewater discharge to surface-water impoundments and the subsurface water (see Chapter 3, Section 3.2.6.3.1), have slowed and will continue to slow the migration of existing groundwater contaminant plumes to the Columbia River. Long-term impacts on water resources, including projected changes in groundwater hydrology and transport of contaminants through the Hanford groundwater system and ultimately into the Columbia River, are addressed in Section 6.4.1.

6.3.7 Ecological Resources

Although ecological resources include terrestrial resources, wetlands, aquatic resources, and threatened and endangered species, cumulative impacts were addressed for only terrestrial resources and threatened and endangered species. Because there would be no direct or indirect short-term impacts on wetlands or aquatic resources under any of the *TC & WM EIS* alternatives, actions associated with them would not contribute to cumulative impacts within the ROI. For terrestrial resources, the cumulative impacts on the terrestrial habitat as a whole, and, more specifically, on the shrub-steppe habitat, were examined. For threatened and endangered species, the analysis included federally and state-listed threatened and endangered species and other special status species. The ROI for both terrestrial resources and threatened and endangered species included the proposed *TC & WM EIS* action areas, Hanford, and areas up to 80 kilometers (50 miles) from Hanford. The analysis was limited to an 80-kilometer (50-mile) radius because that distance included a large portion of southeastern Washington, an area within which shrub-steppe habitat historically has occurred.

6.3.7.1 Terrestrial Resources

Thirty-five activities within the ROI were analyzed in regard to the area of terrestrial and shrub-steppe habitat that they would disturb. These projects either were recently completed or are reasonably expected to be completed in the near future (see Appendix T, Table T-1). Note that the projects evaluated do not represent the only activities affecting terrestrial habitat within the ROI. For example, construction of many smaller subdivisions and commercial developments and conversion of land to agricultural use would also impact terrestrial habitat; however, the number and extent of these smaller activities cannot be readily determined. In addition, uncertainties exist relative to implementation of a number of large

projects within the ROI; specific information regarding their impacts on ecological resources is not available at this time.

Studies have estimated that 6.07 million hectares (15 million acres) of shrub-steppe habitat (60 percent of the landscape) existed in eastern Washington before land conversion began with the arrival of white settlers. Recent studies have estimated that only about 30 percent of the landscape now consists of this habitat type. Thus, there has been a 50 percent decrease in the historical occurrence of shrub-steppe habitat since the 1840s (Jacobson and Snyder 2000:1, 20). Beyond the loss of shrub-steppe habitat, much of that which remains has been fragmented. Shrub steppe is a fragile habitat, and many of the animal species that have evolved with it require large contiguous areas to survive. Thus, fragmentation, which results in small blocks of habitat, can seriously impact wildlife populations (Dobler et al. 1996:21).

Table 6–5 presents estimates of the area of terrestrial and shrub-steppe habitat impacted by the 35 activities analyzed within the ROI. Projects are grouped by the three *TC & WM EIS* alternative combinations, other DOE activities at Hanford, non-DOE activities at Hanford, and other projects and activities within the ROI. The term “terrestrial habitat” is used in a broader sense to include shrub-steppe habitat, other native and nonnative habitat, grazing land, and cropland. Because of the importance of shrub-steppe habitat, it is identified separately in the table. While it was possible to calculate the specific area of terrestrial and shrub-steppe habitat projected to be impacted by the three alternative combinations, such information was not always available for other projects identified within the ROI. As these projects were not generally located in highly developed portions of the region, the entire project area was classified as terrestrial habitat. This approach is conservative because it likely overestimates the area of terrestrial habitat lost. In some cases, although the identified projects may disturb terrestrial habitat, including shrub-steppe habitat, the disturbance may not lead to its complete loss. For example, most habitats impacted by training operations at the U.S. Army Yakima Training Center would be degraded rather than completely lost. Further, both on Hanford and for certain offsite projects, disturbance to terrestrial habitat, especially shrub-steppe habitat, would be mitigated by replanting affected areas. Thus, while the total area of habitat affected by the 35 activities is presented in Table 6–5, the total area of habitat actually lost would be less.

The cumulative total terrestrial habitat that could be disturbed (due to activities associated with the selected alternative combination, other DOE and non-DOE activities at Hanford, and other activities within the ROI) ranges from 25,000 hectares (61,800 acres) for the cumulative impacts scenario that includes Alternative Combination 1 to 25,800 hectares (63,800 acres) for that including Alternative Combination 3. The cumulative total shrub-steppe habitat that could be disturbed ranges from 16,900 hectares (41,800 acres) for the cumulative impacts scenario that includes Alternative Combination 1 to 17,200 hectares (42,600 acres) for that including Alternative Combination 3. To determine the contribution of the three *TC & WM EIS* alternative combinations to the cumulative disturbance of terrestrial habitat within the ROI, the area expected to be impacted under each of the three combinations was divided by the cumulative total area of terrestrial habitat disturbed. Similarly, the contribution of the three alternative combinations to the cumulative disturbance of shrub-steppe habitat was determined. Thus, Alternative Combination 1 represents less than 0.01 percent and 0 percent, respectively, of the cumulative terrestrial and shrub-steppe habitat impacted in the ROI; Alternative Combination 2, 0.8 and 0.4 percent, respectively; and Alternative Combination 3, 2.9 and 2.0 percent, respectively. Although not one of the three alternative combinations selected for analysis, a combination of alternatives that includes Tank Closure Alternative 6A, Option Case; FFTF Decommissioning Alternative 3 (with all facilities to be built at Hanford); and Waste Management Alternative 3 (with Disposal Group 2 or 3) would affect the greatest area of terrestrial habitat. Such a combination would represent 3.8 and 2.5 percent, respectively, of the cumulative terrestrial and shrub-steppe habitat affected.

Table 6–5. Cumulative Area of Terrestrial Habitat Disturbed

Actions/Activities	Total Terrestrial Habitat Disturbed ^a	Shrub-Steppe Habitat Disturbed ^b
	Hectares	
TC & WM EIS Combined Impacts (see Chapter 4, Table 4–156)		
Alternative Combination 1 ^c	2	0
Alternative Combination 2 ^c	207	65.6
Alternative Combination 3 ^c	753	348
Other DOE Actions at the Hanford Site (see Appendix T, Table T–1)	752	555
Non-DOE Actions at the Hanford Site (see Appendix T, Table T–1)	449	142
Other Projects/Activities in the Region of Influence (see Appendix T, Table T–1)	23,800	16,200
Cumulative Totals^d		
Alternative Combination 1	25,000	16,900
Alternative Combination 2	25,200	17,000
Alternative Combination 3	25,800	17,200

^a For those cases where the area of undeveloped land impacted by project implementation was not reported, it was conservatively assumed that the entire project area could be classified as terrestrial habitat. Terrestrial habitat could include shrub-steppe habitat, other native and nonnative habitat, grazing land, and cropland.

^b Shrub-steppe habitat includes areas specifically described as such in project documents, as well as areas conservatively estimated to be shrub steppe.

^c The specific elements of the TC & WM EIS alternative combinations are addressed in Chapter 4, Section 4.4.

^d The cumulative totals are the sums of the impacts under the TC & WM EIS alternative combinations; the other DOE and non-DOE activities at the Hanford Site; and other activities in the region of influence.

Note: To convert hectares to acres, multiply by 2.471. Totals may not equal the sum of the contributions due to rounding.

Key: DOE=U.S. Department of Energy; TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington.

The total area of terrestrial and shrub-steppe habitat within the ROI is unknown, so the change in the proportion of habitat disturbed within the region resulting from the 35 analyzed activities cannot be determined. However, because the approximate area of terrestrial habitat at Hanford is known (144,000 hectares [356,000 acres] [Neitzel 2005]), as is the areal extent of shrub-steppe habitat (approximately 27,924 hectares [69,000 acres] [DOE and Ecology 1996; Neitzel 2005]), it is possible to determine the effect that past, present, and reasonably foreseeable future development may have on Hanford. Thus, considering the land requirement of each of the three alternative combinations, as well as other projects and activities occurring at the site, the total area of terrestrial habitat would be reduced by 0.8, 1.0, and 1.4 percent under Alternative Combinations 1 through 3, respectively. With respect to shrub-steppe habitat, onsite activities would decrease existing habitat by 2.5, 2.7, and 3.7 percent, respectively. Considering the alternative combination that would disturb the greatest land area (given in the previous paragraph), terrestrial habitat and shrub-steppe habitat would be reduced by 1.5 and 4.0 percent, respectively. These estimates are conservative because they do not account for the restoration or compensation of lost shrub-steppe habitat that is required for most projects carried out at Hanford (DOE 2003c).

6.3.7.2 Threatened and Endangered Species

As noted above, the ROI for threatened and endangered species includes the proposed *TC & WM EIS* action areas, Hanford, as well as areas up to 80 kilometers (50 miles) from Hanford. Due to differences in the levels of reporting for the 35 analyzed activities, the ability to assess cumulative impacts on threatened and endangered species is limited. For example, of the projects reviewed, 13 did not report on the status of listed species and, of those that did, 13 indicated there would be no impacts and 10 indicated that impacts were possible.

As no federally or state-listed threatened or endangered species would be impacted under any of the *TC & WM EIS* alternatives, actions associated with these alternatives would not contribute to cumulative impacts within the ROI (see Chapter 4, Sections 4.1.7, 4.2.7, 4.3.7, and 4.4.6.3). However, cumulative impacts on a number of other special status species observed within areas affected by activities associated with the *TC & WM EIS* alternatives are possible. These species include the following: Piper's daisy (state sensitive), crouching milkvetch (state watch), stalked-pod milkvetch (state watch), loggerhead shrike (Federal species of concern and state candidate), sage sparrow (state candidate), long-billed curlew (state monitor), and black-tailed jackrabbit (state candidate). Of these species, crouching milkvetch was not mentioned in any of the 35 activities reviewed, while stalked milkvetch was mentioned in only 1. Piper's daisy, long-billed curlew, and black-tailed jackrabbit were each noted as potentially impacted in 2 of the projects reviewed. Finally, the sage sparrow was reported as potentially impacted by 3 projects and the loggerhead shrike, by 4. Thus, while the available data are limited, they suggest it is unlikely that cumulative impacts on populations of these special status species would either not occur or would be very limited. Cumulative impacts on the two remaining special status species (i.e., sage sparrow and loggerhead shrike) would be limited.

Although none of the federally or state-listed species noted above receives legal protection such as that afforded to threatened or endangered species, they should be considered in project planning. Such planning is undertaken at Hanford when a mitigation action plan is developed and projects may impact listed species (or shrub-steppe habitat). See Chapter 7, Section 7.1, Mitigation, for information on mitigation measures that may be used to reduce impacts. DOE anticipates that a mitigation action plan would be prepared for the alternative selected in the ROD for this *TC & WM EIS*. Mitigation planning related to potentially affected plants and animals was also noted for a number of the regional projects reviewed. Mitigation plans would act to limit potential impacts on species within a project area and, therefore, also act to limit cumulative impacts within the ROI.

6.3.8 Cultural and Paleontological Resources

The assessment of short-term cumulative impacts on cultural and paleontological resources includes prehistoric, historic, and paleontological resources, as well as American Indian interests, each of which is discussed individually below. A general description of cultural and paleontological resources and American Indian interests on and in the vicinity of Hanford is presented in Chapter 3, Section 3.2.8. Cumulative impacts related to cultural and paleontological resources and American Indian interests were evaluated in an ROI that includes Hanford and nearby offsite areas. The potential for cumulative impacts on cultural resources is discussed qualitatively. These cumulative impacts are additive to the impacts of the *TC & WM EIS* alternative combinations described in Chapter 4, Section 4.4.7.

Construction of new facilities and disturbance of previously undeveloped land would have the greatest potential for cumulative impacts on cultural and paleontological resources and American Indian interests. Approximately 60 actions, including the *TC & WM EIS* alternative combinations, other DOE and non-DOE activities at Hanford, and other activities in the ROI, were considered in regard to their cumulative impacts on cultural resources (see Appendix R, Table R-4). Activities that have a potential cumulative impact are discussed further below (also see Appendix T, Table T-2).

6.3.8.1 Prehistoric Resources

The cumulative impacts of the three *TC & WM EIS* alternative combinations would be similar to the combined impacts addressed in Chapter 4, Section 4.4.7.1. Cumulative impacts that include Alternative Combination 1 would involve the least land disturbance and thus would have the least potential to add to cumulative impacts. Cumulative impacts that include Alternative Combinations 2 and 3 would disturb a larger area of land.

As past surveys have indicated, it is unlikely that prehistoric resources are present in areas that would be used for the majority of DOE and non-DOE activities at Hanford. Isolated finds within the ROI have not been deemed eligible for listing in the National Register of Historic Places.

Two activities listed in Appendix T, Table T-2, could possibly add to the impacts on prehistoric resources. Both the Hanford Reach National Monument at Hanford and the GTCC waste disposal facility are or would be located on land that potentially could contain prehistoric resources.

6.3.8.2 Historic Resources

The cumulative impacts of the three *TC & WM EIS* alternative combinations on historic resources would be similar to the combined impacts addressed in Chapter 4, Section 4.4.7.2. Other DOE activities at Hanford could have an impact on historical properties as well. Decommissioning of the eight surplus production reactors and their support facilities in the 100 Areas may have an impact on the 100-B Reactor Building, which is listed in the National Register of Historic Places and, on August 19, 2008, was designated as a National Historic Landmark (DOE and DOI 2008). The rail line associated with construction and operation of the ERDF near the 200-West Area could adversely affect a portion of historic White Bluffs Road. The Atmospheric Dispersion Grid would have been affected by project activities; however, the impacts were mitigated, and no further mitigation is required (Poston et al. 2007). A select representative number of artifacts were removed from the Atmospheric Dispersion Grid and added to the Hanford collection (PNNL 2003). All artifacts that may have interpretive or educational value were transferred to B Reactor or the Columbia River Exhibition of History, Science, and Technology Museum in Richland, Washington.

The management plan for the Hanford Reach National Monument, a non-DOE project, specifies the requirement to “protect and acknowledge the Native American, settler, atomic and Cold War histories of the Monument...” (USFWS 2008:2-6). Cultural resources became more visible following the wildfire events of August 2007 and are more vulnerable to vandalism.

Many of the other non-DOE activities within the ROI would have little or no impact on historic resources because they would not take place in or near areas that contain historic resources.

6.3.8.3 American Indian Interests

Cumulative impacts on the visual character of the land could affect areas of particular interest to American Indians. Construction of new facilities and disturbance of previously undeveloped land are likely to have the greatest impacts. Many of the projects and activities assessed as part of the cumulative impacts analysis are of limited size, occur in presently developed areas, or are located at a distance from Hanford. These activities would produce at most minimal changes in the viewshed.

The cumulative impacts of the three *TC & WM EIS* alternative combinations would be similar to the combined impacts addressed in Chapter 4, Section 4.4.7.3. Accordingly, Alternative Combination 1 would have the least cumulative impact, and Alternative Combination 3, the greatest, due to its disturbance of the largest area and the most extensive alteration of the existing viewshed among the alternative combinations.

The location of facilities is important in determining the cumulative visual impacts on American Indian areas of interest. Some activities at Hanford, as well as some offsite projects and activities, would be visible from Rattlesnake Mountain, Gable Mountain, or Gable Butte, all of which are areas of noted cultural and religious significance to American Indians. Onsite DOE projects and activities that may be visible include excavation and use of geologic materials from borrow pits, transport of materials on the borrow site haul road from State Route 240 through Borrow Area C, construction and operation of the ERDF, and construction and operation of a GTCC LLW disposal unit. Reasonably foreseeable future actions that are expected to affect the viewshed also include remediation efforts at Hanford that may produce short-term adverse impacts, but would generally result in removal of buildings and other structures and the return of the environment to more-natural conditions. These actions include the infrastructure cleanup of the Fitzner-Eberhardt Arid Lands Ecology Reserve on and near Rattlesnake Mountain.

Construction and operation of facilities for the Hanford Reach National Monument, a non-DOE activity at Hanford, could affect American Indian interests because the Columbia River has special significance to American Indians in the region. Increased access to the Columbia River corridor by visitors could impact the area.

Other reasonably foreseeable future activities located off site, but nearby, such as the Red Mountain American Viticultural Area near Benton City (see Appendix T, Table T-2), are likely to be visible from Rattlesnake Mountain.

6.3.8.4 Paleontological Resources

No paleontological resources of significance have been discovered within any of the areas potentially disturbed by the *TC & WM EIS* alternatives. Other activities listed in Appendix T, Table T-2, would not likely add to the cumulative impacts on paleontological resources.

6.3.9 Socioeconomics

The existing site activities and current socioeconomic status of the ROI are described in Chapter 3, Section 3.2.9, and the impacts of the three alternative combinations are described in detail in Chapter 4, Section 4.4.8. The ROI for the cumulative socioeconomic analysis comprises Benton and Franklin Counties, where the majority of Hanford workers currently reside.

Actions that could potentially have impacts on the socioeconomics of the ROI are listed in Appendix T, Table T-3. These impacts might affect local employment figures, subsequent commuter traffic, and/or offsite truck activity.¹ For example, completion of some activities (e.g., deactivation of the Plutonium Finishing Plant) may reduce employment. Uncertainties in this analysis result in additional conservatism in the cumulative impact estimates. For example, some or all of the construction workers needed for fuel storage activities at the K Basins may already be employed in other construction activities described in this cumulative impacts section. As a result, workers performing fuel storage activities at the K Basins may be doubly counted in the analysis.

Some activities analyzed have already occurred or have been suspended; therefore, their impacts were not included in this cumulative impacts analysis. For example, Hanford's cleanup, restoration, and facility decommissioning activities are ongoing activities that are already included in the existing site activity statistics. In addition, projects that did not identify quantitative employment figures and/or traffic or truck load estimates were not included in the analysis. For example, plans to create 10 more wineries in the near future in the Red Mountain American Viticultural Area in Benton County could increase the number

¹ Socioeconomic impacts are quantified using the number of full-time-equivalent workers needed to complete a job, who were assumed to work 2,080 hours per year.

of employees and tourists in the ROI, but quantitative estimates were not available for this activity (Benton County 2007). Therefore, these types of activities were not included in the quantitative cumulative impacts analysis.

Table 6–6 summarizes indicator parameters for socioeconomic cumulative impacts. The estimated direct peak employment in support of activities analyzed under the *TC & WM EIS* alternative combinations, plus selected site and regional activities in the ROI, would range from 5,130 full-time-equivalent (FTE) workers under Alternative Combination 1 to 15,800 FTEs under Alternative Combination 3. This represents as high as 10.5 percent of the projected labor force in the region (150,000 in 2021, the peak year under Tank Closure Alternative 6B, Base Case). Employment in support of the *TC & WM EIS* alternatives alone would range from 1,840 to 12,500 FTEs. Because the timing of peak employment would vary for each activity, these projections are likely to be conservative. In addition, some of the projected employees could be drawn from the existing workforce and thus would not represent additional employees moving into the ROI. For comparison, in 2006, employment of approximately 10,000 people at Hanford represented about 10 percent of employment in the Hanford ROI.

Table 6–6. Cumulative Socioeconomic Impacts

Actions/Activities	Peak Annual Employment (FTEs)	Peak Daily Traffic	
		Employee Trips ^a	Offsite Truck Trips
<i>TC & WM EIS</i> Combined Impacts (see Chapter 4, Table 4–157)			
Alternative Combination 1	1,840	1,470	4
Alternative Combination 2	8,190	6,550	79
Alternative Combination 3	12,500	10,000	102
Other DOE Actions at the Hanford Site (from Appendix T, Table T–3)	2,220	1,860	70
Non-DOE Actions at the Hanford Site (from Appendix T, Table T–3)	41	76	4
Other Projects/Activities in the Region of Influence (from Appendix T, Table T–3)	1,030	915	74
Cumulative Totals^b			
Alternative Combination 1	5,130	4,330	152
Alternative Combination 2	11,500	9,410	227
Alternative Combination 3	15,800	12,900	250

^a Employee trips were calculated based on FTEs (see Chapter 4, Section 4.1.9).

^b The cumulative totals are the sums of the impacts under the *TC & WM EIS* alternative combinations, the other DOE and non-DOE activities at the Hanford Site, and other activities in the region of influence.

Note: Totals may not equal the sum of the contributions due to rounding.

Key: DOE=U.S. Department of Energy; FTE=full-time equivalent; *TC & WM EIS*=*Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*.

Foreseeable future activities analyzed include construction activities that have short-term impacts, including construction of the PNNL Physical Sciences Facility, biofuels facilities, and ongoing activities (e.g., fuel storage at the K Basins). Other activities resulting from implementing the ROD (64 FR 61615) and amended ROD (73 FR 55824) for the *Hanford Comprehensive Land-Use Plan EIS* (DOE 1999a), as well as other non-DOE activities in the ROI, could have longer-term impacts. The non-DOE activities analyzed include management of the Hanford Reach National Monument and Saddle Mountain National Wildlife Refuge and increased operations at the Perma-Fix Northwest waste treatment facility. The total projected FTEs required to support these future activities (approximately 3,290) are small compared with the FTEs required to support Alternative Combination 3 (approximately 12,500), the alternative combination with the greatest labor demand.

The level of service on offsite roads in the Hanford ROI is expected to be impacted from the peak daily traffic resulting from all activities analyzed in this cumulative impacts section. The bulk of daily traffic (as high as 12,900 vehicles per day) would come from commuters. There could be as many as 250 additional offsite truck trips per day. These trip totals would be variable; both employee and truck trips would reach their peak during large construction projects.

6.3.10 Public and Occupational Health and Safety—Normal Operations

This section evaluates cumulative short-term public and occupational health and safety impacts on (1) the Hanford worker population, (2) a maximally exposed individual (MEI) in the public, and (3) the population occurring within an 80-kilometer (50-mile) radius of the potential sources of emissions. Radiological and nonradiological impacts were analyzed.

6.3.10.1 Cumulative Radiological Impacts

Table 6–7 presents the estimated cumulative impacts of radioactive emissions and direct radiological exposure on workers, the MEI, and the surrounding population. The worker population dose of 320 person-rem under Alternative Combination 1 would represent a negligible contribution to the total cumulative dose of 97,000 person-rem received by workers since the beginning of Hanford operations in 1944. Alternative Combinations 2 and 3 would represent 13 percent and 48 percent of the cumulative doses of 111,000 and 186,000 person-rem, respectively. The cumulative worker population doses would impact several generations of workers rather than the same worker population.

Table 6–7. Cumulative Radiological Impacts on Hanford Site Workers and the Public

Actions/Activities	Hanford Involved Workers		Public		
	Collective Dose (person-rem)	LCF Risk ^a	MEI Dose (millirem per year)	Collective Dose (person-rem)	LCF Risk ^a
TC & WM EIS Combined Impacts^b (see Chapter 4, Tables 4–158 and 4–159)					
Alternative Combination 1	320	0 (2×10^{-1})	0.041	74	0 (4×10^{-2})
Alternative Combination 2	14,000	9	10	1,600	1
Alternative Combination 3	89,000	53	9.8	1,700	1
Historical Exposure					
Historical cumulative dose 1944–1972 (DOE 1995)	90,000	54	N/A	106,000	64
Historical cumulative dose 1972–2007 (using annual 2006 data over 36 years) (Poston et al. 2007:10.144) ^b	6,876	4	N/A	23	0 (1.4×10^{-2})
Other DOE Actions at Hanford					
Canyon disposition (DOE 2004b:4-31-4-32, 5-28-5-29)	210	0 (1×10^{-1})	NR ^c	NR	NR
Surplus production reactor decommissioning for nine reactors (DOE 2005a:21)	14.1	0 (8×10^{-3})	NR	NR	NR
300 Area facilities: 313 and 314 Facilities and the Fuel Supply Shutdown Facilities only (DOE 2005b:B-3)	NR	NR	0.12	NR	NR
Retrieval of TRU waste (DOE 2002b:5-2, 5-3)	6	0 (4×10^{-3})	NR	NR	NR
Historical Exposure and Other DOE Actions Subtotal^d	97,000	58	0.12 ^e	106,000	64

Table 6–7. Cumulative Radiological Impacts on Hanford Site Workers and the Public (continued)

Actions/Activities	Hanford Involved Workers		Public		
	Collective Dose (person-rem)	LCF Risk ^a	MEI Dose (millirem per year)	Collective Dose (person-rem)	LCF Risk ^a
Non-DOE Actions in the Region of Influence					
US Ecology Commercial Low-Level Radioactive Waste Disposal Site (US Ecology 2007:2-6)	N/A	N/A	<0.01	NR	NR
Energy Northwest Columbia Generating Station (Energy Northwest 2007:51, 53; Poston et al. 2007:10.149; Rhoads 2007)	N/A	N/A	0.02 ^f	2.11 ^g	0 (1×10 ⁻³)
Naval reactor compartment disposal ^h (Navy 1996:4–7)	<13	0 (<8×10 ⁻³)	NR	<13	0 (<8×10 ⁻³)
AREVA NP, Inc., facility (Poston et al. 2007:10.149; Rhoads 2007)	N/A	N/A	0.02 ^f	NR	NR
Perma-Fix Northwest waste treatment facility (Poston et al. 2007:10.149; Rhoads 2007)	N/A	N/A	0.02 ^f	NR	NR
IsoRay Medical, Inc. (IsoRay 2009, 2011a, 2011b)	N/A	N/A	0.03 ⁱ	NR	NR
Moravek Biochemicals (Moravek 2005)	N/A	N/A	1.5	NR	NR
Non-DOE Actions Subtotal	<13	0 (3×10 ⁻³)	1.56 ^e	15	0 (9×10 ⁻³)
Cumulative Totals^j					
Alternative Combination 1	97,000	58	2	106,000	64
Alternative Combination 2	111,000	67	12	108,000	65
Alternative Combination 3	186,000	110	11	108,000	65
Most Stringent Standard or Guideline	N/A	N/A	10 ^k	N/A	N/A

^a The reported value is the projected number of LCFs in the population and is therefore presented as a whole number. When the reported value is zero, the result calculated by multiplying the collective dose to the population by the risk factor of 0.0006 LCFs per person-rem (DOE 2003d) is shown in parentheses (see Appendix K, Section K.1.1.6).

^b Worker dose obtained from Chapter 3, Section 3.2.10.1. The Hanford baseline represents all exposure pathways and includes doses attributed to portions of the other DOE actions that occurred in 2006.

^c For cells stating “NR,” no values were provided in the documentation, but it was generally assumed that, because only minor air releases would occur, there would be little to no public exposure.

^d Subtotals do not include the Hanford 1-year baseline. Values were rounded.

^e For conservatism, it was assumed that the MEI would receive a dose from each action even though the location of each action, and thus MEI, would differ.

^f Reflects the combined dose to the Hanford MEI from operations at the Columbia Generating Station, AREVA NP facility, and Perma-Fix Northwest waste treatment facility (Poston et al. 2007:10.149; Rhoads 2007).

^g The annual population dose in 2006 was multiplied by 17 years, the time left on the Columbia Generating Station operating license, which expires in 2024 (Energy Northwest 2006a:9).

^h Includes dose to the public and workers during transportation of the reactor packages to Hanford. Assumes 220 transports; scaled up from value in source document (Navy 1996).

ⁱ This dose was calculated at the emission point. Reflects 3-year average.

^j The cumulative totals are the sums of the impacts under the *TC & WM EIS* alternative combinations and the other DOE and non-DOE activities.

^k The regulatory limit for exposure of an individual to radioactive air emissions from DOE facilities is 10 millirem per year (40 CFR 61, Subpart H).

Note: Subtotals and totals may not equal the sum of the contributions due to rounding.

Key: DOE=U.S. Department of Energy; Hanford=Hanford Site; LCF=latent cancer fatality; MEI=maximally exposed individual; N/A=not applicable; NR=not reported; *TC & WM EIS*=*Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*; TRU=transuranic.

The cumulative dose to the offsite MEI of 11 or 12 millirem per year under Alternative Combinations 2 and 3 would exceed the 10-millirem-per-year limit (from DOE sources) established in the “National Emission Standards for Hazardous Air Pollutants” (40 CFR 61, Subpart H). The DOE contribution would be controlled to ensure it remains below the limit. This conclusion conservatively assumes that the doses to the MEI from each DOE and non-DOE action are additive, despite the fact that the MEI location for most actions listed in Table 6–7 would be different. For comparison, the natural background radiation dose a person may receive near Hanford was estimated to be about 311 millirem per year (see Chapter 3, Table 3–12 and Section 3.2.10.1.1).

The cumulative population dose to the public would be dominated by the historical cumulative dose received by the public (approximately 106,000 person-rem) for the period between 1944 and 1972. The 77 to 1,700 person-rem contributed by the three *TC & WM EIS* alternative combinations would increase the cumulative population dose received by less than 2 percent. Implementation of Alternative Combination 2 or 3, while increasing the cumulative dose to the public in the short term, would decrease the long-term impacts, as discussed in Section 6.4.

6.3.10.1.1 Historical Exposures

An estimate of the potential cumulative dose to the population within 80 kilometers (50 miles) of Hanford for the period from 1944 through 1972 was calculated to be approximately 106,000 person-rem (DOE 1995), which could result in up to approximately 64 latent cancer fatalities (LCFs). The majority of this dose was received through air pathways in 1945. The cumulative population dose received through water pathways during this period was estimated to be about 6,000 person-rem (which could result in approximately 4 LCFs); most of this dose was received between 1954 and 1964 as a result of higher production reactor power levels for Cold War plutonium production. Since 1972, this cumulative population dose increased by less than 0.1 percent based on data from Hanford annual environmental reports. The primary contributors to the population and MEI doses in 2010 were inhalation of air emissions downwind of Hanford, consumption of food products grown downwind of Hanford, consumption of food irrigated with water from the Columbia River, and consumption of fish (Poston, Duncan, and Dirkes 2011:8.130).

Cancer incidence and mortality rates in the Hanford region can be used as possible indicators of cumulative impacts caused by past operational practices at Hanford. As discussed in Chapter 3, Section 3.2.10.3, the question of whether the population surrounding Hanford is subject to elevated cancer incidence or mortality rates is unresolved. Some studies indicate that there are no statistically significant increases in cancer rates; in fact, one study concluded that workers that have routine potential exposure to plutonium have lower mortality rates than other Hanford workers (NIOSH 2005).

Other epidemiological studies have shown a statistically significant elevated risk of death from multiple myeloma associated with radiological exposure among male Hanford workers. The elevated risk was observed only among workers exposed to approximately 10 rem or more. Other studies have also identified an elevated risk of death from pancreatic cancer, but a recent reanalysis did not conclude there was an elevated risk. Studies of female Hanford workers have shown an elevated risk of death from musculoskeletal system and connective tissue conditions (DOE 1996c:M-224–M-230).

In addition to the studies summarized in Chapter 3, Section 3.2.10.3, a study entitled *The Hanford Birth Cohort: Autoimmune and Cardiovascular Disease in Residents Near the Hanford Nuclear Reservation* was conducted by the Agency for Toxic Substances and Disease Registry to address public concerns related to public exposure to iodine-131 primarily in calendar years (CYs) 1944 through 1957. Preliminary results from this study showed a small increased risk for certain men to develop a thyroid disease, although a final determination has yet to be published (ATSDR 2006).

Because studies have been inconclusive regarding whether cancer incidence or mortality rates have risen due to Hanford operations, no definitive conclusions can be made in this EIS concerning the cumulative effects of radiological exposure to Hanford workers or the public from historical environmental releases and occupational exposures.

6.3.10.1.2 Other DOE Activities at Hanford

Other DOE activities at Hanford that are not within the scope of this EIS (i.e., activities that are not part of DOE's proposed actions) include environmental restoration activities being performed under RCRA and CERCLA in accordance with the TPA requirements. Major environmental restoration activities currently planned or under way that could cause exposures to radiation include environmental restoration activities in the 100 and 200 Areas, disposition of the five canyon facilities, decommissioning of eight surplus production reactors, remediation and closure of 300 Area facilities and operable units, retrieval of transuranic (TRU) waste, and operation of the ERDF. Table 6–7 summarizes the contributions of these activities to cumulative impacts. Some activities described in Appendix R are not included in Table 6–7 because applicable information was not available. Note that it is difficult to differentiate between the human health impacts of DOE Hanford operations and non-DOE activities using actual monitoring data due to the proximity of effluents from the various operations.

Five canyon buildings (U, B, T, PUREX Plant, and the REDOX [Reduction-Oxidation] Facility) are located at Hanford. All five of these buildings will eventually undergo CERCLA closure. Closure of only one of these buildings, 221-U, has been studied in detail. The selected remedy for 221-U includes demolishing the canyon to the canyon deck, filling portions of the canyon with rubble, grouting empty spaces, constructing an engineered barrier over the remnants of the canyon, and performing postclosure activities. Radiological exposure to workers from performing these activities at Building 221-U was estimated to be 42 person-rem (DOE 2004b:4-31, 4-32, 5-28, 5-29). Information regarding exposures to the public due to remediation activities is not available, but is expected to be minimal due to the inaccessibility of Building 221-U to the public and limited radioactive air emissions. The results from the analysis of remediating Building 221-U may be applied to the other four canyon buildings for a total worker population exposure of 168 person-rem, but, due to the varying types and locations of radioactive materials and contamination at these buildings, actual exposures could vary significantly (DOE 2004b:1-1). Canyon demolition activities have yet to commence, but demolition of 10 of the 17 U Plant ancillary facilities has been completed (DOE 2006a:2.50).

Nine surplus production reactors (B, C, D, DR, F, H, N, KE, and KW) are located at Hanford. These reactors are in various stages of decommissioning and are being placed in a safe storage condition for a period of approximately 75 years. It was assumed that after 75 years the reactor core for each reactor would be removed in one piece for disposal in the 200 Areas. An EIS for decommissioning eight of these reactors (excluding the N Reactor) was completed in 1992. The information in that EIS was reevaluated to update estimates and include the N Reactor. Assuming one-piece removal, the dose to workers from decommissioning the nine reactors would be 14.1 person-rem. There would be little or no radiological exposure to the public. Currently, five of the nine reactors are in safe storage; one of the reactors (the B Reactor) has been designated a National Historic Landmark and will not be dismantled (DOE 2005a:10, 21, 22; DOE and DOI 2008).

The 300 Area facilities currently undergoing decontamination, decommissioning, and removal include 82 buildings and structures in the northern portion of the 300 Area, the 324 and 327 Buildings, and 145 buildings and structures located primarily in the southern portion of the 300 Area (DOE 2004c, 2006b, 2006c). These 300 Area cleanup activities have the potential for creating radiological and chemical exposures to workers and the public. These exposures have not been quantified, except for deactivation, decontamination, and decommissioning of the 313 and 314 Facilities and the Fuel Supply

Shutdown Facilities. The radiation dose to the MEI resulting from removing each of these facilities was calculated to be 0.04 millirem per year over 3 years (DOE 2005b:B-3).

Per TPA Milestone M-091-41, retrieval of the 200 Area remote-handled, retrievably stored TRU waste in low-level radioactive waste burial ground (LLBG) 218-W-4B is required to be completed by December 31, 2018. Retrieval of this waste could incur a projected total worker dose of approximately 6 person-rem over a 5-year period (DOE 2002b:5-2, 5-3). A public dose was not calculated, but is expected to be negligible due to the location of this activity at LLBG 218-W-4B.

Operation of the ERDF involves the potential for exposure during waste transport to, and placement in, the ERDF. The *Remedial Investigation and Feasibility Study Report for the Environmental Restoration Disposal Facility* (DOE 1994) predicted that health risks to ERDF workers, other Hanford workers, and the public due to exposure to contaminants would be significantly less than generally accepted standards. Annual environmental monitoring (Poston et al. 2006, 2007; Poston, Hanf, and Dirkes 2005) has confirmed these predictions.

6.3.10.1.3 Non-DOE Activities

In addition to the radiation dose from DOE activities at Hanford, DOE workers and the public could also receive a dose from radionuclide releases associated with non-DOE operations occurring within and near Hanford. These releases are associated with US Ecology, the Energy Northwest Columbia Generating Station, naval reactor compartment disposal, the AREVA NP facility, the Perma-Fix Northwest waste treatment facility, the IsoRay Medical facility, and the Moravek Biochemicals facility. Table 6-7 summarizes the actual exposures from these facilities.

US Ecology is located at Hanford near the 200 Areas. Doses to the general public from the site's air emissions have been calculated to be indistinguishable (less than 0.01 millirem) from background levels. For direct radiation, the maximum net (background subtracted) radiological exposure as measured at the site boundary west of trench 18 was 55 millirem per year for exposure 24 hours a day, 365 days a year. As this location is within the boundaries of Hanford, a Hanford employee would be exposed to 13 millirem, assuming the employee were present at this location 40 hours per week. This radiological exposure level is consistent with levels measured in past years. There was no site impact on groundwater in 2006 (US Ecology 2007:1-2, 2-3, 2-6, 2-11). Potential long-term impacts of the waste disposed of at this location are included in the evaluation of long-term cumulative impacts in Section 6.4.

The Columbia Generating Station is located at Hanford northeast of the Fast Flux Test Facility (FFTF). This nuclear plant is licensed for operations through 2024 (Energy Northwest 2006a:9). The maximum annual dose at the Columbia Generating Station site boundary from air releases was estimated to be 0.0194 millirem. The collective dose to the population within 80 kilometers (50 miles) of the Columbia Generating Station in 2006 was estimated to be 0.124 person-rem, with the average individual in that population receiving a dose of 3.49×10^{-4} millirem during that year (Energy Northwest 2007:51, 53). There has been no measurable impact on other potential human exposure pathways, such as food, surface water, groundwater, and soils (Energy Northwest 2006b:5-5-5-7).

Reactor compartments removed from decommissioned nuclear ships and submarines will continue to be transported to Hanford for disposal. Future Naval Reactor Program shipments will consist of naval reactor compartments from which the spent nuclear fuel has been removed. Approximately 122 naval reactor compartments had been disposed of at Hanford as of 2010 (Poston, Duncan, and Dirkes 2011:6.23). Two EISs have been published to address the decommissioning, transportation, and disposal of naval reactor compartments. The most recent EIS showed that the radiological exposure to transportation workers was 5.8 person-rem, with the same dose to the population. This dose corresponds to a risk of 0 (3×10^{-3}) LCFs to each group (Navy 1996). These results correspond to decommissioning, transportation, and disposal of 100 reactor compartments. Between the two EISs, a total of 220 reactor

compartments would be decommissioned and transported to Hanford for disposal (Navy 1996). To account for all the reactor compartments, the above results for 100 reactor compartments were scaled up to represent 220 reactor compartments. Therefore, the dose to each group (transportation workers and the population) would be less than 13 person-rem, corresponding to a risk of $0 (8 \times 10^{-3})$ LCFs.

AREVA NP operates a fuel fabrication facility just south of Hanford on Horn Rapids Road. This facility produces nuclear fuel for sale to commercial nuclear power plants. Calculated doses to the MEI from this facility's radioactive stack emissions (ignoring radon) from 2000 to 2005 ranged from 0.000164 to 0.012 millirem per year, indicating negligible impacts of radioactive point source emissions. Environmental monitoring activities have provided no indication of air pollutant deposition in the surrounding environs, and liquid waste discharges have been within the allowed limits for radioactivity, indicating negligible impacts on human health (AREVA 2006:3-5).

The Perma-Fix Northwest facility is located south of Hanford in Horn Rapids Industrial Park. The site houses processing facilities for the treatment of LLW and MLLW. In 2006, the calculated dose to the MEI from radioactive air emissions was 0.1 millirem. The MEI was assumed to reside 100 meters (110 yards) from the stacks. The MEI dose from direct radiation was calculated to be 1.63 millirem per year; this MEI was assumed to be a local business employee who takes daily walks during lunch along the northern perimeter of the Perma-Fix Northwest facility (Pacific EcoSolutions 2007:6).

The radioactive emissions reported by the Columbia Generating Station, AREVA NP, and Perma-Fix Northwest were used to compute a non-DOE source dose to the Hanford MEI. In 2006, this value was 0.02 millirem (Poston et al. 2007:10.149; Rhoads 2007).

IsoRay Medical, Inc., produces medical isotopes for commercial use. The facility is located at Energy Northwest's Applied Process Engineering Laboratory in Richland, Washington, just east of the Hanford boundary. Based on average emissions over a 3-year period, the dose at the emission point would be about 0.03 millirem per year (IsoRay 2009, 2011a, 2011b).

Moravek Biochemicals, located in the Richland Industrial Center in Richland, Washington, manufactures radiochemicals and inorganic compounds for industrial use (Moravek 2009). The calculated radiation dose to an MEI 40 meters (130 feet) to the north of the facility is 1.5 millirem per year based on actual emissions of hydrogen-3 (tritium) and carbon-14 in 2004 (Moravek 2005).

6.3.11 Public and Occupational Health and Safety—Transportation

The assessment of cumulative impacts on the health and safety of workers and the public from radioactive material transportation concentrated on impacts of offsite transportation, which would result in the greatest potential radiological exposure from incident-free transportation. The collective dose to workers and the general population was the primary measure used to quantify cumulative transportation impacts. This measure of impact was chosen because it can be directly related to LCFs using a cancer risk coefficient.

Table 6–8 summarizes the cumulative impacts of transportation activities. The cumulative impacts of the transportation of radioactive material consist of impacts of (1) historical shipments of radioactive waste and spent nuclear fuel, (2) general radioactive material transportation unrelated to a particular action, and (3) reasonably foreseeable actions. The duration of impacts was assumed to begin in 1944, when Hanford began operation, and continue to an end date of about 2073. Note that the estimated end dates under Tank Closure Alternatives 2A, 6A, and 6B are beyond 2073 (up to 2193). Further note that Table 6–8 does not consider transportation activities that occur on Hanford roads closed to the public. An example of such actions would be intrasite transportation of waste to the ERDF. As presented in Chapter 4, Table 4–159, transportation of materials and waste to and from INL is included in Alternative Combinations 2 and 3.

Table 6–8. Cumulative Transportation Impacts

Actions/Activities	Workers		General Population	
	Collective Dose (person-rem)	Risk (LCFs)	Collective Dose (person-rem)	Risk (LCFs)
TC & WM EIS Combined Impacts (see Chapter 4, Table 4–160)				
Alternative Combination 1	2.6	0.0	0.08	0.0
Alternative Combination 2	2,800	1.7	420	0.25
Alternative Combination 3	3,100	1.8	440	0.26
Other Transportation Impacts Not Related to This TC & WM EIS (see Appendix T, Table T–4)^a				
Historical shipments to the Hanford Site	292	0.18	317	0.19
General radioactive material transport	374,000	224	338,000	203
Reasonably foreseeable actions	29,800	18	36,900	22
Subtotal, Other Transportation Impacts	404,000^b	242	375,000^b	225
Cumulative Totals^c				
Alternative Combination 1	404,000 ^b	242	375,000 ^b	225
Alternative Combination 2	407,000 ^b	244	376,000 ^b	225
Alternative Combination 3	407,000 ^b	244	376,000 ^b	225

^a Appendix T, Table T–4, provides a detailed compilation of the transportation impacts of other activities that are not related to this TC & WM EIS.

^b The dose values are rounded to the nearest thousand.

^c The cumulative totals are the sums of the impacts under the TC & WM EIS alternative combinations and the other, unrelated transportation activities.

Note: Subtotals and totals may not equal the sum of the contributions due to rounding.

Key: LCF=latent cancer fatality; TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington.

6.3.11.1 Historical Shipments to Hanford

The impact values provided in Table 6–8 for historical shipments to Hanford include shipments of spent nuclear fuel and radioactive waste from 1944 through 1993 (DOE 1995:Appendix I). Over the years, Hanford has received various types of wastes from the Government, research institutes, and commercial nuclear facilities for disposal and testing purposes. A survey of Hanford's SWITS [Solid Waste Information and Tracking System] indicates that about 60,000 cubic meters (78,500 cubic yards) of solid waste from offsite generators have been disposed of at Hanford (CEES 2007). The list of offsite generators indicates locations all across the United States. The transportation risk analysis in the *Final Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste (WM PEIS)* (DOE 1997), which included analyses of waste transportation from multiple locations in the United States to Hanford, was used to estimate collective worker and population doses for the historical shipments. As SWITS does not identify the number of shipments, the waste volume per truck shipment assumption in the WM PEIS was used to estimate the number of historical shipments, resulting in an estimate of 3,750 shipments from 1944 through 1993. Using the estimated doses to workers and the general population in the WM PEIS, conservative collective doses to workers and the general population from historical shipments were estimated to be 292 and 317 person-rem, respectively.

Note that there are considerable uncertainties in these historical estimates of collective dose. For example, the population densities and transportation routes used in the dose assessment were based on 1990 census data and the U.S. highway system as it existed in 1995. Using the 1990 census data results in an overestimate of historical collective doses because the U.S. population has increased since 1990. In contrast, using the interstate highway system as it existed in 1995 may slightly underestimate doses for

shipments that occurred in the 1940s, 1950s, and 1960s because a larger portion of the transport routes would have comprised non-interstate highways, where the population may have been closer to the road. By the 1970s, the structure of the interstate highway system was largely fixed, and most shipments would have been made on interstate highways.

6.3.11.2 General Radioactive Material Transport

General radioactive material transports are shipments that are not related to a particular action, including shipments of radiopharmaceuticals to nuclear medicine laboratories and shipments of industrial and radiography sources, fresh and spent nuclear fuel, and LLW. Collective dose estimates resulting from transportation of these types of materials from 1944 through 1982 were based on a U.S. Nuclear Regulatory Commission (NRC) analysis of shipments made in 1975, as documented in NUREG-0170, the *Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes* (NRC 1977). Collective dose estimate projections for shipments of these types of materials from 1983 through 2043 were based on analyses of unclassified shipments made in 1983, as documented in the *Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement* (DOE 1995). The NRC report estimated collective doses to the workers and general population of 5,600 and 4,200 person-rem, respectively, for truck, train, and airplane transports in 1975. Collective doses to workers and the general population for transports from 1944 through 1982 (39 years) were estimated to be 220,000 and 170,000 person-rem, respectively.

Collective doses to workers and the general population from truck and airplane shipments in 1983 were estimated to be 1,690 and 1,850 person-rem, respectively (DOE 1995). These doses were calculated using more-refined models than those used in the NRC report. Even though the number of shipments was higher than those analyzed for the NRC report, the estimated doses were smaller by a factor of two to three. The collective doses over 91 years from 1983 through 2073 were estimated to be 154,000 and 168,000 person-rem for workers and the general population, respectively. Most of the radioactive materials are shipped incidental to other freight shipments (i.e., the shipment is nonexclusive use and would take place regardless of the presence of radioactive materials on board).

6.3.11.3 Reasonably Foreseeable Actions

Appendix T, Table T-4, lists the reasonably foreseeable actions that were considered in the cumulative transportation impacts analysis. The values provided for reasonably foreseeable actions could lead to some double counting of impacts. For example, LLW transportation impacts addressed in the *WM PEIS* (DOE 1997) may also be included in the individual DOE facilities' sitewide EISs.

6.3.11.4 Conclusions

Table 6-8 shows that the combined impacts of the *TC & WM EIS* alternative combinations, including the impacts of shipments of materials to and from INL, would be quite small compared with the overall cumulative transportation impacts. The cumulative worker dose from all types of shipments was estimated to range from 404,000 to 407,000 person-rem (from about 242 to 244 LCFs). The cumulative dose to the general population was estimated to range from 375,000 to 376,000 person-rem (about 225 LCFs). To provide a full range of cumulative impacts, other alternative combinations were also examined. The cumulative worker dose from all types of shipments was estimated to reach a maximum of 407,000 person-rem (about 244 LCFs). The cumulative dose to the general population was estimated to reach 376,000 person-rem (about 225 LCFs).

To place these numbers in perspective, the National Center for Health Statistics states that the annual cancer death rate in the United States between 1999 and 2004 was about 554,000, with less than 1 percent fluctuation in the number of cancer deaths in any given year (CDC 2007). A total of about 470 LCFs among the workers and general population were estimated to result from radioactive material

transportation from 1944 to 2073, an average of about 4 LCFs per year. Transportation-related LCFs represented about 0.0007 percent of the annual number of cancer deaths and were indistinguishable from the natural fluctuation in the total annual cancer death rate. Note that the majority of the cumulative risks to workers and the general population were due to the general transportation of radioactive materials that is unrelated to the activities evaluated in this *TC & WM EIS*. In other words, the impacts of *TC & WM EIS* activities would be quite small compared with overall cumulative impacts of radioactive material transportation.

6.3.12 Waste Management

Expected cumulative waste generation is presented in Table 6–9. It is unlikely that there would be major impacts on the waste management infrastructure at Hanford because sufficient capacity exists or would be constructed under the proposed Waste Management alternatives.

To estimate the cumulative waste management impacts, the waste volumes generated under the *TC & WM EIS* alternative combinations (see Chapter 4, Section 4.4.12) and other past, present, and reasonably foreseeable future actions were summed. The cumulative waste volumes include all known or possible future actions that would generate waste and/or require waste disposal. These cumulative waste volumes also include waste already disposed of in the 600 Area and the LLBGs; 100 and 300 Area CERCLA waste resulting from closure of the Columbia River corridor (the volume of 200 Area CERCLA waste is unknown at this time); GTCC waste that could be disposed of at Hanford; and Naval Reactor Program waste that is being disposed of at Hanford.

A general description of the existing waste management infrastructure is presented in Chapter 3, Section 3.2.12. Additional detailed information on the cumulative impacts methodology and past, present, and reasonably foreseeable future actions is provided in Appendix R.

Table 6–9. Cumulative Waste Volumes

Actions/Activities	Waste Type (cubic meters)				
	HLW ^a	Mixed TRU	LLW/MLLW	Hazardous ^b	Nonradioactive/ Nonhazardous ^c
<i>TC & WM EIS</i> Alternative Combinations (see Chapter 4, Table 4–166)					
Alternative Combination 1	N/A	22,500	7,110	1,320	307
Alternative Combination 2	16,000	22,700	854,000	80,500	2,360
Alternative Combination 3	576,000	22,900	3,120,000	81,900	2,480,000
Other DOE Actions at the Hanford Site					
200 Area LLBGs ^d	N/A	NR	405,000	N/A	N/A
600 Area Nonradioactive Dangerous Waste Landfill	N/A	N/A	N/A	141 ^e	N/A
600 Area Central Landfill	N/A	N/A	N/A	N/A	596,000
CERCLA waste ^f	N/A	NR	21,400,000	NR	NR
Decommissioned, defueled naval reactor compartments	N/A	N/A	122,000	N/A	N/A
Other Possible Future DOE Actions at the Hanford Site					
Disposal of GTCC waste ^g	N/A	N/A	12,000	N/A	N/A
Subtotal, Other DOE Actions and Possible Future Actions	N/A	N/A	21,900,000	141	596,000
Cumulative Totals^h					
Alternative Combination 1	0	22,500	21,900,000	1,460	596,000
Alternative Combination 2	16,000	22,700	22,800,000	80,600	598,000
Alternative Combination 3	576,000	22,900	25,000,000	82,000	3,080,000

Table 6–9. Cumulative Waste Volumes (continued)

- a Includes HLW canisters, cesium and strontium canisters, HLW melters, and other HLW. Also includes immobilized low-activity waste and tank debris under Alternative Combination 3.
- b Dangerous waste generated at the site is shipped off site for disposal or recycling.
- c Nonradioactive, nonhazardous, and nondangerous waste is disposed of off site at municipal or commercial solid-waste disposal facilities and is generally not held in long-term storage.
- d Total estimated waste buried in the 200-East and 200-West Area burial grounds: (200-East Area) 218-E-2, 218-E-4, 218-E-5, 218-E-5A, 218-E-10 trench, 218-E-1, 218-E-8, 218-E-12A, and 218-E-12B; (200-West Area) 218-W-1, 218-W-1A, 218-W-2, 218-W-2A, 218-W-3, 218-W-3A, 218-W-4A, 218-W-3AE, 218-W-4B, 218-W-4C, 218-W-5, 218-W-7, and 218-C-9. Some of the burial grounds may contain TRU waste.
- e The volume of buried waste in the Nonradioactive Dangerous Waste Landfill originally was 141,000 kilograms. A conversion using the density of water was used to get 141 cubic meters.
- f Total estimated CERCLA waste (LLW and MLLW) to be generated in the 100 and 300 Areas only; the amount of waste from the 200 Areas is unknown (Wood et al. 1995).
- g This is an estimate of GTCC and similar DOE waste that could be disposed of at the Hanford Site (DOE 2011a).
- h The cumulative totals are the sums of the impacts under the *TC & WM EIS* alternative combinations and the other DOE and other possible future DOE activities.

Note: All values are in cubic meters except as noted. To convert cubic meters to cubic yards, multiply by 1.308. Subtotals and totals may not equal the sum of the contributions due to rounding.

Key: CERCLA=Comprehensive Environmental Response, Compensation, and Liability Act; DOE=U.S. Department of Energy; GTCC=greater-than-Class C; HLW=high-level radioactive waste; LLBG=low-level radioactive waste burial ground; LLW=low-level radioactive waste; MLLW=mixed low-level radioactive waste; N/A=not applicable; NR=not reported; *TC & WM EIS*=*Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*; TRU=transuranic.

Source: DOE 2007b; SAIC 2010a, 2010b, 2010c.

6.3.12.1 TC & WM EIS Alternative Combinations

Chapter 4, Section 4.4.12, describes the three alternative combinations and the impacts they might have on the waste management system. Although generation of both primary and secondary waste would contribute to the overall combined impact on existing Hanford facilities devoted to treatment, storage, and disposal, as described in Chapter 4, Section 4.3.14, the Waste Management alternatives were developed to accommodate this additional generation of waste. Therefore, waste generated under any of the three alternative combinations would not exceed the capacity of the current or planned Hanford waste management infrastructure.

6.3.12.2 Other DOE Actions at Hanford

6.3.12.2.1 200 Area Burial Grounds

The LLBGs consist of eight burial grounds located in the 200-East and 200-West Areas that are used for disposal of LLW and MLLW. The LLBGs have been permitted under an RCRA Part A permit since 1985.

Three trenches receive mixed waste regulated by WAC 173-303, “Dangerous Waste Regulations.” Trenches 31 and 34 in LLBG 218-W-5 are lined trenches with leachate collection and removal systems. Trench 94 in LLBG 218-E-12B is used for disposal of defueled U.S. Navy reactor compartments (see below). LLW and TRU waste have been placed in the other LLBGs. The TRU waste was placed in a manner that allows future retrieval and/or removal. Soil was placed over some of the waste containers to provide radiation protection (Poston et al. 2007). TRU waste has not been placed in the LLBGs without specific DOE approval since August 19, 1987.

DOE Order 435.1, *Radioactive Waste Management*, requires a disposal authorization statement to allow operation (or continued operation) of LLW disposal facilities. In fulfillment of these requirements, such a statement was issued on October 25, 1999, authorizing Hanford to transfer, receive, possess, and dispose of LLW at the 200-East Area and 200-West Area LLBGs. By agreement between DOE and Ecology, use of the LLBGs as disposal facilities for LLW and MLLW has been restricted to lined trenches and the naval reactor compartment trench only. Hence, as of July 2004, only the two lined trenches in LLBG 218-W-5 (trenches 31 and 34) and the naval reactor compartment trench in LLBG 218-E-12B

(trench 94) are allowed to receive waste. When the two lined trenches are filled, the LLBGs will cease to operate except for reactor compartment disposal in trench 94. The remaining operational lifetimes of the LLBGs depend on the waste volume disposal rates (DOE 2006d).

The LLBGs are included in a draft remedial investigation/feasibility study work plan completed in September 2007 (DOE 2007b). The remedial investigation/feasibility study process will be used to reach a decision that will meet requirements for both National Priorities List cleanup and RCRA corrective action. Retrieval of suspect-TRU retrievably stored waste in LLBG 218-W-4C was initiated in October 2003 in accordance with TPA Milestone M-91-03-01.

6.3.12.2.2 600 Area Nonradioactive Dangerous Waste Landfill and Central Landfill

The Nonradioactive Dangerous Waste Landfill (NRDWL) is an inactive landfill. Although an NRDWL site closure plan was written in 1990 (DOE 1990), the closure plan has not been approved. In May 2010, DOE prepared a draft environmental assessment, *Closure of Nonradioactive Dangerous Waste Landfill (NRDWL) and Solid Waste Landfill (SWL), Hanford Site, Richland, Washington* (DOE 2010), and in August 2011 issued a revised version (DOE 2011b). This environmental assessment provides information on, and analyses of, the proposed DOE activities for closure of the NRDWL and the Solid Waste Landfill (also known as the 600 Area Central Landfill). The landfill provided a site for disposal of dangerous waste generated from process operations, research and development laboratory maintenance activities, and transportation functions throughout Hanford. The NRDWL is located about 5.6 kilometers (3.5 miles) southeast of the 200-East Area on Army Loop Road, southwest of the Route 4 intersection and southeast of the 200-East Area. It began operations in 1975 and occupies an area of 4.5 hectares (11 acres). It consists of 19 parallel trenches, each 122 meters (400 feet) long, 5.5 meters (18 feet) wide at the base, and 4.6 meters (15 feet) deep. A triangular column of undisturbed soil with approximately 1:1 side slopes separated the trenches as they were constructed. The final profile of the trench varied depending on the type of waste received. The trenches typically were backfilled and covered with 2 to 3 meters (6 to 10 feet) of soil at the end of each operating day. Beginning in 1975, chemical waste was disposed of in 6 trenches, asbestos in 9 trenches, and nonhazardous solid waste in 1 trench; 3 were unused. The last receipt of dangerous waste occurred in May 1985; the last receipt of asbestos, in May 1988 (DOE 2007b).

The 600 Area Central Landfill is a non-RCRA solid-waste landfill adjacent to the NRDWL on the south side. It is a larger facility (27 hectares [67 acres]) that principally received solid waste, including paper, construction debris, asbestos, and lunchroom waste. It also received up to 5 million liters (1.32 million gallons) of sewage and 380,000 liters (100,000 gallons) of garage wash water. The liquid waste was discharged to east-west-oriented trenches at the perimeter of the main solid-waste area, along the northeastern and northwestern boundaries of the 600 Area Central Landfill. The 600 Area Central Landfill is regulated under WAC 173-304, "Minimum Functional Standards for Solid Waste Handling" (DOE 2007b).

The two landfills (the NRDWL and the 600 Area Central Landfill) were operated as a single landfill that was originally known as the Central Landfill. Because of the presence of dangerous waste in the chemical trenches, the 19 northernmost trenches were designated as the NRDWL under Hanford's RCRA permit. The southern two-thirds of the area were later designated as the 600 Area Central Landfill, which is a treatment, storage, and disposal unit (DOE 1990).

The TPA outlines the approach that DOE will take for permitting and closure of the Hanford RCRA-regulated treatment, storage, and disposal units. These two landfills are included in a draft remedial investigation/feasibility study work plan completed in September 2007 (DOE 2007b). The remedial investigation/feasibility study process will be used to reach a decision that will meet requirements for both National Priorities List cleanup and RCRA corrective action (DOE 2007b).

6.3.12.2.3 CERCLA Waste: Closure of the Columbia River Corridor

Other DOE actions at Hanford include cleanup and closure of the Columbia River corridor, an area of roughly 540 square kilometers (210 square miles) along the outer edge of Hanford that includes major portions of the Hanford Reach National Monument. These actions include the following:

- Deactivating, decommissioning, decontaminating, and demolishing 510 facilities, many of which are contaminated with radioactive and/or hazardous materials.
- Remediating and closing 486 waste sites, including trenches where plutonium production reactor liquid wastes were discharged.
- Placing the K-East and K-West reactors in interim safe storage. (The K-East and K-West were large plutonium production reactors that operated from 1955 until the early 1970s. A “cocooning” method will be used that will involve in situ encapsulation of the reactor piles. Five of eight reactors have already been cocooned.)
- Remediating burial grounds 618-10 and 618-11. (These burial grounds contain some highly radioactive irradiated nuclear fuel; hazardous chemicals; and plutonium, cesium, and other radioactive material.)
- Operating the ERDF.

In 1988, Hanford was scored using the U.S. Environmental Protection Agency’s (EPA’s) hazard ranking system. Based on the scoring, Hanford was added to the National Priorities List in July 1989 as four sites: the Richland North Area, formerly the 1100 Area; 100 Areas; 200 Areas; and 300 Area. Each of these areas was further divided into operable units (groupings of individual waste units based primarily on geographic area and common waste sources). These operable units contain contamination in the form of hazardous waste, radioactive/hazardous mixed waste, and other CERCLA hazardous substances. In anticipation of Hanford’s addition to the National Priorities List, DOE, EPA, and Ecology entered into the TPA in May 1989. This agreement established a procedural framework and schedule for developing, implementing, and monitoring remedial response actions at Hanford. The TPA also addresses RCRA compliance and permitting.

Wastes from cleanup and closure of the Columbia River corridor are being disposed of in the ERDF, a CERCLA disposal facility in the Hanford 200 Areas. The ERDF is also designed and operated to meet the substantive RCRA requirements. Construction of the first two cells began in May 1995, and the first shipment of waste was received on July 1, 1996. Each cell is 152 meters (500 feet) wide at the bottom, 21 meters (70 feet) deep, and over 304 meters (1,000 feet) wide at the surface. The ERDF’s liner is a system composed of multiple barriers that form a primary and secondary protection system. Each system is designed to contain and collect moisture to prevent migration of contaminants to the soil and groundwater. Once the ERDF is filled with waste, an RCRA-compliant engineered barrier will be placed on top to prevent rain infiltration. The ERDF is expected to receive about 15 million metric tons of waste from Hanford cleanup activities (Brockman 2009).

6.3.12.2.4 Disposal of Decommissioned, Defueled Naval Reactor Compartments

The retirement of aging weapon systems and cutbacks in the number of U.S. Navy ships in the post–Cold War era have resulted in reductions in the naval nuclear fleet. On August 9, 1996, a ROD associated with the *Final Environmental Impact Statement on the Disposal of Decommissioned, Defueled Cruiser, Ohio Class, and Los Angeles Class Naval Reactor Plants* (Navy 1996) was issued for disposal of defueled reactor plants from Navy nuclear-powered cruisers and Ohio Class and Los Angeles class submarines (61 FR 41596). The Navy, with DOE’s concurrence, decided to dispose of these reactor

compartments in LLBG 218-E-12B, trench 94. LLBG 218-E-12B is a 70-hectare (173-acre) facility in the 200-East Area at Hanford. The EIS stated that the environmental impacts of disposing of the additional reactor compartments would be very small, based on the Navy's past method of disposing of pre-Los Angeles class submarine reactor compartments (55 of which had already been disposed of in LLBG 218-E-12B) using very conservative engineering practices.

In 1999, under this ROD, DOE began accepting additional reactor compartments for disposal in LLBG 218-E-12B. Through 2010, 122 reactor compartments had been transported safely and disposed of (Poston, Duncan, and Dirkes 2011:6.23). The reactor compartments are classified as LLW. The iron and metal alloys within the reactor vessel have become radioactive after years of reactor operations; their exteriors are not contaminated. The reactor compartments were estimated to include a total of approximately 120,000 cubic meters (4,240,000 cubic feet) of LLW.

DOE oversees placement of reactor compartments into LLBG 218-E-12B and manages the disposal operations in accordance with all applicable requirements. Ecology regulates the reactor compartment disposal packages as a dangerous waste under WAC 173-303, "Dangerous Waste Regulations," due to the over 100 tons of permanent lead shielding in each reactor compartment. Treatment before disposal is not required because the solid elemental lead shielding is encapsulated by thick metal sheathing plates that meet RCRA treatment standards for disposal of radioactive lead solids.

6.3.12.3 Other Possible Future DOE Actions at Hanford

6.3.12.3.1 Greater-Than-Class C Low-Level Radioactive Waste

The Low-Level Radioactive Waste Policy Act of 1980, as amended (42 U.S.C. 2021 et seq.), assigned the U.S. Government the responsibility for disposing of GTCC LLW generated by activities licensed by NRC or agreement states. The act requires the Federal Government to provide for the disposal of GTCC LLW in a facility that adequately protects the safety and health of the public and is licensed by NRC. As part of its assigned responsibilities under the act, DOE has issued the *Draft Environmental Impact Statement for the Disposal of Greater-Than-Class C (GTCC) Low-Level Radioactive Waste and GTCC-Like Waste (Draft GTCC EIS)*, DOE/EIS-0375-D (DOE 2011a), which evaluates environmental impacts associated with potential disposal sites. Sites under consideration for disposal of GTCC LLW include other DOE sites and generic commercial sites (DOE 2011a).

Hanford is being considered as a candidate location for a new GTCC waste disposal facility in the *Draft GTCC EIS*. Such a facility is not expected to be operational until after 2019. As shown in Table 6-9, it could receive about 12,000 cubic meters (420,000 cubic feet) of GTCC LLW and similar DOE waste (DOE 2011a) already in storage or projected to be generated from existing facilities or that may be generated in the future as a result of actions proposed by DOE or commercial entities. Detailed information on this waste is provided in the *Draft GTCC EIS* (DOE 2011a).

6.3.12.3.2 Combined Community Communications Facility and Infrastructure Cleanup on the Fitzner-Eberhardt Arid Lands Ecology Reserve

DOE prepared an EA (DOE 2009a) and issued a *Finding of No Significant Impact for the "Combined Community Communications Facility and Infrastructure Cleanup on the Fitzner/Eberhardt Arid Lands Ecology Reserve, Hanford Site, Richland, Washington"* (DOE 2009b). This EA provides information and analyses of the proposed DOE activities associated with consolidating existing communications operations and removing excess facilities and infrastructure within the Fitzner-Eberhardt Arid Lands Ecology Reserve at Hanford. In this EA, DOE proposes to remove most facilities on the reserve, except those needed by DOE and the U.S. Fish and Wildlife Service, and communications equipment used by local governments and other organizations. Existing communications capabilities would be consolidated

into a single facility on the ridgeline, consisting of an equipment building and two towers to support multiple antennas and radio repeaters. In addition, DOE would remove miscellaneous debris from past activities from the site and repair the boundary fence as necessary.

6.3.12.4 Summary

Because the Waste Management alternatives were developed to accommodate the additional waste generation described above, the cumulative waste generated under the alternative combinations, other DOE actions, and possible future DOE actions would not exceed the capacity of the planned Hanford waste management infrastructure and would therefore be unlikely to have any major impacts. As stated in Chapter 4, Section 4.4.12, although Alternative Combination 3 reflects the upper end of waste management needs of the three combinations chosen for analysis in this EIS, it does not require the maximum waste management infrastructure considering all possible combinations. A combination that includes Tank Closure Alternative 6A, Base or Option Cases; FFTF Decommissioning Alternative 2 (with all facilities to be built at Hanford); and Waste Management Alternative 2 or 3 (with Disposal Group 3) would have the greatest combined impact on the waste management infrastructure for high-level radioactive waste, MLLW, and hazardous and liquid LLW. It is unlikely that there would be major cumulative impacts on the waste management infrastructure at Hanford because sufficient capacity exists or would be constructed under the Waste Management alternatives.

6.3.13 Industrial Safety

This section identifies the cumulative industrial safety impacts on Hanford workers. Appendix K contains the methodology used in estimating industrial safety impacts. Chapter 4, Sections 4.1.15, 4.2.15, and 4.3.15, provides the impacts and projected total recordable cases (TRCs) under each alternative. Section 4.4.13 presents the impacts of the three alternative combinations.

The number of TRCs at Hanford has decreased over the period from 1993 through 2006, as reported in the DOE *Computerized Accident/Incident Reporting and Recordkeeping System* (DOE 2008). This decline reflects the type and scope of work that has been conducted in the past and is currently being conducted at Hanford. Other factors contributing to the decrease include safe work procedures, policies, and practices observed by the workforce. Figure 6–1 shows the number of TRCs and the incident rate per 200,000 labor hours. The baseline TRCs and fatality rates are 2.0 and 0.26, respectively. Applying the process outlined in Appendix K using the average annual hours worked between 2001 and 2006, there would be an estimated 36,030 TRCs and 4.5 fatalities over the short term.

Table 6–10 shows the potential cumulative impacts on Hanford worker industrial safety under each of the alternative combinations. The baseline projections of TRCs and fatalities resulting from site activities are those expected to occur over the period of short-term impacts. The baseline TRCs and number of fatalities were then added to those expected under the alternative combinations to yield cumulative impact totals. This is likely to be conservative because the baseline values include workers performing Waste Treatment Plant construction activities.

Alternative Combination 1 (No Action) would not have an impact on the number or rate of TRCs. It can reasonably be expected that future TRCs would remain equal to or decline from present levels (see Figure 6–1). Factors influencing this include the anticipated work effort in terms of the type and amount required in the foreseeable future. Although projected to generate approximately 173 TRCs over the duration of the selected alternatives, as shown in Table 6–10, Alternative Combination 1 includes a 100-year administrative control period in which access to and use of Hanford would be restricted. Averaging the number of TRCs over the duration of short-term impacts (130 years) would increase the TRCs by one to two per year.

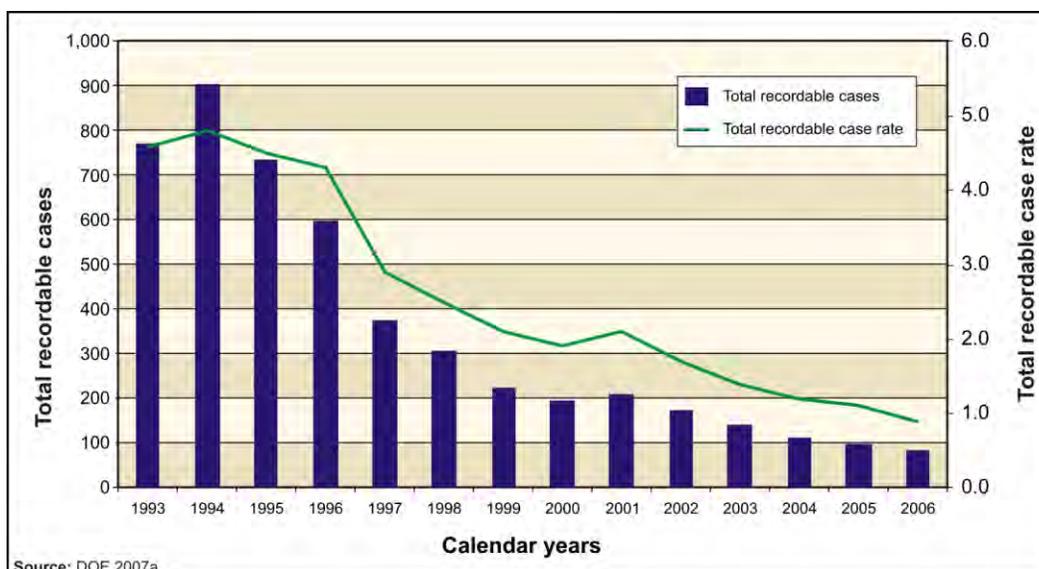


Figure 6–1. Richland Operations Industrial Safety Total Recordable Cases and Incident Rate, 1993–2006

Table 6–10. Estimated Industrial Safety Cumulative Impacts

Actions/Activities	Number of Total Recordable Cases	Number of Fatalities ^a
TC & WM EIS Alternative Combinations (see Chapter 4, Table 4–162)		
Alternative Combination 1	173	0 (0.02)
Alternative Combination 2	4,470	1 (0.58)
Alternative Combination 3	6,830	1 (0.88)
Other DOE Actions at the Hanford Site		
Hanford Site baseline	36,000	5 (4.5)
Cumulative Totals^b		
Alternative Combination 1	36,200	5 (4.5)
Alternative Combination 2	40,500	6 (5.7)
Alternative Combination 3	42,800	6 (6.3)

^a The reported value represents the number of fatalities per 200 million work hours and is therefore presented as a whole number, followed by the calculated value in parentheses.

^b The cumulative totals are the sums of the impacts under the TC & WM EIS alternative combinations.

Note: Totals may not equal the sum of the contributions due to rounding.

Key: DOE=U.S. Department of Energy; TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington.

The impact of Alternative Combination 2 would result in an increase in the cumulative number of illnesses, injuries, and fatalities. The magnitude of the increase would be influenced by the number of workers, hours worked, and type of work. Typically, the greatest increase would be realized during the construction phase. Averaging the number of additional recordable cases over the duration of short-term impacts (147 years) for all phases of the work for this alternative combination would increase the TRCs by approximately 30 annually. However, that number would increase during the peak construction periods and decrease during the operation and decommissioning phases. The lowest number of TRCs is expected during the closure phase. Assuming current safe work policies and practices are continued, cumulative fatalities are not expected from the additional TRCs associated with this alternative combination.

Alternative Combination 3 would generate the greatest increase in the cumulative number of TRCs. An overall increase of approximately 6,830 TRCs over all phases of work activity was projected under Alternative Combination 3. The increased TRCs would be influenced by the annual changes in the size of the workforce and the type of work performed. The construction phase of the project would generate the most cases, while postclosure care of the site would result in the fewest cases. The magnitude of the increase, when averaged over the duration of short-term impacts (197 years), would be 35 to 37 additional cases annually. Similar to Alternative Combination 2, the greatest increase in TRCs would occur during the construction phase, while the fewest TRCs would occur during the postclosure phase. Although the possibility of fatalities is always present during the construction of any large facility, this cumulative impacts analysis indicates a fatality would be unlikely over the entire period of analysis, assuming that safe work policies, procedures, and techniques remain in force throughout the duration of work.

6.4 LONG-TERM CUMULATIVE IMPACTS

Long-term cumulative impacts occur following the active project phase of each alternative. In this *TC & WM EIS*, long-term cumulative impacts were assessed out to approximately 10,000 years in the future.

This section presents the long-term cumulative impacts on the following resource areas: groundwater quality, public health, ecological risk, and environmental justice. The detailed tables that support the long-term cumulative impact analyses are presented in Appendix U.

6.4.1 Groundwater Quality

In this section, the long-term cumulative groundwater-quality impacts are presented in conjunction with the long-term impacts of the three alternative combinations. The long-term impacts of the three alternative combinations are presented in Chapter 5, Section 5.4. The long-term impacts associated with past, present, and reasonably foreseeable future actions unrelated to the proposed actions analyzed in this *TC & WM EIS* are presented in Appendix U, Section U.1. As discussed in Appendix U, the methodology for calculating the long-term cumulative groundwater impacts of non-*TC & WM EIS* sources is fully consistent with the methodology for calculating the impacts of the *TC & WM EIS* alternatives. The discussion at the beginning of Chapter 5 contains information relevant to the interpretation of the tables and graphics used to present the groundwater results for the *TC & WM EIS* alternatives analysis. Those same considerations are relevant to interpreting the tables and graphics that contain the groundwater results for the cumulative impacts analysis. Appendix U also contains a discussion of the comparison of model predictions with field measurements at the regional and subregional scales to provide the reader with an estimate of the model's ability to reproduce current conditions.

6.4.1.1 Other Past, Present, and Reasonably Foreseeable Future Actions

Table 6-11 lists the maximum constituent of potential concern (COPC) concentrations for the non-*TC & WM EIS* alternative sources and the corresponding peak year. Values are provided for the Core Zone Boundary, the Columbia River nearshore, and the benchmark concentration. In interpreting this table, note that a number of the non-*TC & WM EIS* alternative sources are located outside the Core Zone Boundary and that, for some COPCs (strontium-90 for example), sources in the 100 Areas near the Columbia River dominate the impacts. For these COPCs, the Columbia River nearshore maximum concentration values are much higher than those of the Core Zone Boundary. Dominant non-*TC & WM EIS* sources with major impacts on the Core Zone Boundary are mostly associated with high discharges of liquids to cribs and trenches (ditches). The two most significant sets of sources inside the Core Zone Boundary include the cribs and trenches (ditches) associated with the PUREX Plant in the 200-East Area and the cribs and trenches (ditches) associated with the REDOX Facility in the 200-West Area. Dominant non-*TC & WM EIS* alternative sources with major impacts on the Columbia River are

mostly associated with high discharges of liquids to production reactor retention basins and cooling ponds in the 100 Areas. Further discussion of the spatial distribution of the groundwater contamination plumes associated with non-TC & WM EIS alternative sources can be found in Appendix U. Note that the list of COPCs in the tables can change as the alternative combinations are added to the non-TC & WM EIS alternative sources (e.g., Table 6-11 versus Tables 6-15, 6-19, and 6-23).

Table 6-11. Maximum Groundwater COPC Concentrations for Non-TC & WM EIS Sources^a

Contaminant	Core Zone Boundary (peak year)	Columbia River Nearshore (peak year)	Benchmark Concentration ^b
Radionuclide (picocuries per liter)			
Hydrogen-3 (tritium)	112,000,000 (1997)	4,140,000 (1986)	20,000
Carbon-14	1,090 (1998)	5 (1992)	2,000
Strontium-90	1,730 (1998)	27,600 (1991)	8
Technetium-99	657 (1980)	212 (1991)	900
Iodine-129	42.2 (1962)	19.8 (2017)	1
Cesium-137	0 N/A	1,430 (1985)	200
Uranium isotopes (includes uranium-233, -234, -235, -238)	839 (1959)	6,190 (1979)	15
Neptunium-237	7 (2061)	2 (3662)	15
Plutonium isotopes (includes plutonium-239, -240) ^c	26 (7725)	2 (1991)	15
Chemical (micrograms per liter)			
1-Butanol	518 (1998)	2 (3891)	3,600
Boron and compounds	0.2 (3270)	1 (2364)	7,000
Carbon tetrachloride	577 (2035)	208 (2067)	5
Chromium ^d	13,300 (1959)	7,210 (1979)	100
Dichloromethane	0.2 (3321)	0.1 (3923)	5
Fluoride	160,000 (2008)	30,700 (2032)	4,000
Hydrazine/hydrazine sulfate	0.009 (3308)	0.043 (3281)	0.022
Lead	0 N/A	32 (2397)	15
Manganese	93 (3705)	0.4 (2223)	1,600

Table 6–11. Maximum Groundwater COPC Concentrations for Non–TC & WM EIS Sources^a (continued)

Contaminant	Core Zone Boundary (peak year)	Columbia River Nearshore (peak year)	Benchmark Concentration ^b
<i>Chemical (micrograms per liter) (continued)</i>			
Mercury	1.7 (2016)	0.002 (10,973)	2
Nitrate	1,040,000 (1947)	846,000 (1976)	45,000
Total uranium	1,220 (1959)	1,910 (1979)	30
Trichloroethylene (TCE)	0.02 (3220)	0.07 (3297)	5

^a The peak cumulative concentration of some constituents occurred in the past. The relationship of past to future cumulative constituent concentrations is presented in the concentration-versus-time plots in Appendix U, Figures U–85 through U–93.

^b The sources of the benchmark concentrations are provided in Appendix O, Section O.3.

^c The plutonium isotopes' impact at the Core Zone Boundary is due primarily to the 216-B-5 reverse well, where plutonium was injected directly into groundwater. Negligible contributions were predicted from all other waste sites (including burial grounds) within the Central Plateau.

^d It was assumed, for analysis purposes, that all chromium was hexavalent.

Key: COPC=constituent of potential concern; N/A=not applicable; TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington.

6.4.1.2 Alternative Combination 1

This section presents the results of the long-term cumulative groundwater impacts analysis for the scenario that includes Alternative Combination 1, which is composed of Tank Closure Alternative 1, FFTF Decommissioning Alternative 1, and Waste Management Alternative 1 (all No Action Alternatives). All of the non–TC & WM EIS sources discussed in Appendix S are included.

This discussion of long-term impacts is focused on the following COPCs:

- Radiological risk drivers: tritium, iodine-129, technetium-99, and uranium-238
- Chemical hazard drivers: carbon tetrachloride, chromium, nitrate, and total uranium

The COPC drivers listed above comprise those from the three individual alternatives that make up Alternative Combination 1 and those from non–TC & WM EIS sources. They fall into three categories. Iodine-129, technetium-99, carbon tetrachloride, 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 12.3 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. The other COPCs that were analyzed do not significantly contribute to risk or hazard during the period of analysis because of limited inventory, high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of these factors. The level of protection provided for the drinking water pathway was evaluated by comparison against EPA maximum contaminant levels (40 CFR 141) and other benchmarks presented in Appendix O.

6.4.1.2.1 Analysis of Release and Mass Balance

This section presents the total amount of the COPC drivers released to the vadose zone, to groundwater, and to the Columbia River. Releases of radionuclides are totaled in curies; chemicals, in kilograms. Both are totaled over the 10,000-year period of analysis.

Table 6–12 lists the release of COPC drivers to the vadose zone. The release of COPCs from Alternative Combination 1 and non-*TC & WM EIS* sources to the vadose zone is controlled by inventory; the entire inventory of all sources was released to the vadose zone during the period of analysis. The release of COPCs from these sources to the vadose zone is dominated by non-*TC & WM EIS* sources for tritium, by Tank Closure Alternative 1 sources for technetium-99, and by a combination of non-*TC & WM EIS* and Tank Closure Alternative 1 sources for the other COPCs. For all of the COPC drivers, releases from FFTF Decommissioning alternative and Waste Management alternative sources account for less than 1 percent of the total.

Table 6–12. Alternative Combination 1 Releases of COPC Drivers to Vadose Zone

Source	Radioactive COPCs (curies)				Chemical COPCs (kilograms)		
	Hydrogen-3 (Tritium)	Technetium-99	Iodine-129	Uranium-238	Chromium ^a	Nitrate	Total Uranium
Other activities	2.38×10 ⁶	1.17×10 ³	1.15×10 ¹	3.60×10 ³	3.52×10 ⁵	7.62×10 ⁷	7.08×10 ⁶
Tank Closure Alternative 1	4.90×10 ⁴	2.58×10 ⁴	4.78×10 ¹	9.33×10 ²	6.91×10 ⁵	9.67×10 ⁷	6.24×10 ⁵
FFTF Decommissioning Alternative 1	3.72×10 ⁻¹	2.72×10 ¹	0	0	5.72×10 ⁻³	0	3.77×10 ⁴
Waste Management Alternative 1	3.50×10 ³	1.21	1.31×10 ⁻³	2.13×10 ⁻¹	1.79×10 ²	2.98×10 ³	2.74×10 ⁻¹
Total	2.43×10⁶	2.70×10⁴	5.92×10¹	4.54×10³	1.04×10⁶	1.73×10⁸	7.74×10⁶

^a It was assumed, for analysis purposes, that all chromium was hexavalent.

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: COPC=constituent of potential concern; FFTF=Fast Flux Test Facility.

Table 6–13 lists the release of COPC drivers to groundwater. In addition to the inventory consideration discussed in the previous paragraph, the 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 iodine-129, technetium-99, chromium, and nitrate, the amount released to groundwater is essentially equal to the amount released to the vadose zone. For tritium, the amount released to groundwater is attenuated by radioactive decay during transit through the vadose zone. About 85 percent of the tritium released to the vadose zone reaches the unconfined aquifer. Because of retardation, less than 5 percent of the uranium-238 and 2 percent of the total uranium released to the vadose zone reach the unconfined aquifer during the period of analysis.

Table 6–14 lists the release of COPC drivers to the Columbia River. The release to the Columbia River is controlled by the transport properties of the COPC drivers in the unconfined aquifer. For 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 4 percent of the tritium released to groundwater reaches the Columbia River. Because of retardation, about 93 percent of the uranium-238 and 78 percent of the total uranium released to groundwater during the period of analysis reach the Columbia River.

Table 6–13. Alternative Combination 1 Releases of COPC Drivers to Groundwater

Source	Radioactive COPCs (curies)				Chemical COPCs (kilograms)		
	Hydrogen-3 (Tritium)	Technetium-99	Iodine-129	Uranium-238	Chromium ^a	Nitrate	Total Uranium
Other activities	2.03×10 ⁶	1.15×10 ³	1.14×10 ¹	2.16×10 ²	3.57×10 ⁵	7.66×10 ⁷	1.31×10 ⁵
Tank Closure Alternative 1	3.12×10 ⁴	2.53×10 ⁴	4.70×10 ¹	1.46×10 ¹	6.84×10 ⁵	9.63×10 ⁷	1.75×10 ⁴
FFTF Decommissioning Alternative 1	5.79×10 ⁻⁷	2.71×10 ¹	0	0	5.58×10 ⁻³	0	4.24×10 ³
Waste Management Alternative 1	3.80×10 ⁻⁷	1.19	1.30×10 ⁻³	3.95×10 ⁻⁶	1.77×10 ²	2.94×10 ³	4.94×10 ⁻⁶
Total	2.06×10⁶	2.64×10⁴	5.84×10¹	2.31×10²	1.04×10⁶	1.73×10⁸	1.53×10⁵

^a It was assumed, for analysis purposes, that all chromium was hexavalent.

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: COPC=constituent of potential concern; FFTF=Fast Flux Test Facility.

Table 6–14. Alternative Combination 1 Releases of COPC Drivers to the Columbia River

Source	Radioactive COPCs (curies)				Chemical COPCs (kilograms)		
	Hydrogen-3 (Tritium)	Technetium-99	Iodine-129	Uranium-238	Chromium ^a	Nitrate	Total Uranium
Other activities	7.21×10 ⁴	1.15×10 ³	1.14×10 ¹	2.12×10 ²	3.77×10 ⁵	7.90×10 ⁷	1.15×10 ⁵
Tank Closure Alternative 1	3.90×10 ²	2.54×10 ⁴	4.71×10 ¹	3.58	6.82×10 ⁵	9.71×10 ⁷	4.18×10 ³
FFTF Decommissioning Alternative 1	2.50×10 ⁻⁸	2.70×10 ¹	0	0	5.74×10 ⁻³	0	2.68×10 ³
Waste Management Alternative 1	0	1.20	1.31×10 ⁻³	0	1.78×10 ²	2.96×10 ³	0
Total	7.25×10⁴	2.66×10⁴	5.85×10¹	2.16×10²	1.06×10⁶	1.76×10⁸	1.22×10⁵

^a It was assumed, for analysis purposes, that all chromium was hexavalent.

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: COPC=constituent of potential concern; FFTF=Fast Flux Test Facility.

6.4.1.2.2 Analysis of Concentration Versus Time

This section presents the contaminant concentrations in groundwater versus time at the Core Zone Boundary and the Columbia River. The benchmark concentration of each radionuclide and chemical is also shown in the graphs. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over five orders of magnitude. Table 6–15 lists the maximum cumulative groundwater COPC concentrations at the Core Zone Boundary and Columbia River nearshore in the peak year of the 10,000-year period of analysis. Comparison of the results in Table 6–11 (non-TC & WM EIS sources only) with the results in Table 6–15 (cumulative with Alternative Combination 1 sources) shows that the peak concentrations of some of the COPC drivers do not change with the addition of Tank Closure Alternative 1, FFTF Decommissioning Alternative 1, and Waste Management Alternative 1 sources. This indicates that these peaks are driven primarily by the non-TC & WM EIS sources. These COPC drivers include tritium, uranium-238, carbon tetrachloride, chromium, and total uranium. For other COPC drivers, primarily technetium-99, the TC & WM EIS alternative sources are the dominant contributor with respect to peak concentration. Finally, for iodine-129 and nitrate, contributions from TC & WM EIS alternative sources and non-TC & WM EIS sources are approximately equal contributors to peak concentration.

Table 6–15. Alternative Combination 1 Maximum Cumulative Groundwater COPC Concentrations^a

Contaminant	Core Zone Boundary (peak year)	Columbia River Nearshore (peak year)	Benchmark Concentration^b
Radionuclide (picocuries per liter)			
Hydrogen-3 (tritium)	112,000,000 (1997)	4,140,000 (1986)	20,000
Carbon-14	1,090 (1998)	5 (1992)	2,000
Strontium-90	1,730 (1998)	27,600 (1991)	8
Technetium-99	35,000 (1956)	1,790 (2999)	900
Iodine-129	58.8 (3577)	20.1 (2017)	1
Cesium-137	0 N/A	1,430 (1985)	200
Uranium isotopes (includes uranium-233, -234, -235, -238)	839 (1959)	6,190 (1979)	15
Neptunium-237	7 (2061)	2 (3662)	15
Plutonium isotopes (includes plutonium-239, -240)	26 (7725)	2 (1991)	15
Chemical (micrograms per liter)			
1-Butanol	518 (1998)	2 (3891)	3,600
Boron and compounds	0.2 (3270)	1 (2364)	7,000
Carbon tetrachloride	577 (2035)	208 (2067)	5
Chromium ^c	13,300 (1959)	7,210 (1979)	100
Dichloromethane	0.2 (3321)	0.1 (3923)	5
Fluoride	160,000 (2008)	30,700 (2032)	4,000
Hydrazine/hydrazine sulfate	0.009 (3308)	0.043 (3281)	0.022
Lead	0 N/A	32 (2397)	15
Manganese	93 (3705)	0.4 (2223)	1,600
Mercury	1.7 (2016)	0.002 (10,973)	2
Nitrate	2,040,000 (1956)	846,000 (1976)	45,000

**Table 6–15. Alternative Combination 1 Maximum Cumulative Groundwater
COPC Concentrations^a (continued)**

Contaminant	Core Zone Boundary (peak year)	Columbia River Nearshore (peak year)	Benchmark Concentration ^b
Chemical (micrograms per liter) (continued)			
Total uranium	1,220 (1959)	1,910 (1979)	30
Trichloroethylene (TCE)	0.02 (3220)	0.07 (3297)	5

^a The peak cumulative concentration of some constituents occurred in the past. The relationship of past to future cumulative constituent concentrations is presented in the concentration-versus-time plots in Figures 6–2 through 6–9.

^b The sources of the benchmark concentrations are provided in Appendix O, Section O.3.

^c It was assumed, for analysis purposes, that all chromium was hexavalent.

Key: COPC=constituent of potential concern; N/A=not applicable.

Figure 6–2 shows concentration versus time for tritium. Note that, for visual clarity, the time period shown in this figure is from 1940 through 2440 rather than the full 10,000-year period of analysis.

Tritium concentrations at the Core Zone Boundary exceed the benchmark concentration by about three to four orders of magnitude for a short period of time during the early part of the period of analysis. During this time, groundwater concentrations at the Columbia River nearshore peak at about two orders of magnitude above the benchmark concentration. The higher early tritium concentrations not only are the result of contributions from cribs and trenches (ditches) and past tank leaks, but also the additional non-*TC & WMEIS* sources. Because the half-life of tritium is less than 13 years, radioactive decay rapidly attenuates groundwater concentration; thus, tritium is essentially not a factor beyond CY 2140.

Figures 6–3 through 6–7 show concentration versus time for iodine-129, technetium-99, carbon tetrachloride, chromium, and nitrate. Groundwater concentrations of iodine-129 at the Core Zone Boundary exceed benchmark concentrations by one to two orders of magnitude during the first several thousand years of the analysis. During this time, groundwater concentrations at the Columbia River nearshore exceed the benchmark concentration by about an order of magnitude. During later times in the analysis, the concentrations at the Core Zone Boundary exceed the benchmark by one to two orders of magnitude and drop below benchmark concentrations around CY 7900. The primary contribution of iodine-129 inside the Core Zone Boundary is from Tank Closure Alternative 1. The sharp inflections in the concentration-versus-time curves from about CY 1956 until CY 1980 result from releases from cribs and trenches (ditches) and past tank leaks, whereas the broader inflection from about CY 3000 to CY 7000 results from tank residuals. The concentration-versus-time graph for technetium-99 exhibits behavior similar to iodine-129 because the primary source of technetium-99 is also from Tank Closure Alternative 1. Groundwater technetium-99 concentrations exceed benchmark concentrations by more than one order of magnitude at the Core Zone Boundary for several thousand years. During the same timeframe, concentrations hover around the benchmark concentrations at the Columbia River nearshore; concentrations drop below the benchmark around CY 6500.

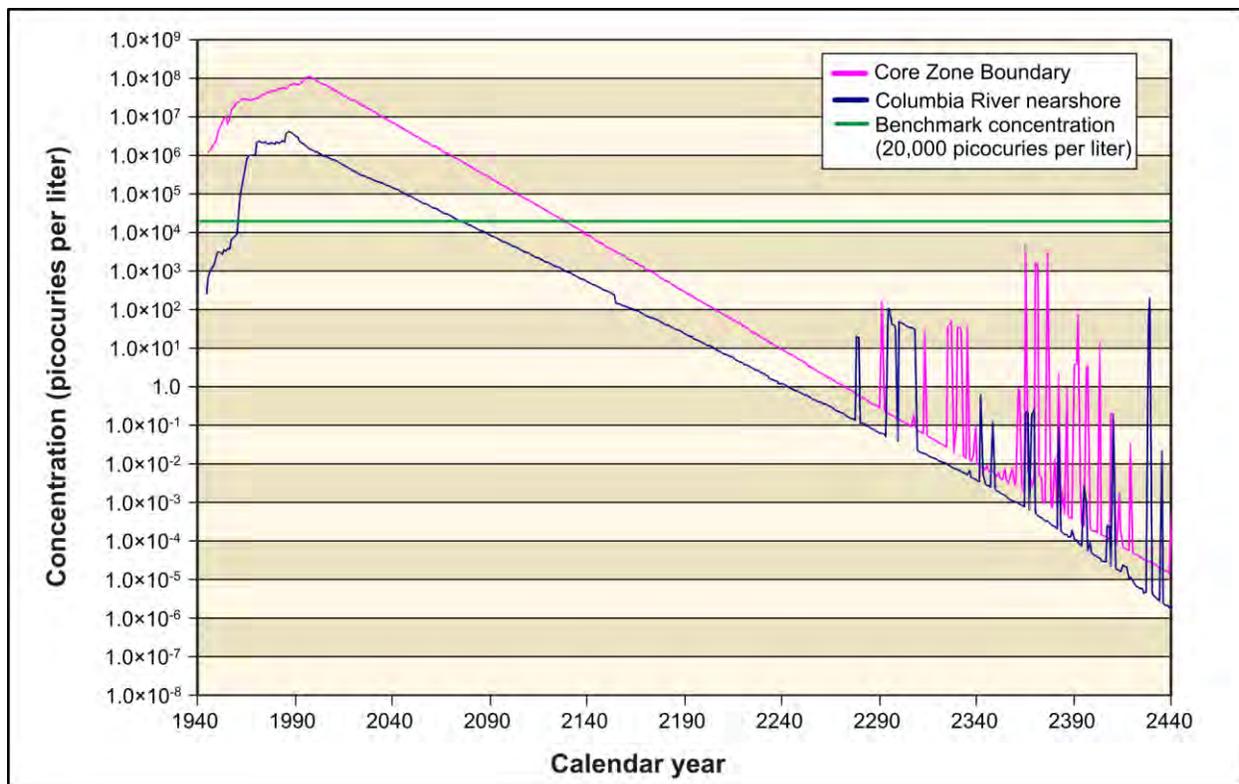


Figure 6–2. Alternative Combination 1 Cumulative Hydrogen-3 (Tritium) Concentration Versus Time

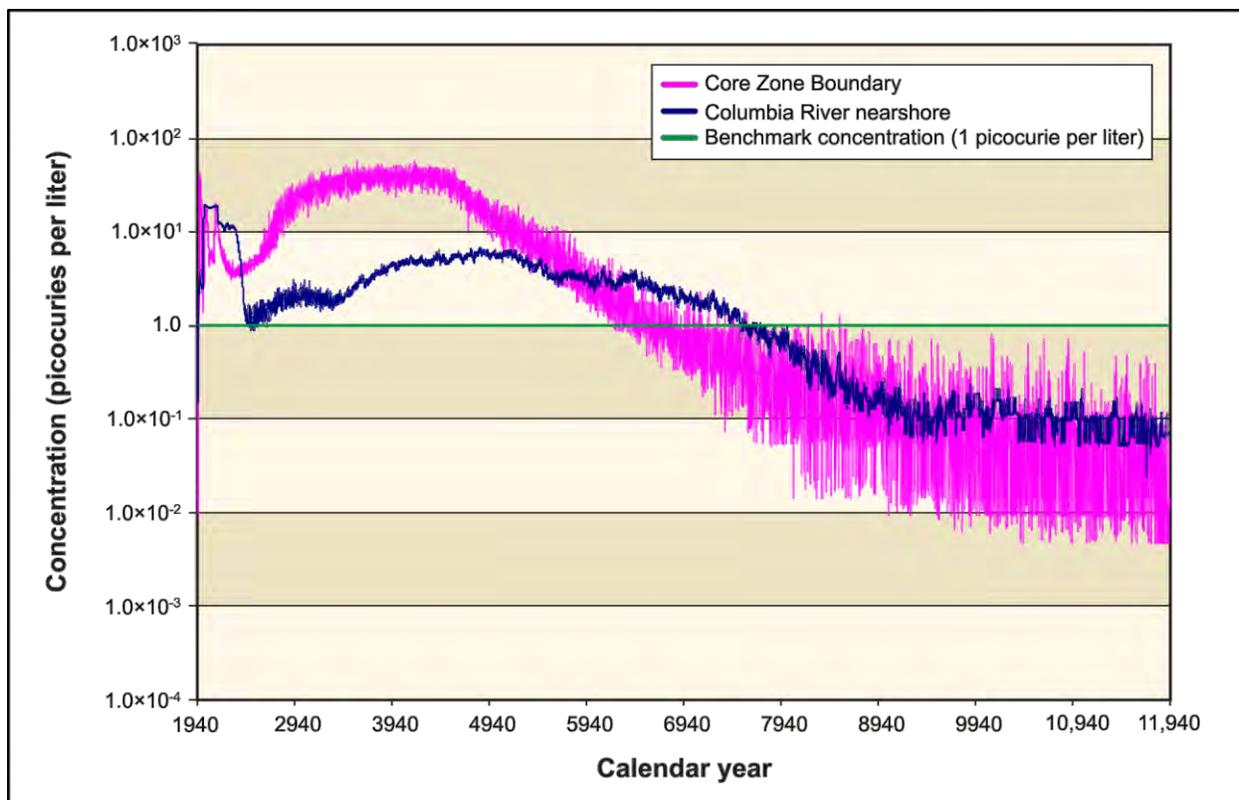


Figure 6–3. Alternative Combination 1 Cumulative Iodine-129 Concentration Versus Time

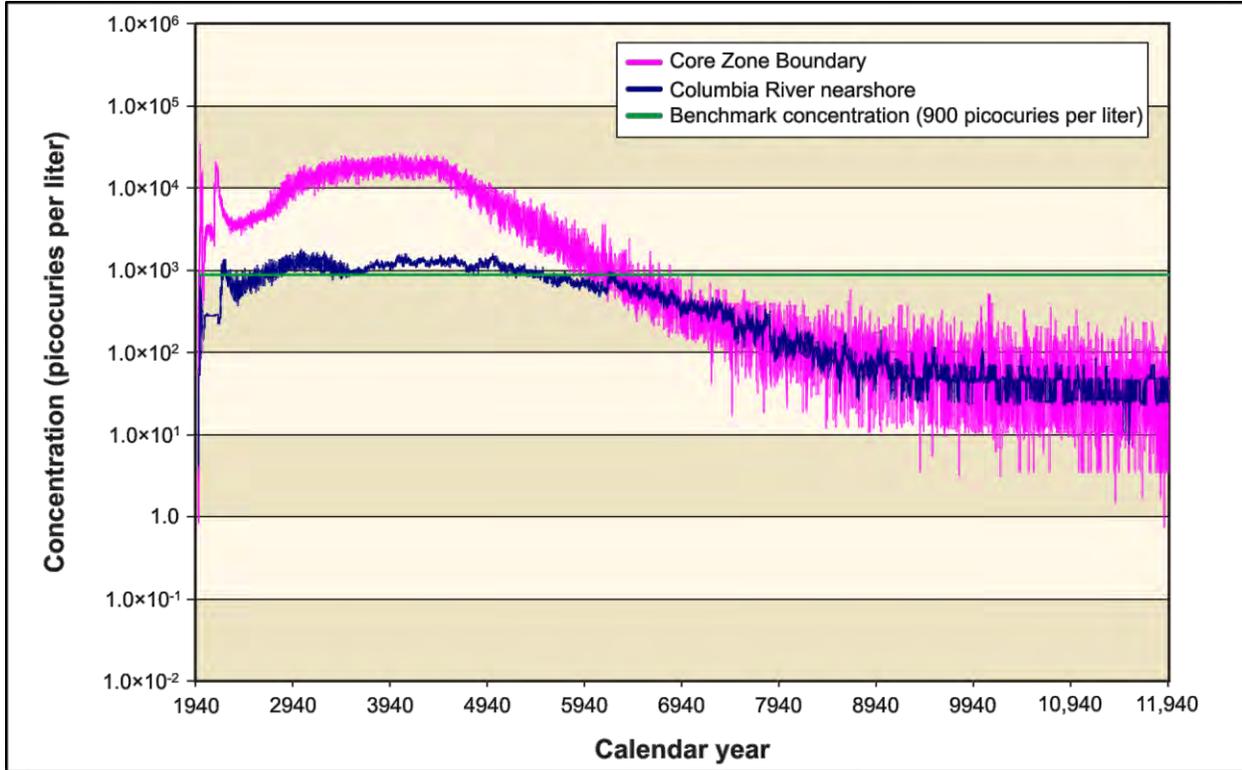


Figure 6-4. Alternative Combination 1 Cumulative Technetium-99 Concentration Versus Time

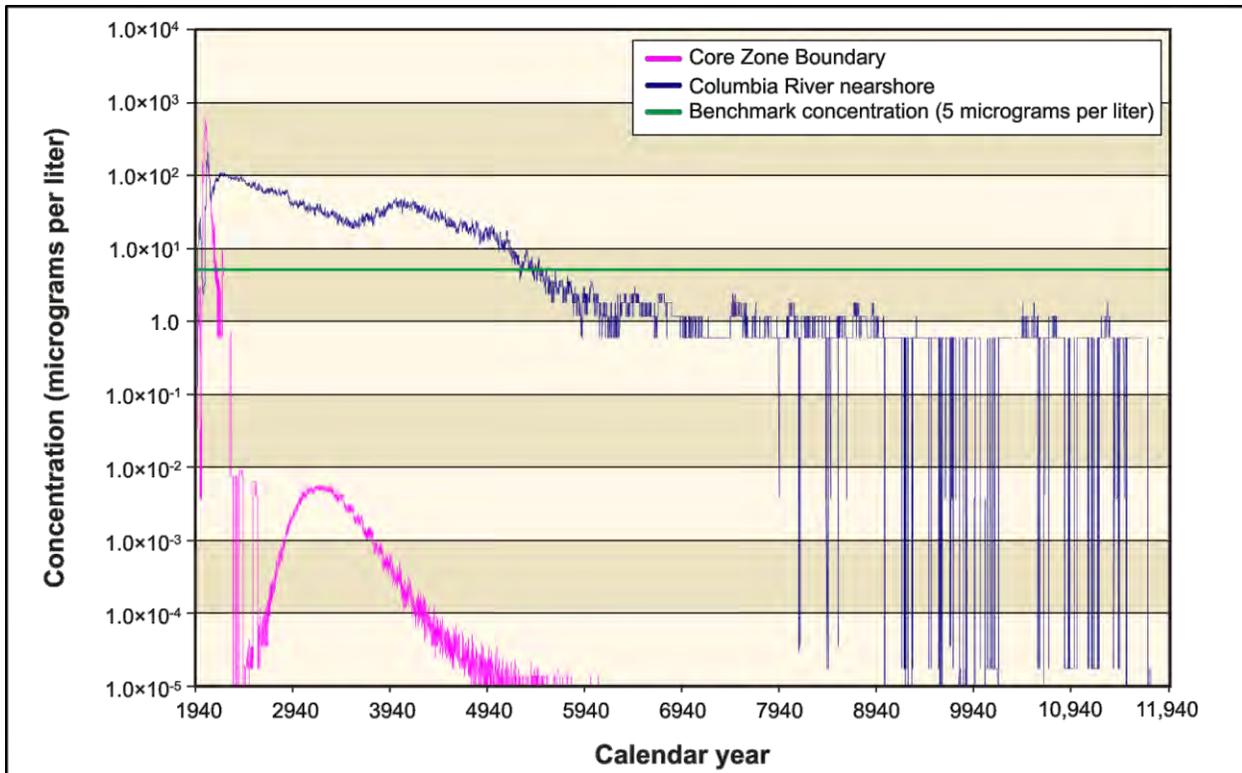


Figure 6-5. Alternative Combination 1 Cumulative Carbon Tetrachloride Concentration Versus Time

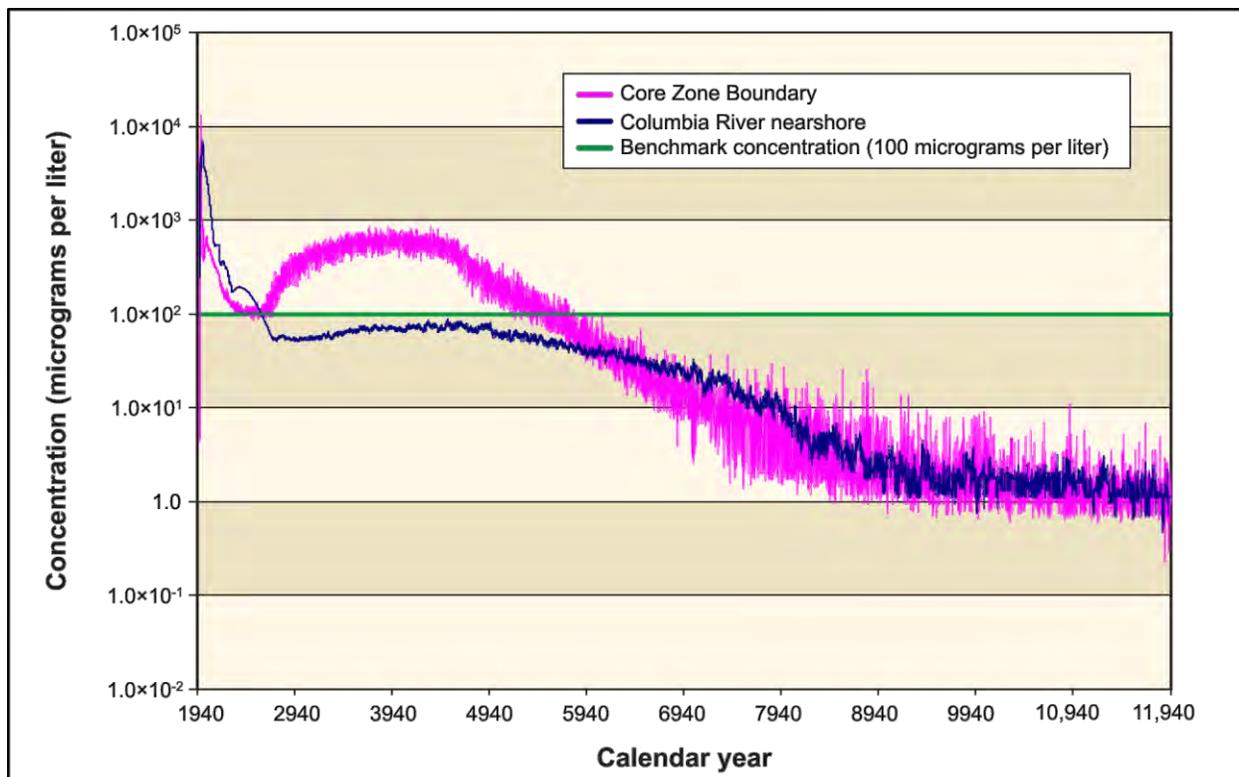


Figure 6–6. Alternative Combination 1 Cumulative Chromium Concentration Versus Time

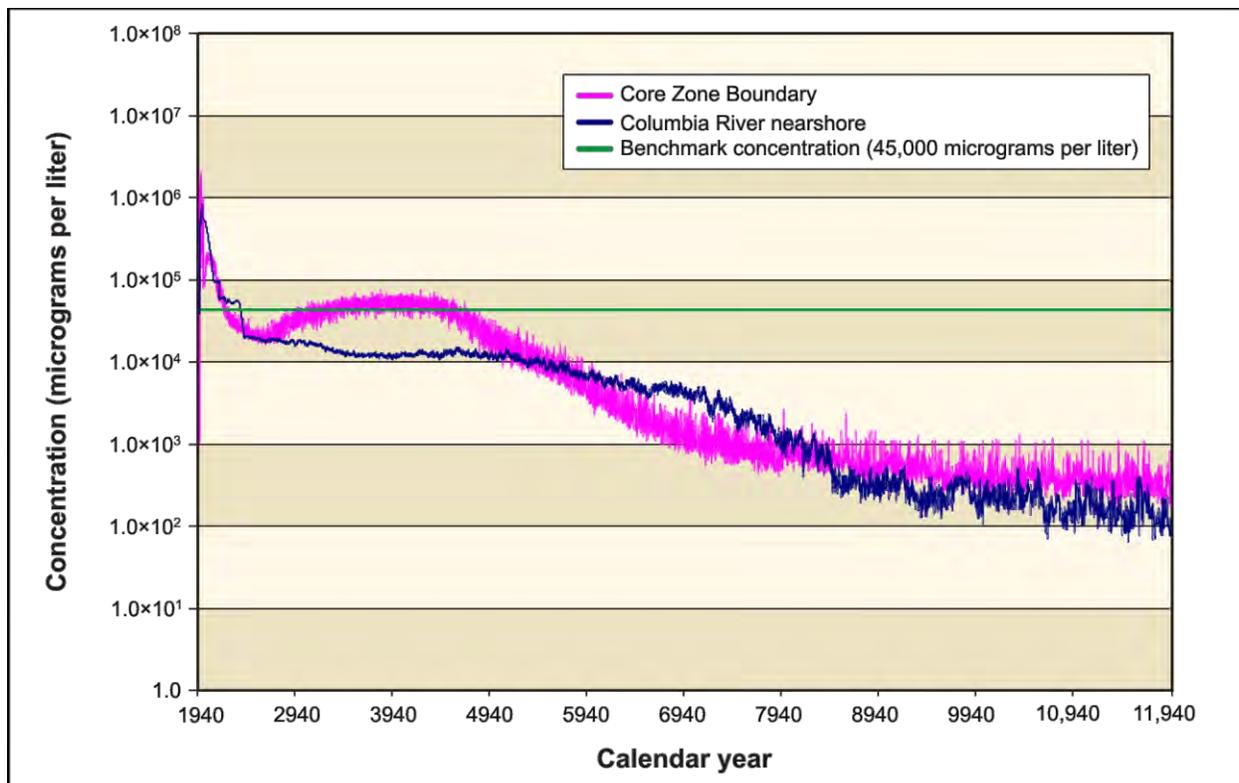


Figure 6–7. Alternative Combination 1 Cumulative Nitrate Concentration Versus Time

The bulk of carbon tetrachloride is from non-*TC & WM EIS* sources. Carbon tetrachloride concentrations at the Core Zone Boundary drop well below the benchmark concentration around CY 2135. Groundwater concentrations at the Columbia River nearshore exceed benchmark concentrations by more than one order of magnitude early in the simulation period, then drop to below benchmark concentrations around CY 5300. Chromium concentrations are impacted by releases from both *TC & WM EIS* and non-*TC & WM EIS* sources. Chromium concentrations at the Core Zone Boundary exceed the benchmark concentration by about two orders of magnitude for a short period of time during the early part of the period of analysis. Chromium concentrations at these early times are slightly higher than for Tank Closure Alternative 1 because of the additional contribution from non-*TC & WM EIS* sources. The impact of the non-*TC & WM EIS* sources is even greater at the Columbia River nearshore relative to the sources in Tank Closure Alternative 1. Around CY 2550, concentrations at both the Core Zone Boundary and the Columbia River nearshore fall to the benchmark concentration. Concentrations at the Columbia River nearshore continue to drop below the benchmark concentrations, while concentrations at the Core Zone Boundary increase after that by about one order of magnitude until around CY 6000, at which time they dip down below the benchmark concentration. This second rise in chromium concentrations results from the tank residual releases in Tank Closure Alternative 1. Nitrate concentrations behave similarly to chromium, except that groundwater concentrations at the Core Zone Boundary dip below benchmark concentrations after the initial spike in the early period and rise to concentrations around the benchmark concentration.

Figures 6–8 and 6–9 show concentration versus time for uranium-238 and total uranium. The travel times of these COPCs from the source locations to the Core Zone Boundary and Columbia River are about seven times slower than groundwater flow. Uranium-238 and total uranium concentrations are influenced by both *TC & WM EIS* and non-*TC & WM EIS* sources; however, the non-*TC & WM EIS* sources are dominant and exert the most influence over uranium transport. Concentrations of uranium-238 and total uranium peak early in the period of analysis to more than two orders of magnitude above benchmark concentrations, then drop sharply, with the Columbia River nearshore reaching the benchmark around CY 2500 for uranium-238 and around CY 2300 for total uranium. Concentrations of both uranium-238 and total uranium spike again around CY 2500 at the Core Zone Boundary by about one order of magnitude before dropping well below the benchmark concentrations around CY 2800. Concentrations of uranium-238 and total uranium early in the simulation period are much higher than for Tank Closure Alternative 1 because of non-*TC & WM EIS* source contributions.

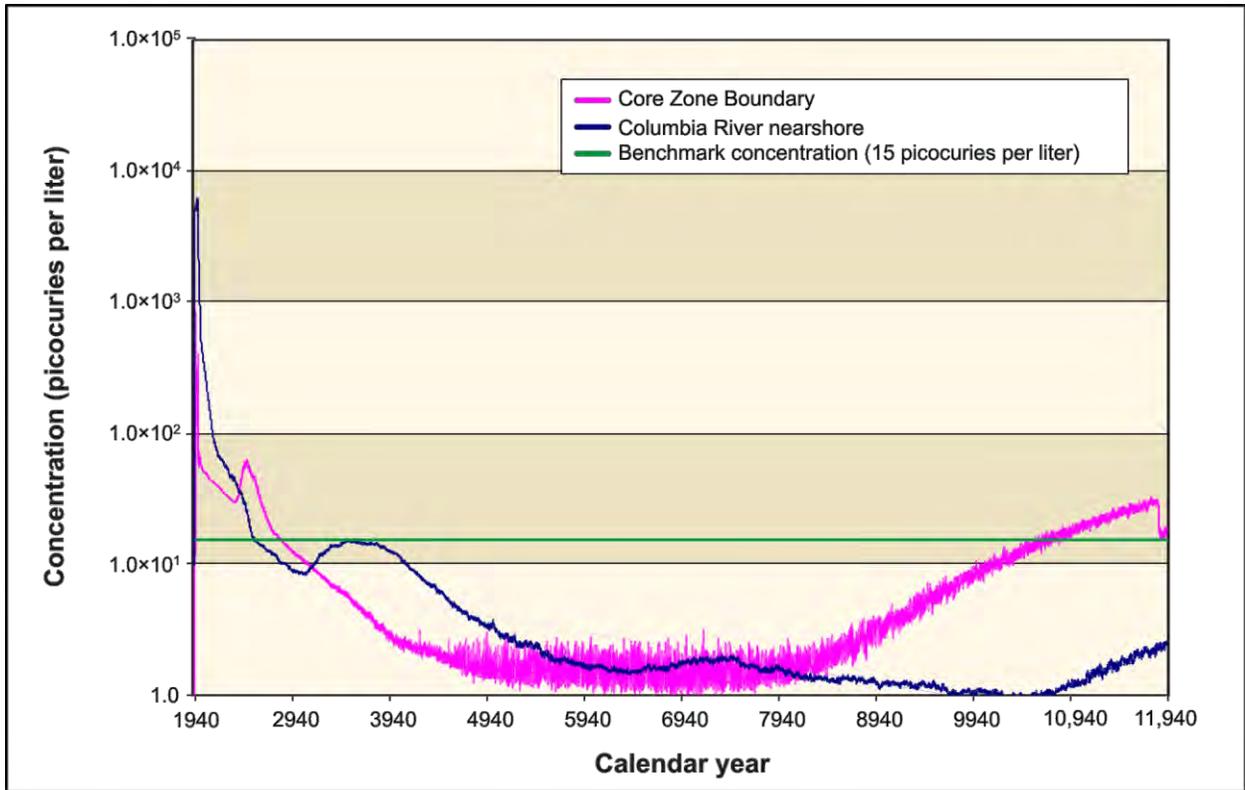


Figure 6–8. Alternative Combination 1 Cumulative Uranium-238 Concentration Versus Time

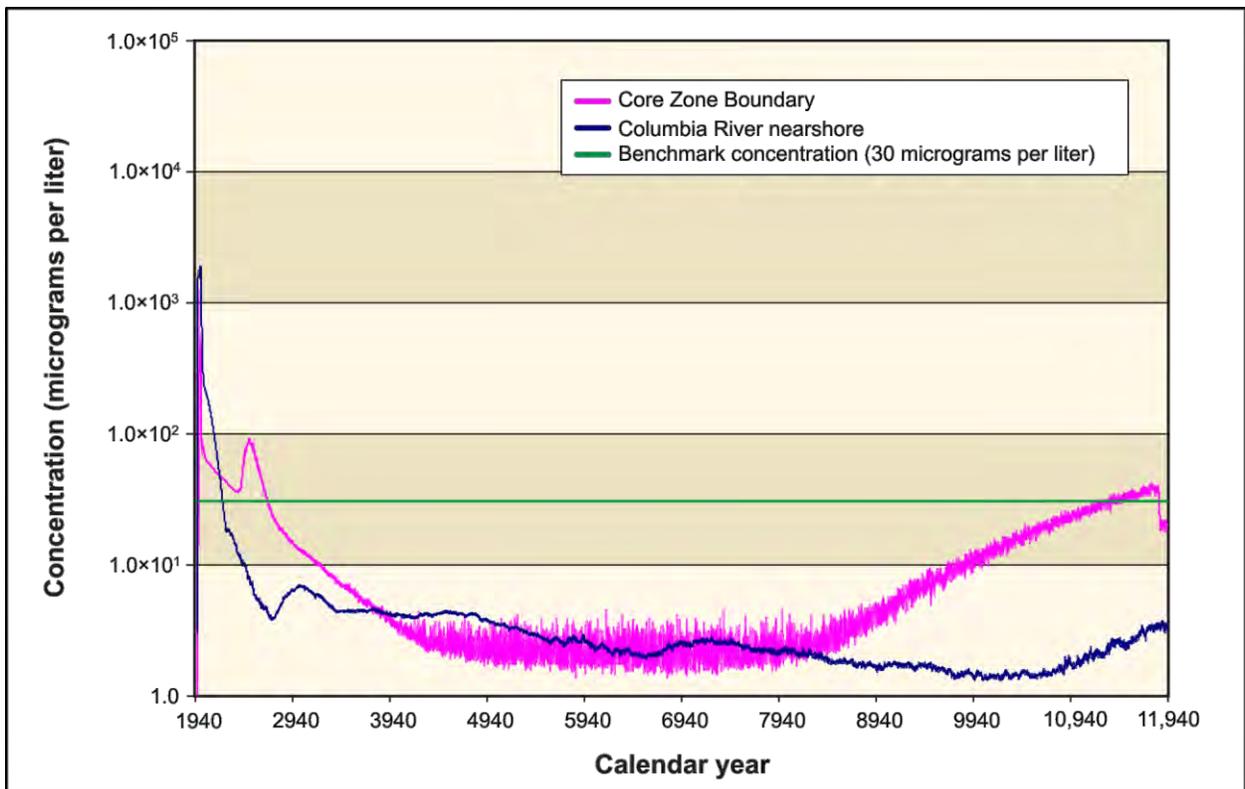
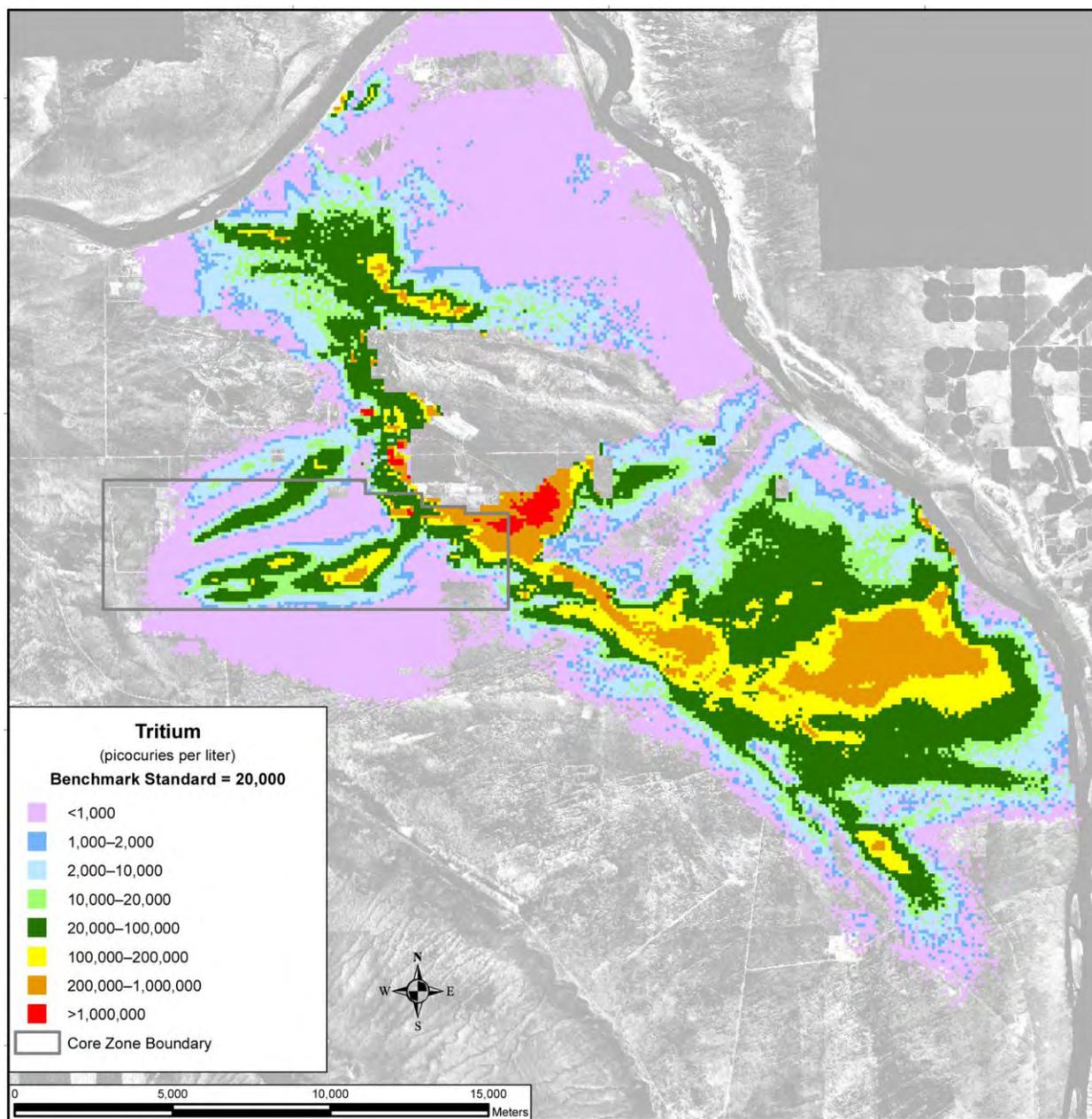


Figure 6–9. Alternative Combination 1 Cumulative Total Uranium Concentration Versus Time

6.4.1.2.3 Analysis of Spatial Distribution of Concentration

This section presents the spatial distribution of contaminant concentrations in groundwater at selected times. 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 6–10 shows the spatial distribution of tritium concentrations in groundwater in CY 2010. The spatial pattern of the tritium plumes is an indicator of the different sources and release areas. The release from *TC & WM EIS* sources results from cribs and trenches (ditches) and past tank leaks and is evident as the plume originating at the center of the 200-West Area and crossing the northern Core Zone Boundary at concentrations 1 to 10 times the benchmark concentration. The tritium plumes originating along the southern Core Zone Boundary in the 200-West Area are from non-*TC & WM EIS* sources associated with the REDOX Facility. The tritium plumes originating in the 200-West Area cross the northern Core Zone Boundary and move through Gable Mountain–Gable Butte Gap (Gable Gap) to the northern part of Hanford. The more intense tritium plume that originates at the east edge of the Core Zone Boundary and extends southeast to the Columbia River is the release from the PUREX Plant, a non-*TC & WM EIS* source. Peak concentrations in the PUREX plume are up to 50 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.



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

Figure 6–10. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Hydrogen-3 (Tritium) Concentration, Calendar Year 2010

Figure 6–11 shows the spatial distribution of iodine-129 concentrations in groundwater in CY 2010. Releases from cribs and trenches (ditches) and past leaks associated with the A, B, S, and T Barriers result in groundwater concentration plumes that exceed the benchmark concentration. Peak concentrations in this plume are about 10 to 50 times greater than the benchmark and are mostly contained within the Core Zone. There also is a separate plume along the southern Core Zone Boundary associated with the REDOX Facility (non-TC & WM EIS source). Releases from the PUREX Plant area (non-TC & WM EIS sources) produce a plume extending south and east of the Core Zone, with peak concentrations about 10 to 50 times the benchmark concentration. Around CY 3890, releases from other tank farm sources create a large iodine-129 plume extending from the tank farm barriers to the Columbia River (see Figure 6–12). 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 6–13). Figure 6–14 shows the total area for which groundwater iodine-129 concentrations exceed the benchmark concentration as a function of time. After an early peak related to releases during the past-practice period, the area of exceedance peaks between CYs 3400 and 4600, driven primarily by releases from other tank farm sources. Other tank farm sources include tank farm residuals, ancillary equipment, retrieval losses, and unplanned releases.

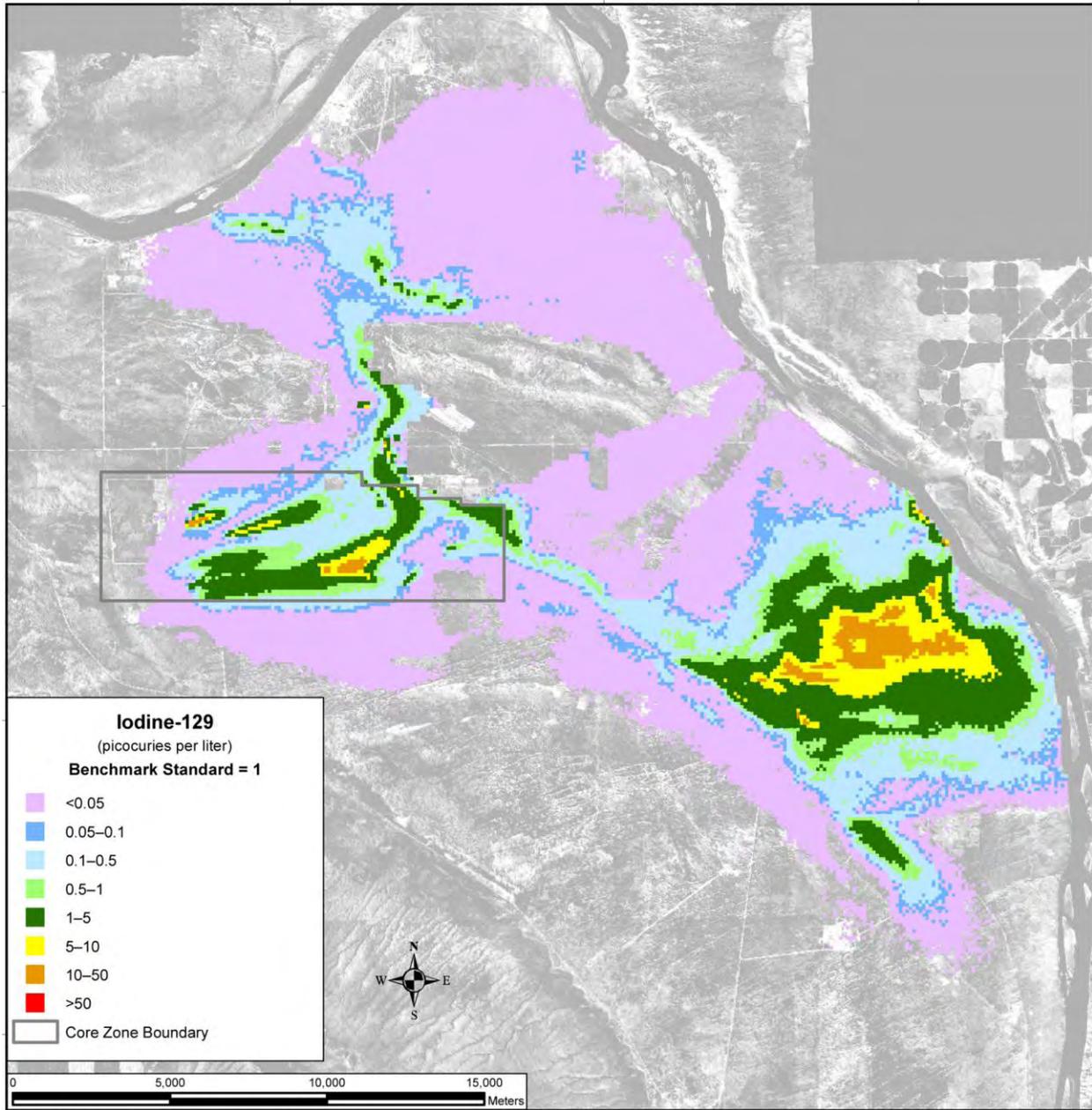
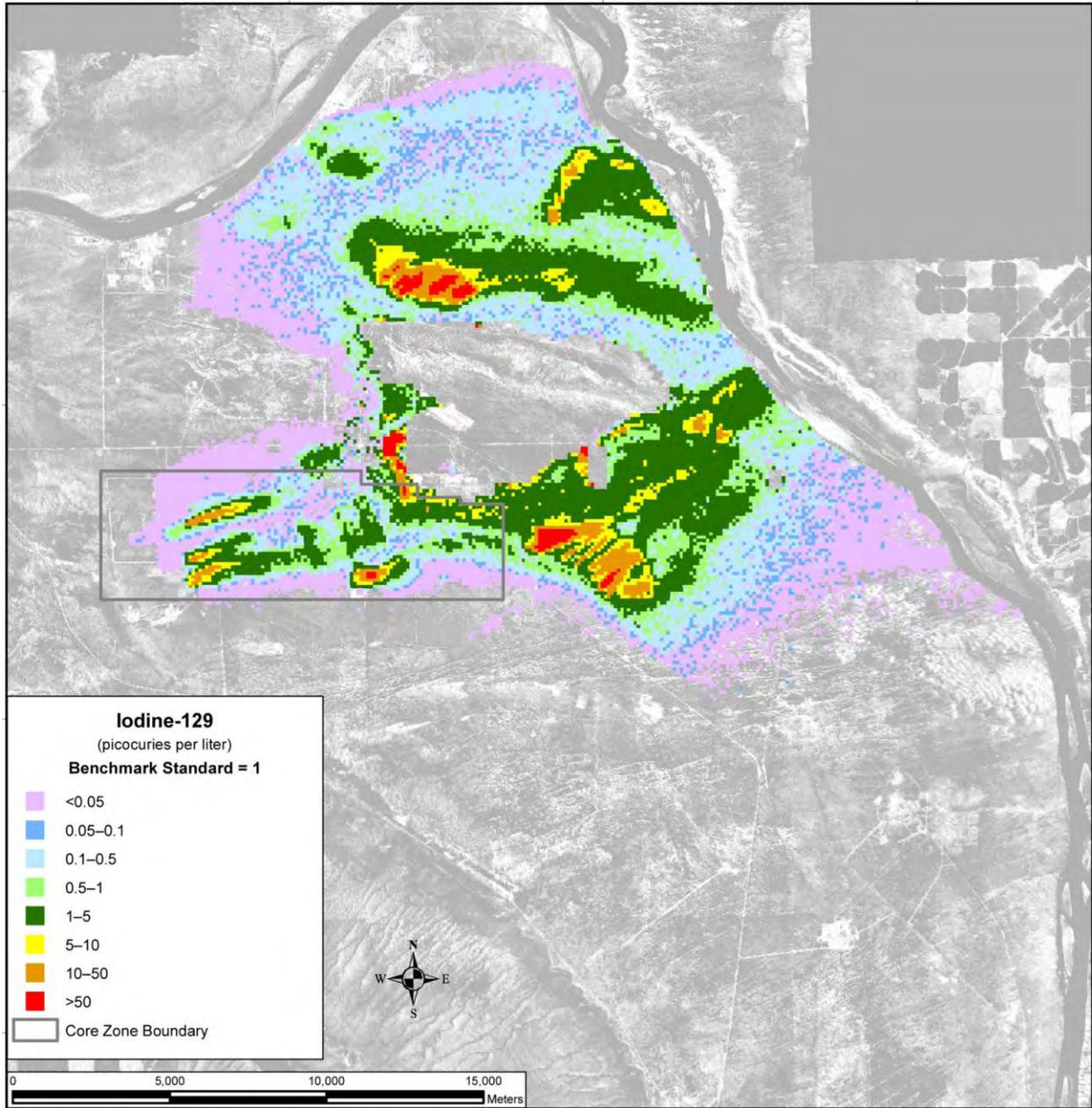
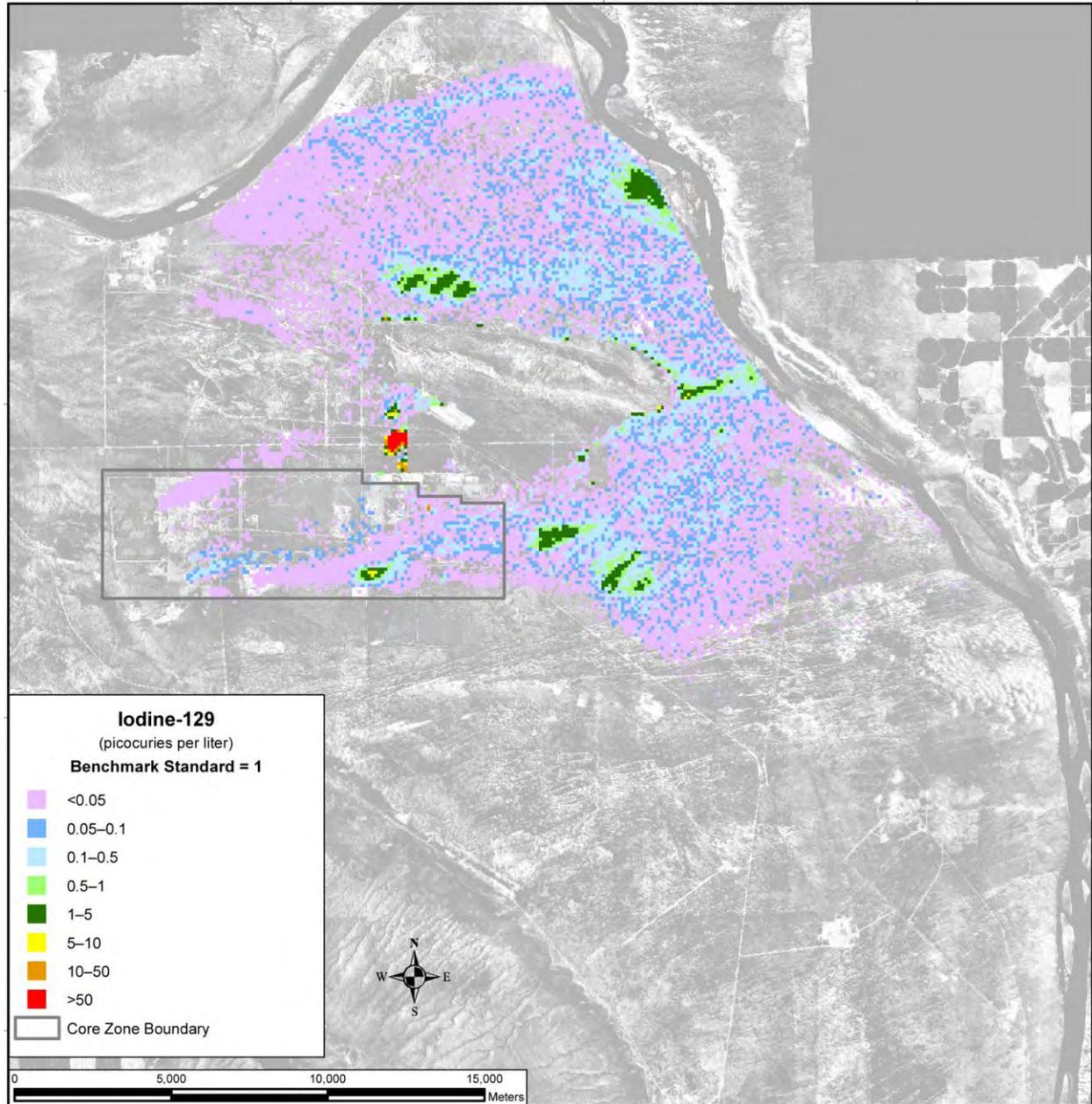


Figure 6–11. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Iodine-129 Concentration, Calendar Year 2010



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

Figure 6–12. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Iodine-129 Concentration, Calendar Year 3890



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

Figure 6-13. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Iodine-129 Concentration, Calendar Year 7140

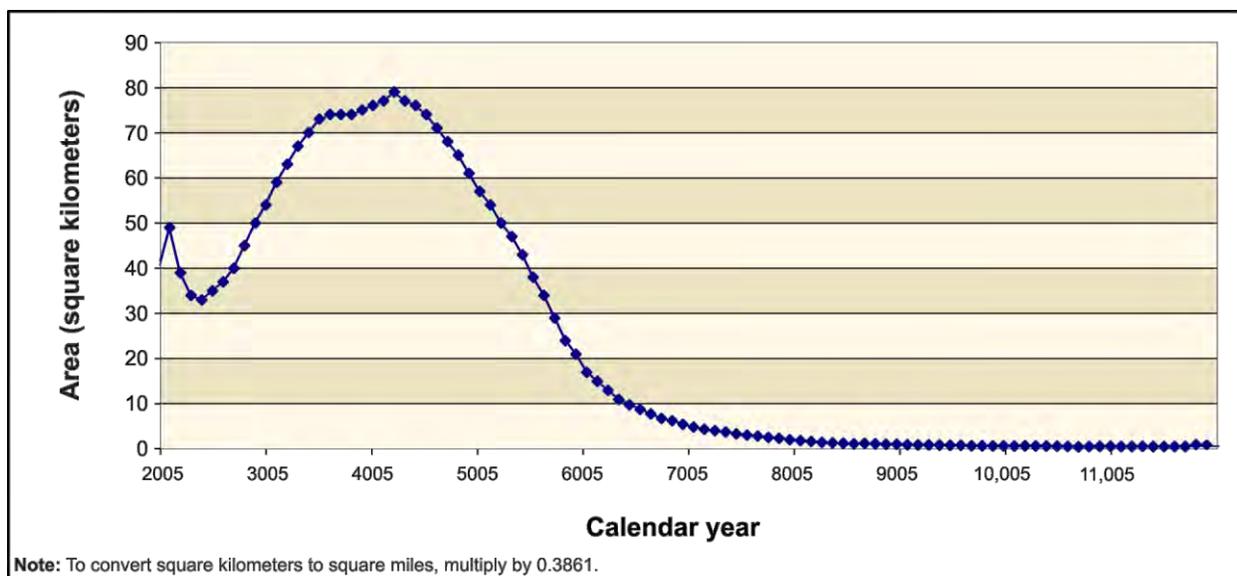


Figure 6–14. Alternative Combination 1 Total Area of Cumulative Groundwater Iodine-129 Concentrations Exceeding the Benchmark Concentration as a Function of Time

Figures 6–15 through 6–17 show the spatial distributions of technetium-99 concentrations in groundwater in the same years presented for iodine-129, CYs 2010, 3890, and 7140. Non-TC & WM EIS sources have a minor contribution to technetium-99 (compared with iodine-129 distributions), and the spatial distributions are dominated by releases from other tank farm sources. Figure 6–18 shows the total area of exceedance versus time for technetium-99. Chromium (see Figures 6–19 through 6–21) and nitrate (see Figures 6–22 through 6–24) show similar spatial distributions to iodine-129.

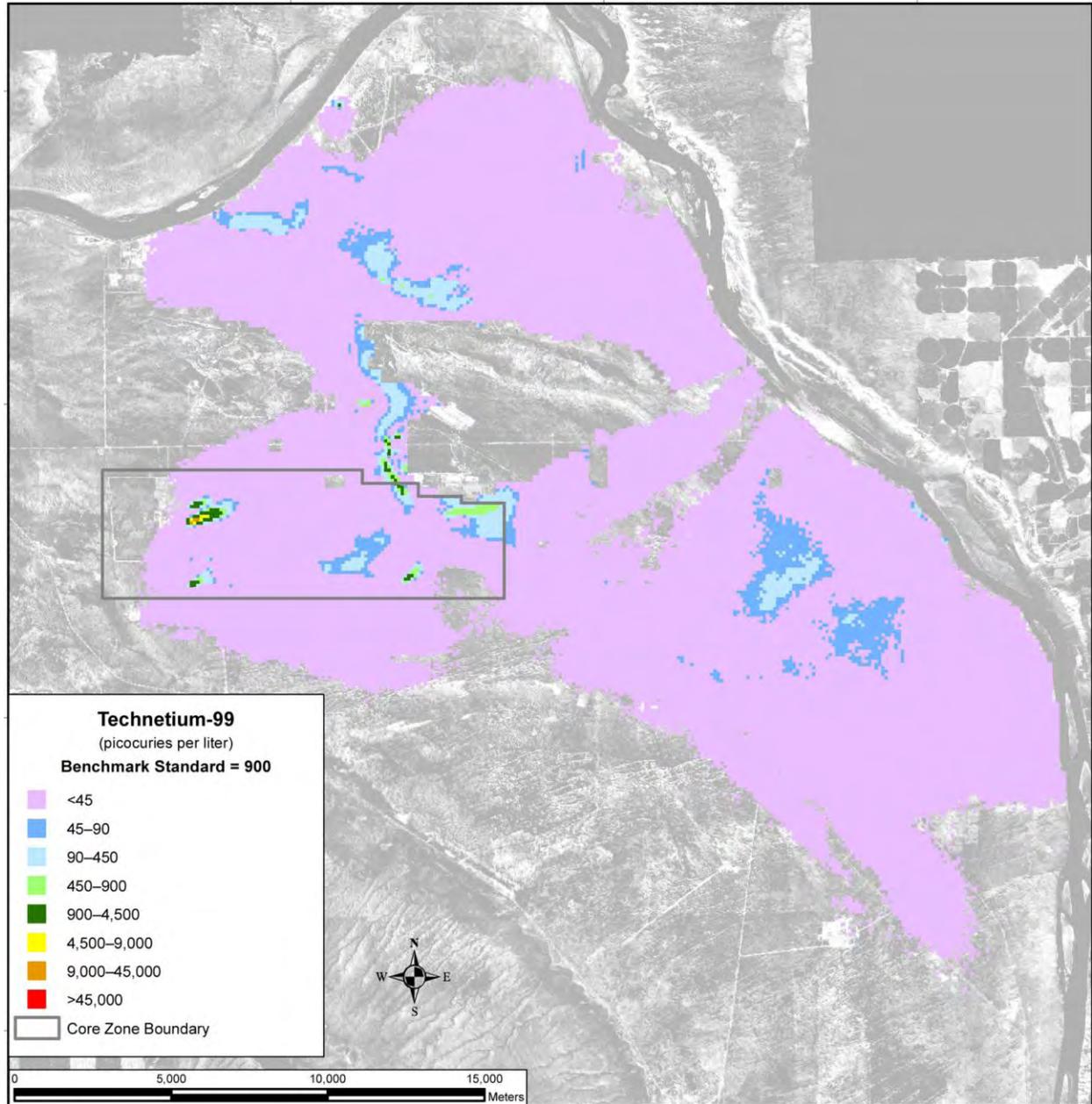


Figure 6-15. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Technetium-99 Concentration, Calendar Year 2010

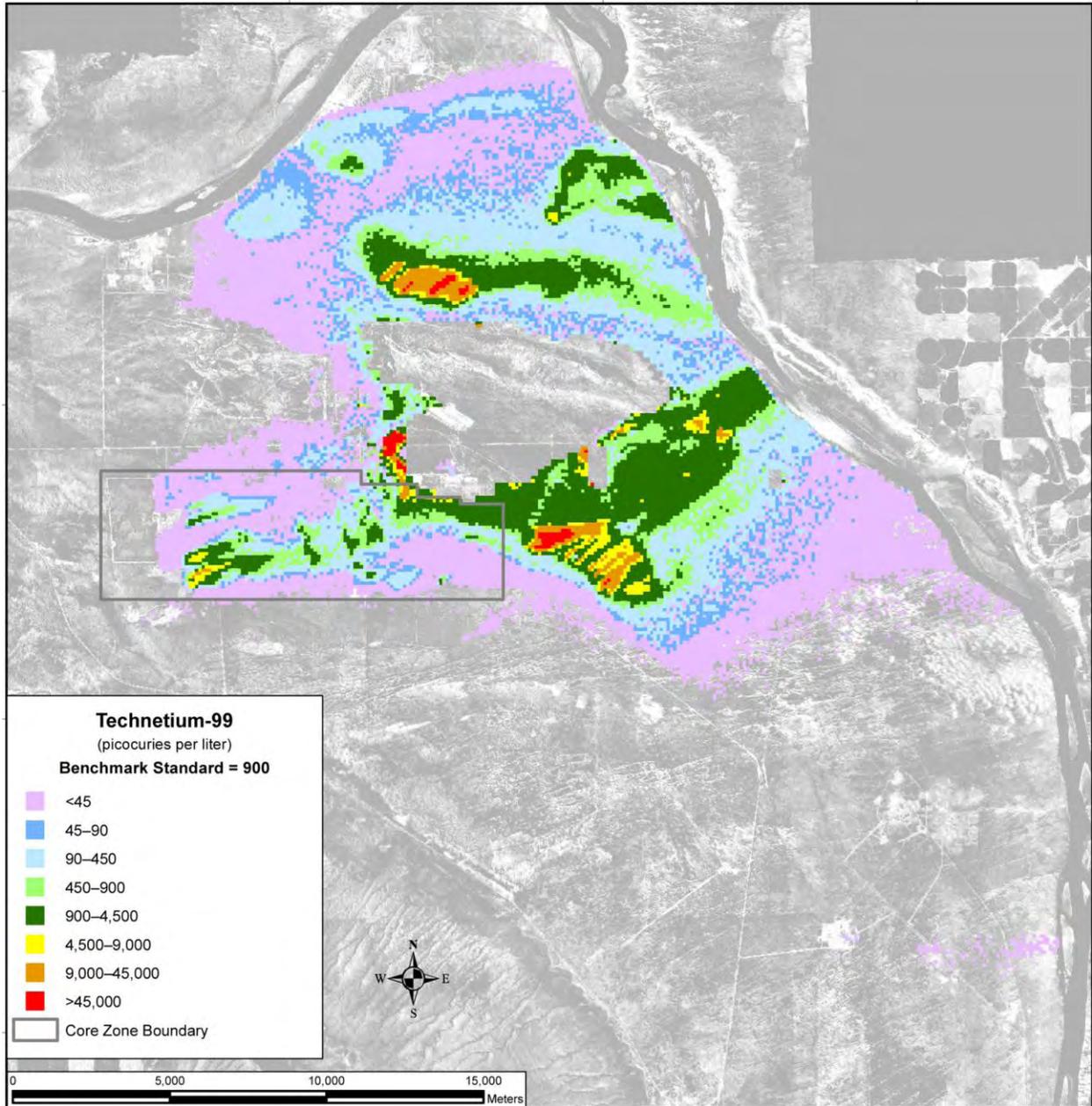


Figure 6-16. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Technetium-99 Concentration, Calendar Year 3890

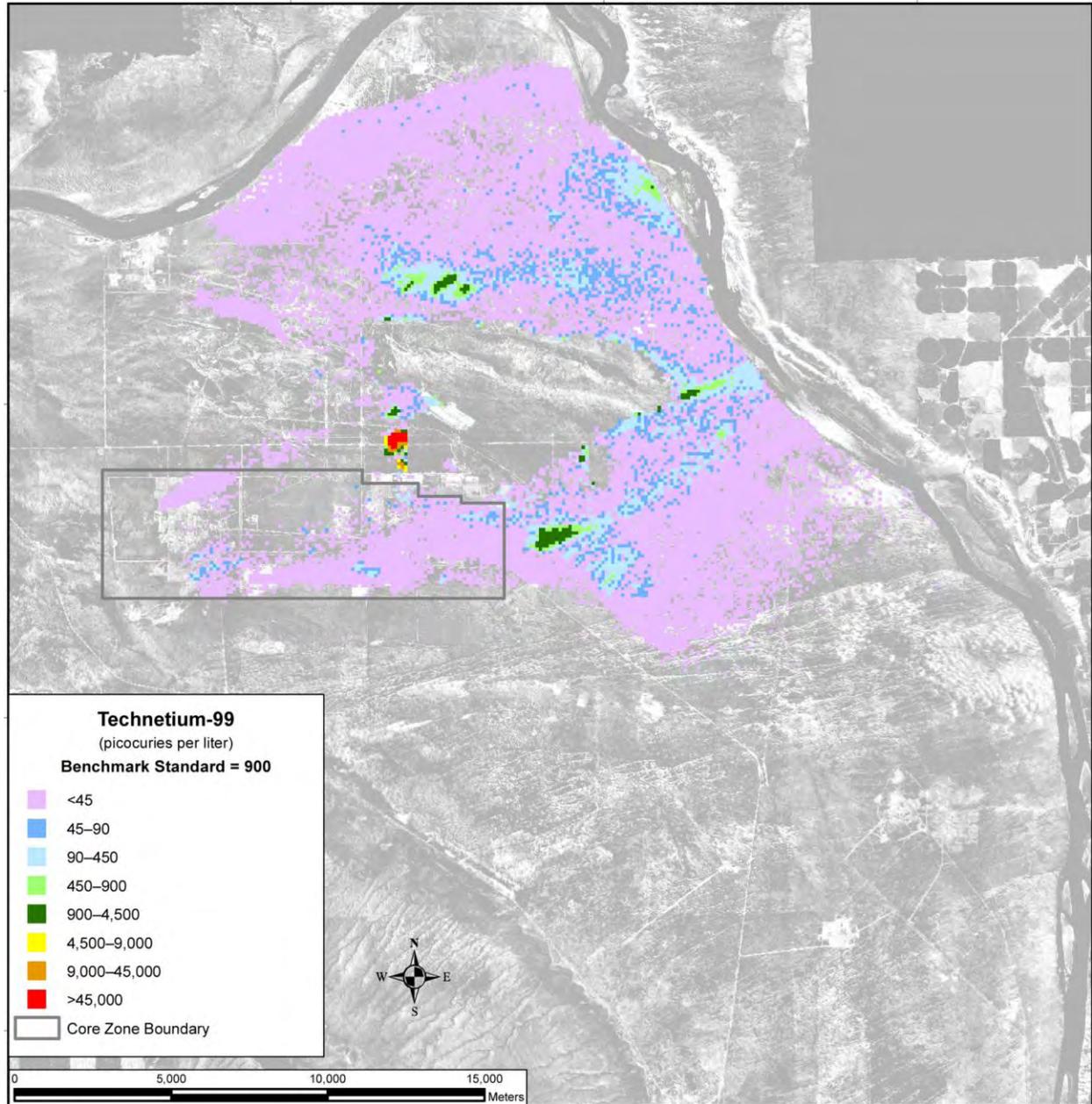


Figure 6-17. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Technetium-99 Concentration, Calendar Year 7140

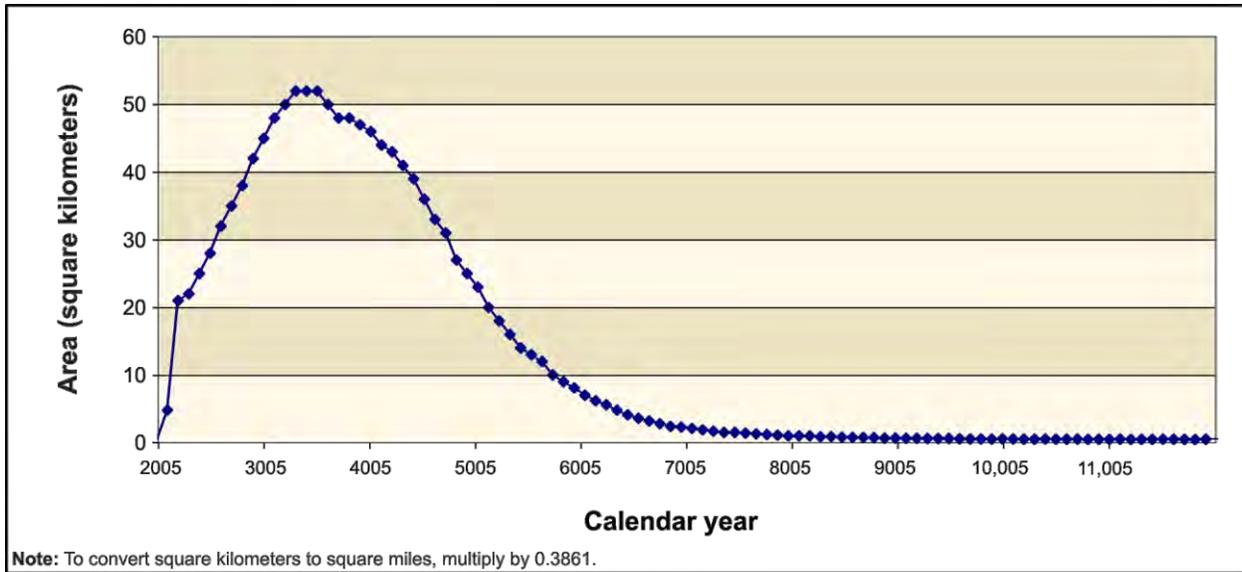


Figure 6–18. Alternative Combination 1 Total Area of Cumulative Groundwater Technetium-99 Concentrations Exceeding the Benchmark Concentration as a Function of Time

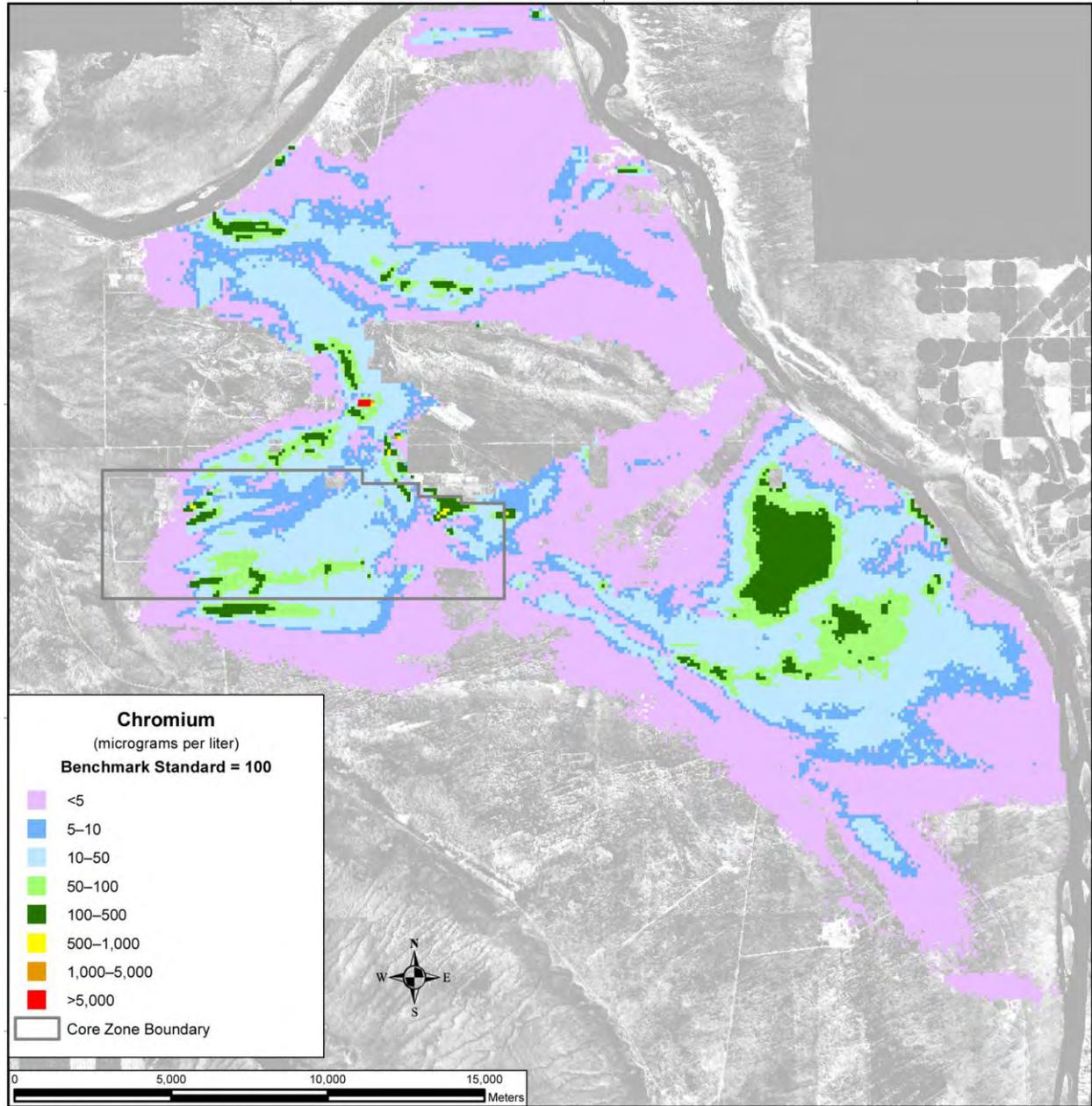


Figure 6-19. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Chromium Concentration, Calendar Year 2010

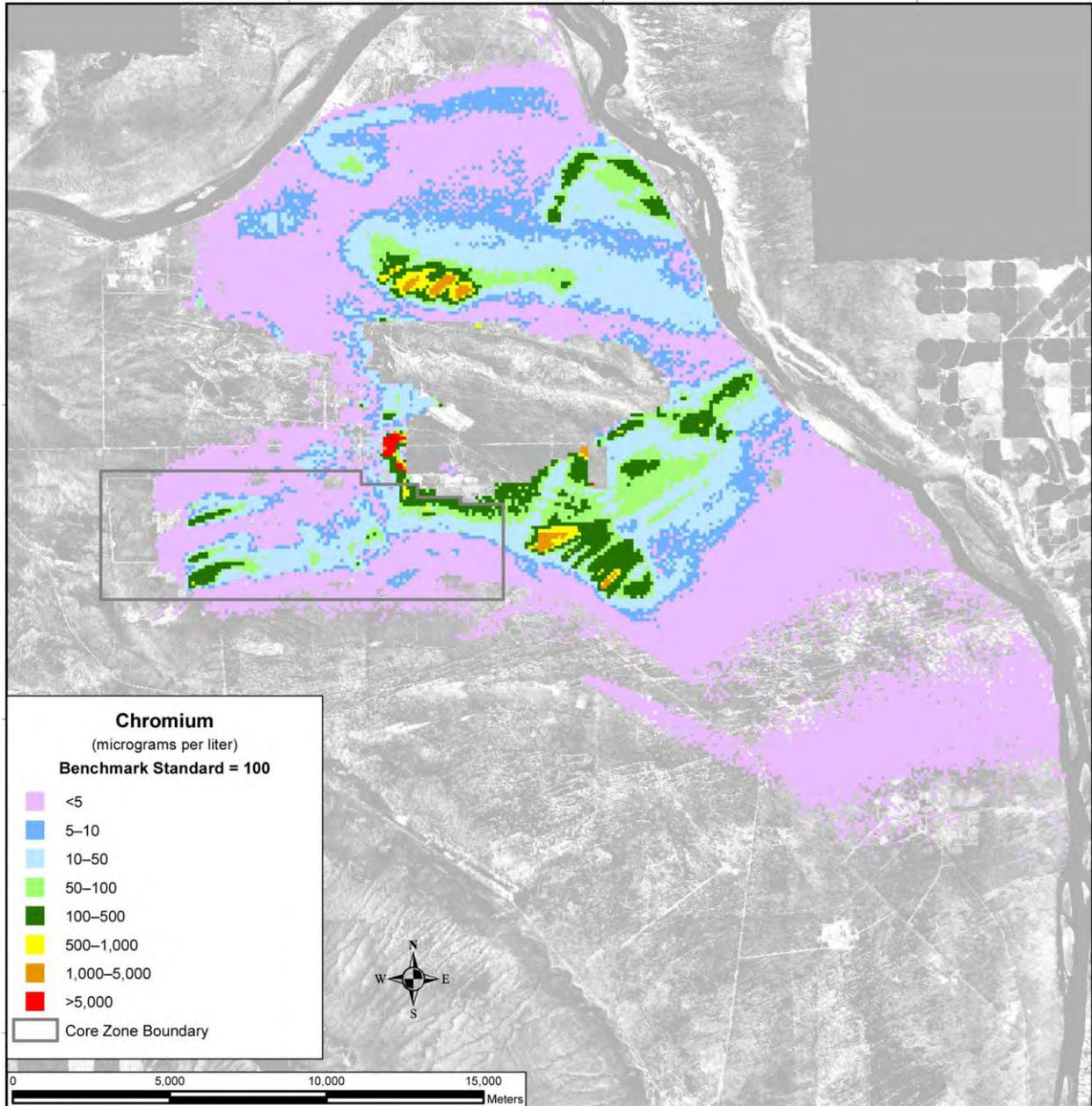


Figure 6-20. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Chromium Concentration, Calendar Year 3890

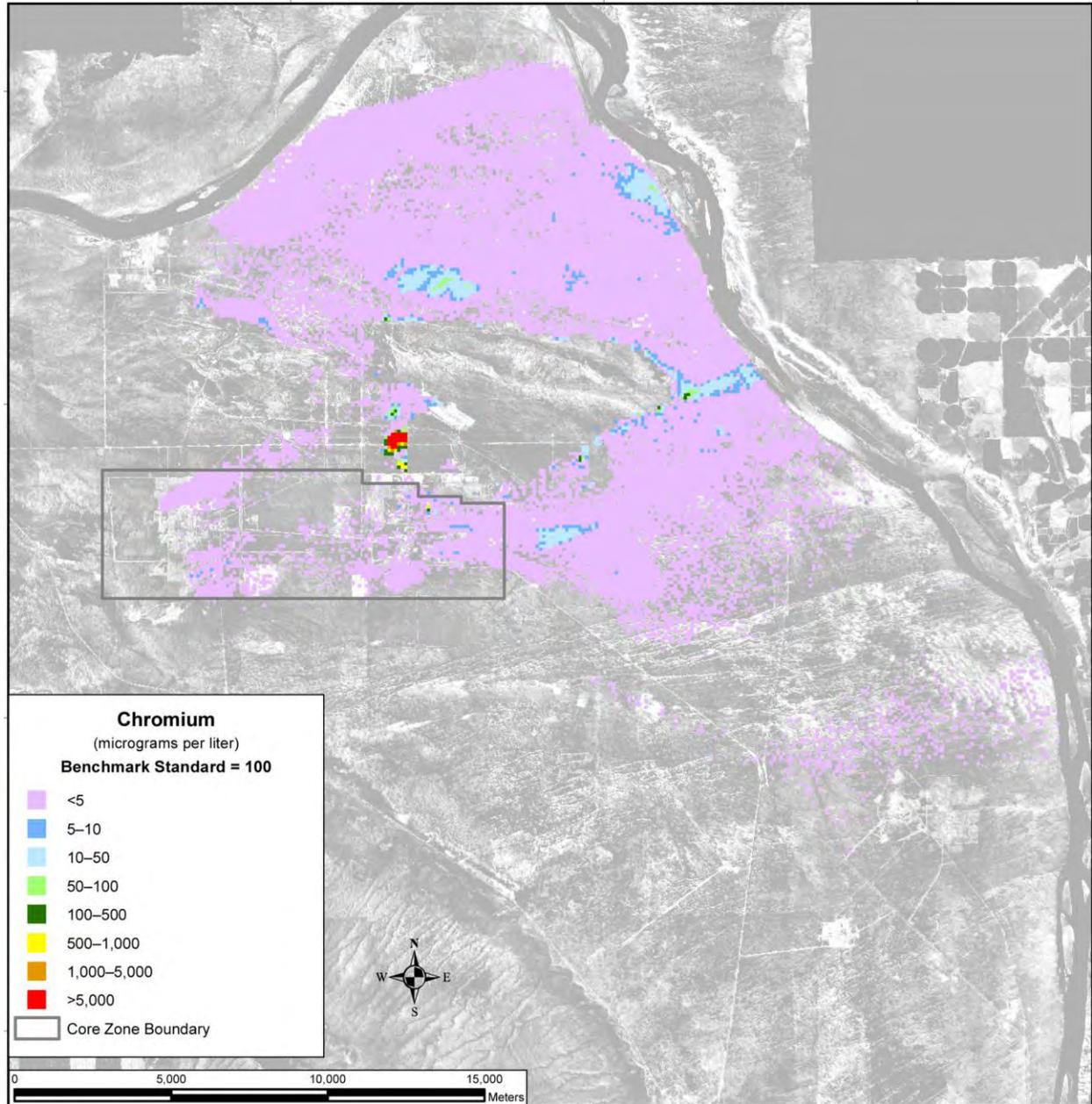
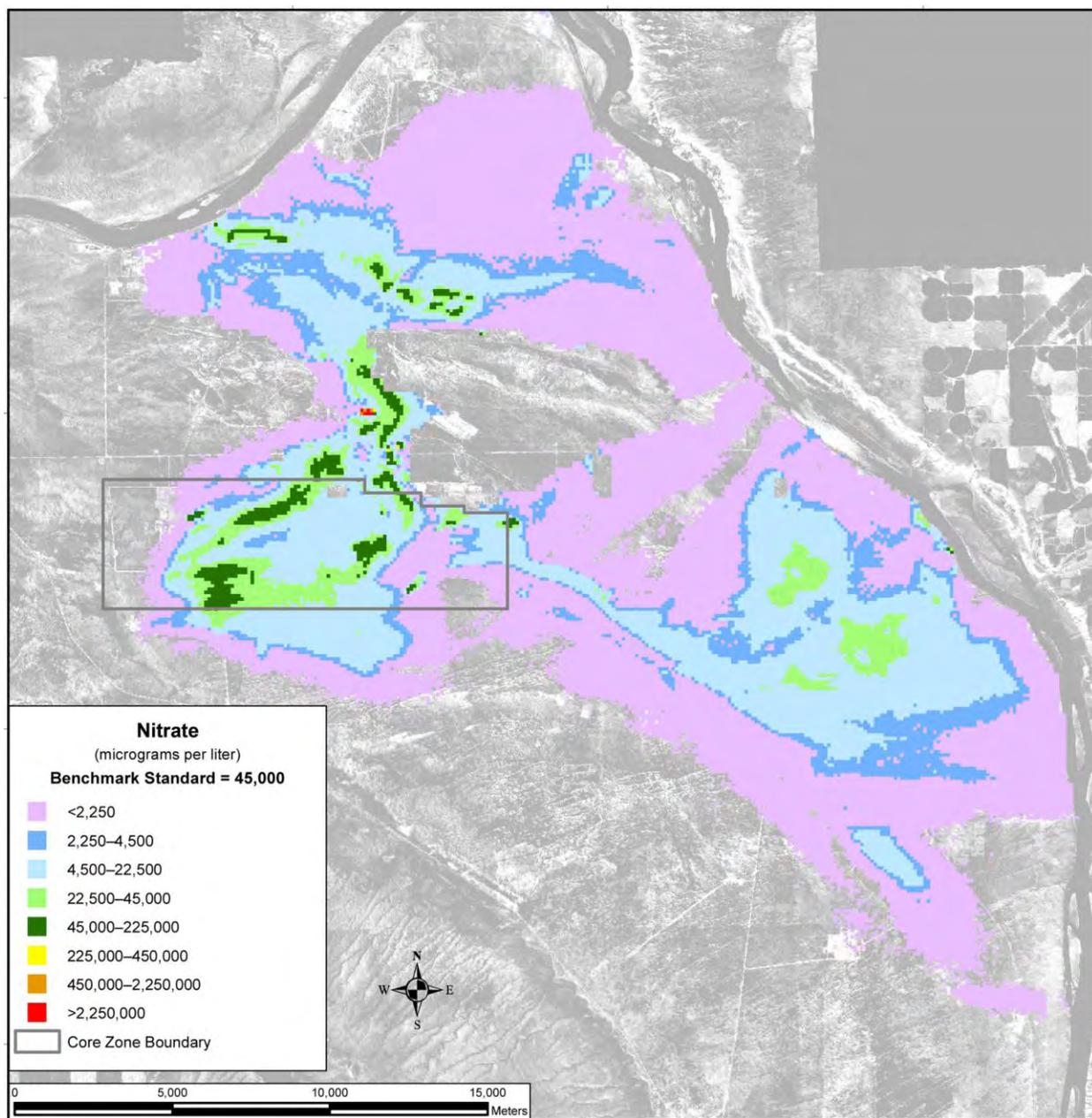


Figure 6-21. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Chromium Concentration, Calendar Year 7140



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

Figure 6–22. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Nitrate Concentration, Calendar Year 2010

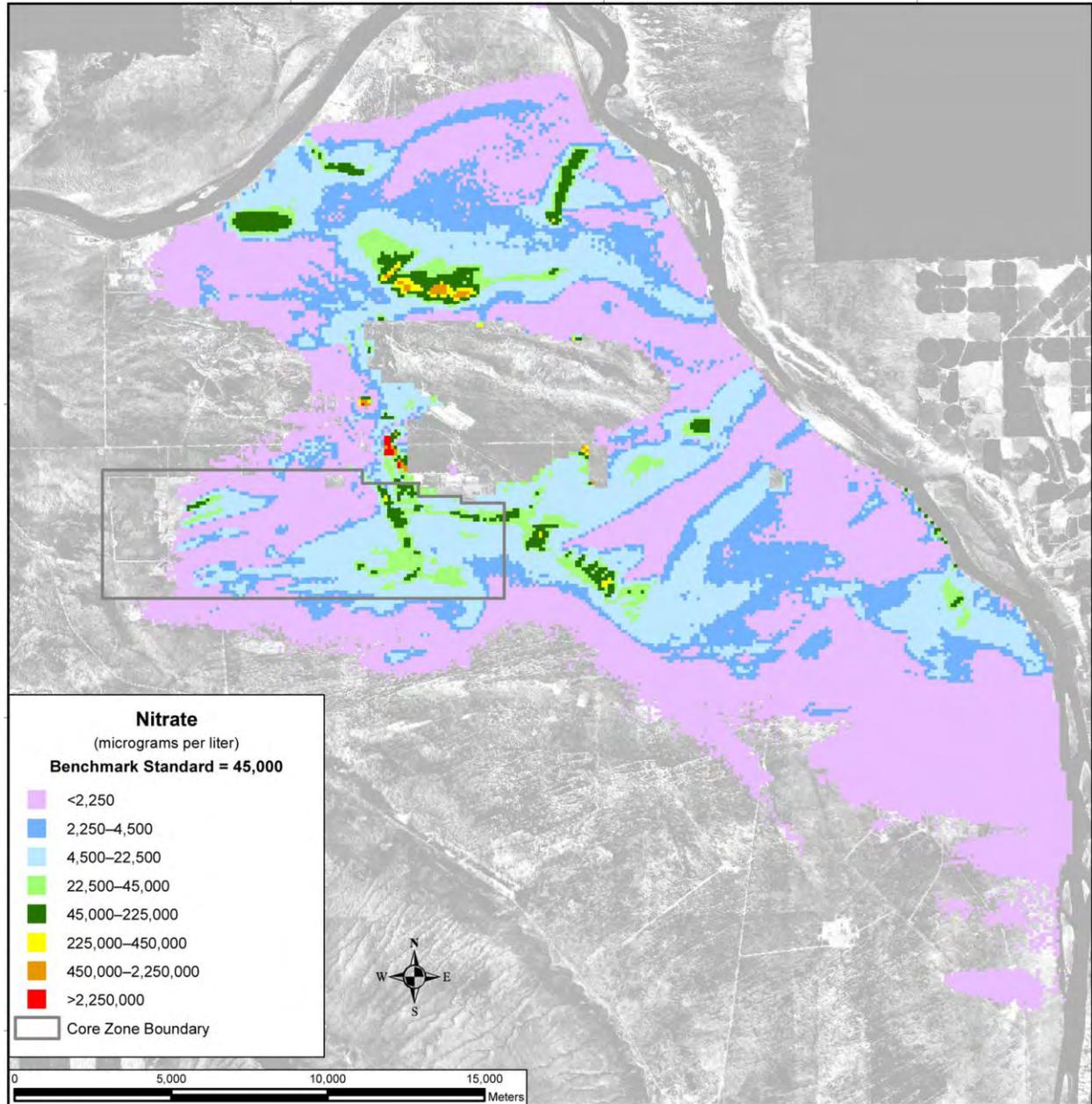
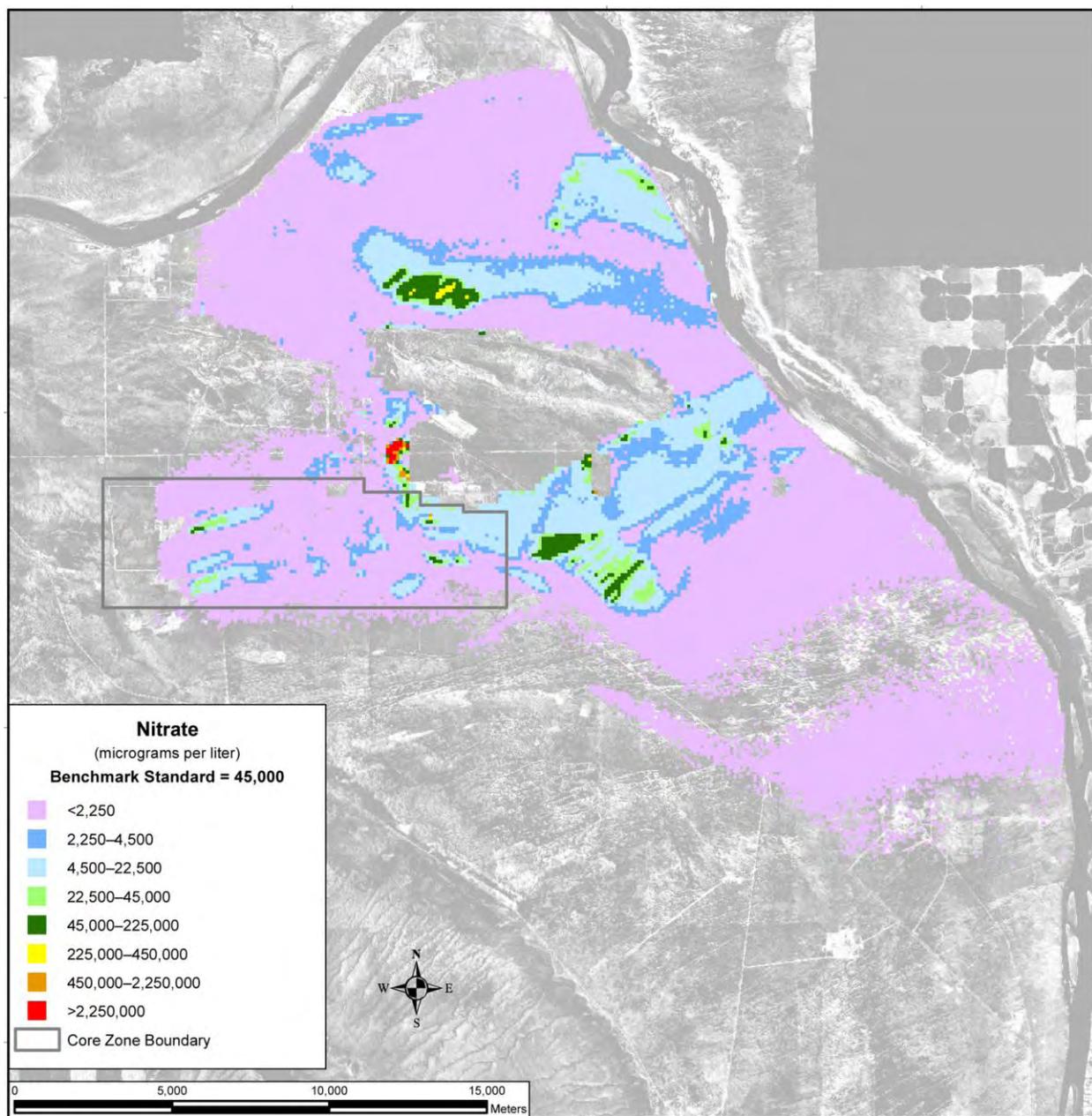


Figure 6–23. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Nitrate Concentration, Calendar Year 2135



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

Figure 6–24. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Nitrate Concentration, Calendar Year 3890

The spatial distribution of carbon tetrachloride concentrations in groundwater is dominated by non-TC & WMEIS sources associated with the Z Area within the 200-West Area. The spatial distribution in CY 2010, shown in Figure 6-25, is a large plume covering most of the 200-West Area, with peak concentrations more than 50 times greater than the benchmark concentration. By CY 2135, shown in Figure 6-26, much of the plume has moved outside of the Core Zone Boundary to the north. Note that this model result does not include the effects of carbon tetrachloride removal and containment in the 200-West Area. Figure 6-27 shows the dissipation of the plume over time in CY 3890.

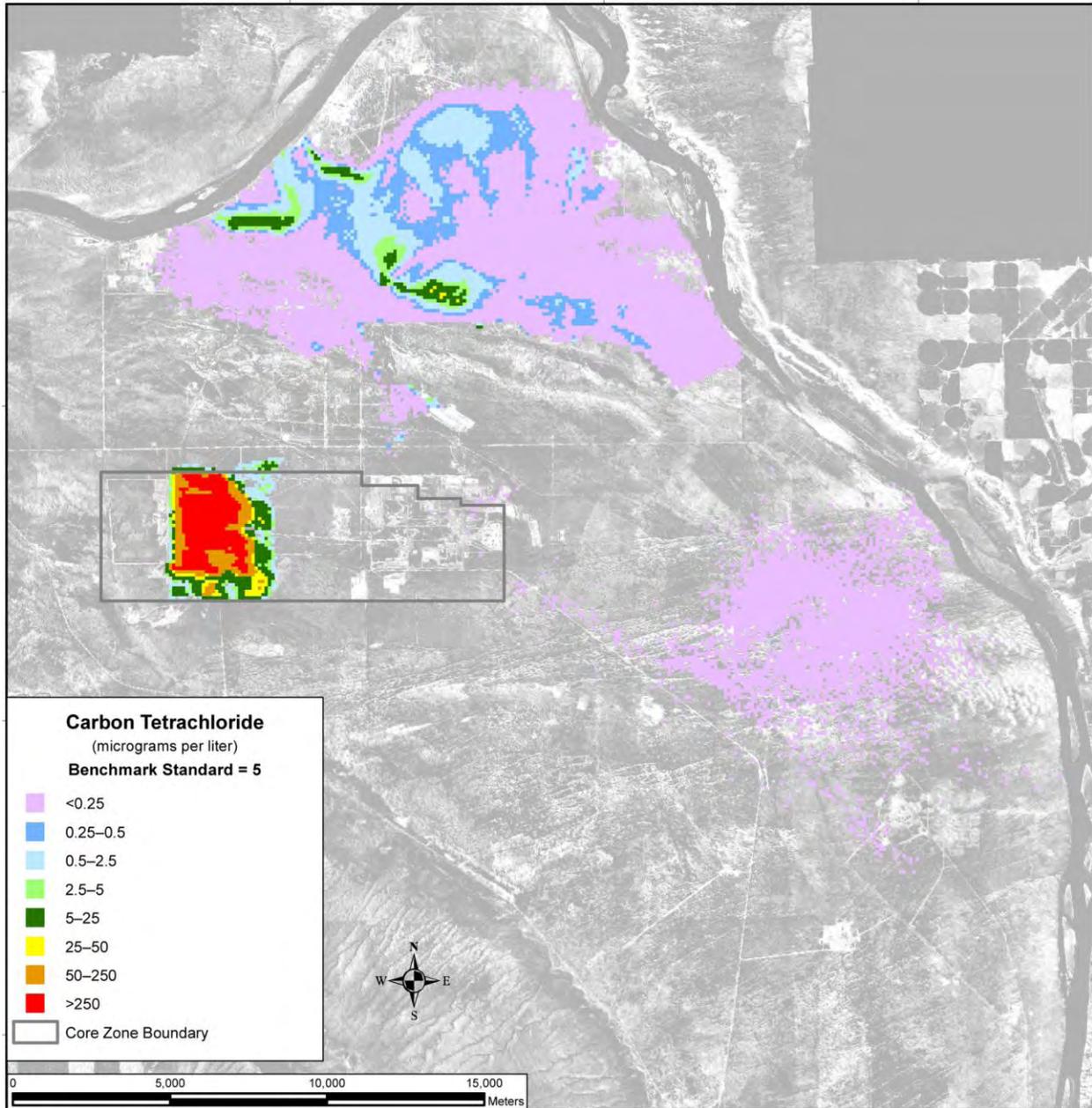


Figure 6-25. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Carbon Tetrachloride Concentration, Calendar Year 2010

The part of the carbon tetrachloride plume north of Gable Mountain includes contributions from the 200-West Area plume and Gable Mountain Pond. By mass, the dominant source is the 200-West Area plume. The rate of migration from the 200-West Area through Gable Gap is strongly influenced by the location of the highly conductive aquifer materials in this area, which is relatively uncertain (see Appendix L). The model overpredicts the rate of northward migration because of this uncertainty and because no credit is taken for the groundwater containment and removal system in the 200-West Area.

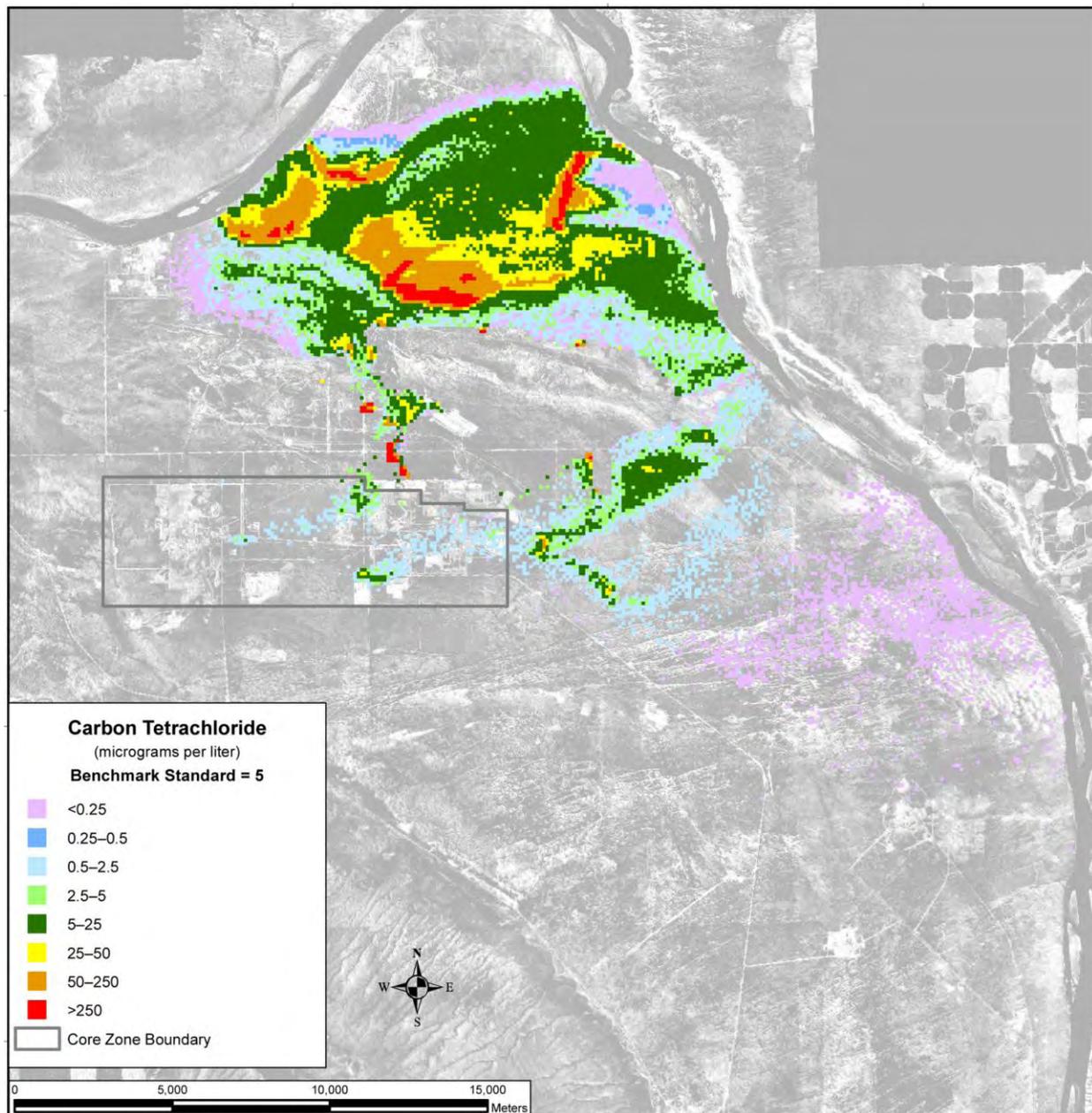


Figure 6–26. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Carbon Tetrachloride Concentration, Calendar Year 2135

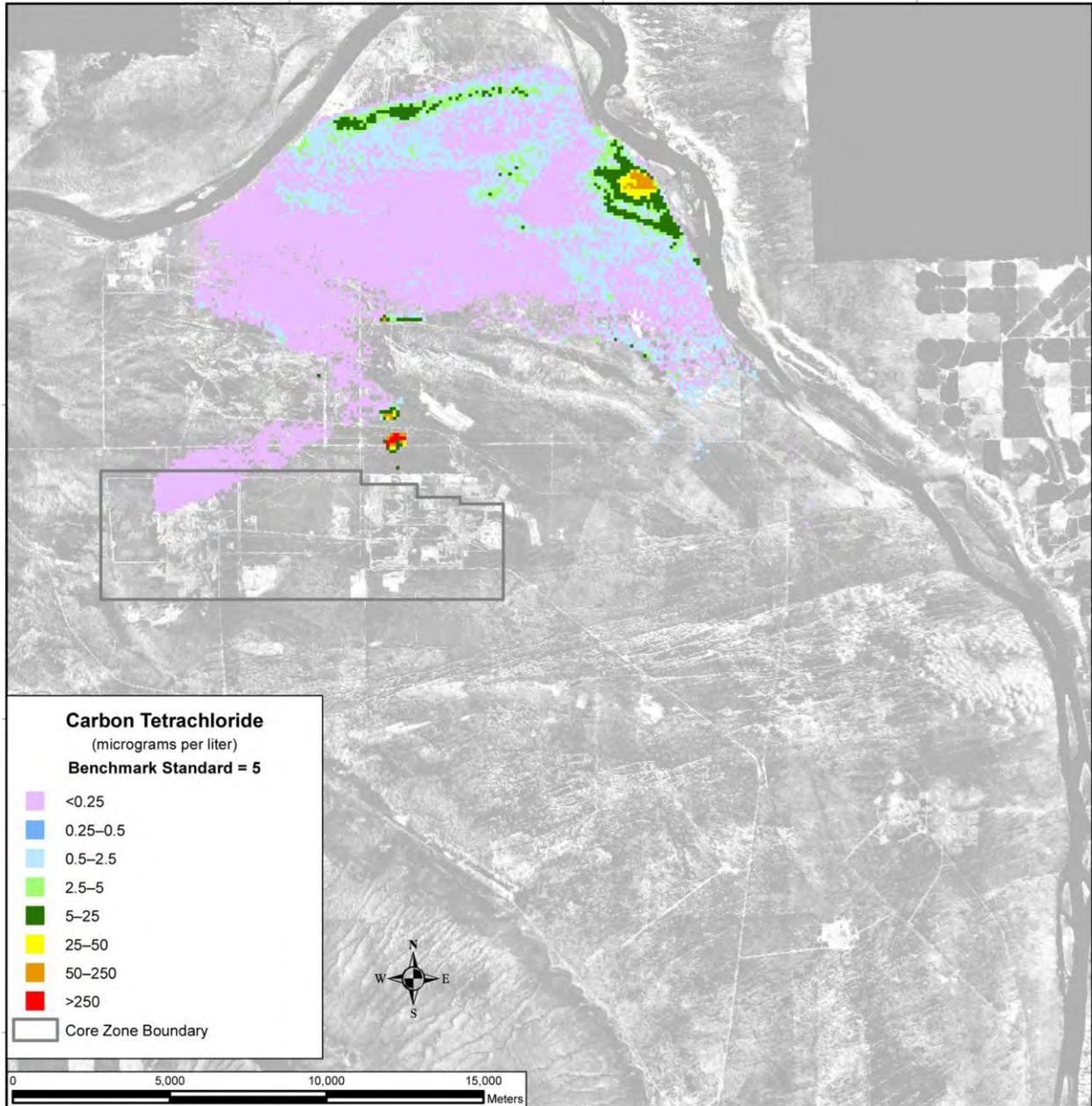


Figure 6–27. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Carbon Tetrachloride Concentration, Calendar Year 3890

Uranium-238 and total uranium show a different spatial distribution in groundwater 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 6–28 shows the distribution of uranium-238 in CY 2135. There are two plumes associated with releases from the ponds (non-TC & WM EIS sources) in the 200-East and 200-West Areas with peak concentrations that are 10 to 50 times greater than the benchmark. By CY 3890 (see Figure 6–29), these plumes have dissipated, but releases from other tank farm sources (primarily within the A Barrier) have produced a second plume east of the Core Zone, with peak concentrations that are 3 to 10 times greater than the benchmark. By CY 11,885 (see Figure 6–30), the plumes from other tank farm sources have extended this plume and

produced additional plumes in the 200-West Area. Figure 6–31 shows the total area for which groundwater uranium-238 concentrations exceed the benchmark concentration as a function of time. The area of exceedance is largest early in the analysis (non-TC & WM EIS sources, primarily ponds), decreasing shortly before another peak that occurs in CY 2590. Following this second peak, a downward trend occurs toward the end of the period of analysis (other tank farm sources). Figures 6–32 through 6–34 show the corresponding spatial distributions for total uranium.

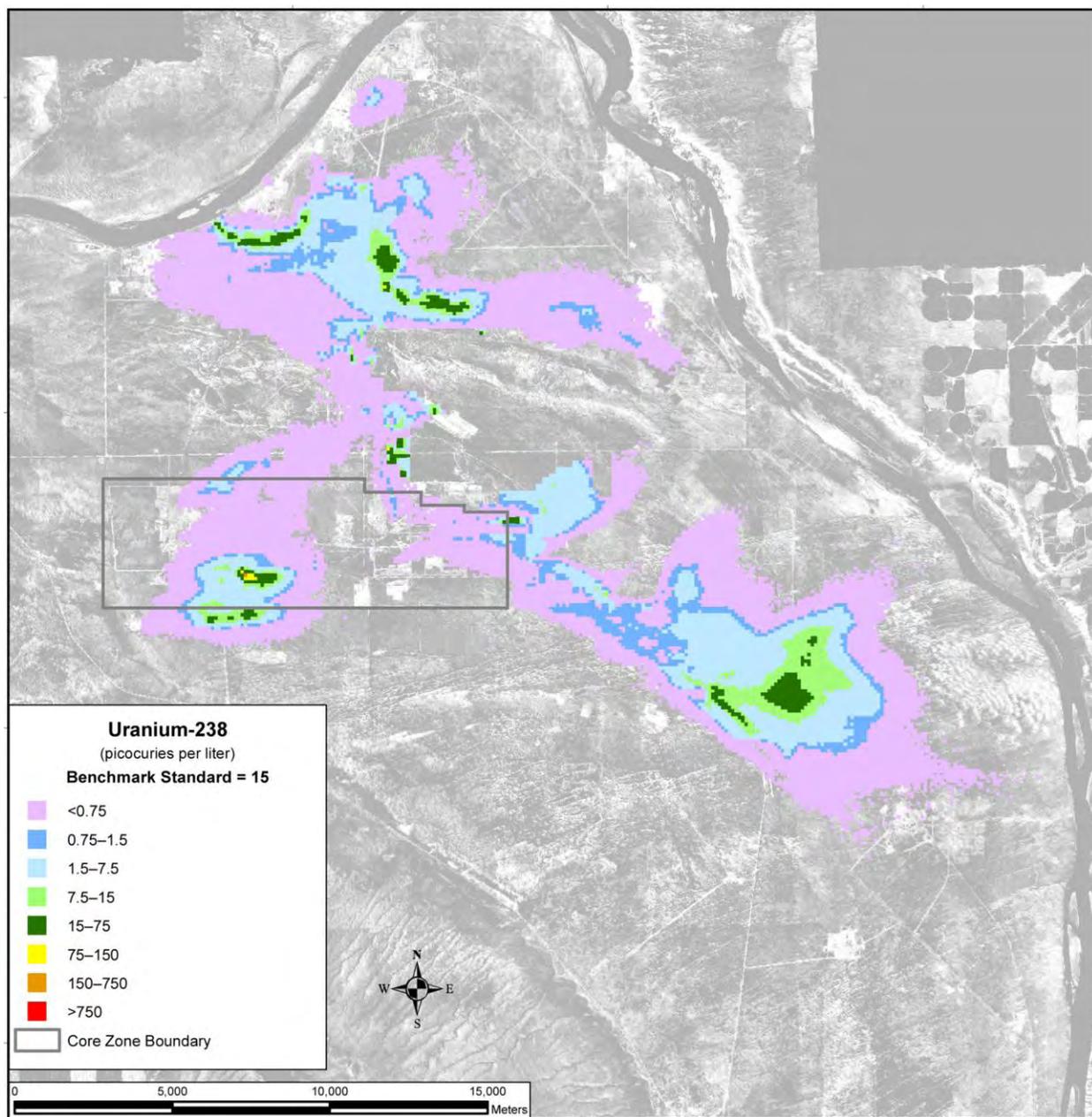


Figure 6–28. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Uranium-238 Concentration, Calendar Year 2135

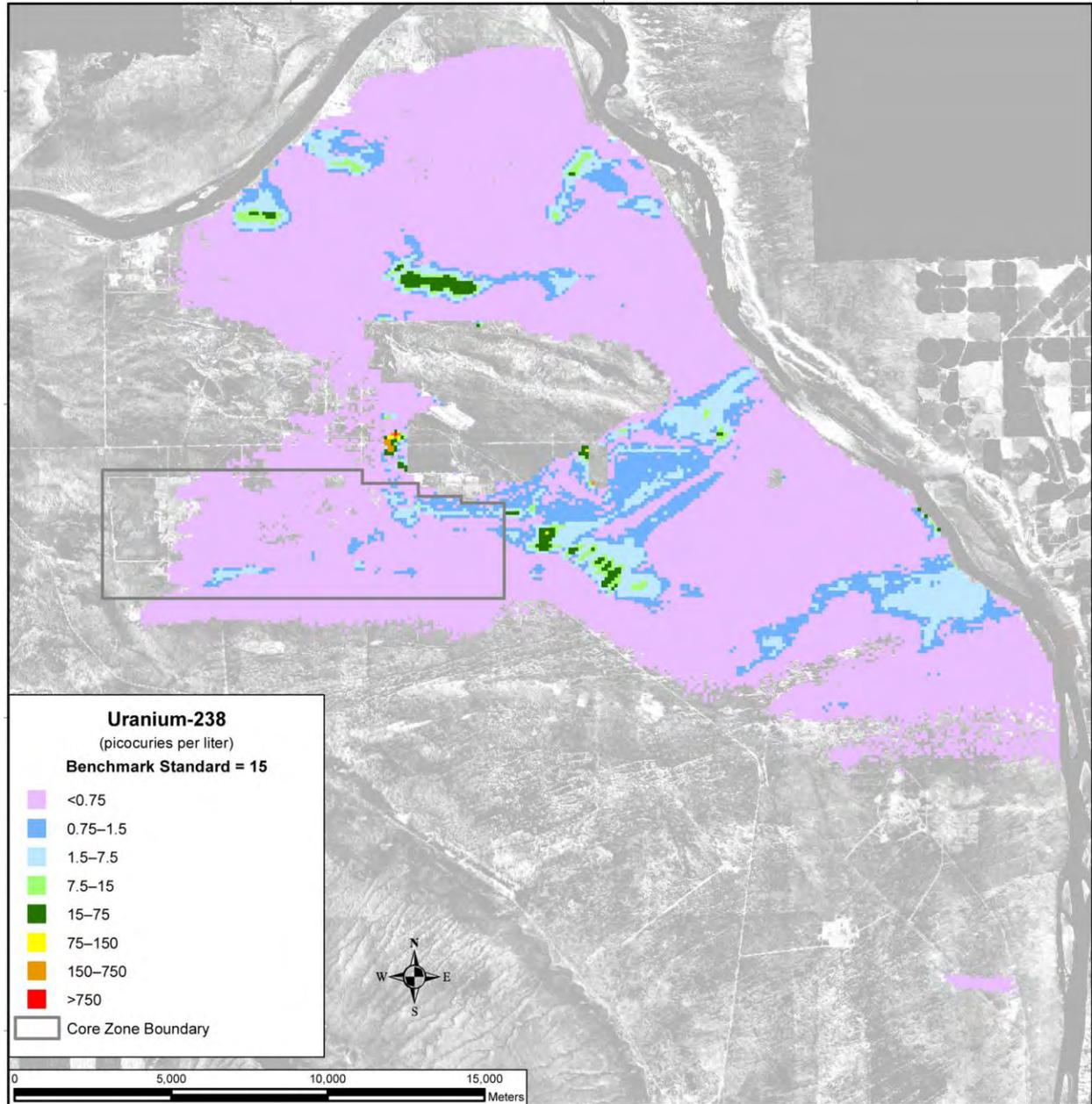
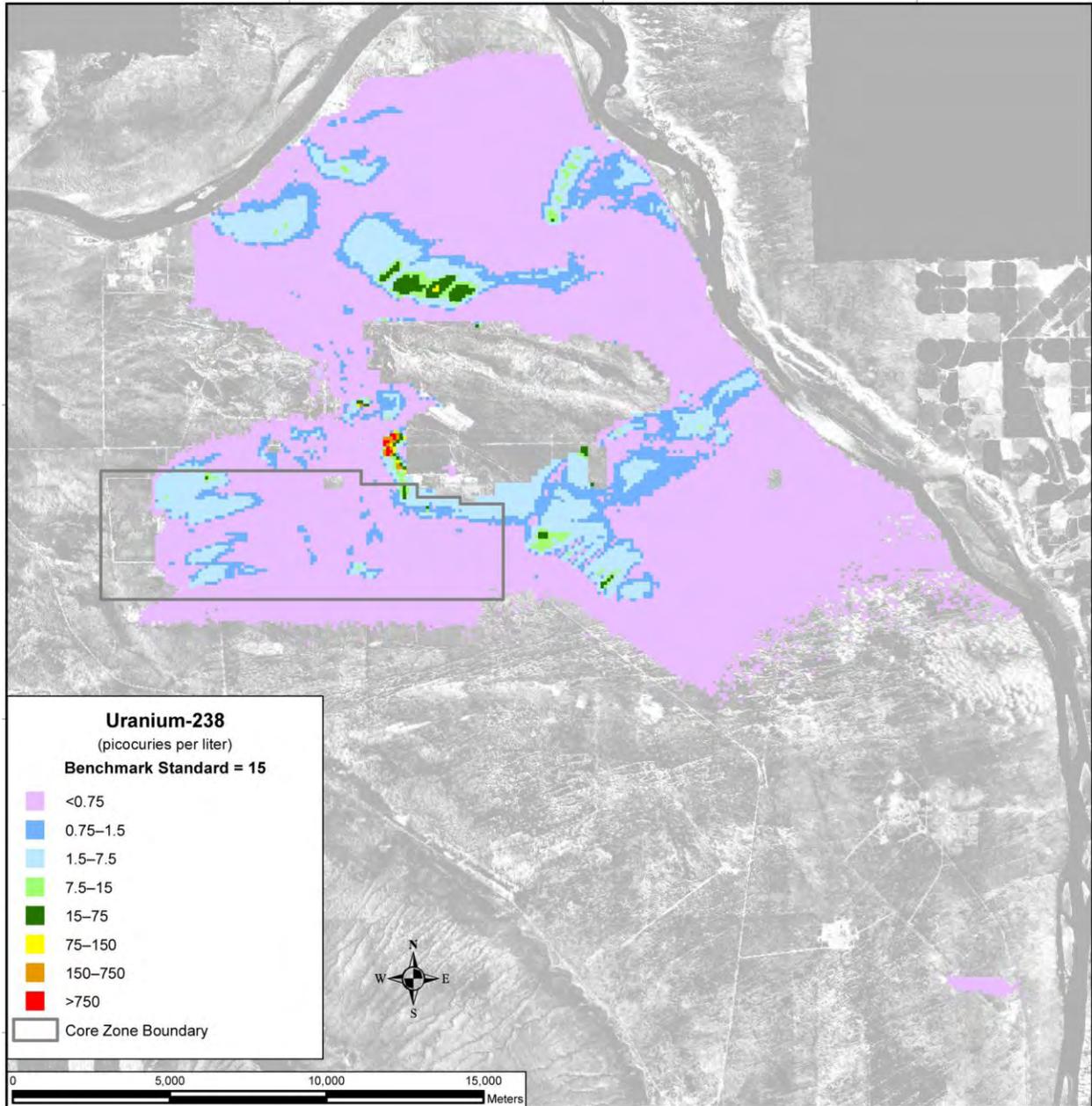
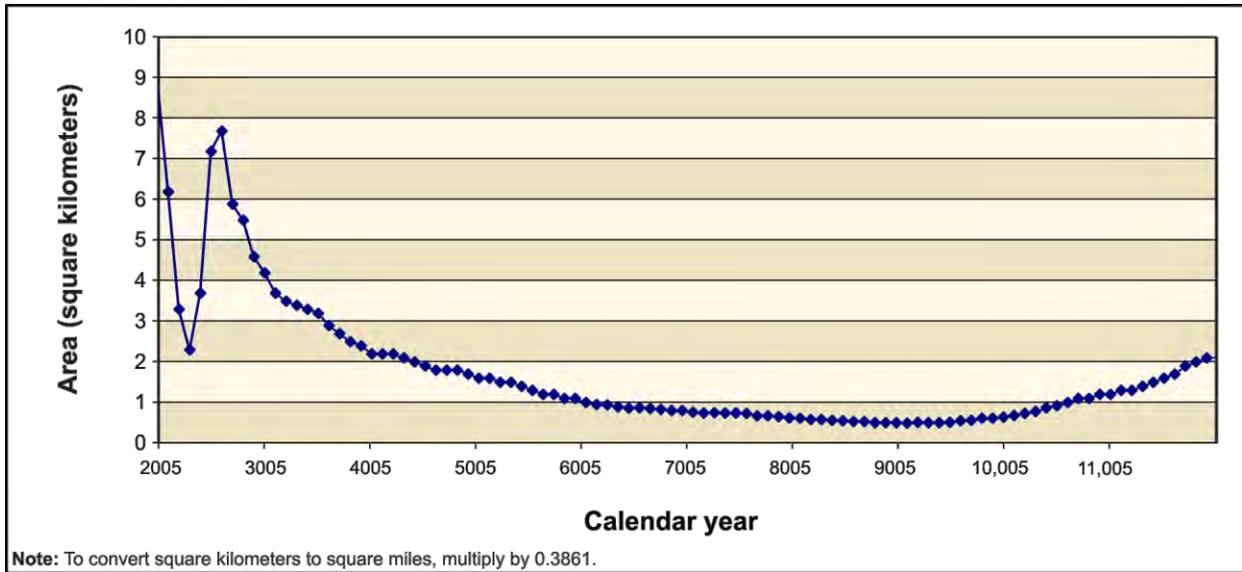


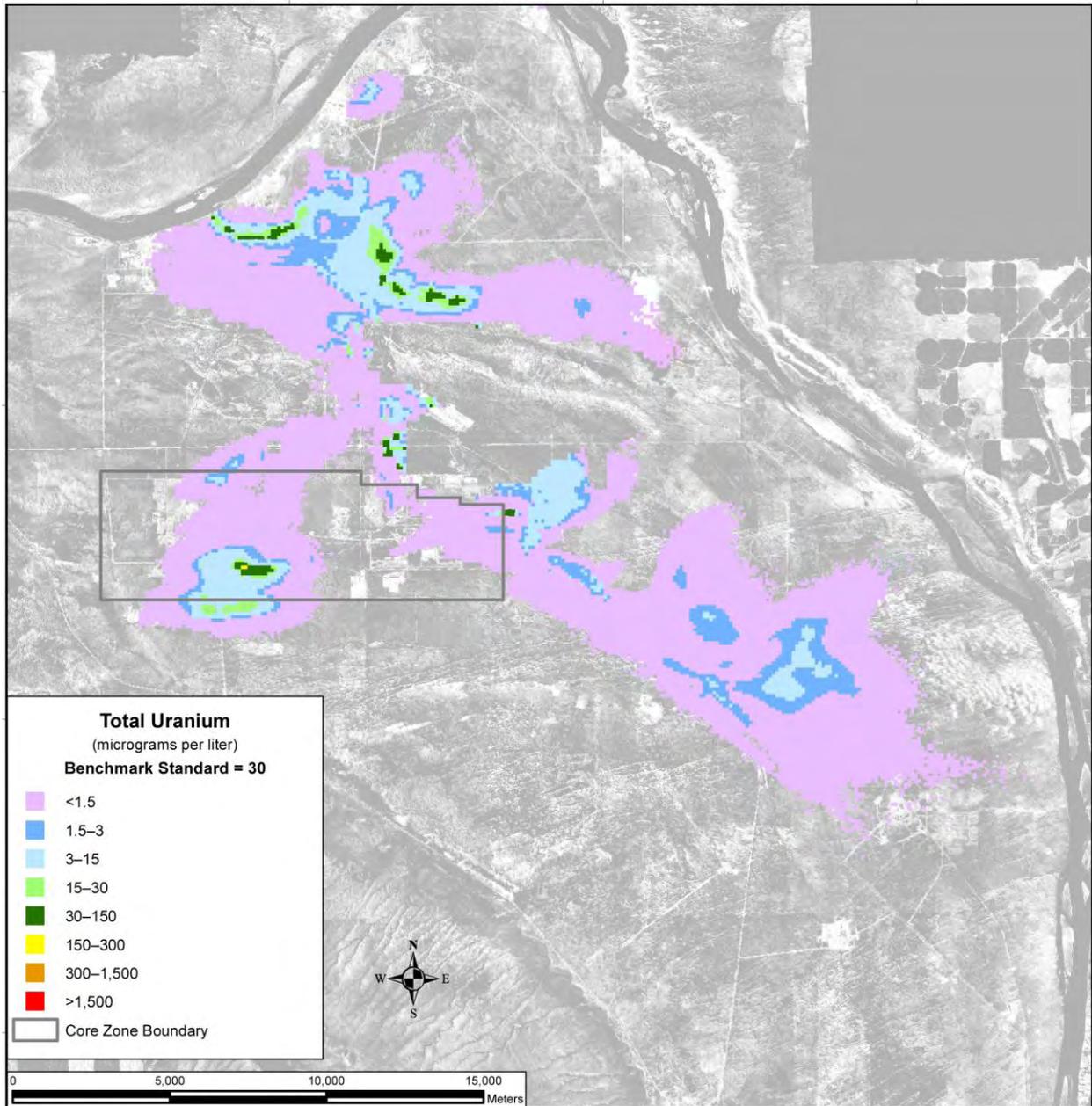
Figure 6–29. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Uranium-238 Concentration, Calendar Year 3890



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

Figure 6–30. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Uranium-238 Concentration, Calendar Year 11,885





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

Figure 6-32. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Total Uranium Concentration, Calendar Year 2135

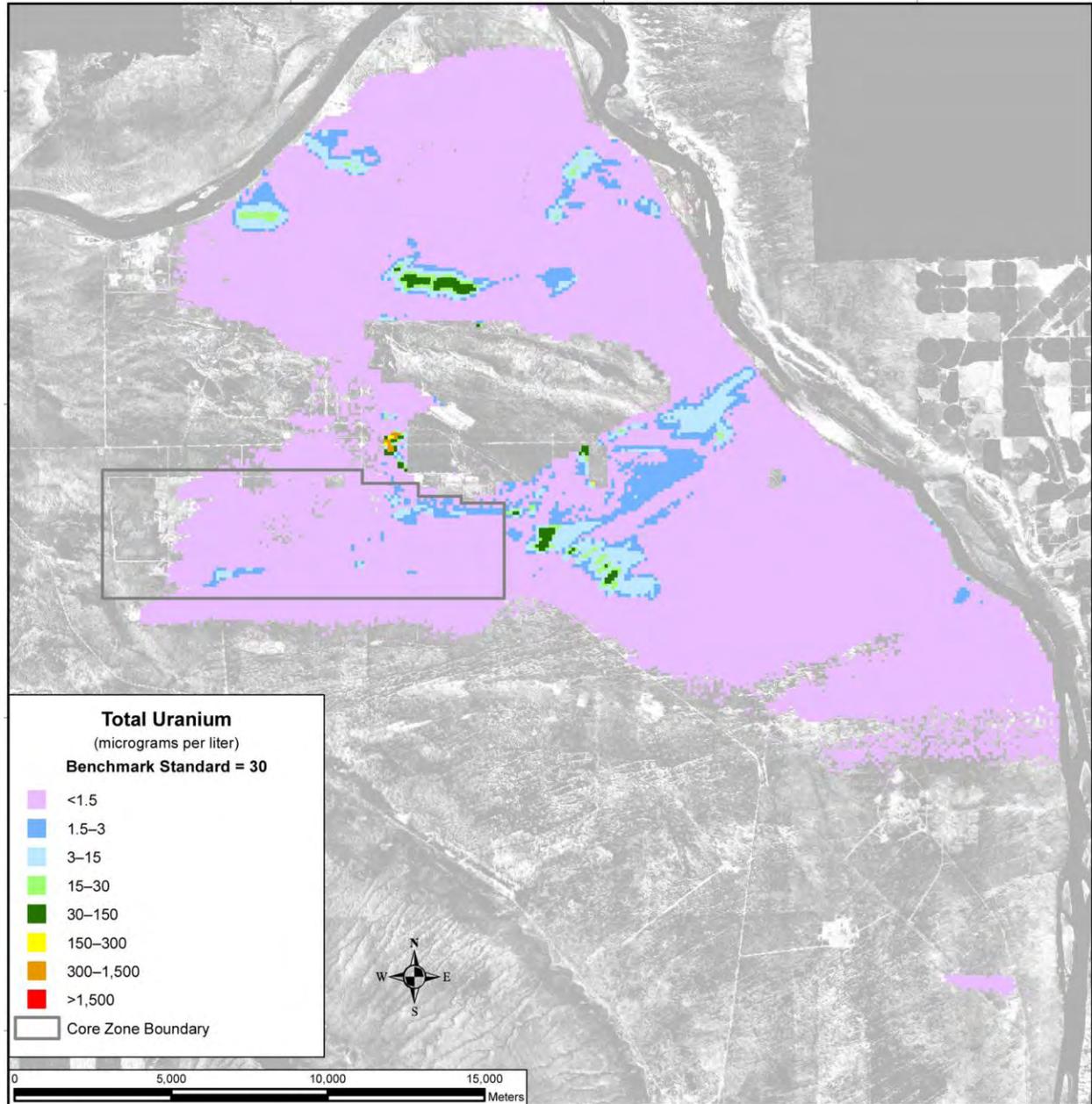


Figure 6-33. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Total Uranium Concentration, Calendar Year 3890

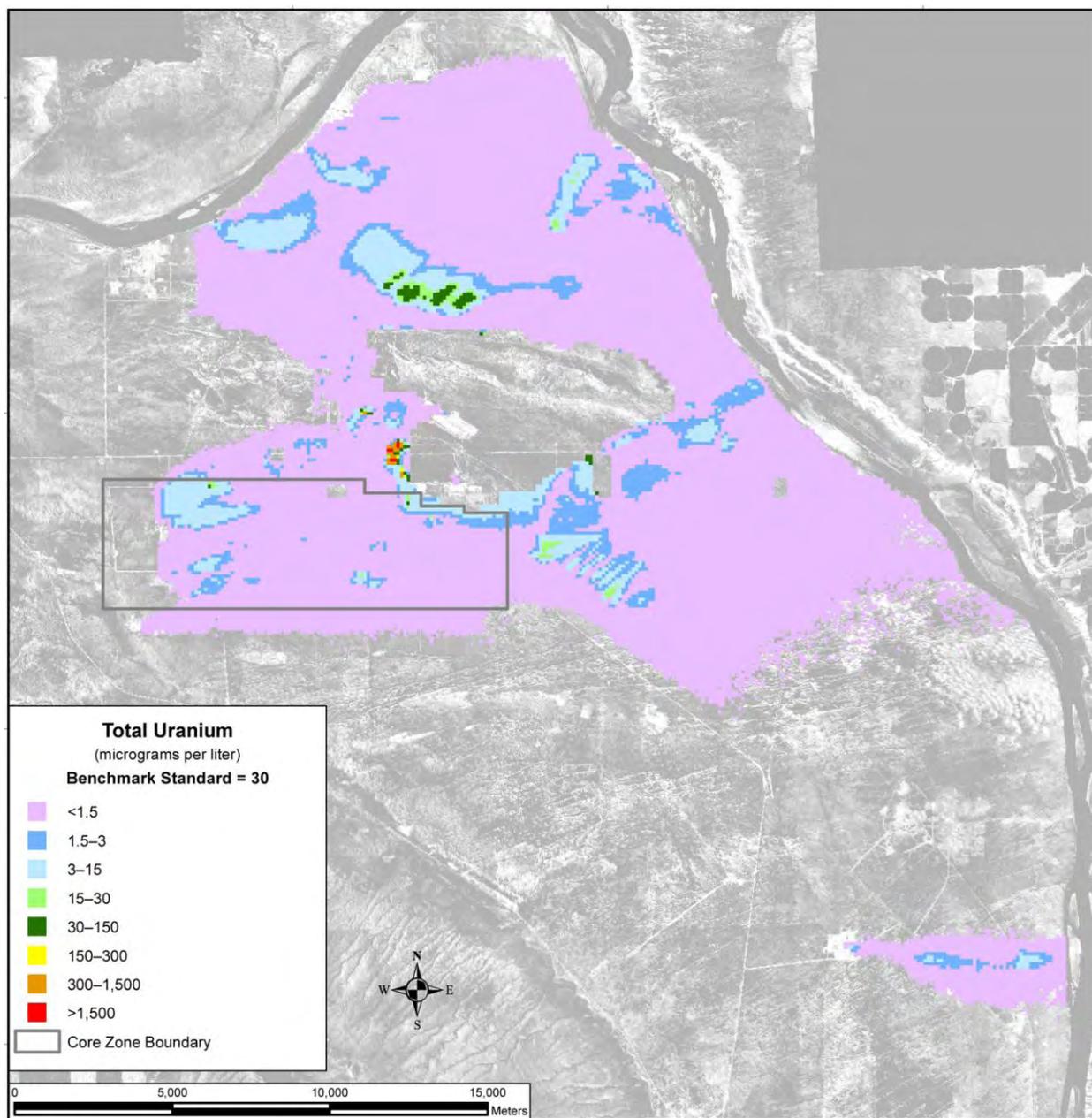


Figure 6–34. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Total Uranium Concentration, Calendar Year 11,885

6.4.1.2.4 Summary of Impacts

Long-term impacts figures in this chapter, Chapter 5, and Appendix U show how groundwater concentrations vary with time and space for cumulative impacts; Alternative Combinations 1, 2, and 3; and non-TC & WM EIS sources, respectively. The figures in these sections were compared to evaluate the relative contribution to cumulative impacts of the alternative combinations and non-TC & WM EIS sources and how they change over time. The results of this evaluation are briefly summarized below.

The long-term cumulative impacts of the scenario that includes Alternative Combination 1 on groundwater quality are dominated by Tank Closure Alternative 1 sources (for releases of technetium-99),

non-*TC & WM EIS* sources (for releases of tritium and carbon tetrachloride), or a combination of both (for releases of iodine-129, uranium-238, chromium, nitrate, and total uranium). COPC contributions from Waste Management Alternative 1 sources and FFTF Decommissioning Alternative 1 sources account for well under 1 percent of the total amount of COPCs released to the environment.

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

Concentrations of iodine-129, technetium-99, chromium, and nitrate at the Core Zone Boundary exceed benchmark standards by two to three orders of magnitude during the first half of the period of analysis. COPC concentrations at the Columbia River are about one order of magnitude smaller. The intensities and areas of these groundwater plumes peak between CYs 3200 and 4000.

Concentrations of carbon tetrachloride at the Core Zone Boundary exceed the benchmark by about two orders of magnitude during the first 200 years of the period of analysis. Concentrations at the Columbia River exceed the benchmark by about two orders of magnitude during this time, and decrease below the benchmark around CY 5300.

Discharges of uranium-238 and total uranium from ponds (non-*TC & WM EIS* sources) are the dominant contributors during the early period of the analysis. Other tank farm sources are a secondary contributor for which limited mobility is an important factor governing the timeframes and scale of groundwater impacts.

6.4.1.3 Alternative Combination 2

This section presents the results of the long-term cumulative groundwater impacts analysis for the scenario that includes Alternative Combination 2. This section focuses on the combined long-term groundwater impacts of Alternative Combination 2 sources, discussed in Chapter 5, Section 5.4, and non-*TC & WM EIS* sources, discussed in Appendix S. Alternative Combination 2 is composed of Tank Closure Alternative 2B (landfill closure); FFTF Decommissioning Alternative 2 (entombment); and Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A (disposal in 200-East Area Integrated Disposal Facility [IDF-East] only).

This discussion of long-term impacts is focused on the following COPCs:

- Radiological risk drivers: tritium, iodine-129, technetium-99, and uranium-238
- Chemical hazard drivers: carbon tetrachloride, chromium, nitrate, and total uranium

The COPC drivers listed above comprise those from the three individual alternatives that make up Alternative Combination 2 and those from non-*TC & WM EIS* sources. They fall into three categories. Iodine-129, technetium-99, carbon tetrachloride, 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. Tritium is also mobile, but short lived. The half-life of tritium is about 12.3 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. The other COPCs that were analyzed do not significantly contribute to risk or hazard during the period of analysis because of limited inventory, high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of these factors. The level of protection provided for the

drinking water pathway was evaluated by comparison against EPA maximum contaminant levels (40 CFR 141) and other benchmarks presented in Appendix O.

6.4.1.3.1 Analysis of Release and Mass Balance

This section presents the total amount of the COPC drivers released to the vadose zone, to groundwater, and to the Columbia River. Releases of radionuclides are totaled in curies; chemicals, in kilograms. Both are totaled over the 10,000-year period of analysis.

Table 6–16 lists the release of COPC drivers to the vadose zone. The release of COPCs from Alternative Combination 2 sources to the vadose zone is controlled by a combination of inventory and waste form. The entire inventory of tank closure and FFTF decommissioning sources was released to the vadose zone during the period of analysis. The inventories of some waste management sources (e.g., ILAW glass) were not fully released to the vadose zone during the 10,000-year period of analysis because of retention in the waste form. The release of COPCs from Alternative Combination 2 and non-TC & WM EIS sources to the vadose zone is dominated by non-TC & WM EIS sources for tritium, uranium-238, chromium, and total uranium; by non-TC & WM EIS and waste management sources for iodine-129; by non-TC & WM EIS sources and tank closure sources for nitrate; and by a combination of all three types of sources for technetium-99.

Table 6–16. Alternative Combination 2 Releases of COPC Drivers to Vadose Zone

Source	Radioactive COPCs (curies)				Chemical COPCs (kilograms)		
	Hydrogen-3 (Tritium)	Technetium-99	Iodine-129	Uranium-238	Chromium ^a	Nitrate	Total Uranium
Other activities	2.38×10 ⁶	1.17×10 ³	1.15×10 ¹	3.60×10 ³	3.52×10 ⁵	7.62×10 ⁷	7.08×10 ⁶
Tank Closure Alternative 2B	4.58×10 ⁴	8.19×10 ²	1.42	4.05×10 ¹	9.98×10 ⁴	2.70×10 ⁷	3.39×10 ⁴
FFTF Decommissioning Alternative 2	4.66×10 ⁻⁷	2.72×10 ¹	0.00	0.00	0.00	0.00	0.00
Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A	5.94×10 ⁴	2.08×10 ³	4.92	3.49×10 ²	2.96×10 ³	9.05×10 ⁶	2.94×10 ³
Total	2.48×10⁶	4.10×10³	1.78×10¹	3.99×10³	4.55×10⁵	1.12×10⁸	7.12×10⁶

^a It was assumed, for analysis purposes, that all chromium was hexavalent.

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: COPC=constituent of potential concern; FFTF=Fast Flux Test Facility.

Table 6–17 lists the release of COPC drivers to groundwater. In addition to the inventory consideration discussed in the previous paragraph, the 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 iodine-129, technetium-99, chromium, and nitrate, the amount released to groundwater is essentially equal to the amount released to the vadose zone. For tritium, the amount released to groundwater is attenuated by radioactive decay during transit through the vadose zone. About 83 percent of the tritium released to the vadose zone reaches the unconfined aquifer. Because of retardation, less than 5 percent of the uranium-238 and less than 2 percent of the total uranium released to the vadose zone reach the unconfined aquifer during the period of analysis.

Table 6–18 lists the release of COPC drivers to the Columbia River. The release to the Columbia River is controlled by the transport properties of the COPC drivers in the unconfined aquifer. For iodine-129, technetium-99, chromium, nitrate, and uranium-238, 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 4 percent of the tritium released to groundwater reaches the Columbia River. Because of retardation, about 86 percent of the total uranium released to groundwater during the period of analysis reaches the Columbia River.

Table 6–17. Alternative Combination 2 Releases of COPC Drivers to Groundwater

Source	Radioactive COPCs (curies)				Chemical COPCs (kilograms)		
	Hydrogen-3 (Tritium)	Technetium-99	Iodine-129	Uranium-238	Chromium ^a	Nitrate	Total Uranium
Other activities	2.03×10 ⁶	1.15×10 ³	1.14×10 ¹	2.16×10 ²	3.57×10 ⁵	7.66×10 ⁷	1.31×10 ⁵
Tank Closure Alternative 2B	3.12×10 ⁴	8.20×10 ²	1.42	1.66	1.03×10 ⁵	2.78×10 ⁷	1.46×10 ³
FFTF Decommissioning Alternative 2	0.00	2.71×10 ¹	0.00	0.00	0.00	0.00	0.00
Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A	0.00	1.80×10 ³	3.41	1.51×10 ⁻⁸	2.87×10 ³	9.02×10 ⁶	1.38×10 ⁻⁴
Total	2.06×10⁶	3.79×10³	1.63×10¹	2.18×10²	4.63×10⁵	1.13×10⁸	1.33×10⁵

^a It was assumed, for analysis purposes, that all chromium was hexavalent.

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: COPC=constituent of potential concern; FFTF=Fast Flux Test Facility.

Table 6–18. Alternative Combination 2 Releases of COPC Drivers to the Columbia River

Source	Radioactive COPCs (curies)				Chemical COPCs (kilograms)		
	Hydrogen-3 (Tritium)	Technetium-99	Iodine-129	Uranium-238	Chromium ^a	Nitrate	Total Uranium
Other activities	7.21×10 ⁴	1.15×10 ³	1.14×10 ¹	2.12×10 ²	3.77×10 ⁵	7.90×10 ⁷	1.15×10 ⁵
Tank Closure Alternative 2B	3.90×10 ²	8.16×10 ²	1.41	4.94×10 ⁻¹	1.06×10 ⁵	2.86×10 ⁷	3.82×10 ²
FFTF Decommissioning Alternative 2	0.00	2.70×10 ¹	0.00	0.00	0.00	0.00	0.00
Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A	0.00	1.78×10 ³	3.37	0.00	2.86×10 ³	9.02×10 ⁶	6.01×10 ⁻⁶
Total	7.25×10⁴	3.77×10³	1.62×10¹	2.13×10²	4.86×10⁵	1.17×10⁸	1.15×10⁵

^a It was assumed, for analysis purposes, that all chromium was hexavalent.

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: COPC=constituent of potential concern; FFTF=Fast Flux Test Facility.

6.4.1.3.2 Analysis of Concentration Versus Time

This section presents the contaminant concentrations in groundwater versus time at the Core Zone Boundary and the Columbia River. The benchmark concentration of each radionuclide and chemical is also shown in the graphs. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over five orders of magnitude. Table 6–19 lists the maximum COPC concentrations at the Core Zone Boundary and the Columbia River nearshore in the peak year of the 10,000-year period of analysis. Comparison of the results in Table 6–11 (non-TC & WM EIS sources only) with the results in Table 6–19 (cumulative with Alternative Combination 2

sources) shows that the peak concentrations of some of the COPC drivers do not change with the addition of Tank Closure Alternative 2B, FFTF Decommissioning Alternative 2, and Waste Management Alternative 2 (Disposal Group 1, Subgroup 1-A) sources. This indicates that these peaks are driven primarily by the non-TC & WM EIS sources. These COPC drivers include tritium, iodine-129, uranium-238, carbon tetrachloride, chromium, and total uranium. For other COPC drivers, primarily technetium-99, the TC & WM EIS alternative sources are the dominant contributor with respect to peak concentration. Finally, for nitrate, contributions from TC & WM EIS alternative sources and non-TC & WM EIS sources are approximately equal contributors to peak concentration.

Table 6–19. Alternative Combination 2 Maximum Cumulative Groundwater COPC Concentrations^a

Contaminant	Core Zone Boundary (peak year)	Columbia River Nearshore (peak year)	Benchmark Concentration ^b
Radionuclide (picocuries per liter)			
Hydrogen-3 (tritium)	112,000,000 (1997)	4,140,000 (1986)	20,000
Carbon-14	1,090 (1998)	5 (1992)	2,000
Strontium-90	1,730 (1998)	27,600 (1991)	8
Technetium-99	33,700 (1956)	868 (1965)	900
Iodine-129	42 (1956)	20 (2017)	1
Cesium-137	0 N/A	1,430 (1985)	200
Uranium isotopes (includes uranium-233, -234, -235, -238)	839 (1959)	6,190 (1979)	15
Neptunium-237	7 (2061)	2 (3662)	15
Plutonium isotopes (includes plutonium-239, -240)	26 (7725)	2 (1991)	15
Chemical (micrograms per liter)			
1-Butanol	518 (1998)	2 (3891)	3,600
Boron and compounds	0.2 (3270)	1 (2364)	7,000
Carbon tetrachloride	577 (2035)	208 (2067)	5
Chromium ^c	13,400 (1959)	7,210 (1979)	100
Dichloromethane	0.2 (3321)	0.1 (3923)	5
Fluoride	160,000 (2008)	30,700 (2032)	4,000
Hydrazine/hydrazine sulfate	0.009 (3308)	0.043 (3281)	0.022
Lead	0 N/A	32 (2397)	15

**Table 6–19. Alternative Combination 2 Maximum Cumulative Groundwater
COPC Concentrations^a (continued)**

Contaminant	Core Zone Boundary (peak year)	Columbia River Nearshore (peak year)	Benchmark Concentration ^b
Chemical (micrograms per liter) (continued)			
Manganese	93 (3705)	0.4 (2223)	1,600
Mercury	1.7 (2016)	0.002 (10,973)	2
Nitrate	2,130,000 (1956)	846,000 (1976)	45,000
Total uranium	1,220 (1959)	1,910 (1979)	30
Trichloroethylene (TCE)	0.02 (3220)	0.07 (3297)	5

^a The peak cumulative concentration of some constituents occurred in the past. The relationship of past to future cumulative constituent concentrations is presented in the concentration-versus-time plots in Figures 6–35 through 6–42.

^b The sources of the benchmark concentrations are provided in Appendix O, Section O.3.

^c It was assumed, for analysis purposes, that all chromium was hexavalent.

Key: COPC=constituent of potential concern; N/A=not applicable.

Figure 6–35 shows concentration versus time for tritium. Note that, for visual clarity, the time period shown in this figure is from 1940 through 2440 rather than the full 10,000-year period of analysis. Tritium concentrations at the Core Zone Boundary exceed the benchmark concentration by about three orders of magnitude for a short period of time during the early part of the period of analysis. During this time, groundwater concentrations at the Columbia River nearshore peak at about two orders of magnitude above the benchmark concentration. *TC & WM EIS* sources contribute to the tritium releases, but the concentrations approach four orders of magnitude greater than the benchmark concentration because of the additional contributions from non-*TC & WM EIS* sources. Because the half-life of tritium is less than 13 years, radioactive decay rapidly attenuates groundwater concentration; thus, tritium is essentially not a factor beyond CY 2140, when concentrations fall below the benchmark concentration at the Core Zone Boundary.

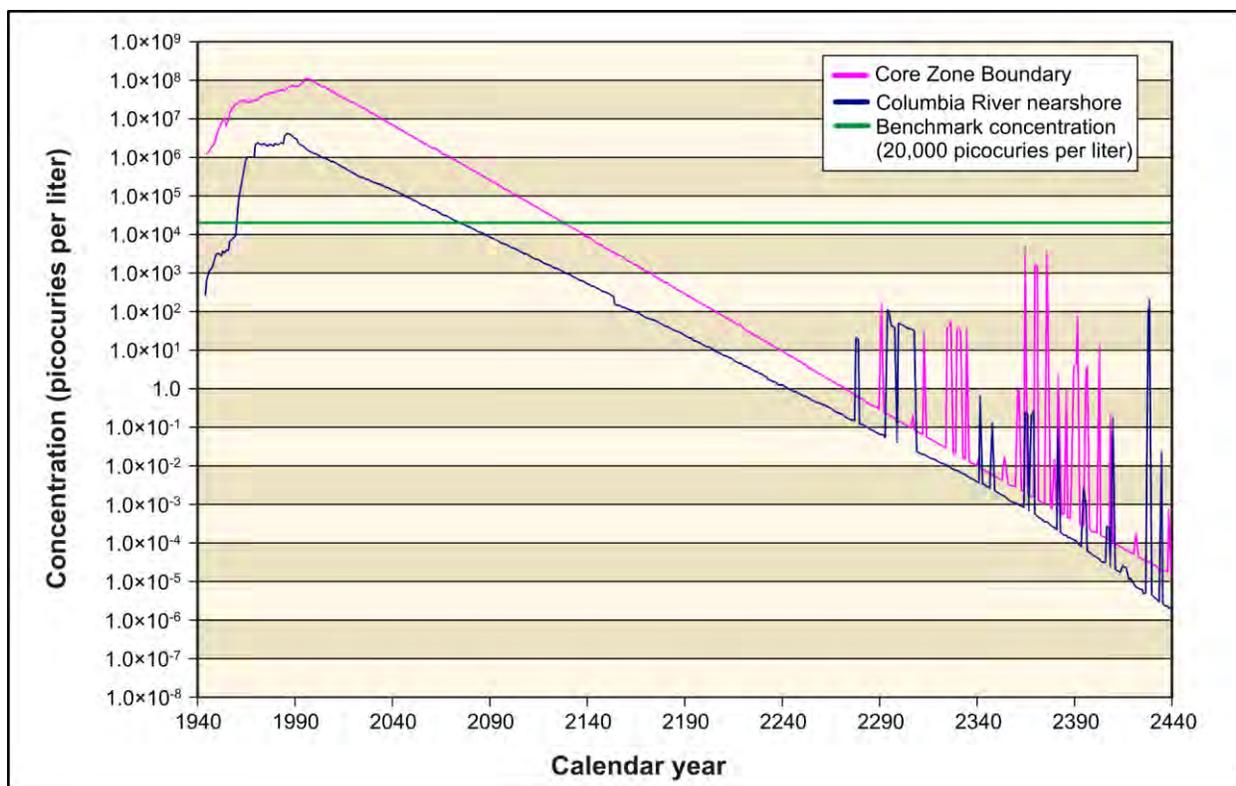


Figure 6–35. Alternative Combination 2 Cumulative Hydrogen-3 (Tritium) Concentration Versus Time

Figures 6–36 through 6–40 show concentration versus time for iodine-129, technetium-99, carbon tetrachloride, chromium, and nitrate (the conservative tracers). Groundwater concentrations of these conservative tracers at the Core Zone Boundary and Columbia River nearshore exceed benchmark concentrations by more than an order of magnitude during the past-practice period. For some of the COPC drivers (iodine-129, chromium, nitrate), concentrations during the past-practice period are higher because of the additional contributions from non-*TC & WM EIS* sources. After the past-practice period, concentrations of technetium-99 and iodine-129 rise again between around CY 2900 and CY 5100 before dropping below benchmark concentrations for the remainder of the period of analysis. Concentrations of chromium and nitrate all fall well below benchmark concentrations by CY 2500 for the duration of the period of analysis. After the peak around CY 2030, concentrations of carbon tetrachloride at the Core Zone Boundary drop, reaching the benchmark concentration around CY 2140, and continue to drop rapidly after that time. Concentrations at the Columbia River nearshore drop at a more gradual rate, attaining the benchmark concentration around CY 5600, and remain below the benchmark concentration for the remainder of the period of analysis.

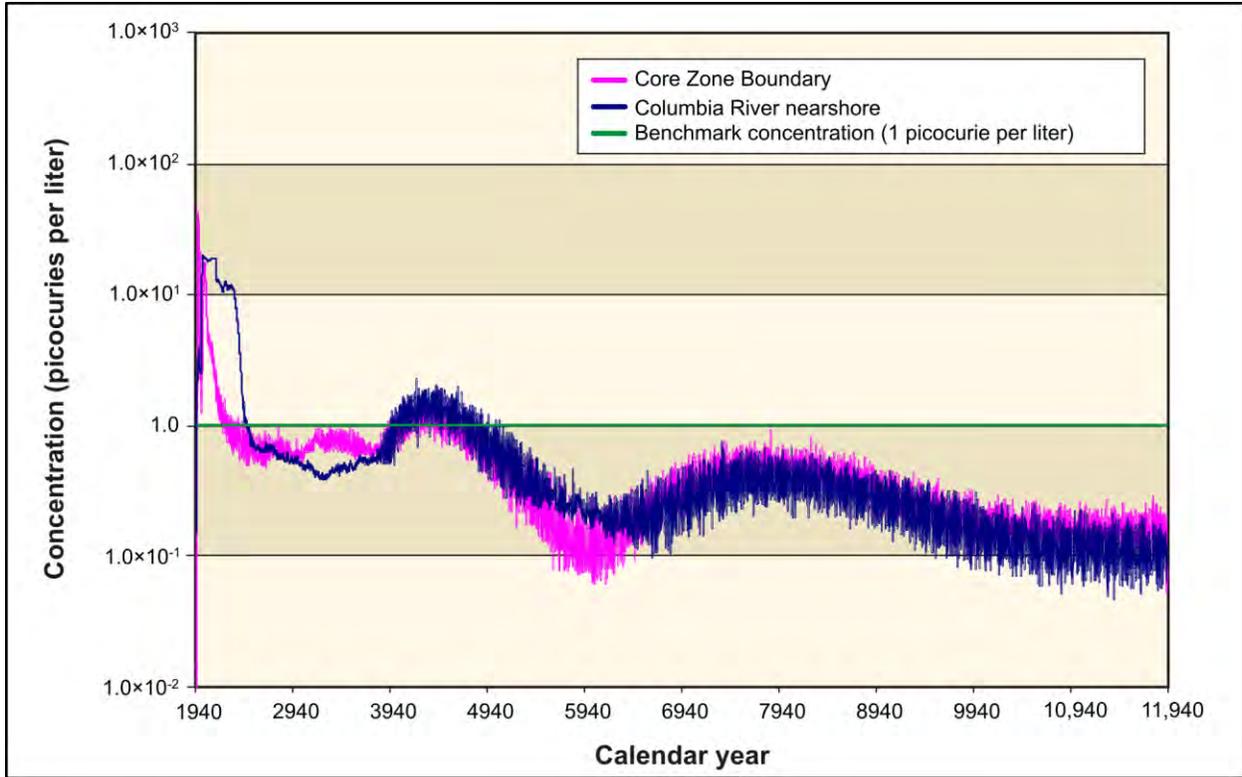


Figure 6-36. Alternative Combination 2 Cumulative Iodine-129 Concentration Versus Time

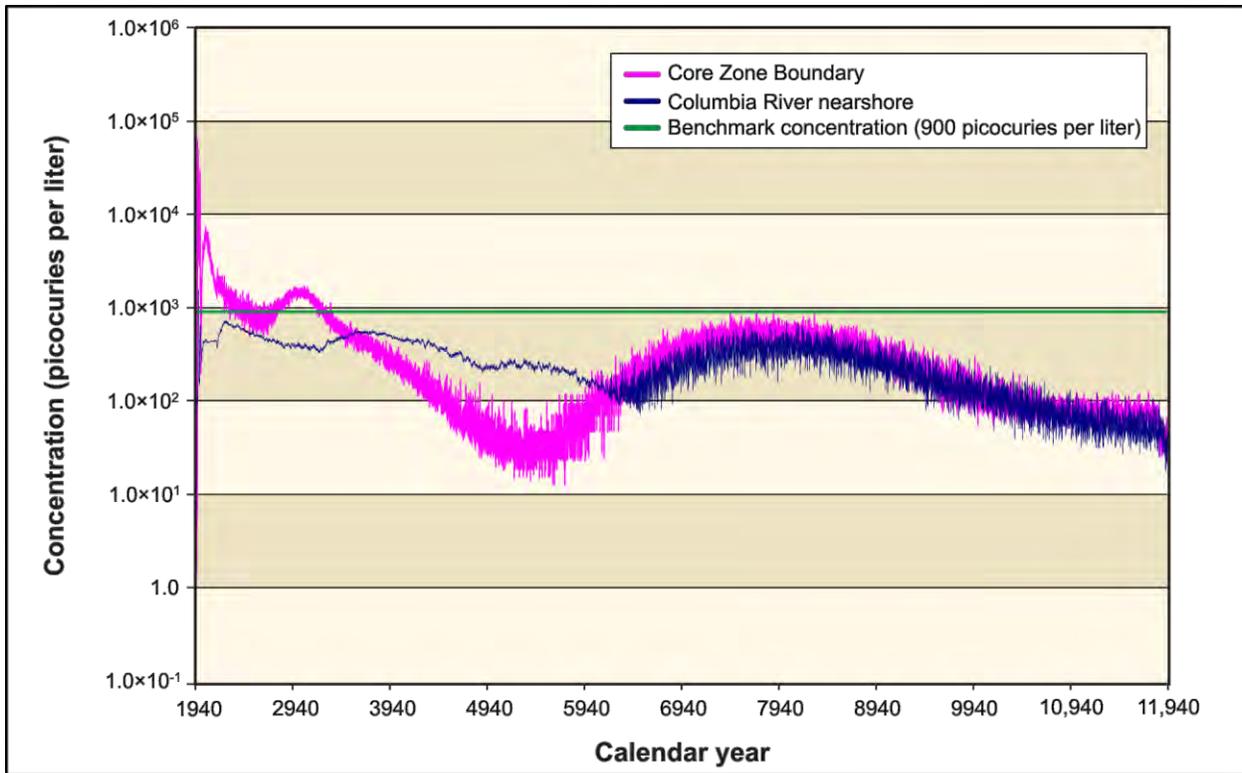


Figure 6-37. Alternative Combination 2 Cumulative Technetium-99 Concentration Versus Time

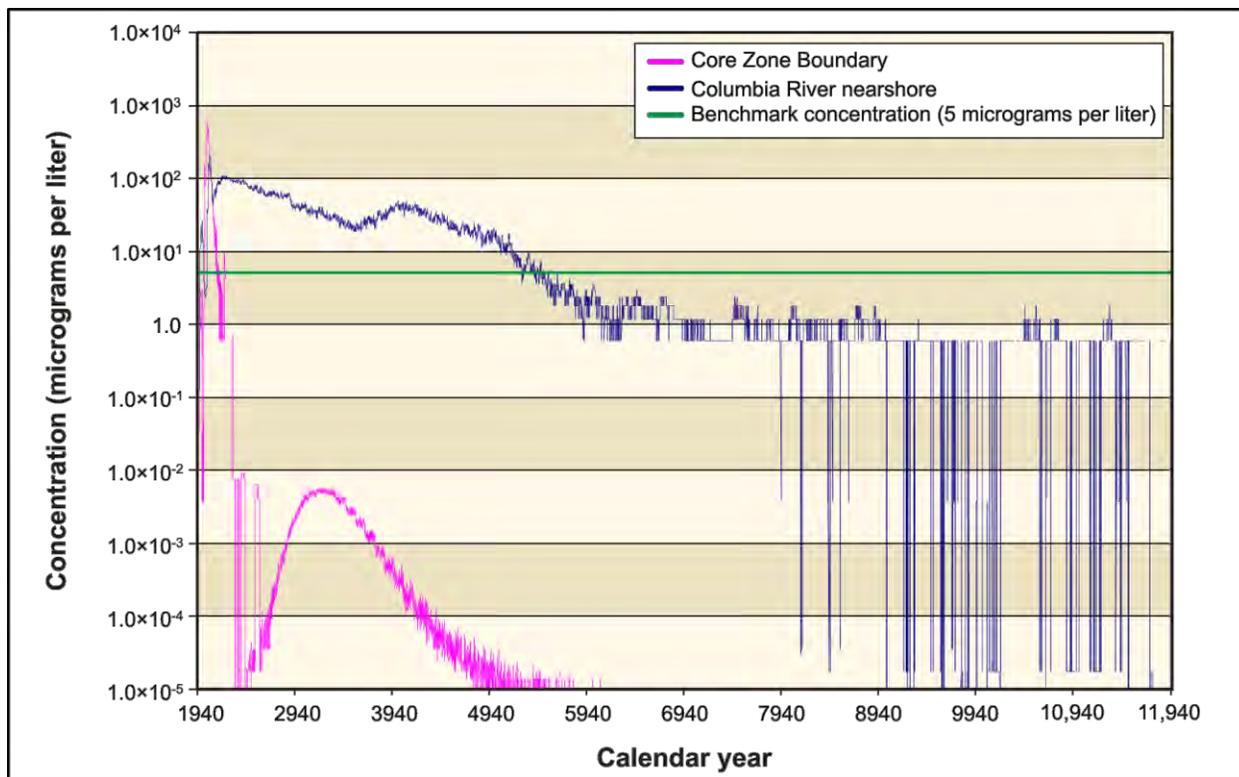


Figure 6–38. Alternative Combination 2 Cumulative Carbon Tetrachloride Concentration Versus Time

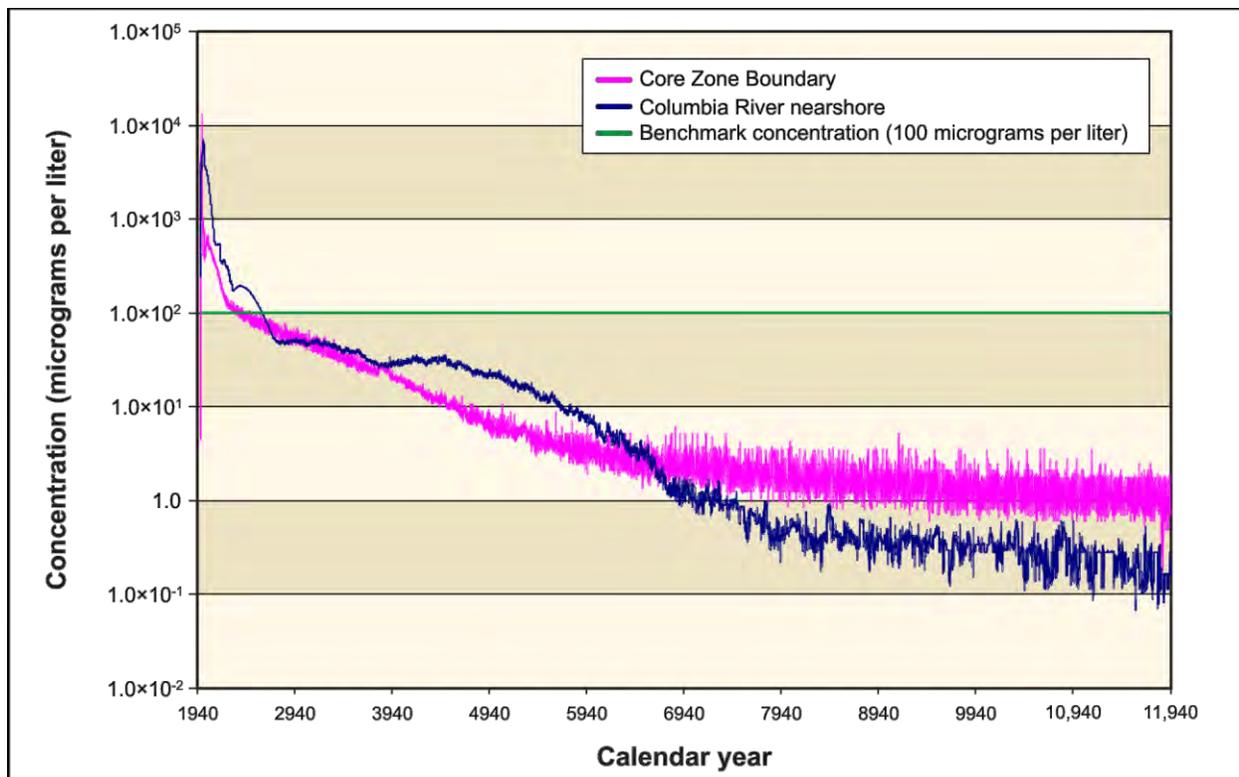


Figure 6–39. Alternative Combination 2 Cumulative Chromium Concentration Versus Time

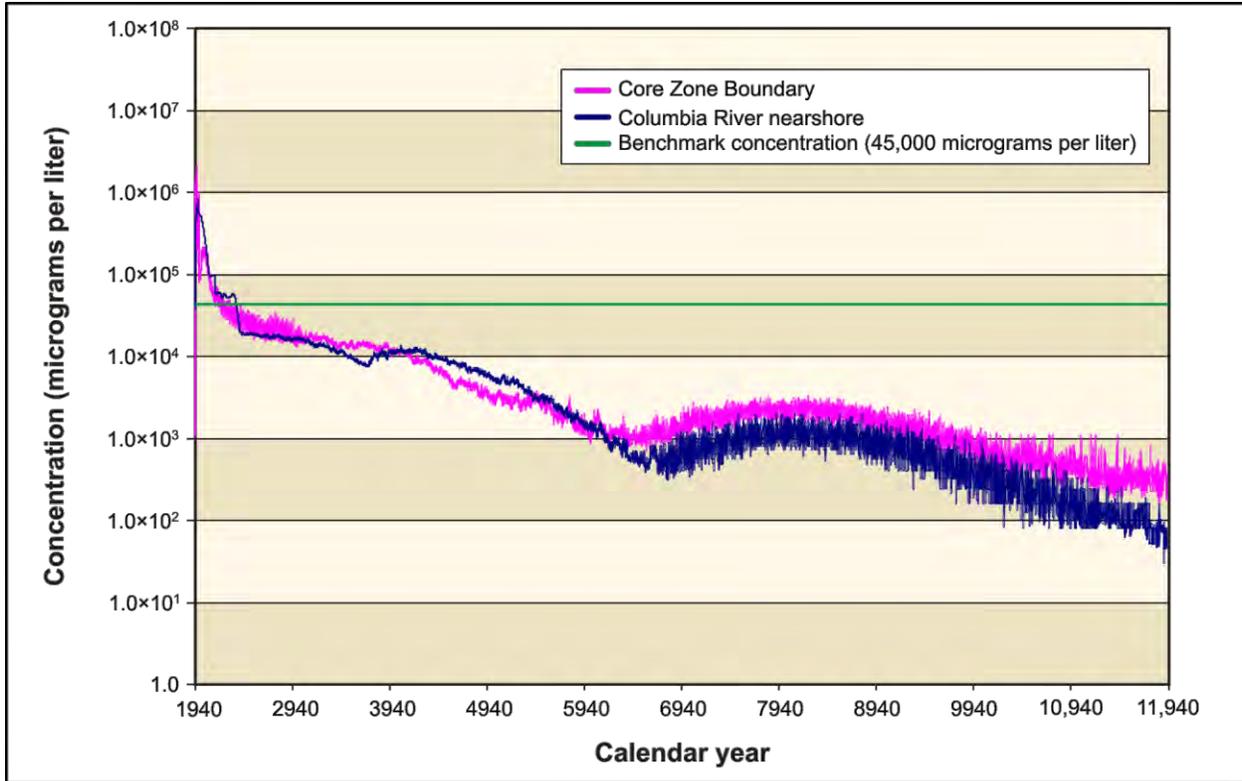


Figure 6-40. Alternative Combination 2 Cumulative Nitrate Concentration Versus Time

Figures 6-41 and 6-42 show concentration versus time for uranium-238 and total uranium. The travel times of these COPCs from the source locations to the Core Zone Boundary and Columbia River are about seven times slower than groundwater flow. Concentrations of uranium-238 and total uranium peak early in the period of analysis to more than two orders of magnitude above benchmark concentrations, then drop sharply, with the Columbia River nearshore reaching the benchmark around CY 2500 for uranium-238 and around CY 2200 for total uranium. Contributions from non-TC & WM EIS sources result in the higher concentrations at the Core Zone Boundary and Columbia River nearshore early in the past-practice period. Both uranium-238 and total uranium drop below the benchmark concentrations around CY 2800 and remain below that for the remainder of the period of analysis.

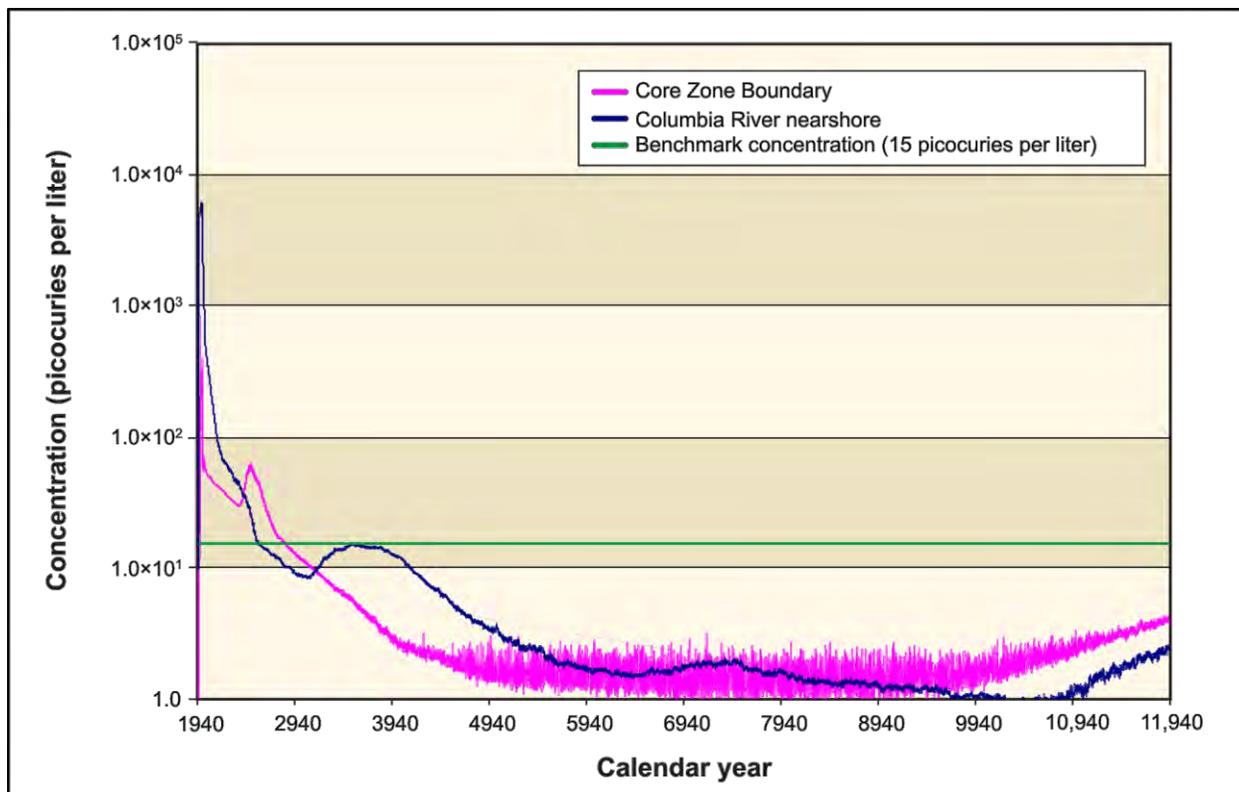


Figure 6-41. Alternative Combination 2 Cumulative Uranium-238 Concentration Versus Time

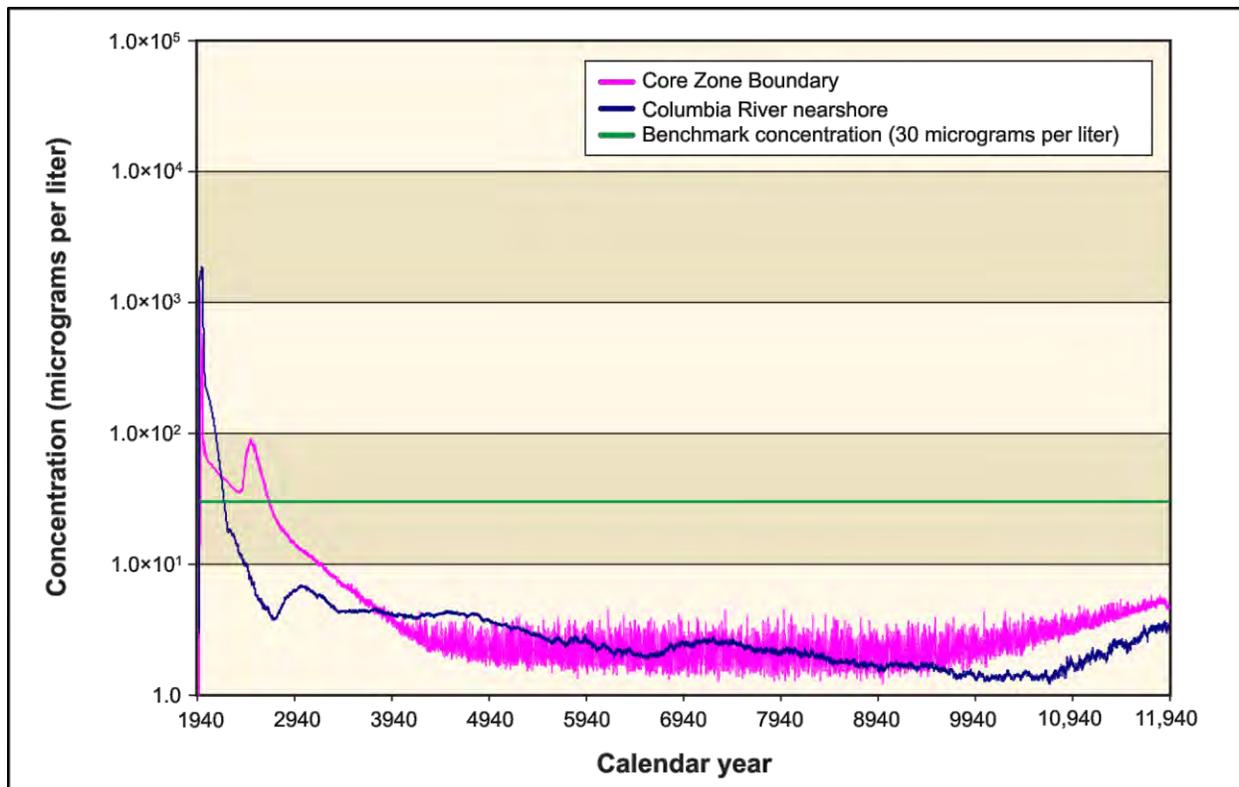
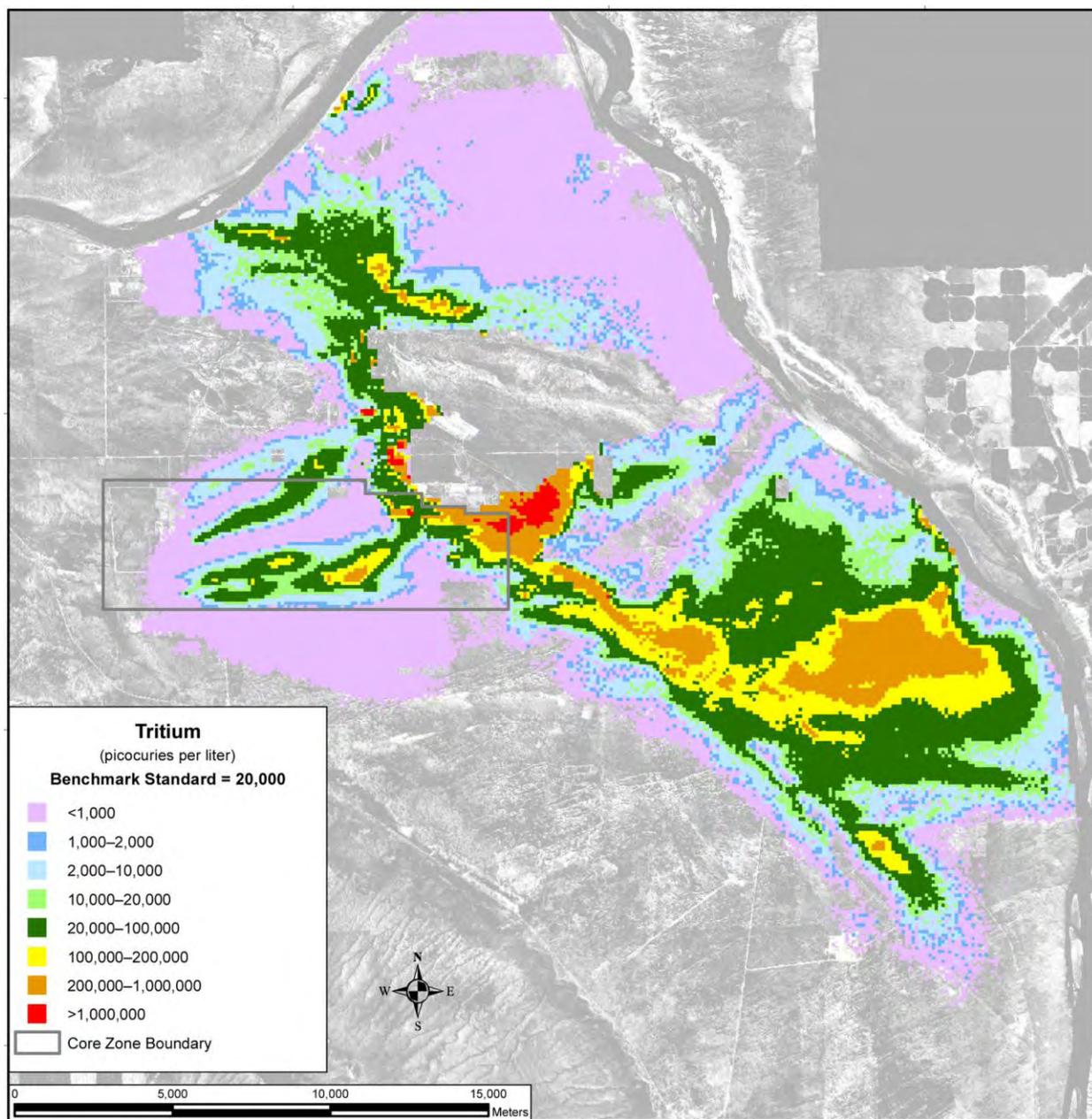


Figure 6-42. Alternative Combination 2 Cumulative Total Uranium Concentration Versus Time

6.4.1.3.3 Analysis of Spatial Distribution of Concentration

This section presents the spatial distribution of contaminant concentrations in groundwater at selected times. 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 6-43 shows the spatial distribution of tritium concentrations in groundwater in CY 2010 and contrasts the behavior of the releases from *TC & WM EIS* and non-*TC & WM EIS* sources. The release from *TC & WM EIS* sources results from cribs and trenches (ditches) and past tank leaks and is evident as the plume originating at the center of the 200-West Area and crossing the northern Core Zone Boundary. Tritium concentrations in this plume are up to 10 times the benchmark concentration. The remaining areas of tritium contamination are the result of releases from non-*TC & WM EIS* sources. These primary sources include the REDOX Facility plume originating in the southern portion of the 200-West Area and the PUREX Plant plume that originates at the eastern edge of the Core Zone Boundary and continues toward the Columbia River to the southeast. Peak concentrations in these plumes are up to 50 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.



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

Figure 6–43. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Hydrogen-3 (Tritium) Concentration, Calendar Year 2010

Figure 6–44 shows the spatial distribution of iodine-129 concentrations in groundwater in CY 2010. Releases from cribs and trenches (ditches) and past leaks associated with the A, B, S, and T Barriers result in groundwater concentration plumes that exceed the benchmark concentration. Peak concentrations in this plume are about 10 to 50 times greater than the benchmark and are mostly contained within the Core Zone. The plume along the southern Core Zone Boundary is associated with the REDOX Facility, a non-TC & WMEIS source. Releases from the PUREX Plant area (another non-TC & WMEIS source) produce a plume extending south and east of the Core Zone, with peak concentrations about 10 to 50 times the benchmark concentration. Around CY 3890, releases from other tank farm sources create an iodine-129 plume extending east of the Core Zone Boundary (see Figure 6–45). By CY 7140, the groundwater concentration distribution is driven primarily by waste

management sources located at IDF-East (see Figure 6-46). The impact is characterized by a plume located east of the Core Zone that exceeds the benchmark concentration by more than an order of magnitude. Because of retention in the waste forms, this impact lasts to the end of the 10,000-year period of analysis (see Figure 6-47). Figure 6-48 shows the total area for which groundwater iodine-129 concentrations exceed the benchmark concentration as a function of time. The early intense peak where the area over the benchmark concentration is approximately 50 square kilometers (19 square miles) is related to non-TC & WM EIS releases during the past-practice period. The contaminated area decreases rapidly during the retrieval and post-administrative control period, and the secondary peak between CYs 4000 and 5000 is driven primarily by releases from other tank farm sources. Other tank farm sources include tank farm residuals, ancillary equipment, retrieval losses, and unplanned releases.

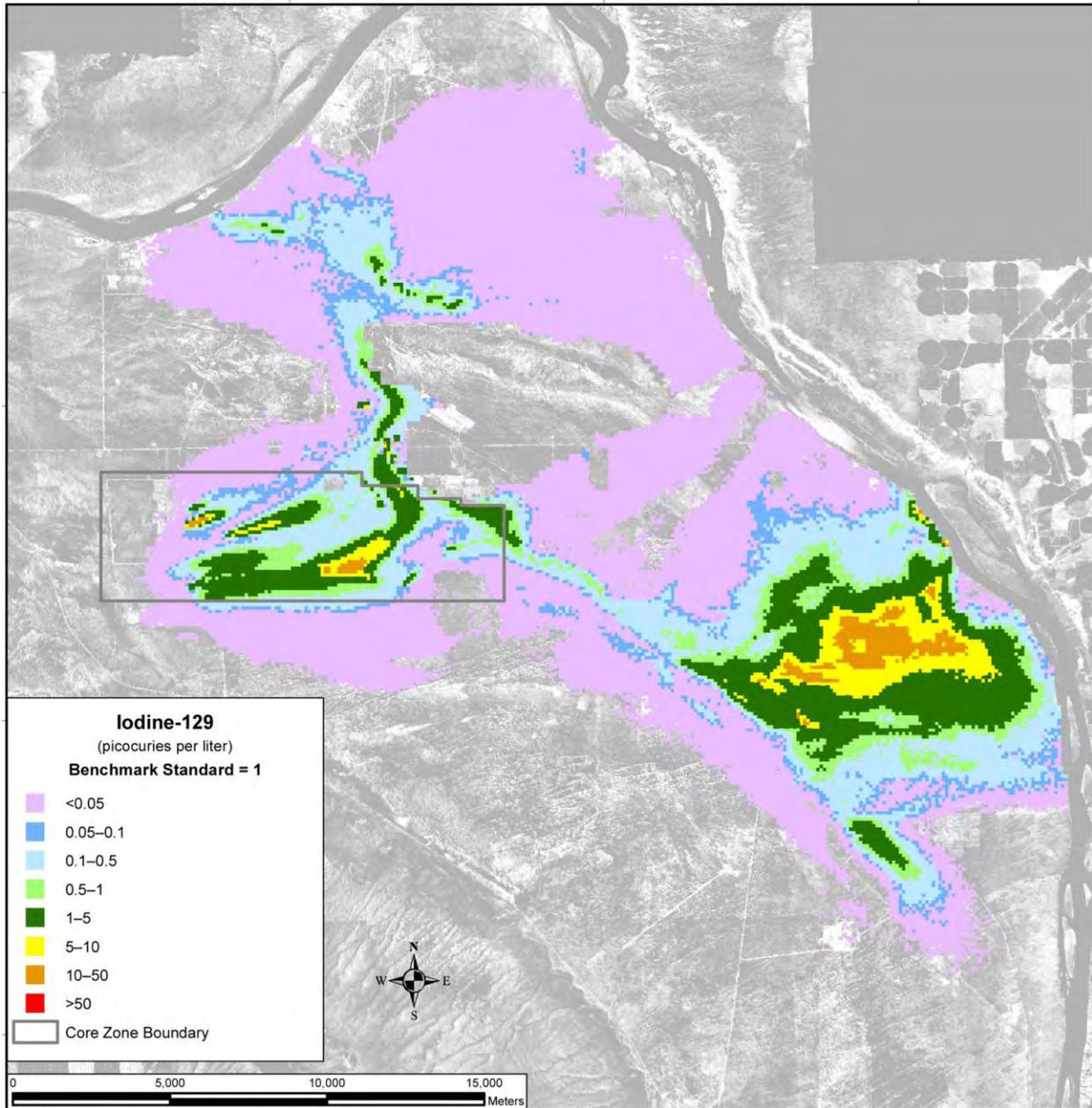


Figure 6-44. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Iodine-129 Concentration, Calendar Year 2010

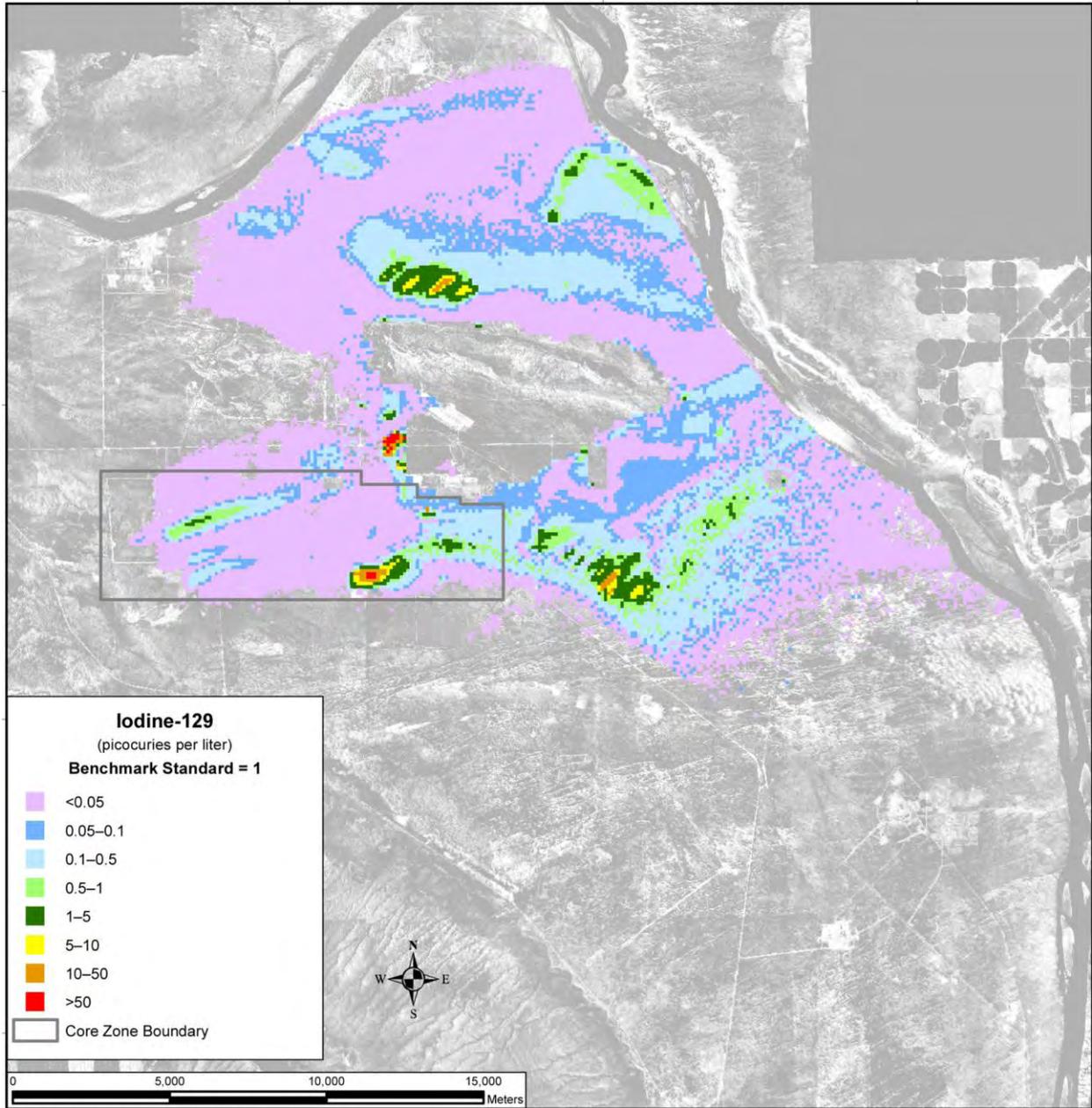


Figure 6–45. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Iodine-129 Concentration, Calendar Year 3890

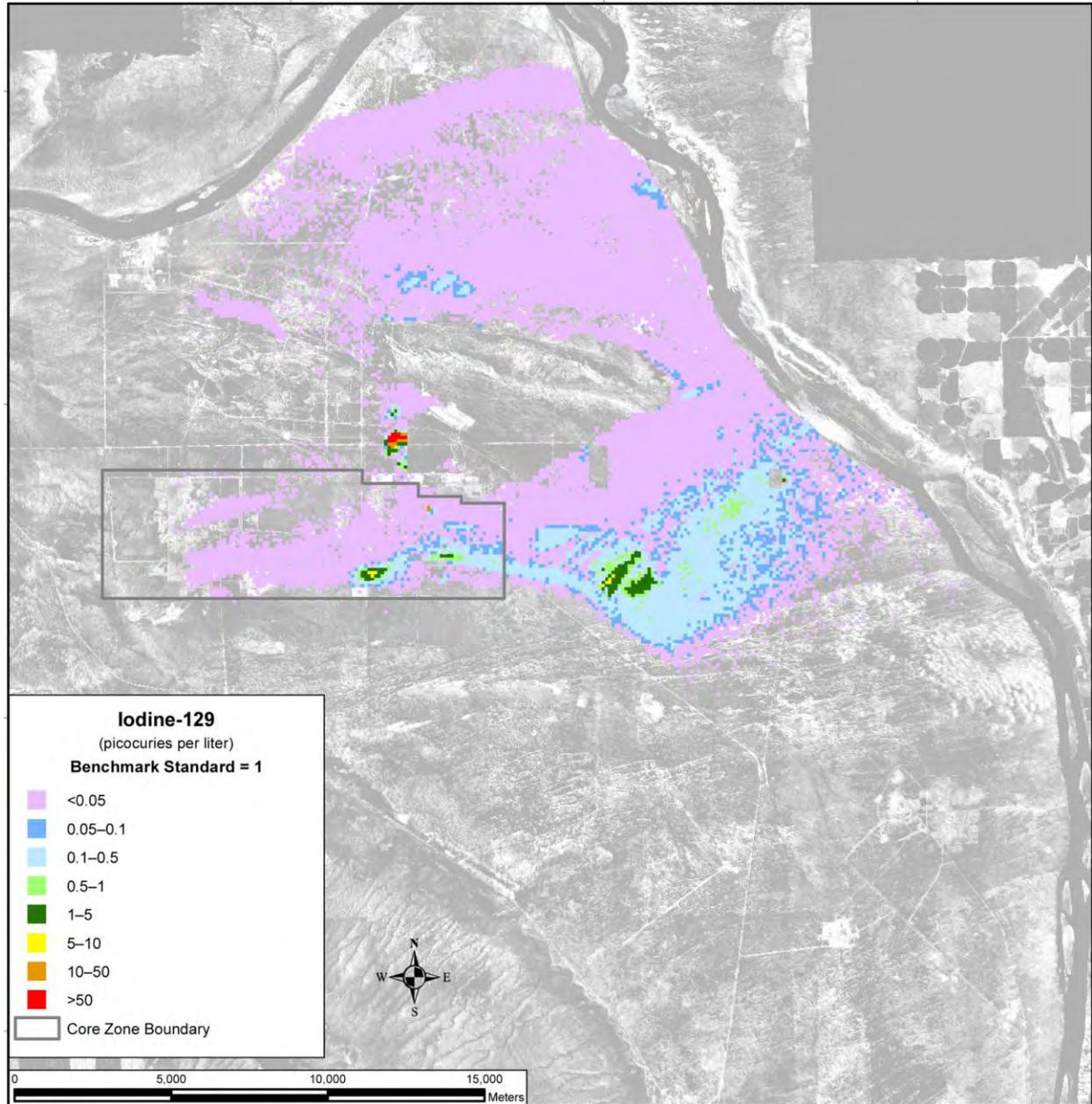
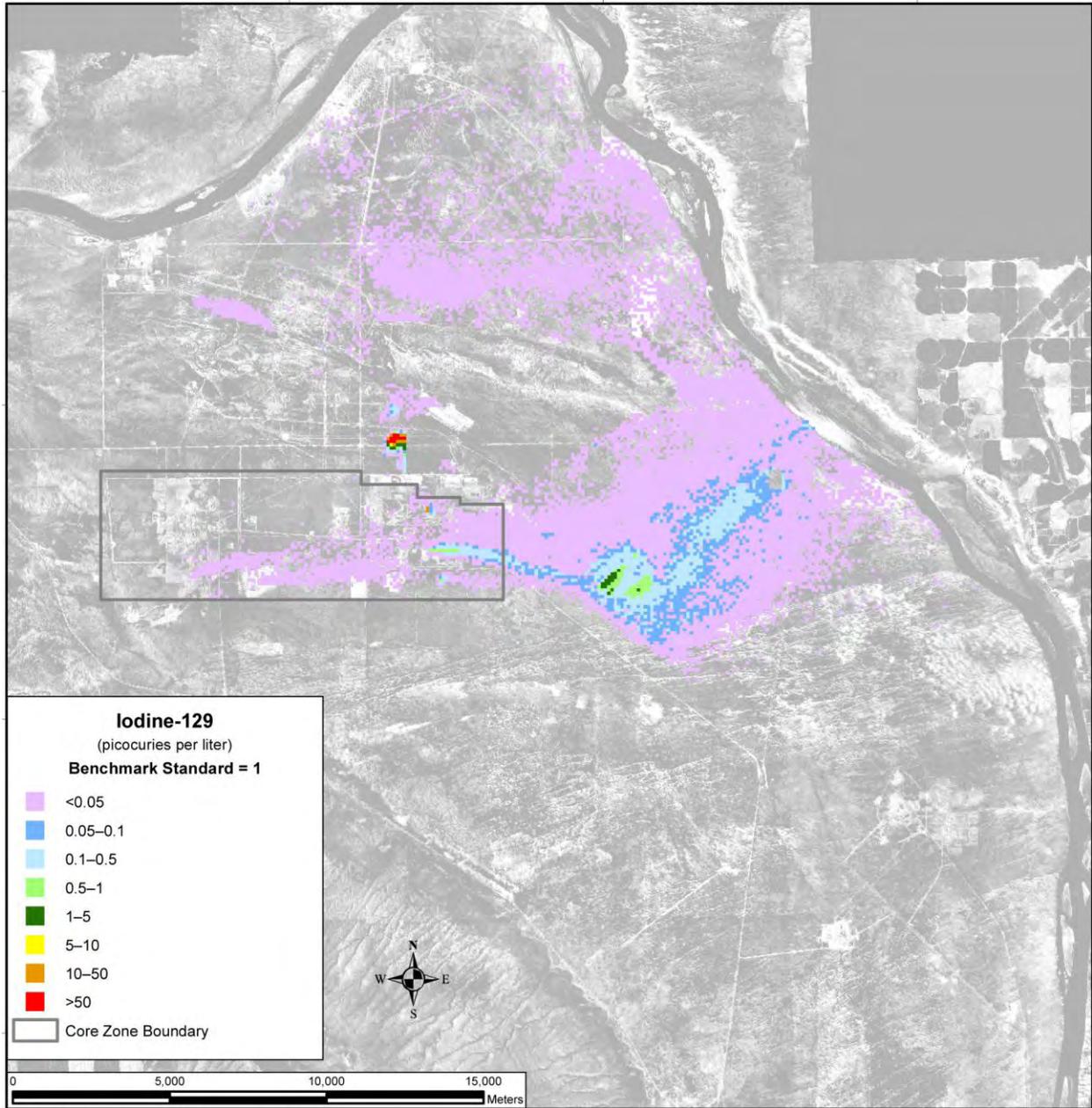


Figure 6–46. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Iodine-129 Concentration, Calendar Year 7140



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

Figure 6–47. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Iodine-129 Concentration, Calendar Year 11,885

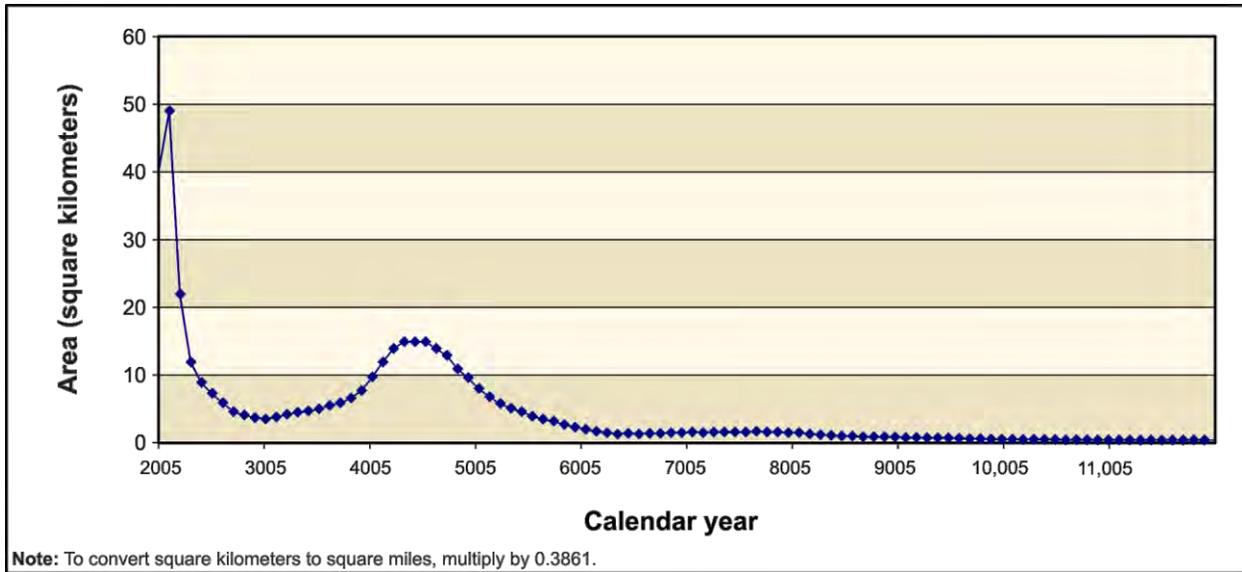


Figure 6-48. Alternative Combination 2 Total Area of Cumulative Groundwater Iodine-129 Concentrations Exceeding the Benchmark Concentration as a Function of Time

Figures 6-49 through 6-52 show the spatial distributions of technetium-99 concentrations in groundwater in CYs 2010, 3890, 7140, and 11,885. Figure 6-53 shows the total area of exceedance versus time for technetium-99. These spatial distributions of technetium-99 do not include major contributions from the non-*TC & WM EIS* sources (compared with iodine-129 distributions) and are dominated by releases from other tank farm sources and IDF-East. Chromium (see Figures 6-54 through 6-57) and nitrate (see Figures 6-58 through 6-61) show increased spatial distributions relative to technetium-99 because of the additional contributions from non-*TC & WM EIS* sources.

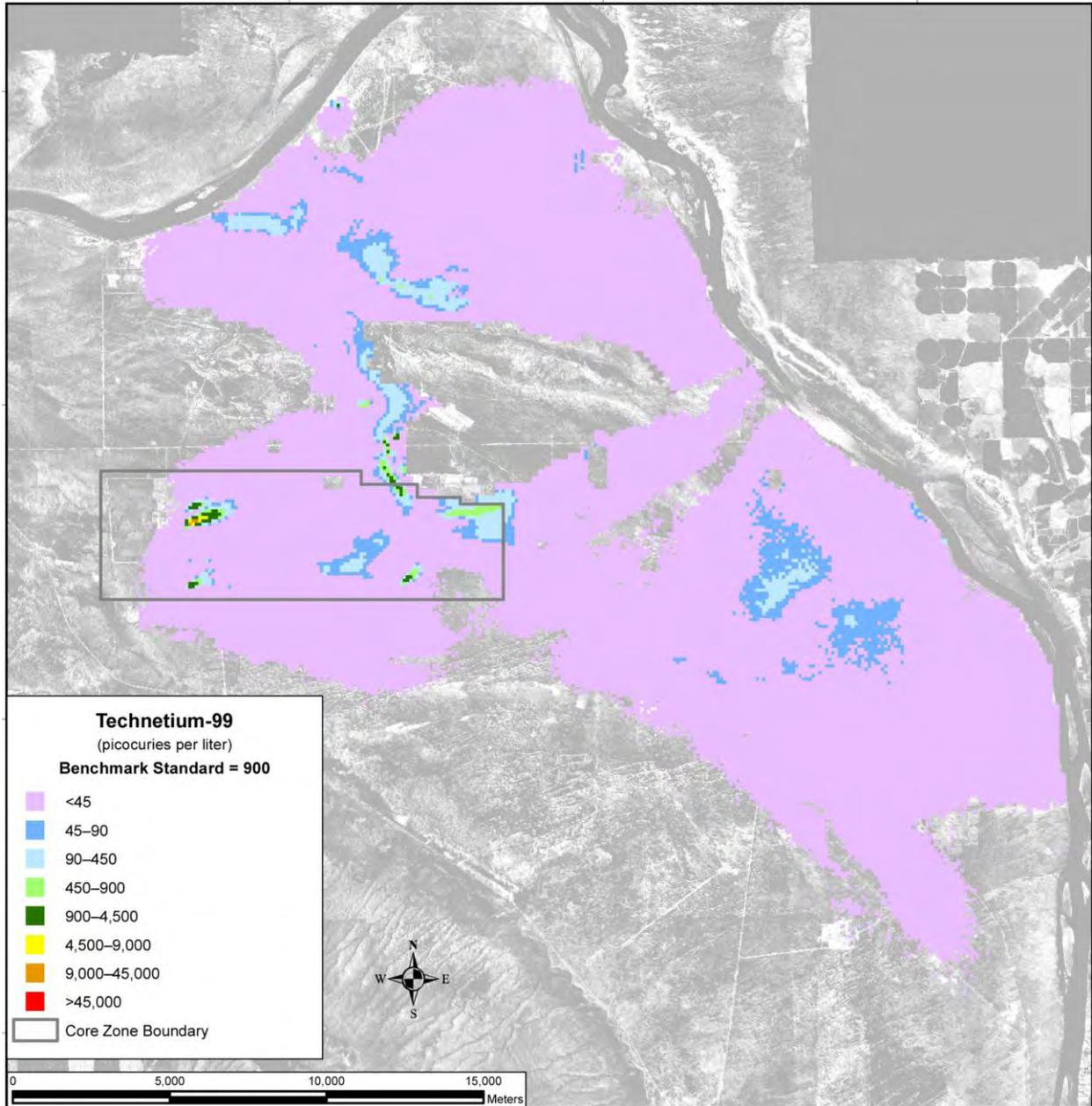


Figure 6-49. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Technetium-99 Concentration, Calendar Year 2010

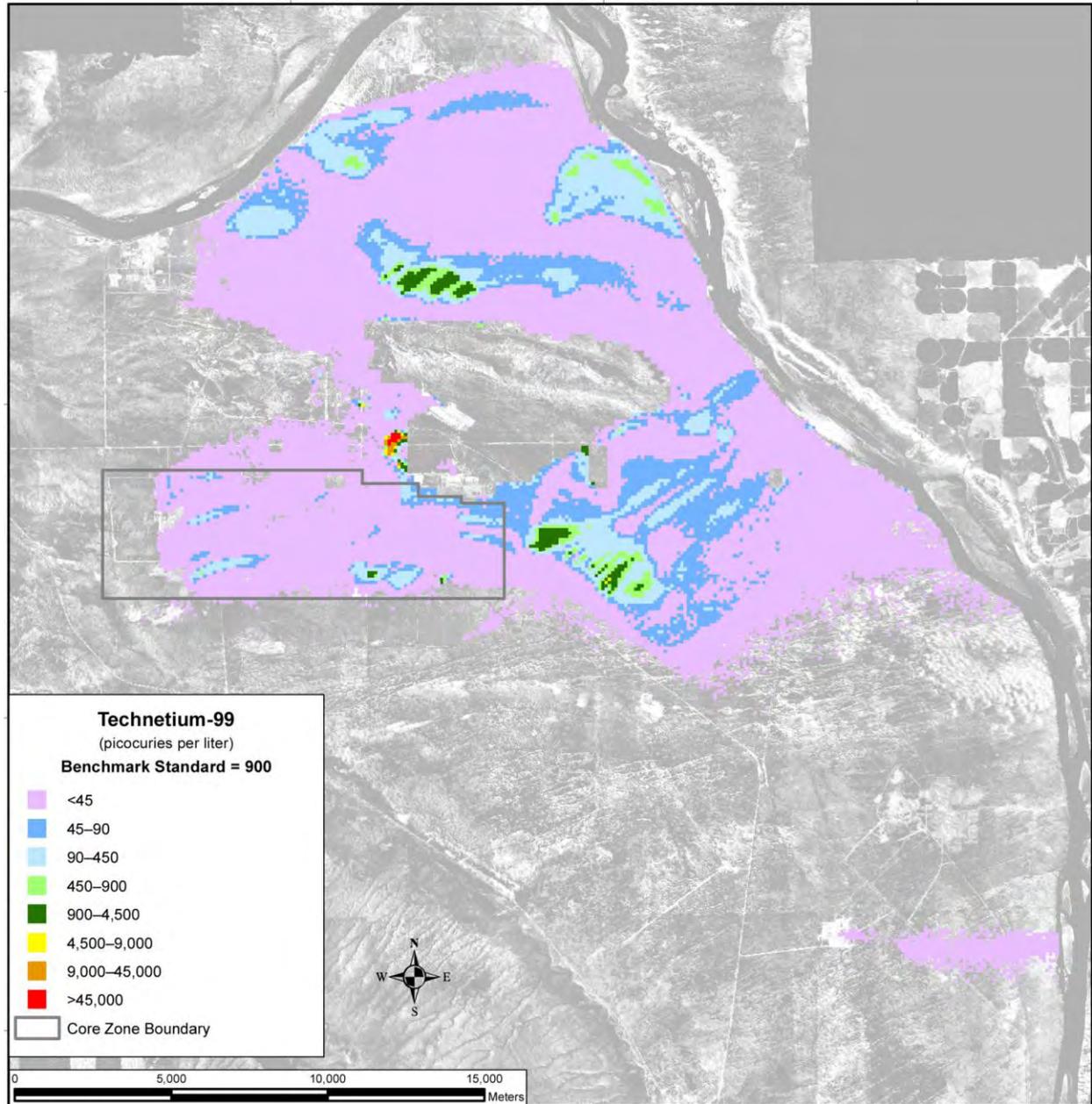
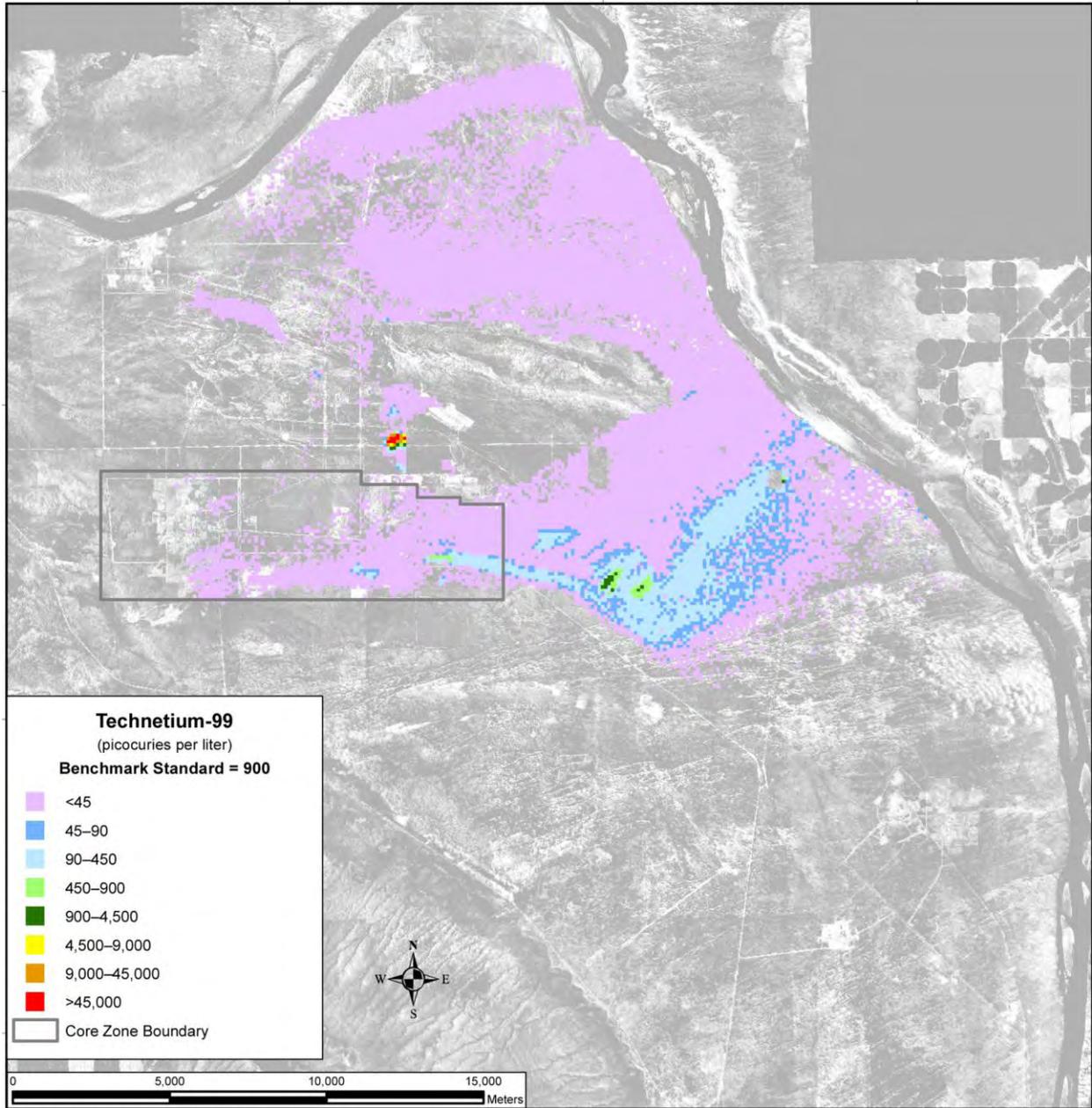


Figure 6-50. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Technetium-99 Concentration, Calendar Year 3890



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

Figure 6-51. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Technetium-99 Concentration, Calendar Year 7140

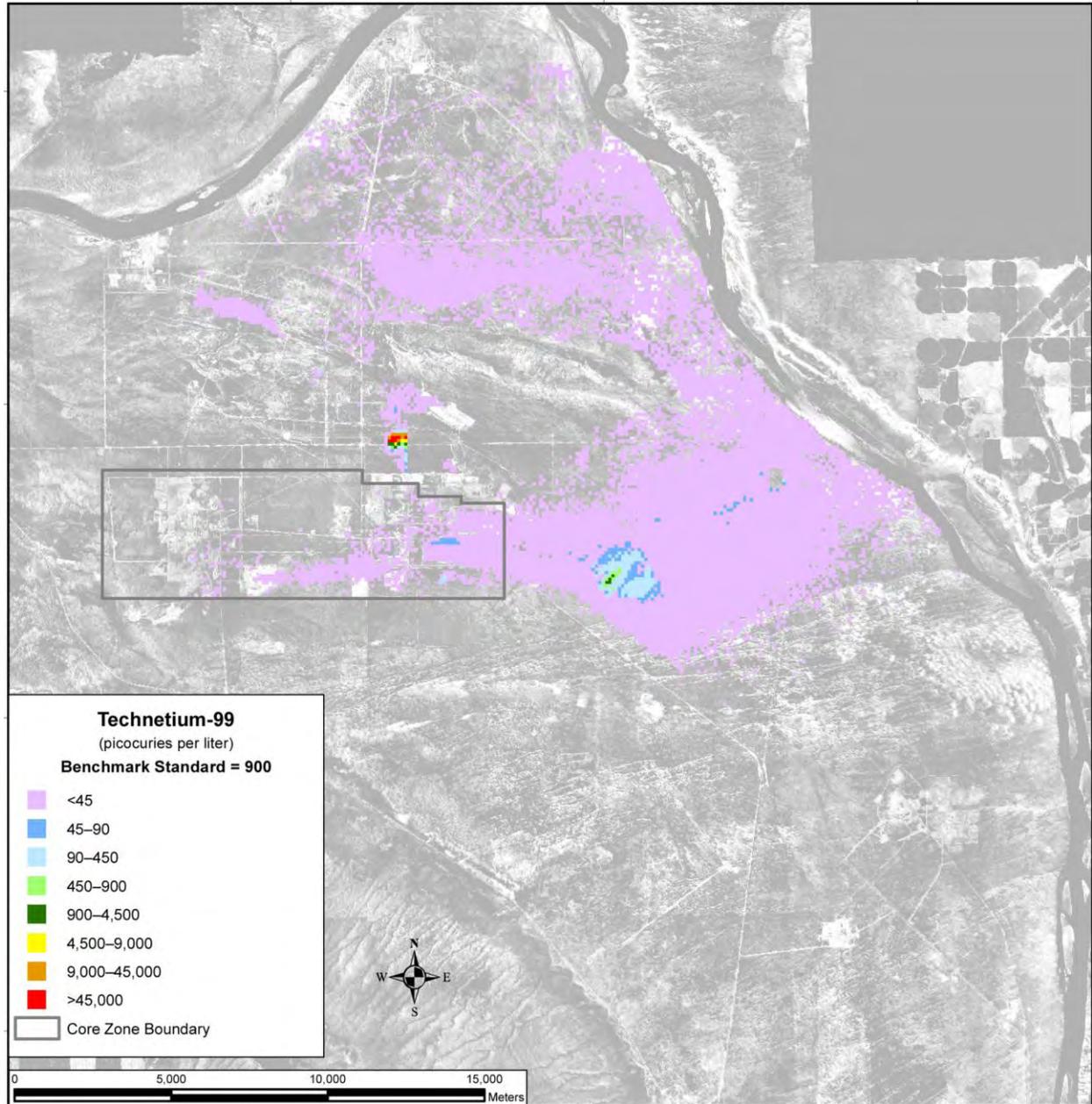


Figure 6-52. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Technetium-99 Concentration, Calendar Year 11,885

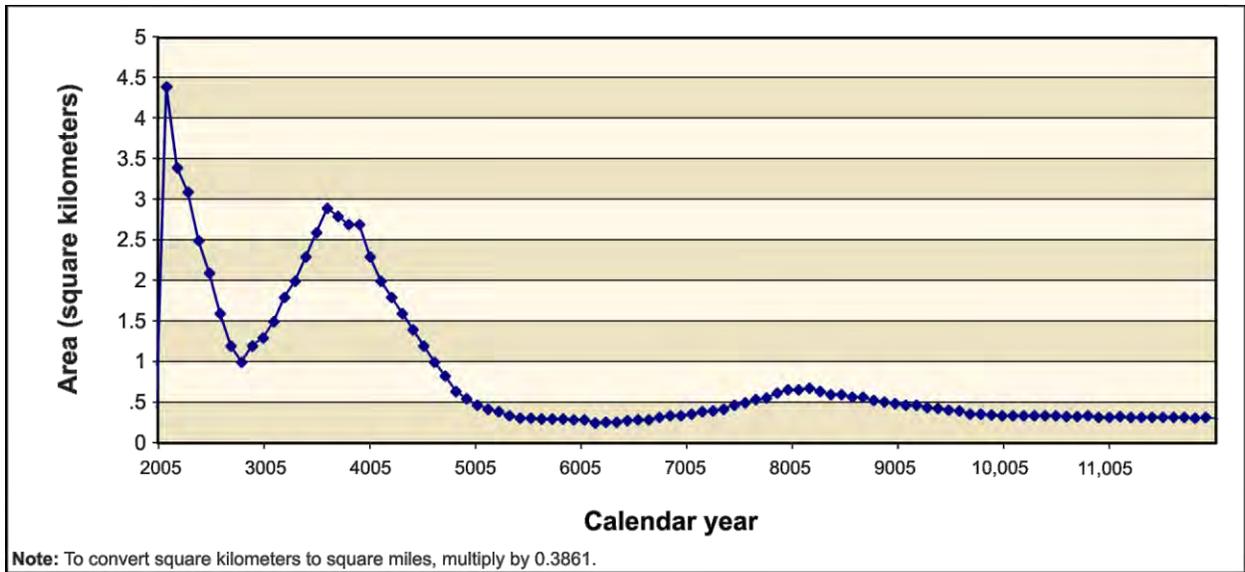


Figure 6–53. Alternative Combination 2 Total Area of Cumulative Groundwater Technetium-99 Concentrations Exceeding the Benchmark Concentration as a Function of Time

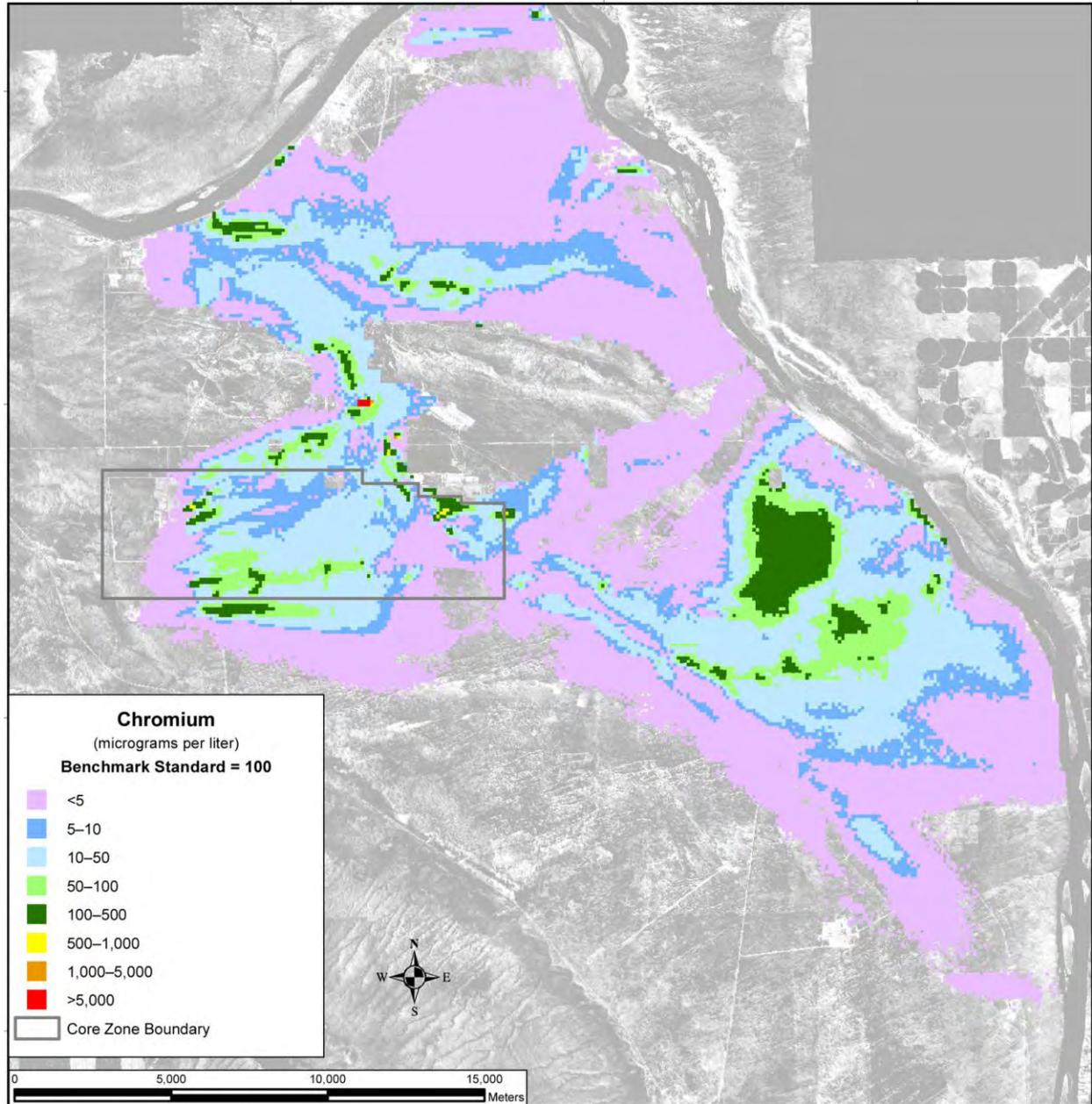


Figure 6-54. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Chromium Concentration, Calendar Year 2010

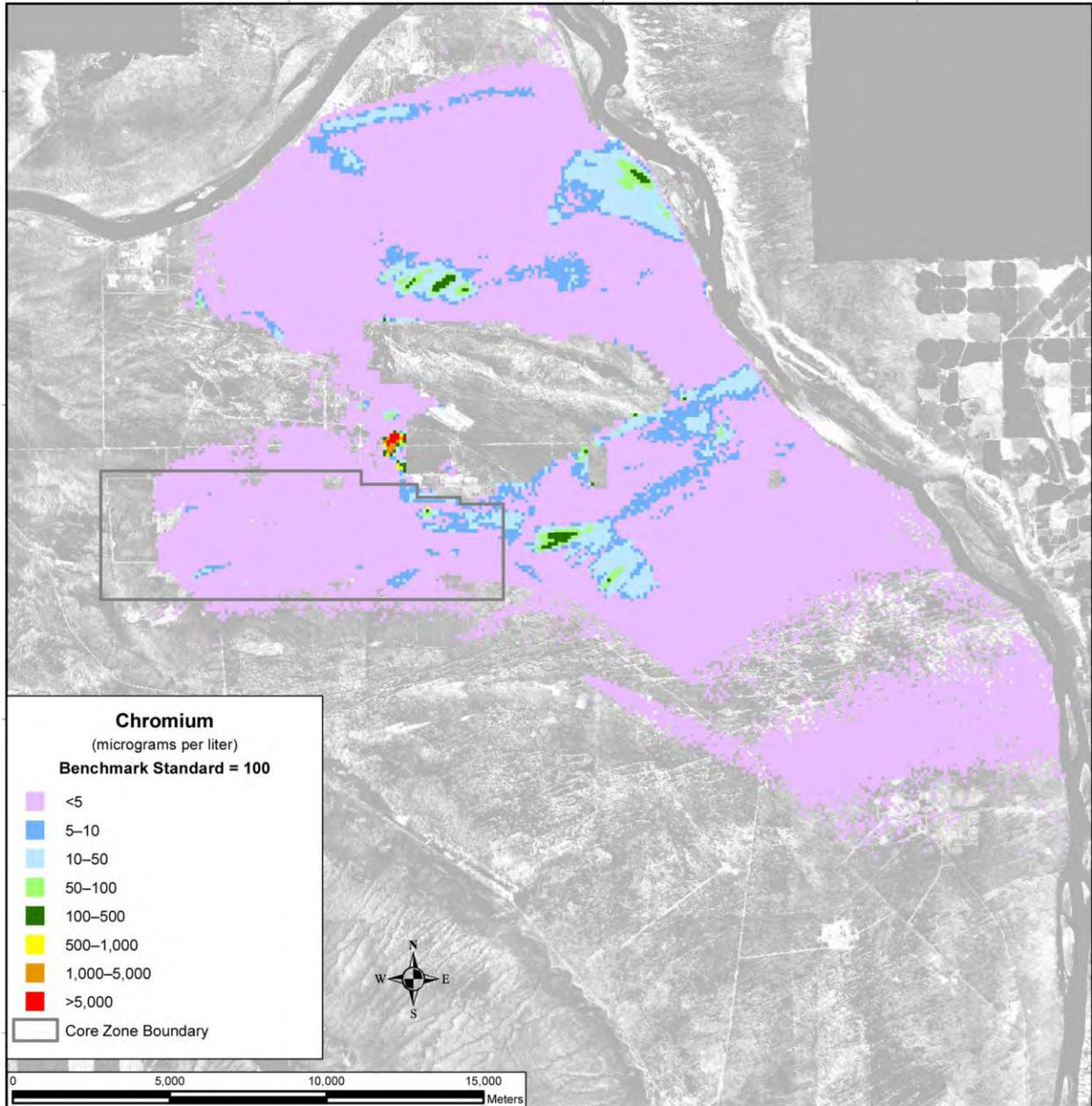


Figure 6-55. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Chromium Concentration, Calendar Year 3890

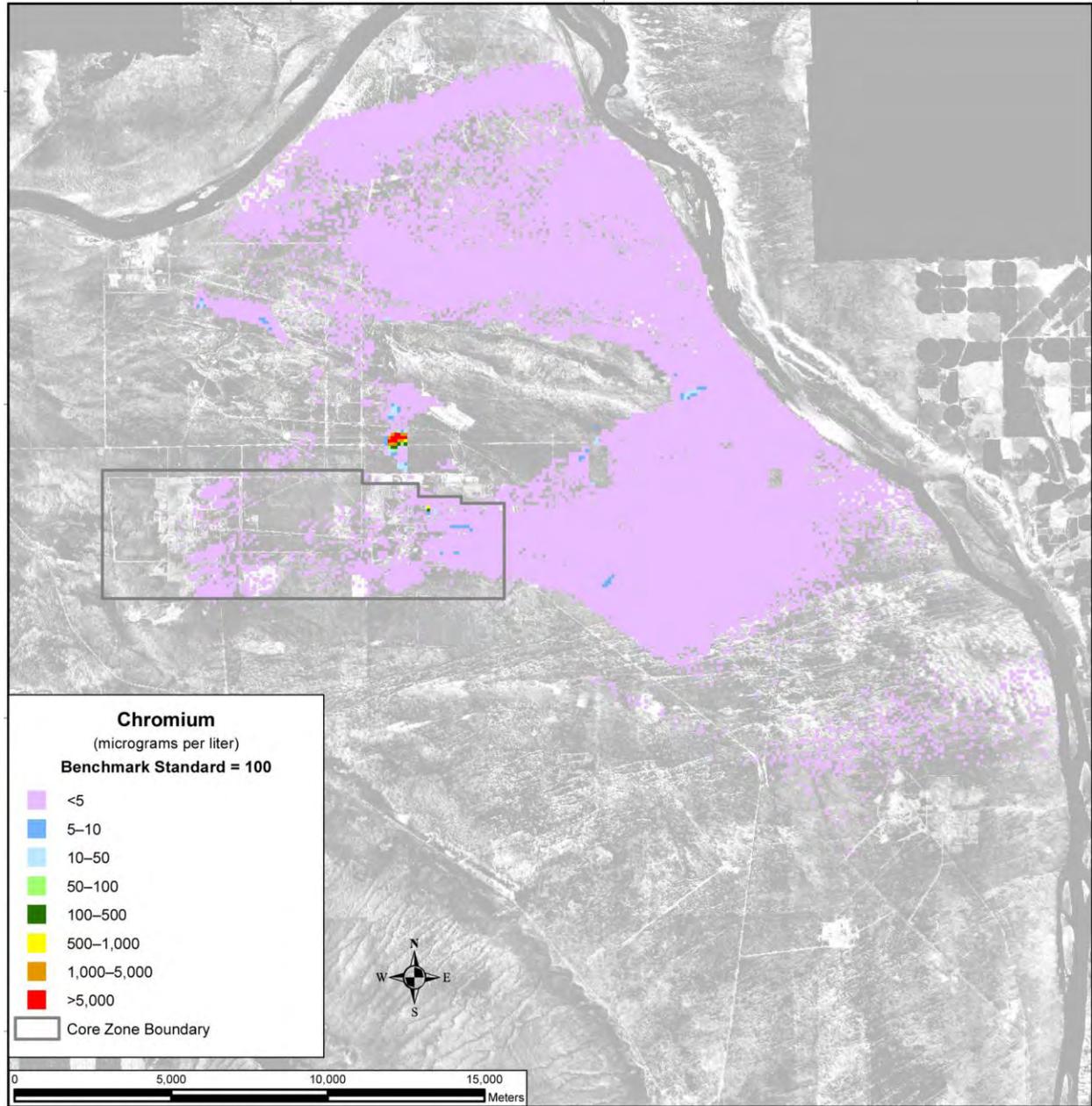
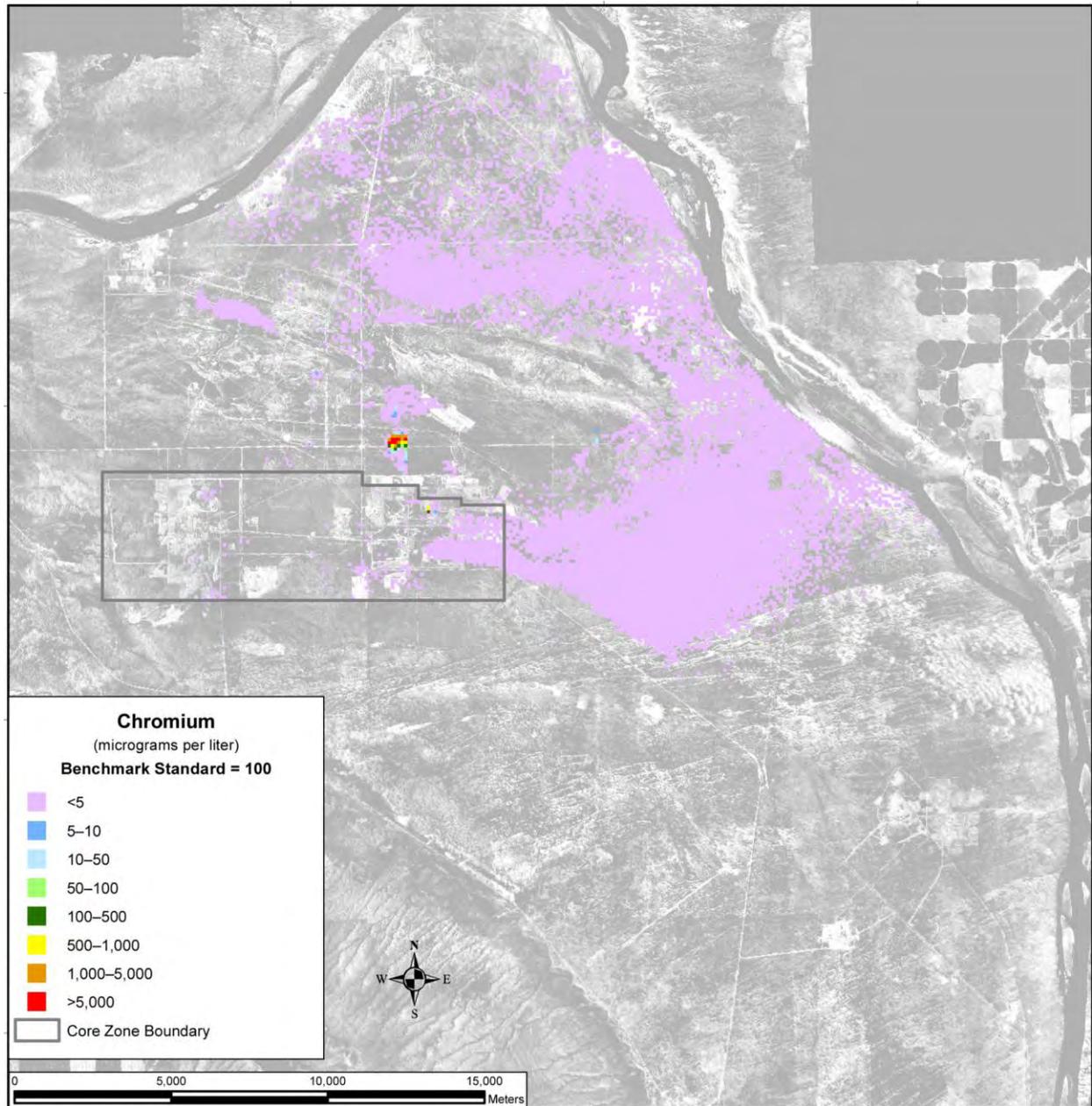


Figure 6-56. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Chromium Concentration, Calendar Year 7140



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

Figure 6-57. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Chromium Concentration, Calendar Year 11,885

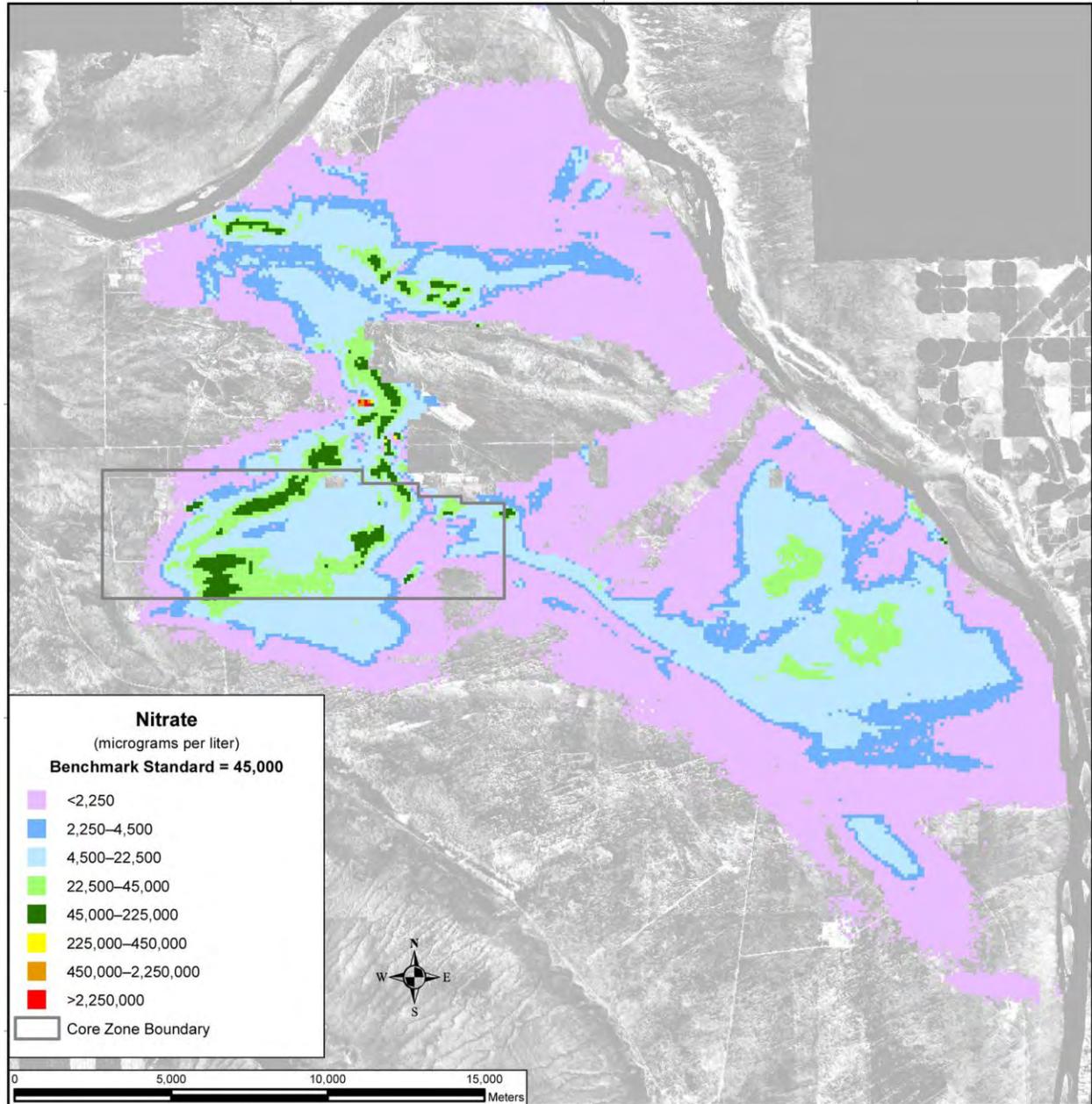
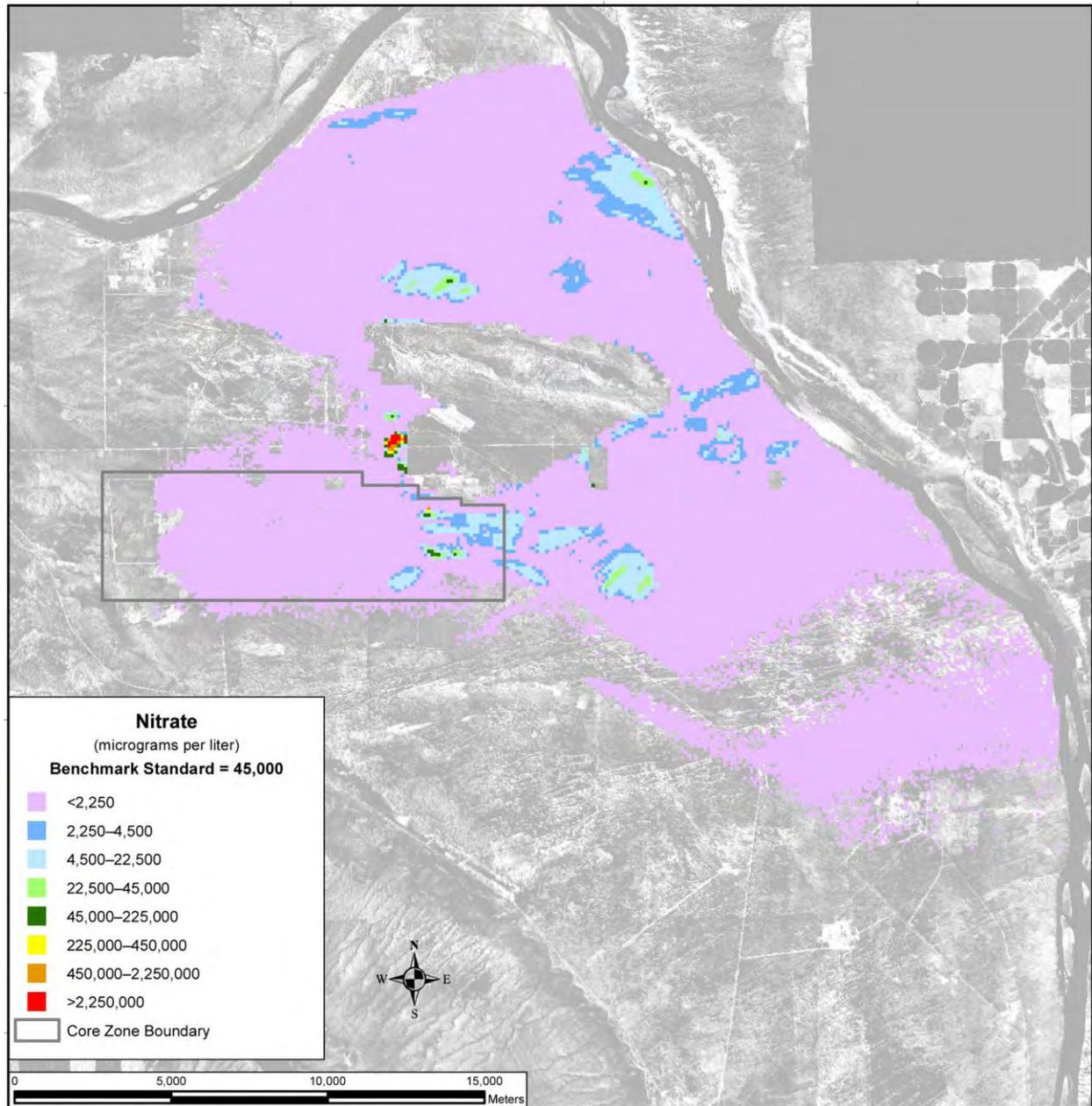


Figure 6–58. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Nitrate Concentration, Calendar Year 2010



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

Figure 6–59. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Nitrate Concentration, Calendar Year 3890

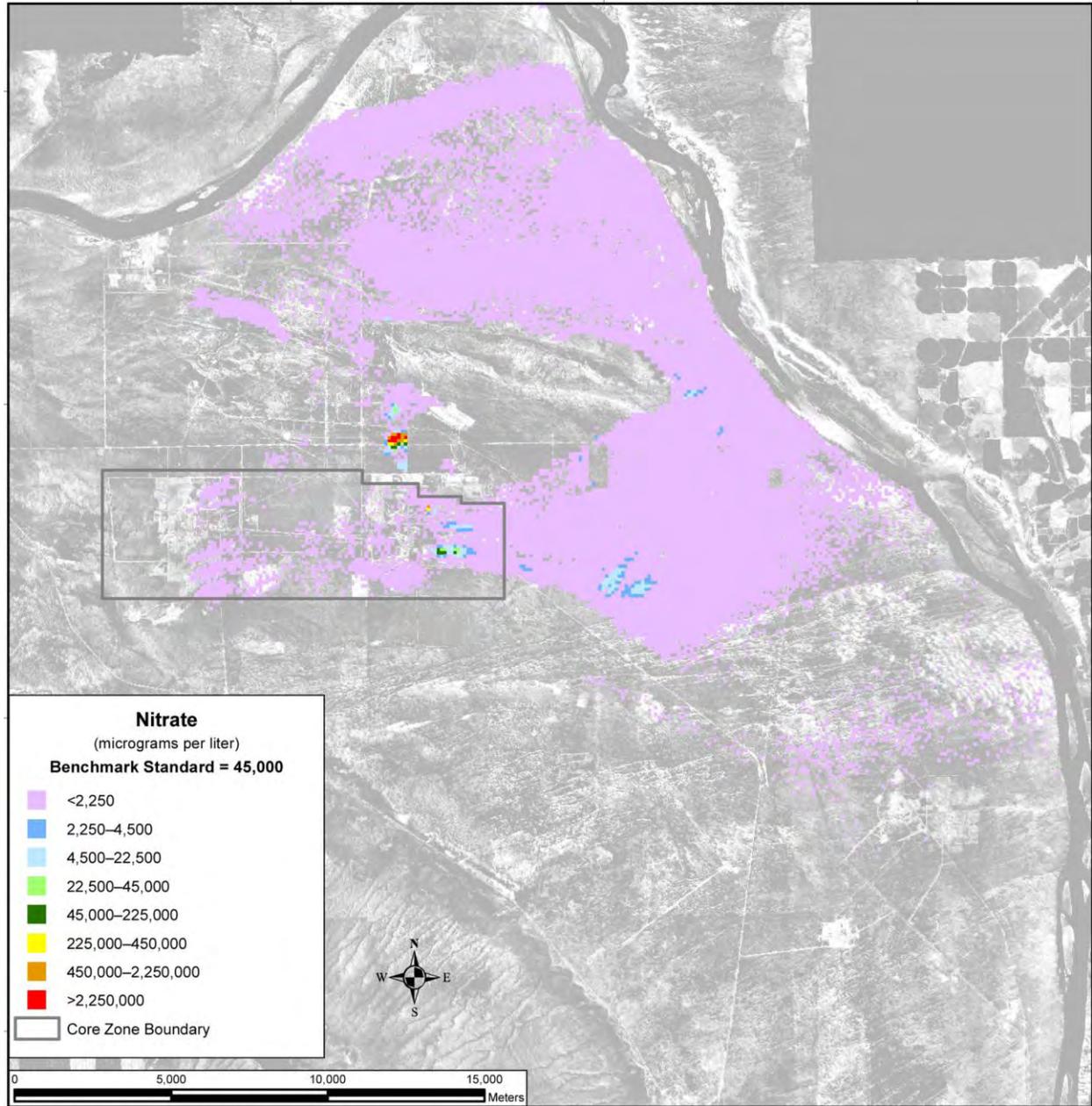
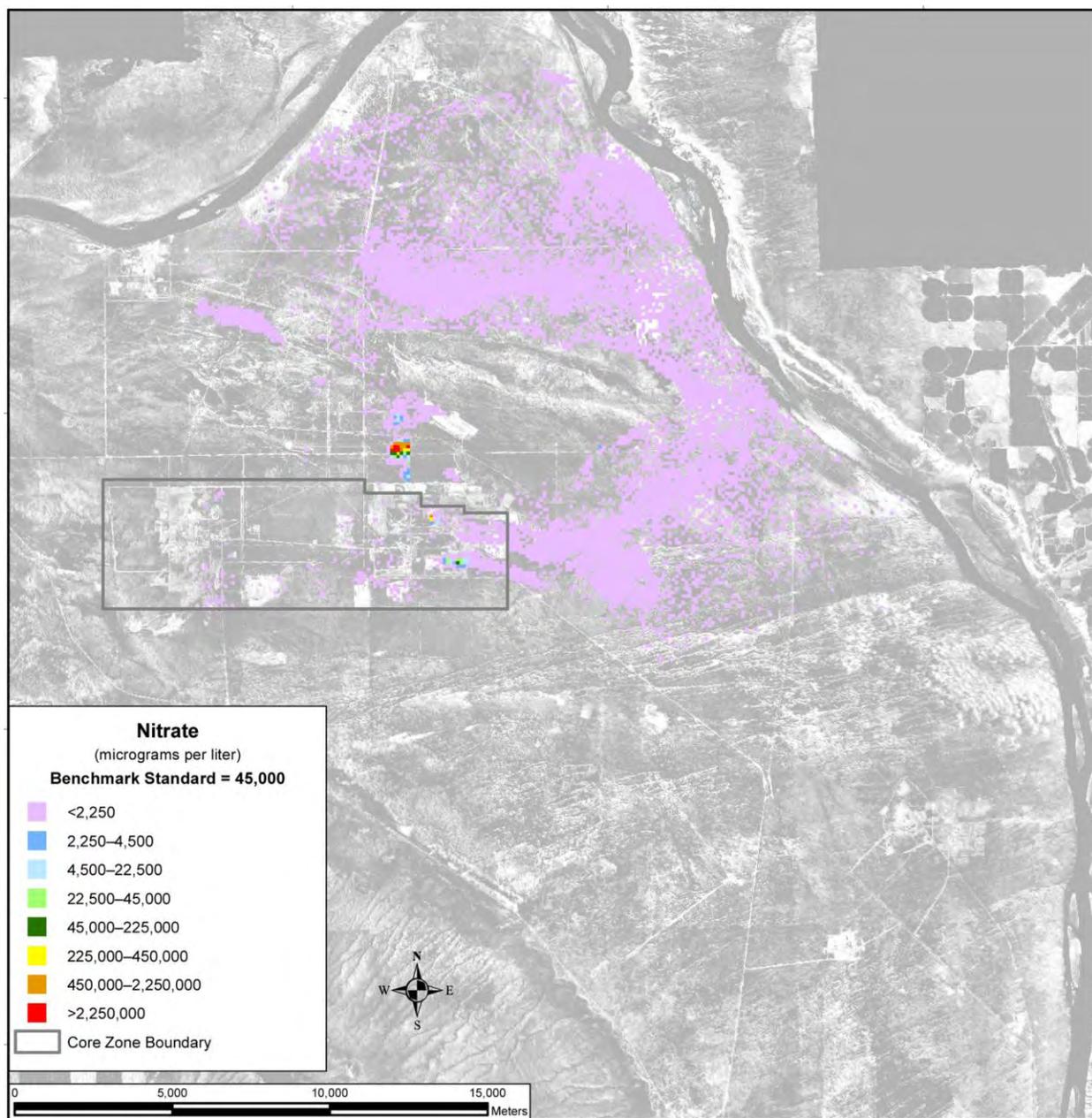


Figure 6–60. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Nitrate Concentration, Calendar Year 7140

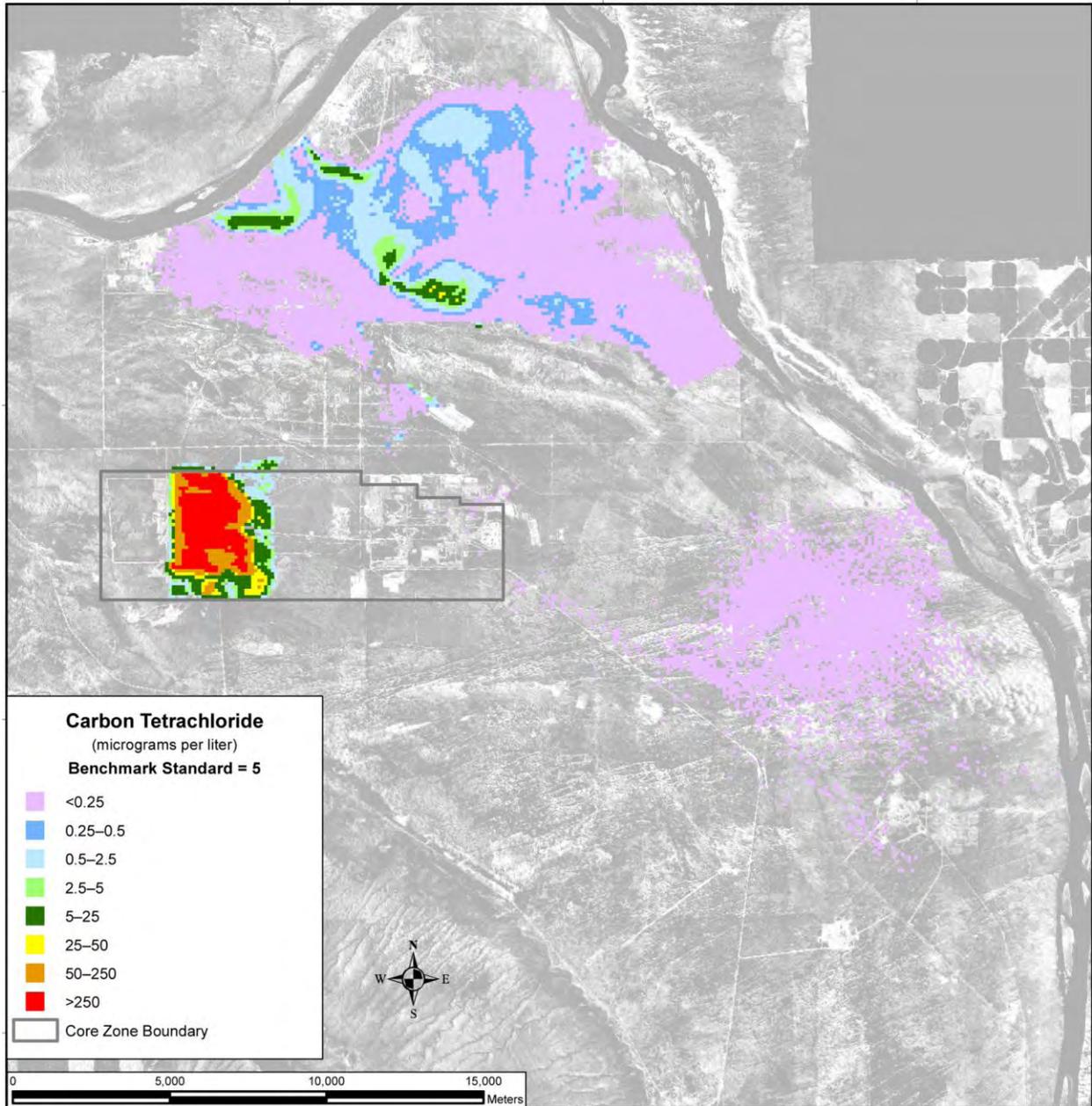


Note: To convert meters to feet, multiply by 3.281.

Figure 6–61. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Nitrate Concentration, Calendar Year 11,885

The spatial distribution of carbon tetrachloride concentrations in groundwater is dominated by non-TC & WMEIS sources associated with the Z Area within the 200-West Area. The spatial distribution in CY 2010, shown in Figure 6–62, is a large plume covering most of the 200-West Area, with peak concentrations more than 50 times greater than the benchmark concentration. By CY 2135, shown in Figure 6–63, the plume has moved almost entirely out of the Core Zone Boundary and to the north. Note that this model result does not include the effects of carbon tetrachloride removal and containment in the 200-West Area. Figure 6–64 show the dissipation of the plume over time in CY 3890.

The part of the carbon tetrachloride plume north of Gable Mountain includes contributions from the 200-West Area plume and Gable Mountain Pond. By mass, the dominant source is the 200-West Area plume. The rate of migration from the 200-West Area through Gable Gap is strongly influenced by the location of the highly conductive aquifer materials in this area, which is relatively uncertain (see Appendix L). The model overpredicts the rate of northward migration because of this uncertainty and because no credit is taken for the groundwater containment and removal system in the 200-West Area.



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

Figure 6–62. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Carbon Tetrachloride Concentration, Calendar Year 2010

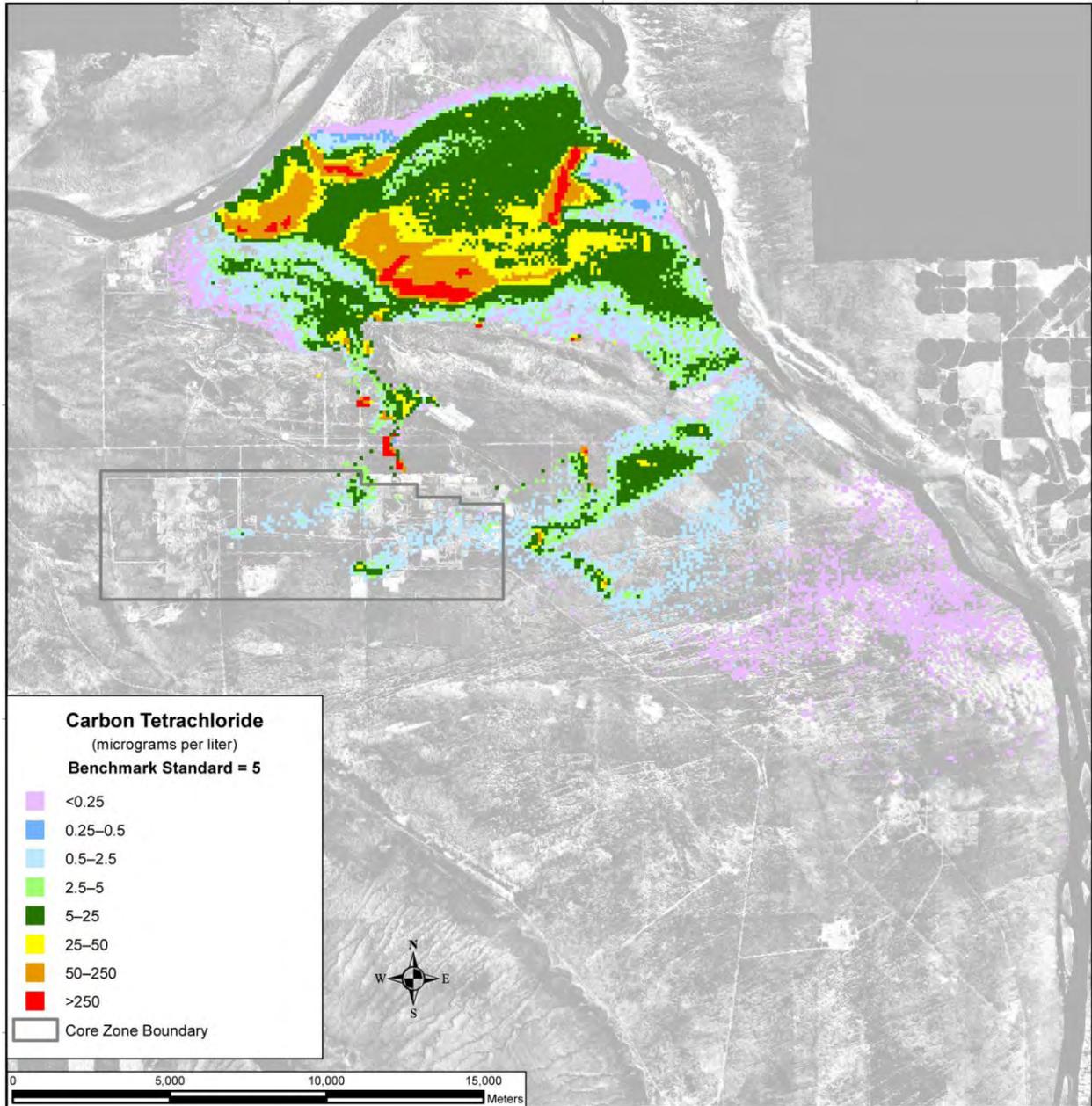


Figure 6–63. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Carbon Tetrachloride Concentration, Calendar Year 2135

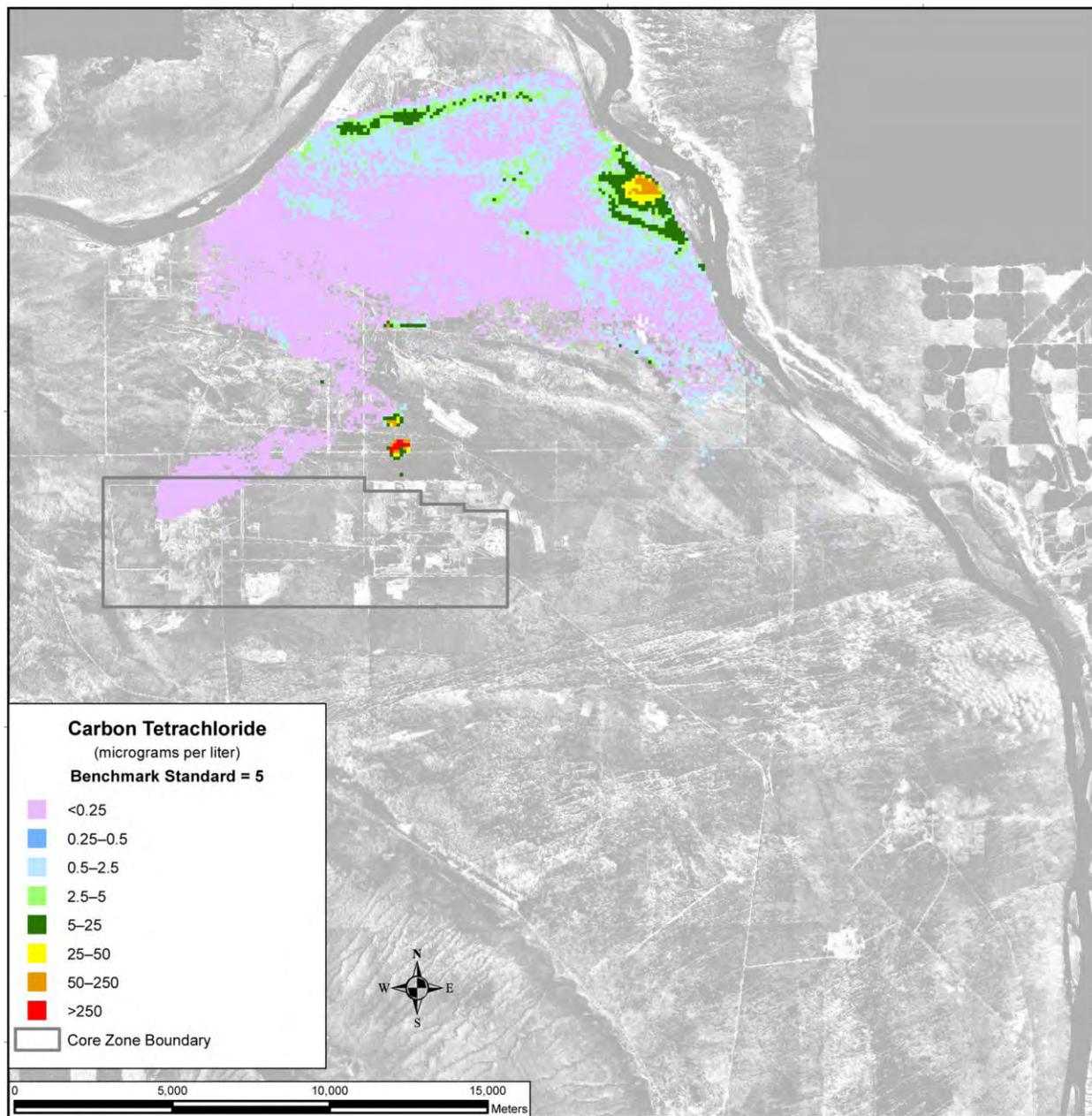


Figure 6–64. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Carbon Tetrachloride Concentration, Calendar Year 3890

Uranium-238 and total uranium show a different spatial distribution in groundwater 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 6–65 shows the distribution of uranium-238 in CY 2135. There are two small plumes associated with releases from the ponds (non-TC & WM EIS sources) in the 200-East and 200-West Areas. Peak concentrations in the 200-East Area are 1 to 5 times greater than benchmark; in the 200-West Area they are 10 to 50 times greater. By CY 3890 (see Figure 6–66), these plumes have dissipated, but releases from other tank farm sources (primarily within the A Barrier) have produced a second plume east of the Core Zone, with peak concentrations 3 to 10 times greater than the benchmark. By CY 11,885 (see Figure 6–67), the plumes

from other tank farm sources have extended this plume and produced additional plumes in the 200-West Area. Figure 6–68 shows the total area for which groundwater uranium-238 concentrations exceed the benchmark concentration as a function of time. The area of exceedance is largest early in the analysis (non-TC & WM EIS sources, primarily ponds) and continues on a downward trend toward the end of the period of analysis (other tank farm sources). Figures 6–69 through 6–71 show the corresponding spatial distributions for total uranium.

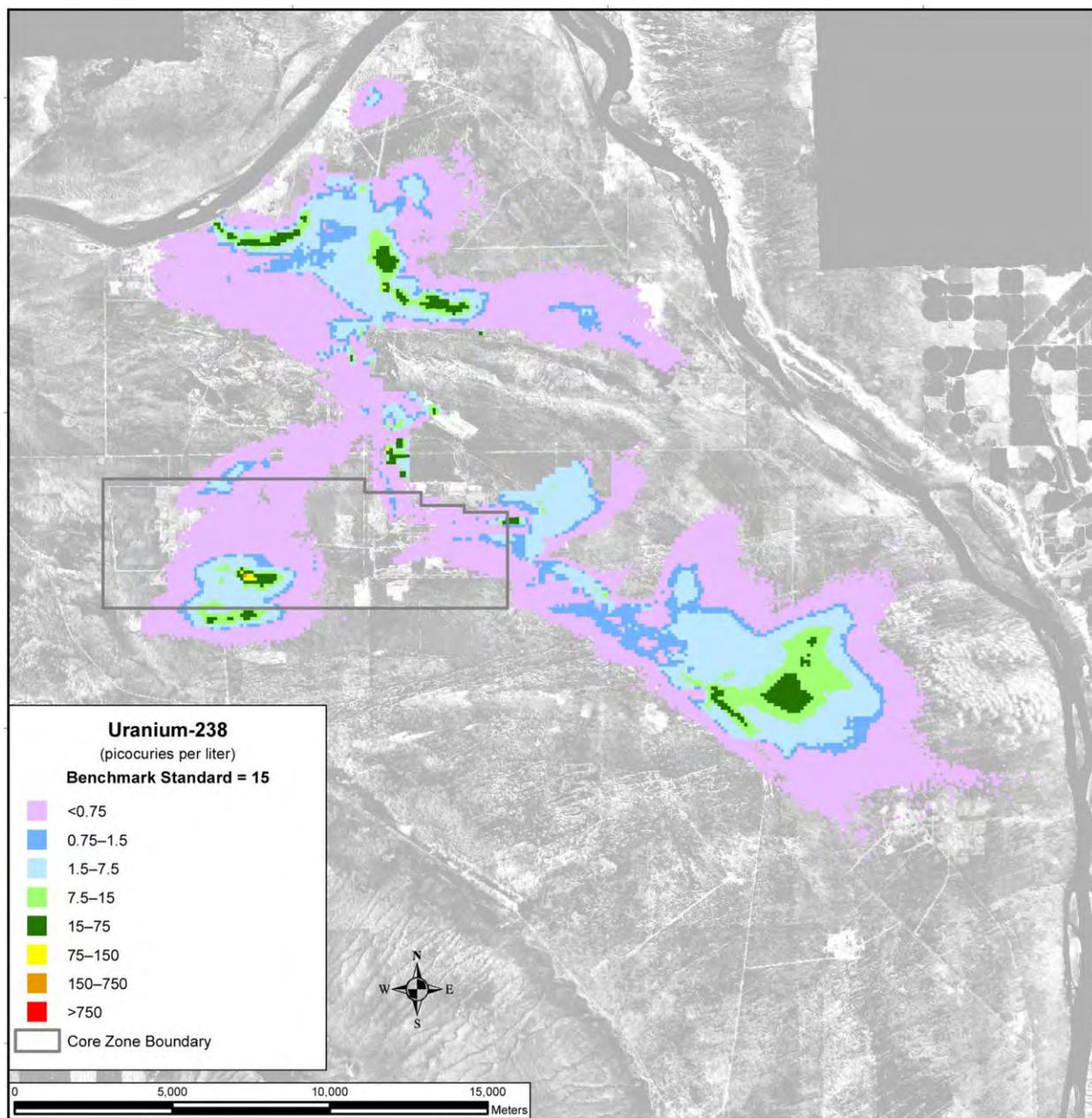


Figure 6–65. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Uranium-238 Concentration, Calendar Year 2135

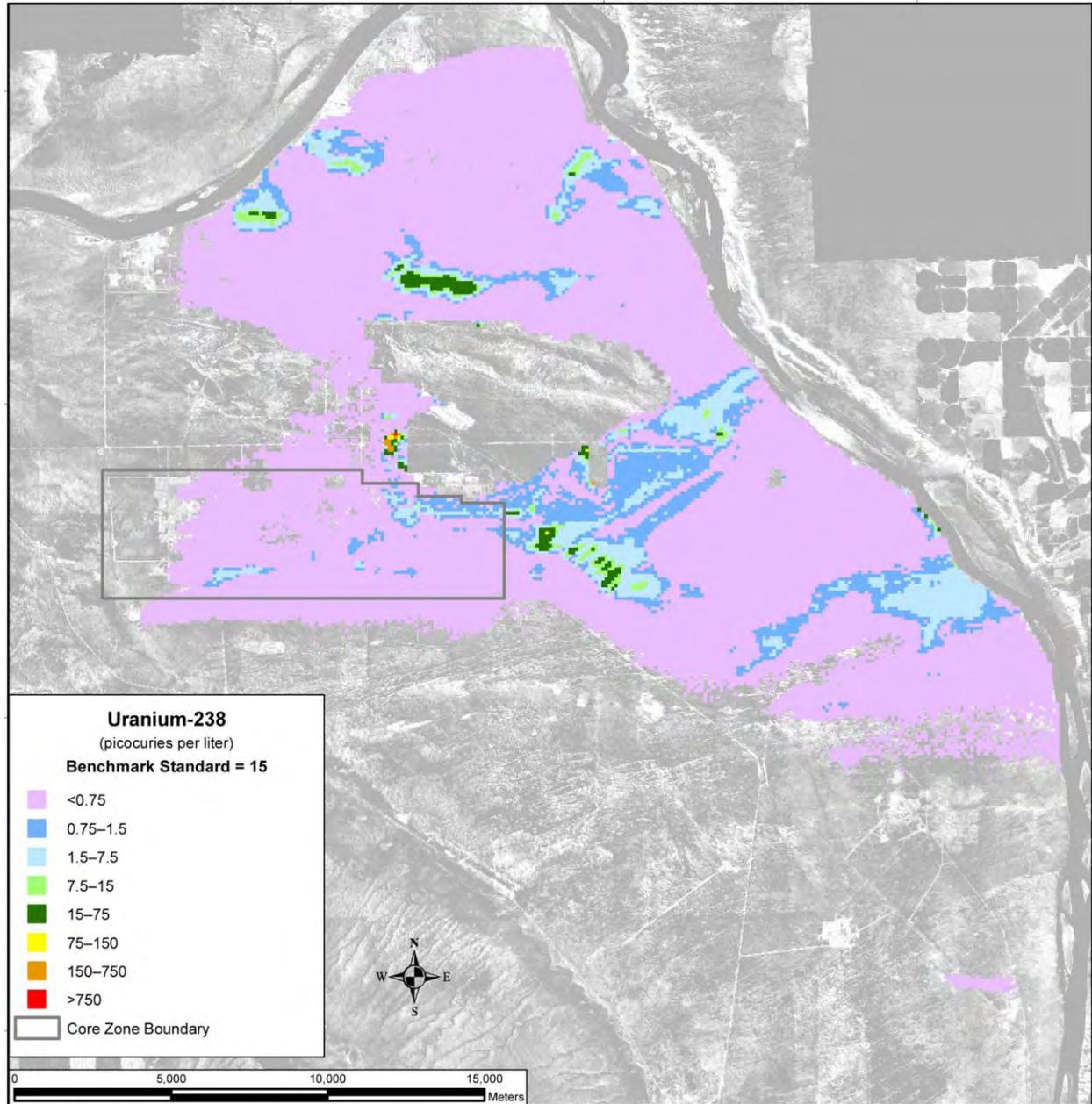
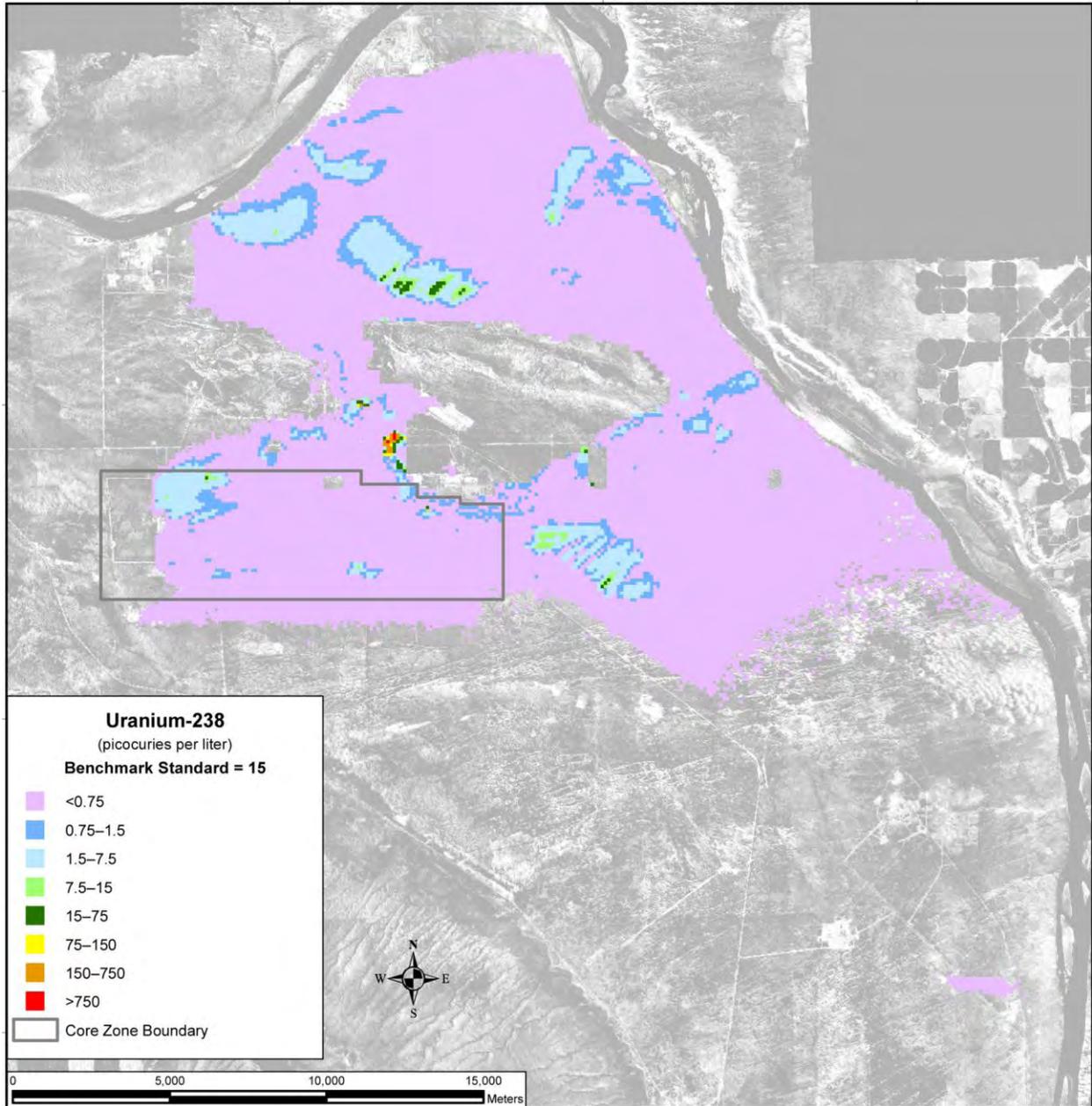
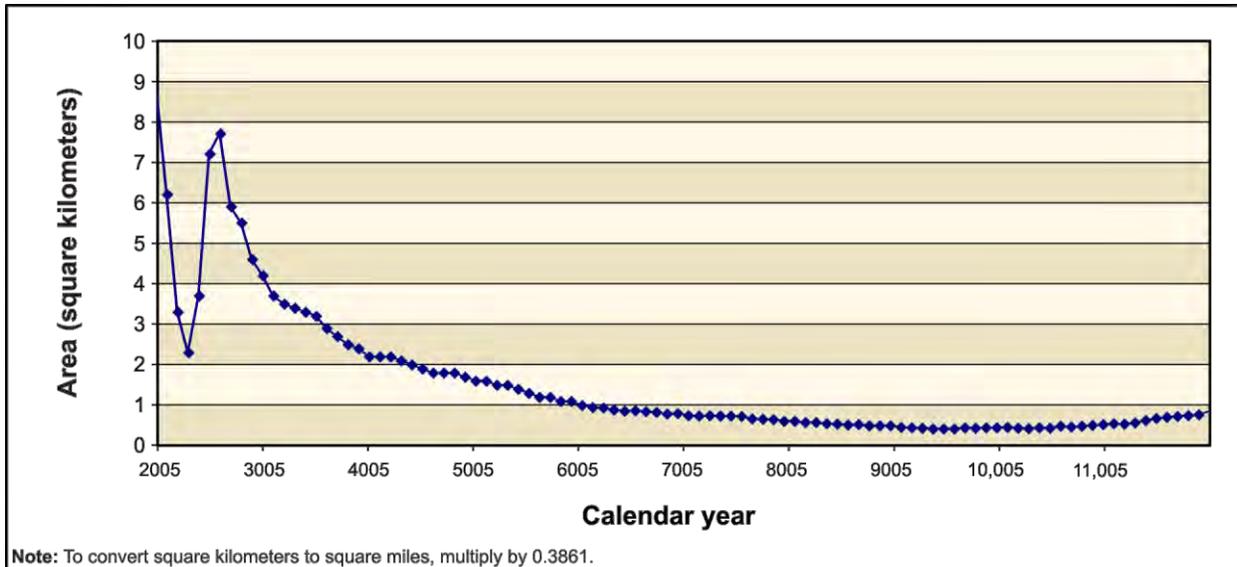


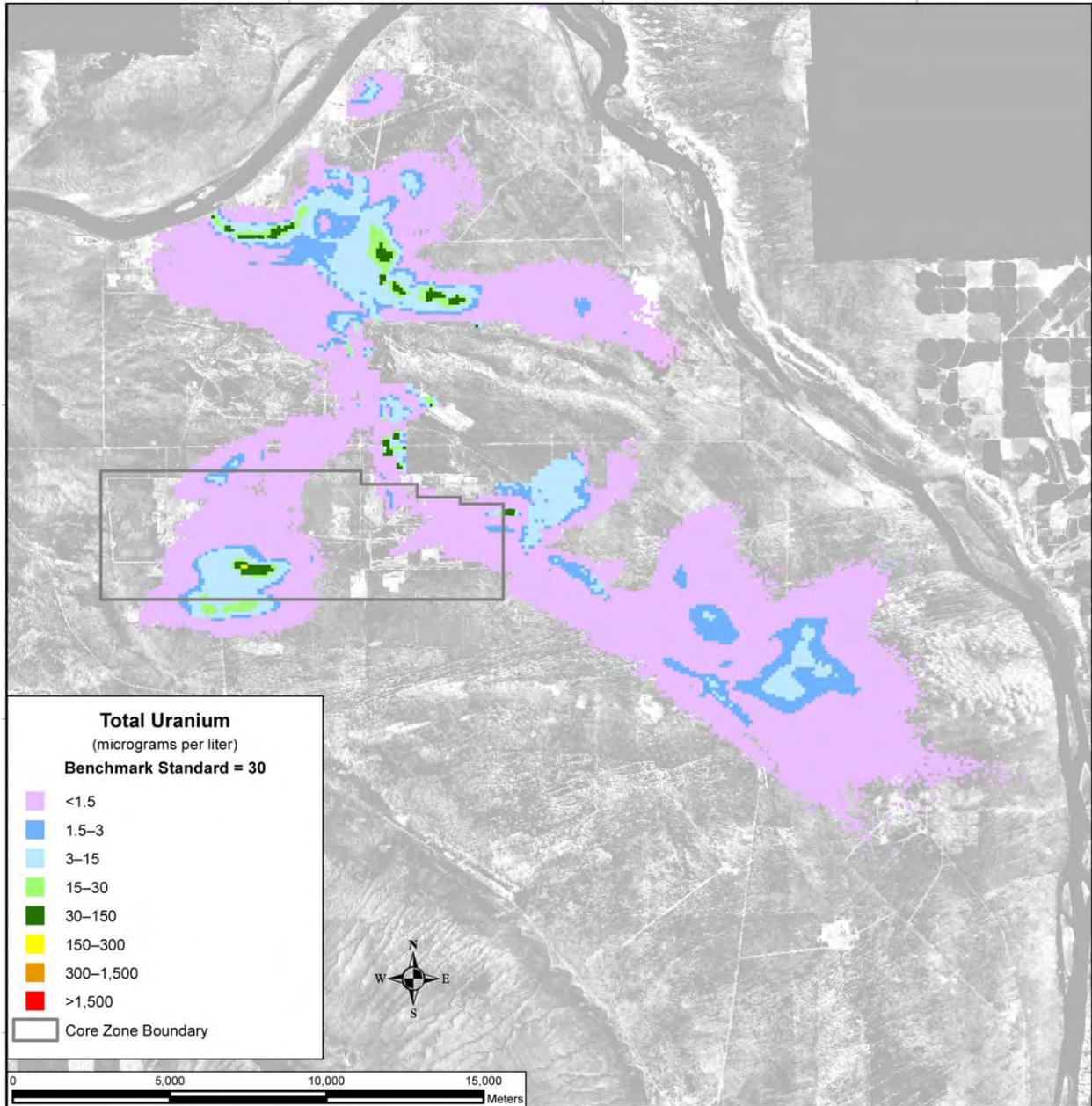
Figure 6–66. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Uranium-238 Concentration, Calendar Year 3890



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

Figure 6–67. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Uranium-238 Concentration, Calendar Year 11,885





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

Figure 6–69. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Total Uranium Concentration, Calendar Year 2135

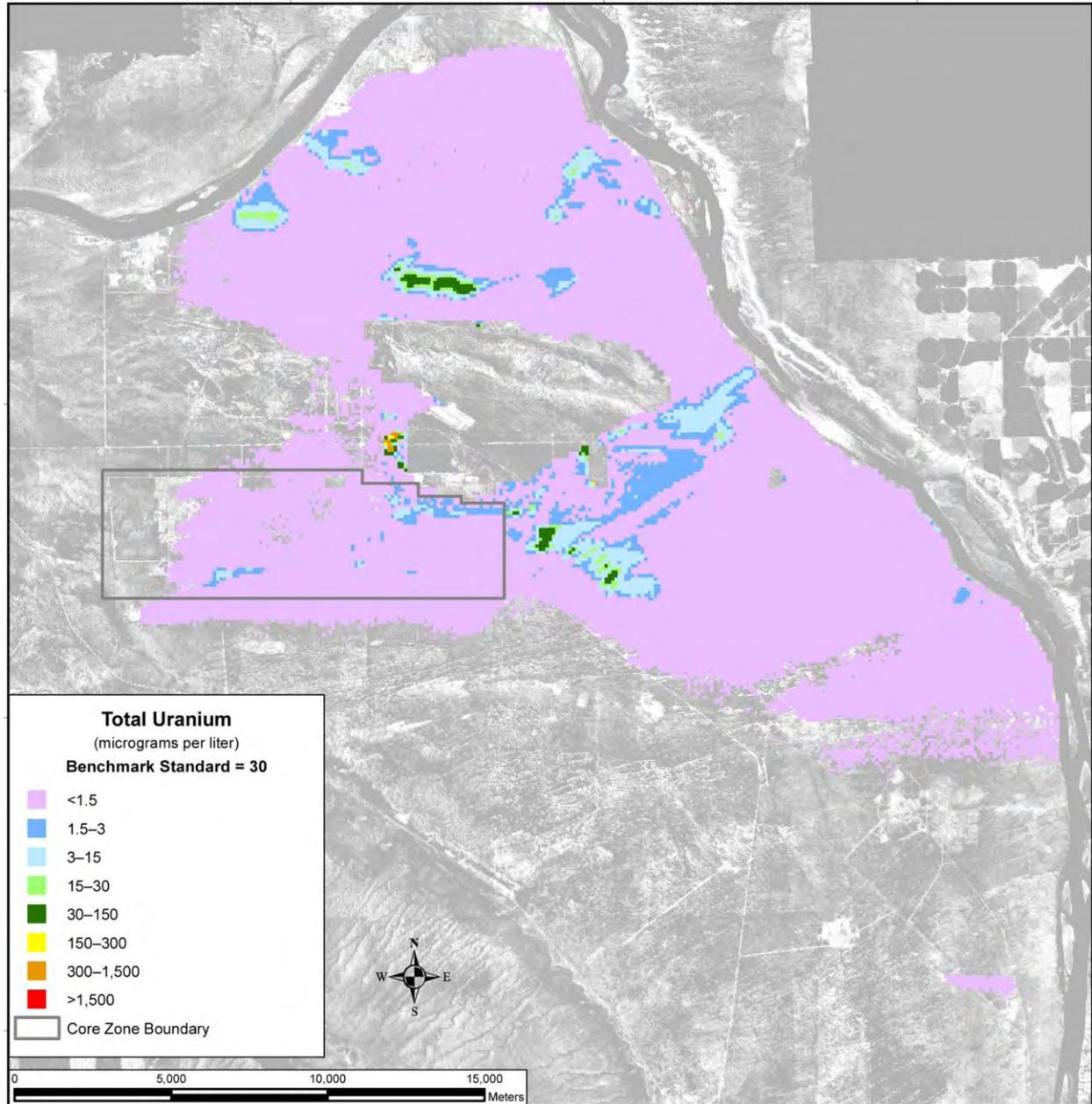
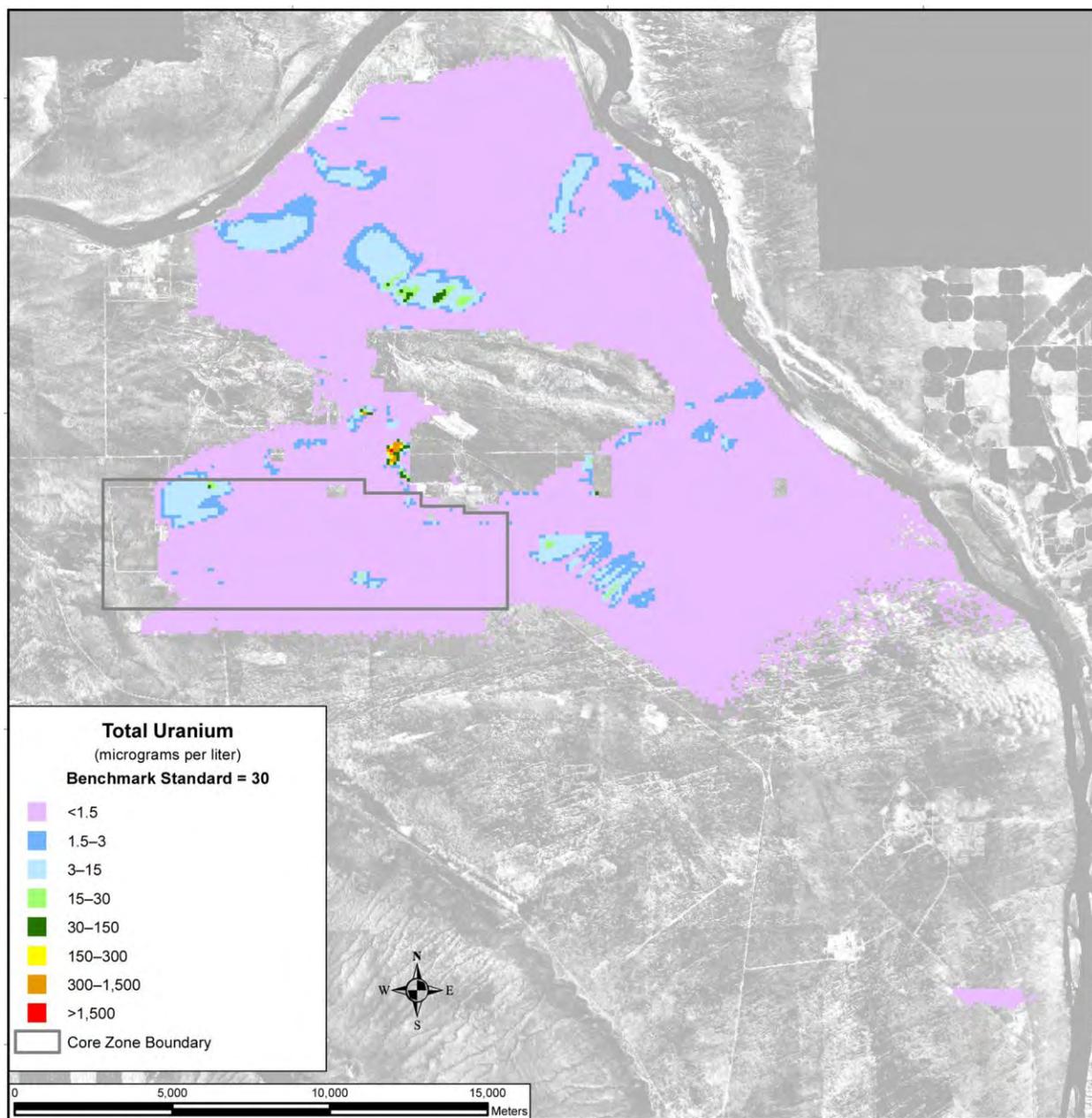


Figure 6-70. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Total Uranium Concentration, Calendar Year 3890



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

Figure 6-71. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Total Uranium Concentration, Calendar Year 11,885

6.4.1.3.4 Summary of Impacts

Long-term impacts figures in this chapter, Chapter 5, and Appendix U show how groundwater concentrations vary with time and space for cumulative impacts; Alternative Combinations 1, 2, and 3; and non-TC & WM EIS sources, respectively. The figures in these sections were compared to evaluate the relative contribution to cumulative impacts of the alternative combinations and non-TC & WM EIS sources and how they change over time. The results of this evaluation are briefly summarized below.

The long-term cumulative impacts of the scenario that includes Alternative Combination 2 on groundwater quality are dominated by non-*TC & WM EIS* sources (for releases of tritium, uranium-238, carbon tetrachloride, chromium, and total uranium); a combination of non-*TC & WM EIS* sources and Waste Management alternative sources (for releases of iodine-129); a combination of non-*TC & WM EIS* sources and tank closure sources (for releases of nitrate); or all three (for releases of technetium-99). COPC contributions from FFTF Decommissioning Alternative 2 sources account for well under 1 percent of the total amount of COPCs released to the environment.

Concentrations of tritium at the Core Zone Boundary exceed the benchmark by about three orders of magnitude during the first 100 years of the period of analysis. Concentrations at the Columbia River exceed the benchmark by about two orders of magnitude during this time. Attenuation by radioactive decay is a predominant mechanism that limits the intensity and duration of tritium's impacts on groundwater. After CY 2140, tritium's impacts are essentially negligible.

Concentrations of iodine-129, technetium-99, carbon tetrachloride, chromium, and nitrate at the Core Zone Boundary and Columbia River nearshore exceed benchmark standards by more than an order of magnitude during the past-practice period and drop significantly after that. By CY 5600, concentrations of all of these conservative tracers are below the benchmark concentration.

Discharges of uranium-238 and total uranium from the ponds (non-*TC & WM EIS* sources) are the dominant contributors during the early period of the analysis. Other tank farm sources are a secondary contributor, for which limited mobility is an important factor governing the timeframes and scale of groundwater impacts.

6.4.1.4 Alternative Combination 3

This section presents the results of the long-term cumulative groundwater impacts analysis for the scenario that includes Alternative Combination 3. This section focuses on the combined long-term groundwater impacts of Alternative Combination 3 sources, discussed in Chapter 5, Section 5.4, and non-*TC & WM EIS* sources, discussed in Appendix S. Alternative Combination 3 is composed of Tank Closure Alternative 6B (clean closure); FFTF Decommissioning Alternative 3 (removal); and Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case (disposal in IDF-East only).

This discussion of long-term impacts is focused on the following COPCs:

- Radiological risk drivers: tritium, iodine-129, technetium-99, and uranium-238
- Chemical hazard drivers: carbon tetrachloride, chromium, nitrate, and total uranium

The COPC drivers listed above comprise those from the three individual alternatives that make up Alternative Combination 3 and those from non-*TC & WM EIS* sources. They fall into three categories. Iodine-129, technetium-99, carbon tetrachloride, 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. Tritium is also mobile, but short lived. The half-life of tritium is about 12.3 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. The other COPCs that were analyzed do not significantly contribute to risk or hazard during the period of analysis because of limited inventory, high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of these factors. The level of protection provided for the drinking water pathway was evaluated by comparison against EPA maximum contaminant levels (40 CFR 141) and other benchmarks presented in Appendix O.

6.4.1.4.1 Analysis of Release and Mass Balance

This section presents the total amount of the COPC drivers released to the vadose zone, to groundwater, and to the Columbia River. Releases of radionuclides are totaled in curies; chemicals, in kilograms. Both are totaled over the 10,000-year period of analysis.

Table 6–20 lists the release of COPC drivers to the vadose zone. The release of COPCs from Alternative Combination 3 sources to the vadose zone is controlled by a combination of inventory and waste form. The entire inventory of tank closure and FFTF decommissioning sources was released to the vadose zone during the period of analysis. The inventories of some waste management sources (e.g., ILAW glass) were not fully released to the vadose zone during the 10,000-year period of analysis because of retention in the waste form. The release of COPCs from Alternative Combination 3 and non-TC & WM EIS sources to the vadose zone is dominated by non-TC & WM EIS sources for tritium, uranium-238, chromium, and total uranium; by non-TC & WM EIS and waste management sources for iodine-129; by non-TC & WM EIS sources and tank closure sources for nitrate; and by a combination of all three types of sources for technetium-99.

Table 6–20. Alternative Combination 3 Releases of COPC Drivers to Vadose Zone

Source	Radioactive COPCs (curies)				Chemical COPCs (kilograms)		
	Hydrogen-3 (Tritium)	Technetium-99	Iodine-129	Uranium-238	Chromium ^a	Nitrate	Total Uranium
Other activities	2.38×10 ⁶	1.17×10 ³	1.15×10 ¹	3.60×10 ³	3.52×10 ⁵	7.62×10 ⁷	7.08×10 ⁶
Tank Closure Alternative 6B, Base Case	4.57×10 ⁴	4.05×10 ²	7.46×10 ⁻¹	2.10×10 ¹	9.04×10 ⁴	2.55×10 ⁷	2.19×10 ⁴
FFTF Decommissioning Alternative 3	2.96×10 ⁻⁶	4.52×10 ⁻⁶	0	0	0	0	0
Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case	5.94×10 ⁴	2.19×10 ³	5.25	3.58×10 ²	6.39×10 ³	9.45×10 ⁶	9.92×10 ³
Total	2.48×10⁶	3.77×10³	1.75×10¹	3.98×10³	4.49×10⁵	1.11×10⁸	7.11×10⁶

^a It was assumed, for analysis purposes, that all chromium was hexavalent.

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: COPC=constituent of potential concern; FFTF=Fast Flux Test Facility.

Table 6–21 lists the release of COPC drivers to groundwater. In addition to the inventory consideration discussed in the previous paragraph, the 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 iodine-129, technetium-99, chromium, and nitrate, the amount released to groundwater is essentially equal to the amount released to the vadose zone. For tritium, the amount released to groundwater is attenuated by radioactive decay during transit through the vadose zone. About 83 percent of the tritium released to the vadose zone reaches the unconfined aquifer. Because of retardation, less than 5 percent of the uranium-238 and 18 percent of the total uranium released to the vadose zone reach the unconfined aquifer during the period of analysis.

Table 6–21. Alternative Combination 3 Releases of COPC Drivers to Groundwater

Source	Radioactive COPCs (curies)				Chemical COPCs (kilograms)		
	Hydrogen-3 (Tritium)	Technetium-99	Iodine-129	Uranium-238	Chromium ^a	Nitrate	Total Uranium
Other activities	2.03×10 ⁶	1.15×10 ³	1.14×10 ¹	2.16×10 ²	3.57×10 ⁵	7.66×10 ⁷	1.31×10 ⁵
Tank Closure Alternative 6B, Base Case	3.12×10 ⁴	3.66×10 ²	6.56×10 ⁻¹	5.83×10 ⁻¹	9.21×10 ⁴	2.62×10 ⁷	2.02×10 ²
FFTF Decommissioning Alternative 3	1.91×10 ⁻⁷	4.54×10 ⁻⁶	0	0	0	0	0
Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case	0.00	1.93×10 ³	3.72	4.83×10 ⁻⁶	6.37×10 ³	9.39×10 ⁶	1.36×10 ⁻²
Total	2.06×10⁶	3.44×10³	1.58×10¹	2.17×10²	4.56×10⁵	1.12×10⁸	1.31×10⁵

^a It was assumed, for analysis purposes, that all chromium was hexavalent.

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: COPC=constituent of potential concern; FFTF=Fast Flux Test Facility.

Table 6–22 lists the release of COPC drivers to the Columbia River. The release to the Columbia River is controlled by the transport properties of the COPC drivers in the unconfined aquifer. For iodine-129, technetium-99, chromium, nitrate, and uranium-238, 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 4 percent of the tritium released to groundwater reaches the Columbia River. Because of retardation, about 88 percent of the uranium-238 and total uranium released to groundwater during the period of analysis reach the Columbia River.

Table 6–22. Alternative Combination 3 Releases of COPC Drivers to Columbia River

Source	Radioactive COPCs (curies)				Chemical COPCs (kilograms)		
	Hydrogen-3 (Tritium)	Technetium-99	Iodine-129	Uranium-238	Chromium ^a	Nitrate	Total Uranium
Other activities	7.21×10 ⁴	1.15×10 ³	1.14×10 ¹	2.12×10 ²	3.77×10 ⁵	7.90×10 ⁷	1.15×10 ⁵
Tank Closure Alternative 6B, Base Case	3.90×10 ²	3.63×10 ²	6.51×10 ⁻¹	2.26×10 ⁻¹	9.45×10 ⁴	2.70×10 ⁷	7.26×10 ¹
FFTF Decommissioning Alternative 3	0	4.55×10 ⁻⁶	0	0	0	0	0
Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case	0	1.91×10 ³	3.66	0	6.35×10 ³	9.37×10 ⁶	5.70×10 ⁻⁴
Total	7.25×10⁴	3.42×10³	1.57×10¹	2.13×10²	4.78×10⁵	1.15×10⁸	1.15×10⁵

^a It was assumed, for analysis purposes, that all chromium was hexavalent.

Note: To convert kilograms to pounds, multiply by 2.2046.

Key: COPC=constituent of potential concern; FFTF=Fast Flux Test Facility.

6.4.1.4.2 Analysis of Concentration Versus Time

This section presents the contaminant concentrations in groundwater versus time at the Core Zone Boundary and the Columbia River. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over five orders of magnitude. Table 6–23 lists the maximum COPC concentrations at the Core Zone Boundary and the Columbia River nearshore in the peak year of the 10,000-year period of analysis. Comparison of the results in Table 6–11 (non-*TC & WM EIS* sources only) with the results in Table 6–23 (cumulative with Alternative Combination 3 sources) shows that the peak concentrations of some of the COPC drivers do not change with the addition of Tank Closure Alternative 6B, FFTF Decommissioning Alternative 3, and Waste Management Alternative 2 (Disposal Group 2, Subgroup 2-B) sources. This indicates that these peaks are driven primarily by the non-*TC & WM EIS* sources. These COPC drivers include tritium, iodine-129, uranium-238, carbon tetrachloride, chromium, and total uranium. For other COPC drivers, primarily technetium-99, the *TC & WM EIS* alternative sources are the dominant contributor with respect to peak concentration. Finally, for nitrate, contributions from *TC & WM EIS* alternative sources and non-*TC & WM EIS* sources are approximately equal contributors to peak concentration.

Table 6–23. Alternative Combination 3 Maximum Cumulative Groundwater COPC Concentrations^a

Contaminant	Core Zone Boundary (peak year)	Columbia River Nearshore (peak year)	Benchmark Concentration ^b
Radionuclide (picocuries per liter)			
Hydrogen-3 (tritium)	112,000,000 (1997)	4,140,000 (1986)	20,000
Carbon-14	1,090 (1998)	5 (1992)	2,000
Strontium-90	1,730 (1998)	27,600 (1991)	8
Technetium-99	33,700 (1956)	868 (1965)	900
Iodine-129	42.3 (1956)	20.0 (2017)	1
Cesium-137	0 N/A	1,430 (1985)	200
Uranium isotopes (includes uranium-233, -234, -235, -238)	839 (1959)	6,190 (1979)	15
Neptunium-237	7 (2061)	2 (3662)	15
Plutonium isotopes (includes plutonium-239, -240)	26 (7725)	2 (1991)	15

**Table 6–23. Alternative Combination 3 Maximum Cumulative Groundwater
COPC Concentrations^a (continued)**

Contaminant	Core Zone Boundary (peak year)	Columbia River Nearshore (peak year)	Benchmark Concentration ^b
Chemical (micrograms per liter)			
1-Butanol	518 (1998)	2 (3891)	3,600
Boron and compounds	0.2 (3270)	1 (2364)	7,000
Carbon tetrachloride	577 (2035)	208 (2067)	5
Chromium ^c	13,400 (1959)	7,210 (1979)	100
Dichloromethane	0.2 (3321)	0.1 (3923)	5
Fluoride	160,000 (2008)	30,600 (2032)	4,000
Hydrazine/hydrazine sulfate	0.009 (3308)	0.043 (3281)	0.022
Lead	0 N/A	32 (2397)	15
Manganese	93 (3705)	0.4 (2223)	1,600
Mercury	1.7 (2016)	0.002 (10,973)	2
Nitrate	2,130,000 (1956)	846,000 (1976)	45,000
Total uranium	1,220 (1959)	1,910 (1979)	30
Trichloroethylene (TCE)	0.02 (3220)	0.07 (3297)	5

^a The peak cumulative concentration of some constituents occurred in the past. The relationship of past to future cumulative constituent concentrations is presented in the concentration-versus-time plots in Figures 6–72 through 6–79.

^b The sources of the benchmark concentrations are provided in Appendix O, Section O.3.

^c It was assumed, for analysis purposes, that all chromium was hexavalent.

Key: COPC=constituent of potential concern; N/A=not applicable.

Figure 6–72 shows concentration versus time for tritium. Note that, for visual clarity, the time period shown in this figure is from 1940 through 2440 rather than the full 10,000-year period of analysis. Tritium concentrations at the Core Zone Boundary exceed the benchmark concentration by about three orders of magnitude for a short period of time during the early part of the period of analysis. During this time, groundwater concentrations at the Columbia River nearshore peak at about two orders of magnitude above the benchmark concentration. *TC & WM EIS* sources contribute to the tritium releases, but the concentrations approach four orders of magnitude greater than the benchmark concentration because of the additional contributions from non-*TC & WM EIS* sources. Because the half-life of tritium is less than 13 years, radioactive decay rapidly attenuates groundwater concentration; thus, tritium is essentially not a factor beyond CY 2140.

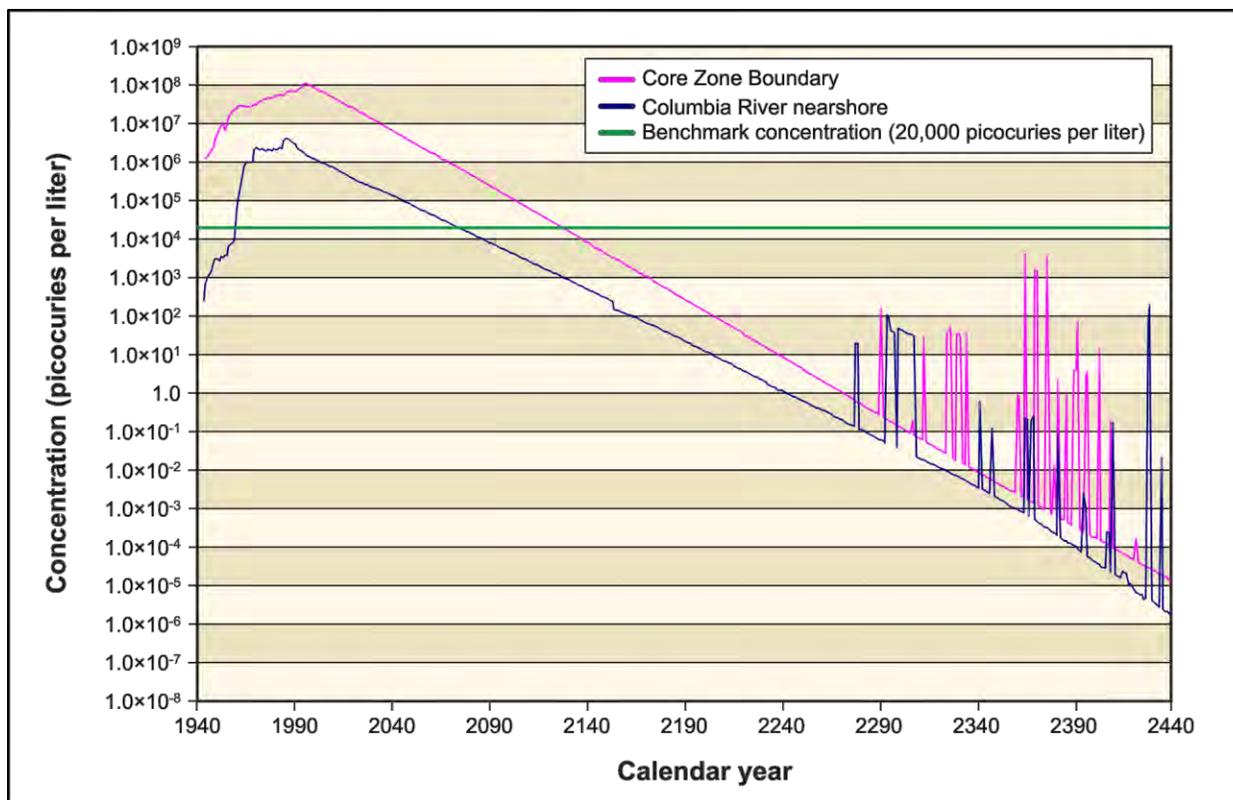


Figure 6-72. Alternative Combination 3 Cumulative Hydrogen-3 (Tritium) Concentration Versus Time

Figures 6-73 through 6-77 show concentration versus time for iodine-129, technetium-99, carbon tetrachloride, chromium, and nitrate. Groundwater concentrations of these conservative tracers at the Core Zone Boundary and Columbia River nearshore exceed benchmark concentrations by more than an order of magnitude during the past-practice period. For some of the COPC drivers (iodine-129, chromium, nitrate), concentrations during the past-practice period are higher because of the additional contributions from non-TC & WMEIS sources. After the past-practice period, concentrations of iodine-129 rise again between around CY 3900 and CY 5100, before dropping below benchmark concentrations for the remainder of the period of analysis. The broad peak in the iodine-129 concentration-versus-time curve at approximately CY 4000 is attributable to US Ecology. The impact of this site is discussed in more detail in Appendix U. Concentrations of technetium-99, chromium, and nitrate all fall well below benchmark concentrations by CY 2500 and for the remainder of the period of analysis. After the peak around CY 2030, concentrations of carbon tetrachloride at the Core Zone Boundary drop, reaching the benchmark concentration around CY 2140, and continue to drop rapidly after that time. Concentrations at the Columbia River nearshore drop at a more gradual rate, attaining the benchmark concentration around CY 5600, and remain below the benchmark concentration for the remainder of the period of analysis.

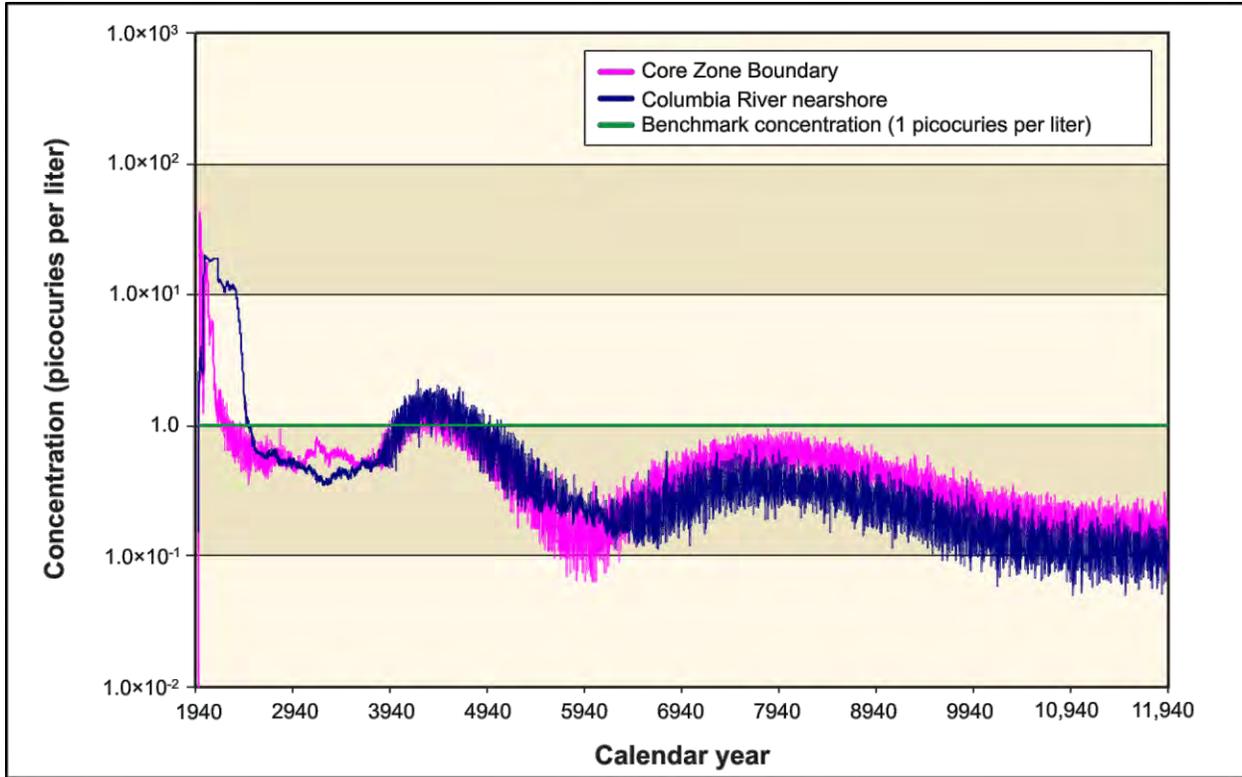


Figure 6-73. Alternative Combination 3 Cumulative Iodine-129 Concentration Versus Time

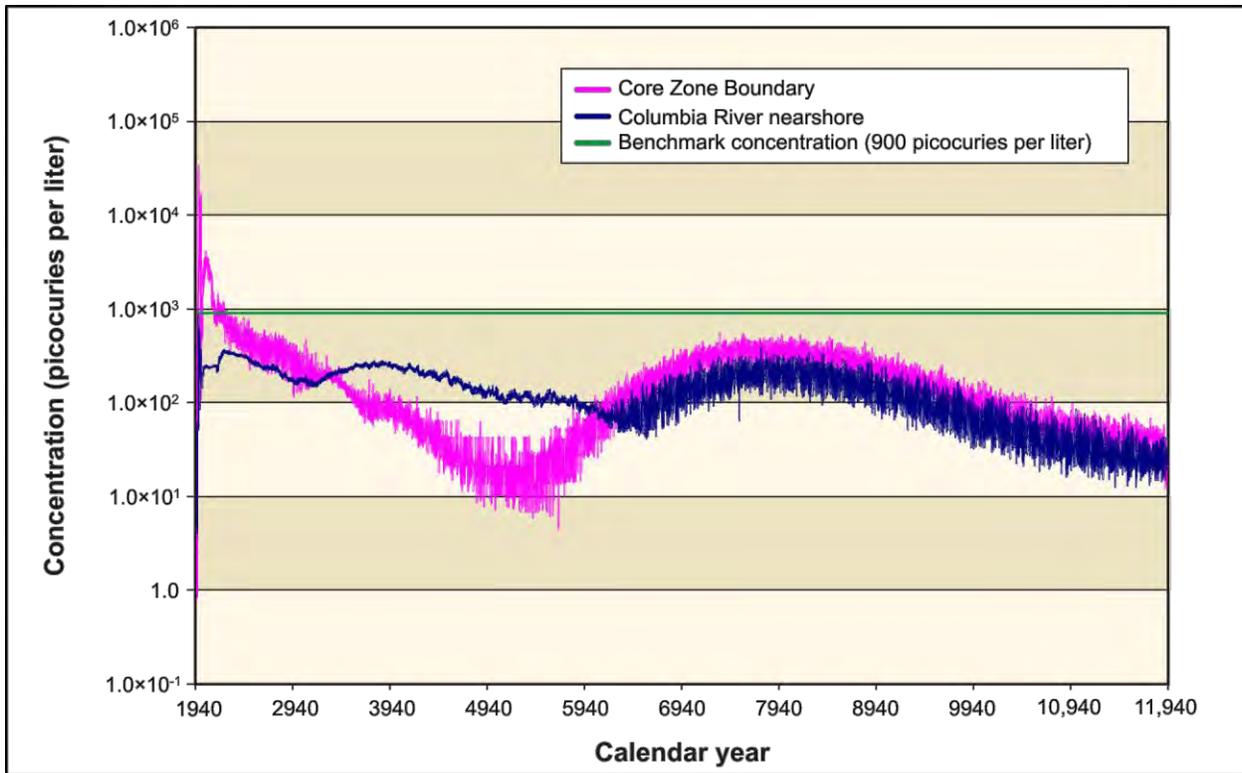


Figure 6-74. Alternative Combination 3 Cumulative Technetium-99 Concentration Versus Time

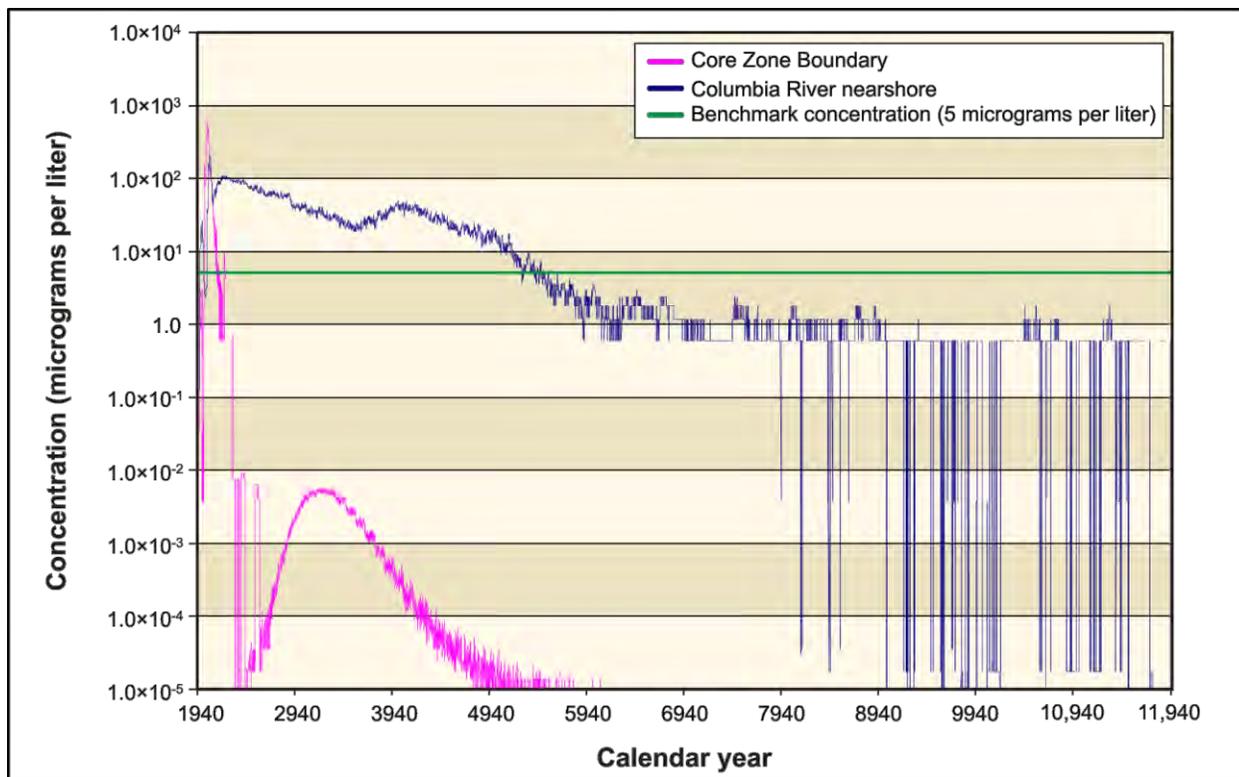


Figure 6–75. Alternative Combination 3 Cumulative Carbon Tetrachloride Concentration Versus Time

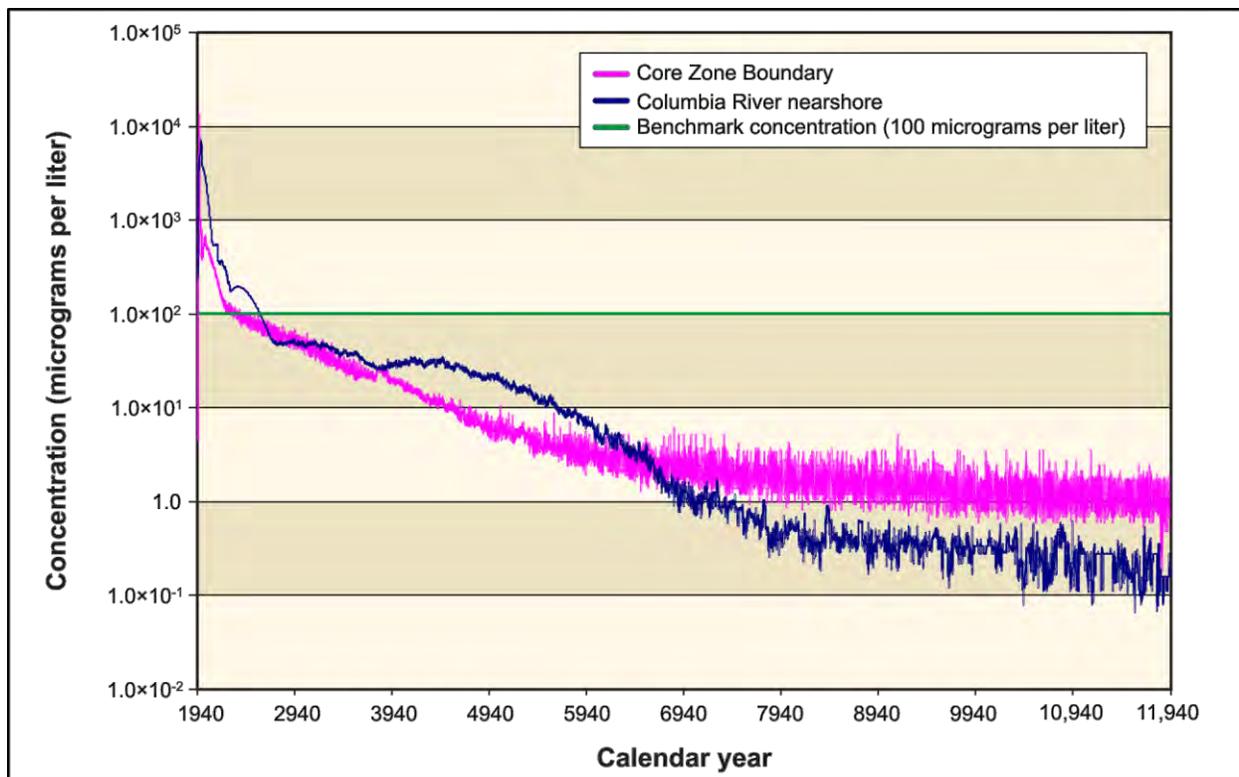


Figure 6–76. Alternative Combination 3 Cumulative Chromium Concentration Versus Time

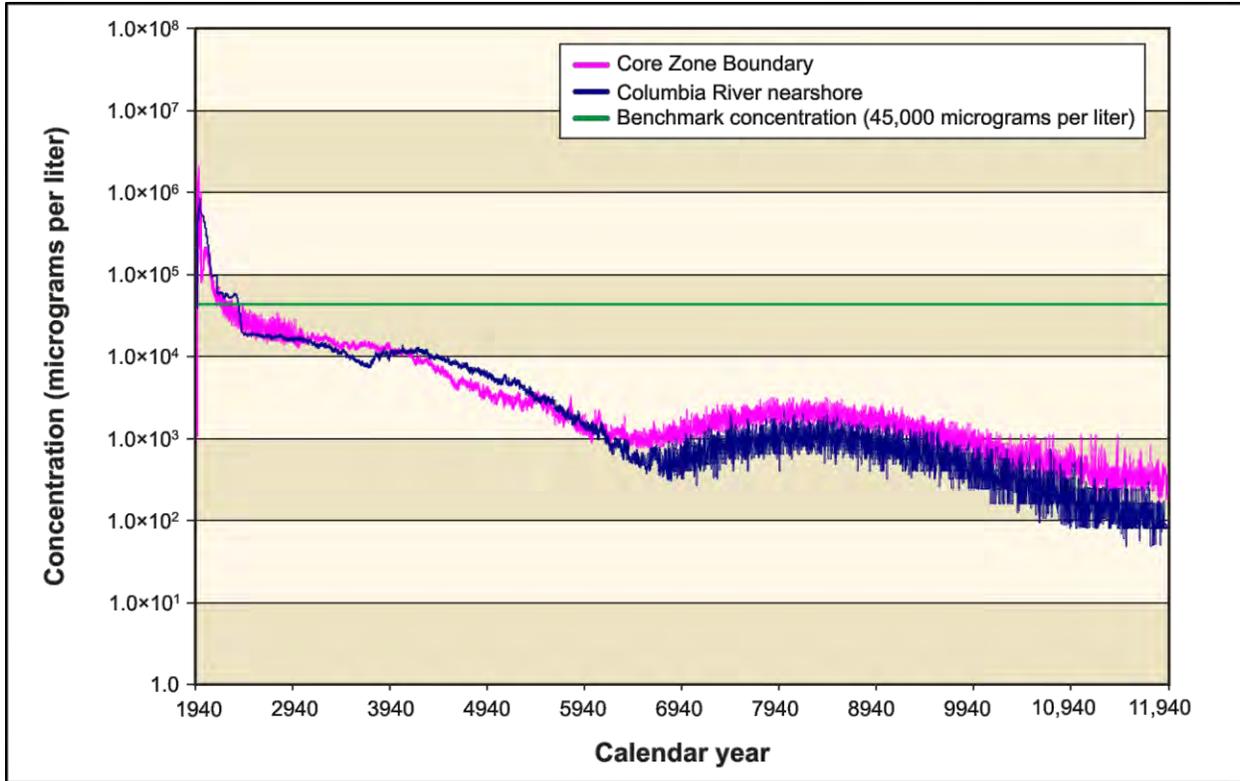


Figure 6-77. Alternative Combination 3 Cumulative Nitrate Concentration Versus Time

Figures 6-78 and 6-79 show concentration versus time for uranium-238 and total uranium. The travel times of these COPCs from the source locations to the Core Zone Boundary and Columbia River are about seven times slower than groundwater flow. Concentrations of uranium-238 and total uranium peak early in the period of analysis to more than two orders of magnitude above benchmark concentrations, then drop sharply, with the Columbia River nearshore reaching the benchmark around CY 2500 for uranium-238 and around CY 2200 for total uranium. Contributions from non-TC & WM EIS sources result in the higher concentrations at the Core Zone Boundary and Columbia River nearshore early in the past-practice period. Both uranium-238 and total uranium drop below the benchmark concentrations around CY 2800 and remain below that for the remainder of the period of analysis.

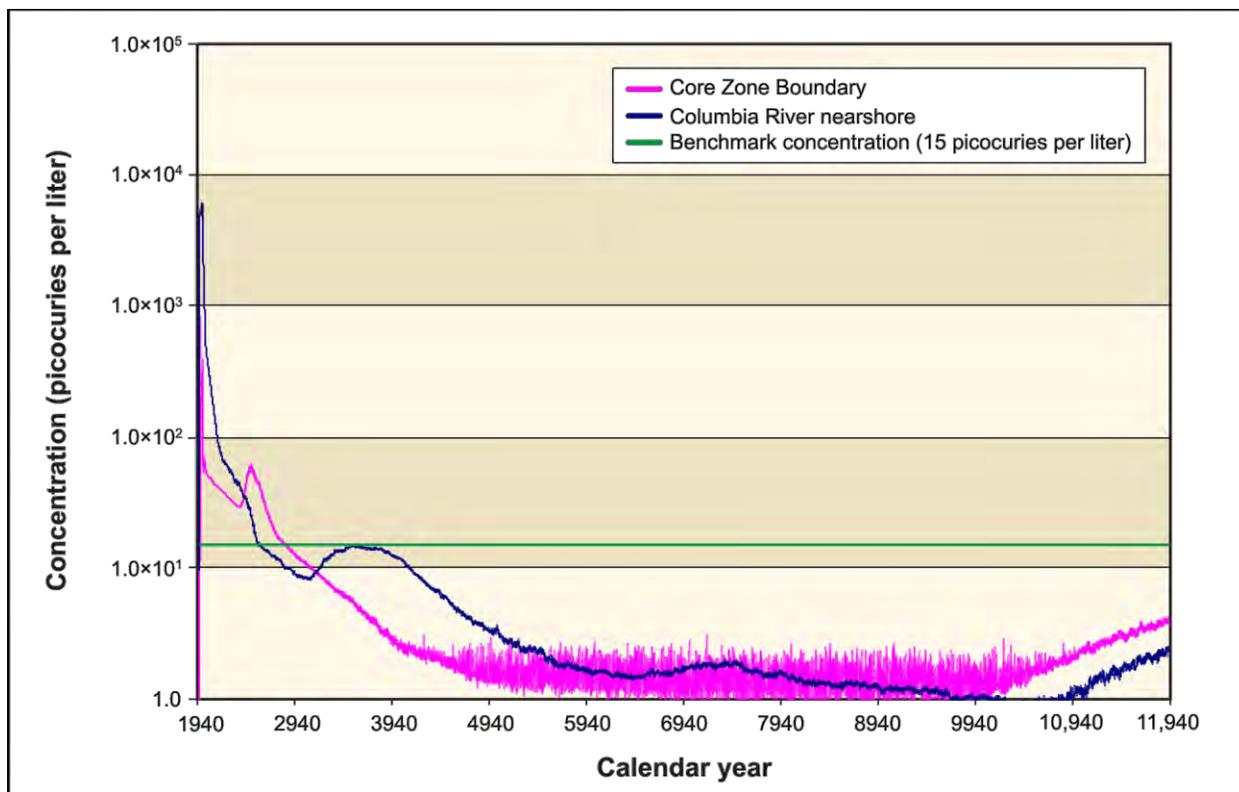


Figure 6–78. Alternative Combination 3 Cumulative Uranium-238 Concentration Versus Time

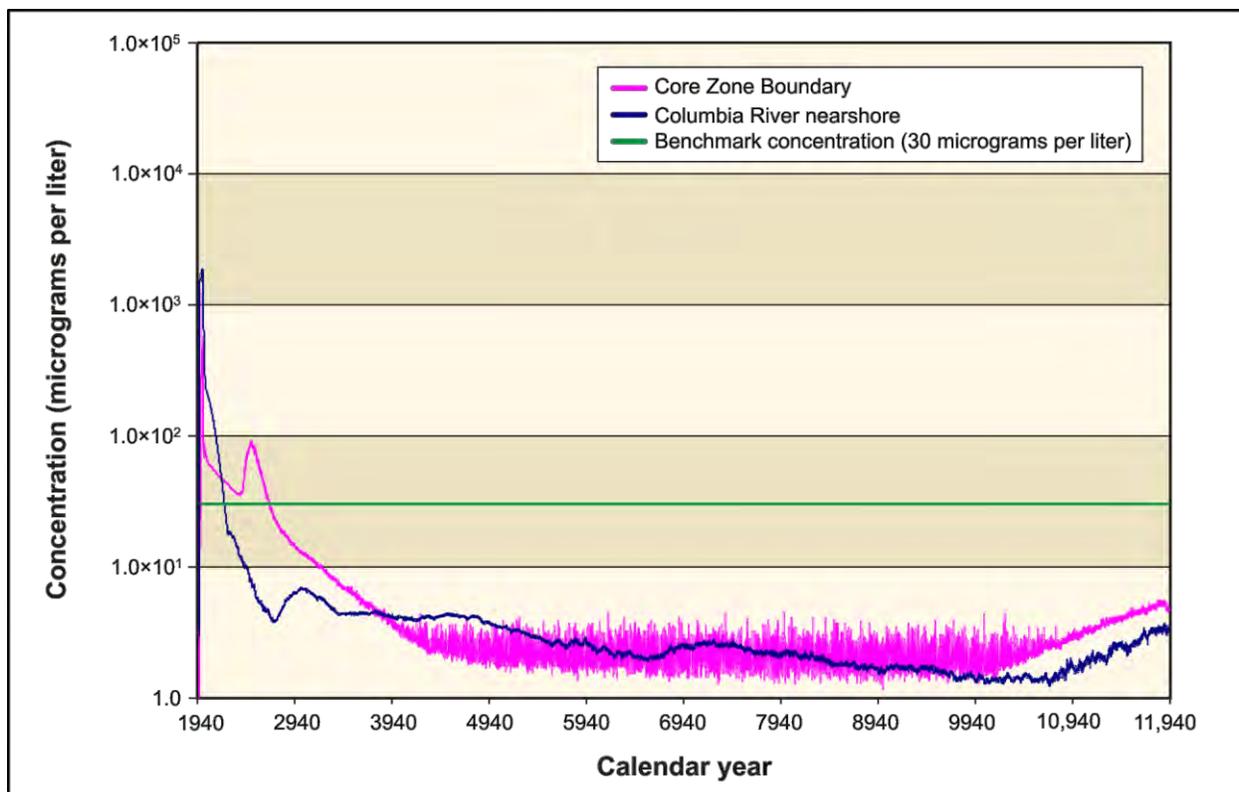


Figure 6–79. Alternative Combination 3 Cumulative Total Uranium Concentration Versus Time

6.4.1.4.3 Analysis of Spatial Distribution of Concentration

This section presents the spatial distribution of contaminant concentrations in groundwater at selected times. 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 6–80 shows the spatial distribution of tritium concentrations in groundwater in CY 2010 and contrasts the behavior of the releases from *TC & WM EIS* and non-*TC & WM EIS* sources. The release from *TC & WM EIS* sources results from cribs and trenches (ditches) and past tank leaks and is evident as the plume originating at the center of the 200-West Area and crossing the northern Core Zone Boundary. Tritium concentrations in this plume are up to 10 times the benchmark concentration. The remaining areas of tritium contamination are the result of releases from non-*TC & WM EIS* sources. These primary sources include the REDOX Facility plume originating in the southern portion of the 200-West Area and the PUREX Plant plume that originates at the eastern edge of the Core Zone Boundary and continues toward the Columbia River to the southeast. Peak concentrations in these plumes are up to 50 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.

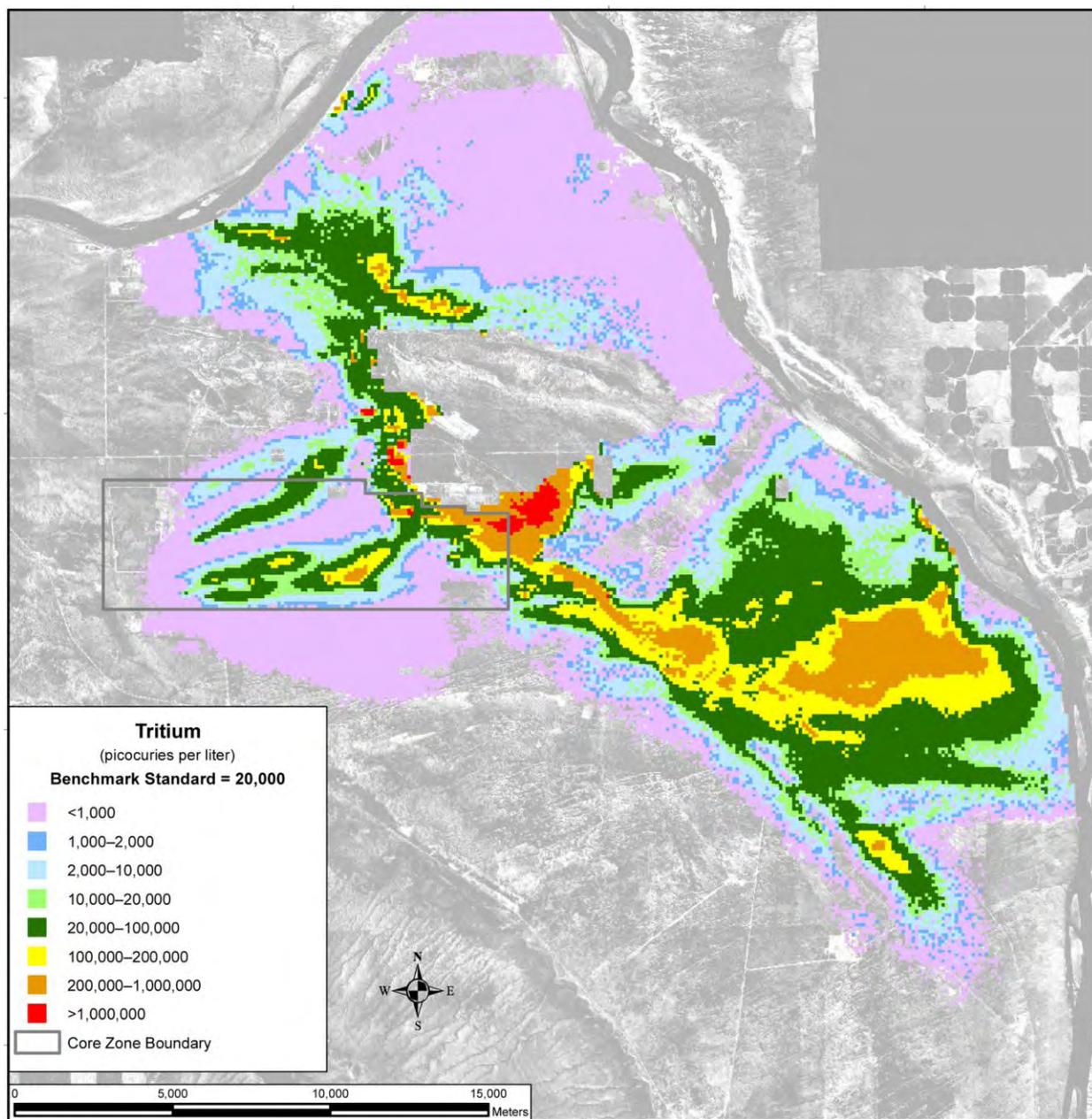


Figure 6–80. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Hydrogen-3 (Tritium) Concentration, Calendar Year 2010

Figure 6–81 shows the spatial distribution of iodine-129 concentrations in groundwater in CY 2010. Releases from cribs and trenches (ditches) and past leaks associated with the A, B, S, and T Barriers result in groundwater concentration plumes that exceed the benchmark concentration. Peak concentrations in this plume are about 10 to 50 times greater than the benchmark and are mostly contained within the Core Zone. The plume along the southern Core Zone Boundary is associated with the REDOX Facility, a non-TC & WMEIS source. Releases from the PUREX Plant area (another non-TC & WMEIS source) produce a plume extending south and east of the Core Zone, with peak concentrations about 1 to 5 times the benchmark concentration. Around CY 3890, releases from other tank farm sources create an iodine-129 plume east of the Core Zone Boundary (see Figure 6–82). By CY 7140, the groundwater concentration distribution is driven primarily by waste management sources

located at IDF-East (see Figure 6–83). The impact is characterized by a plume located east of the Core Zone with peak concentrations at 10 to 50 times the benchmark concentrations. Because of retention in the waste forms, this impact lasts to the end of the 10,000-year period of analysis (see Figure 6–84). Figure 6–85 shows the total area for which groundwater iodine-129 concentrations exceed the benchmark concentration as a function of time. The early intense peak where the area over the benchmark concentration is approximately 50 square kilometers (19 square miles) is related to non-TC & WM EIS releases during the past-practice period. The contaminated area decreases rapidly during the retrieval and post-administrative control period, and the secondary peak between CYs 4000 and 5000 is driven primarily by releases from other tank farm sources. Other tank farm sources include tank farm residuals, ancillary equipment, retrieval losses, and unplanned releases.

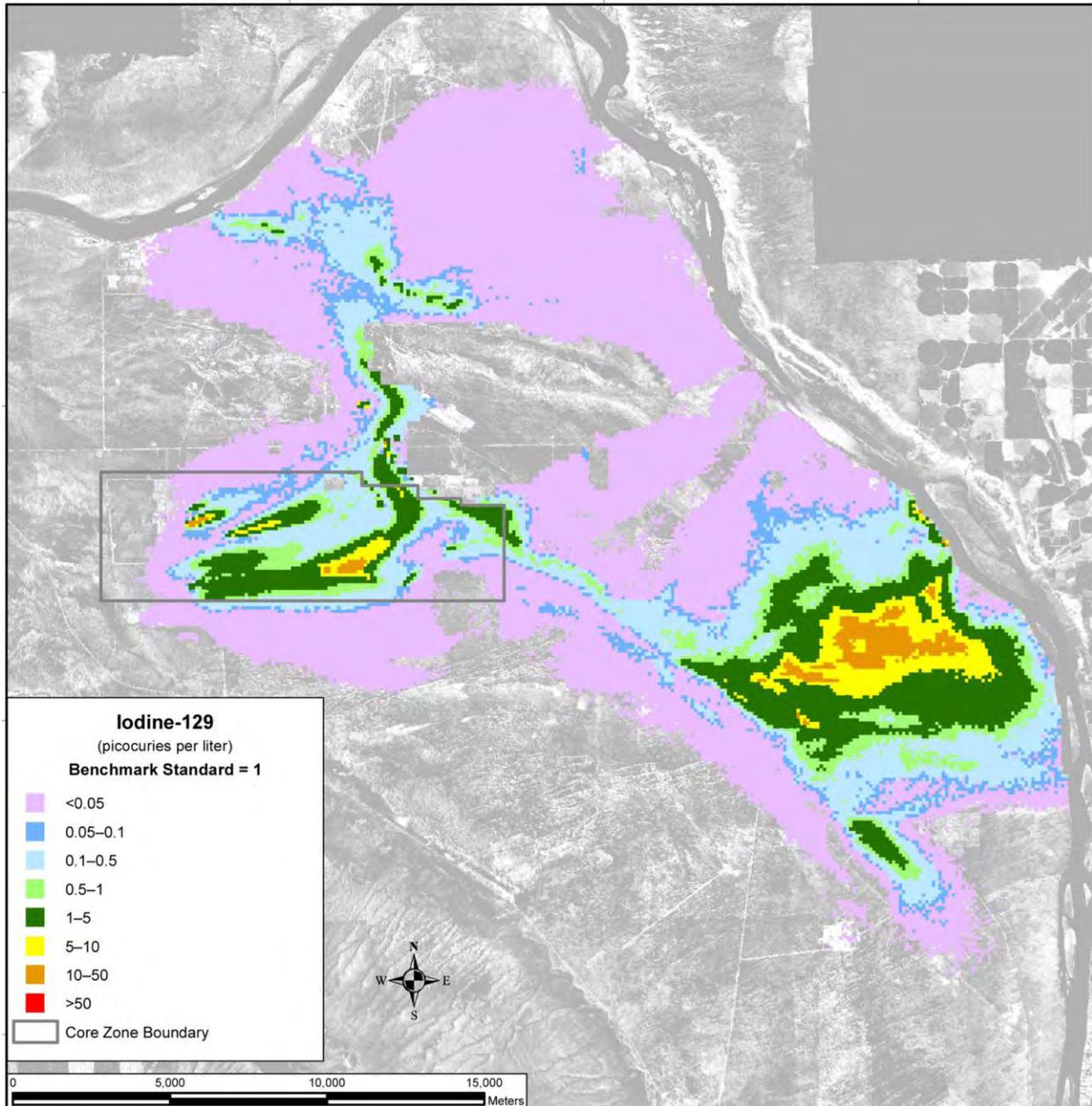


Figure 6–81. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Iodine-129 Concentration, Calendar Year 2010

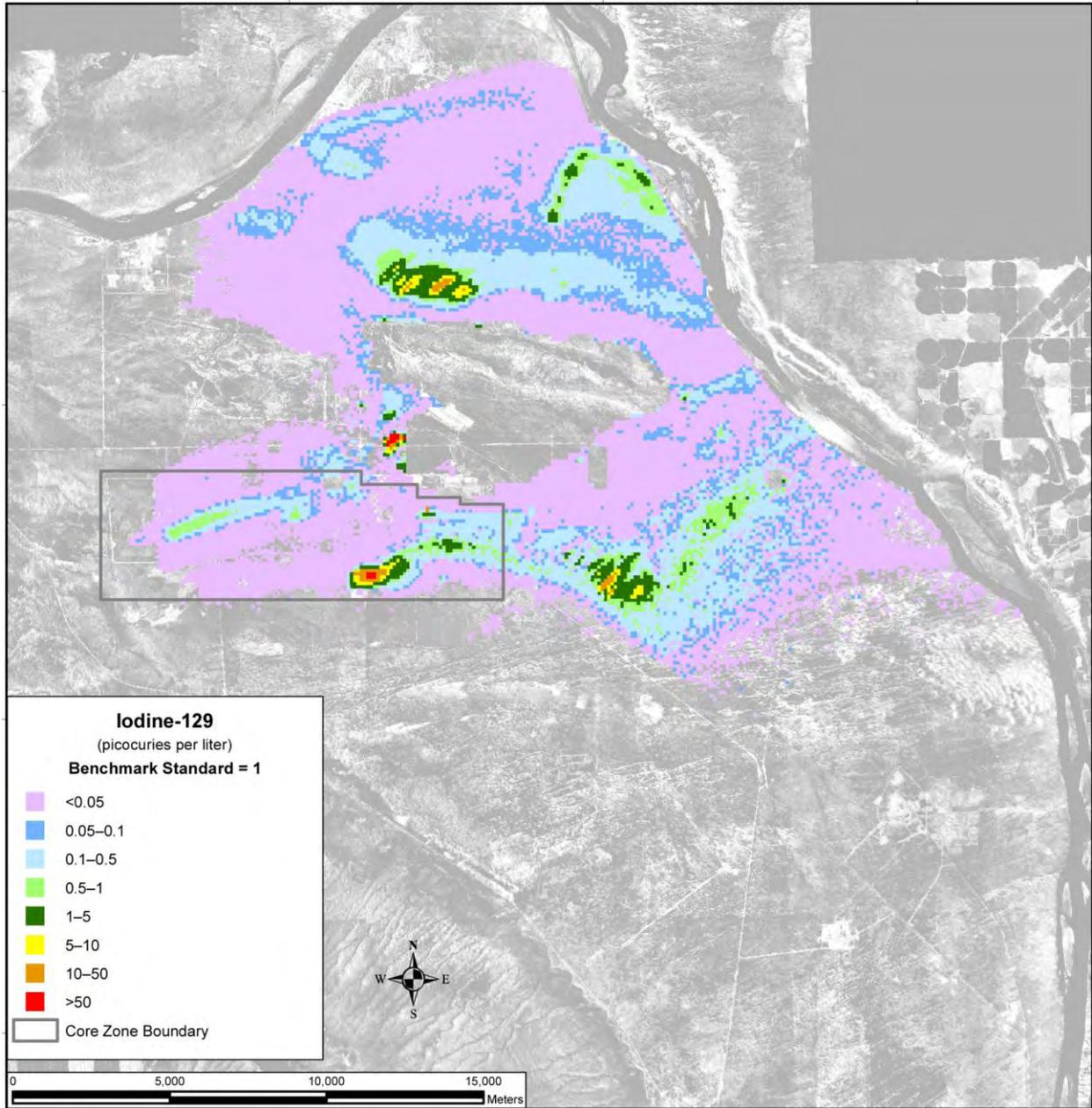


Figure 6-82. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Iodine-129 Concentration, Calendar Year 3890

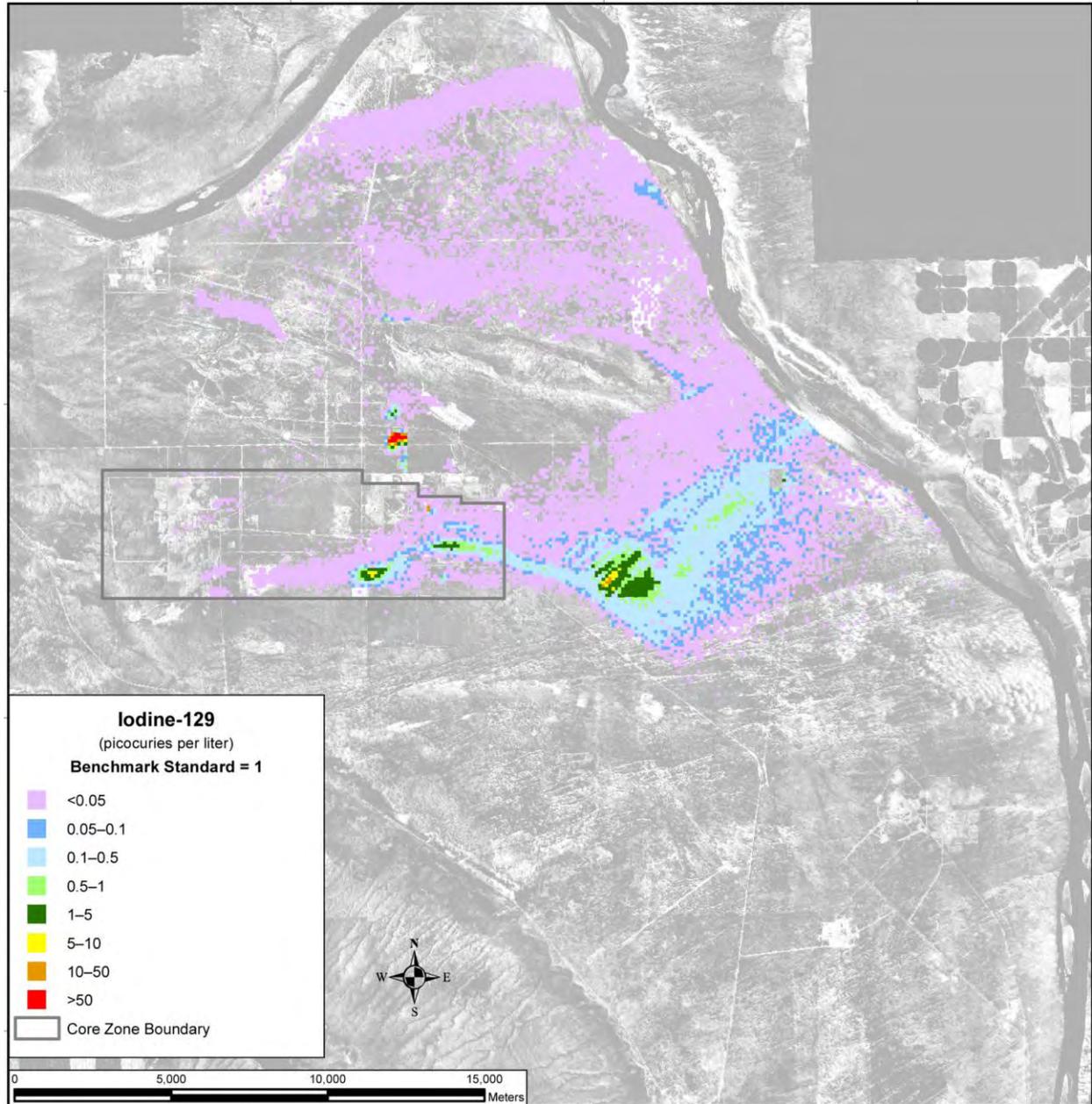
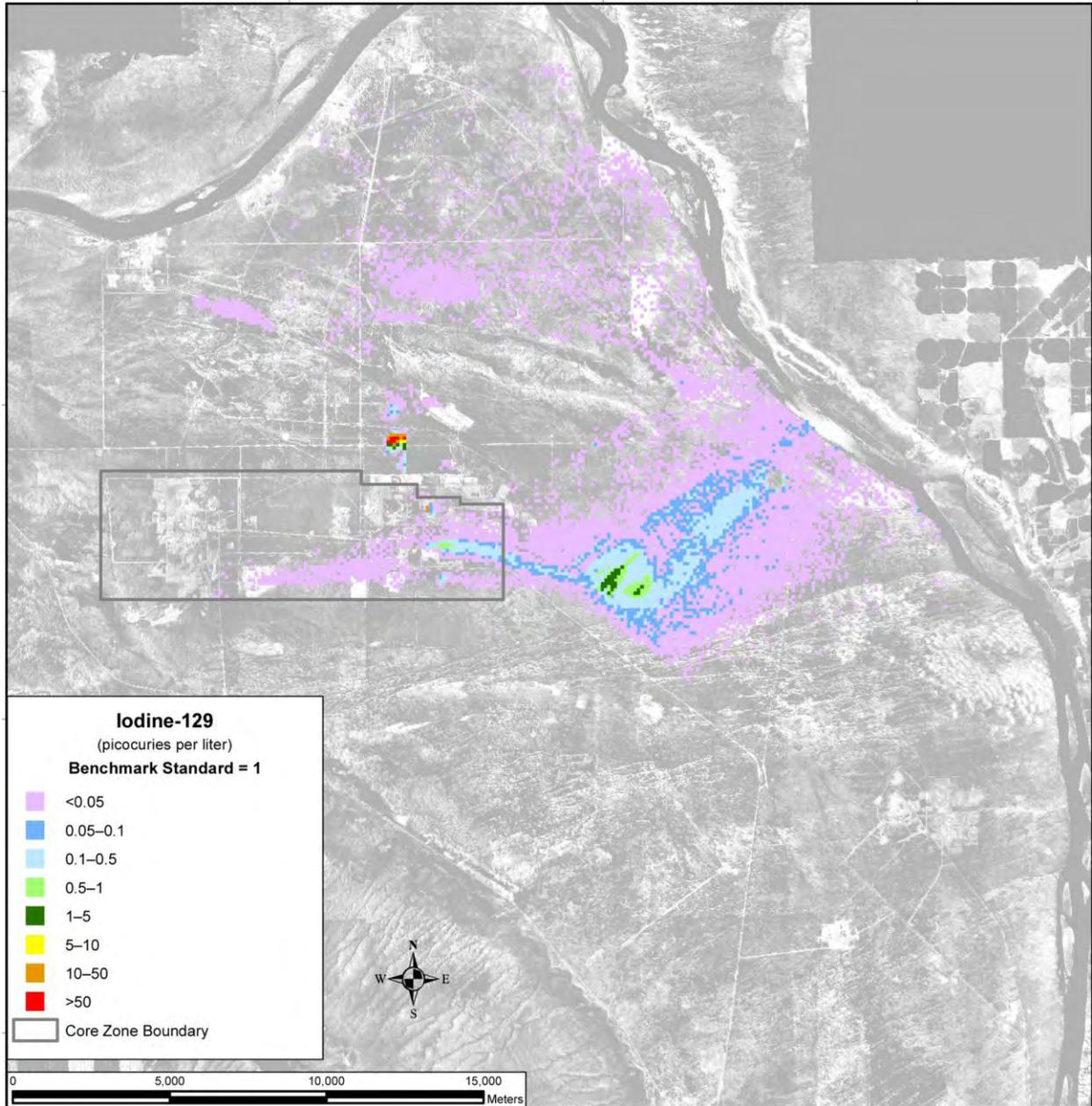
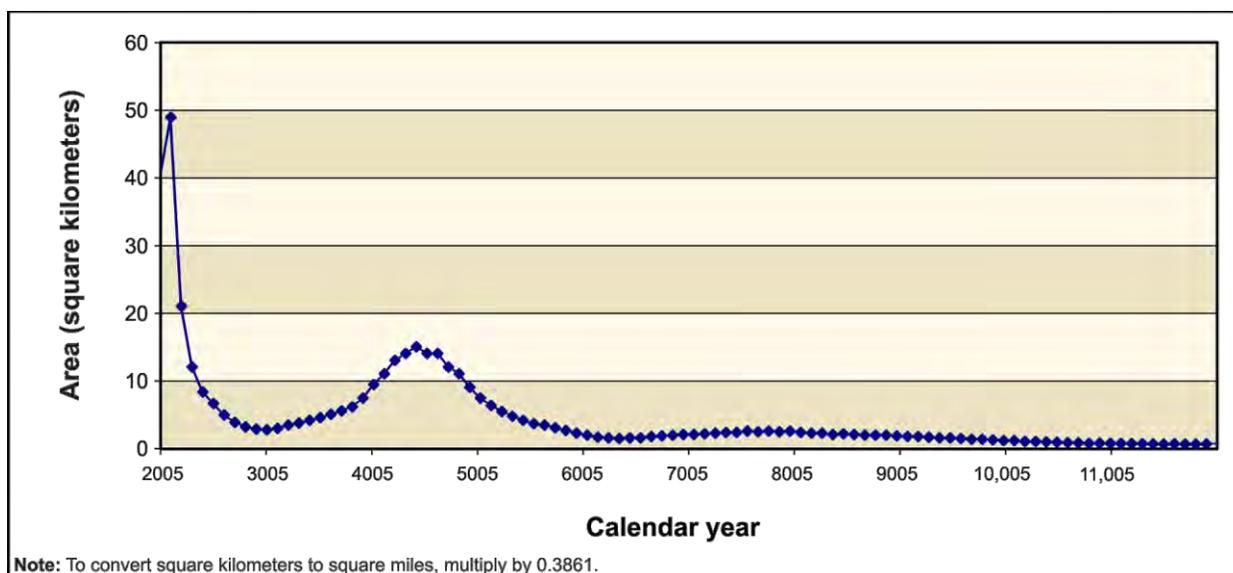


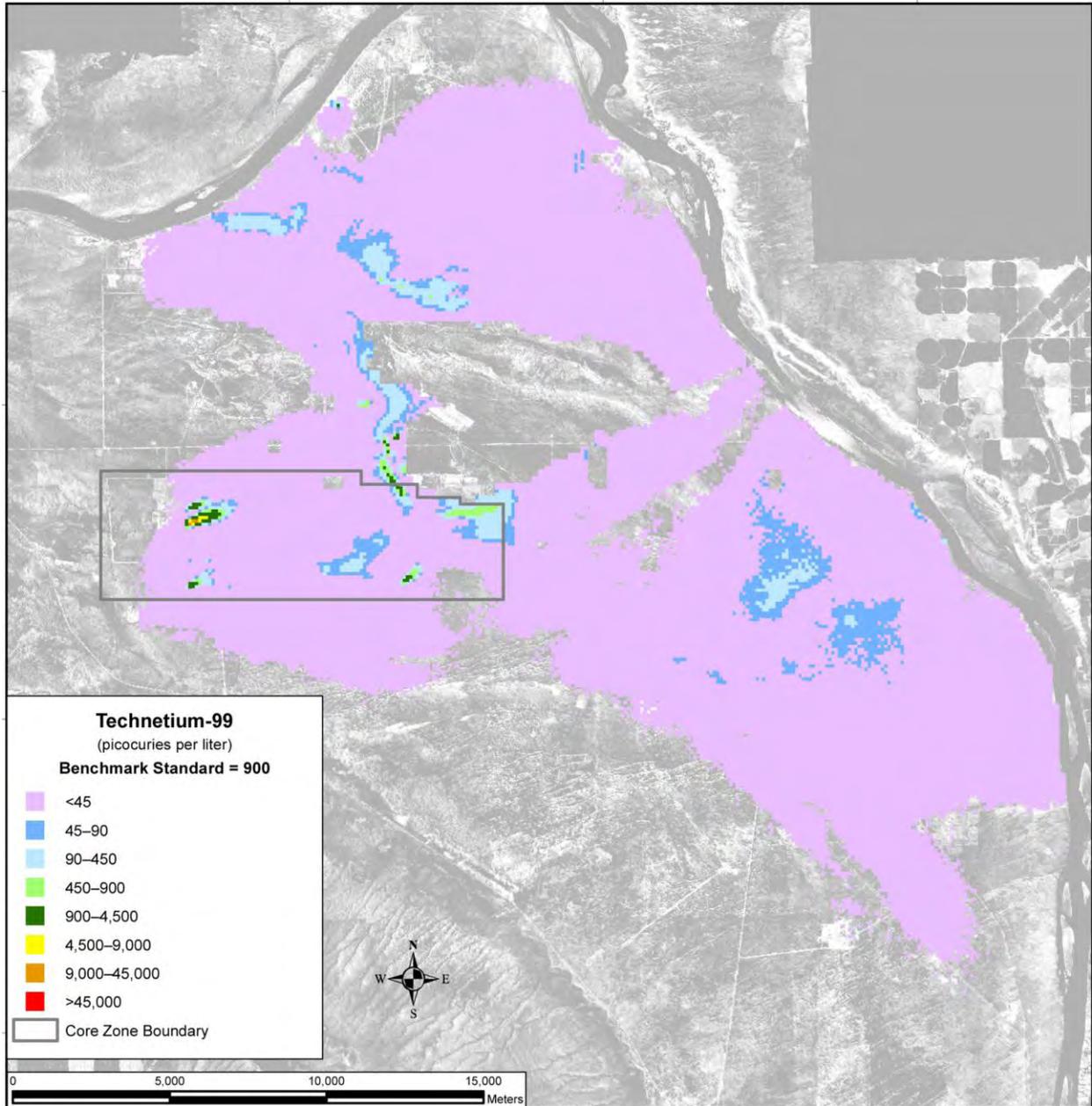
Figure 6-83. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Iodine-129 Concentration, Calendar Year 7140



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

Figure 6–84. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Iodine-129 Concentration, Calendar Year 11,885





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

Figure 6-86. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Technetium-99 Concentration, Calendar Year 2010

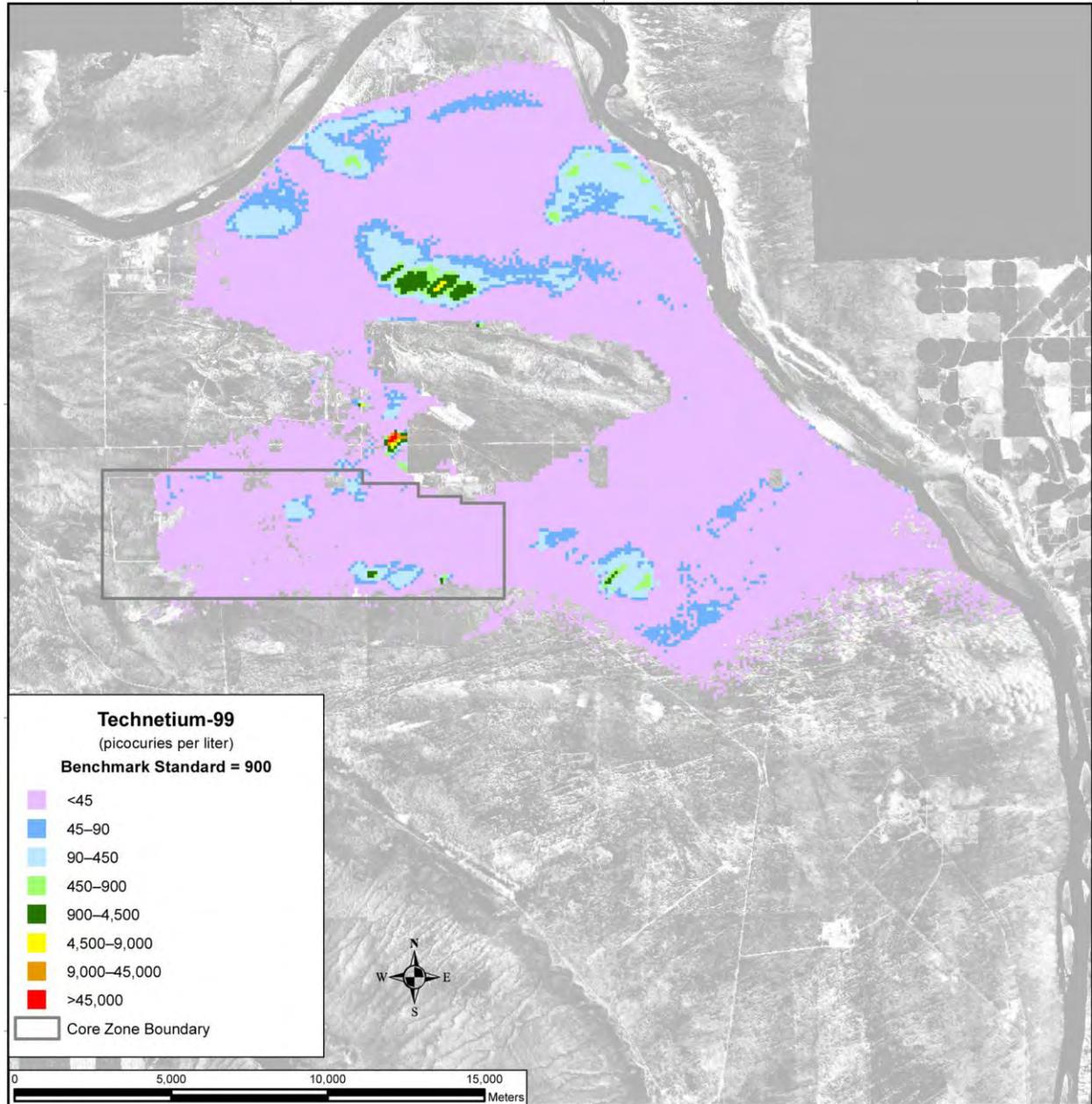
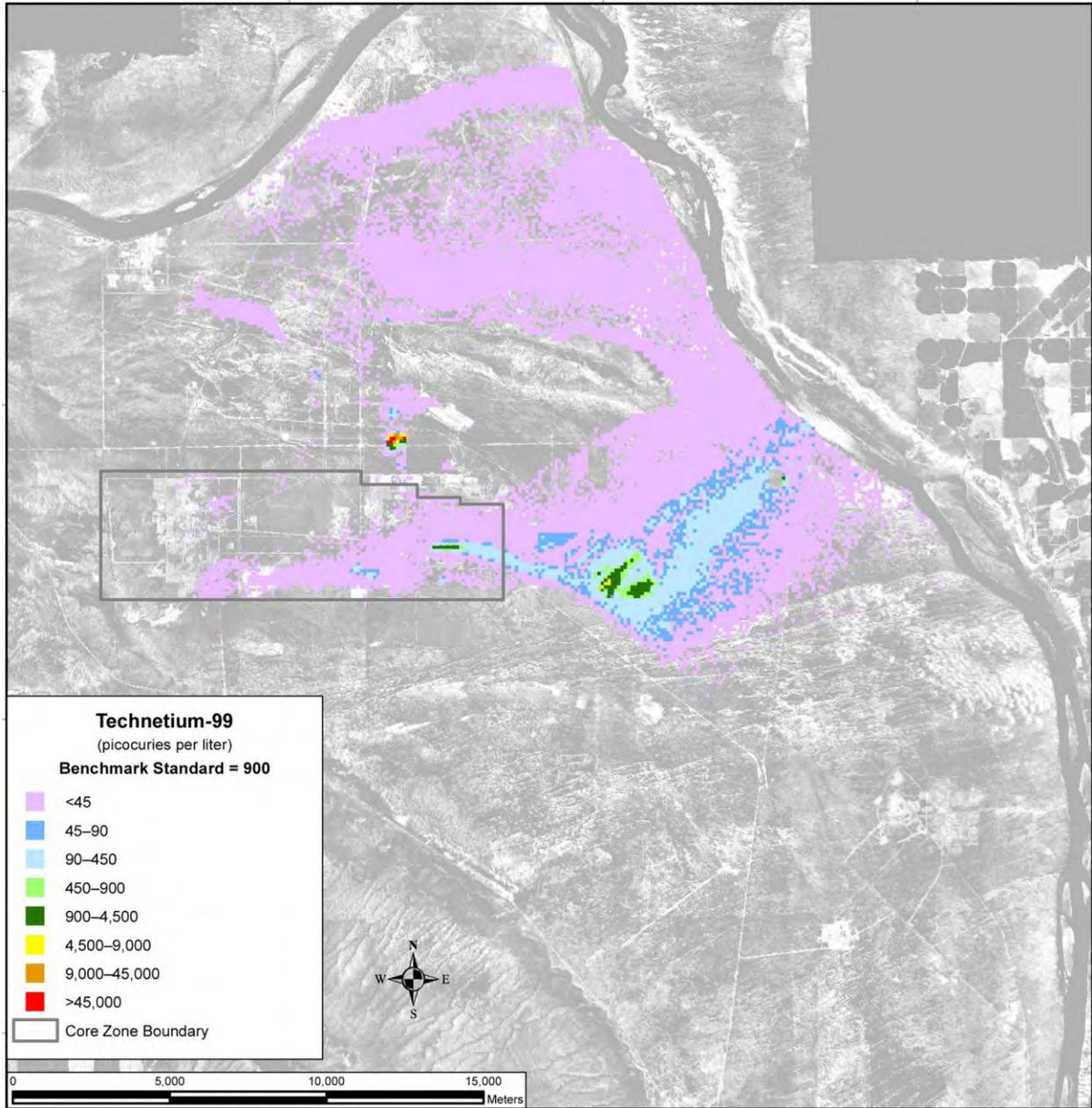


Figure 6-87. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Technetium-99 Concentration, Calendar Year 3890



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

Figure 6-88. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Technetium-99 Concentration, Calendar Year 7140

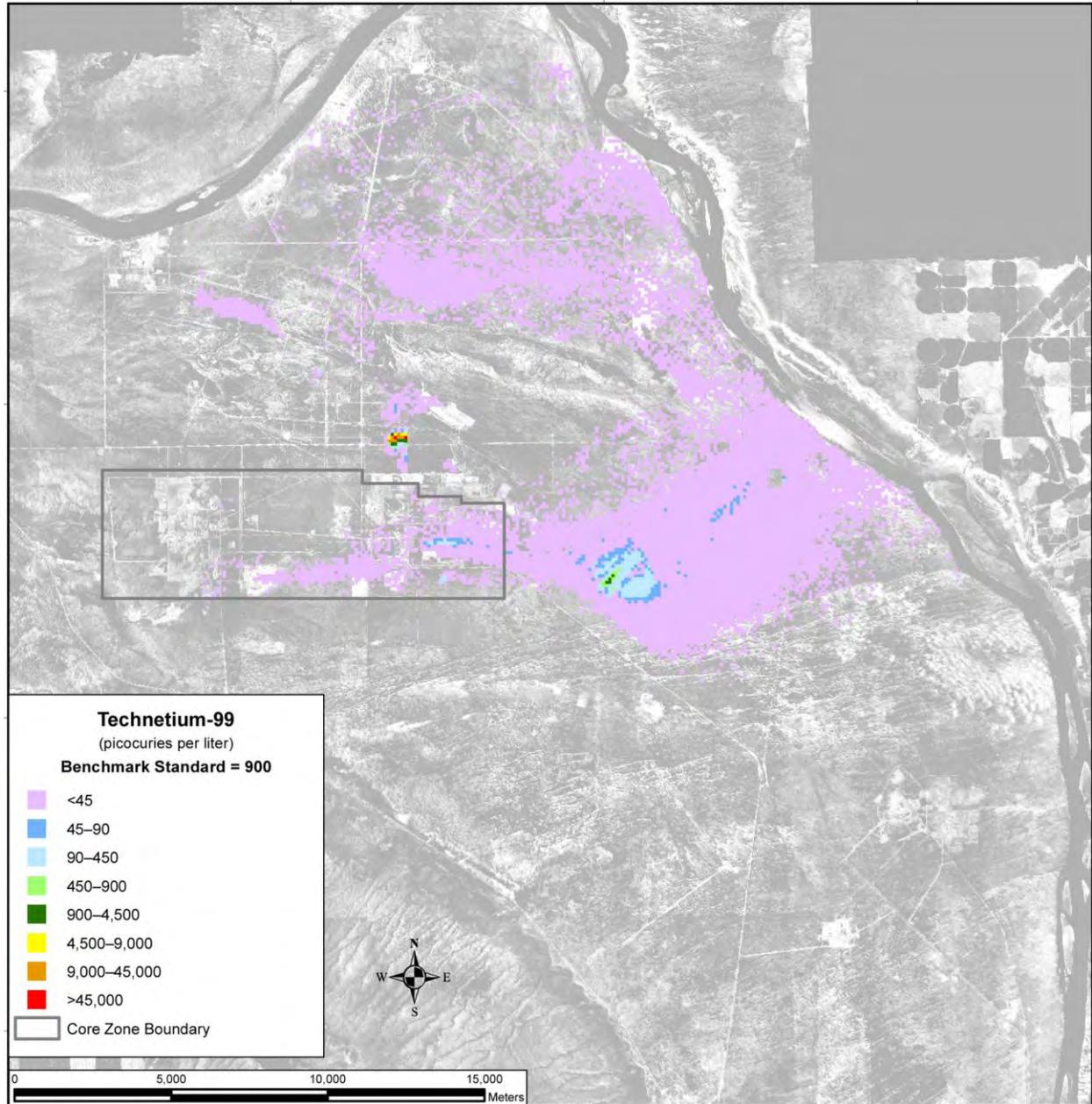


Figure 6-89. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Technetium-99 Concentration, Calendar Year 11,885

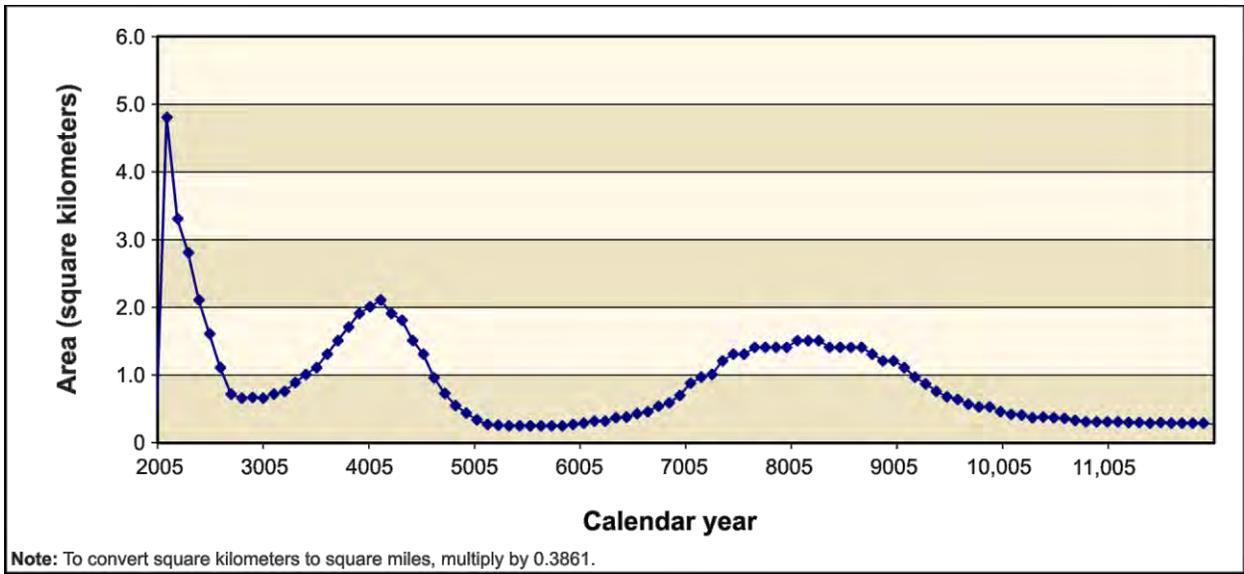


Figure 6-90. Alternative Combination 3 Total Area of Cumulative Groundwater Technetium-99 Concentrations Exceeding the Benchmark Concentration as a Function of Time

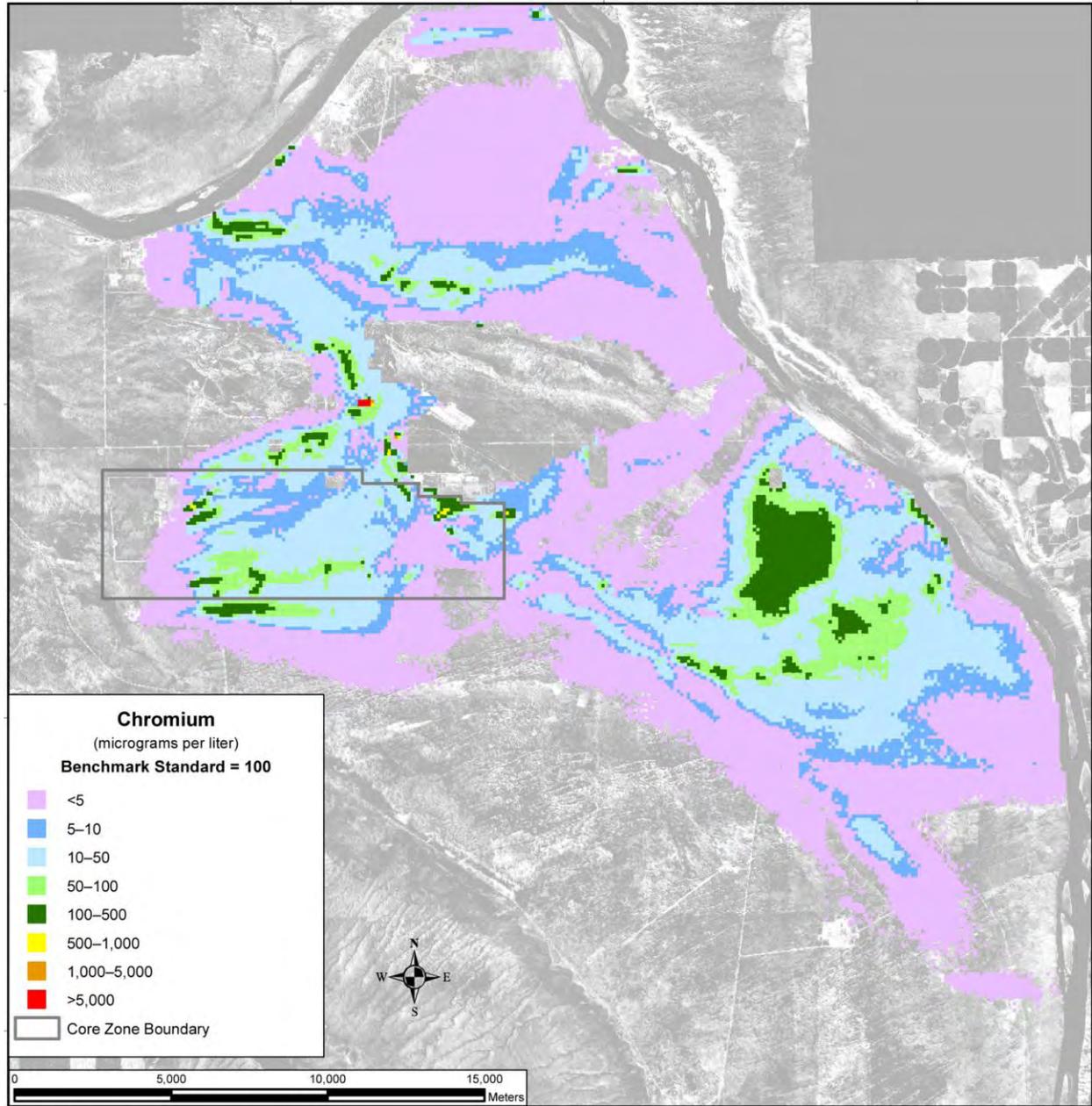


Figure 6-91. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Chromium Concentration, Calendar Year 2010

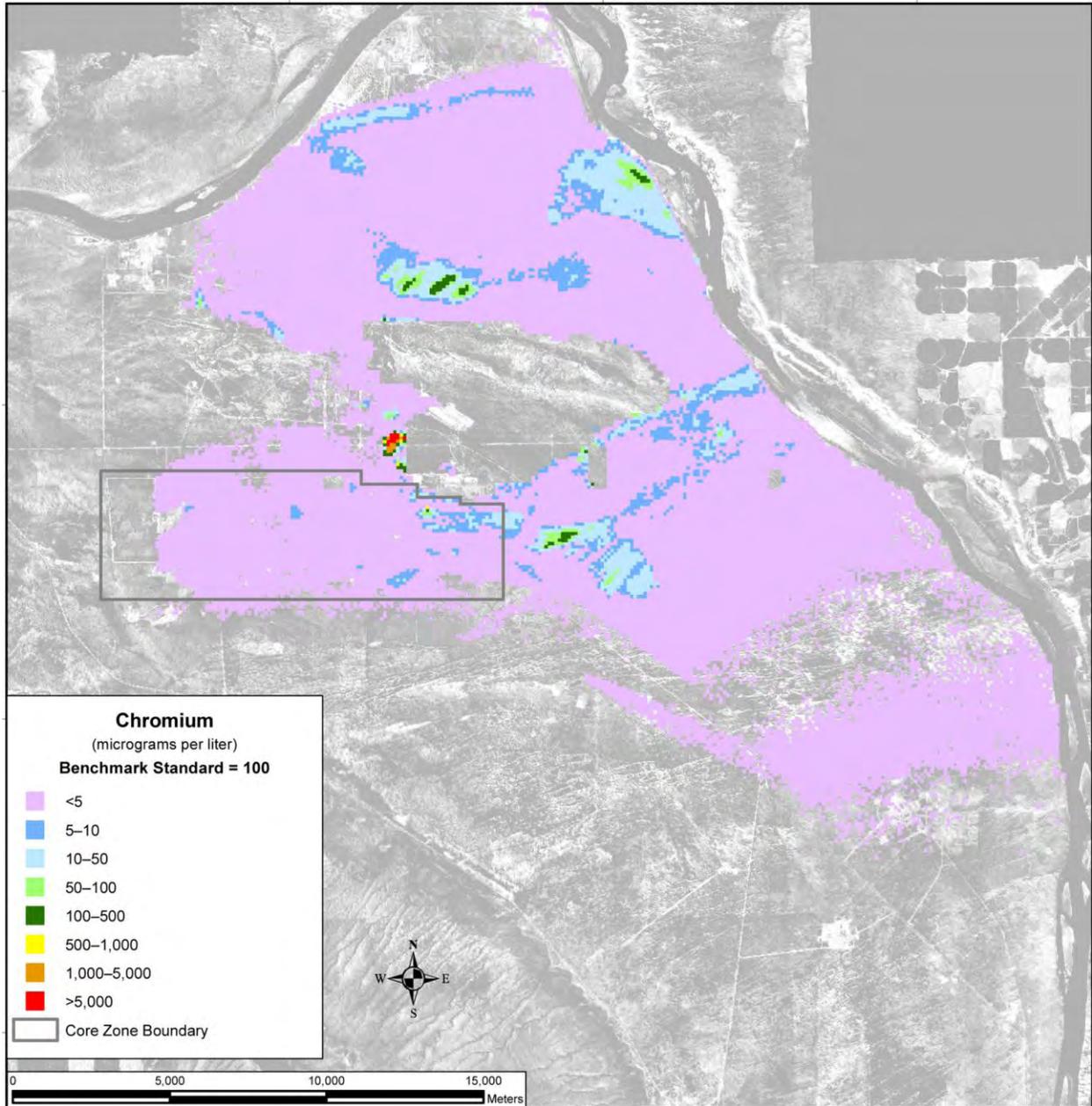


Figure 6-92. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Chromium Concentration, Calendar Year 3890

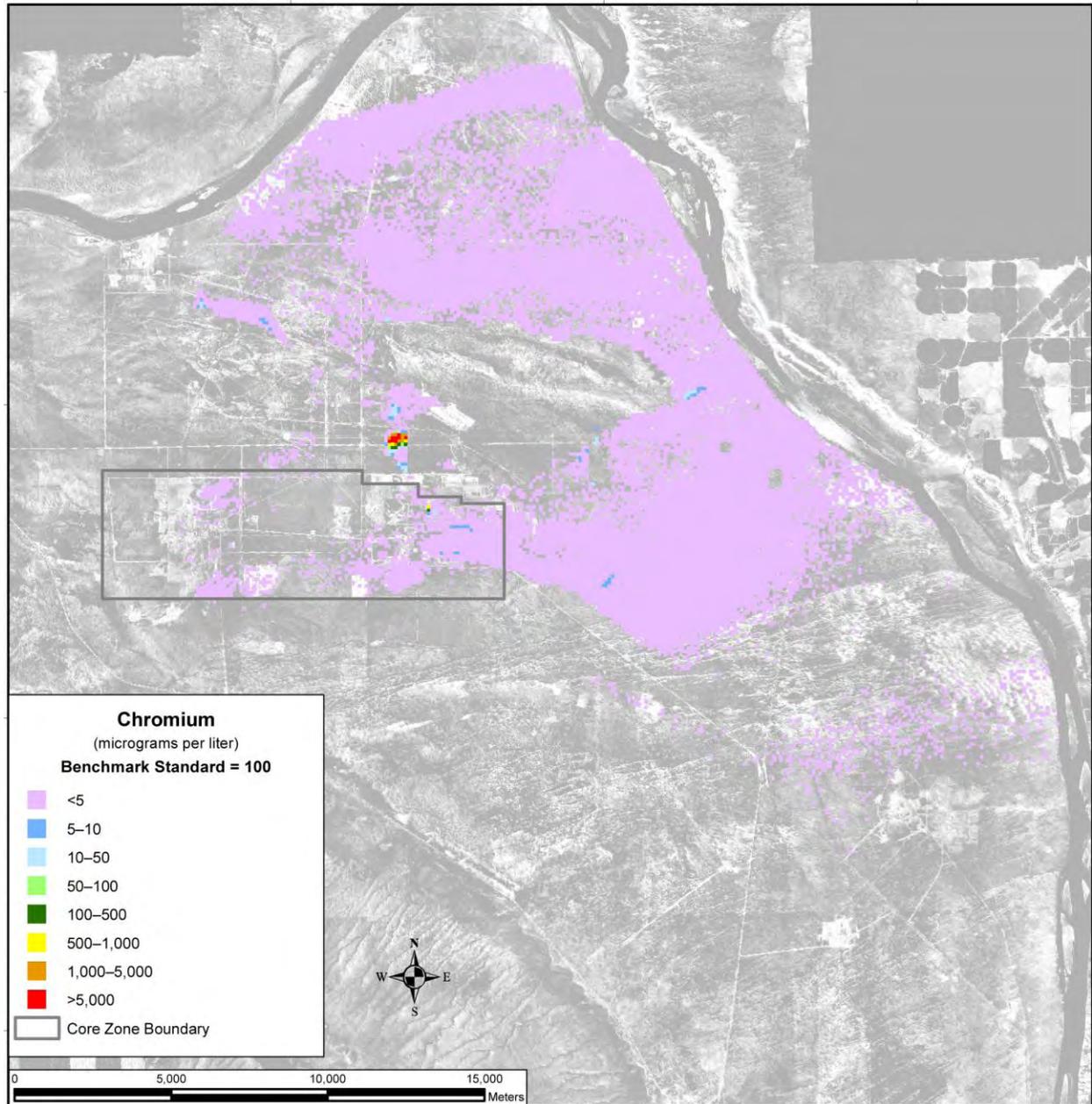
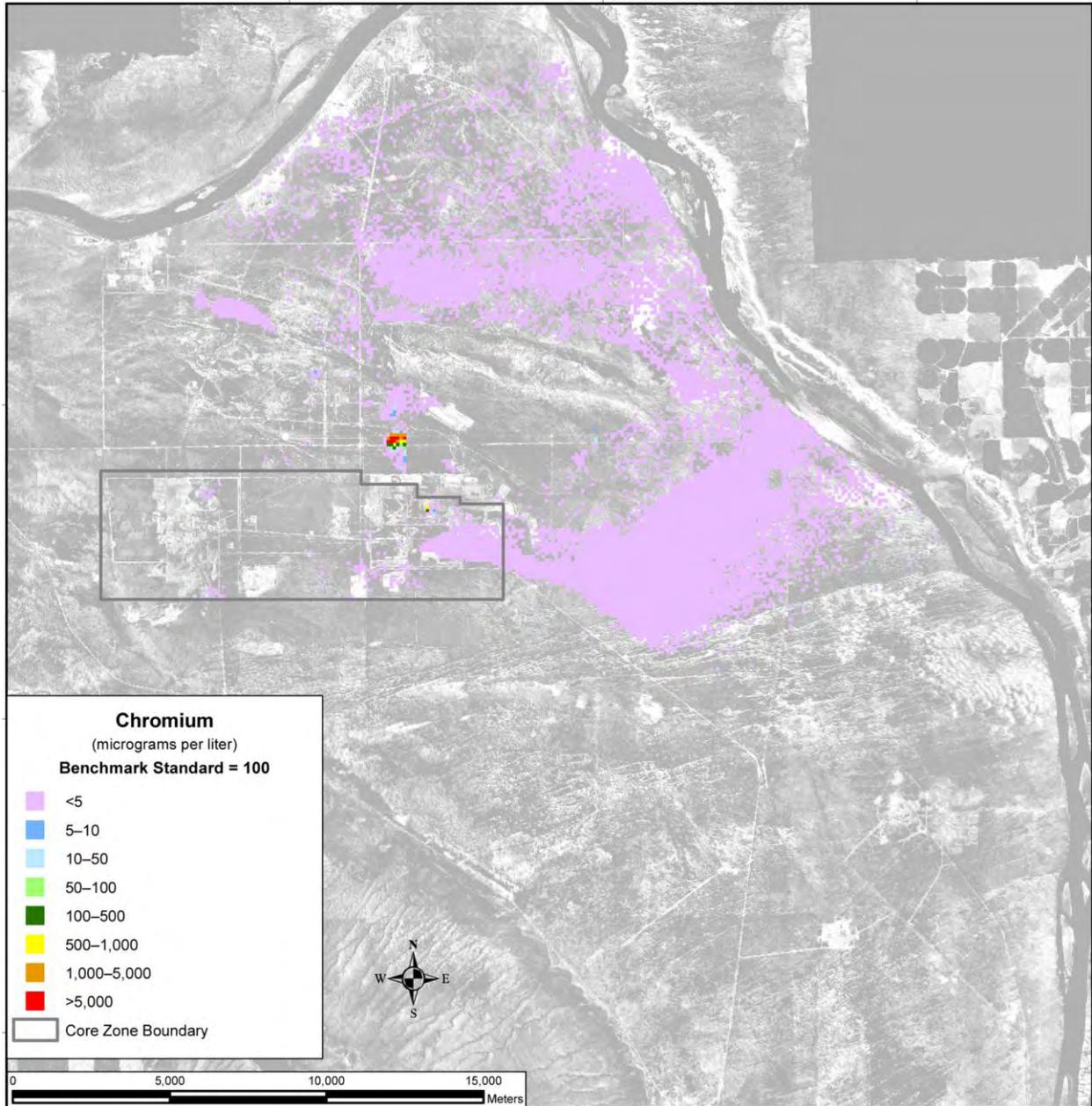


Figure 6-93. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Chromium Concentration, Calendar Year 7140



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

Figure 6-94. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Chromium Concentration, Calendar Year 11,885

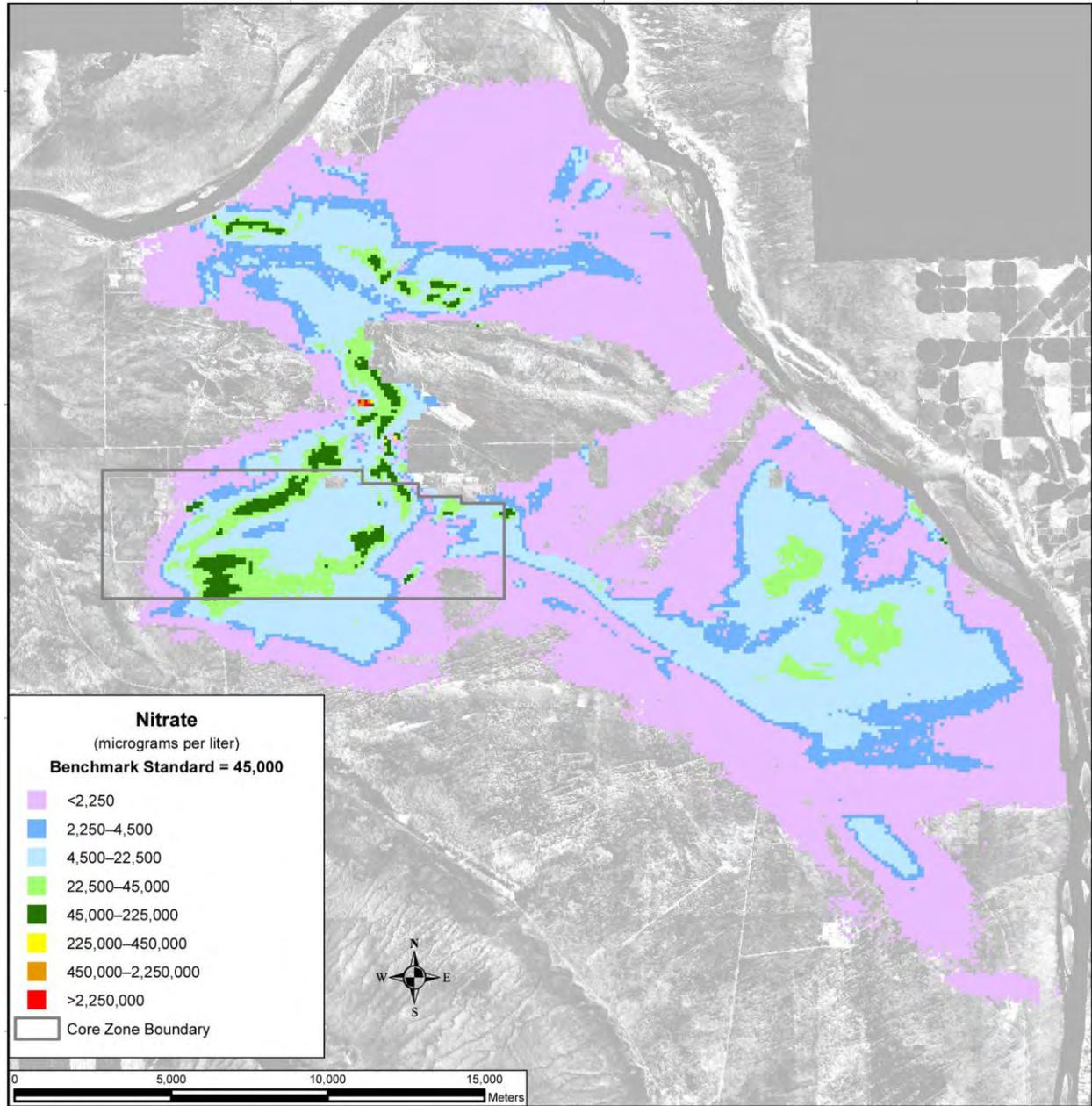
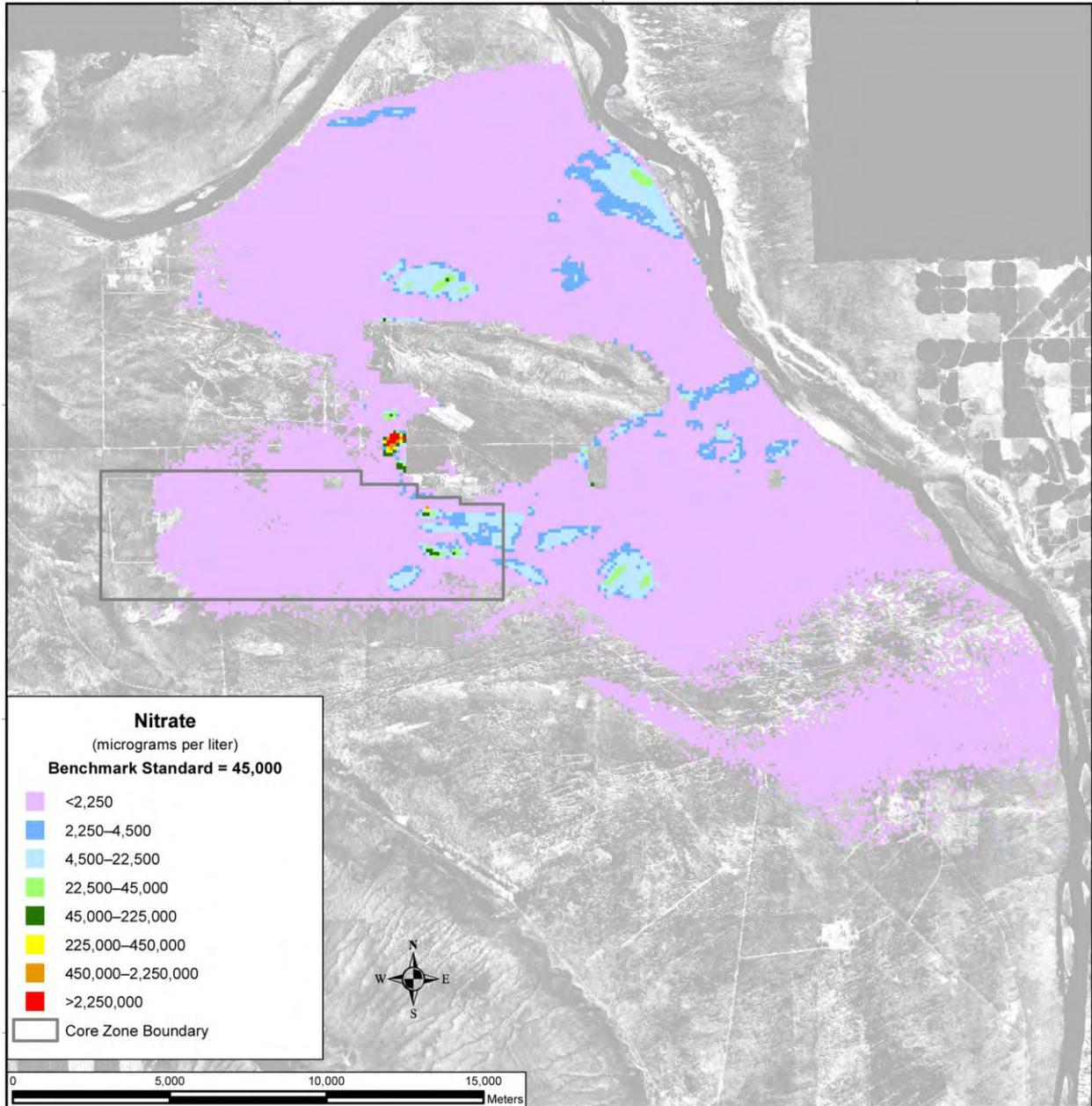


Figure 6-95. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Nitrate Concentration, Calendar Year 2010



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

Figure 6–96. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Nitrate Concentration, Calendar Year 3890

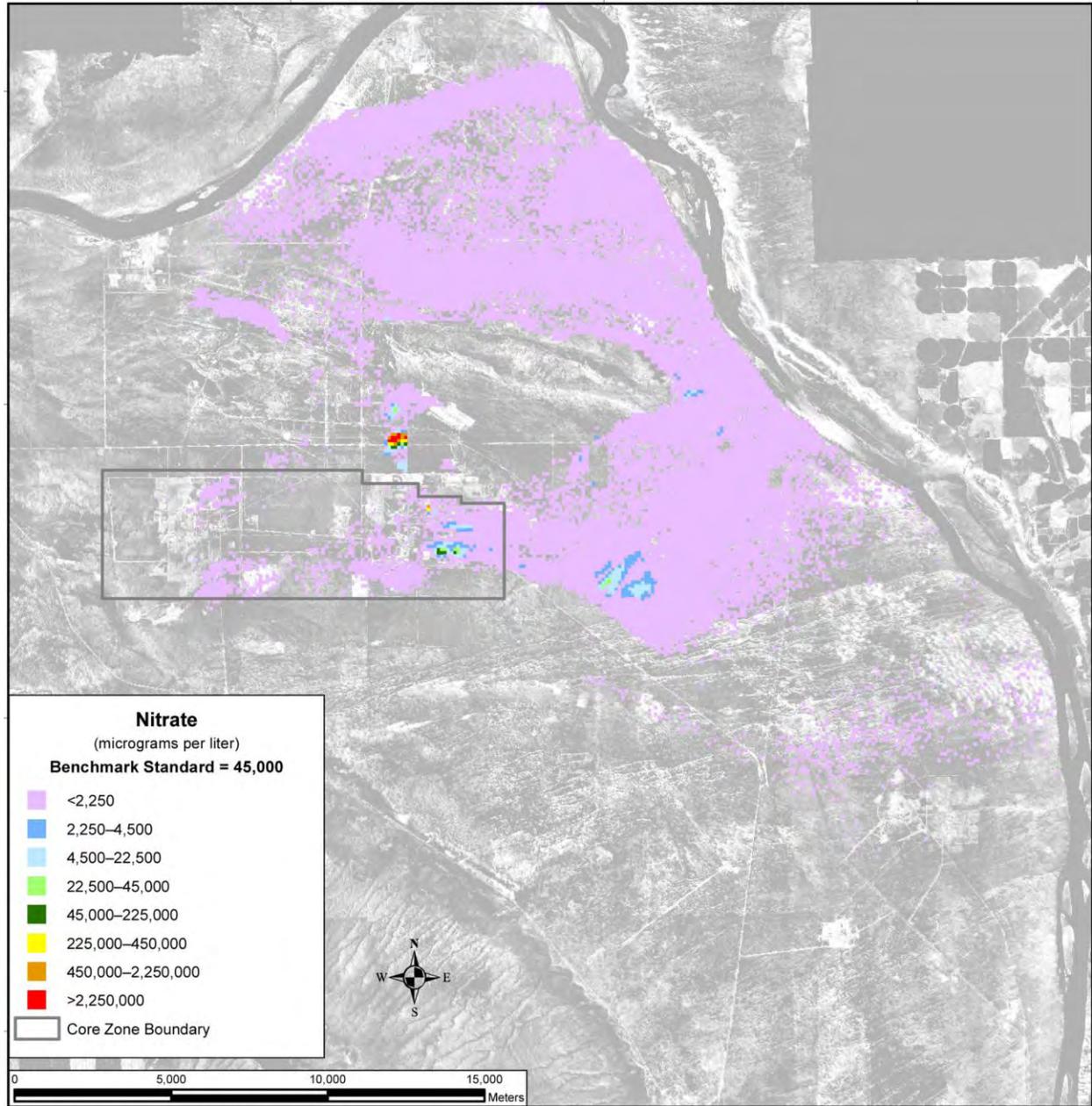
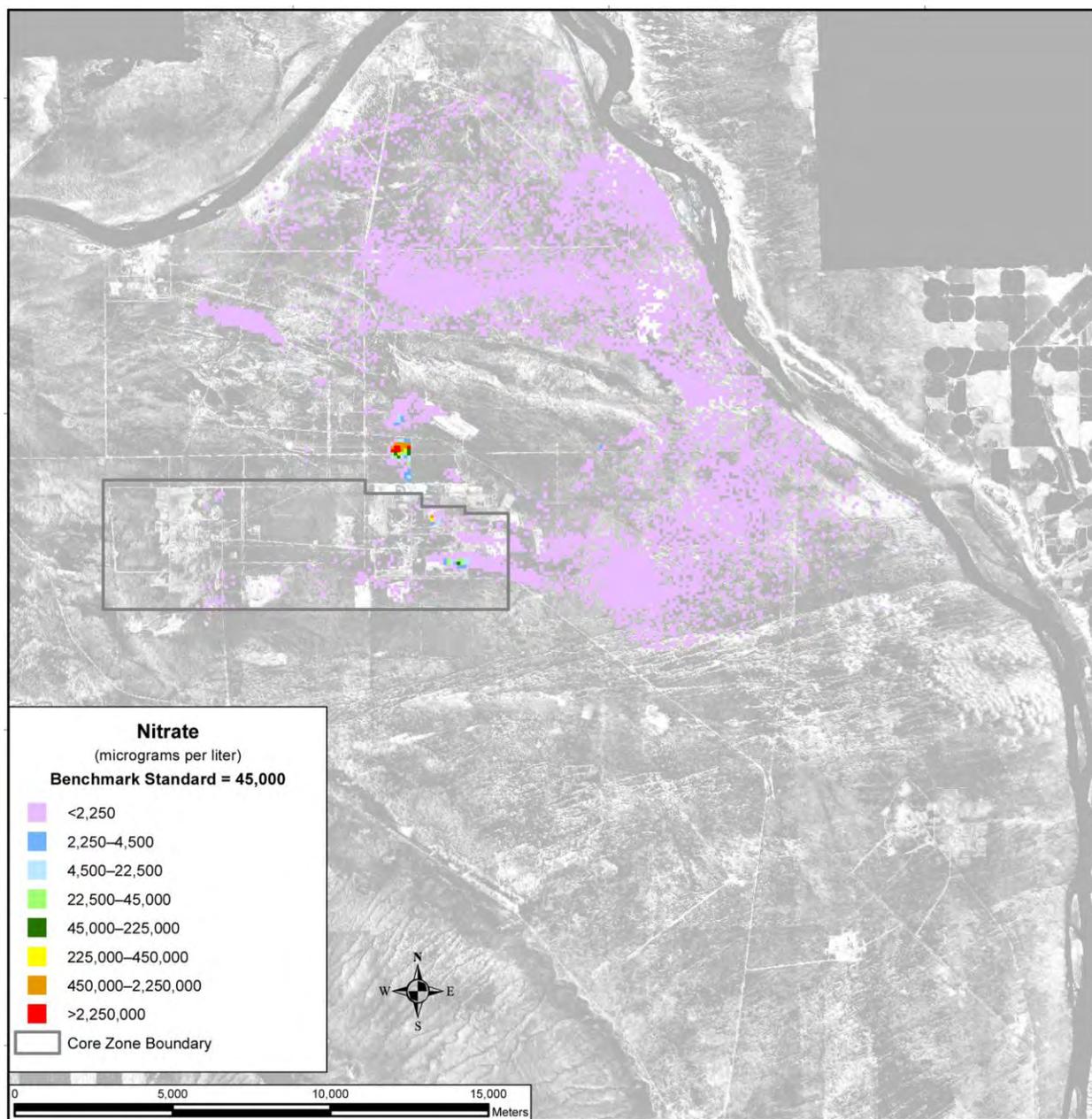


Figure 6-97. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Nitrate Concentration, Calendar Year 7140

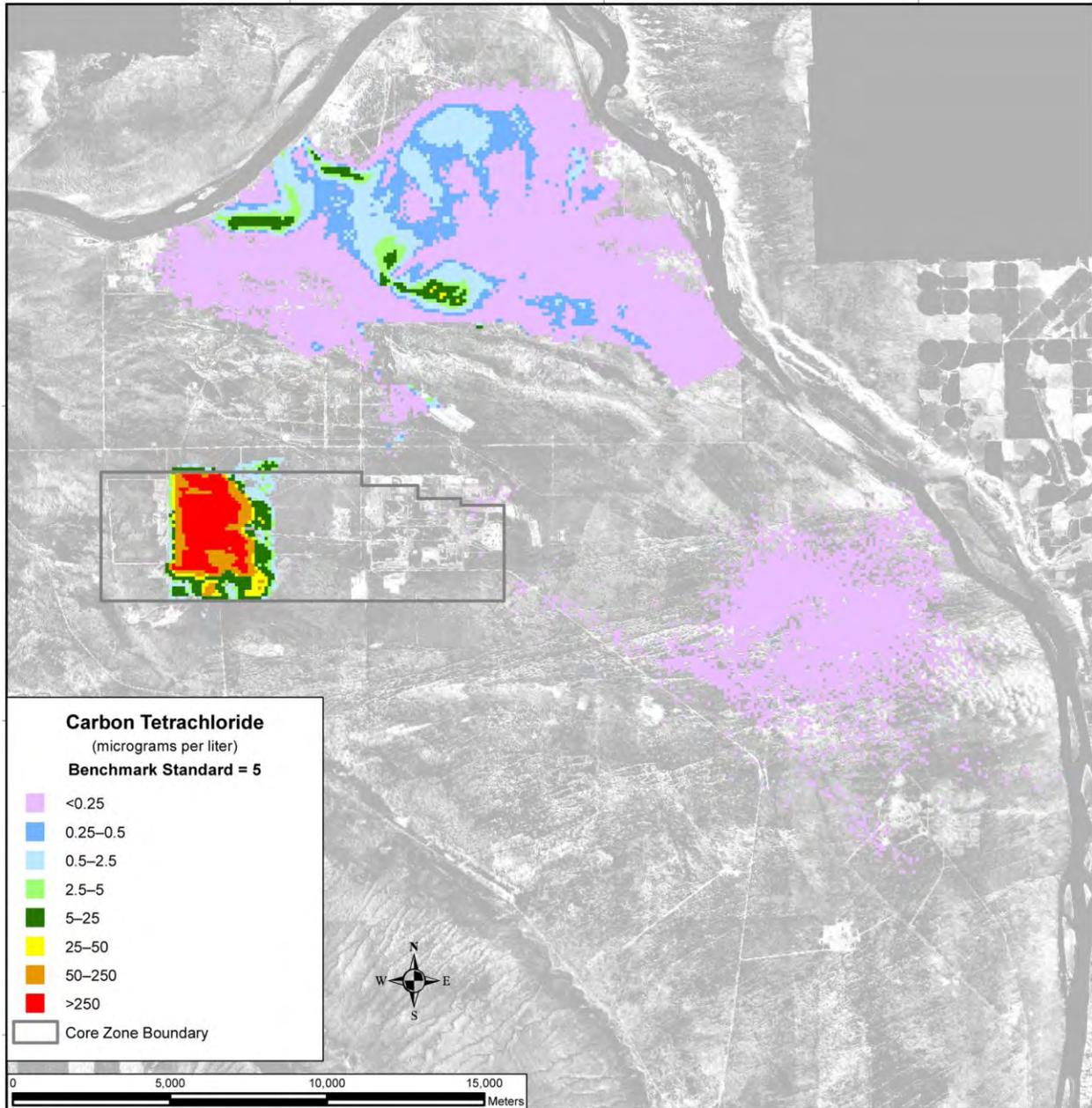


Note: To convert meters to feet, multiply by 3.281.

Figure 6–98. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Nitrate Concentration, Calendar Year 11,885

The spatial distribution of carbon tetrachloride concentrations in groundwater is dominated by non-TC & WMEIS sources associated with the Z Area within the 200-West Area. The spatial distribution in CY 2010, shown in Figure 6–99, is a large plume covering most of the 200-West Area, with peak concentrations more than 50 times greater than the benchmark concentration. By CY 2135, shown in Figure 6–100, the plume has moved almost entirely out of the Core Zone Boundary and to the north. Note that this model result does not include the effects of carbon tetrachloride removal and containment in the 200-West Area. Figure 6–101 shows the dissipation of the plume over time in CY 3890.

The part of the carbon tetrachloride plume north of Gable Mountain includes contributions from the 200-West Area plume and Gable Mountain Pond. By mass, the dominant source is the 200-West Area plume. The rate of migration from the 200-West Area through Gable Gap is strongly influenced by the location of the highly conductive aquifer materials in this area, which is relatively uncertain (see Appendix L). The model overpredicts the rate of northward migration because of this uncertainty and because no credit is taken for the groundwater containment and removal system in the 200-West Area.



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

Figure 6-99. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Carbon Tetrachloride Concentration, Calendar Year 2010

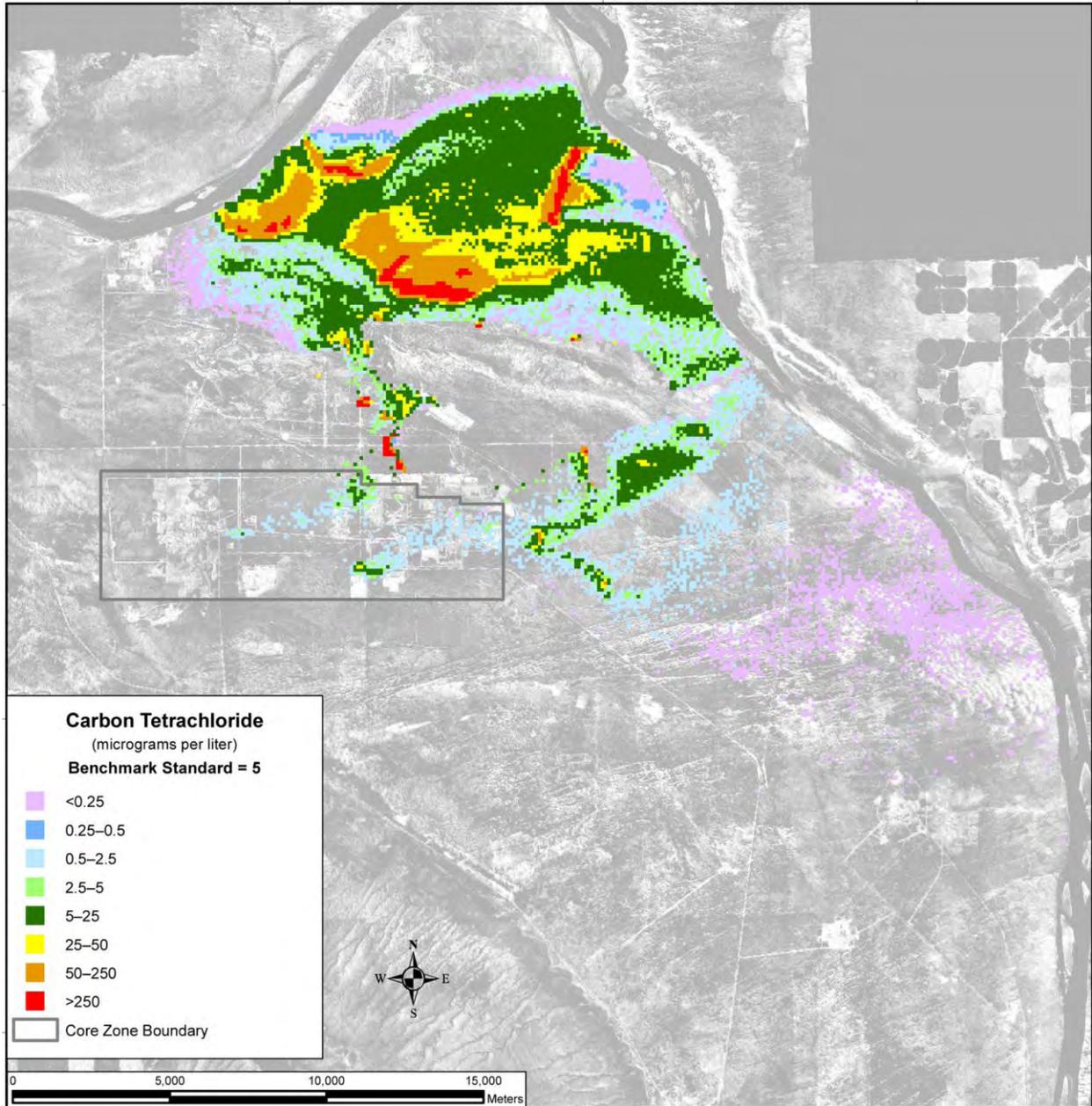
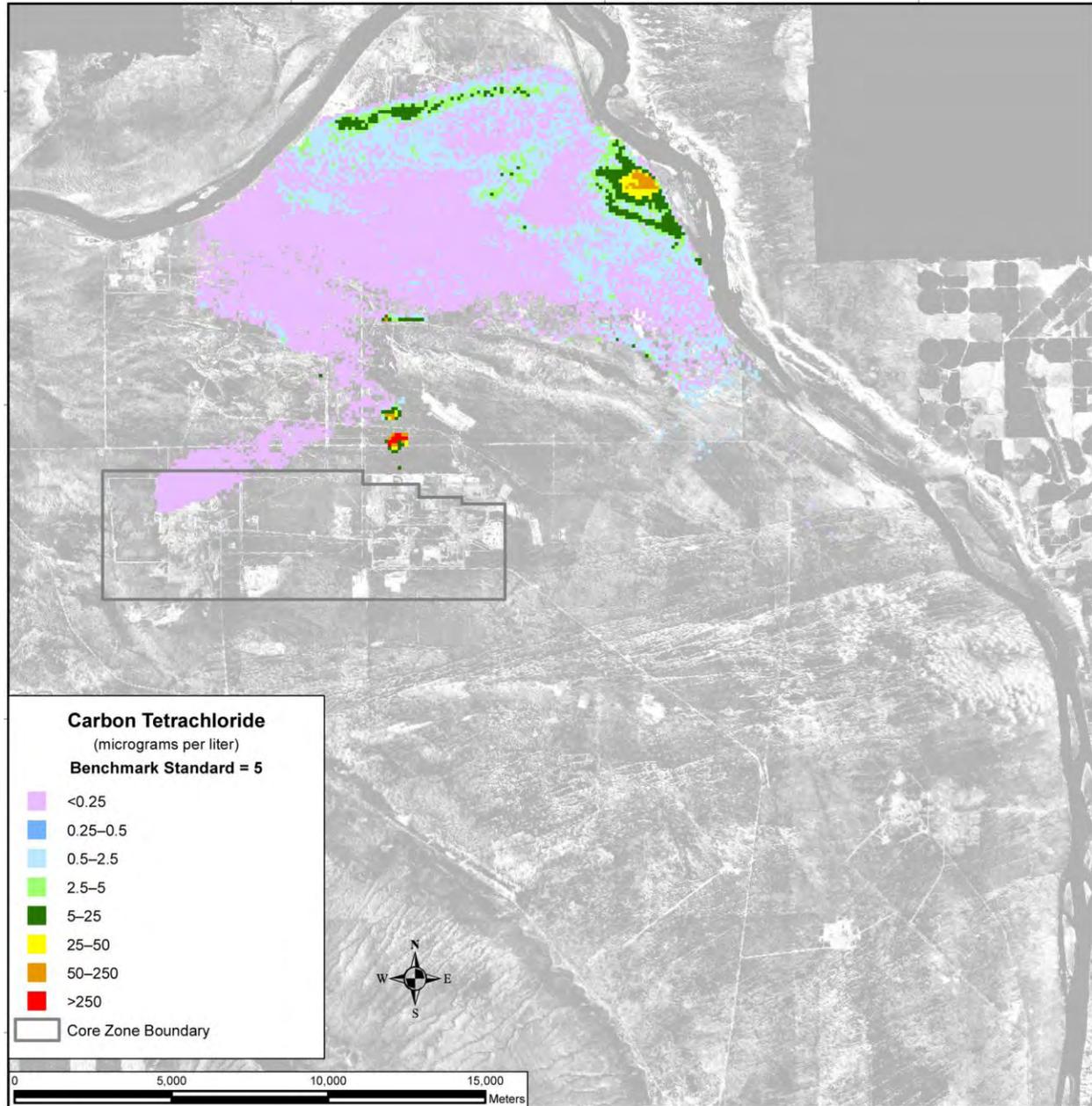


Figure 6–100. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Carbon Tetrachloride Concentration, Calendar Year 2135



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

Figure 6–101. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Carbon Tetrachloride Concentration, Calendar Year 3890

Uranium-238 and total uranium show a different spatial distribution in groundwater 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 6–102 shows the distribution of uranium-238 in CY 2135. There are two small plumes associated with releases from the ponds (non-TC & WM EIS sources) in the 200-East and 200-West Areas. Peak concentrations in the 200-East Area are 1 to 5 times greater than benchmark; in the 200-West Area, they are 10 to 50 times greater. By CY 3890 (see Figure 6–103), these plumes have dissipated, but releases from other tank farm sources (primarily within the A Barrier) have produced a second plume east of the Core Zone, with peak concentrations 3 to 10 times greater than the benchmark. By CY 11,885 (see Figure 6–104), the plumes

from other tank farm sources have extended this plume and produced additional plumes in the 200-West Area. Figure 6–105 shows the total area for which groundwater uranium-238 concentrations exceed the benchmark concentration as a function of time. The area of exceedance is largest early in the analysis (non-TC & WM EIS sources, primarily ponds) and continues on a downward trend toward the end of the period of analysis (other tank farm sources). Figures 6–106 through 6–108 show the corresponding spatial distributions for total uranium.

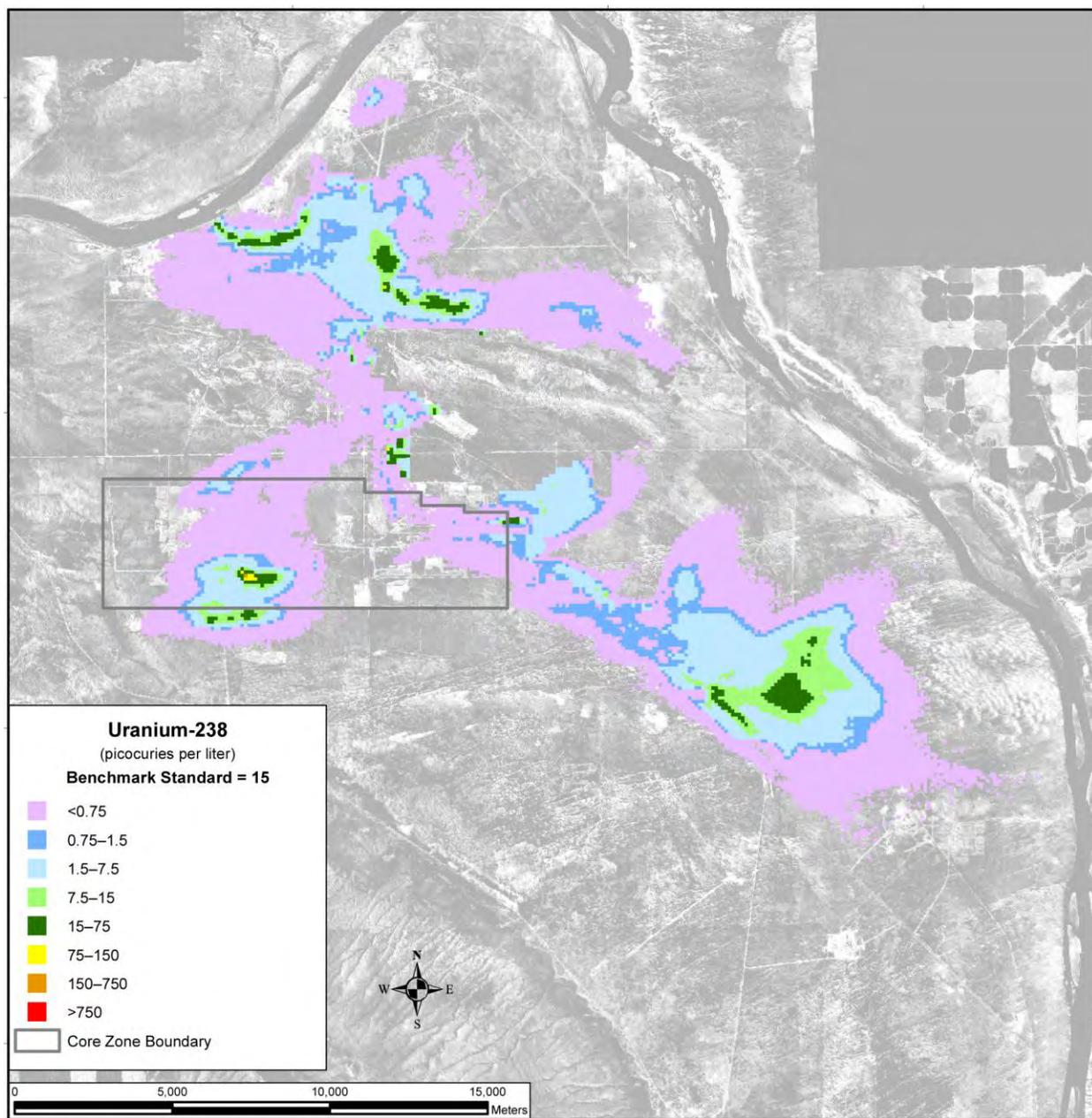


Figure 6–102. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Uranium-238 Concentration, Calendar Year 2135

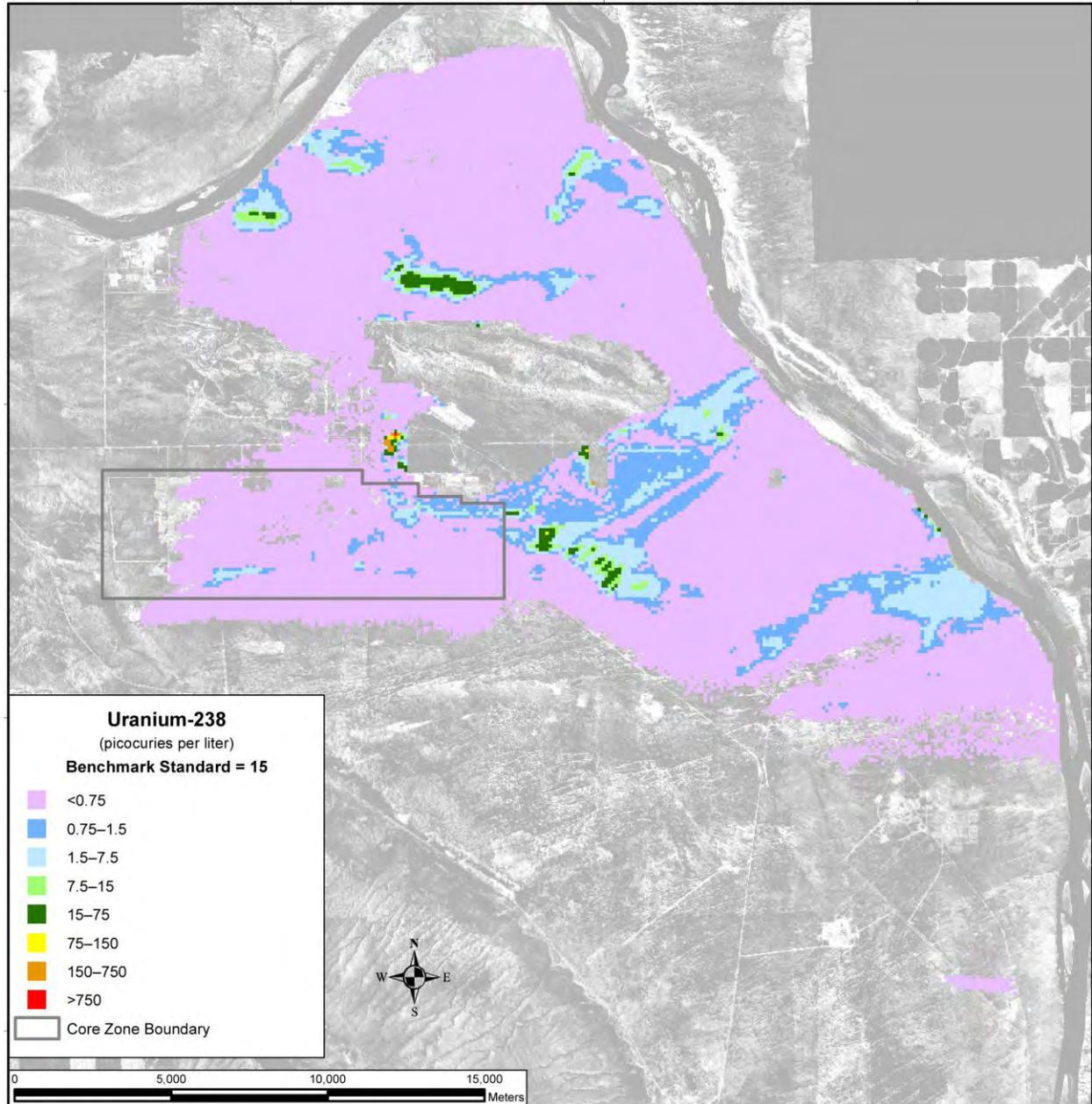
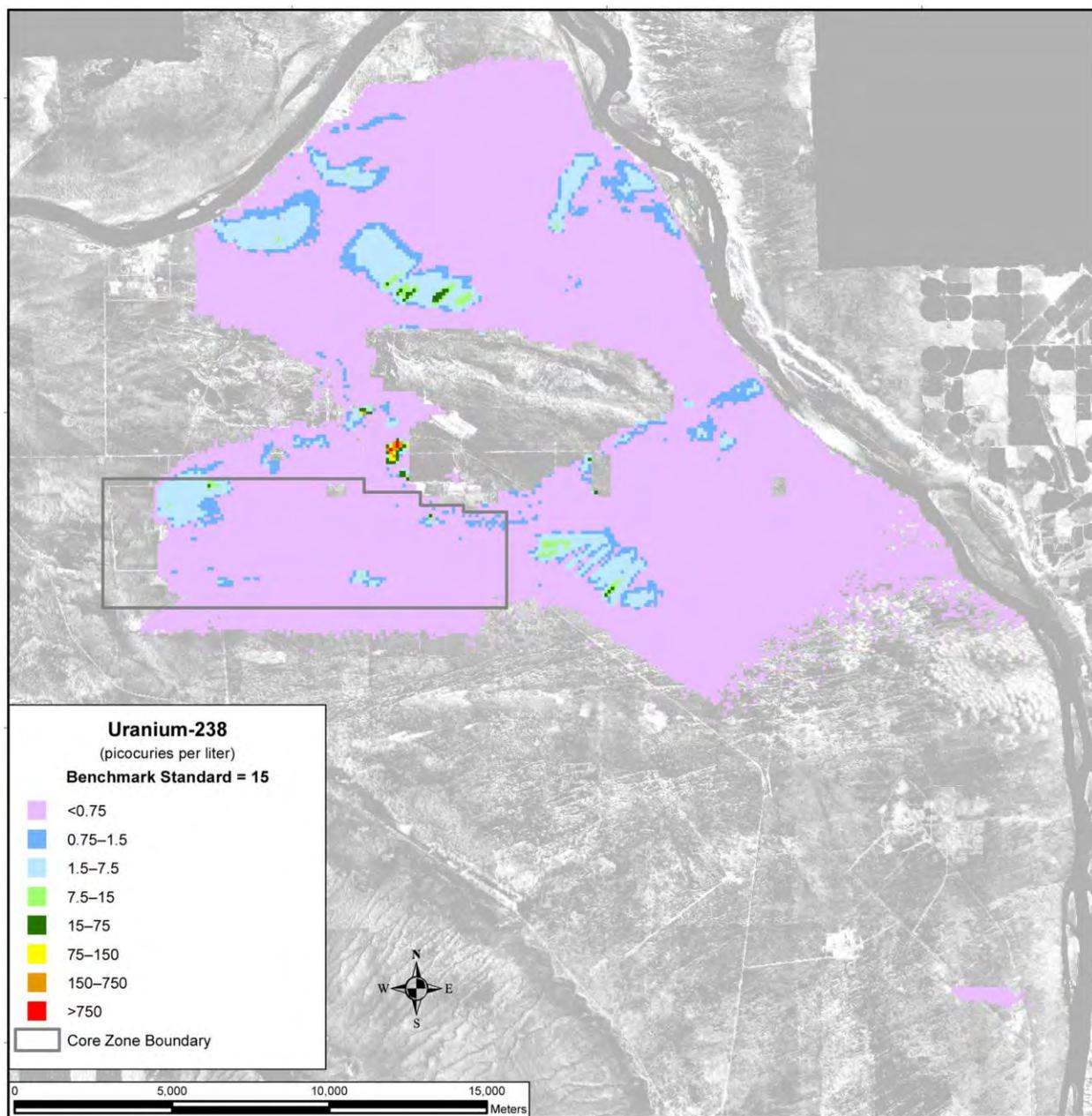
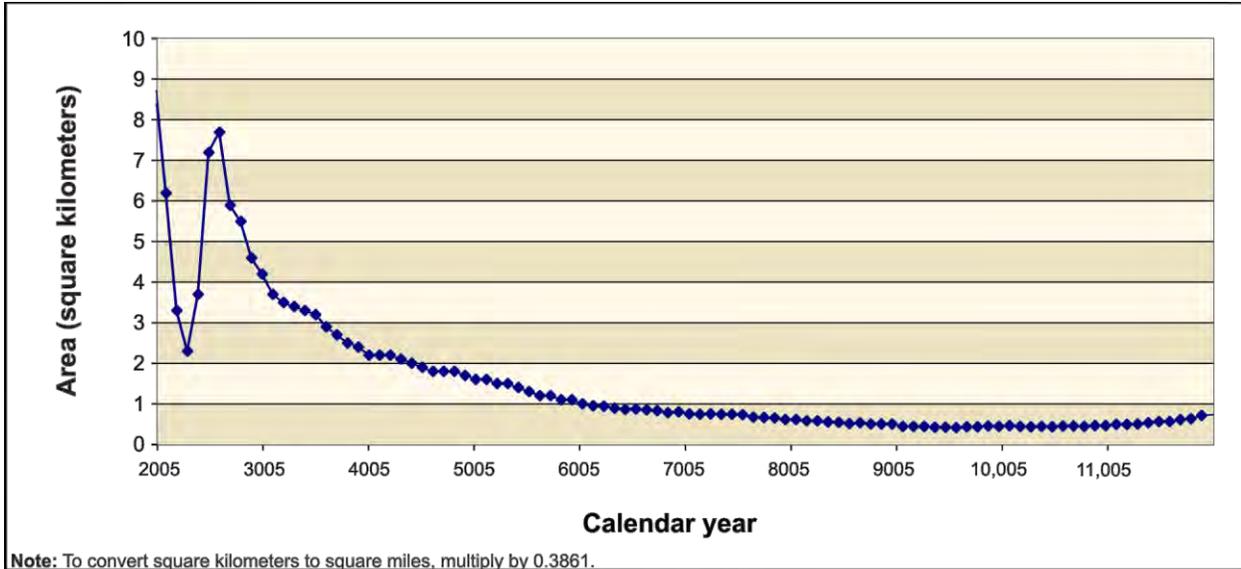


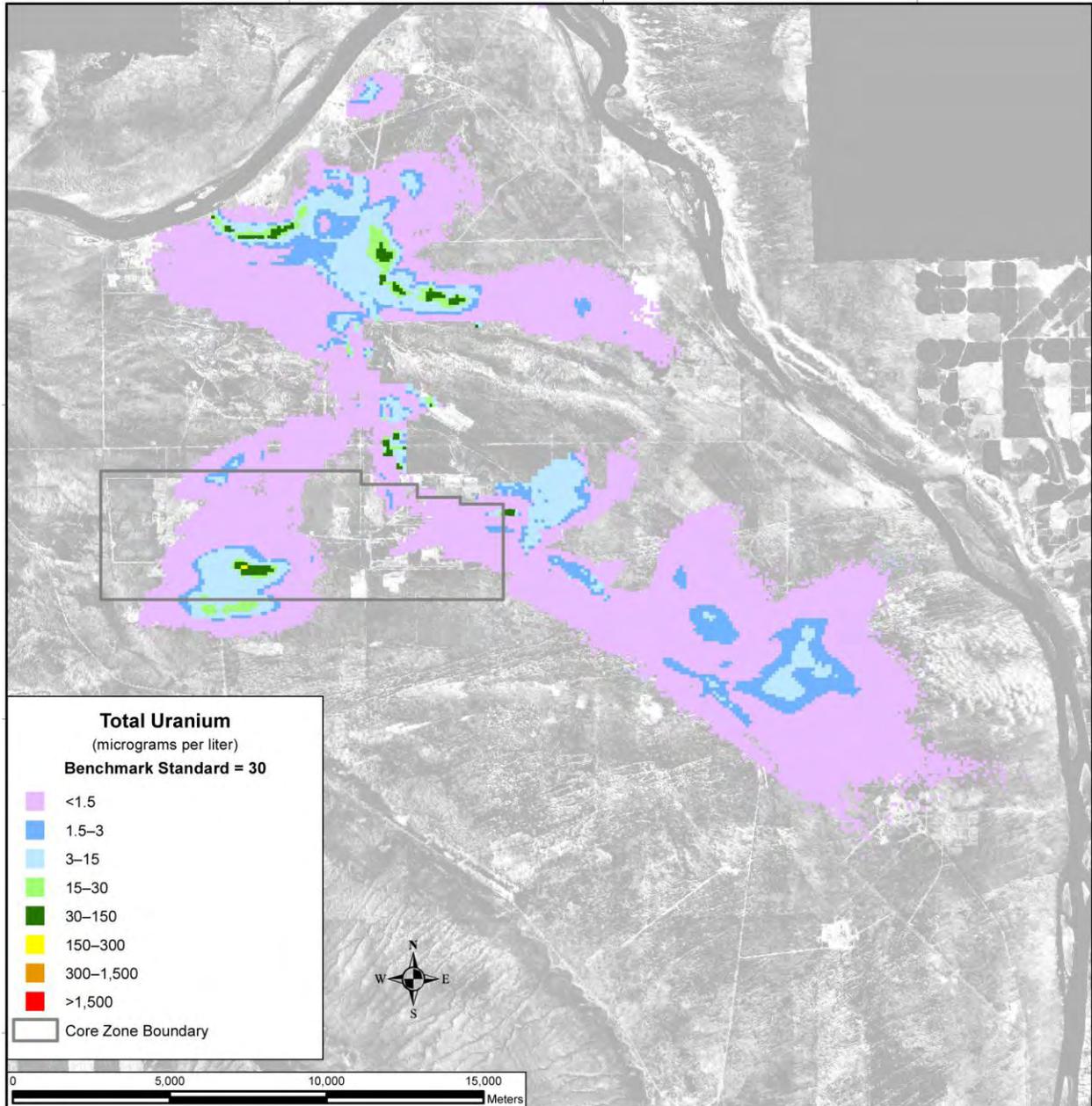
Figure 6–103. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Uranium-238 Concentration, Calendar Year 3890



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

Figure 6–104. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Uranium-238 Concentration, Calendar Year 11,885





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

Figure 6–106. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Total Uranium Concentration, Calendar Year 2135

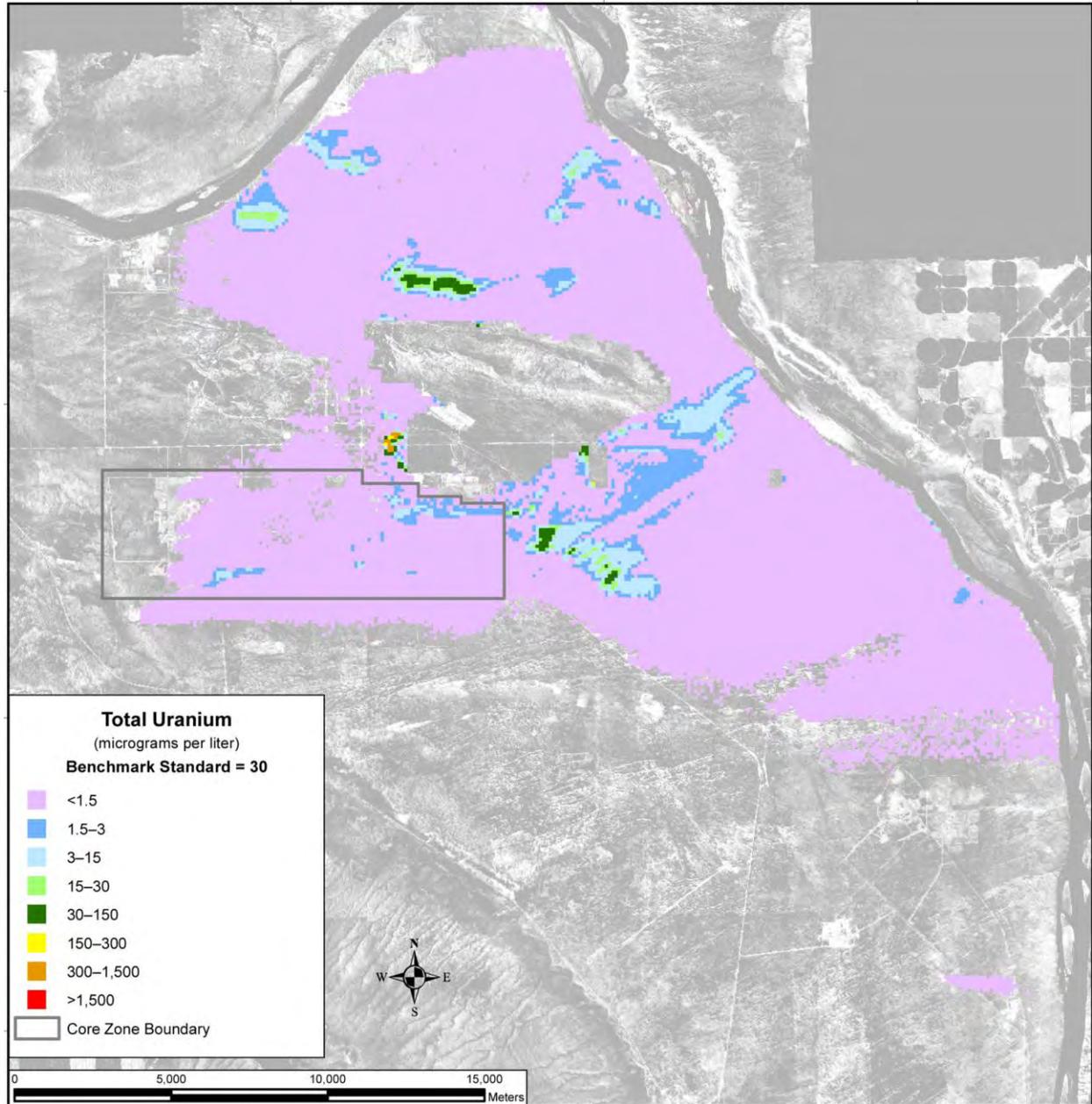
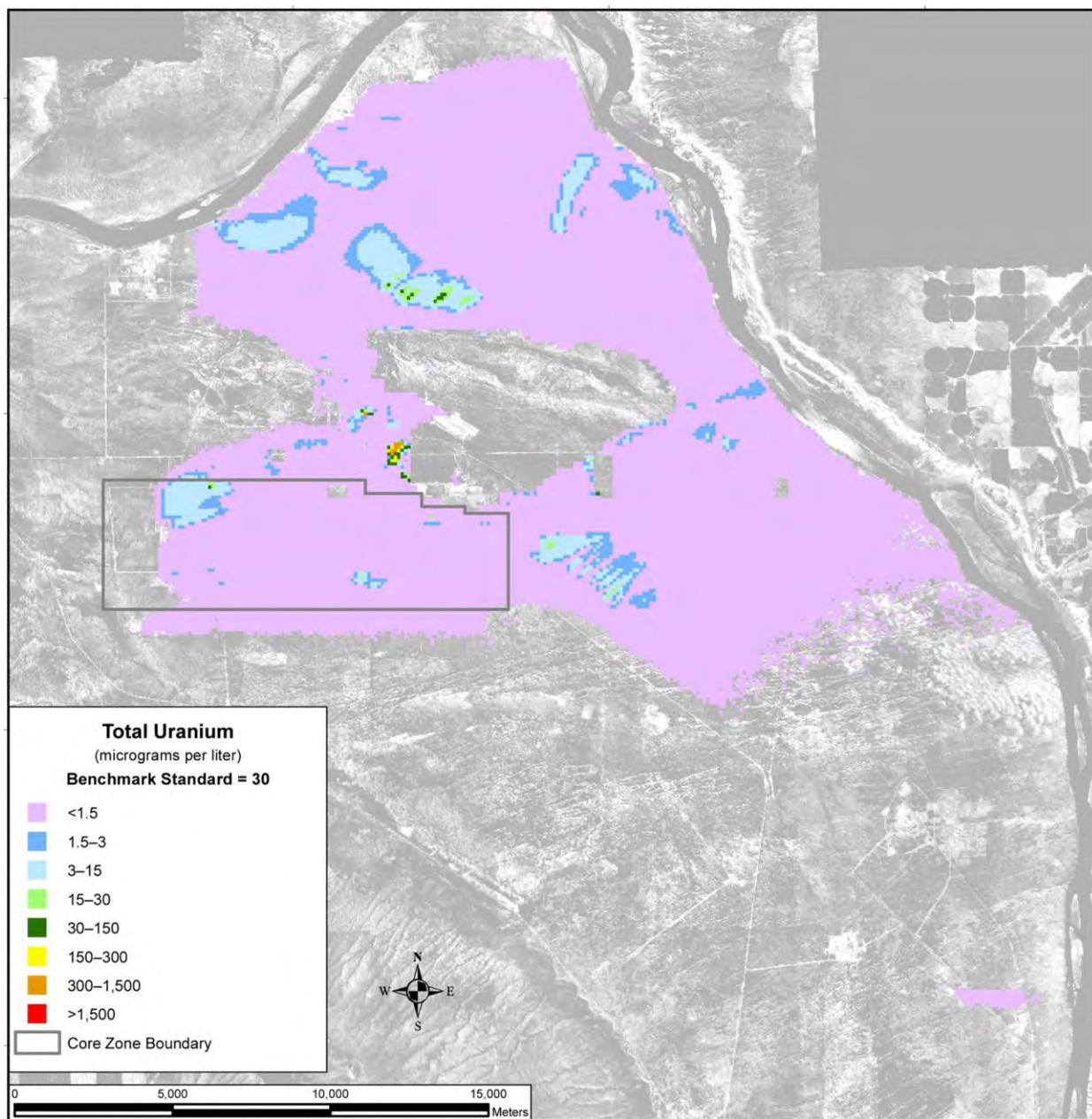


Figure 6-107. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Total Uranium Concentration, Calendar Year 3890



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

Figure 6–108. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Total Uranium Concentration, Calendar Year 11,885

6.4.1.4.4 Summary of Impacts

Long-term impacts figures in this chapter, Chapter 5, and Appendix U show how groundwater concentrations vary with time and space for cumulative impacts; Alternative Combinations 1, 2, and 3; and non-TC & WM EIS sources, respectively. The figures in these sections were compared to evaluate the relative contribution to cumulative impacts of the alternative combinations and non-TC & WM EIS sources and how they change over time. The results of this evaluation are briefly summarized below.

The long-term cumulative impacts of the scenario that includes Alternative Combination 3 are dominated by non-*TC & WM EIS* sources (for releases of tritium, uranium-238, carbon tetrachloride, chromium, and total uranium); a combination of non-*TC & WM EIS* sources and Waste Management alternative sources (for releases of iodine-129); a combination of non-*TC & WM EIS* sources and tank closure sources (for releases of nitrate); or all three (for releases of technetium-99). COPC contributions from FFTF Decommissioning Alternative 3 sources account for well under 1 percent of the total amount released to the environment.

Concentrations of tritium at the Core Zone Boundary exceed the benchmark by about three orders of magnitude for a short period of time during the early part of the period of analysis. Concentrations at the Columbia River exceed the benchmark by about two orders of magnitude during this time. Attenuation by radioactive decay is a predominant mechanism that limits the intensity and duration of tritium's impacts on groundwater. After CY 2140, tritium's impacts are essentially negligible.

Concentrations of iodine-129, carbon tetrachloride, chromium, and nitrate at the Core Zone Boundary and Columbia River nearshore exceed benchmark standards by an order of magnitude during the past-practice period and drop significantly after that. Technetium-99 concentrations at the Core Zone Boundary exceed benchmark concentrations by an order of magnitude during the past-practice period and drop significantly after that; concentrations at the Columbia River approach but never exceed the benchmark. By CY 5600, concentrations of all these conservative tracers are below the benchmark concentration.

Discharges of uranium-238 and total uranium from the ponds (non-*TC & WM EIS* sources) are the dominant contributors during the early period of the analysis. Other tank farm sources are a secondary contributor for which limited mobility is an important factor governing the timeframes and scale of groundwater impacts.

6.4.2 Human Health Impacts

This section presents the results of the long-term cumulative impacts analysis for human health. The same methodology used for the alternatives analysis was used to analyze cumulative impacts. A description of this methodology is presented in Appendix Q, including estimates of the impacts of radioactive and chemical constituents on each receptor, location, and alternative for the year of peak impact. Supporting information for the analysis of cumulative impacts on human health, including contributions from the major radionuclides and chemical constituents in the year of peak cumulative impact, is presented in Appendix U, Section U.2.

The long-term human health impacts due to release of radionuclides were estimated as dose and lifetime risk of incidence of cancer. Potential human health impacts due to release of chemical constituents include both carcinogenic effects and other forms of toxicity. Impacts of carcinogenic chemicals were estimated as lifetime risk of incidence of cancer. Noncarcinogenic effects were estimated as a Hazard Quotient, the ratio of the long-term intake of an individual chemical to the highest intake that produces no observable effect, and as a Hazard Index, the sum of the Hazard Quotients of a group of individual chemical constituents.

These four measures of human health impacts were calculated for each year over 10,000 years for applicable receptors at three locations of analysis (i.e., the Core Zone Boundary, Columbia River nearshore, and Columbia River surface water). This is a large amount of information that must be summarized to allow an interpretation of results. The method chosen was to present the dose for the year of maximum dose, the risk for the year of maximum risk, and the Hazard Index for the year of maximum Hazard Index. This choice was based on regulation of radiological impacts expressed as dose and the observation that peak risk and peak noncarcinogenic impacts expressed as a Hazard Index may occur at times other than that of peak dose.

The three onsite locations of analysis were the Core Zone Boundary, the Columbia River nearshore, and the Columbia River. The offsite locations of analysis were population centers downstream of Hanford. The total offsite population assumed for this analysis was 5 million people. Consistent with DOE guidance (DOE Guide 435.1-1:Section IV.P.(2)), the potential consequences of loss of administrative or institutional controls were considered by estimating the impacts on onsite receptors. Because DOE does not anticipate loss of control of Hanford, these onsite receptors were considered hypothetical and were applied to develop estimates for past and future time periods.

Four types of hypothetical receptors were considered. The first type, a drinking-water well user, was assumed to use groundwater as a source of drinking water. The second type, a resident farmer, was assumed to use groundwater for drinking water consumption and irrigation of crops. It was assumed that garden size and crop yield would be adequate to produce approximately 25 percent of the receptor's average requirements for crops and animal products. The third type, an American Indian resident farmer, was assumed to use groundwater for both drinking water consumption and irrigation of crops. In this case, it was assumed that garden size and crop yield would be adequate to produce the entirety of average requirements for crops and animal products. The fourth type, an American Indian hunter-gatherer, would be impacted by both groundwater and surface water because he or she was assumed to drink surface water and consume both wild plant materials, which use groundwater, and game, which drink surface water. Members of the offsite population are assumed to have the activity pattern of a residential farmer, using surface water to meet the total annual drinking water requirement and to irrigate a garden that provides approximately 25 percent of annual crop and animal product requirements. These receptors are also assumed to consume fish harvested from the river. Impacts on an individual of the offsite population are the same as those reported in tables in this chapter for the resident farmer at the Columbia River surface-water location.

The significance of the dose impacts was evaluated by comparing doses with the 100-millirem-per-year all-pathway standard specified for protection of the public and the environment in DOE Order 458.1, *Radiation Protection of the Public and the Environment*. Perspective on the radiation dose to the offsite population of 5 million individuals potentially using water from the Columbia River is provided by comparison with the background dose for the average individual of 311 millirem per year. The level of protection provided for the drinking water pathway was evaluated by comparison against the applicable drinking water standards presented in Chapter 5, Section 5.1.1. The significance of noncarcinogenic chemical health impacts was evaluated by comparison with a Hazard Index guideline value of less than unity (1).

6.4.2.1 Other Past, Present, and Reasonably Foreseeable Future Actions

The potential cumulative human health impacts of the past, present, and reasonably foreseeable future actions due to releases from non-TC & WM EIS sources are summarized in Table 6-24 for the drinking-water well user and resident farmer and in Table 6-25 for the American Indian resident farmer and American Indian hunter-gatherer. The key radioactive constituents contributing to human health risk are tritium, carbon-14, strontium-90, technetium-99, iodine-129, cesium-137, uranium isotopes, neptunium-237, and plutonium isotopes. The chemical risk and hazard drivers are 1-butanol, carbon tetrachloride, chromium, fluoride, hydrazine/hydrazine sulfate, manganese, mercury, nitrate, and total uranium. For all locations and all receptors, the peak radiation dose and risk have already occurred. For the peak Hazard Index and nonradiological risk, the peak has either already occurred or would occur between CYs 2035 and 3300. For the period prior to CY 2000, lifetime radiological risks for the year of peak risk at the Core Zone Boundary and Columbia River locations were high, approaching unity. For the period after CY 2000, risks remain high, with values between 1×10^{-5} and 1×10^{-4} (see Appendix U, Figure U-134). The estimated offsite population dose of 228 person-rem per year for the year of peak dose is approximately 0.01 percent of the average background dose for the population.

Table 6–24. Summary of Peak Impacts of Releases (Non–TC & WM EIS Sources) on Drinking-Water Well User and Resident Farmer

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (millirem per year)	Hazard Index at Year of Peak Hazard Index	Radiological Risk at Year of Peak Radiological Risk	Nonradiological Risk at Year of Peak Nonradiological Risk	Total Risk at Year of Peak Total Risk	Dose at Year of Peak Dose (millirem per year)	Hazard Index at Year of Peak Hazard Index	Radiological Risk at Year of Peak Radiological Risk	Nonradiological Risk at Year of Peak Nonradiological Risk	Total Risk at Year of Peak Total Risk
On Site										
Core Zone Boundary	1.33×10 ⁴	1.53×10 ²	1.27×10 ⁻¹	9.19×10 ⁻⁴	1.27×10 ⁻¹	1.54×10 ⁴	2.68×10 ²	1.54×10 ⁻¹	5.80×10 ⁻³	1.54×10 ⁻¹
Columbia River nearshore	2.72×10 ³	1.05×10 ²	4.12×10 ⁻²	3.31×10 ⁻⁴	4.12×10 ⁻²	7.81×10 ³	2.17×10 ²	1.55×10 ⁻¹	2.09×10 ⁻³	1.55×10 ⁻¹
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	4.56×10 ⁻²	1.82×10 ⁻³	8.42×10 ⁻⁷	2.46×10 ⁻⁸	8.49×10 ⁻⁷

Note: The total risk for the year of peak total risk may not equal the sum of the radiological and nonradiological risks for the year of peak risk because the peak radiological and nonradiological risks are likely to occur at different times.

Key: N/A=not applicable; TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington.

Table 6–25. Summary of Peak Impacts of Releases (Non–TC & WM EIS Sources) on American Indian Resident Farmer and American Indian Hunter-Gatherer

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (millirem per year)	Hazard Index at Year of Peak Hazard Index	Radiological Risk at Year of Peak Radiological Risk	Nonradiological Risk at Year of Peak Nonradiological Risk	Total Risk at Year of Peak Total Risk	Dose at Year of Peak Dose (millirem per year)	Hazard Index at Year of Peak Hazard Index	Radiological Risk at Year of Peak Radiological Risk	Nonradiological Risk at Year of Peak Nonradiological Risk	Total Risk at Year of Peak Total Risk
On Site										
Core Zone Boundary	1.85×10 ⁴	7.59×10 ²	1.97×10 ⁻¹	2.53×10 ⁻²	1.97×10 ⁻¹	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.86×10 ⁴	4.33×10 ²	4.01×10 ⁻¹	9.30×10 ⁻³	4.03×10 ⁻¹	1.33×10 ⁴	2.38×10 ²	3.06×10 ⁻¹	8.96×10 ⁻³	3.07×10 ⁻¹
Off Site										
Columbia River	5.35×10 ⁻¹	4.52×10 ⁻¹	1.11×10 ⁻⁵	4.06×10 ⁻⁷	1.11×10 ⁻⁵	N/A	N/A	N/A	N/A	N/A

Note: The total risk for the year of peak total risk may not equal the sum of the radiological and nonradiological risks for the year of peak risk because the peak radiological and nonradiological risks are likely to occur at different times.

Key: N/A=not applicable; TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington.

6.4.2.2 Alternative Combination 1

The potential cumulative human health impacts associated with Alternative Combination 1, together with the impacts of past, present, and reasonably foreseeable future actions (discussed above), are summarized in Table 6–26 for the drinking-water well user and resident farmer and in Table 6–27 for the American Indian resident farmer and American Indian hunter-gatherer. The key radioactive constituent contributors to human health risk are tritium, carbon-14, strontium-90, technetium-99, iodine-129, cesium-137, uranium isotopes, neptunium-237, and plutonium isotopes. The chemical risk and hazard drivers are 1-butanol, carbon tetrachloride, chromium, fluoride, hydrazine/hydrazine sulfate, manganese, mercury, nitrate, total uranium, and trichloroethylene. For the periods of time before CY 2000 and after CY 5000, the impacts of Alternative Combination 1 would be dominated by the impacts of releases from the non-*TC & WM EIS* sources. For the periods of time between CYs 2000 and 5000, the impacts of failure of the high-level radioactive waste tanks under Tank Closure Alternative 1 exceed the impacts derived from non-*TC & WM EIS* sources. The estimate of the offsite population dose of 229 person-rem per year for the year of peak dose is approximately 0.01 percent of the average background dose for the population.

Table 6–26. Alternative Combination 1 Summary of Peak Cumulative Impacts on Drinking-Water Well User and Resident Farmer

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (millirem per year)	Hazard Index at Year of Peak Hazard Index	Radiological Risk at Year of Peak Radiological Risk	Nonradiological Risk at Year of Peak Nonradiological Risk	Total Risk at Year of Peak Total Risk	Dose at Year of Peak Dose (millirem per year)	Hazard Index at Year of Peak Hazard Index	Radiological Risk at Year of Peak Radiological Risk	Nonradiological Risk at Year of Peak Nonradiological Risk	Total Risk at Year of Peak Total Risk
On Site										
Core Zone Boundary	1.33×10 ⁴	1.72×10 ²	1.27×10 ⁻¹	9.19×10 ⁻⁴	1.27×10 ⁻¹	1.54×10 ⁴	4.01×10 ²	1.54×10 ⁻¹	5.80×10 ⁻³	1.54×10 ⁻¹
Columbia River nearshore	2.72×10 ³	1.05×10 ²	4.12×10 ⁻²	3.31×10 ⁻⁴	4.12×10 ⁻²	7.81×10 ³	2.17×10 ²	1.55×10 ⁻¹	2.09×10 ⁻³	1.56×10 ⁻¹
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	4.56×10 ⁻²	1.82×10 ⁻³	8.42×10 ⁻⁷	2.46×10 ⁻⁸	8.49×10 ⁻⁷

Note: The total risk for the year of peak total risk may not equal the sum of the radiological and nonradiological risks for the year of peak risk because the peak radiological and nonradiological risks are likely to occur at different times.

Key: N/A=not applicable.

Table 6–27. Alternative Combination 1 Summary of Peak Cumulative Impacts on American Indian Resident Farmer and American Indian Hunter-Gatherer

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (millirem per year)	Hazard Index at Year of Peak Hazard Index	Radiological Risk at Year of Peak Radiological Risk	Nonradiological Risk at Year of Peak Nonradiological Risk	Total Risk at Year of Peak Total Risk	Dose at Year of Peak Dose (millirem per year)	Hazard Index at Year of Peak Hazard Index	Radiological Risk at Year of Peak Radiological Risk	Nonradiological Risk at Year of Peak Nonradiological Risk	Total Risk at Year of Peak Total Risk
On Site										
Core Zone Boundary	1.85×10 ⁴	7.91×10 ²	1.97×10 ⁻¹	2.53×10 ⁻²	1.97×10 ⁻¹	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.86×10 ⁴	4.33×10 ²	4.01×10 ⁻¹	9.30×10 ⁻³	4.03×10 ⁻¹	1.33×10 ⁴	2.38×10 ²	3.06×10 ⁻¹	8.96×10 ⁻³	3.07×10 ⁻¹
Off Site										
Columbia River	5.35×10 ⁻¹	4.52×10 ⁻¹	1.11×10 ⁻⁵	4.06×10 ⁻⁷	1.11×10 ⁻⁵	N/A	N/A	N/A	N/A	N/A

Note: The total risk for the year of peak total risk may not equal the sum of the radiological and nonradiological risks for the year of peak risk because the peak radiological and nonradiological risks are likely to occur at different times.

Key: N/A=not applicable.

6.4.2.3 Alternative Combination 2

The potential cumulative human health impacts associated with Alternative Combination 2, together with the impacts of past, present, and reasonably foreseeable future actions (discussed above), are summarized in Table 6–28 for the drinking-water well user and resident farmer and in Table 6–29 for the American Indian resident farmer and American Indian hunter-gatherer. The key radioactive constituent contributors to human health risk are tritium, carbon-14, strontium-90, technetium-99, iodine-129, cesium-137, uranium isotopes, neptunium-237, and plutonium isotopes. The chemical risk and hazard drivers are 1-butanol, carbon tetrachloride, chromium, fluoride, hydrazine/hydrazine sulfate, lead, manganese, mercury, nitrate, total uranium, and trichloroethylene. The impacts of Alternative Combination 2 would be dominated by the impacts of releases from the non-*TC & WM EIS* sources. The estimate of the offsite population dose of 229 person-rem per year for the year of peak dose is approximately 0.01 percent of the average background dose for the population.

Table 6–28. Alternative Combination 2 Summary of Peak Cumulative Impacts on Drinking-Water Well User and Resident Farmer

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (millirem per year)	Hazard Index at Year of Peak Hazard Index	Radiological Risk at Year of Peak Radiological Risk	Nonradiological Risk at Year of Peak Nonradiological Risk	Total Risk at Year of Peak Total Risk	Dose at Year of Peak Dose (millirem per year)	Hazard Index at Year of Peak Hazard Index	Radiological Risk at Year of Peak Radiological Risk	Nonradiological Risk at Year of Peak Nonradiological Risk	Total Risk at Year of Peak Total Risk
On Site										
Core Zone Boundary	1.33×10 ⁴	1.72×10 ²	1.27×10 ⁻¹	9.19×10 ⁻⁴	1.27×10 ⁻¹	1.54×10 ⁴	4.01×10 ²	1.54×10 ⁻¹	5.80×10 ⁻³	1.54×10 ⁻¹
Columbia River nearshore	2.72×10 ³	1.05×10 ²	4.12×10 ⁻²	3.31×10 ⁻⁴	4.12×10 ⁻²	7.81×10 ³	2.17×10 ²	1.55×10 ⁻¹	2.09×10 ⁻³	1.56×10 ⁻¹
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	4.56×10 ⁻²	1.82×10 ⁻³	8.42×10 ⁻⁷	2.46×10 ⁻⁸	8.49×10 ⁻⁷

Note: The total risk for the year of peak total risk may not equal the sum of the radiological and nonradiological risks for the year of peak risk because the peak radiological and nonradiological risks are likely to occur at different times.

Key: N/A=not applicable.

Table 6–29. Alternative Combination 2 Summary of Peak Cumulative Impacts on American Indian Resident Farmer and American Indian Hunter-Gatherer

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (millirem per year)	Hazard Index at Year of Peak Hazard Index	Radiological Risk at Year of Peak Radiological Risk	Nonradiological Risk at Year of Peak Nonradiological Risk	Total Risk at Year of Peak Total Risk	Dose at Year of Peak Dose (millirem per year)	Hazard Index at Year of Peak Hazard Index	Radiological Risk at Year of Peak Radiological Risk	Nonradiological Risk at Year of Peak Nonradiological Risk	Total Risk at Year of Peak Total Risk
On Site										
Core Zone Boundary	1.85×10 ⁴	7.84×10 ²	1.97×10 ⁻¹	2.53×10 ⁻²	1.97×10 ⁻¹	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.86×10 ⁴	4.33×10 ²	4.01×10 ⁻¹	9.30×10 ⁻³	4.03×10 ⁻¹	1.33×10 ⁴	2.38×10 ²	3.06×10 ⁻¹	8.96×10 ⁻³	3.07×10 ⁻¹
Off Site										
Columbia River	5.35×10 ⁻¹	4.52×10 ⁻¹	1.11×10 ⁻⁵	4.06×10 ⁻⁷	1.11×10 ⁻⁵	N/A	N/A	N/A	N/A	N/A

Note: The total risk for the year of peak total risk may not equal the sum of the radiological and nonradiological risks for the year of peak risk because the peak radiological and nonradiological risks are likely to occur at different times.

Key: N/A=not applicable.

6.4.2.4 Alternative Combination 3

The potential cumulative human health impacts associated with Alternative Combination 3, together with the impacts of past, present, and reasonably foreseeable future actions (discussed above), are summarized in Table 6–30 for the drinking-water well user and resident farmer and in Table 6–31 for the American Indian resident farmer and American Indian hunter-gatherer. The key radioactive constituent contributors to human health risk are tritium, carbon-14, strontium-90, technetium-99, iodine-129, cesium-137, uranium isotopes, neptunium-237, and plutonium isotopes. The chemical risk and hazard drivers are 1-butanol, carbon tetrachloride, chromium, fluoride, hydrazine/hydrazine sulfate, lead, manganese, mercury, nitrate, total uranium, and trichloroethylene. The impacts of Alternative Combination 3 would be dominated by the impacts of releases from the non-*TC & WM EIS* sources. The estimate of the offsite population dose of 229 person-rem per year for the year of peak dose is approximately 0.01 percent of the average background dose for the population.

Table 6–30. Alternative Combination 3 Summary of Peak Cumulative Impacts on Drinking-Water Well User and Resident Farmer

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (millirem per year)	Hazard Index at Year of Peak Hazard Index	Radiological Risk at Year of Peak Radiological Risk	Nonradiological Risk at Year of Peak Nonradiological Risk	Total Risk at Year of Peak Total Risk	Dose at Year of Peak Dose (millirem per year)	Hazard Index at Year of Peak Hazard Index	Radiological Risk at Year of Peak Radiological Risk	Nonradiological Risk at Year of Peak Nonradiological Risk	Total Risk at Year of Peak Total Risk
On Site										
Core Zone Boundary	1.33×10 ⁴	1.72×10 ²	1.27×10 ⁻¹	9.19×10 ⁻⁴	1.27×10 ⁻¹	1.54×10 ⁴	4.01×10 ²	1.54×10 ⁻¹	5.80×10 ⁻³	1.54×10 ⁻¹
Columbia River nearshore	2.72×10 ³	1.05×10 ²	4.12×10 ⁻²	3.31×10 ⁻⁴	4.12×10 ⁻²	7.81×10 ³	2.17×10 ²	1.55×10 ⁻¹	2.09×10 ⁻³	1.56×10 ⁻¹
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	4.56×10 ⁻²	1.82×10 ⁻³	8.42×10 ⁻⁷	2.53×10 ⁻⁸	8.49×10 ⁻⁷

Note: The total risk for the year of peak total risk may not equal the sum of the radiological and nonradiological risks for the year of peak risk because the peak radiological and nonradiological risks are likely to occur at different times.

Key: N/A=not applicable.

Table 6–31. Alternative Combination 3 Summary of Peak Cumulative Impacts on American Indian Resident Farmer and American Indian Hunter-Gatherer

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (millirem per year)	Hazard Index at Year of Peak Hazard Index	Radiological Risk at Year of Peak Radiological Risk	Nonradiological Risk at Year of Peak Nonradiological Risk	Total Risk at Year of Peak Total Risk	Dose at Year of Peak Dose (millirem per year)	Hazard Index at Year of Peak Hazard Index	Radiological Risk at Year of Peak Radiological Risk	Nonradiological Risk at Year of Peak Nonradiological Risk	Total Risk at Year of Peak Total Risk
On Site										
Core Zone Boundary	1.85×10 ⁴	7.84×10 ²	1.97×10 ⁻¹	2.53×10 ⁻²	1.97×10 ⁻¹	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.86×10 ⁴	4.33×10 ²	4.01×10 ⁻¹	9.30×10 ⁻³	4.03×10 ⁻¹	1.33×10 ⁴	2.38×10 ²	3.06×10 ⁻¹	8.96×10 ⁻³	3.07×10 ⁻¹
Off Site										
Columbia River	5.35×10 ⁻¹	4.52×10 ⁻¹	1.11×10 ⁻⁵	4.06×10 ⁻⁷	1.11×10 ⁻⁵	N/A	N/A	N/A	N/A	N/A

Note: The total risk for the year of peak total risk may not equal the sum of the radiological and nonradiological risks for the year of peak risk because the peak radiological and nonradiological risks are likely to occur at different times.

Key: N/A=not applicable.

6.4.3 Ecological Risk

This section presents the results of the analysis of long-term cumulative impacts on ecological resources from exposure to chemicals and radionuclides released to the environment as a result of past, present, and reasonably foreseeable future actions. The cumulative impacts analysis incorporates estimated cumulative concentrations of chemicals and radionuclides in soil and estimated peak concentrations in air, water, and sediment from the ecological risk analysis for the *TC & WM EIS* alternatives. Detailed information on the ecological risk analysis for the *TC & WM EIS* alternatives appears in Appendix P.

As described in Appendix R, cumulative impacts were evaluated in an ROI that includes the proposed *TC & WM EIS* action areas, Hanford, and the Hanford Reach of the Columbia River. A general description of ecological resources at Hanford and within the region is presented in Chapter 3, Section 3.2.7. The long-term ecological risk from chemical and radionuclide releases to air and groundwater as a result of the three combinations of Tank Closure, FFTF Decommissioning, and Waste Management alternatives is summarized in Chapter 5, Section 5.4.3. Section 6.3.7 presents the analysis of cumulative impacts on ecological resources that may occur as a result of land use changes in the ROI.

The analysis of long-term cumulative impacts on ecological receptors presented here focuses on risk from exposure to chemicals and radionuclides released to air and groundwater as a result of DOE actions at Hanford. The releases to air are summarized in Chapter 2, Section 2.8.3.4. The releases to groundwater are summarized in Section 2.9. The cumulative impacts analysis assumes that impacts of different sources of contaminant releases to an environmental medium (e.g., air) would coincide, even though many would not. This provides the most conservative estimate of cumulative impacts. The combined long-term cumulative impacts of releases to air and groundwater on ecological resources were not analyzed because maximum groundwater impacts are not expected to occur until hundreds or thousands of years after the air impacts cease.

For air releases, cumulative impacts were evaluated by combining estimated media (e.g., surface water) concentrations resulting from *TC & WM EIS* alternative combinations with reported baseline media concentrations resulting from past and current practices. Maximum soil concentrations from samples collected by the Hanford environmental monitoring program (Poston, Duncan, and Dirkes 2011; Poston et al. 2006, 2007; Poston, Hanf, and Dirkes 2005) were used to estimate baseline conditions. Estimated media concentrations for the *TC & WM EIS* alternative combinations came from models of transport and deposition of contaminants expected to be released to air and deposited on soil, sediment, and surface water. There are no comparable estimated concentrations of chemical and radioactive contaminants in air or soil for other future DOE actions at Hanford or for non-DOE actions in the ROI. Therefore, estimated concentrations resulting from the *TC & WM EIS* alternative combinations were added to the reported maximum measured baseline concentrations. This was done to focus attention on instances in which the cumulative impacts would pose a potential risk when there is little to no risk from either *TC & WM EIS* alternative combinations or measured baseline conditions separately. No such cases were found (see Section 6.4.3.1).

For groundwater releases, cumulative impacts were estimated as the sum of impacts of predicted contaminant releases associated with *TC & WM EIS* alternative combinations (see Appendix D) and of past, present, and reasonably foreseeable future releases at Hanford unrelated to the alternative combinations, as captured in the cumulative contaminant inventory (see Appendix S). Estimated peak media concentrations for the *TC & WM EIS* alternative combinations and cumulative impacts analysis came from models of release and transport through the vadose zone, groundwater transport, and eventual discharge of contaminants to the Columbia River and its riparian zone. Hazard Quotients were calculated for the cumulative impacts under the three Tank Closure, FFTF Decommissioning, and Waste Management alternative combinations (see Appendix P). Cumulative groundwater impacts are discussed in Section 6.4.3.2.

6.4.3.1 Air

The cumulative long-term impacts on ecological receptors of estimated media concentrations resulting from air releases and actual media concentrations are not different from their separate long-term impacts. Where there is not already a potential risk from either actual media concentrations or those expected under the *TC & WM EIS* alternative combinations, there would be no risk from the cumulative impacts. Where there is a potential risk to ecological receptors, the risk would result from either actual media concentrations or estimated *TC & WM EIS* alternative combination concentrations, but not both.

Table 6–32 presents the maximum concentrations of selected *TC & WM EIS* chemical COPCs with corresponding data from Hanford environmental reports for 2004, 2005, 2006, 2009, and 2010 (Poston, Duncan, and Dirkes 2010, 2011; Poston et al. 2006, 2007; Poston, Hanf, and Dirkes 2005). The selected COPCs are those with the highest Hazard Quotients under the three alternative combinations: mercury for receptors exposed to soil and air at the onsite maximum-impact location and Columbia River sediment, and mercury and benzene for receptors exposed to Columbia River surface water. For these analytes, the estimated cumulative concentrations of mercury in onsite surface soil under Alternative Combinations 2 and 3 would pose a potential for adverse impacts on ecological receptors (e.g., maximum Hazard Quotient = 171). Comparing the estimated mercury soil concentrations under Alternative Combinations 2 and 3 with the maximum mercury concentration reported for the Hanford monitoring program shows that the latter is three orders of magnitude smaller than the estimated value and does not pose a risk to ecological receptors. Maximum baseline concentrations of mercury in Columbia River surface water could potentially have adverse impacts on ecological receptors because they exceed published benchmarks (see Table 6–33), but the estimated concentrations resulting from the *TC & WM EIS* alternative combinations would contribute insignificantly to the risk. Maximum baseline concentrations of mercury in sediment, which are 20 times larger than those estimated under Alternative Combinations 2 and 3, cause the cumulative concentrations to equal or slightly exceed the benchmark. The maximum concentration of benzene reported for the Hanford monitoring program is three to four orders of magnitude higher than the alternative combination concentrations in Columbia River surface water and does not pose a risk to ecological receptors.

Table 6–32. Potential Cumulative Impacts of Releases to Air on Ecological Receptors

Action/Activity	Concentration of COPC in the Environmental Medium			
	Mercury			Benzene
	Soil (mg/kg)	Surface Water (mg/L)	Sediment (mg/kg)	Surface Water (mg/L)
<i>TC & WM EIS</i> Alternative Combinations				
Alternative Combination 1	0	0	0	5.09×10^{-8}
Alternative Combination 2	2.46	2.40×10^{-9}	8.91×10^{-3}	1.11×10^{-7}
Alternative Combination 3	2.57	3.70×10^{-9}	9.24×10^{-3}	2.76×10^{-7}
Other DOE Actions at the Hanford Site				
Hanford Site baseline ^a	7.0×10^{-3}	6.3×10^{-6}	2.0×10^{-1}	3.0×10^{-4}
Other DOE Actions Subtotal	7.0×10^{-3}	6.3×10^{-6}	2.0×10^{-1}	3.0×10^{-4}

Table 6–32. Potential Cumulative Impacts of Releases to Air on Ecological Receptors (continued)

Action/Activity	Concentration of COPC in the Environmental Medium			
	Mercury			Benzene
	Soil (mg/kg)	Surface Water (mg/L)	Sediment (mg/kg)	Surface Water (mg/L)
Cumulative Totals^b				
Alternative Combination 1	7.0×10^{-3}	6.3×10^{-6}	2.0×10^{-1}	3.0×10^{-4}
Alternative Combination 2	2.47	6.3×10^{-6}	2.1×10^{-1}	3.0×10^{-4}
Alternative Combination 3	2.58	6.3×10^{-6}	2.1×10^{-1}	3.0×10^{-4}
Benchmark Concentration^c	1.5×10^{-2}	2.8×10^{-6}	2.0×10^{-1}	3.16×10^{-4}

^a Maximum onsite and Columbia River values in Hanford Site environmental reports for calendar years 2004, 2005, 2006, 2009, and 2010 (Poston, Duncan, and Dirkes 2010, 2011; Poston et al. 2006, 2007; Poston, Hanf, and Dirkes 2005). The value for benzene is the maximum reporting limit for nondetectable concentrations.

^b The cumulative totals are the sums of the impacts under the *TC & WM EIS* alternative combinations and the other DOE activities.

^c From Table 6–33.

Note: Concentrations exceeding the benchmark values are shown in bold text.

Key: COPC=constituent of potential concern; DOE=U.S. Department of Energy; mg/kg=milligrams per kilogram; mg/L=milligrams per liter; *TC & WM EIS*=*Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*.

Source: Poston, Duncan, and Dirkes 2010, 2011; Poston et al. 2006, 2007; Poston, Hanf, and Dirkes 2005.

Table 6–33. Toxicity Benchmark Concentrations for Ecological Receptors Exposed to Chemicals in Soil, Water, and Sediment

Chemical	Water (mg/L)		Soil (mg/kg)		Sediment (mg/kg)	
	Value	Source	Value	Source	Value	Source
Chromium ^a	2.7×10^{-4} (b)	Suter and Tsao 1996	–	–	–	–
Lead	–	–	–	–	3.1×10^1	EPA 1999
Mercury	2.8×10^{-6} (c)	EPA 1999	1.5×10^{-2} (c, d)	–	2.0×10^{-1} (c)	EPA 1999
Uranium	–	–	–	–	1.3×10^1 (e)	–
Benzene	3.16×10^{-4} (f)	Suter and Tsao 1996	–	–	–	–

^a It was assumed, for analysis purposes, that all chromium was hexavalent.

^b Concentration of chromium causing an adverse effect on 20 percent of the individuals of a sensitive species during a toxicity test.

^c Value for methylmercury.

^d Soil mercury concentration producing $HQ = 1$ for side-blotched lizard: $C_{soil} = TRV / (IR_{food} \times BAF-S + IR_{soil})$; $TRV = 0.0064$ mg/kg body weight/day (Sample, Opresko, and Suter 1996); $IR_{food} = 0.05$ kg food/kg body weight/day (Sample et al. 1997); $BAF-S = 8.5$ kg dry soil/kg tissue (EPA 1999); $IR_{soil} = IR_{food} \times SF$; $SF = 0.011$ kg dry soil/kg food (DOE 1998b).

^e Sediment uranium concentration producing $HQ = 1$ for raccoon: $C_{sediment} = TRV / (IR_{food} \times BASF + IR_{sediment})$; $TRV = 3.07$ mg/kg body weight/day (Sample, Opresko, and Suter 1996); $IR_{food} = 0.26$ kg food/kg body weight/day (Sample et al. 1997); $BASF = 0.893$ kg dry sediment/kg tissue (EPA 1999); $IR_{sediment} = IR_{food} \times SF$; $SF = 0.018$ kg dry soil/kg food (DOE 1998b).

^f Acute lowest observed adverse effect level for rainbow trout $\times 0.1$ acute-to-chronic conversion factor.

Key: *BAF-S*=soil-to-soil invertebrate bioaccumulation factor; *BASF*=sediment-to-benthic-invertebrate bioaccumulation factor; *C*=concentration; EPA=U.S. Environmental Protection Agency; *HQ*=Hazard Quotient; *IR*=ingestion rate; mg/kg=milligrams per kilogram; mg/L=milligrams per liter; *SF*=dry soil or sediment ingested as a fraction of daily food (wet weight) ingested; *TRV*=toxicity reference value.

Source: DOE 1998b; EPA 1999; Sample, Opresko, and Suter 1996; Sample et al. 1997; Suter and Tsao 1996.

Contributions to mercury and benzene concentrations from non-DOE actions in or near the ROI would be similar to Hanford baseline contributions. Non-DOE actions are not included in Table 6–32, but the reported data are presented below. Soil grab samples at the AREVA NP facility between 2000 and 2005

did not exceed 3.75 picocuries per gram of uranium (AREVA 2006), which is 10 times smaller than the maximum estimated onsite soil concentration for *TC & WM EIS* alternative combinations (Alternative Combination 1, onsite soil, 32.2 picocuries per gram). Plant stack data for air emissions from the Perma-Fix Northwest LLW and mixed waste treatment facilities in 2006 did not exceed 0.0042 picocuries per cubic meter of cobalt-60 (Pacific EcoSolutions 2007), which is over 10 times less than the maximum estimated onsite air concentration under the *TC & WM EIS* alternative combinations (Alternative Combination 1, onsite air, 0.096 picocuries per cubic meter). Soil samples at US Ecology had activities less than the maximum estimated *TC & WM EIS* values and Hanford baseline values for all radioactive COPCs (Ecology and WSDOH 2004) except total uranium (maximum 0.8 picocuries per cubic meter), which exceeded the baseline uranium-238 value (maximum 0.31 picocuries per cubic meter) in 1998. Tritium in water (Stormwater Outfall Sample 101) from the Energy Northwest Columbia Generating Station was measured as high as 17,100 picocuries per liter (Energy Northwest 2006b), exceeding the Hanford baseline maximum (594 picocuries per liter) by a factor of 25 and the estimated *TC & WM EIS* value (0.07 picocuries per liter) by a factor of 240,000. Not one of these cobalt-60, tritium, and uranium activities poses a risk to ecological receptors (see Chapter 5, Section 5.4.3); thus, a cumulative impact is unlikely. Moravek Biochemicals reported that 2004 air releases of tritium and carbon-14 were within permissible levels (Moravek 2005). Future releases from the Moravek facility could potentially add to impacts of estimated air emissions of tritium and carbon-14 under the *TC & WM EIS* alternatives.

Cumulative impacts on air emissions from offsite construction projects and operations activities could potentially increase impacts on ecological receptors exposed to nitrogen oxides and sulfur oxides from burning diesel fuel. Emissions of volatile organic carbon compounds such as acetaldehyde, acetic acid, ethyl acetate, formaldehyde, ethanol, and methanol from biofuel plants (e.g., the Columbia Ethanol Plant) may have impacts on ecological receptors. The magnitude of those impacts cannot be estimated using the available information. In general, offsite sources of air emissions (see Appendix R, Table R-5) are not expected to contribute significantly to cumulative ecological risk at Hanford.

6.4.3.2 Groundwater

Cumulative impacts on ecological resources from releases to groundwater were calculated for the three *TC & WM EIS* alternative combinations. Hazard Quotients are calculated for the year of peak concentration for each COPC. The largest risk indices for each aquatic and riparian receptor exposed to chemical COPCs in groundwater discharging at the Columbia River are summarized in Table 6-34. Impacts are presented in Table 6-34 for the three *TC & WM EIS* alternative combinations and the cumulative releases (i.e., releases associated with the three alternative combinations plus those unrelated to the alternative combinations). The impacts expected to result from radioactive COPCs are never as high as the highest impacts from chemical COPCs.

Table 6–34. Summary of Long-Term Impacts of Alternative Combinations and Cumulative Impacts on Aquatic and Riparian Resources at the Columbia River Resulting from Contaminant Releases to Groundwater^a

	Hazard Quotient for Maximum COPC						
	Benthic Invertebrates	Raccoon	Spotted Sandpiper	Muskrat	Least Weasel	Bald Eagle	Aquatic Biota/Salmonids
Alternative Combinations							
	Chromium ^b			Nitrate		Chromium ^b	
Alternative Combination 1	1.69×10 ⁻¹	1.39×10 ⁻¹	1.15	1.41×10 ⁻²	1.36	3.71×10 ⁻²	4.32×10¹
Alternative Combination 2	1.67×10 ⁻¹	1.37×10 ⁻¹	1.13	1.43×10 ⁻²	1.37	3.69×10 ⁻²	4.31×10¹
Alternative Combination 3	1.67×10 ⁻¹	1.37×10 ⁻¹	1.13	1.43×10 ⁻²	1.37	3.69×10 ⁻²	4.31×10¹
Cumulative Impacts Under Alternative Combinations							
	Uranium-238	Lead		Chromium ^b	Nitrate	Fluoride	Chromium ^b
Alternative Combination 1	2.14×10¹	1.31×10²	4.59×10²	2.06×10 ⁻¹	2.64	2.21	2.32×10²
Alternative Combination 2	2.14×10¹	1.31×10²	4.59×10²	2.06×10 ⁻¹	2.64	2.21	2.32×10²
Alternative Combination 3	2.14×10¹	1.31×10²	4.59×10²	2.06×10 ⁻¹	2.64	2.21	2.32×10²

^a Hazard Quotients are calculated for the year of peak concentration for each COPC. See Tables 6–15, 6–19, and 6–23 for the year of peak concentration of each COPC under each alternative combination. The Hazard Quotients calculated from these peak concentrations may have occurred in the past and may not be indicative of future concentrations.

^b It was assumed, for analysis purposes, that all chromium was hexavalent.

Note: Hazard Quotients exceeding 1 are shown in **bold** text.

Key: COPC=constituent of potential concern.

The highest risk indices under the alternative combinations for benthic invertebrates; the raccoon, spotted sandpiper, and bald eagle; and aquatic biota, including salmonids, are those for chromium. The highest index for the muskrat and least weasel is that for nitrate in seeps at the Columbia River. Chromium for the spotted sandpiper and aquatic biota, including salmonids, and nitrate for the least weasel are the only COPCs with a Hazard Quotient exceeding 1 under the alternative combinations. Hazard Quotients less than 1 indicate little to no risk to the receptor.

All of the maximum risk indices for receptors, except the muskrat, would exceed 1 for the cumulative impacts. The highest risk index for the cumulative impacts would result from chromium for the muskrat and aquatic biota, including salmonids; lead for the raccoon and spotted sandpiper; nitrate for the least weasel; fluoride for the bald eagle; and uranium-238 for benthic invertebrates. The overall highest risk index for the cumulative impacts analysis would be from lead. Other COPCs identified in the cumulative impacts analysis as potentially causing adverse impacts on aquatic and riparian receptors (risk index greater than 1) would include the chemicals carbon tetrachloride and uranium (see Table 6–35); the results for tabulated COPCs are the same for cumulative impacts under all three alternative combinations. Peak concentrations of uranium (uranium-233, -234, -235, and -238 and total uranium), chromium, and nitrate were predicted to have already occurred, while those of carbon tetrachloride, fluoride, and lead were predicted to occur in the future (see Tables 6–15, 6–19, and 6–23).

Table 6–35. Cumulative Impact Risk Indices for Aquatic and Riparian Receptors and Selected Chemical and Radioactive Constituents of Potential Concern Under Alternative Combinations 1, 2, and 3

Constituents of Potential Concern	Benthic Invertebrates	Muskrat	Spotted Sandpiper	Raccoon	Bald Eagle	Least Weasel	Aquatic Biota/Salmonids
Chemical Constituents of Potential Concern							
Carbon tetrachloride	2.12×10 ¹	2.93×10 ⁻²	No TRV	5.59	No TRV	6.47×10 ⁻²	1.65×10 ⁻¹
Chromium ^a	5.27	2.06×10 ⁻¹	3.58×10¹	4.33	4.81×10 ⁻¹	4.60×10 ⁻¹	2.32×10²
Fluoride	No TRV	9.77×10 ⁻²	3.25×10²	3.48×10¹	2.21	1.68	No TRV
Lead	9.39×10⁻¹	8.62×10⁻²	4.59×10²	1.31×10²	6.08×10⁻¹	1.69	5.17×10 ⁻¹
Nitrate	No TRV	1.67×10 ⁻¹	No TRV	5.37×10 ⁻¹	No TRV	2.64	No TRV
Uranium	No TRV	6.22×10 ⁻²	2.95×10¹	6.63×10¹	9.09×10 ⁻²	1.55	4.91
Radioactive Constituents of Potential Concern							
Uranium-238	2.14×10¹	2.66×10 ⁻⁴	5.21	2.24	5.97×10 ⁻³	2.34×10 ⁻²	3.86×10 ⁻²

^a It was assumed, for analysis purposes, that all chromium was hexavalent.

Note: Risk indices exceeding 1 are shown in **bold** text.

Key: TRV=toxicity reference value.

Whether predicted to occur in the past or the future, peak concentrations and maximum estimated impacts of groundwater releases that are not associated with the *TC & WM EIS* alternatives are greater than those of releases associated with the *TC & WM EIS* alternatives. For example, impacts of estimated concentrations of chromium in surface water and uranium in sediment that are associated with the *TC & WM EIS* alternatives would represent a small fraction of the cumulative impacts (see Table 6–36). Estimated peak concentrations resulting from groundwater releases that are not associated with the *TC & WM EIS* alternatives are approximately four times the estimated peak concentrations associated with the *TC & WM EIS* alternatives for chromium and several orders of magnitude greater than those for uranium. Other COPCs showing this pattern are fluoride and uranium-238. Peak nitrate concentrations in groundwater associated with the *TC & WM EIS* alternatives were estimated to be about 10 percent of the peak concentrations in groundwater due to releases not associated with the *TC & WM EIS* alternatives. Lead was not predicted to occur in groundwater discharging at the Columbia River under the *TC & WM EIS* alternative combinations, but it is a source of cumulative impacts on aquatic and riparian receptors exposed to sediment as a result of releases not associated with the *TC & WM EIS* alternatives (see Table 6–36).

Peak groundwater concentrations, although a useful measure to show the maximum predicted impacts, tell only part of the story. Long-term impacts on ecological resources exposed to groundwater discharging at the Columbia River vary through time with the variation in groundwater concentrations (see Appendix U and Chapter 5 of this EIS). For some COPCs with peak concentrations that have already occurred (chromium, nitrate, and uranium), contributions to cumulative impacts under *TC & WM EIS* alternative combinations in the future dominate the contribution from non-*TC & WM EIS* sources. For chromium and nitrate, the contribution to cumulative impacts under Alternative Combination 1 dominates that of non-*TC & WM EIS* sources after 2150, whereas the contributions under Alternative Combinations 2 and 3 dominate that of non-*TC & WM EIS* sources between 2150 and 3500. The contribution to cumulative impacts of sources of uranium (total uranium and uranium-238) associated with Alternative Combination 1 dominates that of non-*TC & WM EIS* sources after 10,000 years because the contribution from non-*TC & WM EIS* sources declines sooner.

Table 6–36. Summary of Long-Term Impacts of Alternative Combinations and Cumulative Impacts on Aquatic and Riparian Resources at the Columbia River Resulting from Contaminant Releases to Groundwater

Action/Activity	Concentration of COPCs in Environmental Medium		
	Sediment (mg/kg Uranium)	Surface Water (mg/L Chromium) ^a	Sediment (mg/kg Lead)
TC & WM EIS Alternative Combinations			
Alternative Combination 1	0.377	0.012	0
Alternative Combination 2	0.029	0.012	0
Alternative Combination 3	0.009	0.012	0
Other DOE Actions at the Hanford Site			
Other DOE Actions ^b	859	0.050	29.1
Cumulative Total^c			
Alternative Combination 1	859	0.062	29.1
Alternative Combination 2	859	0.062	29.1
Alternative Combination 3	859	0.062	29.1
Benchmark^d	13	0.00027	31

^a It was assumed, for analysis purposes, that all chromium was hexavalent.

^b Difference of model results (concentrations) for *TC & WM EIS* alternative combinations and other DOE releases and results for *TC & WM EIS* alternative combinations excluding past leaks and other releases.

^c Sum of concentrations under *TC & WM EIS* alternative combinations and other DOE actions.

^d From Table 6–33.

Note: Concentrations exceeding the benchmark concentrations are shown in **bold** text.

Key: COPC=constituent of potential concern; DOE=U.S. Department of Energy; mg/kg=milligrams per kilogram; mg/L=milligrams per liter; *TC & WM EIS*=*Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*.

Estimated peak concentrations of carbon tetrachloride, chromium, fluoride, nitrate, lead, and uranium in groundwater discharging to the Columbia River nearshore would exceed benchmark concentrations. Concentrations associated with releases unrelated to the *TC & WM EIS* alternative combinations would remain above benchmarks until sometime between 2500 and 3500 for lead and chromium and 1975 and 2050 for uranium. Concentrations of nitrate in Columbia River water associated with releases unrelated to the *TC & WM EIS* alternative combinations would drop below benchmarks by CY 2050. Nitrate concentrations from sources associated with *TC & WM EIS* alternative combinations would drop below benchmarks by CY 2050. Chromium concentrations associated with *TC & WM EIS* alternative combinations would drop below benchmarks much later, between 3500 and 7000 under Alternative Combination 1 and between 2150 and 3500 under Alternative Combinations 2 and 3.

Impacts of releases to groundwater from upstream sources are discussed in Section 6.4.2. These releases are not expected to contribute substantially to impacts on the Hanford Reach of the Columbia River, given the distances and river-flow volumes.

6.4.4 Environmental Justice

This section presents the cumulative impacts analysis for environmental justice. Sections 6.4.1 and 6.4.2 evaluate cumulative groundwater impacts and associated potential human health effects. The receptors analyzed with the potential for environmental justice concerns include a resident farmer, an American Indian resident farmer, and an American Indian hunter-gatherer. The hypothetical resident farmer and American Indian resident farmer were both assumed to use only groundwater for drinking water ingestion and crop irrigation. While only a portion of the food consumed by the resident farmer was assumed to come from crops and animal products exposed to contaminated groundwater, all of the food consumed by

the American Indian resident farmer was assumed to come from crops and animal products exposed to contaminated groundwater. The American Indian hunter-gatherer was assumed to gather food from indigenous plants and harvest fish from the Columbia River rather than cultivate crops; he or she was assumed to be exposed to a combination of surface water and groundwater. Based on these assumptions, the two American Indian receptors would be most at risk from contaminated groundwater.

As demonstrated in Tables 6–15, 6–19, and 6–23, which show the maximum cumulative concentrations of the COPCs, as well as Figures 6–2 through 6–9, 6–35 through 6–42, and 6–72 through 6–79, which show cumulative concentrations versus time for all locations and all receptors, the peak radiological impacts have already occurred. As shown in Tables 6–26 through 6–31, cumulative releases of radioactive materials would result in doses to the resident farmer, the American Indian resident farmer, and the American Indian hunter-gatherer that exceed regulatory standards at the applicable Core Zone Boundary and Columbia River nearshore locations. In all instances, these releases would exceed regulatory limits by several orders of magnitude.

Peak nonradiological impacts have either already occurred or would occur between CYs 2200 and 2500. Releases of nonradioactive materials from cumulative analysis sources would result in Hazard Indices that exceed guidelines for the resident farmer, the American Indian resident farmer, and the American Indian hunter-gatherer at the applicable Core Zone Boundary and Columbia River nearshore locations.

The human health risk analysis determined that releases from cumulative analysis sources would result in impacts in excess of regulatory limits only if an individual is located on site at the Core Zone Boundary and the Columbia River nearshore location and if all of his or her food is exposed to contaminated groundwater and surface water. There are no such onsite receptors currently at Hanford. The onsite exposure scenarios do not currently exist and have never existed during Hanford operations. Therefore, the estimated high health risks for past years are hypothetical risks only; no persons were ever exposed at these levels. While it is possible for these receptor scenarios to develop in the future, none are expected within a reasonably foreseeable timeframe because the Core Zone is designated for Industrial-Exclusive use, the Columbia River nearshore location is designated for Preservation (Hanford Reach National Monument), and the area between them is designated for Conservation (Mining) (DOE 1999a). Therefore, it is unlikely that cumulative releases would pose a disproportionately high and adverse long-term human health risk to minority or low-income populations. As discussed in Chapter 5, the alternative combination that could have the greatest impact on long-term human health is Alternative Combination 1. The cumulative impacts scenario that includes Alternative Combination 1 would be dominated by impacts due to releases from past, present, and reasonably foreseeable future actions unrelated to the *TC & WM EIS* alternative combinations.

6.5 REGIONAL AND GLOBAL CUMULATIVE IMPACTS

6.5.1 Ozone Depletion

Under the *TC & WM EIS* alternatives, substantial quantities of ozone-depleting compounds are not expected to be used or discharged. Construction and operations activities would be accomplished using materials and equipment formulated to be compliant with laws and regulations to reduce the use of ozone-depleting compounds. Any release of ozone-depleting compounds would be incidental to the conduct of the *TC & WM EIS* activities, such as releases that might occur during demolition of older air conditioning systems that contain unrecovered, ozone-depleting compounds. Emissions of carbon tetrachloride from groundwater plume vapor extraction in the 200-West Area are below reportable quantities (Poston et al. 2007:10.10). Emissions of ozone-depleting compounds would be very small and would represent a negligible contribution to the destruction of Earth's protective ozone layer.

6.5.2 Global Climate Change

The greenhouse effect is the process by which part of terrestrial radiation is absorbed by gases in the atmosphere, warming Earth's surface and atmosphere; this warming effect is referred to as "global warming." This greenhouse or global warming effect and Earth's radiation balance are affected largely by water vapor, carbon dioxide, and trace gases, which absorb infrared radiation and are referred to as "greenhouse gases." Other greenhouse gases include nitrous oxide, halocarbons, and methane. Some greenhouse gases occur naturally, while others are exclusively manmade; human activity may cause emissions of both naturally occurring and manmade greenhouse gases.

There is consensus among scientists, including those on the Intergovernmental Panel on Climate Change (IPCC), that increases in atmospheric concentrations of greenhouse gases produce changes in Earth's atmospheric energy balance and thereby influence global climate. Water vapor (1 percent of the atmosphere) is the most common and dominant greenhouse gas; only small amounts of water vapor are produced as a result of human activities. However, its atmospheric concentration is driven primarily by changes in temperature such that water vapor serves to amplify effects of greenhouse gases. The principal greenhouse gases resulting from human activities are carbon dioxide, methane, nitrous oxide, and halocarbons. Halocarbons include chlorofluorocarbons; hydrofluorocarbons, which are replacing chlorofluorocarbons as refrigerants; and perfluorocarbons, which are byproducts of aluminum smelting. Other gases of concern include sulfur hexafluoride, which is widely used in insulation for electrical equipment. These gases are released in different quantities and have different potencies in their contributions to global warming (IPCC 2007a; Justus and Fletcher 2001).

Sources of anthropogenic carbon dioxide include combustion of fossil fuels such as natural gas, oil, gasoline, and coal. It was estimated that carbon dioxide atmospheric levels have risen by more than 35 percent since the preindustrial period (since 1750) as a result of human activities. Emissions of other greenhouse gases have also risen (IPCC 2007a:3). Annual global emissions of carbon dioxide were 26.4 billion metric tons from fossil fuel use worldwide in 2000 through 2005 and increased to 32.1 billion metric tons in 2008 (preliminary estimates for 2010 were 33.5 billion metric tons) (CDIAC 2011a, 2011b; IPCC 2007a). Carbon dioxide is the most important anthropogenic greenhouse gas and is therefore of primary concern in this EIS.

The IPCC concluded that warming of Earth's climate system is unequivocal and that most of the observed increase in global average temperatures is very likely due to the observed increase in anthropogenic greenhouse gas concentrations. The IPCC reported potential impacts resulting from warming of the climate system, including expansion of seawater volume; decreases in mountain glaciers and snow cover, resulting in sea level rise; changes in arctic temperatures and ice; changes in precipitation, ocean salinity, and wind patterns; and changes in extreme weather (IPCC 2007a:3-8).

6.5.2.1 Impacts of Climate Change

Potential effects of climate change have been considered in this cumulative impacts analysis as suggested in the Council on Environmental Quality memorandum, "Draft NEPA Guidance on Consideration of the Effects of Climate Change and Greenhouse Gas Emissions" (Sutley 2010). As stated in Section 6.3.4, regional climate changes in the northwestern United States, including Hanford, are projected to include a continued increase in the average temperature. Many climate models indicate an increase in winter precipitation in the northwest and a decrease in summer precipitation. Changes in snowpack, earlier snowpack melting, and changes in stream flows are expected to continue. Higher temperatures during cooler months could result in more precipitation falling as rain and in earlier snowpack melting. Early melting of snowpack could result in a reduction in the amount of water available during the warmer season. These changes could result in changes to flood control measures and availability of reservoir capacity for water supply. Electricity demands for cooling could also increase when the availability of

stream flows for hydropower electricity generation decreases. Low stream flows could also occur when water is needed for irrigation, protection of fish species, recreation, and urban water supply, resulting in increased conflicts between water uses. Higher temperatures and changes in precipitation are also expected to increase the risk of fires. There is increased potential for loss of biological diversity if changes outpace species' ability to adapt. Decreased water for irrigation, increased temperature, and increased competition from weeds and invasive species are also expected to affect agricultural production. Increased stream flows, changes in the timing of peak stream flows, lower summer stream flows, and warmer water temperatures would create conditions less favorable to salmon and other cold-water fish species (GCRP 2009:135–138). Some of these effects may necessitate adapting activities at Hanford, including increased consideration of the effects of heat stress on employees' activities, increased attention to dust control, increased power demand to deal with increased cooling needs, and changes in stormwater management practices.

Although estimates of specific long-term impacts are highly uncertain, higher summer temperatures and earlier spring snowmelt could increase the risk of fire by increasing summer moisture deficits. The increased occurrence of fire may impact species composition by eliminating fire-intolerant species. For example, the 24 Command Fire in 2000 altered many sagebrush communities to grasslands. When this fire was followed by the 2007 Wautoma Fire, which burned over much of the same area, sagebrush regeneration (including plantings) was suppressed. Thus, grassland communities now dominate where formerly sagebrush was a major community component. Additional potential impacts of fire would likely include the establishment of noxious weeds, leading to further changes in natural plant communities. Changes in both the amount and timing of precipitation could also lead to changes in species composition of vegetative communities. Alterations in plant communities could, in turn, lead to changes in animal populations and possible extinction of local populations and loss of biological diversity if environmental changes outpace species' ability to shift their ranges and form successful new ecosystems (GCRP 2009:136, 137).

Climate change may also affect salmon throughout its life stages and pose an additional stress. For example, as more winter precipitation falls as rain rather than snow, higher winter stream flows may scour streambeds, damaging spawning nests and washing away incubating eggs. Earlier peak stream flows could flush young salmon from rivers to estuaries before they are physically mature enough for the transition, increasing a variety of stresses, including the risk of being eaten by predators. Lower summer stream flows and warmer water temperatures may also create less-favorable summer stream conditions for salmon, as well as other cold-water fish species. In addition, diseases and parasites that infect salmon tend to flourish in warmer water, causing additional stress (GCRP 2009:137).

Adaptation measures to protect Hanford workers from the effects of increased temperatures could result in changes to the normal workday to limit exposure during the hottest part of the day or extend the amount of time allocated to a project to reduce the normal workday to limit worker exposure over an entire project. The number of workers and hours required to complete tasks are currently unaffected by increases in temperature.

A groundwater flow sensitivity analysis presented in Appendix V and summarized in Chapter 7, Section 7.5.2.10, was performed to illustrate the impacts of regional and focused recharge changes, as might occur if the climate were to change in a significant manner over time. In summary, all three sensitivity cases are predicted to cause a shift in the bifurcating groundwater divide within the Central Plateau, resulting in a change in the predicted flow of particles either to the north through Gable Gap and onward to the Columbia River or to the east directly toward the Columbia River. However, although there may be a shift in the location of the bifurcating groundwater divide due to climate change, none of the sensitivity cases were determined to result in a significant change to the predicted peak technetium-99 concentrations at the Core Zone Boundary or Columbia River receptor locations under the selected *TC & WM EIS* alternatives.

6.5.2.2 Emissions of Greenhouse Gases

As described in Appendix G, the *TC & WM EIS* alternatives could produce 913 metric tons (under FFTF Decommissioning Alternative 1 over a period of 100 years) to 429,000 million metric tons (under Tank Closure Alternative 6A, Option Case, over a period of 257 years) of carbon dioxide per year. Based on Hanford fuel use in 2006 (see Chapter 3, Section 3.2.2.3), baseline carbon dioxide emissions are 14,200 metric tons per year. Based on fuel consumption averages for INL (see Chapter 3, Section 3.3.2.3), baseline carbon dioxide emissions are 35,200 metric tons per year. The emissions under the alternatives would add to global annual emissions of carbon dioxide, which were 26.4 billion metric tons from fossil fuel use worldwide in 2000 through 2005 and increased to 32.1 billion metric tons worldwide in 2008 (preliminary estimates for 2010 were 33.5 billion metric tons) (CDIAC 2011a, 2011b; IPCC 2007a). Total U.S. emissions of carbon dioxide are estimated to be 5.45 billion metric tons per year (DOE 2011c). The emission estimates for the *TC & WM EIS* alternatives account for facility-specific fuel-burning and process sources from construction and operations activity and mobile source emissions from material and waste shipments. Table 6–37 summarizes the estimated annual average carbon dioxide emissions and total project emissions for the alternative combinations. These include emissions from onsite activities, additional employee vehicles, and indirect emissions from additional electricity generation (see Appendix G, Table G–167).

Table 6–37. Estimated Cumulative Carbon Dioxide Emissions

Actions/Activities	Annual Average Emissions (metric tons per year)	Project Total Emissions (metric tons)
<i>TC & WM EIS</i> Combined Impacts		
Alternative Combination 1	25,300	2,610,000
Alternative Combination 2	207,000	24,100,000
Alternative Combination 3	231,000	38,000,000
Other Actions		
Global baseline ^a	26,400,000,000	N/A
Cumulative Total		
Alternative Combination 1	26,400,000,000	N/A
Alternative Combination 2	26,400,000,000	N/A
Alternative Combination 3	26,400,000,000	N/A

^a Based on fossil fuel use worldwide in 2000 through 2005. Since 2005, the global baseline emission has increased from 26.4 billion metric tons to about 33.5 billion metric tons as of 2010.

Note: Carbon dioxide emissions under each alternative are presented in Appendix G, Table G–167.

Key: N/A=not applicable; *TC & WM EIS*=*Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*.

Cumulative impacts of the emission of carbon dioxide and other greenhouse gases from *TC & WM EIS* alternatives and other activities at Hanford and throughout the region would contribute to changes related to global climate discussed above. Although the cumulative emissions of greenhouse gases and the impacts on the global climate and the resulting environmental, economic, and social consequences could be significant, there is currently no threshold or standard against which to evaluate the significance of such emissions from a specific local project.

Greenhouse gas emissions in the Hanford region include carbon dioxide from multiple sources, including the burning of natural gas and fuel oil for home and commercial heating and the use of gasoline and diesel fuel to power automobiles, trucks, construction equipment, and other vehicles. Generation of electricity also results in carbon dioxide emissions in parts of the state of Washington and the United States. In the region near Hanford, most of the electricity (97 percent) is supplied by a combination of hydroelectric

dams, nuclear power plants, and wind turbines (BPUD 2006). These types of power production generate little carbon dioxide. The *TC & WM EIS* alternative combinations could require a total of 0.072 million megawatt-hours (under Alternative Combination 1) to 21.7 million megawatt-hours (under Alternative Combination 3) of electricity. The State of Washington has implemented regulations to mitigate emissions of carbon dioxide from certain fossil-fueled, thermal-electricity-generating facilities larger than the station-generating capability of 25 megawatts of electricity. Recently adopted amendments to these regulations are intended to establish goals for statewide reduction of greenhouse gas emissions and immediately reduce greenhouse gas emissions from electric power generation (WAC 173-407). Participation of Washington State in the Western Climate Initiative's proposed Cap-and-Trade Program may also result in a reduction in greenhouse gas emissions (Ecology 2009).

There also are emissions of chlorofluorocarbons and hydrofluorocarbons, which are used locally in the Hanford region in refrigeration and air conditioning units at residential, commercial, industrial, and government facilities.

A number of opportunities for reductions in greenhouse gases at Hanford have been pursued, including the reduction and phaseout of chlorofluorocarbon use and the reduction of carbon dioxide emissions and other trace gases through energy conservation. Other potential mitigation technologies that are currently available and could be applicable at Hanford include alternative fuels and renewable heat and power sources, carbon capture and storage, more-fuel-efficient vehicles, cleaner diesel vehicles, hybrid vehicles, biofuels, efficient lighting and daylighting, more-efficient electrical equipment, improved insulation, passive and active solar design for heating and cooling, and use of alternative refrigeration fluids (IPCC 2007b). DOE is evaluating a proposal to substantially reduce future greenhouse gas emissions from the Waste Treatment Plant and the Central Plateau by using natural gas rather than diesel fuel.

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