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)	Peak Annualized Requirement: 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 (PM_{10}) 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 PM_{10}, 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	*10,000*	*100*	*150*	*197*

[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; PM_{10}=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 PM_{10} 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 PM_{10}). 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)
***TC & WM EIS* Combined Impacts (see Chapter 4, Table 4–155)**	
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**
Site Resource Availability[e]	*49,600,000*

[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] (Hectares)	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
***TC & WM EIS* 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 $(<8\times10^{-3})$	NR	<13	0 $(<8\times10^{-3})$
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 (8×10^{-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

	Waste Type (cubic meters)				
Actions/Activities	**HLW[a]**	**Mixed TRU**	**LLW/MLLW**	**Hazardous[b]**	**Nonradioactive/ Nonhazardous[c]**
***TC & WM EIS* 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.

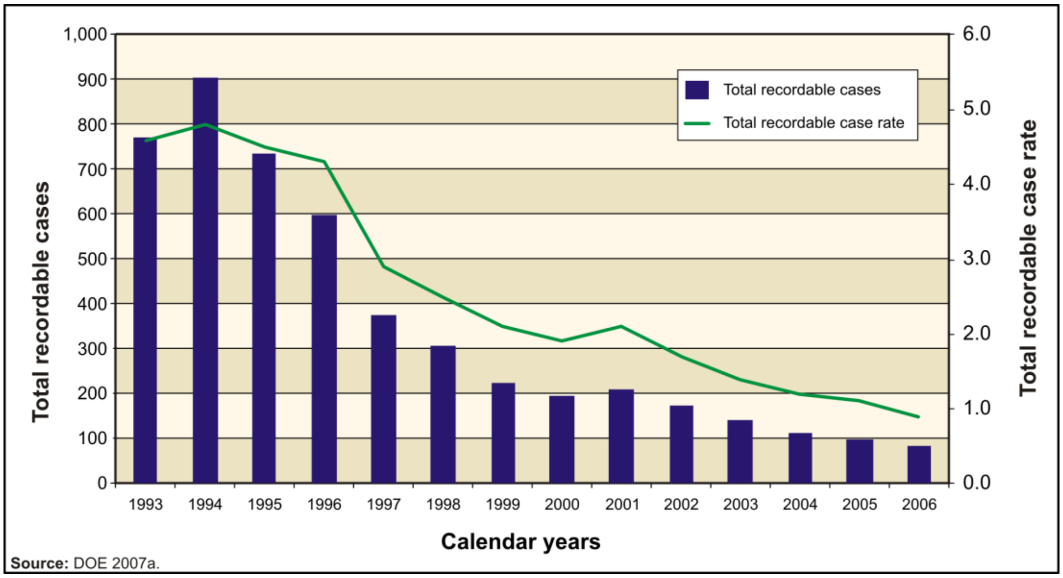


Figure 6–1. Richland Operations Industrial Safety Total Recordable Cases and Incident Rate, 1993–2006

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]
Chemical (micrograms per liter) (continued)			
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	**2.43×10^{6}**	**2.70×10^{4}**	**5.92×10^{1}**	**4.54×10^{3}**	**1.04×10^{6}**	**1.73×10^{8}**	**7.74×10^{6}**

[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	$\mathbf{2.06\times10^{6}}$	$\mathbf{2.64\times10^{4}}$	$\mathbf{5.84\times10^{1}}$	$\mathbf{2.31\times10^{2}}$	$\mathbf{1.04\times10^{6}}$	$\mathbf{1.73\times10^{8}}$	$\mathbf{1.53\times10^{5}}$

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	$\mathbf{7.25\times10^{4}}$	$\mathbf{2.66\times10^{4}}$	$\mathbf{5.85\times10^{1}}$	$\mathbf{2.16\times10^{2}}$	$\mathbf{1.06\times10^{6}}$	$\mathbf{1.76\times10^{8}}$	$\mathbf{1.22\times10^{5}}$

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 & 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.

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.

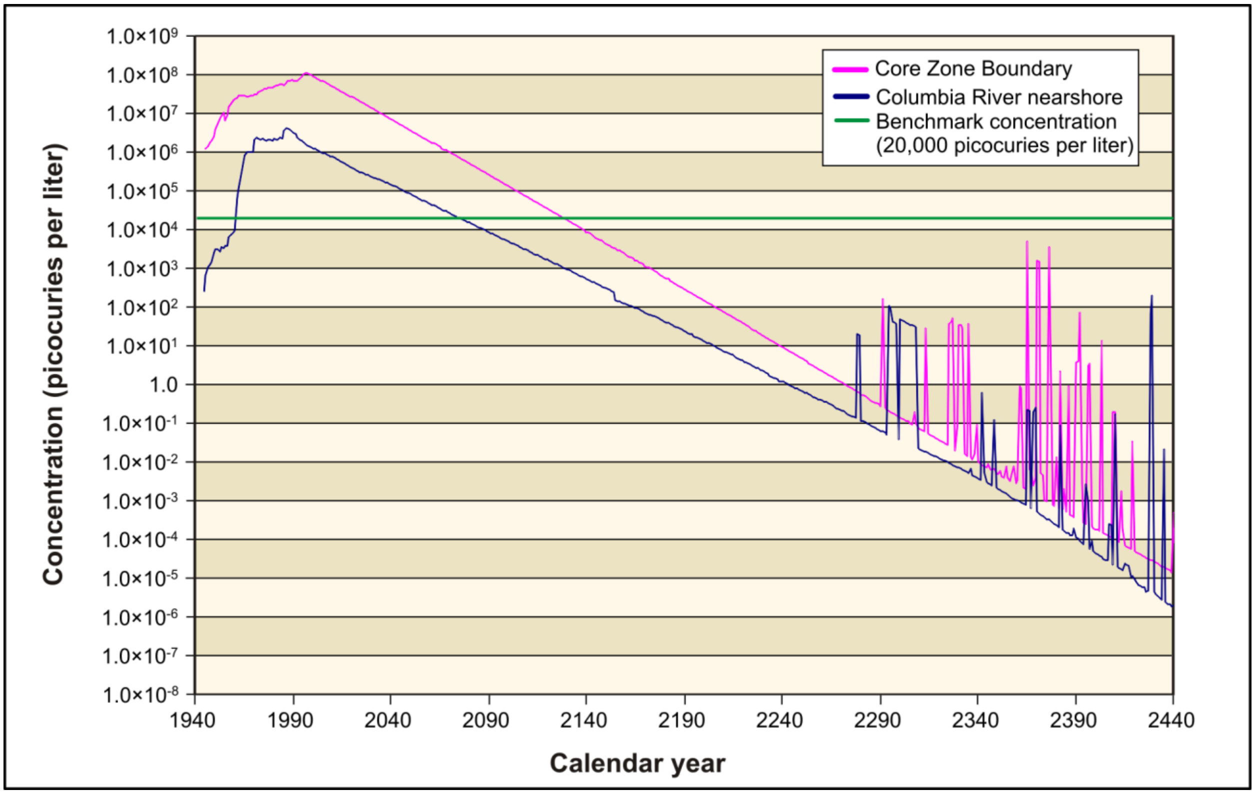


Figure 6–2. Alternative Combination 1 Cumulative Hydrogen-3 (Tritium) Concentration Versus Time

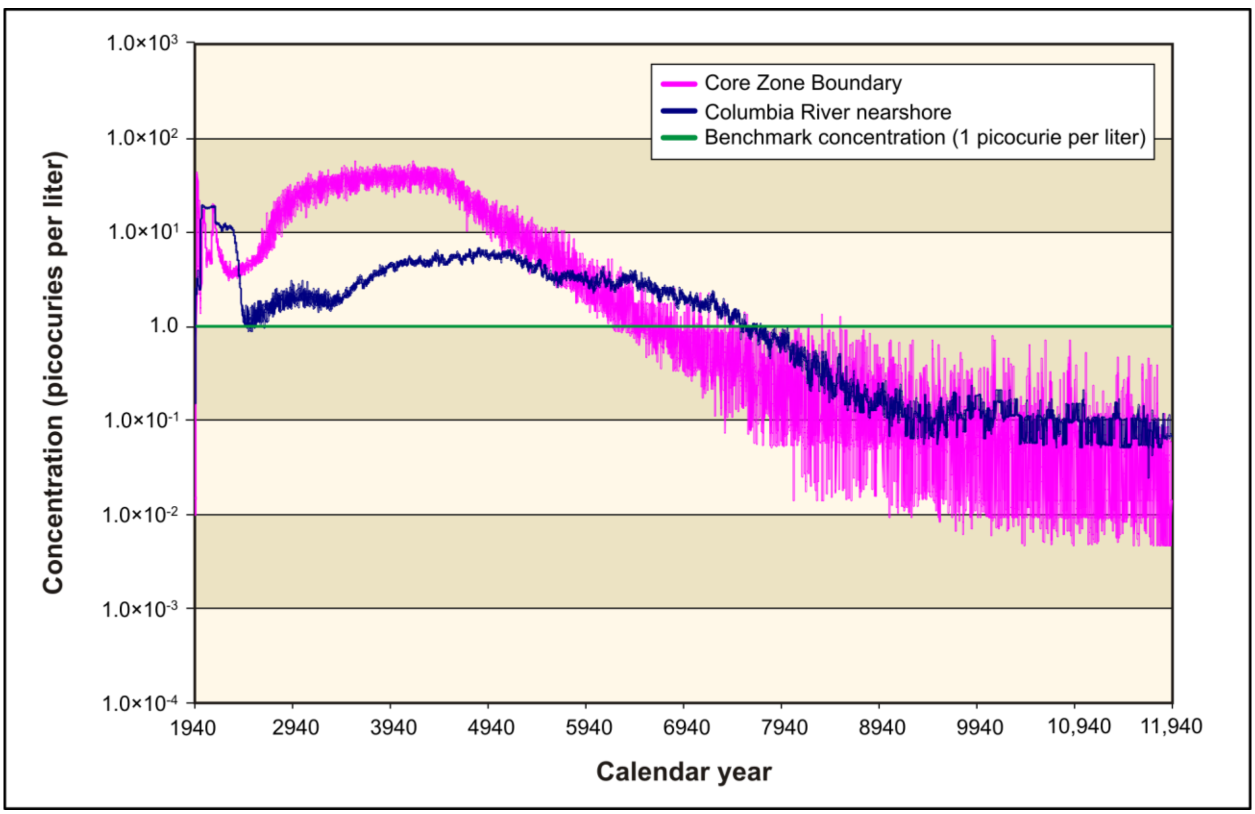


Figure 6–3. Alternative Combination 1 Cumulative Iodine-129 Concentration Versus Time

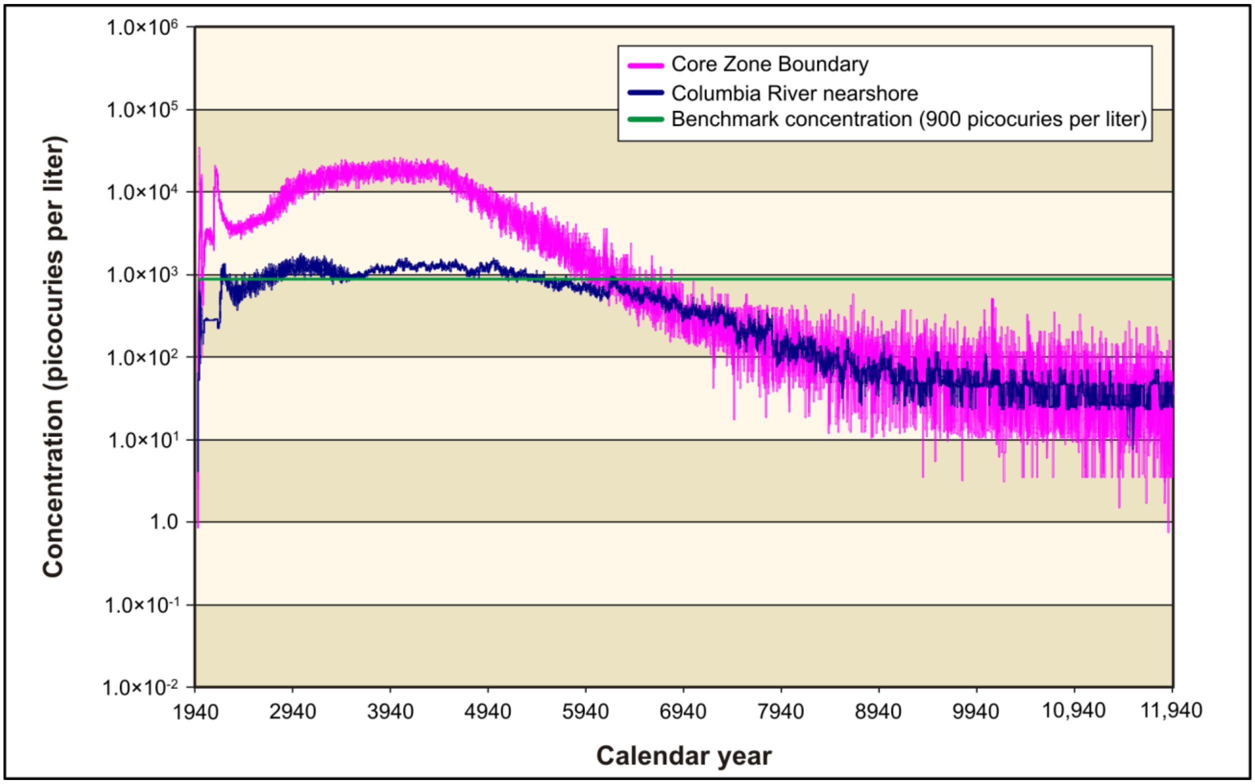


Figure 6–4. Alternative Combination 1 Cumulative Technetium-99 Concentration Versus Time

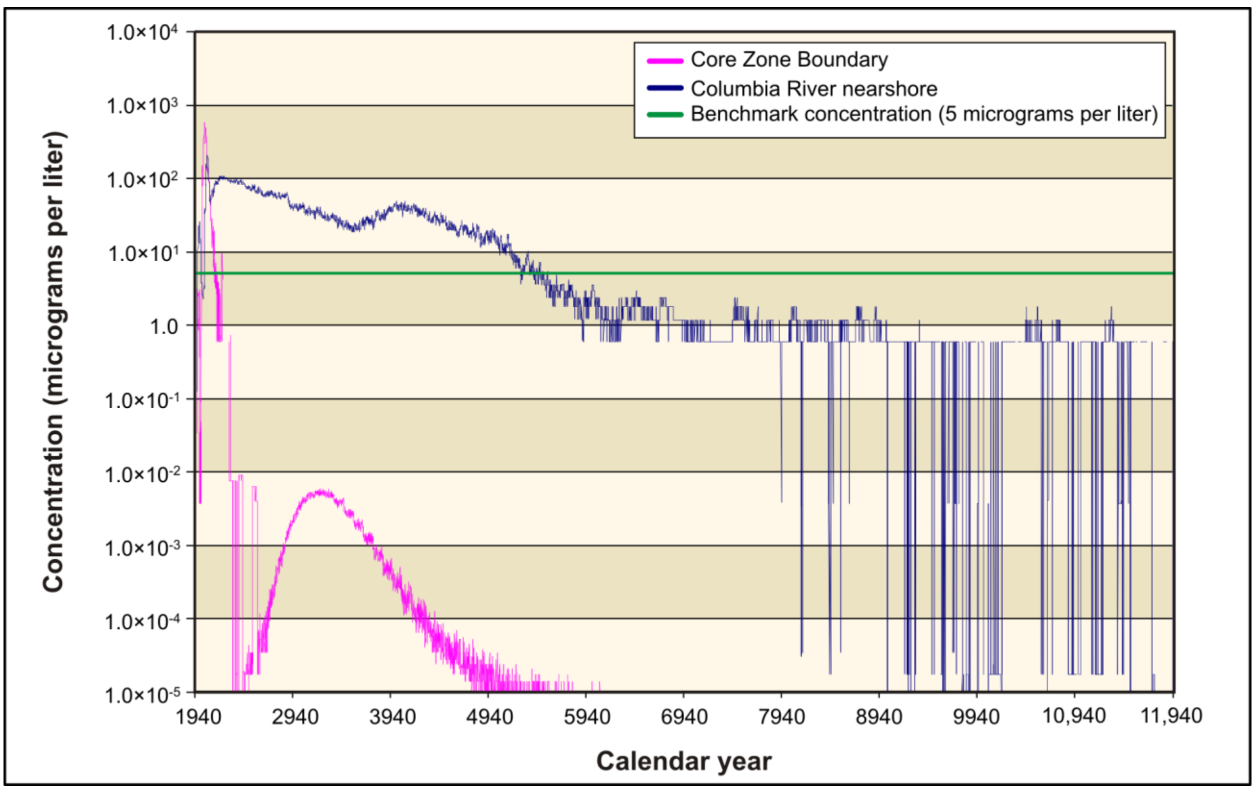


Figure 6–5. Alternative Combination 1 Cumulative Carbon Tetrachloride Concentration Versus Time

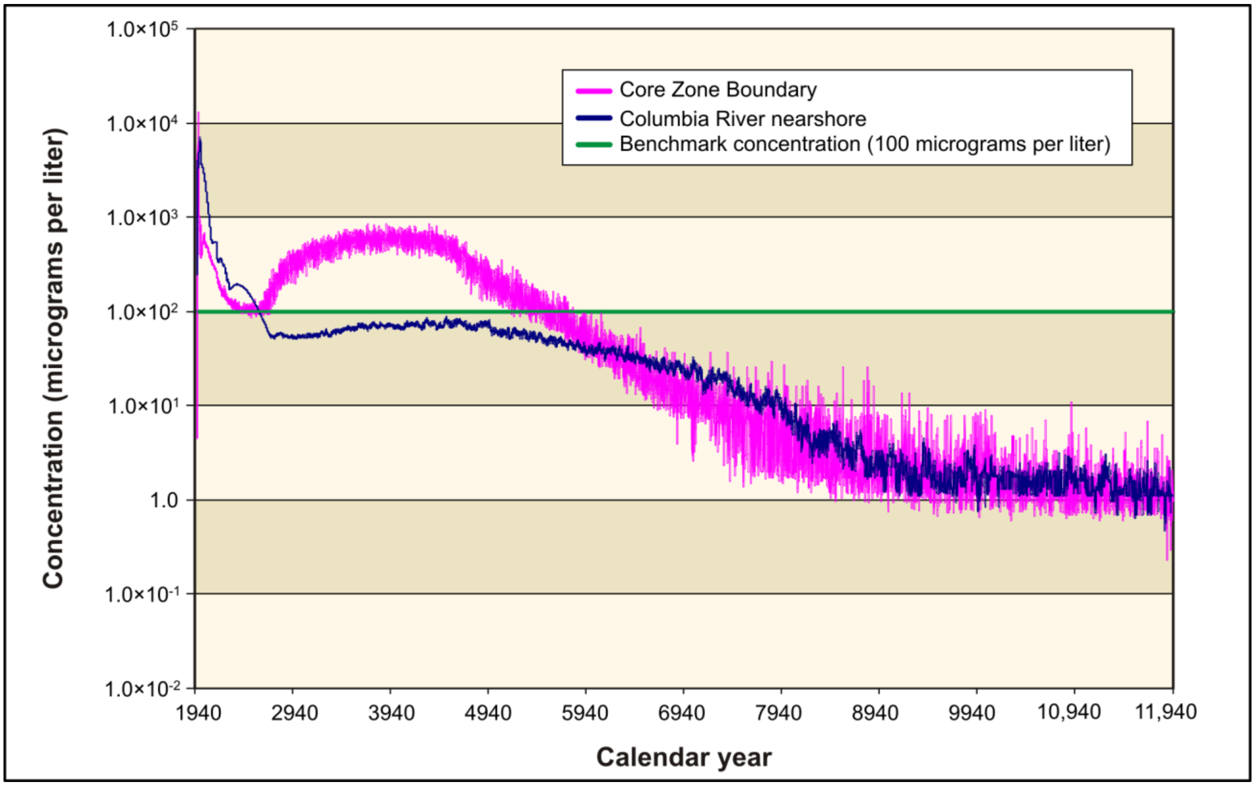


Figure 6–6. Alternative Combination 1 Cumulative Chromium Concentration Versus Time

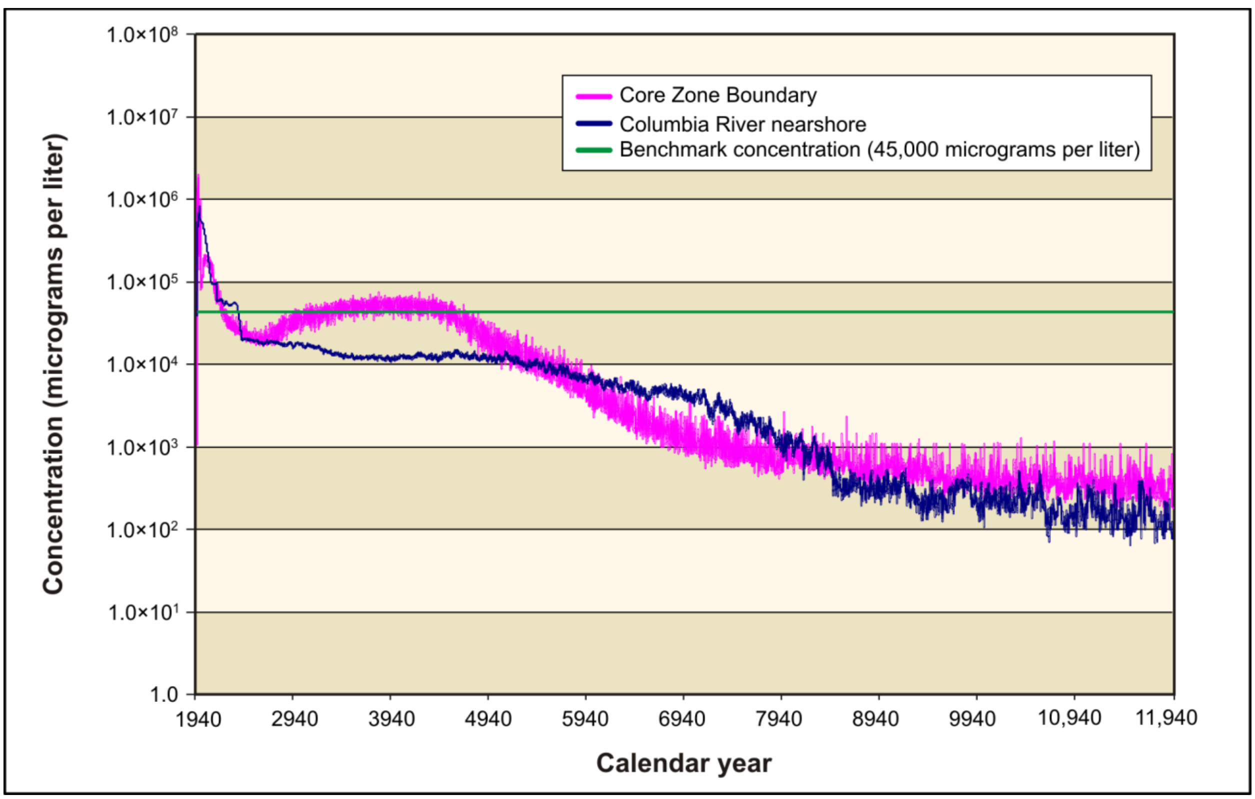


Figure 6–7. Alternative Combination 1 Cumulative Nitrate Concentration Versus Time

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.

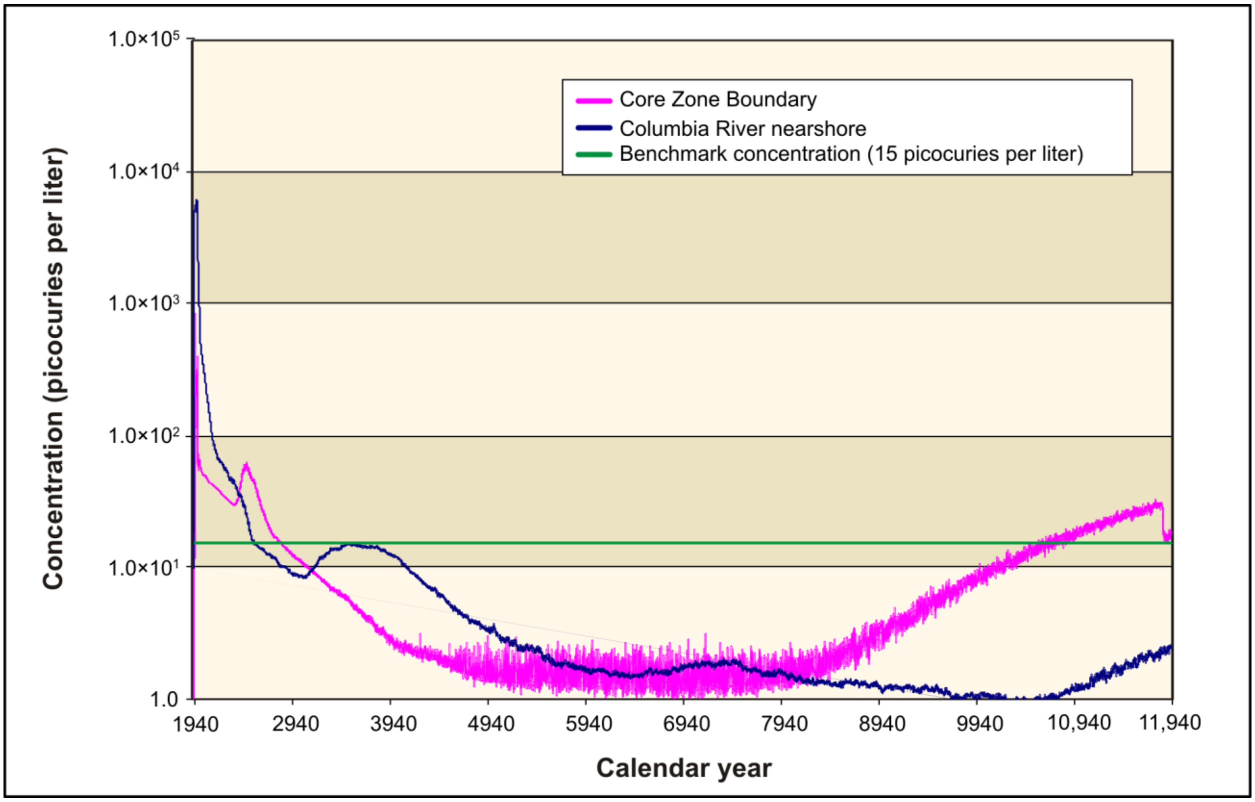


Figure 6–8. Alternative Combination 1 Cumulative Uranium-238 Concentration Versus Time

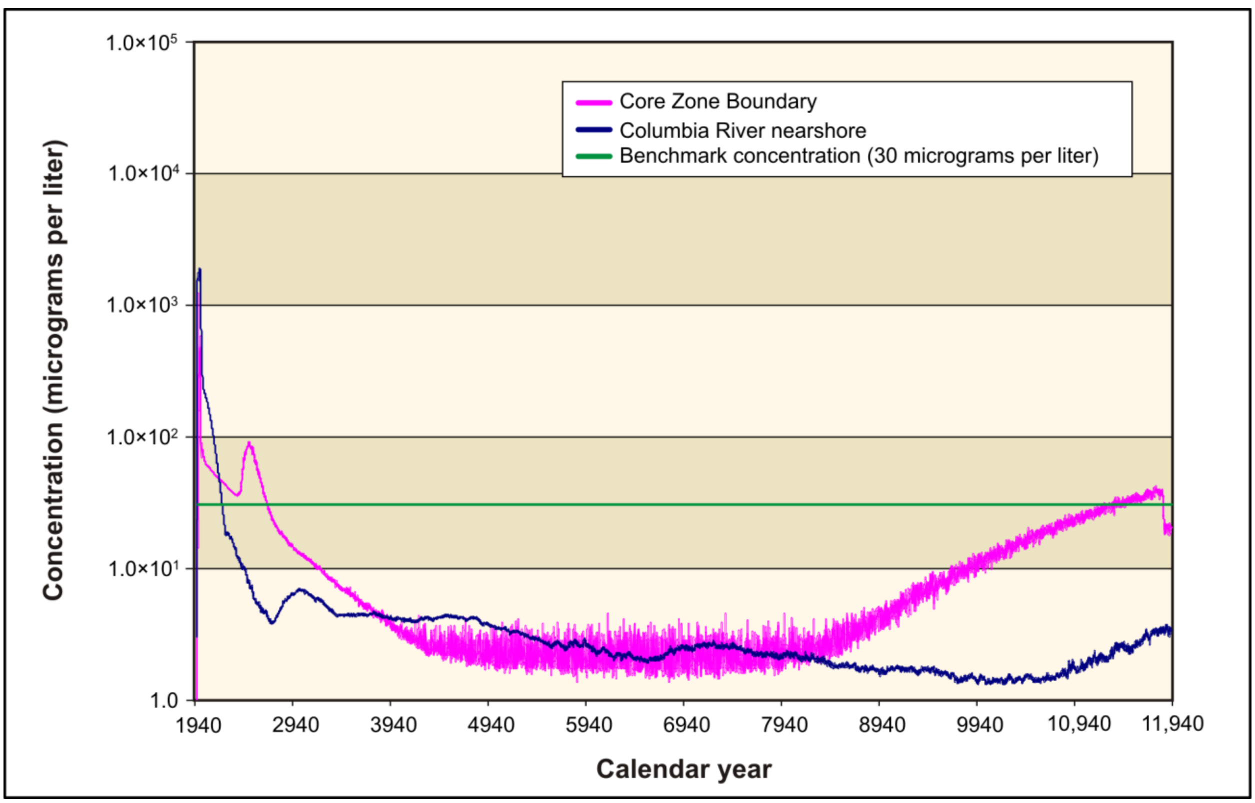
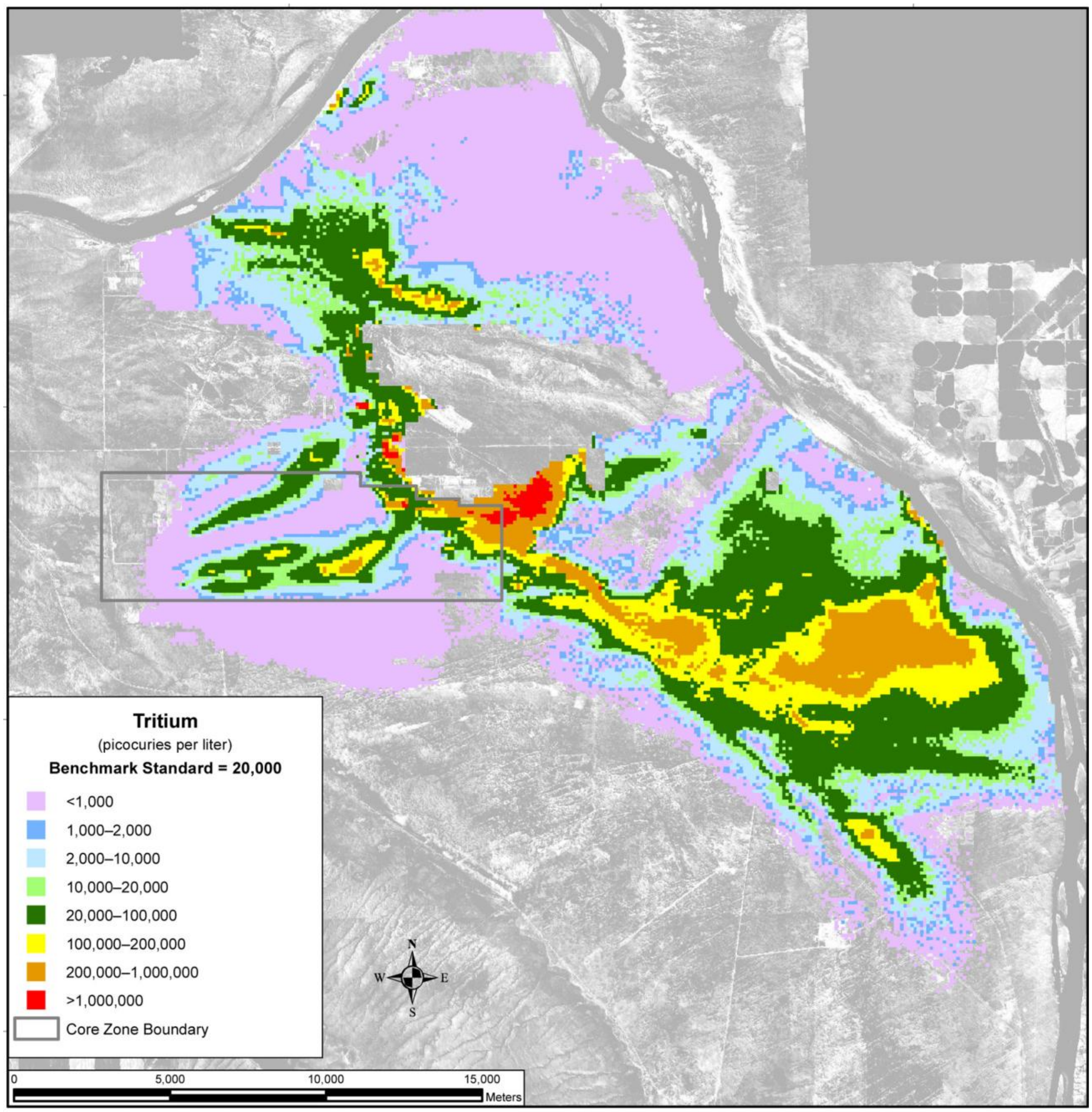


Figure 6–9. Alternative Combination 1 Cumulative Total Uranium Concentration Versus Time

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.

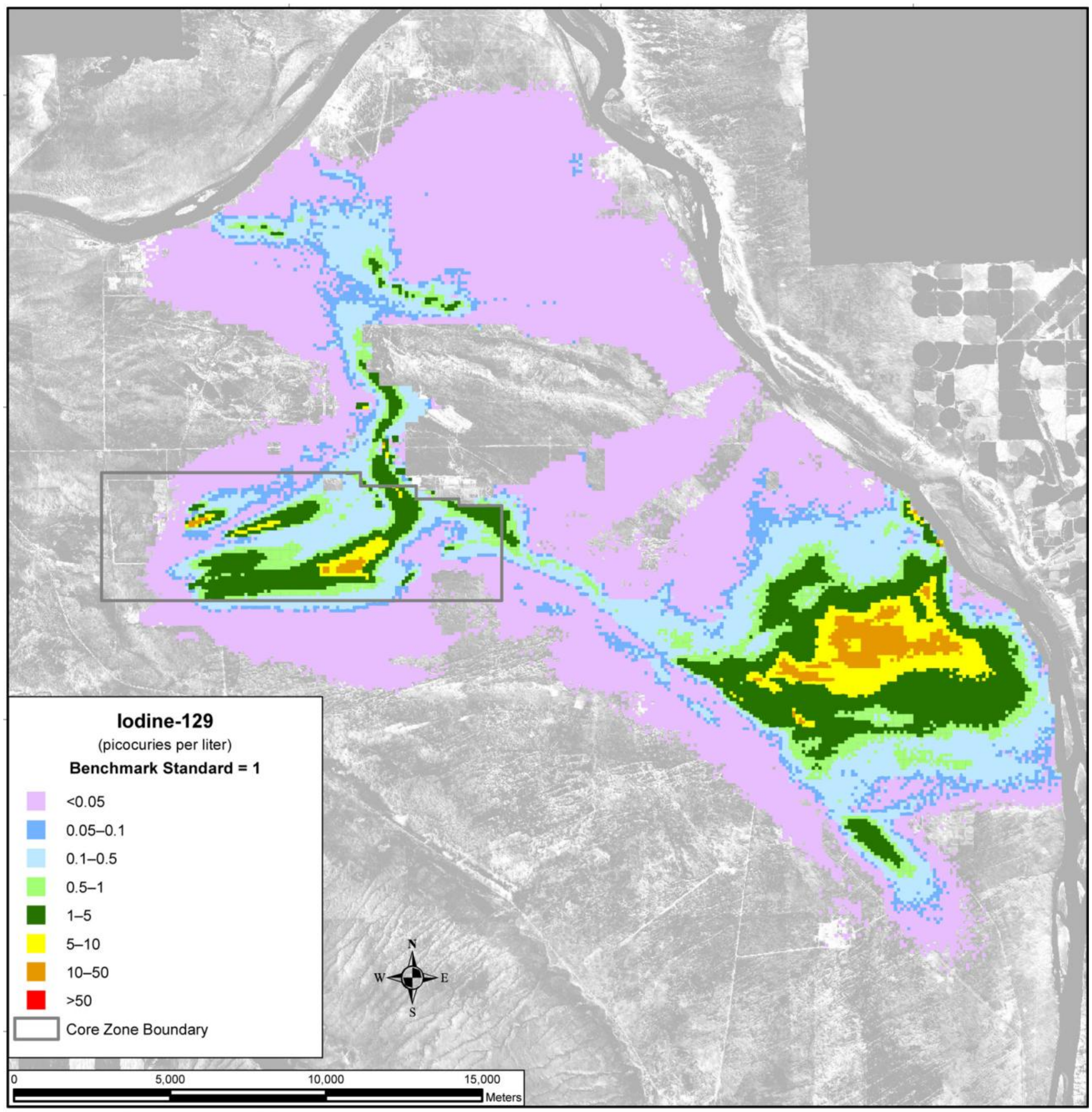
Figure 6–10 shows the spatial distribution of tritium concentrations in groundwater in CY 2010. The spatial pattern of the tritium plumes is an indicator of the different sources and release areas. The release from *TC & WM EIS* sources results from cribs and trenches (ditches) and past tank leaks and 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.

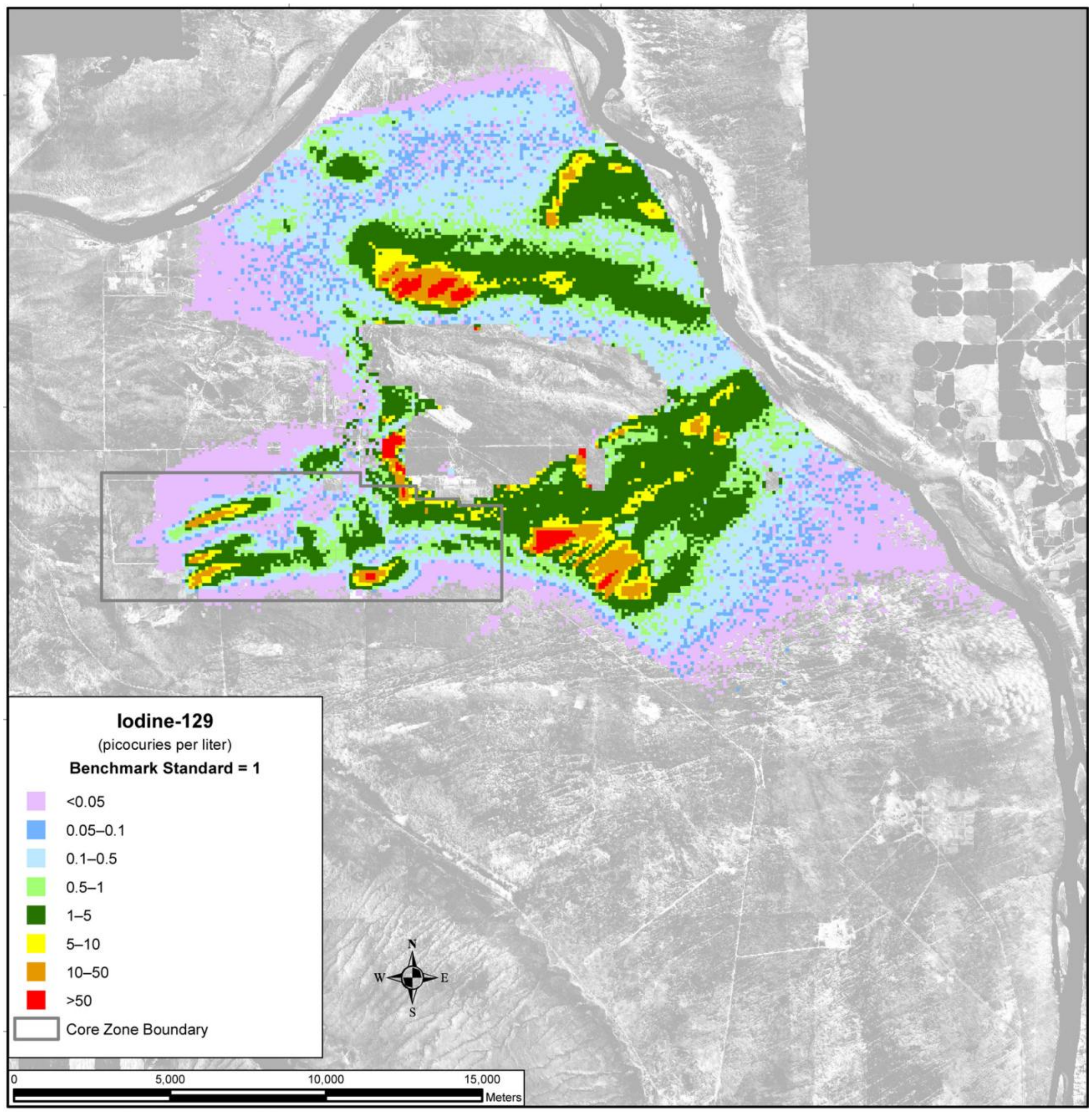
Figure 6–10. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Hydrogen-3 (Tritium) Concentration, Calendar Year 2010

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.



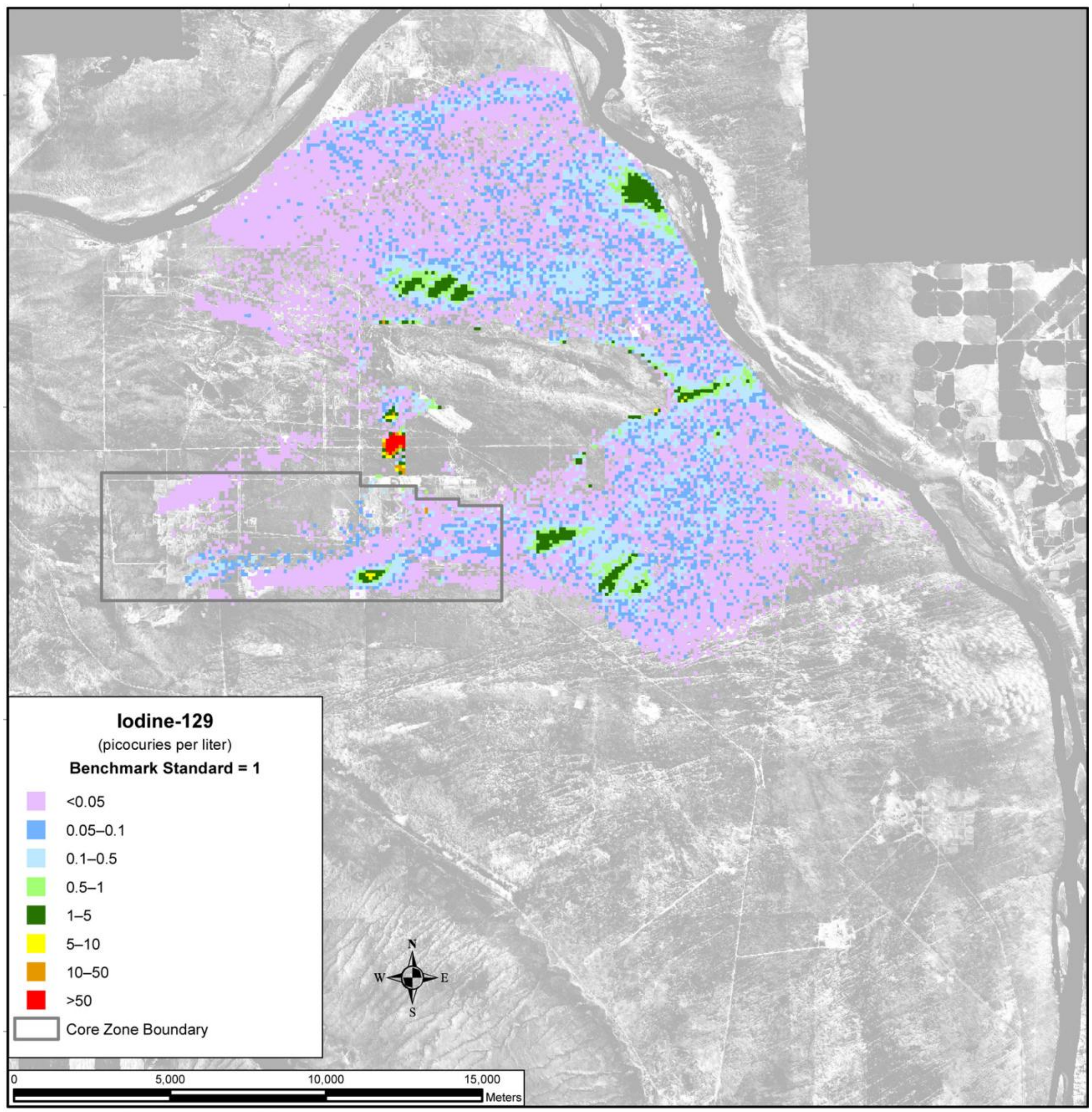
Note: To convert meters to feet, multiply by 3.281.

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

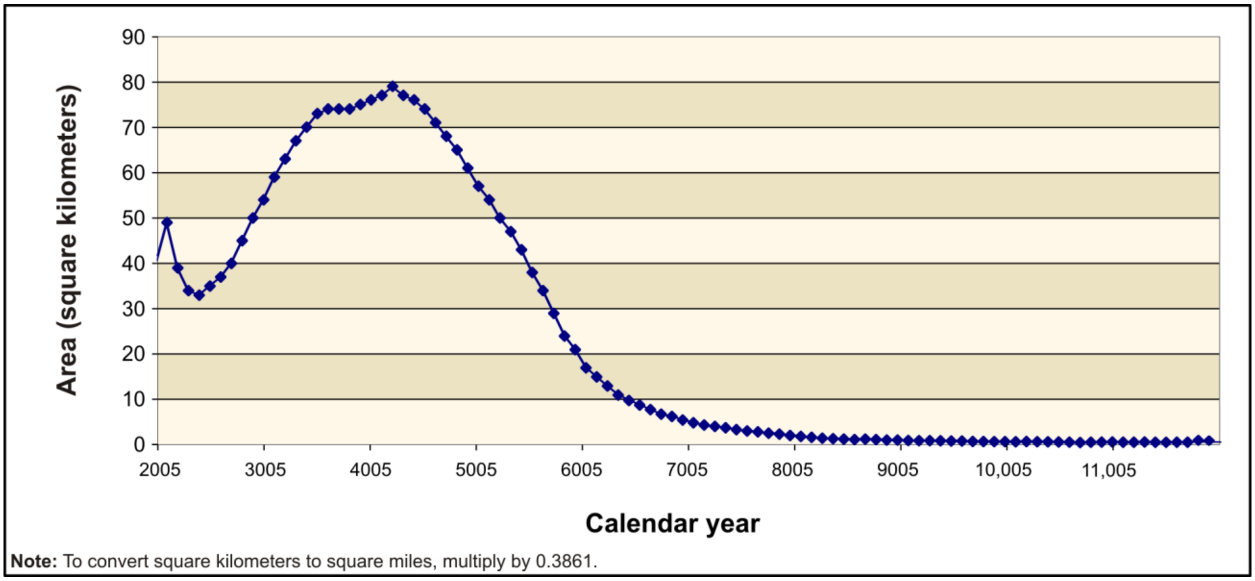
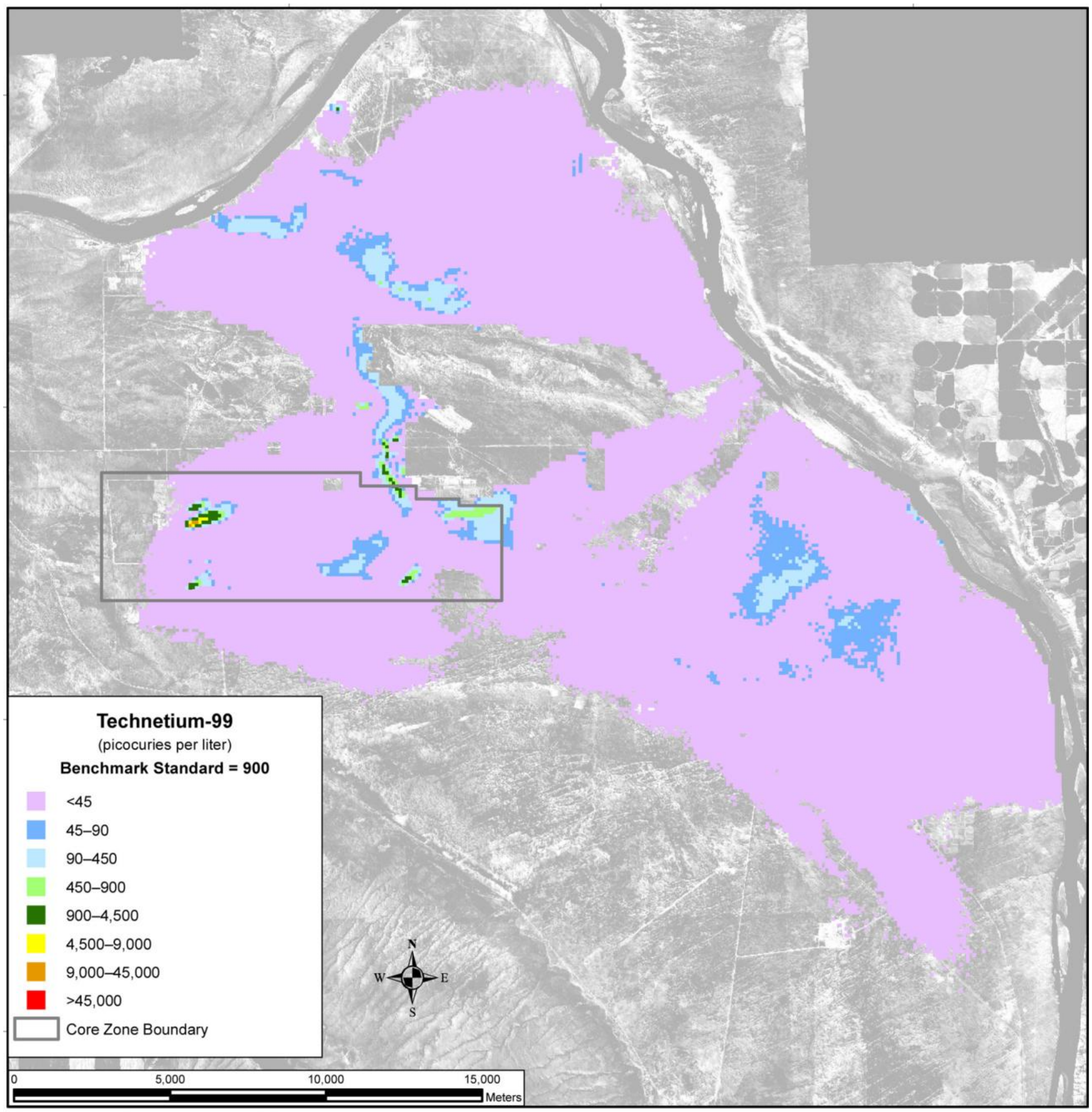


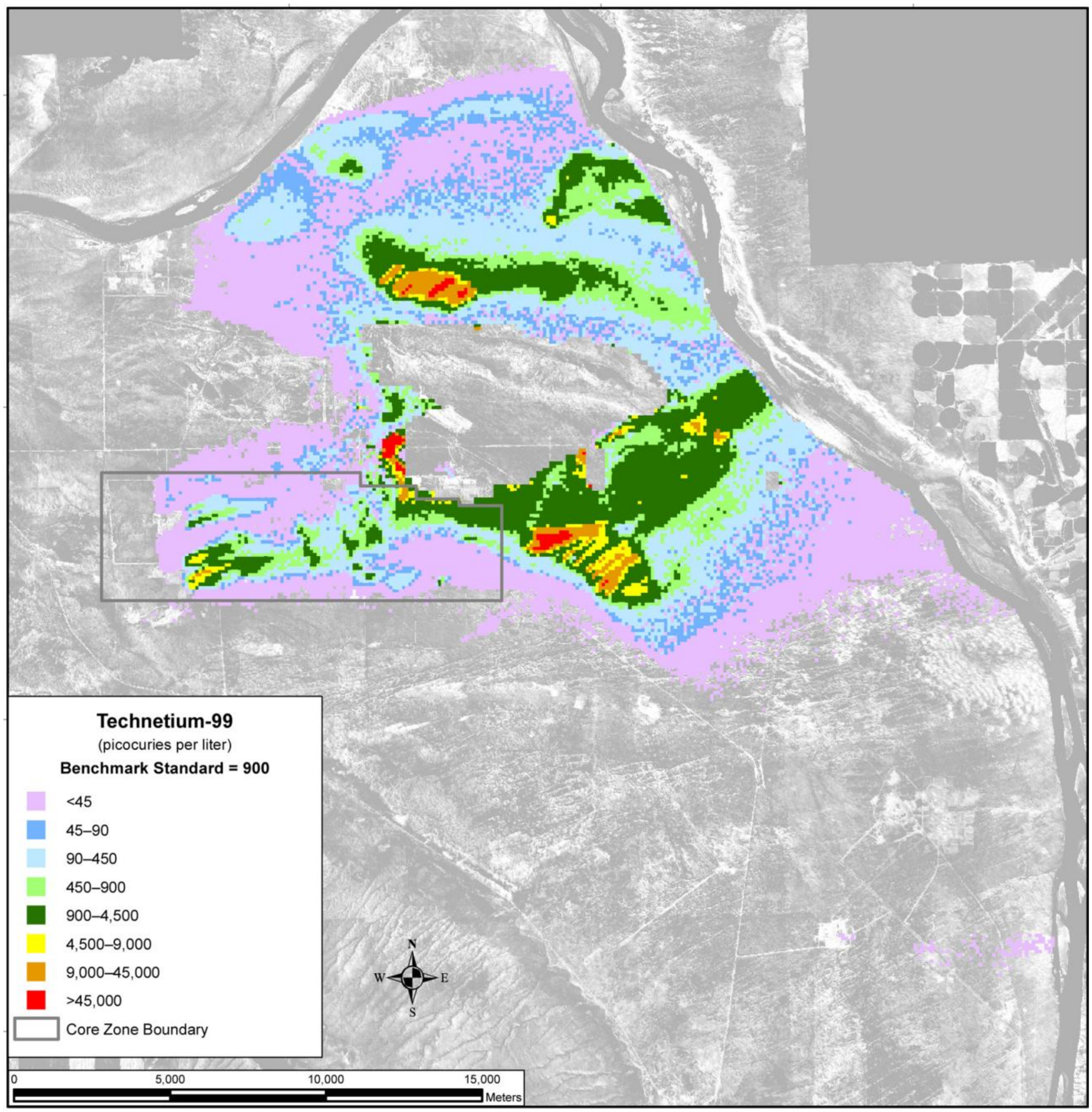
Figure 6–14. Alternative Combination 1 Total Area of Cumulative Groundwater Iodine-129 Concentrations Exceeding the Benchmark Concentration as a Function of Time

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.



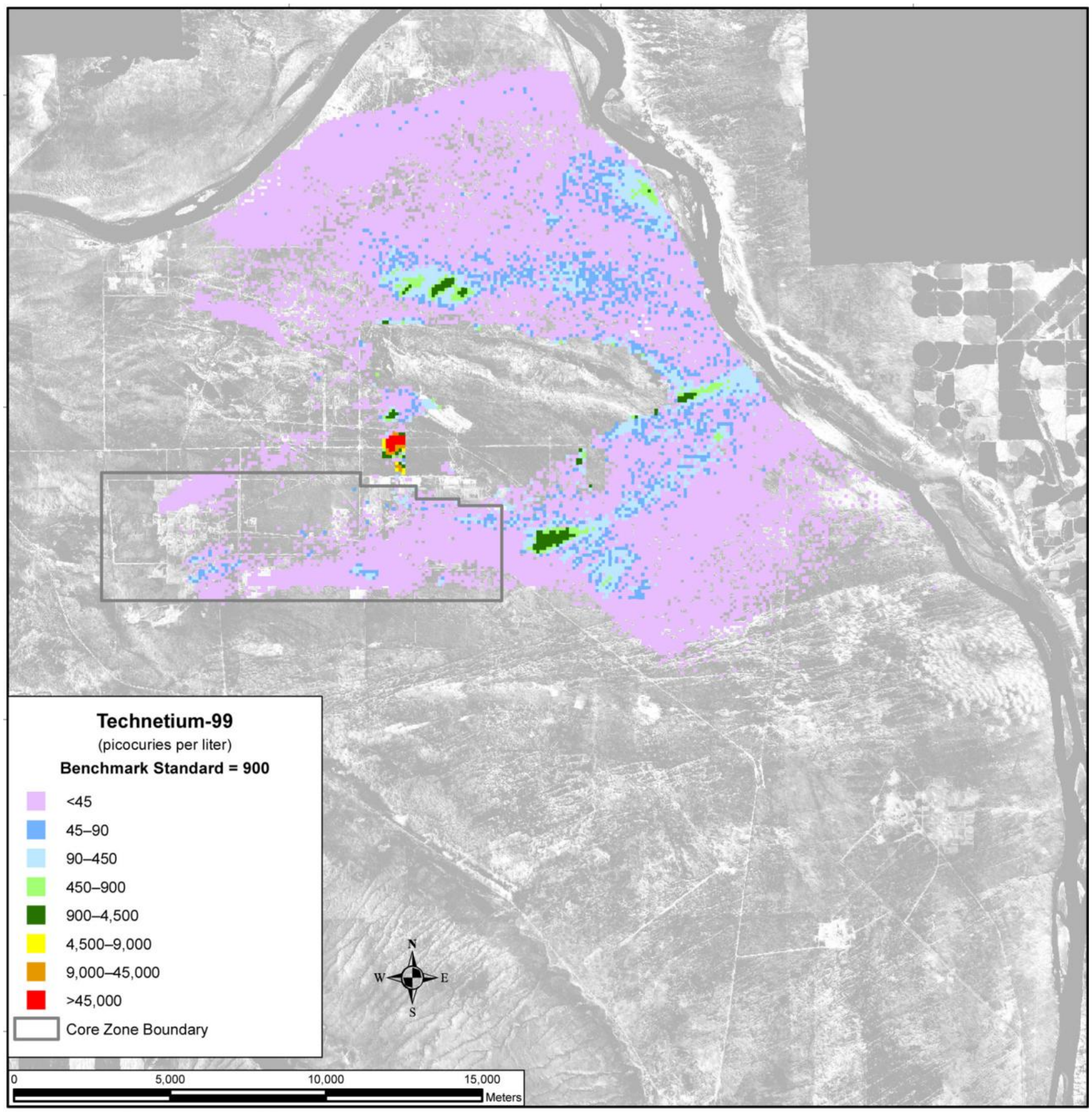
Note: To convert meters to feet, multiply by 3.281.

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



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

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



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

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

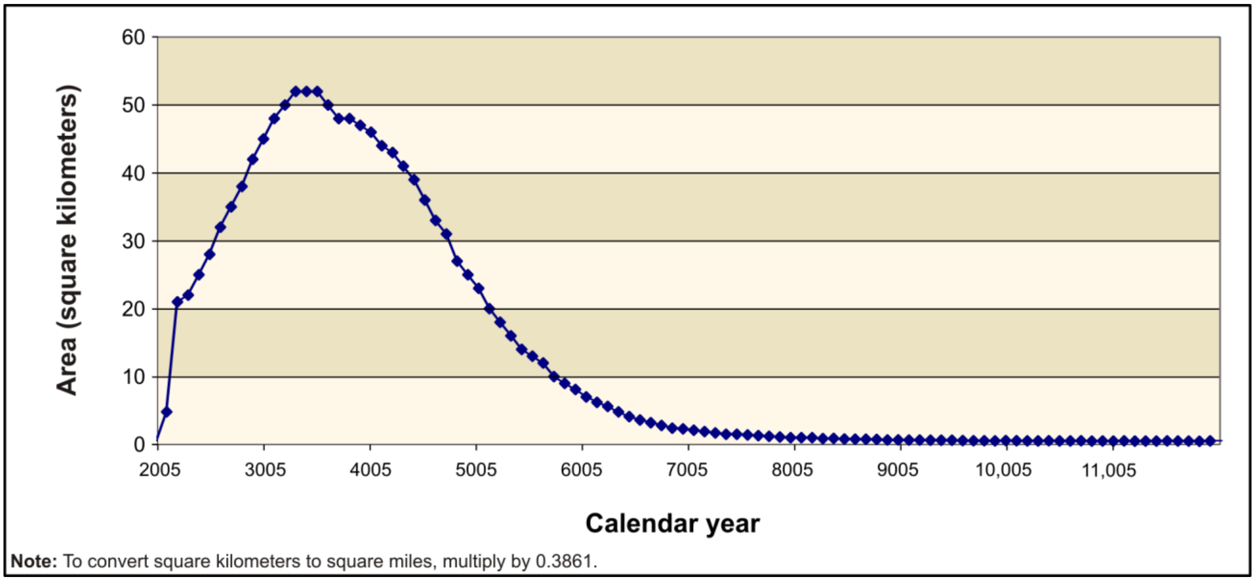
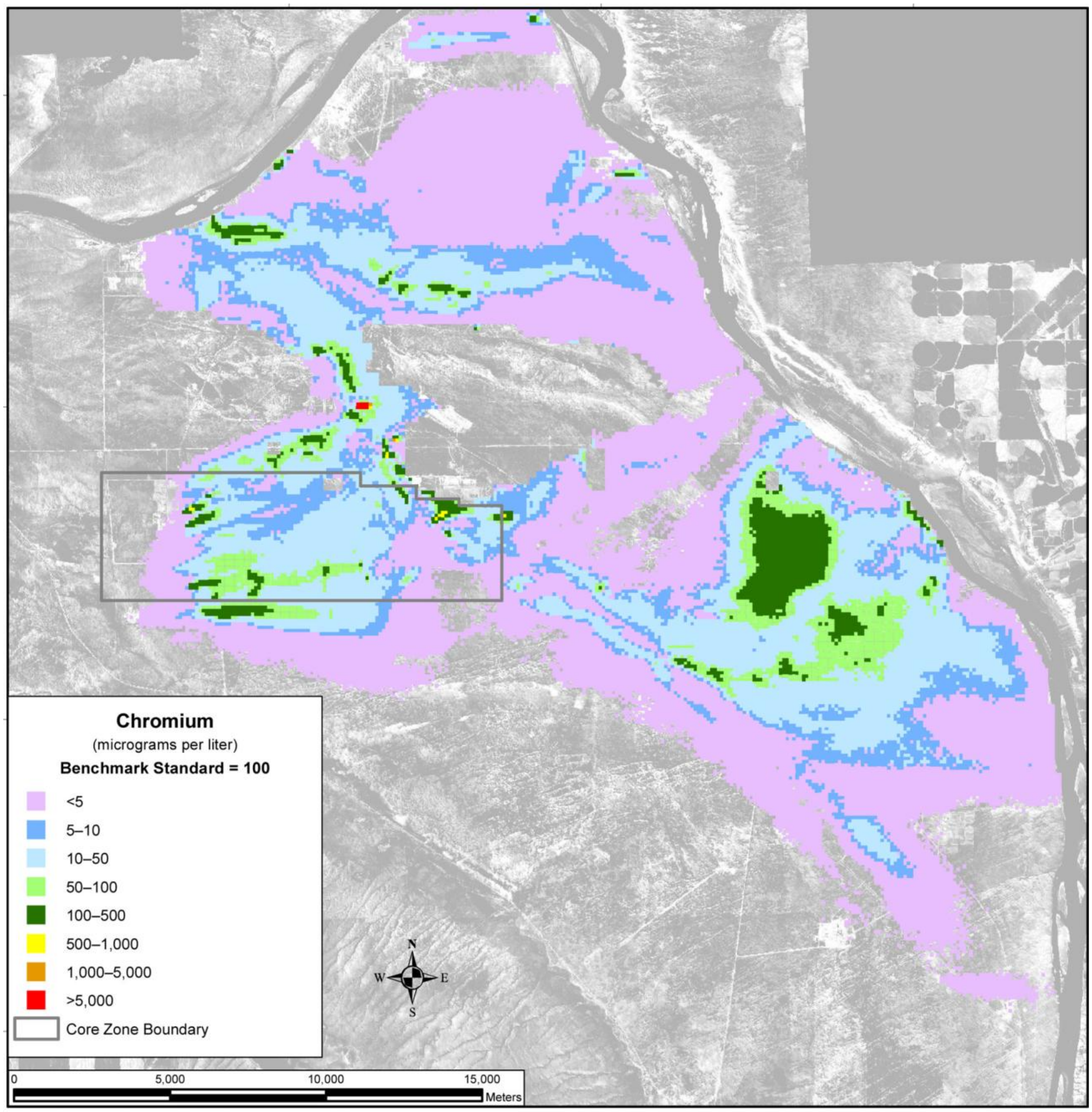
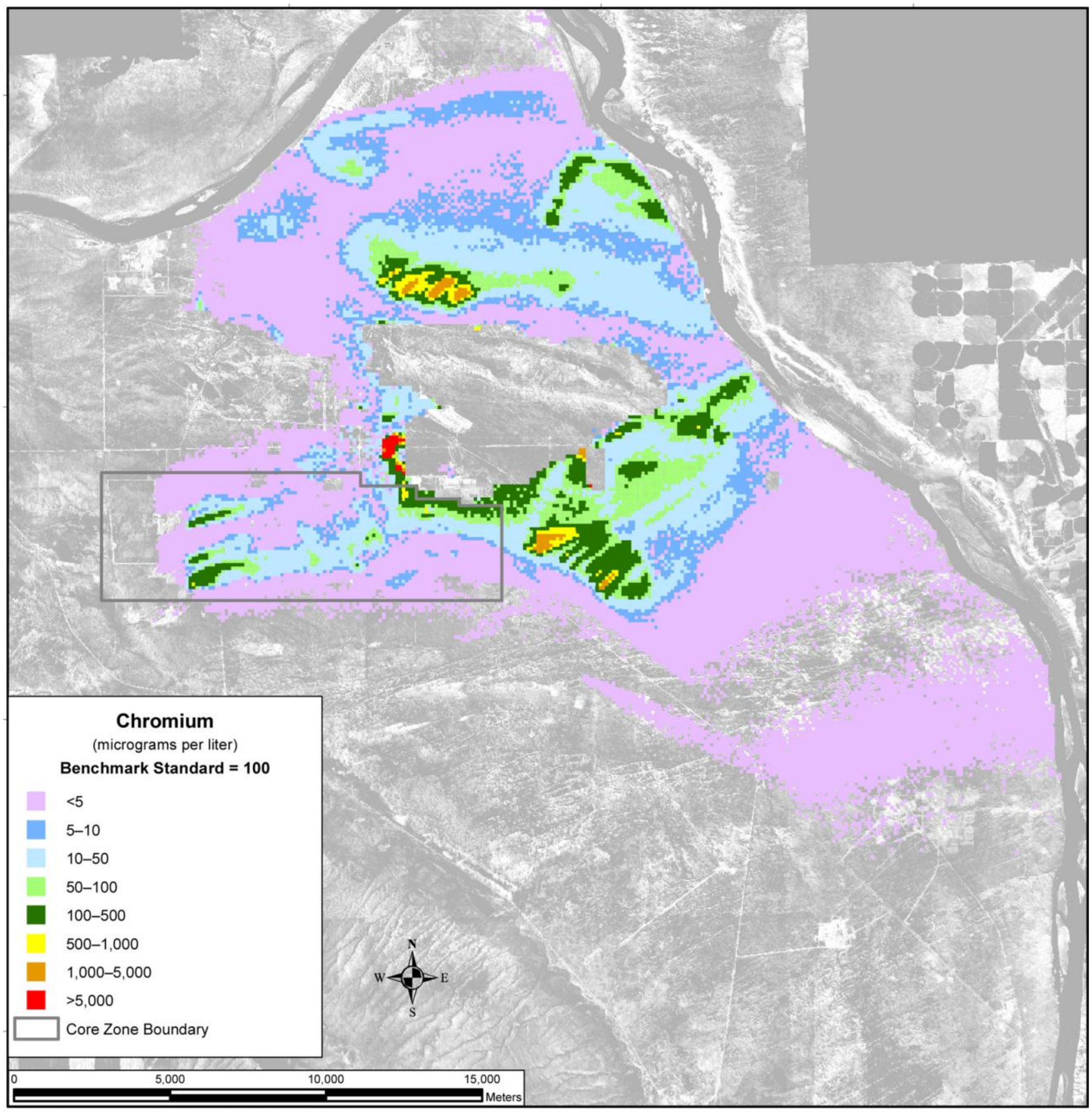


Figure 6–18. Alternative Combination 1 Total Area of Cumulative Groundwater Technetium-99 Concentrations Exceeding the Benchmark Concentration as a Function of Time



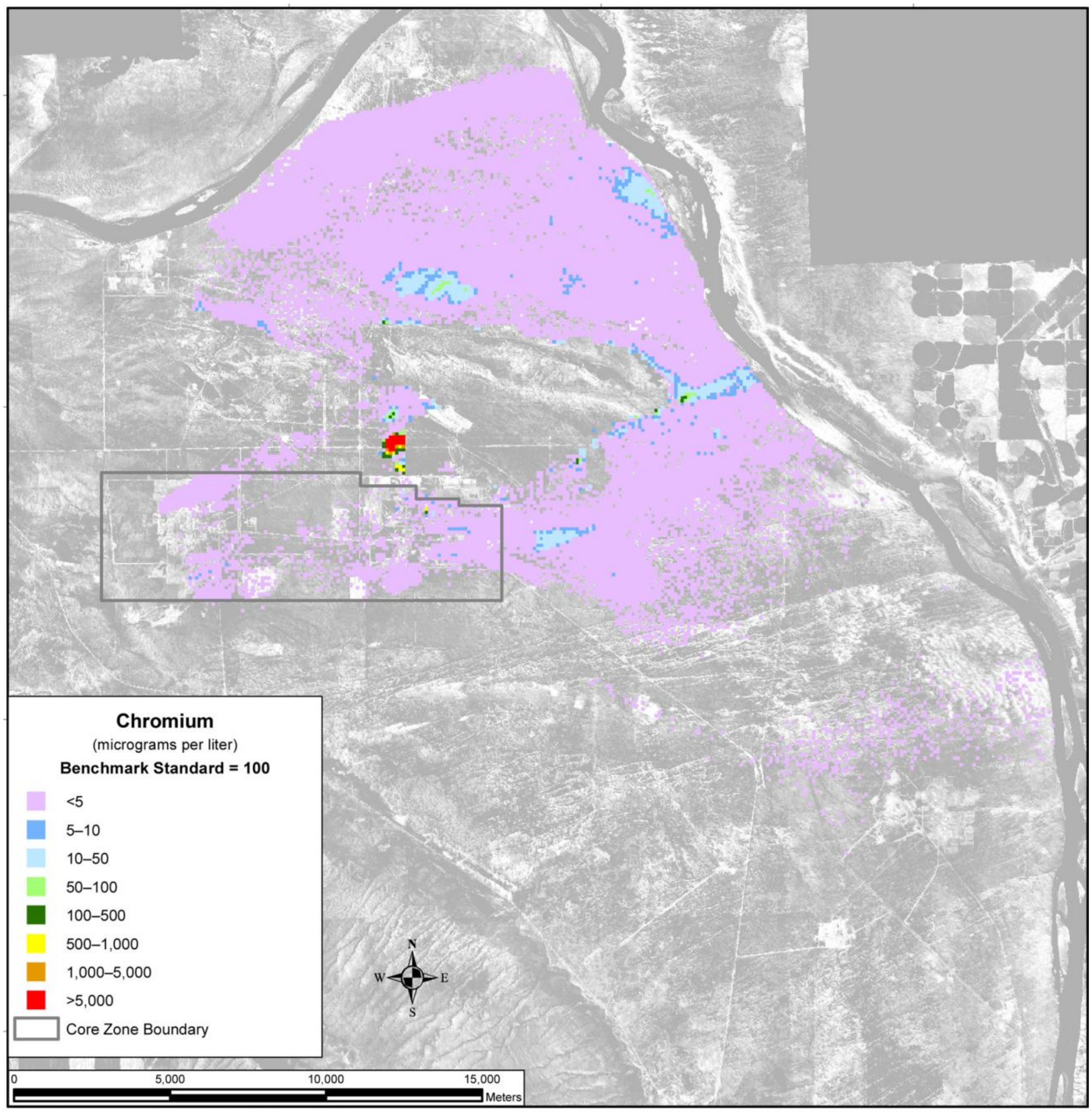
Note: To convert meters to feet, multiply by 3.281.

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



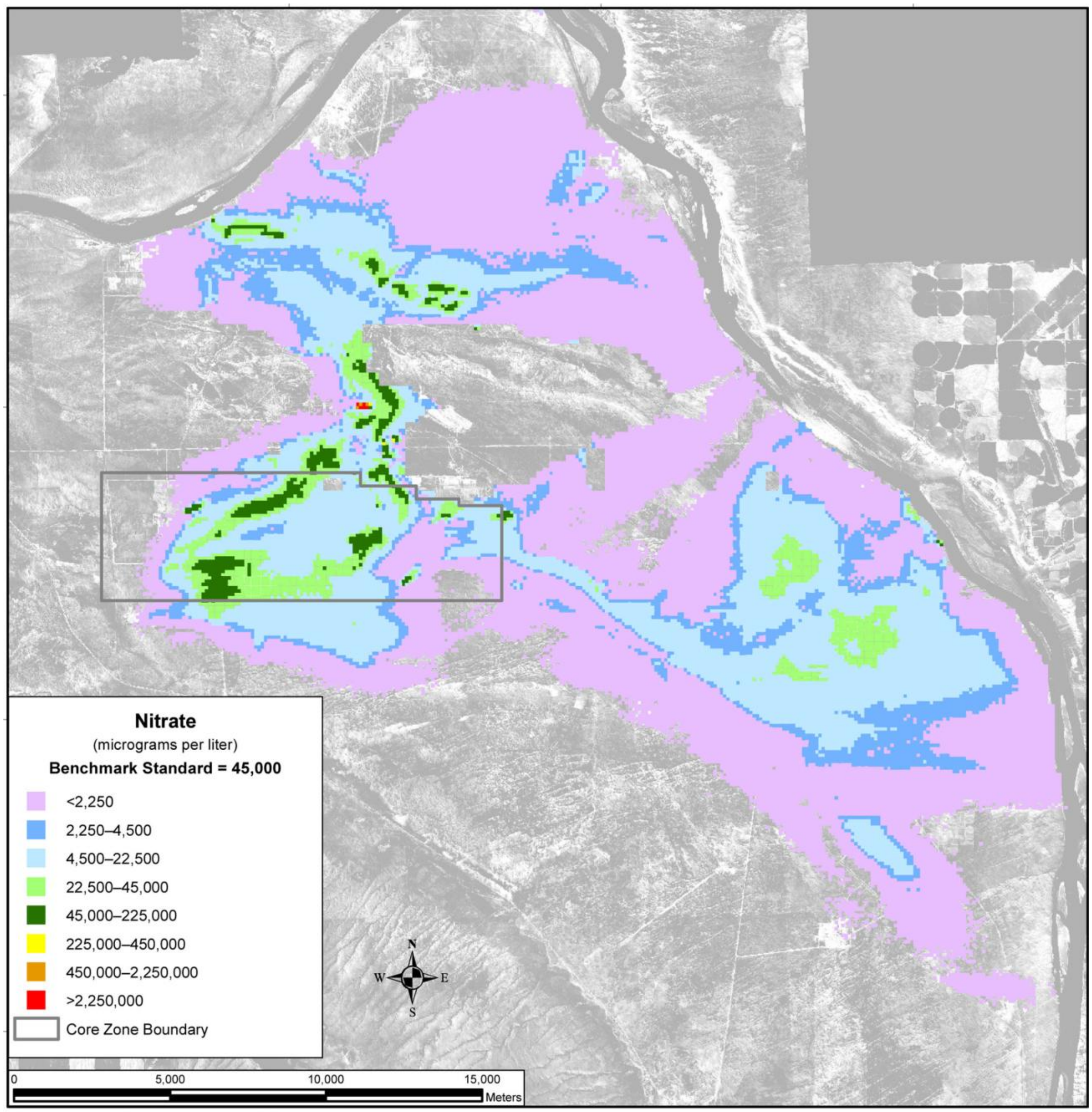
Note: To convert meters to feet, multiply by 3.281.

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



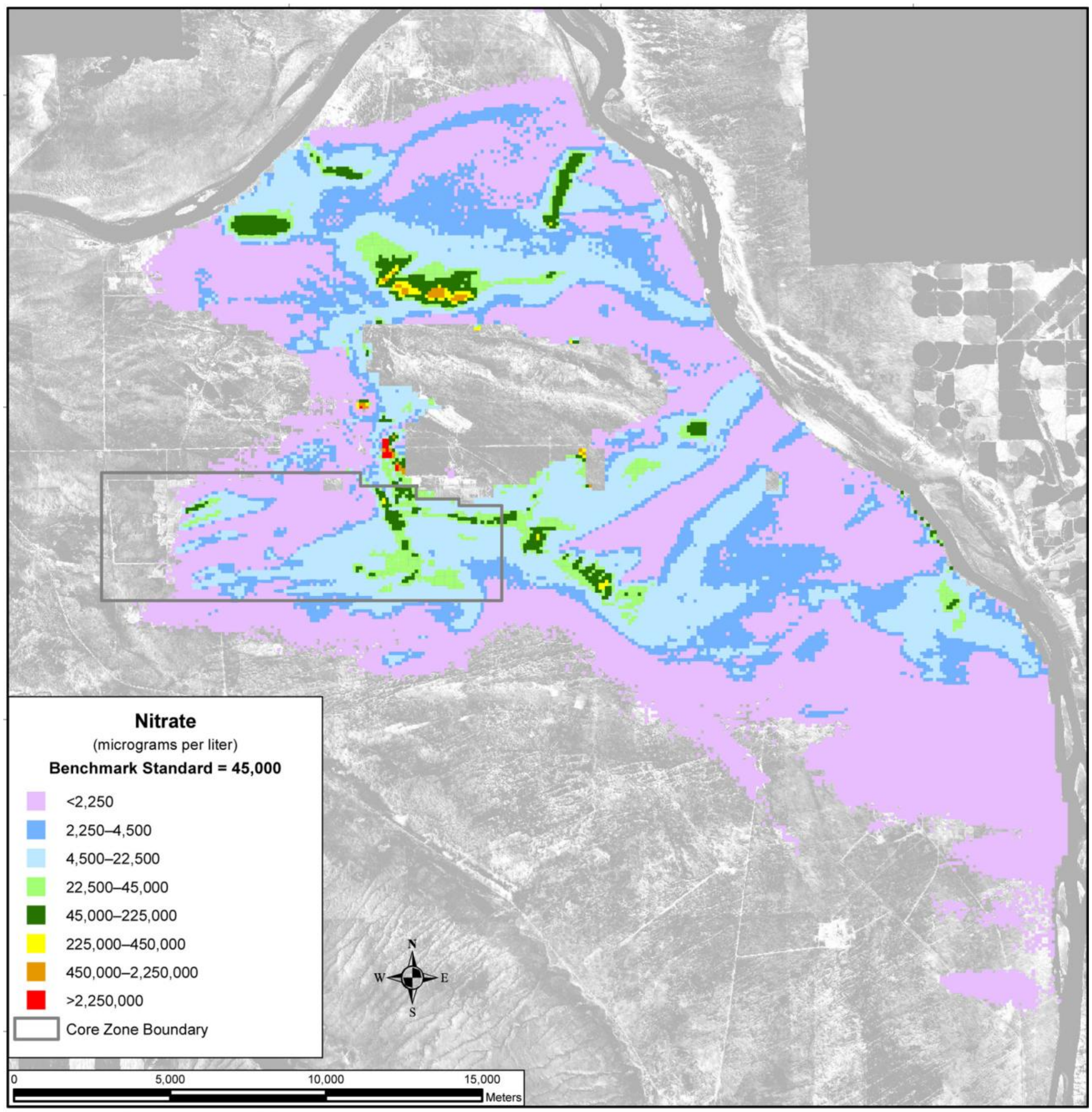
Note: To convert meters to feet, multiply by 3.281.

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



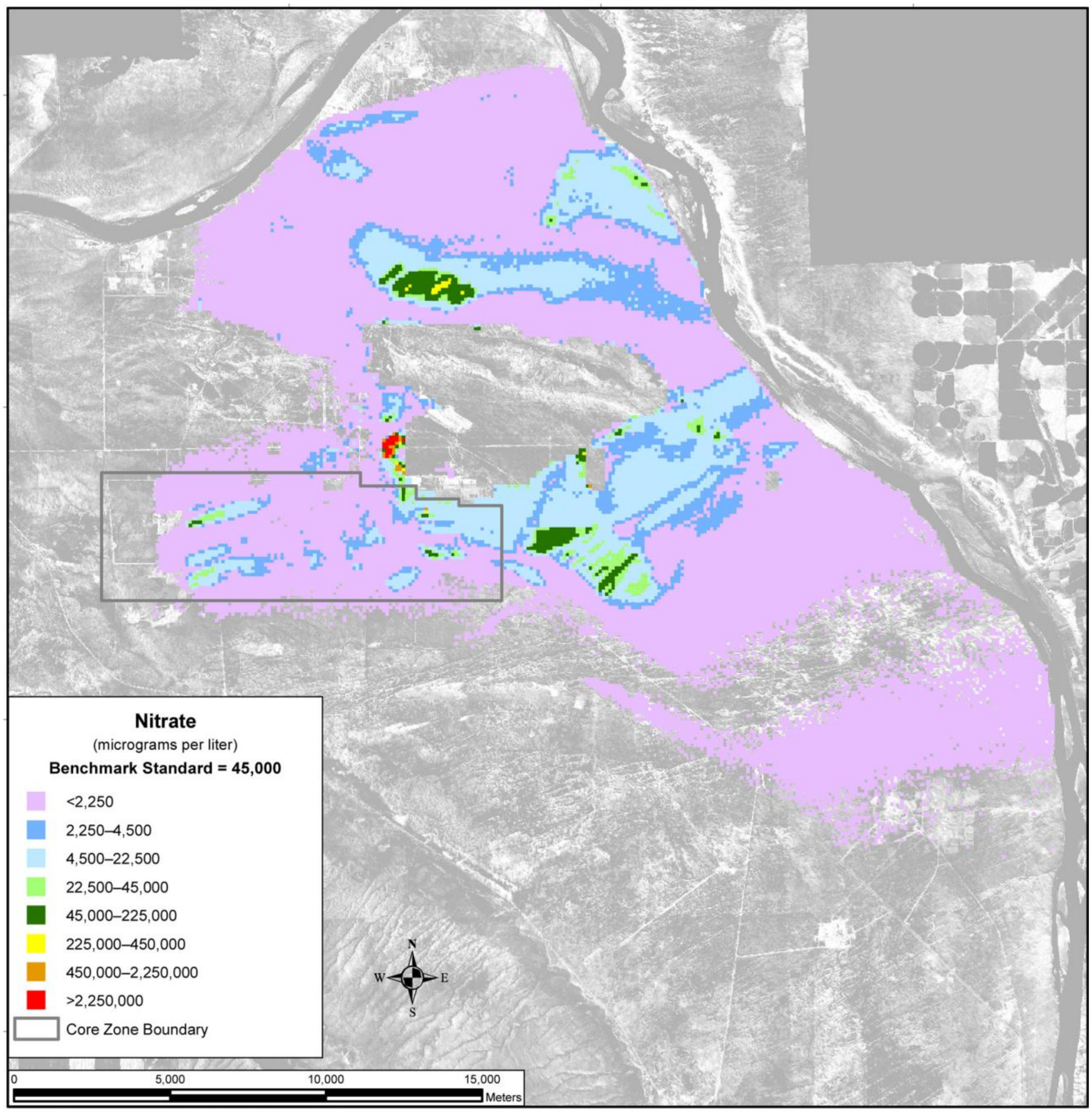
Note: To convert meters to feet, multiply by 3.281.

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



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

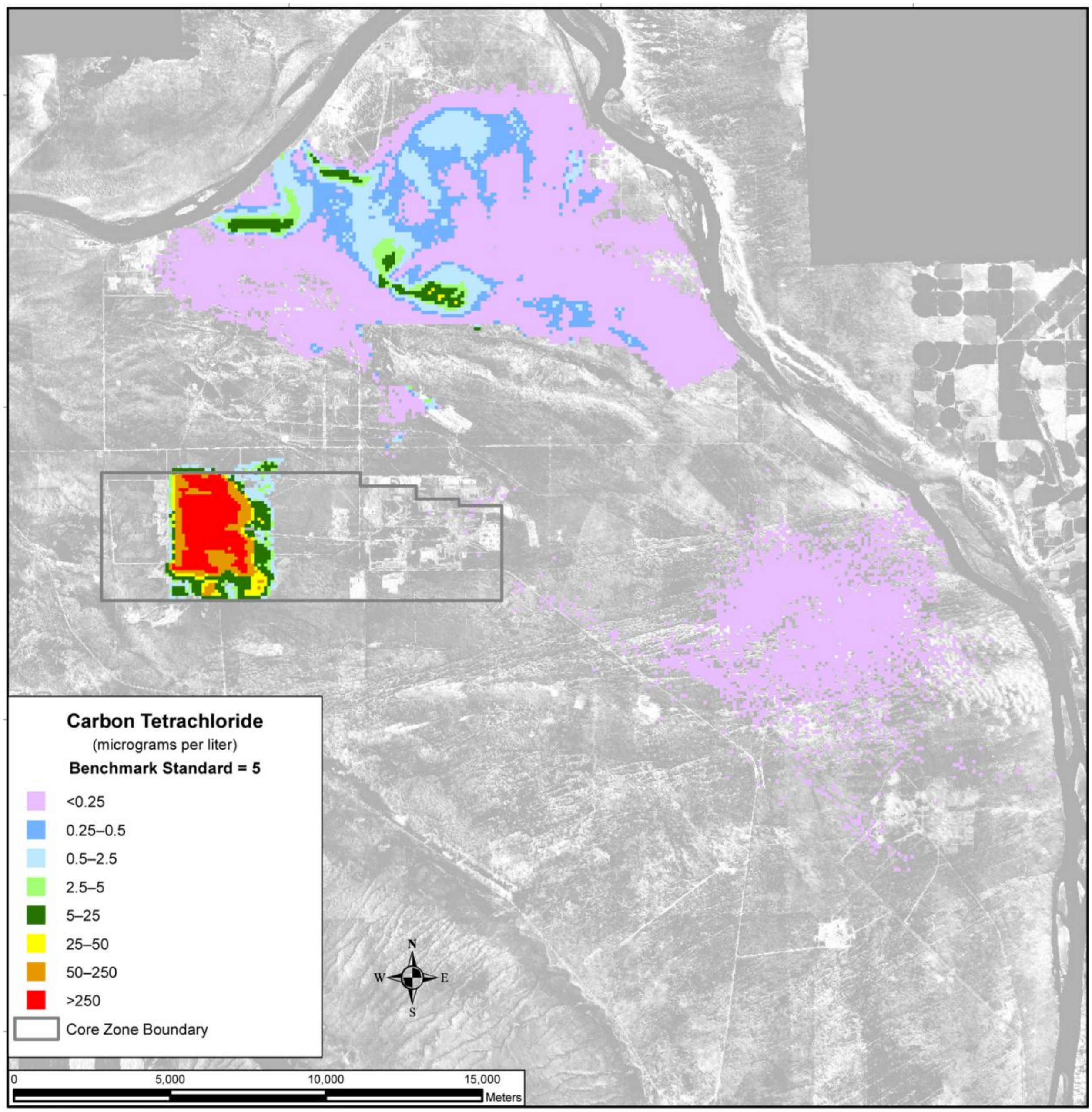
Figure 6–23. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Nitrate Concentration, Calendar Year 2135



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

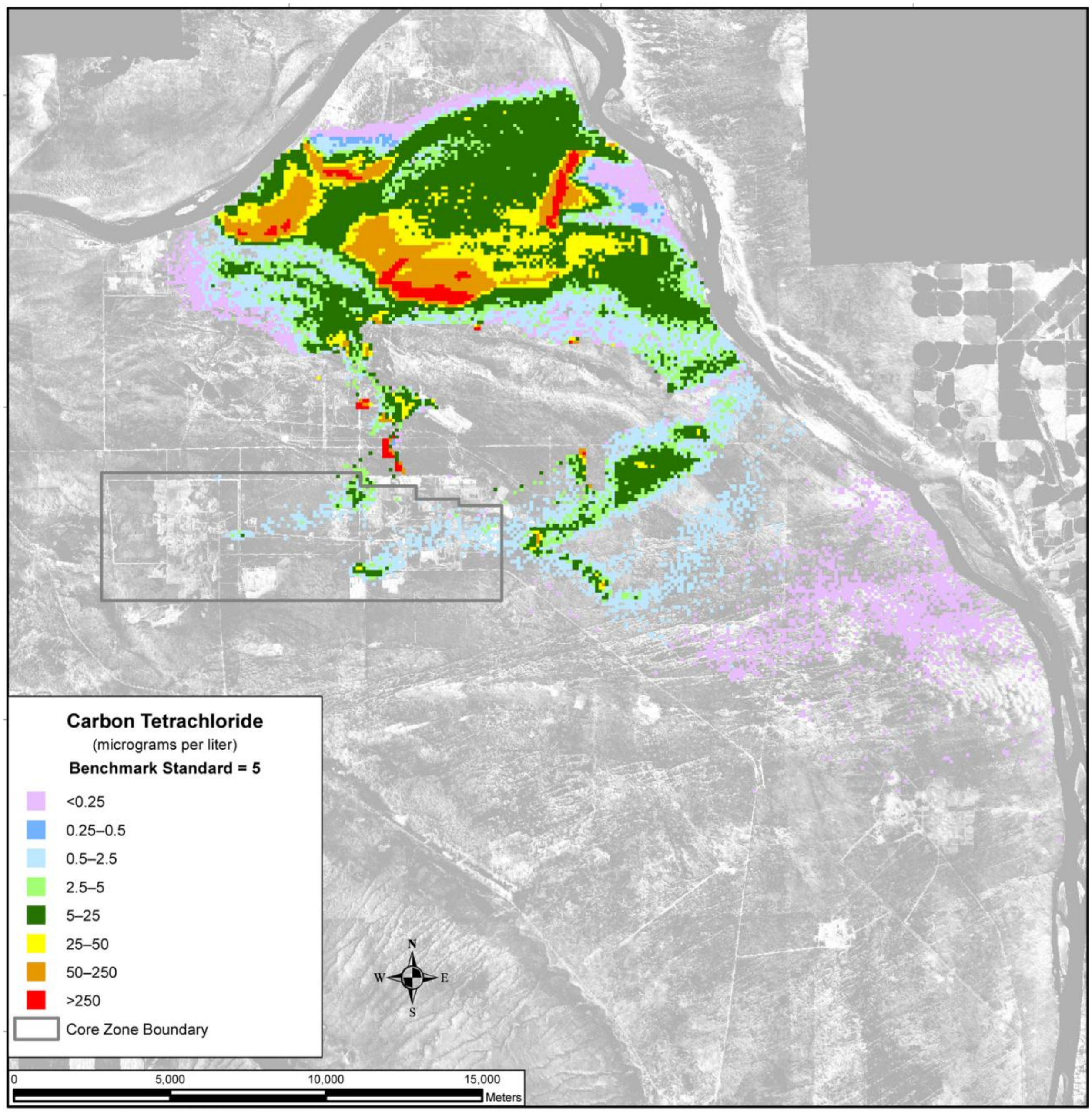
The spatial distribution of carbon tetrachloride concentrations in groundwater is dominated by non–*TC & WM EIS* sources associated with the Z Area within the 200-West Area. The spatial distribution in CY 2010, shown in Figure 6–25, is a large plume covering most of the 200-West Area, with peak concentrations 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.



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

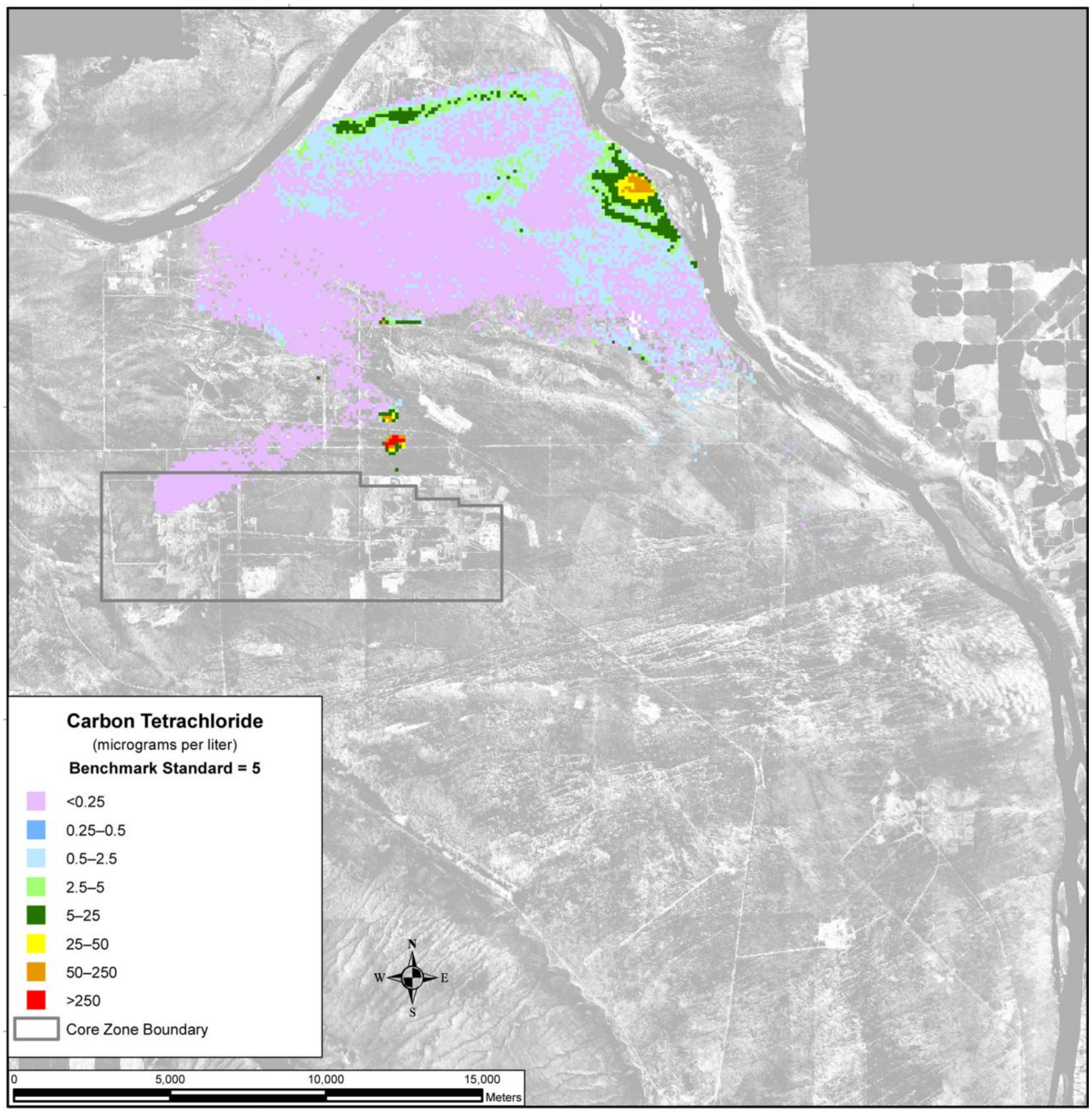
Figure 6–25. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Carbon Tetrachloride Concentration, Calendar Year 2010

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.



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

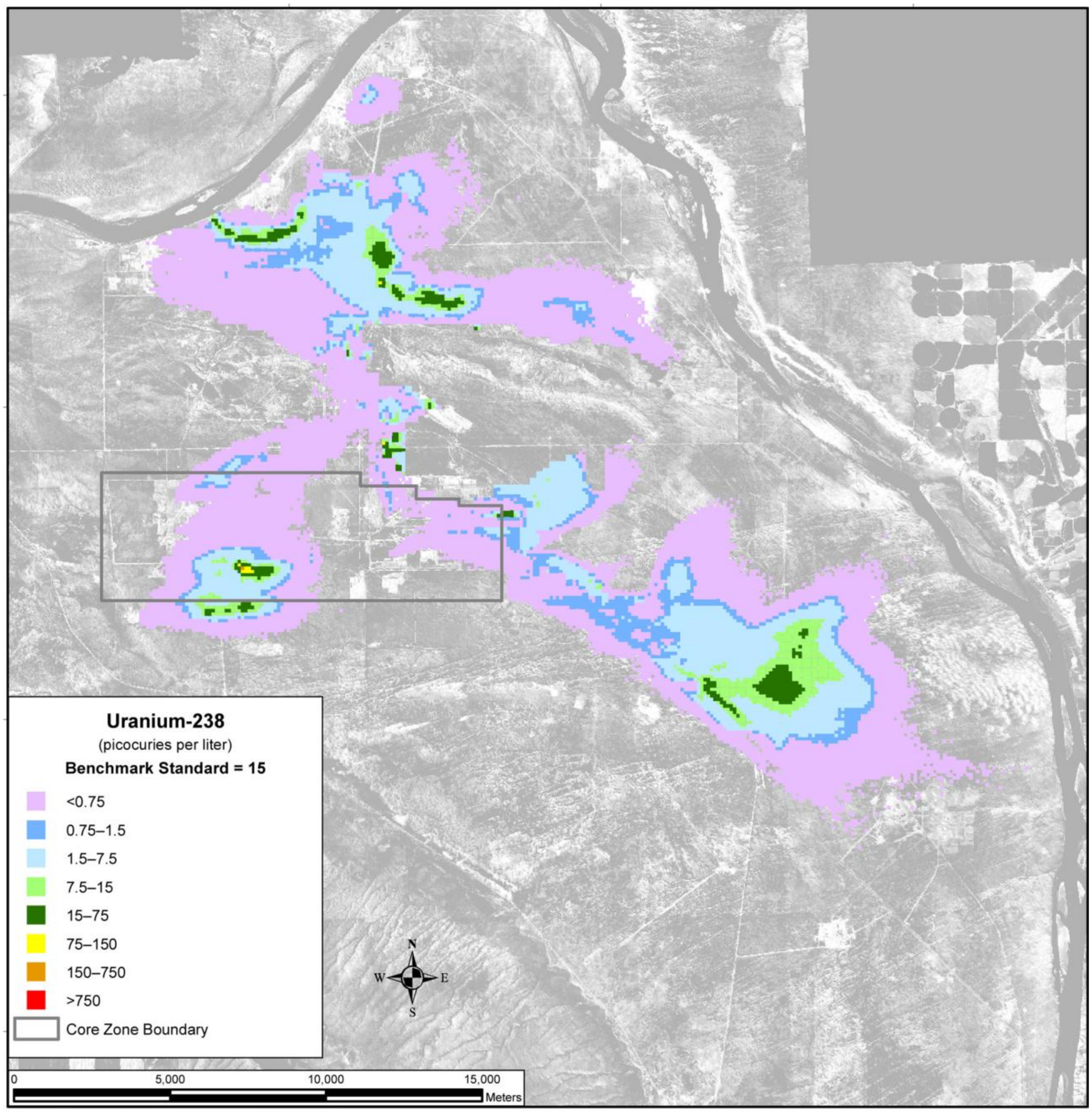
Figure 6–26. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Carbon Tetrachloride Concentration, Calendar Year 2135



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

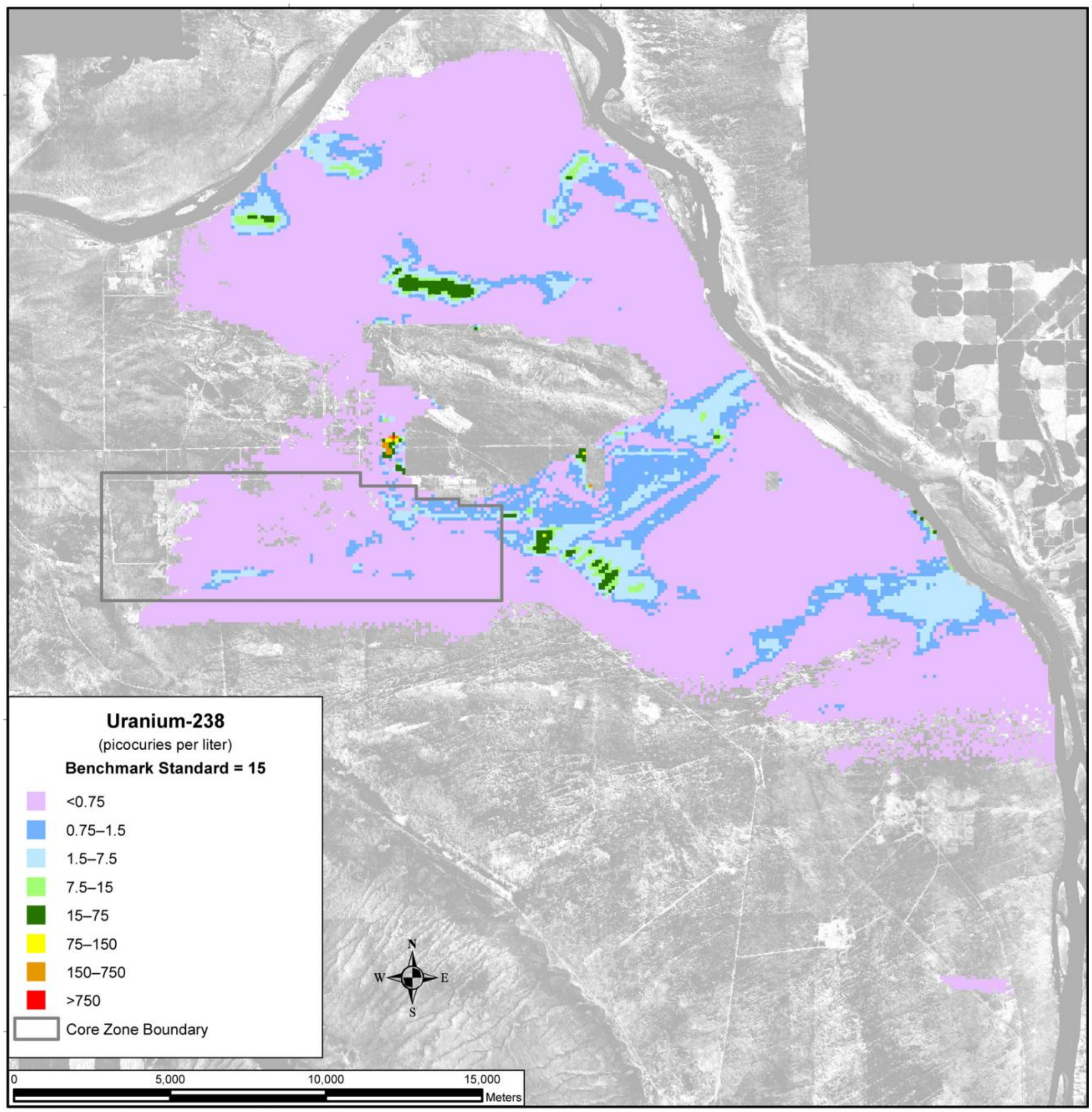
Figure 6–27. Alternative Combination 1 Spatial Distribution of Cumulative Groundwater Carbon Tetrachloride Concentration, Calendar Year 3890

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.



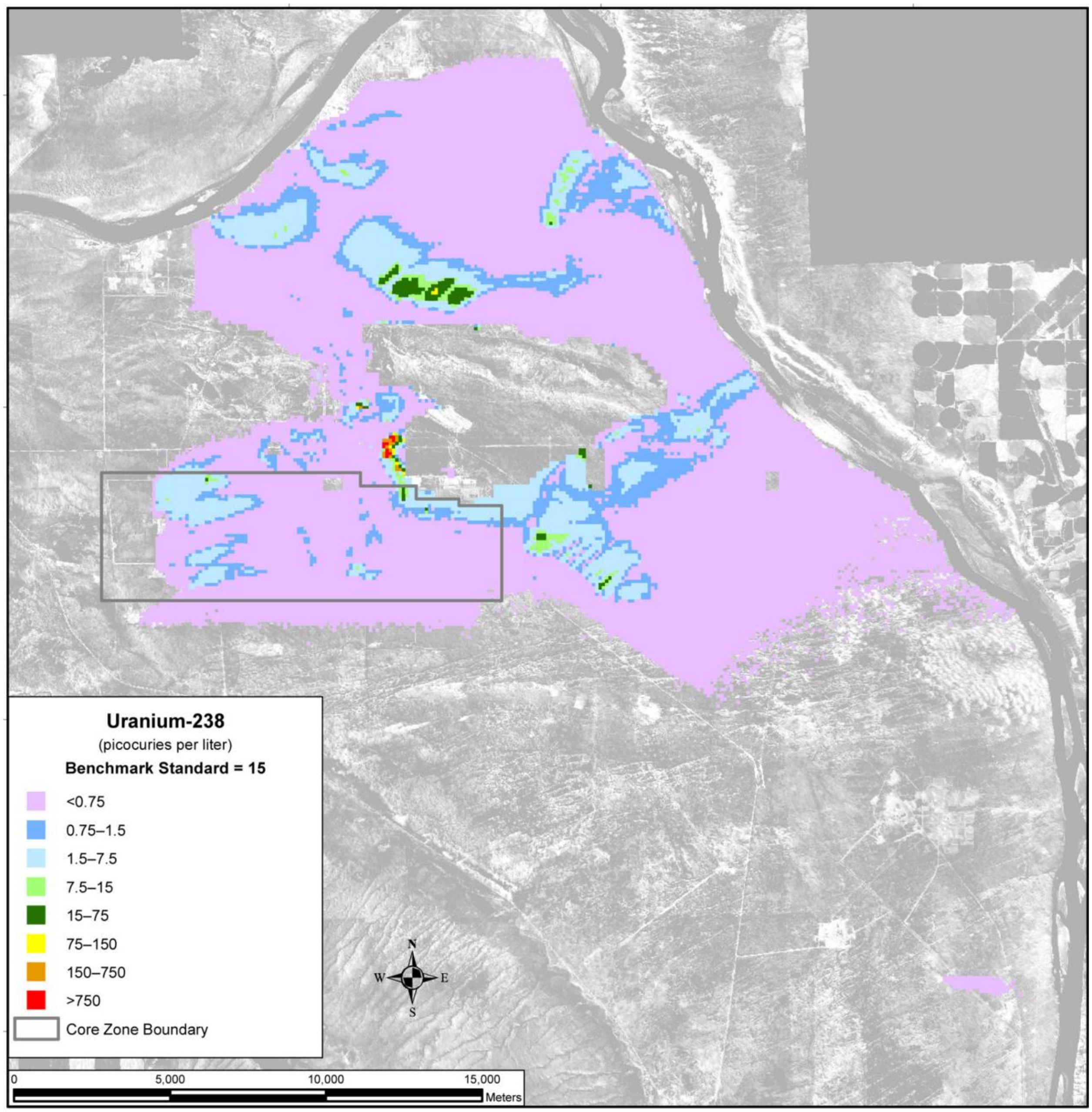
Note: To convert meters to feet, multiply by 3.281.

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



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

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

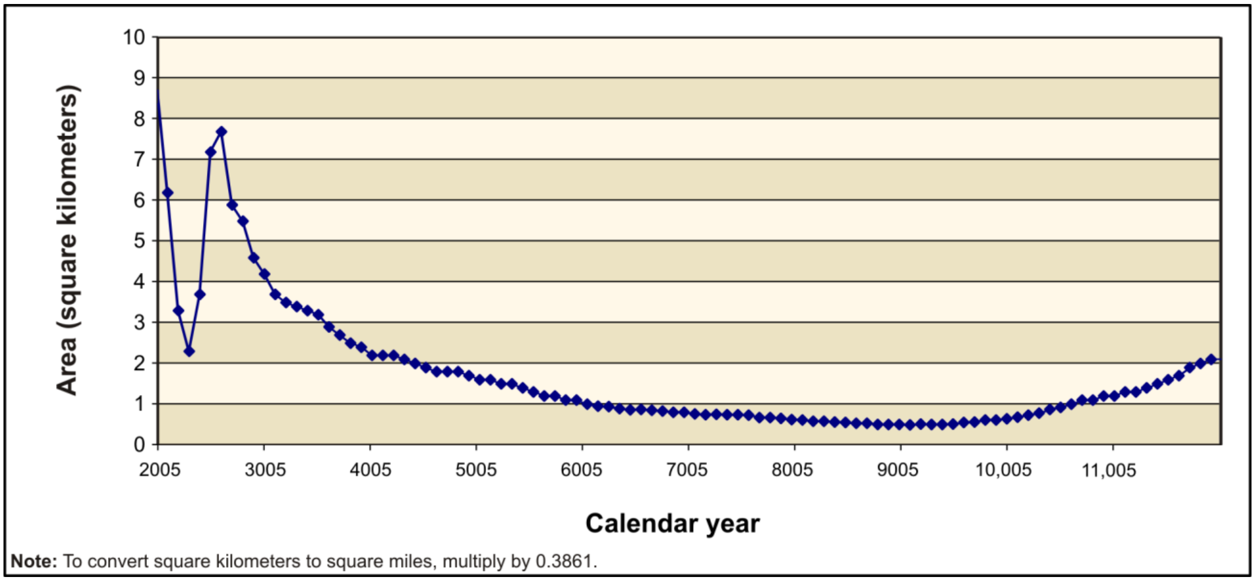
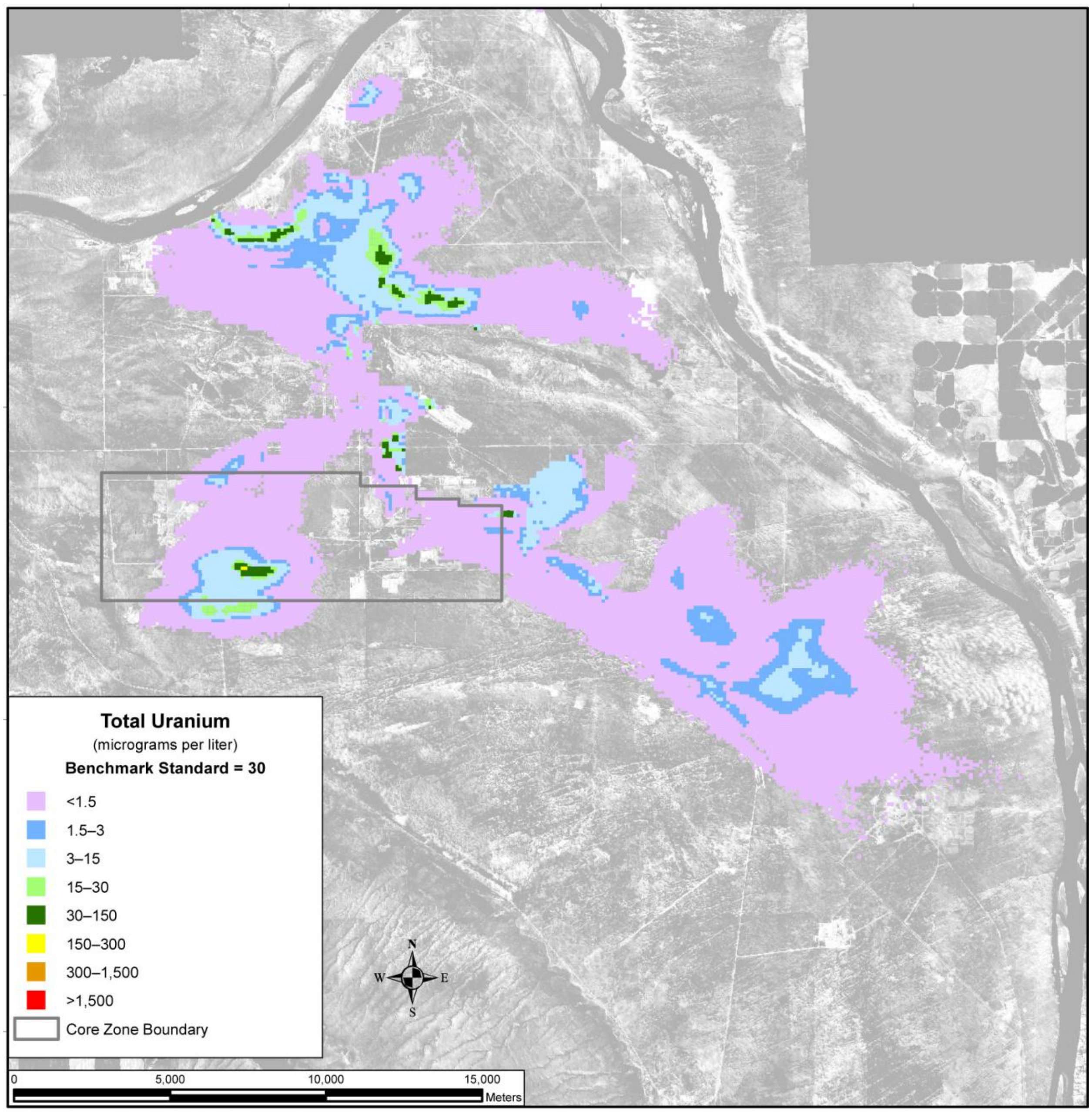
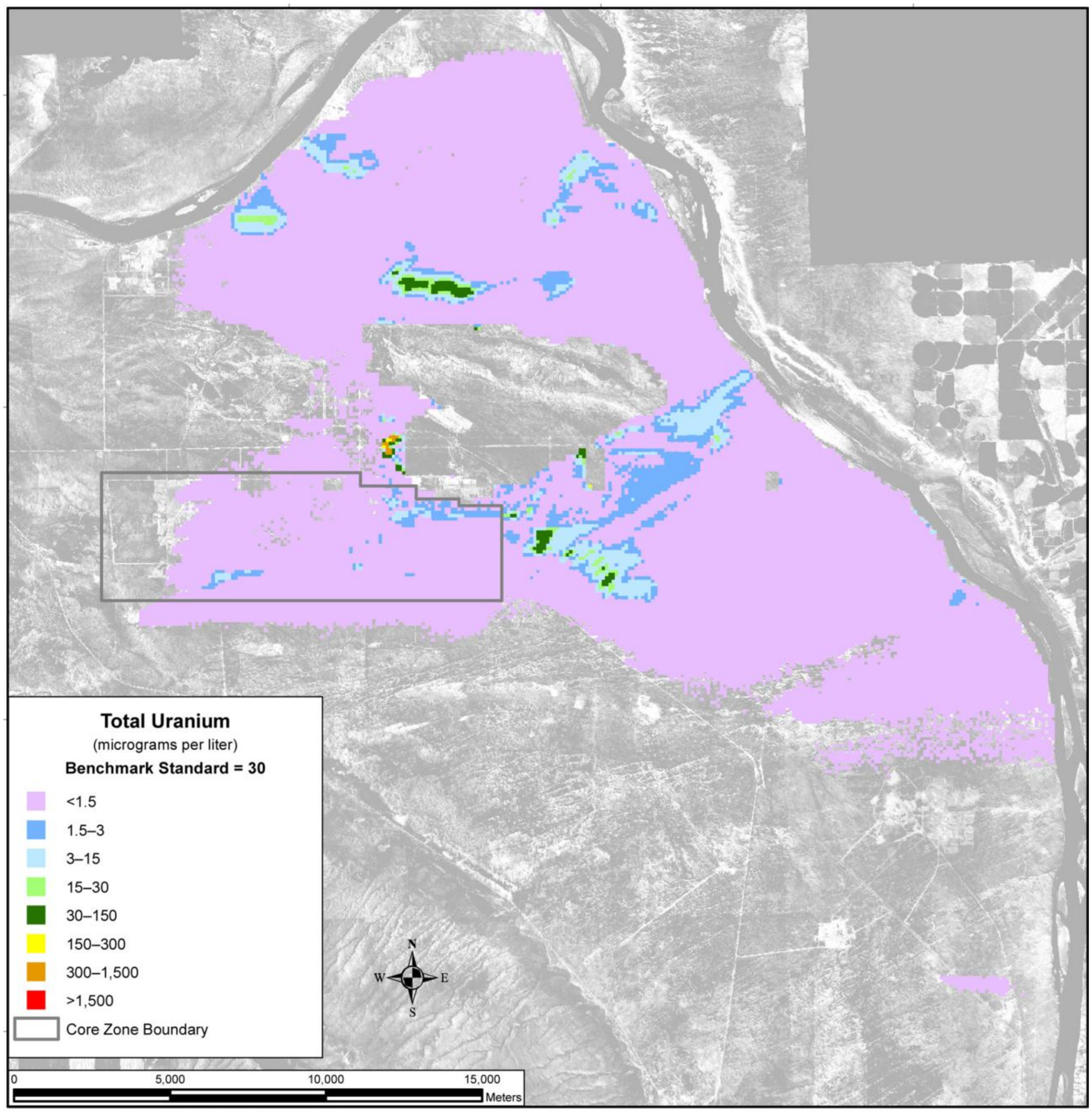


Figure 6–31. Alternative Combination 1 Total Area of Cumulative Groundwater Uranium-238 Concentrations Exceeding the Benchmark Concentration as a Function of Time



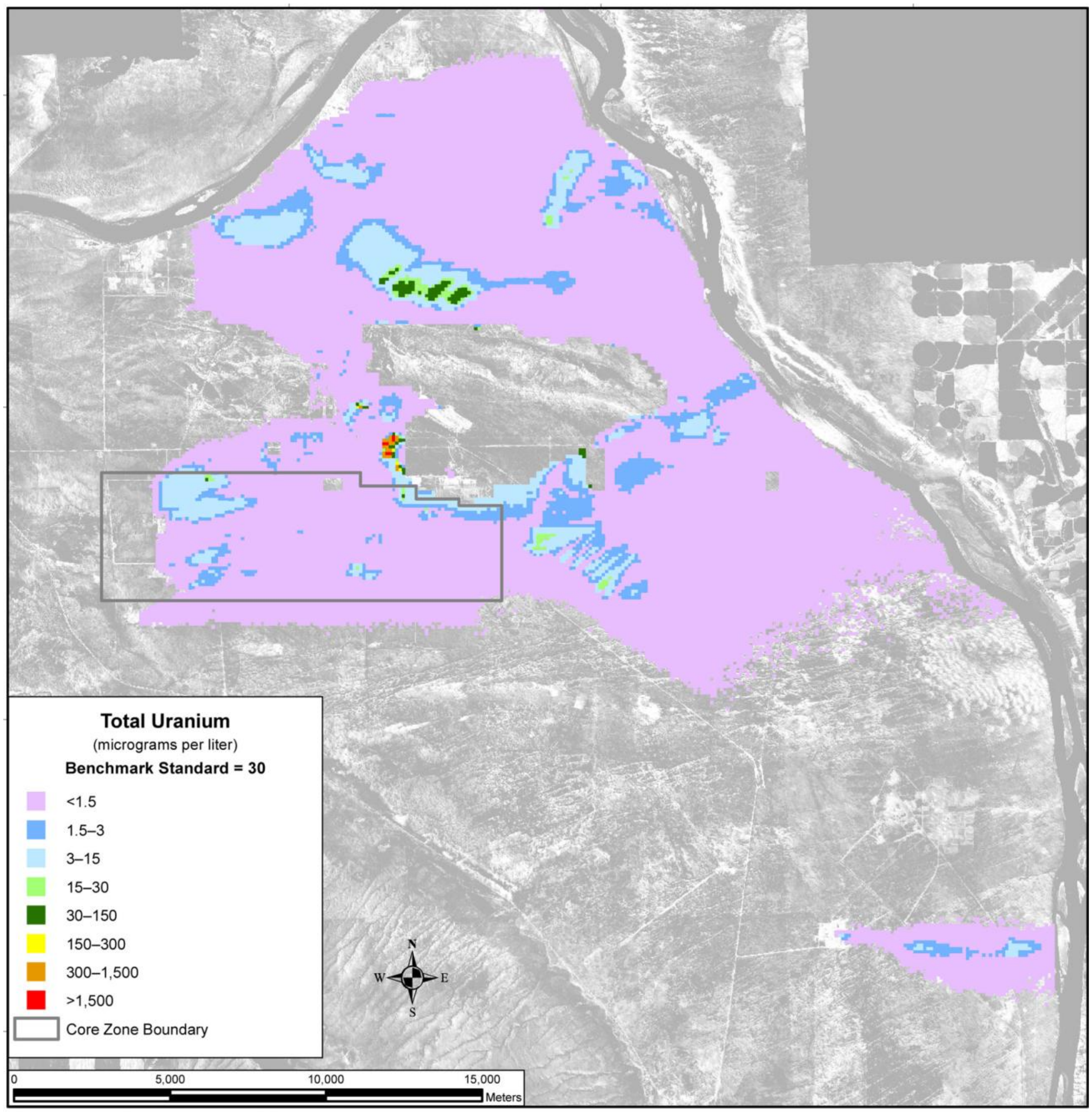
Note: To convert meters to feet, multiply by 3.281.

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



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

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



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

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

	Radioactive COPCs (curies)				Chemical COPCs (kilograms)		
Source	**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	$\mathbf{2.48\times10^{6}}$	$\mathbf{4.10\times10^{3}}$	$\mathbf{1.78\times10^{1}}$	$\mathbf{3.99\times10^{3}}$	$\mathbf{4.55\times10^{5}}$	$\mathbf{1.12\times10^{8}}$	$\mathbf{7.12\times10^{6}}$

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	$\mathbf{2.06\times10^{6}}$	$\mathbf{3.79\times10^{3}}$	$\mathbf{1.63\times10^{1}}$	$\mathbf{2.18\times10^{2}}$	$\mathbf{4.63\times10^{5}}$	$\mathbf{1.13\times10^{8}}$	$\mathbf{1.33\times10^{5}}$

[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	$\mathbf{7.25\times10^{4}}$	$\mathbf{3.77\times10^{3}}$	$\mathbf{1.62\times10^{1}}$	$\mathbf{2.13\times10^{2}}$	$\mathbf{4.86\times10^{5}}$	$\mathbf{1.17\times10^{8}}$	$\mathbf{1.15\times10^{5}}$

[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.

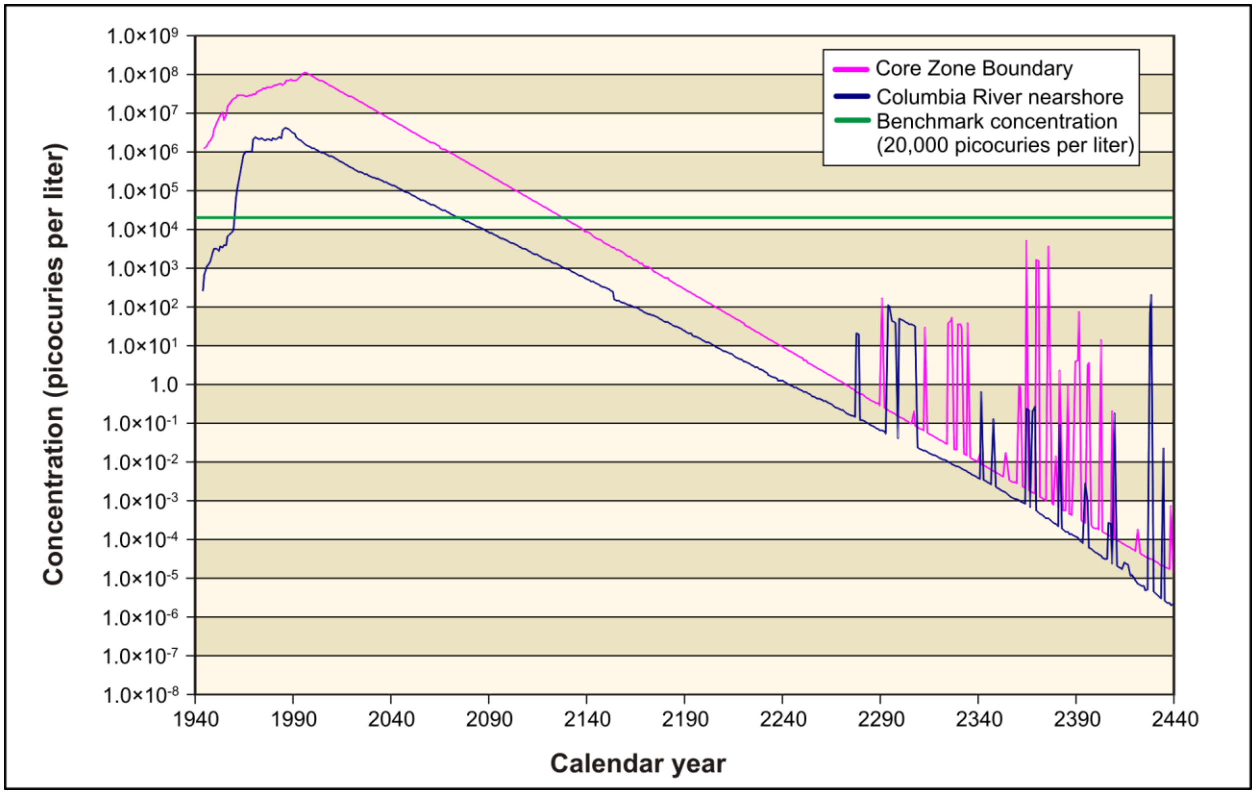


Figure 6–35. Alternative Combination 2 Cumulative Hydrogen-3 (Tritium) Concentration Versus Time

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.

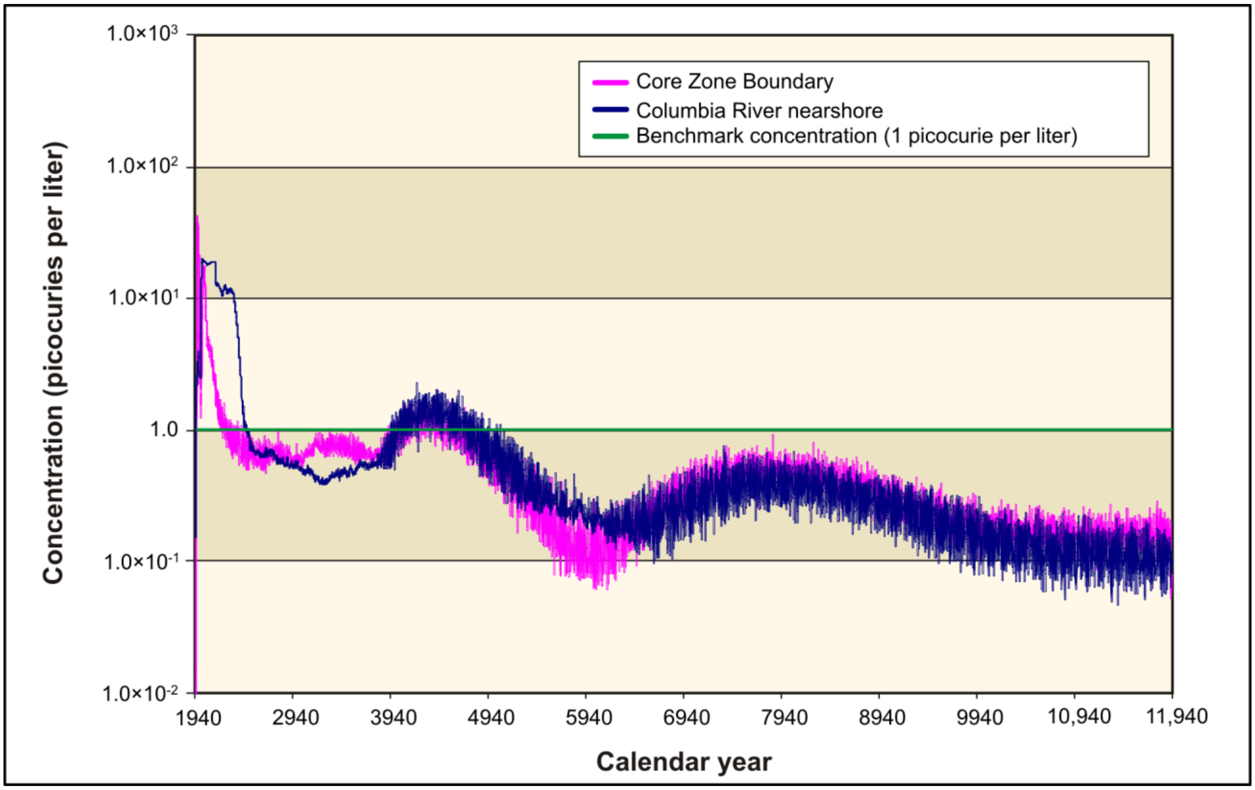


Figure 6–36. Alternative Combination 2 Cumulative Iodine-129 Concentration Versus Time

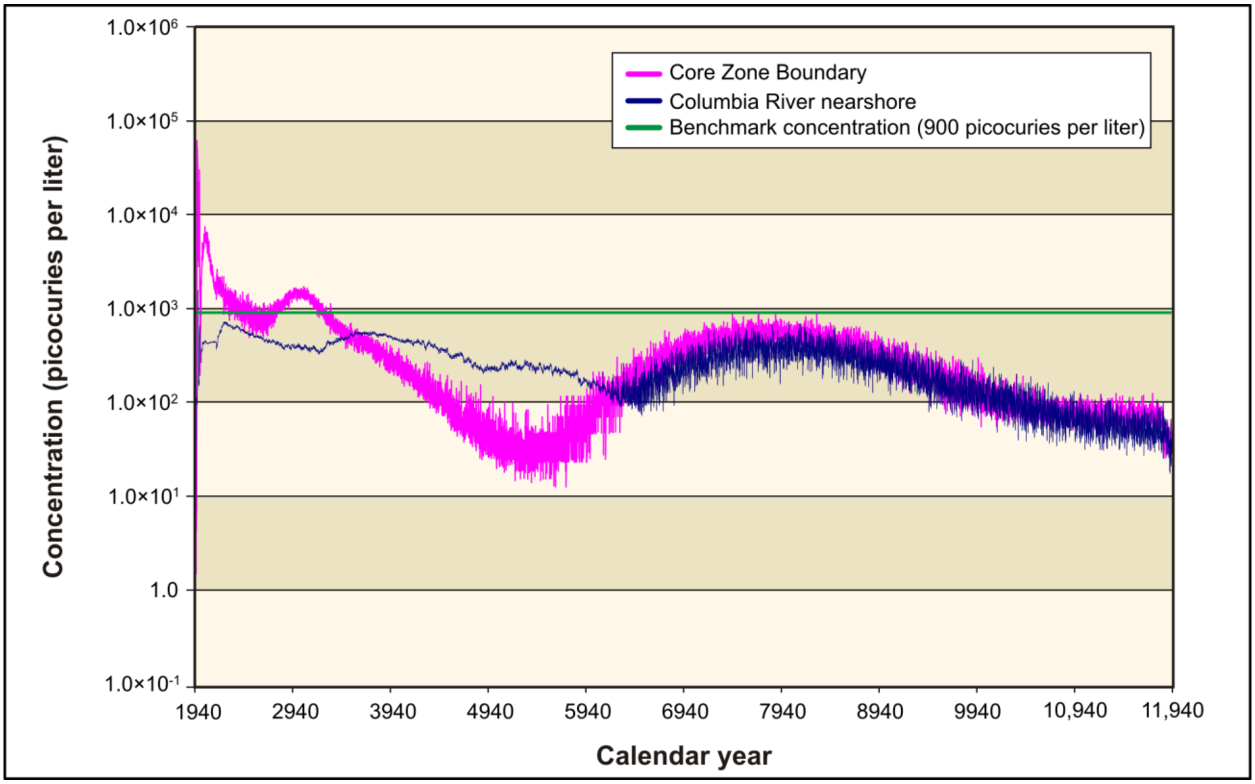


Figure 6–37. Alternative Combination 2 Cumulative Technetium-99 Concentration Versus Time

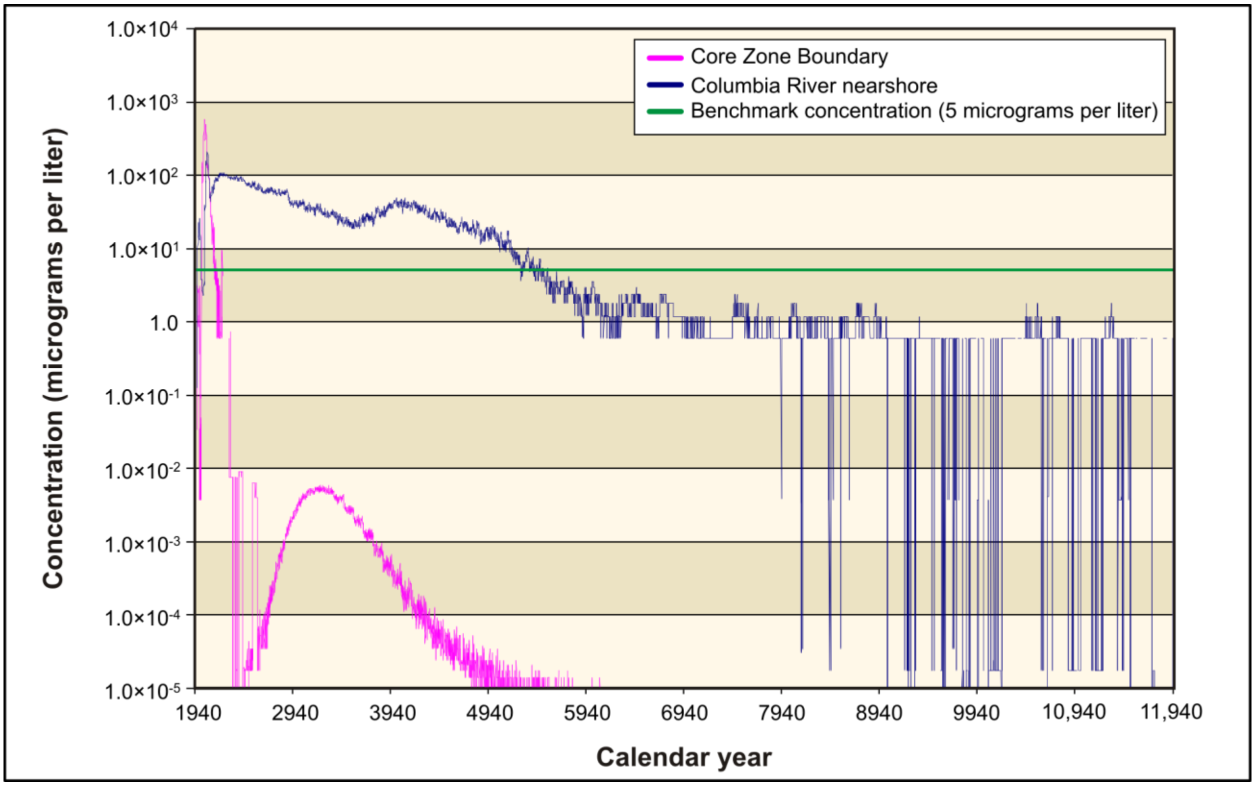


Figure 6–38. Alternative Combination 2 Cumulative Carbon Tetrachloride Concentration Versus Time

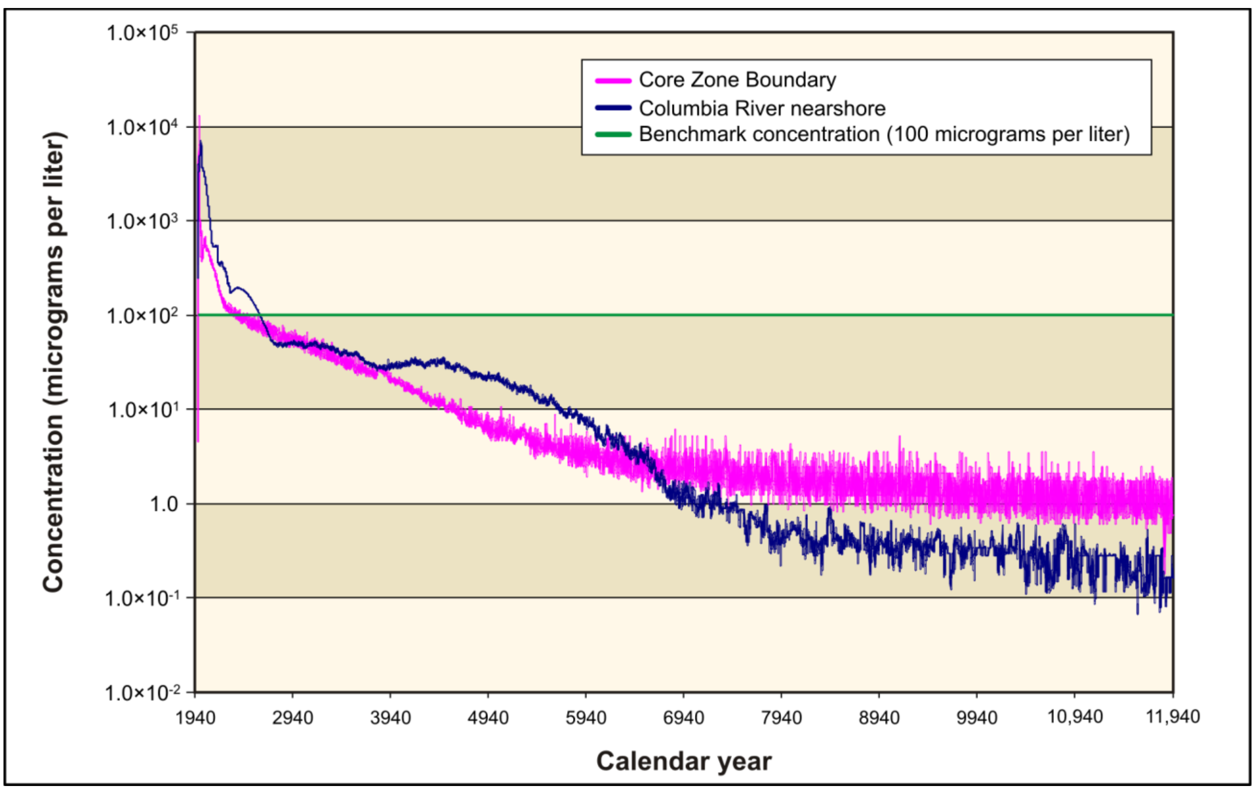


Figure 6–39. Alternative Combination 2 Cumulative Chromium Concentration Versus Time

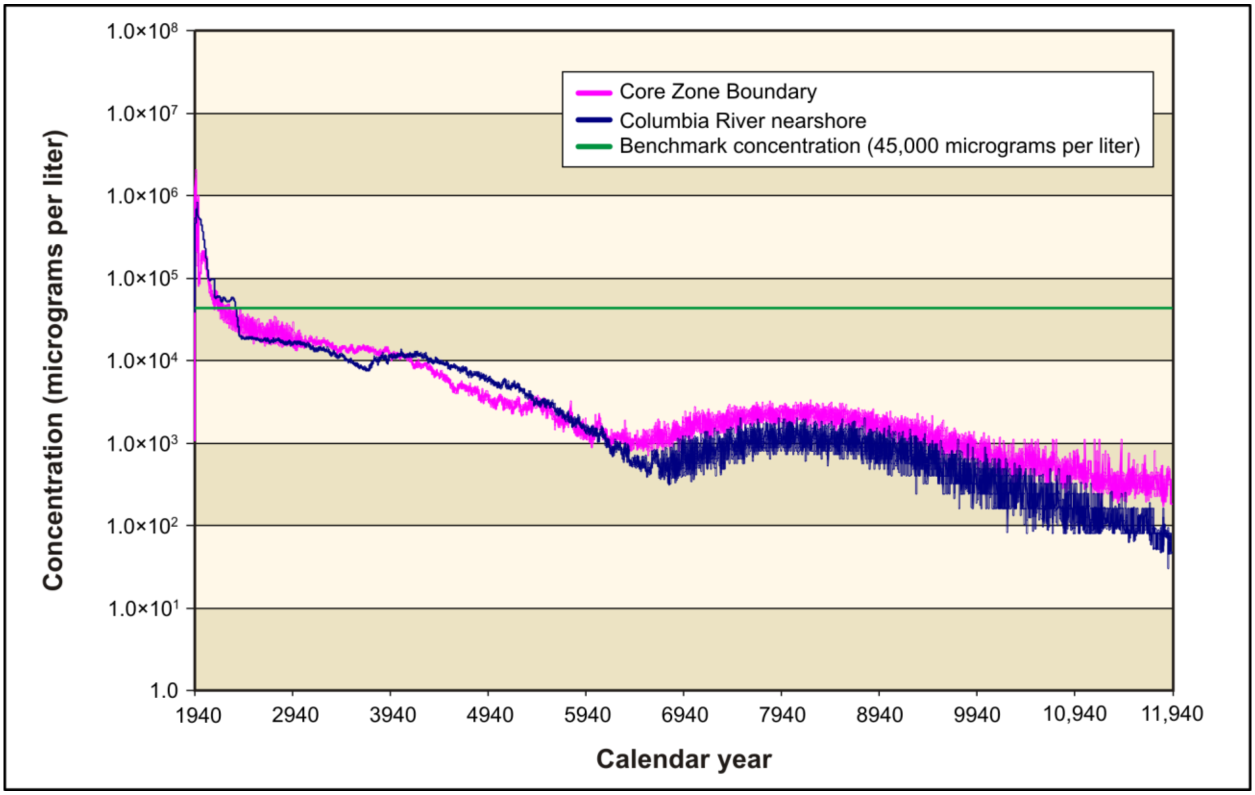


Figure 6–40. Alternative Combination 2 Cumulative Nitrate Concentration Versus Time

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.

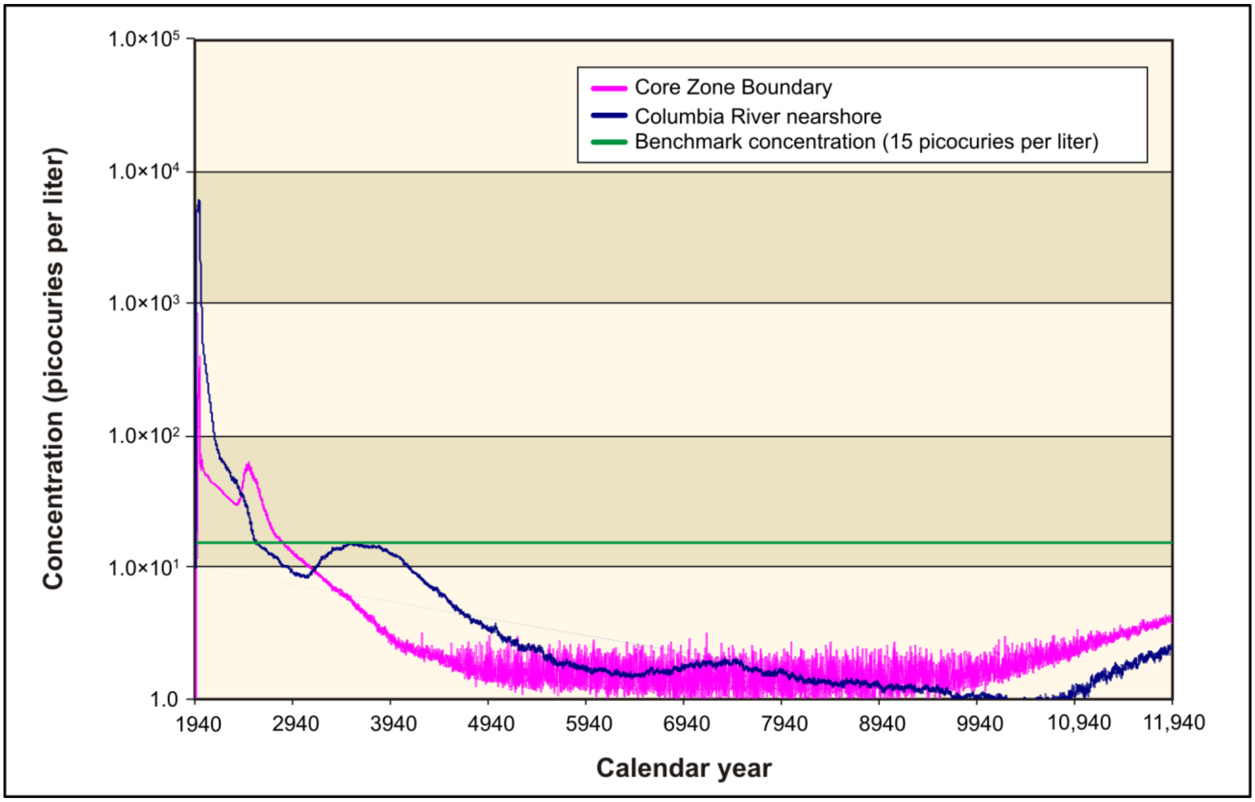


Figure 6–41. Alternative Combination 2 Cumulative Uranium-238 Concentration Versus Time

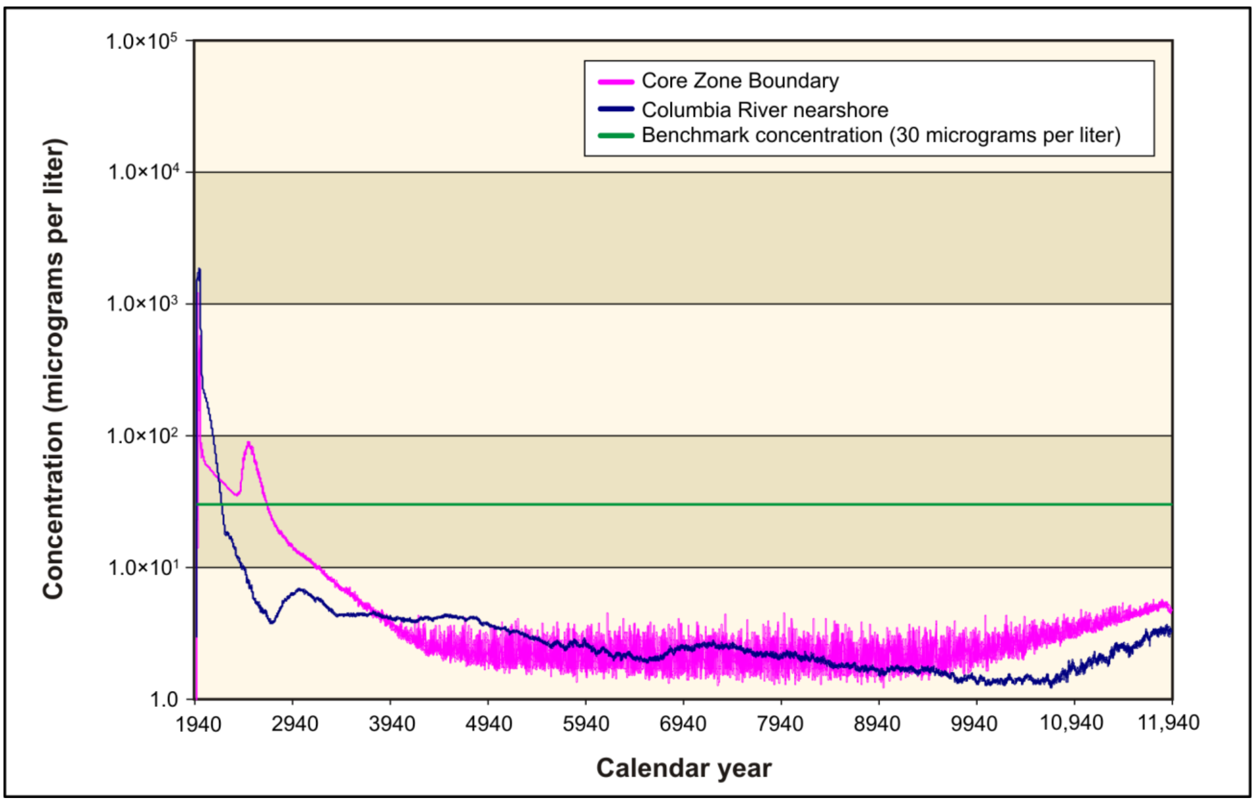
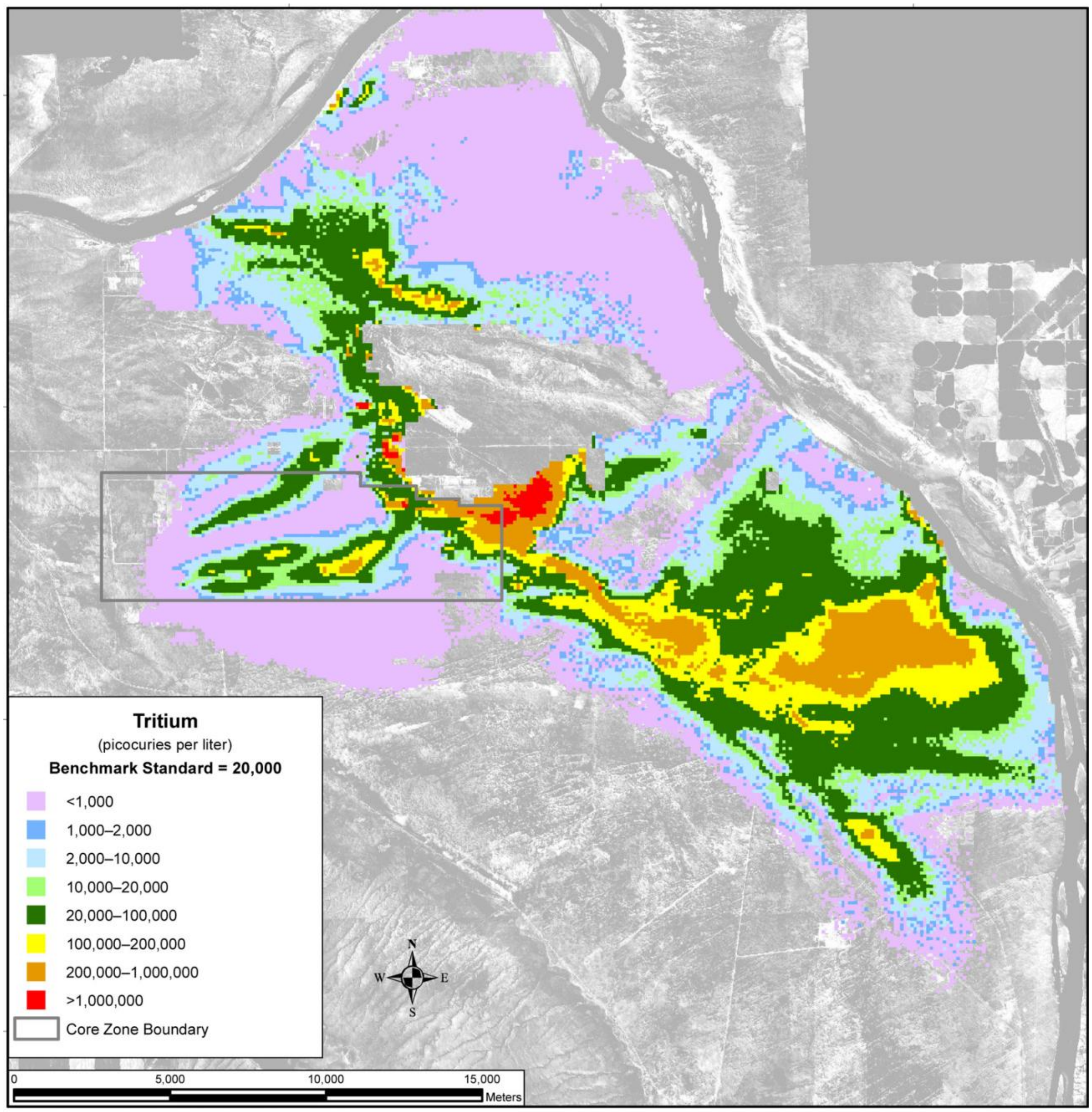


Figure 6–42. Alternative Combination 2 Cumulative Total Uranium Concentration Versus Time

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.

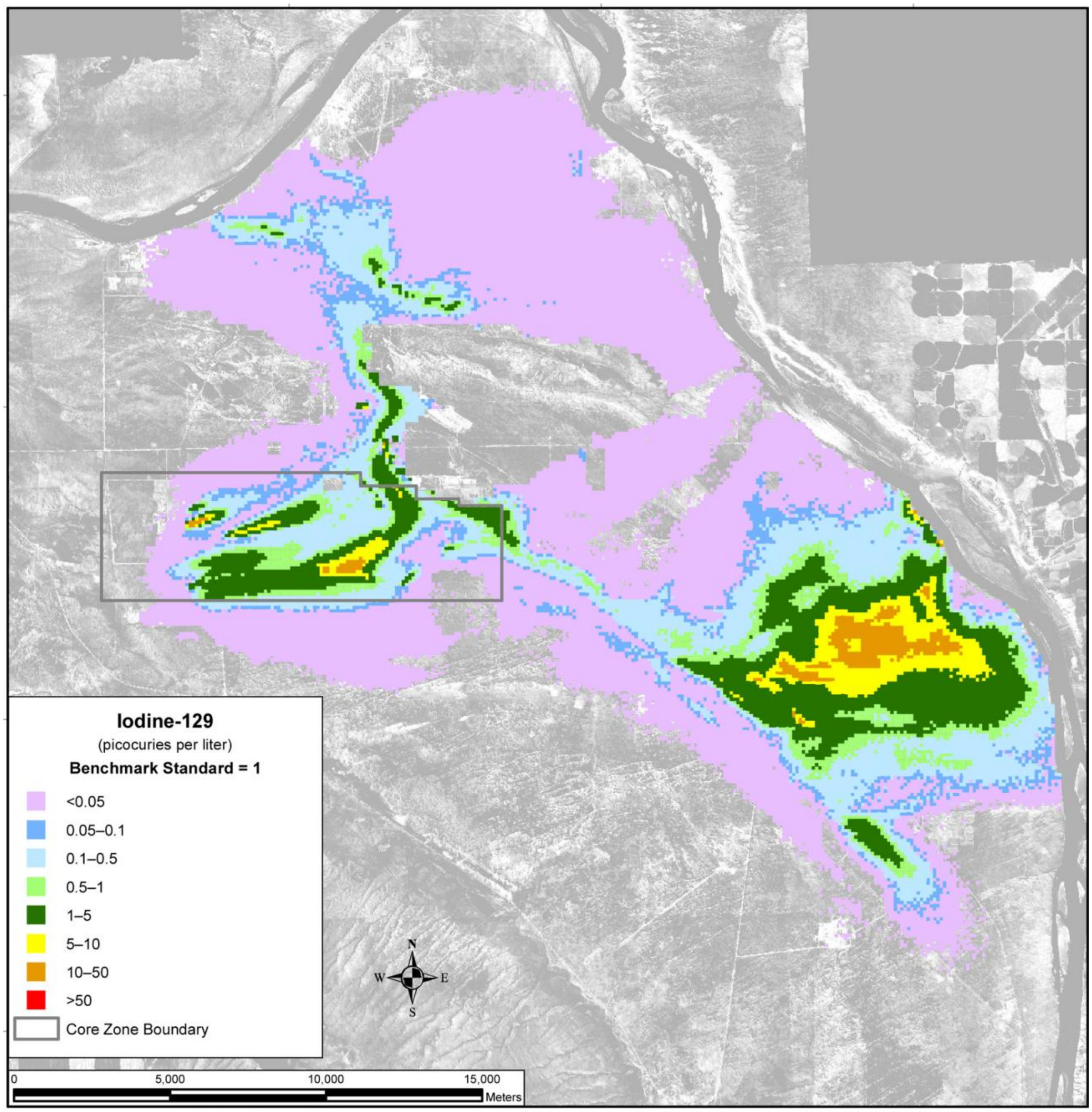
Figure 6–43 shows the spatial distribution of tritium concentrations in groundwater in CY 2010 and contrasts the behavior of the releases from *TC & WM EIS* and non–*TC & WM EIS* sources. The release from *TC & WM EIS* sources results from cribs and trenches (ditches) and past tank leaks and is evident 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 theses 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.

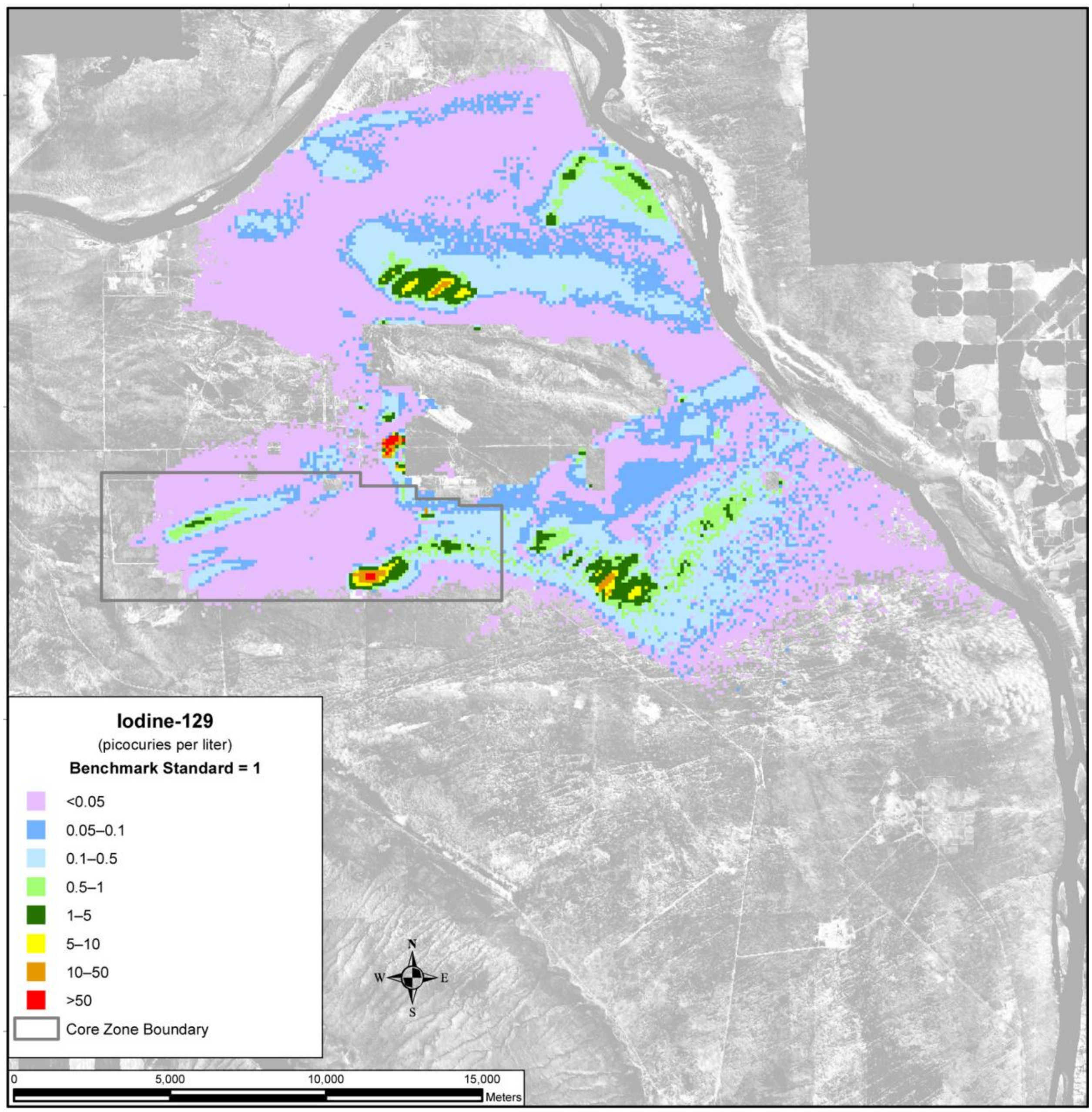
Figure 6–43. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Hydrogen-3 (Tritium) Concentration, Calendar Year 2010

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 & WM EIS* source. Releases from the PUREX Plant area (another non–*TC & WM EIS* 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.



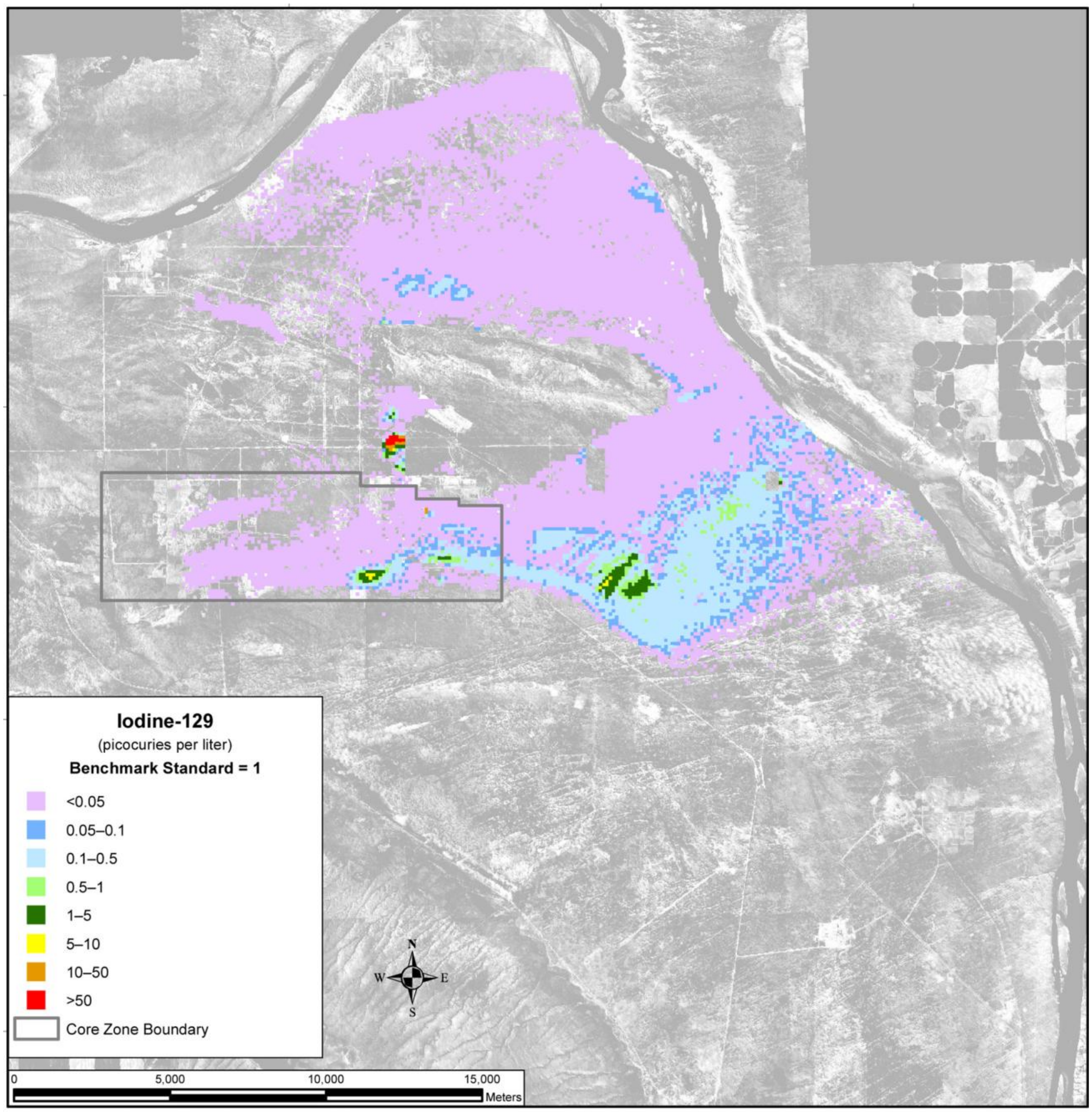
Note: To convert meters to feet, multiply by 3.281.

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



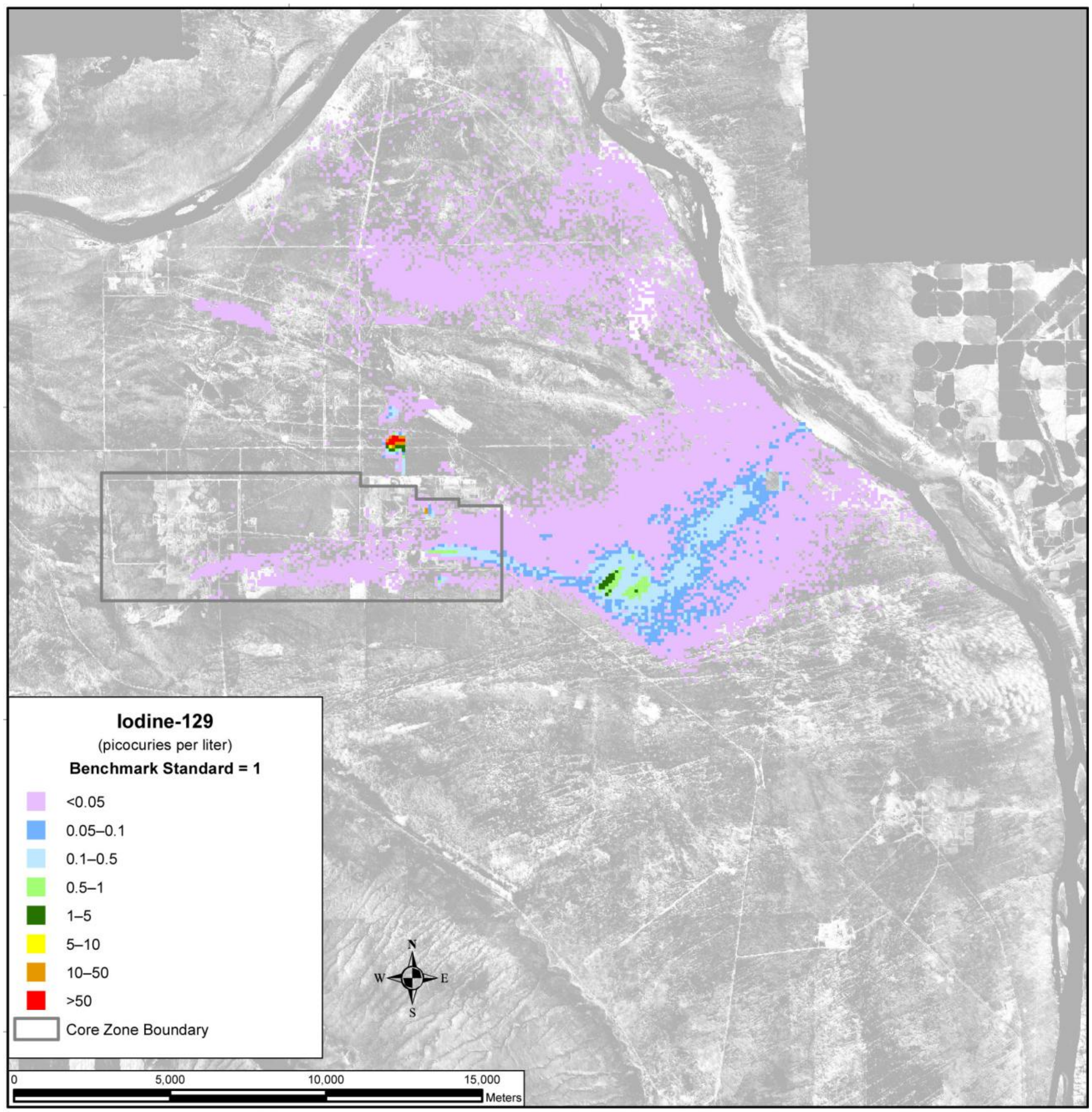
Note: To convert meters to feet, multiply by 3.281.

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



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

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

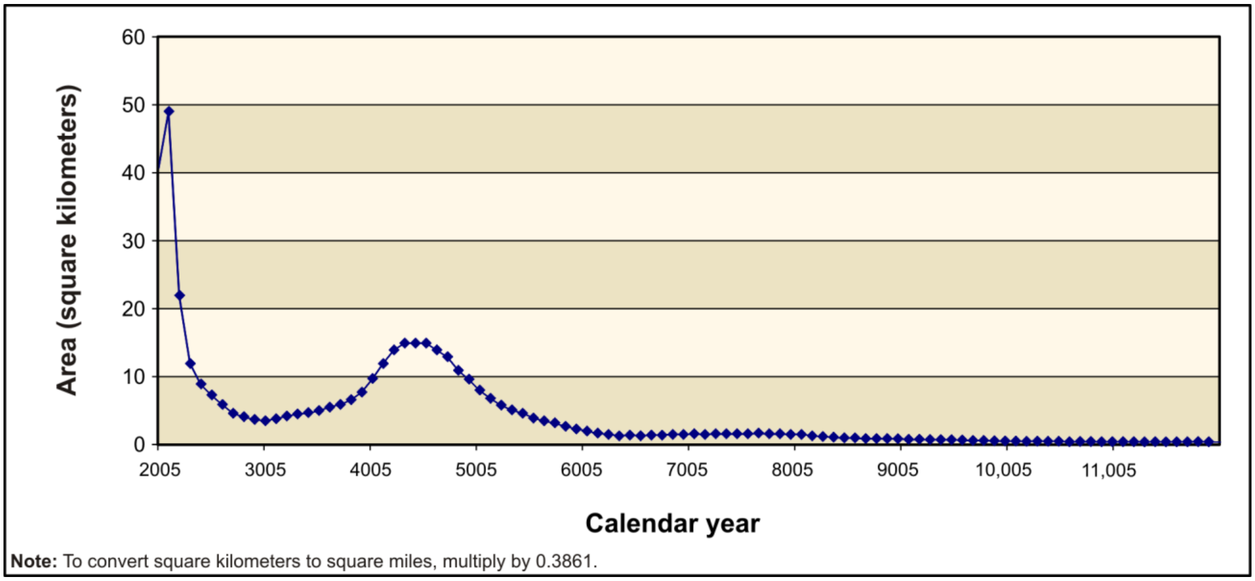
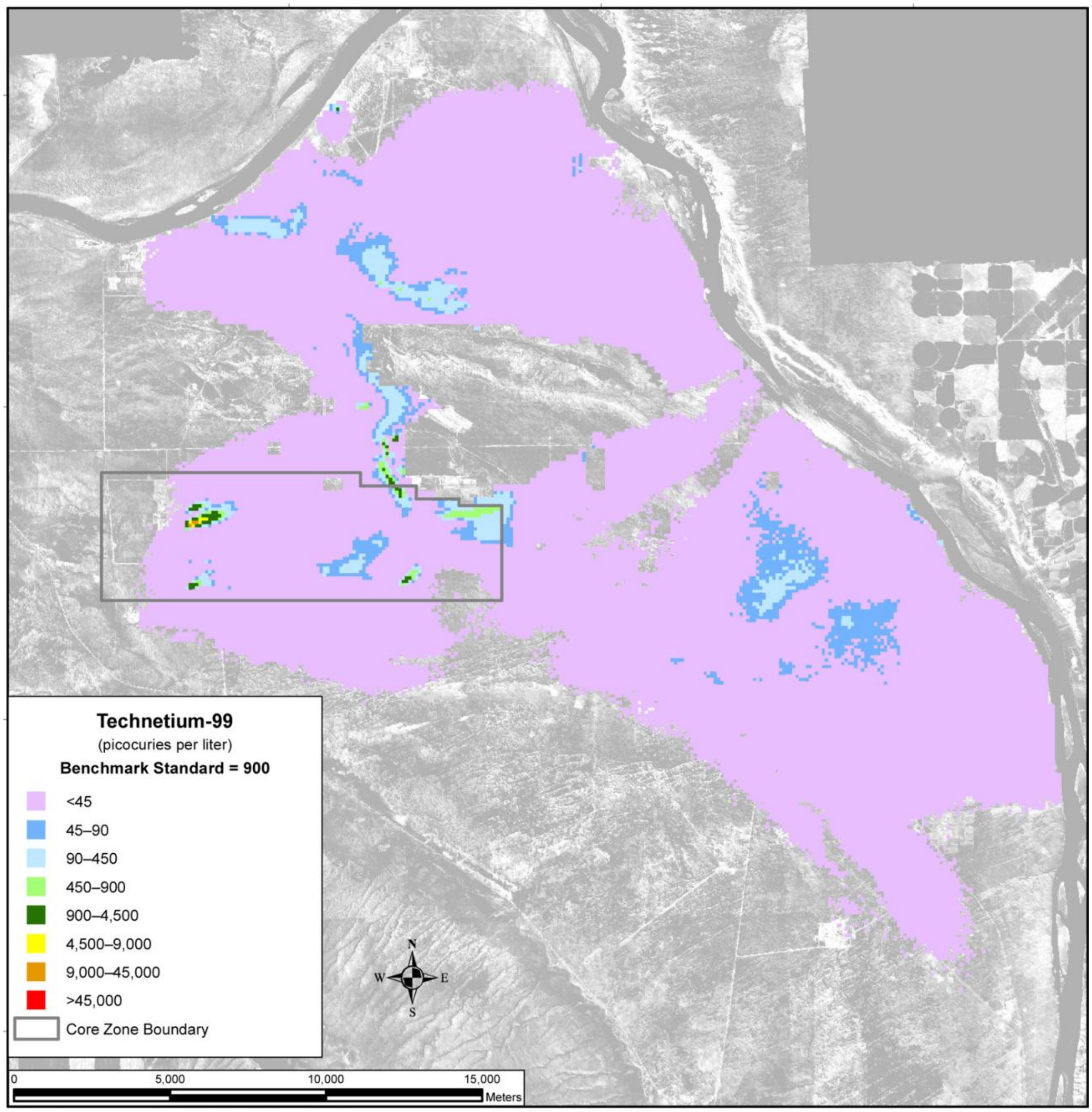


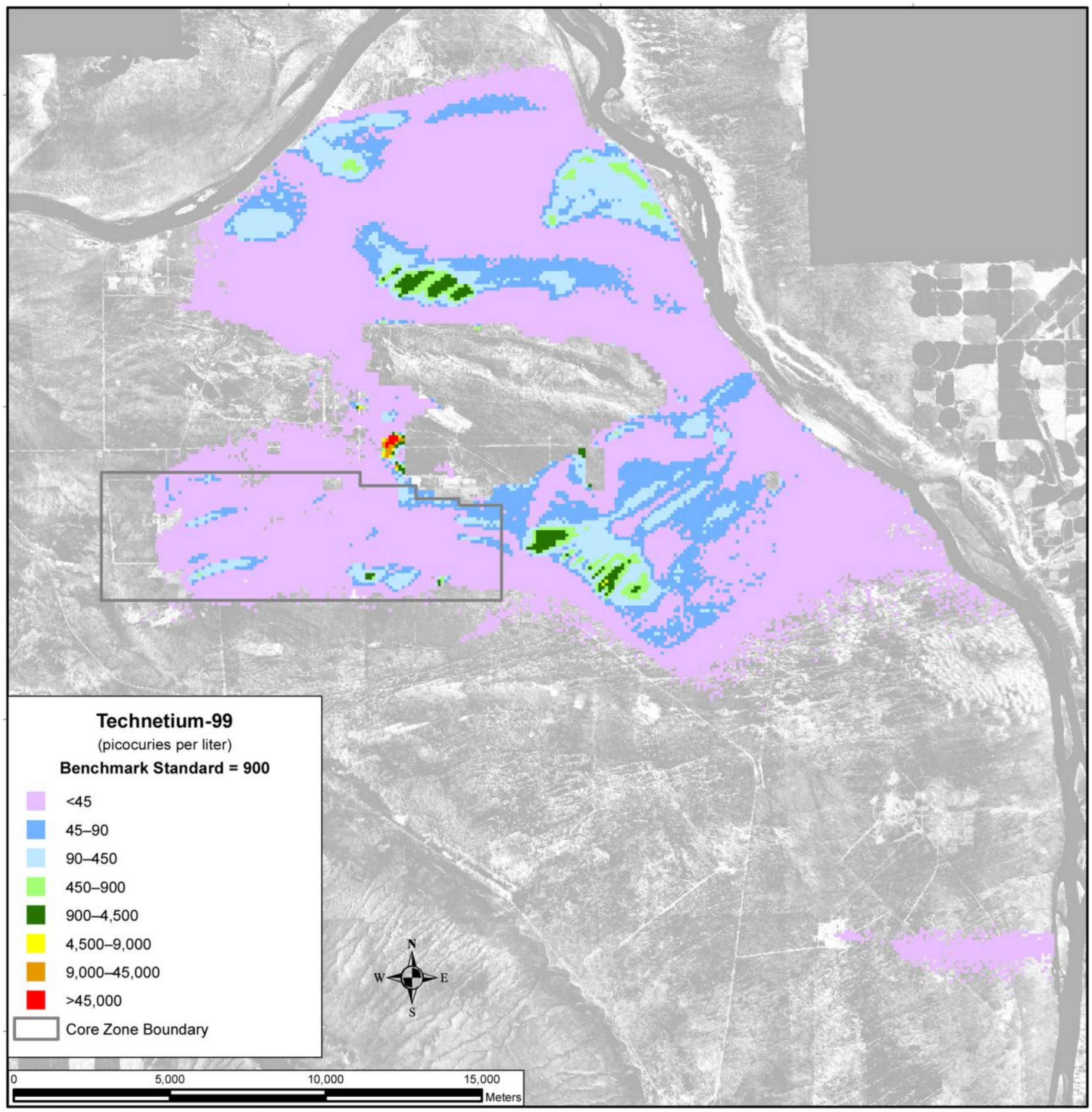
Figure 6–48. Alternative Combination 2 Total Area of Cumulative Groundwater Iodine-129 Concentrations Exceeding the Benchmark Concentration as a Function of Time

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.



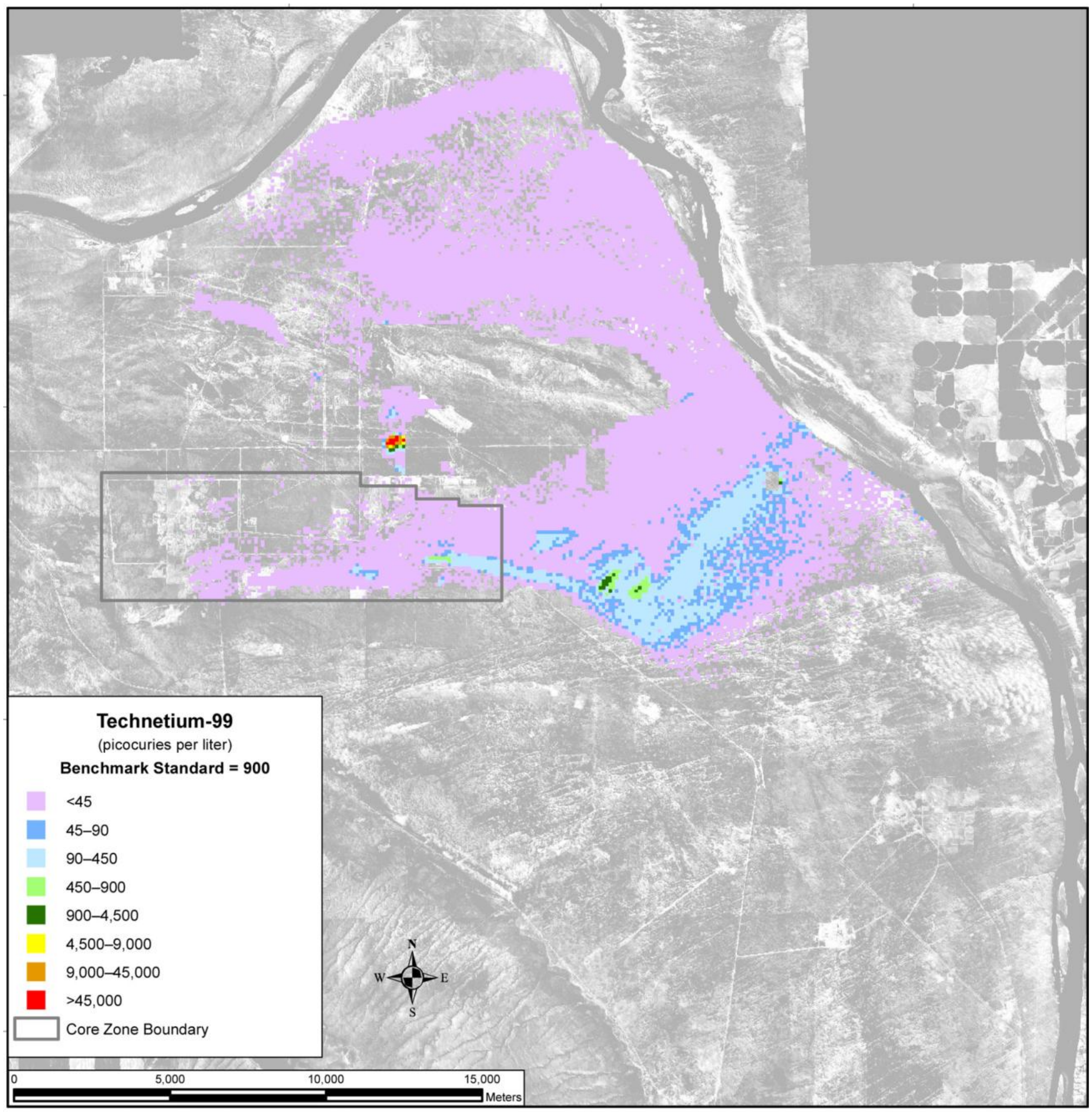
Note: To convert meters to feet, multiply by 3.281.

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



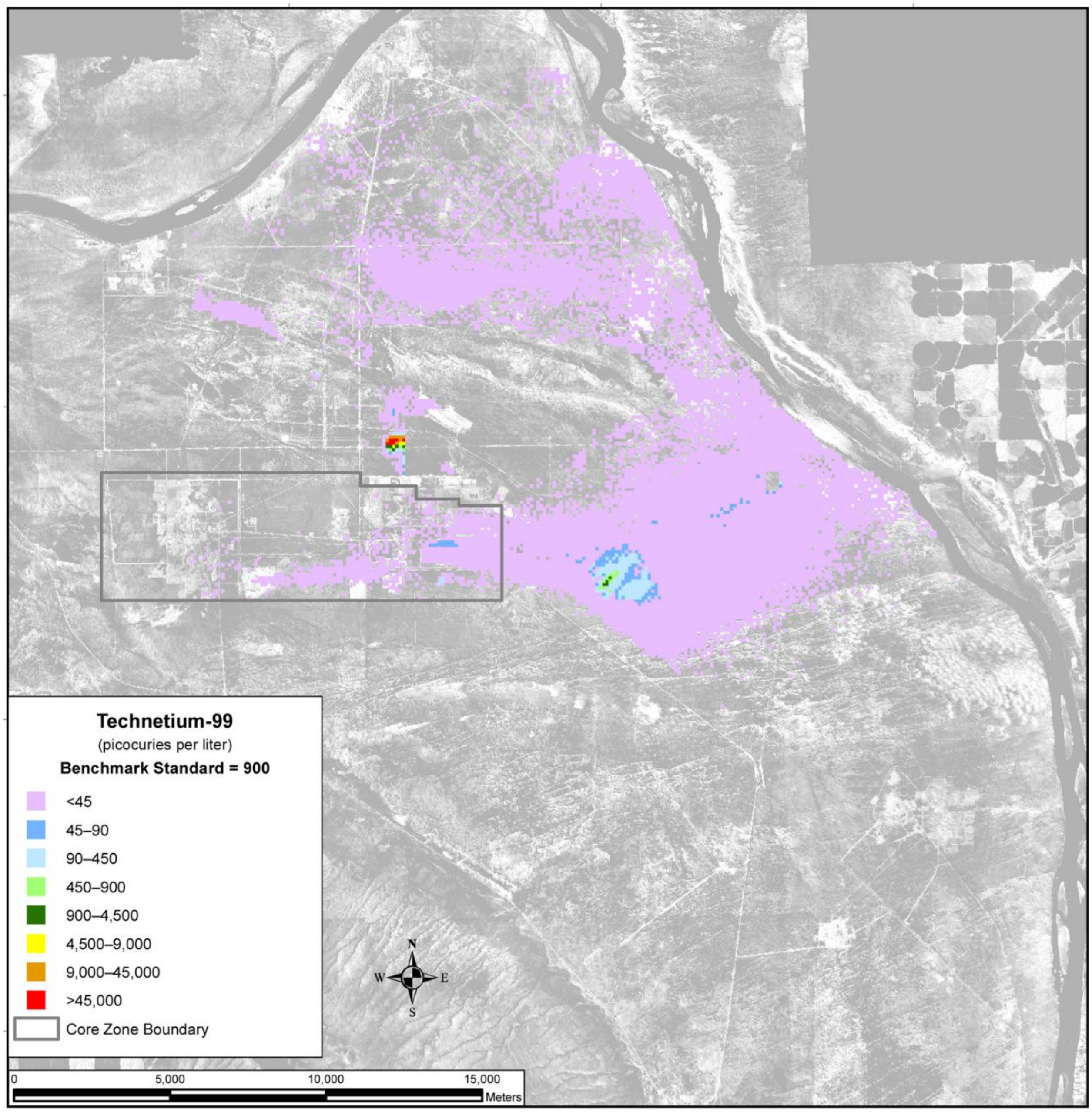
Note: To convert meters to feet, multiply by 3.281.

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



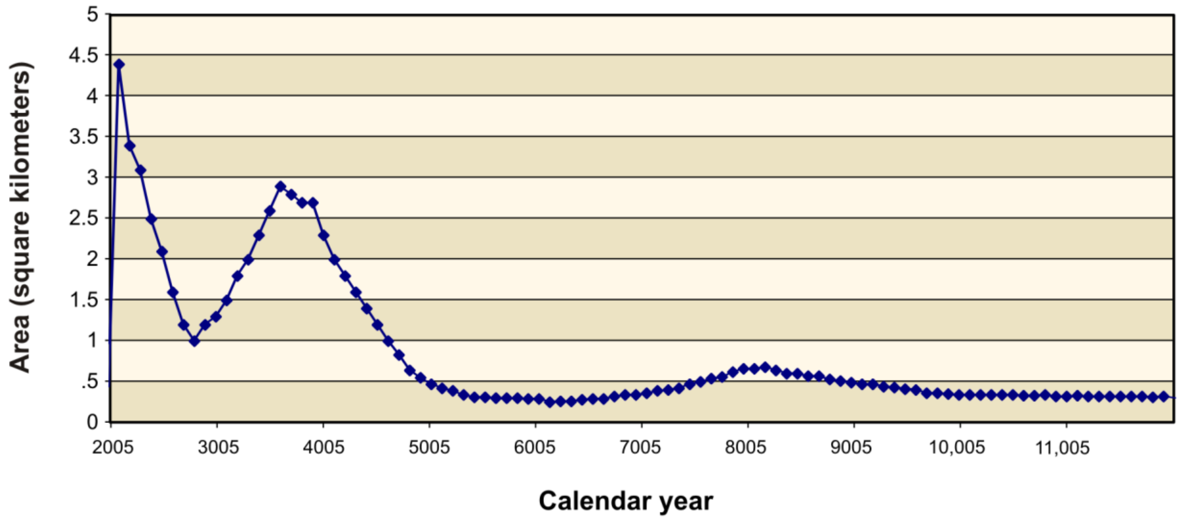
Note: To convert meters to feet, multiply by 3.281.

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



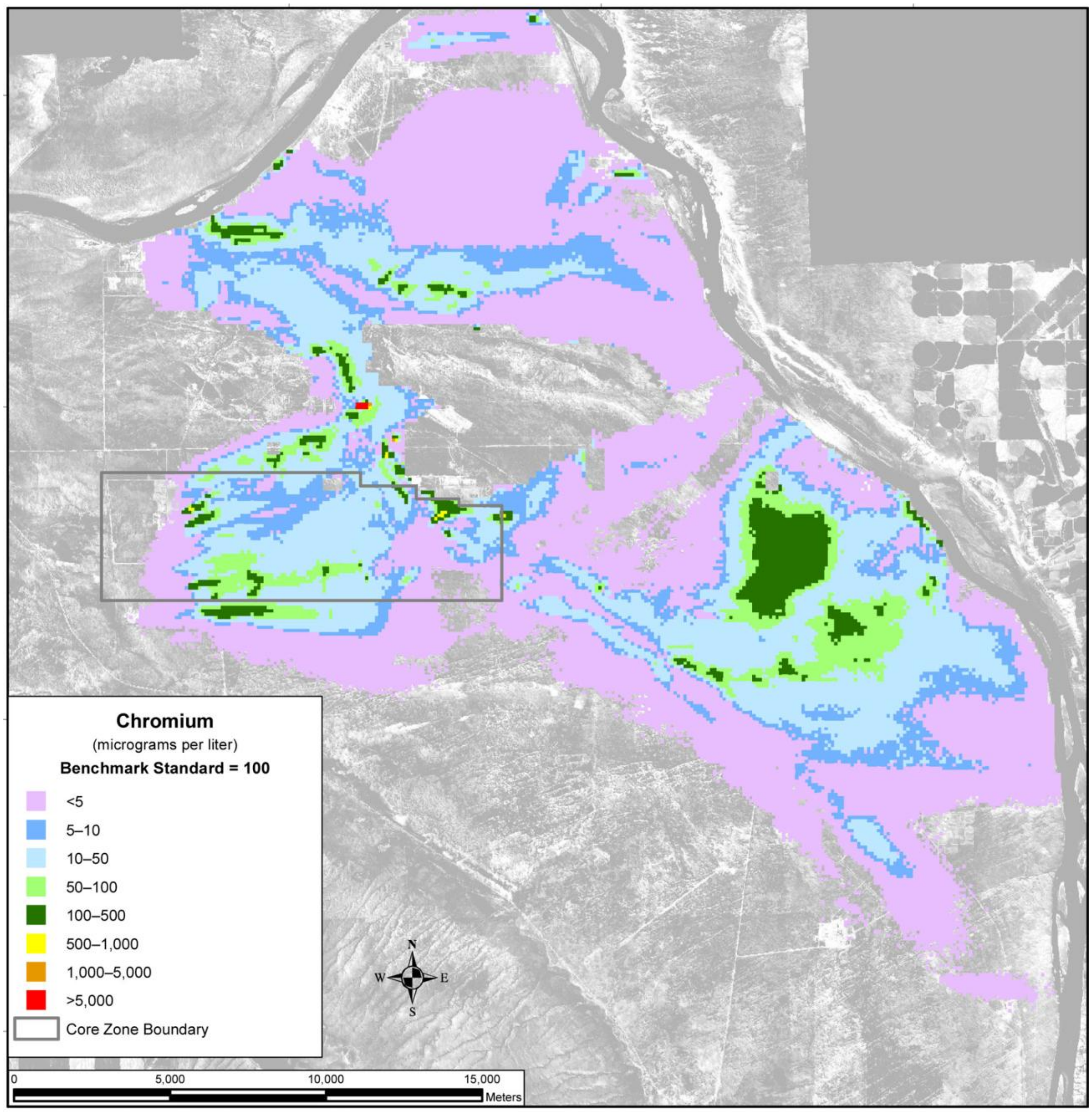
Note: To convert meters to feet, multiply by 3.281.

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



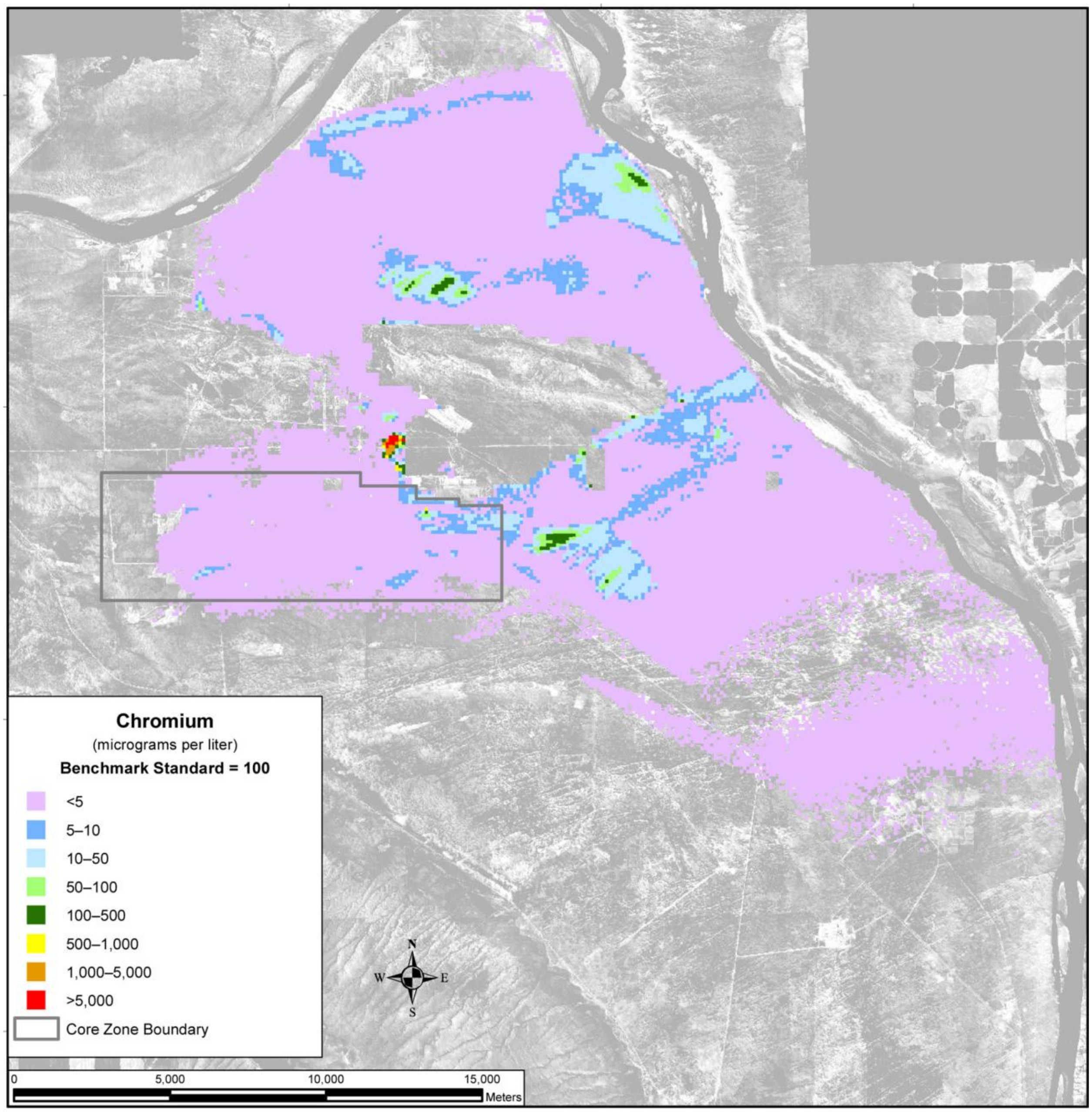
Note: To convert square kilometers to square miles, multiply by 0.3861.

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



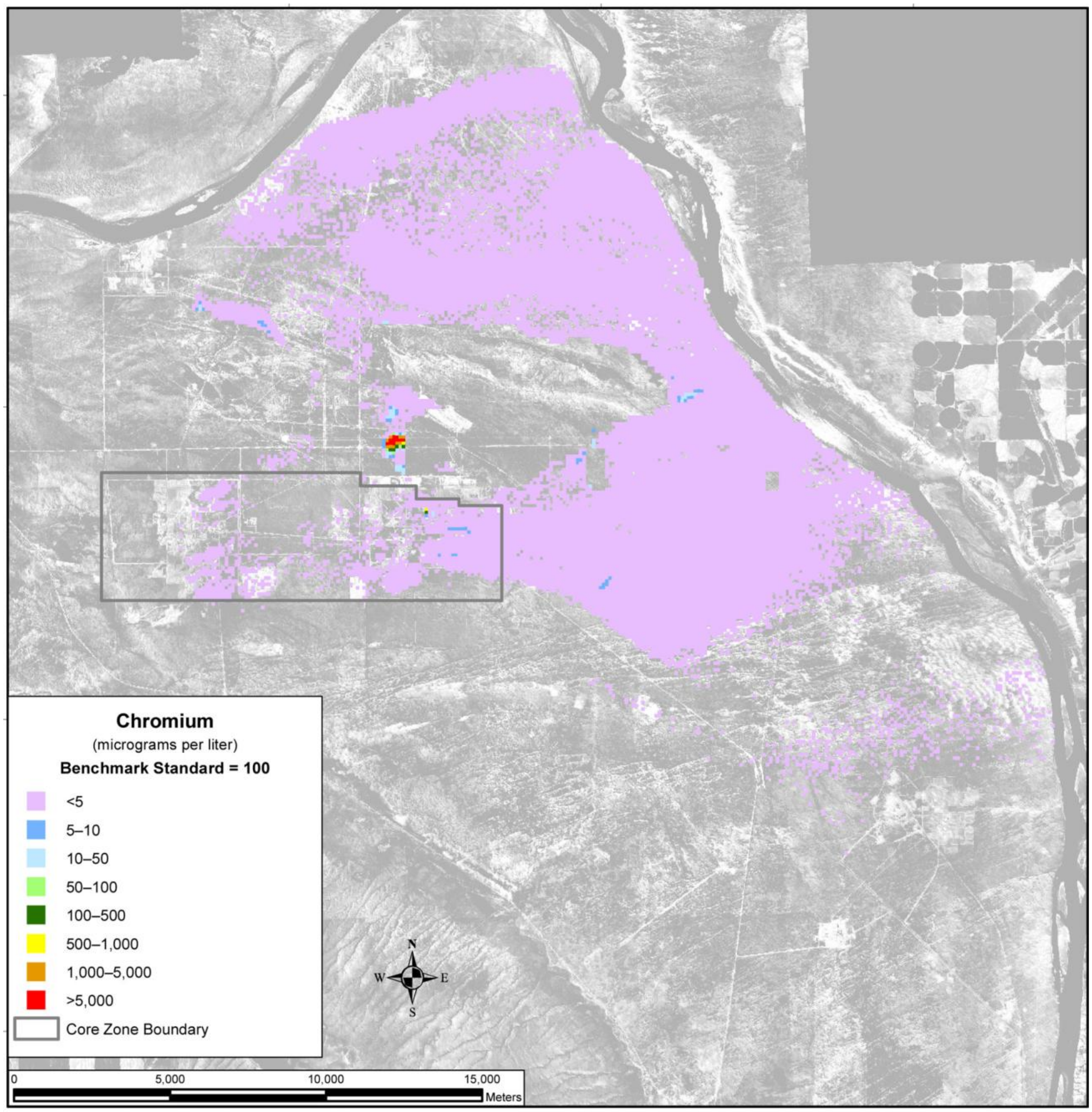
Note: To convert meters to feet, multiply by 3.281.

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



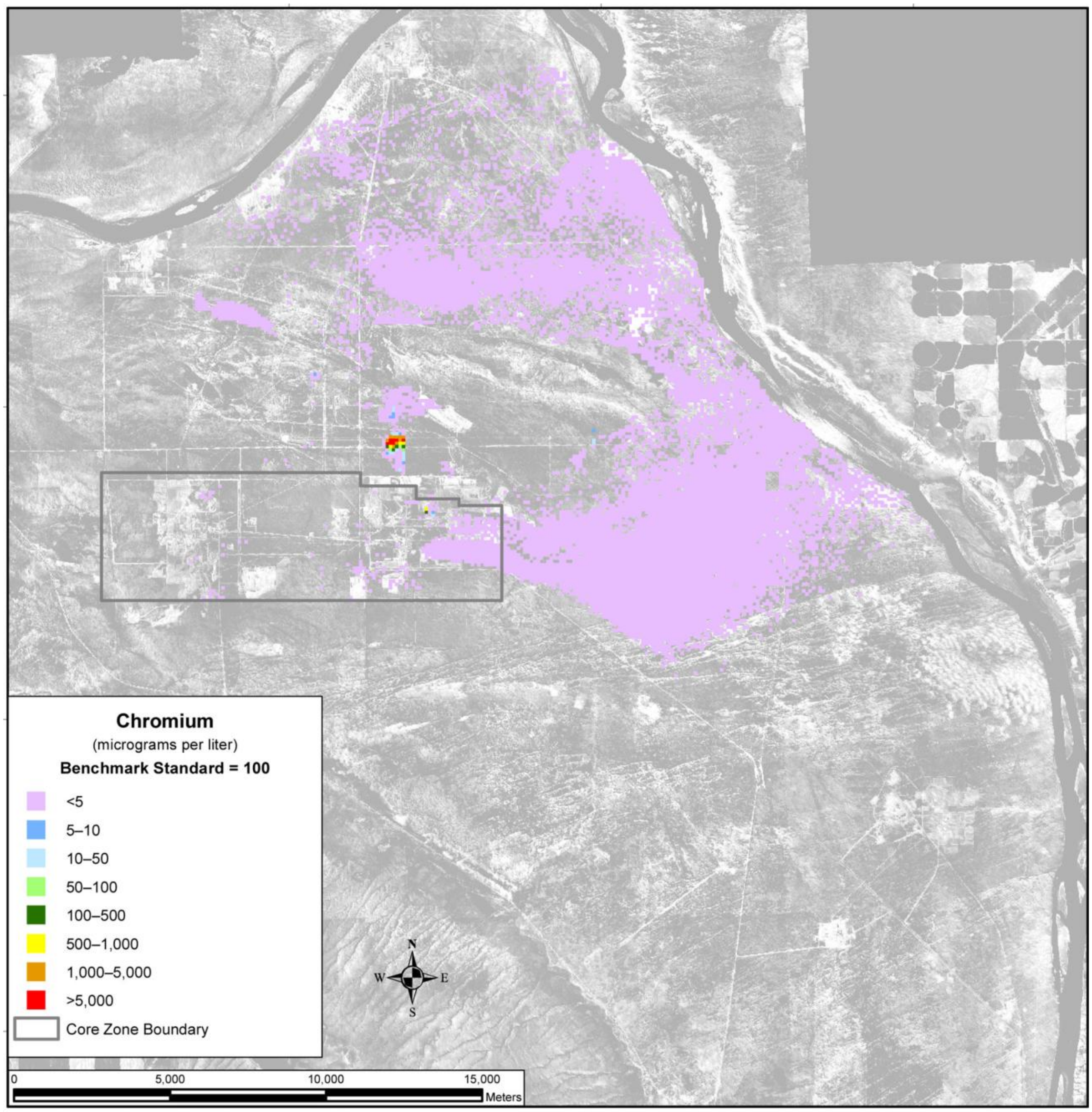
Note: To convert meters to feet, multiply by 3.281.

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



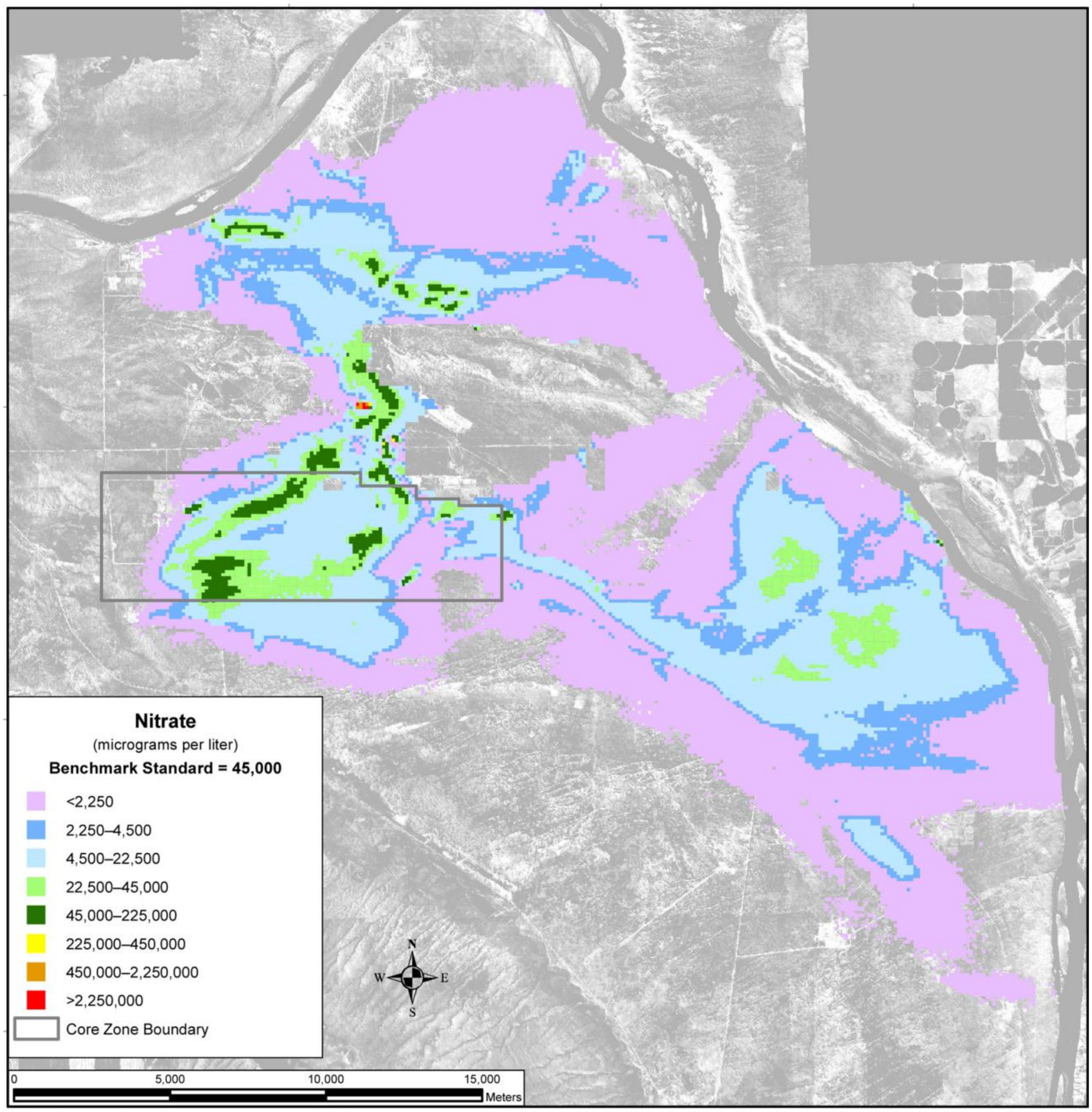
Note: To convert meters to feet, multiply by 3.281.

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



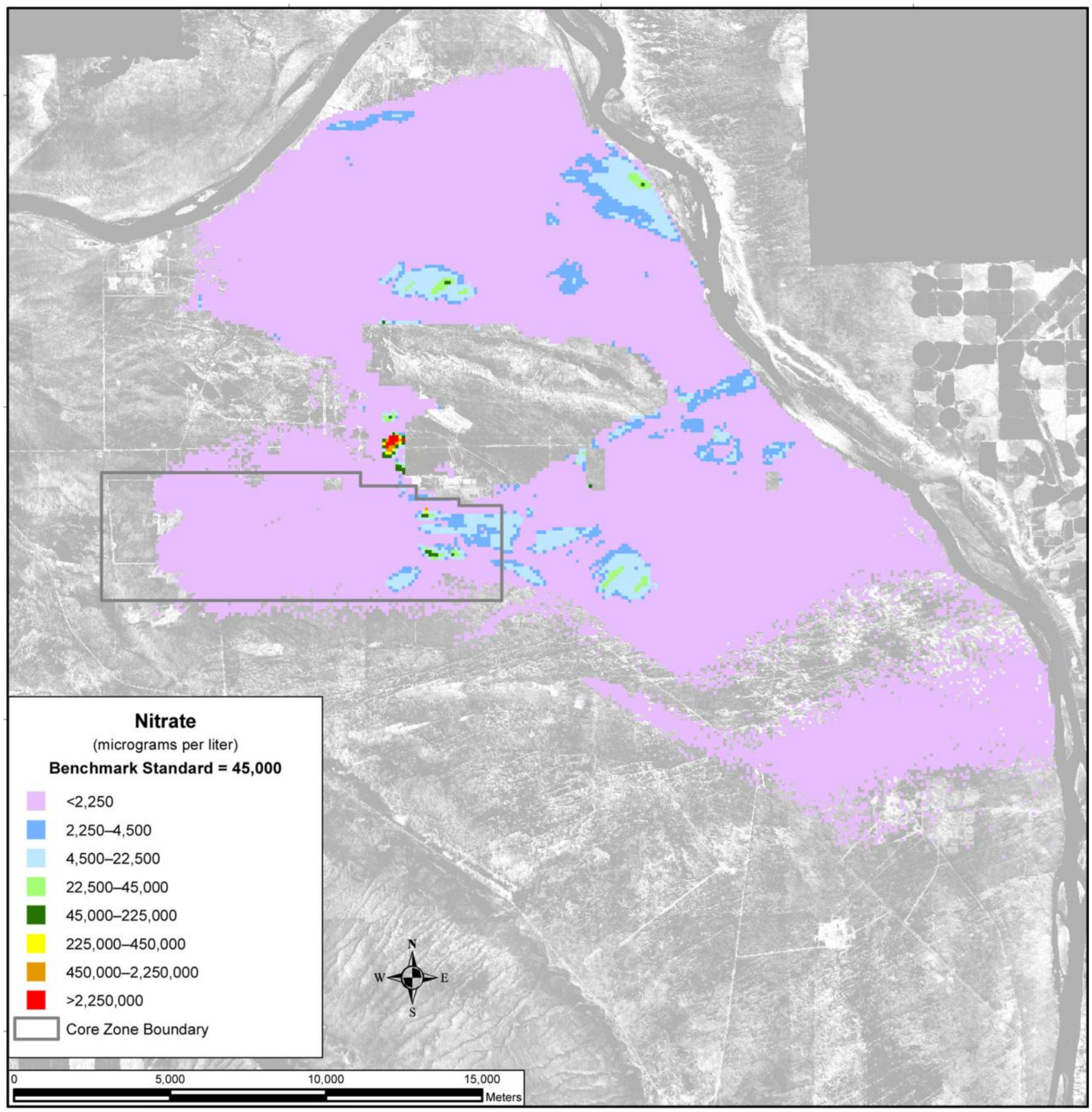
Note: To convert meters to feet, multiply by 3.281.

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



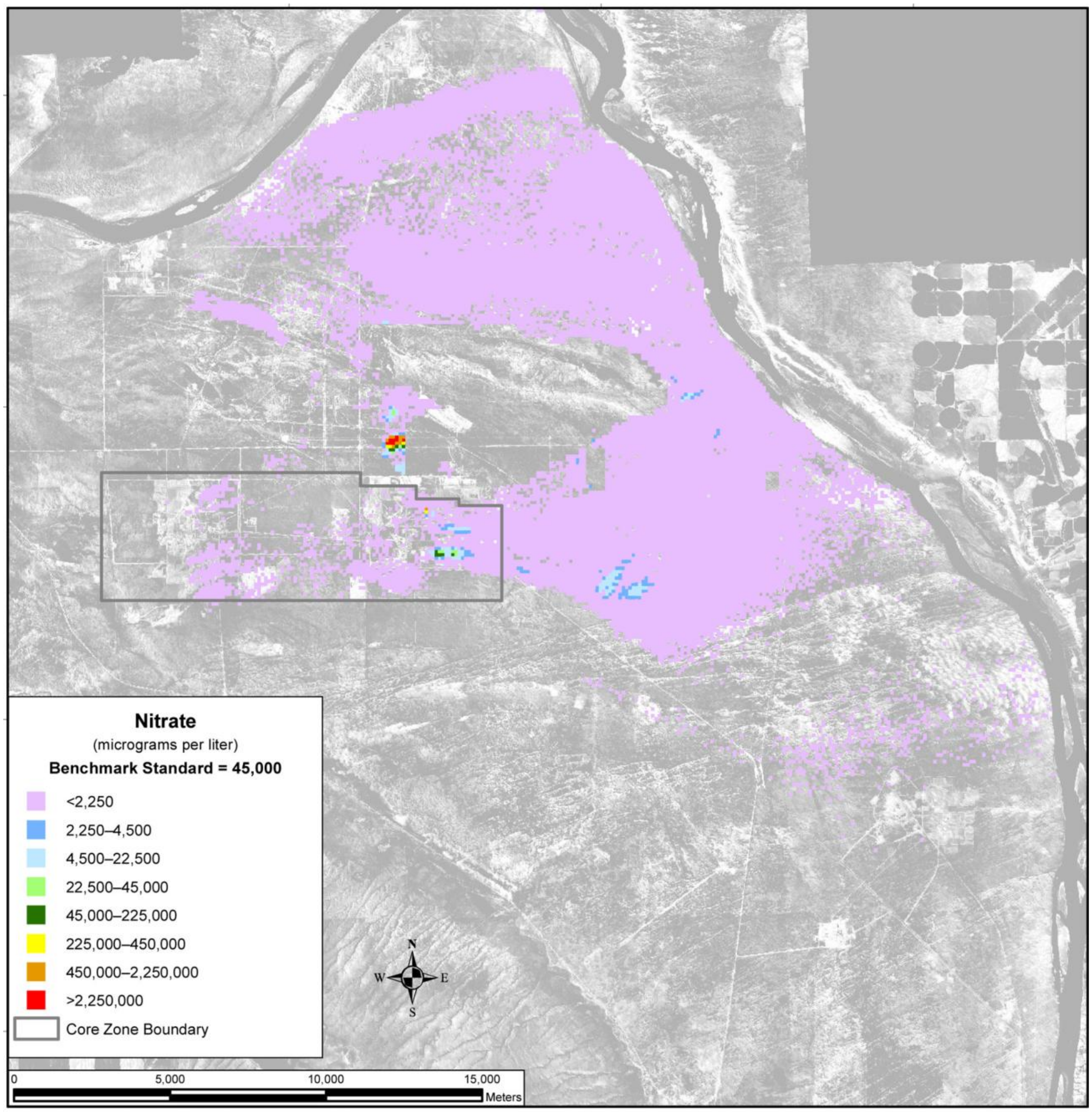
Note: To convert meters to feet, multiply by 3.281.

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



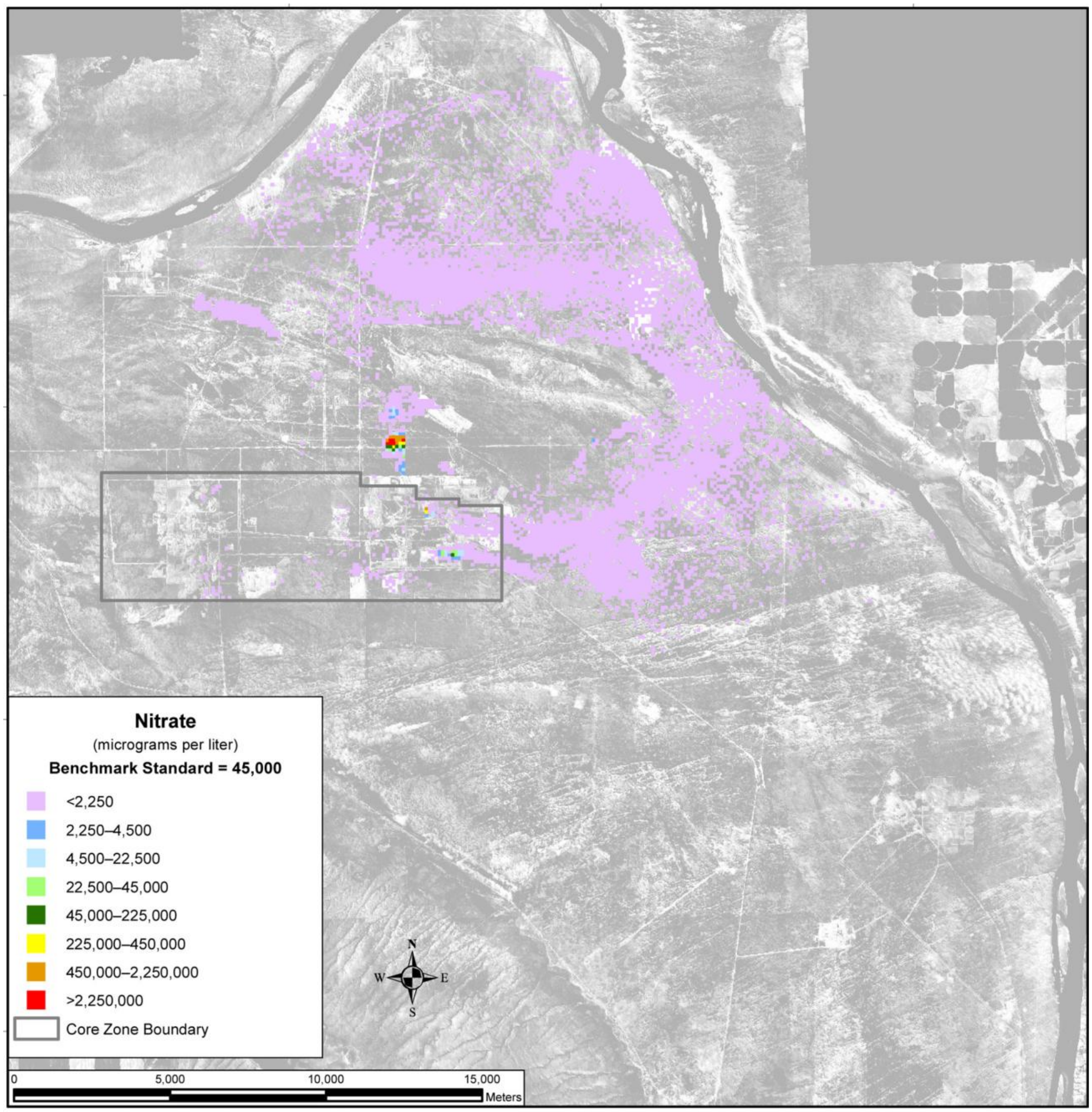
Note: To convert meters to feet, multiply by 3.281.

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



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

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

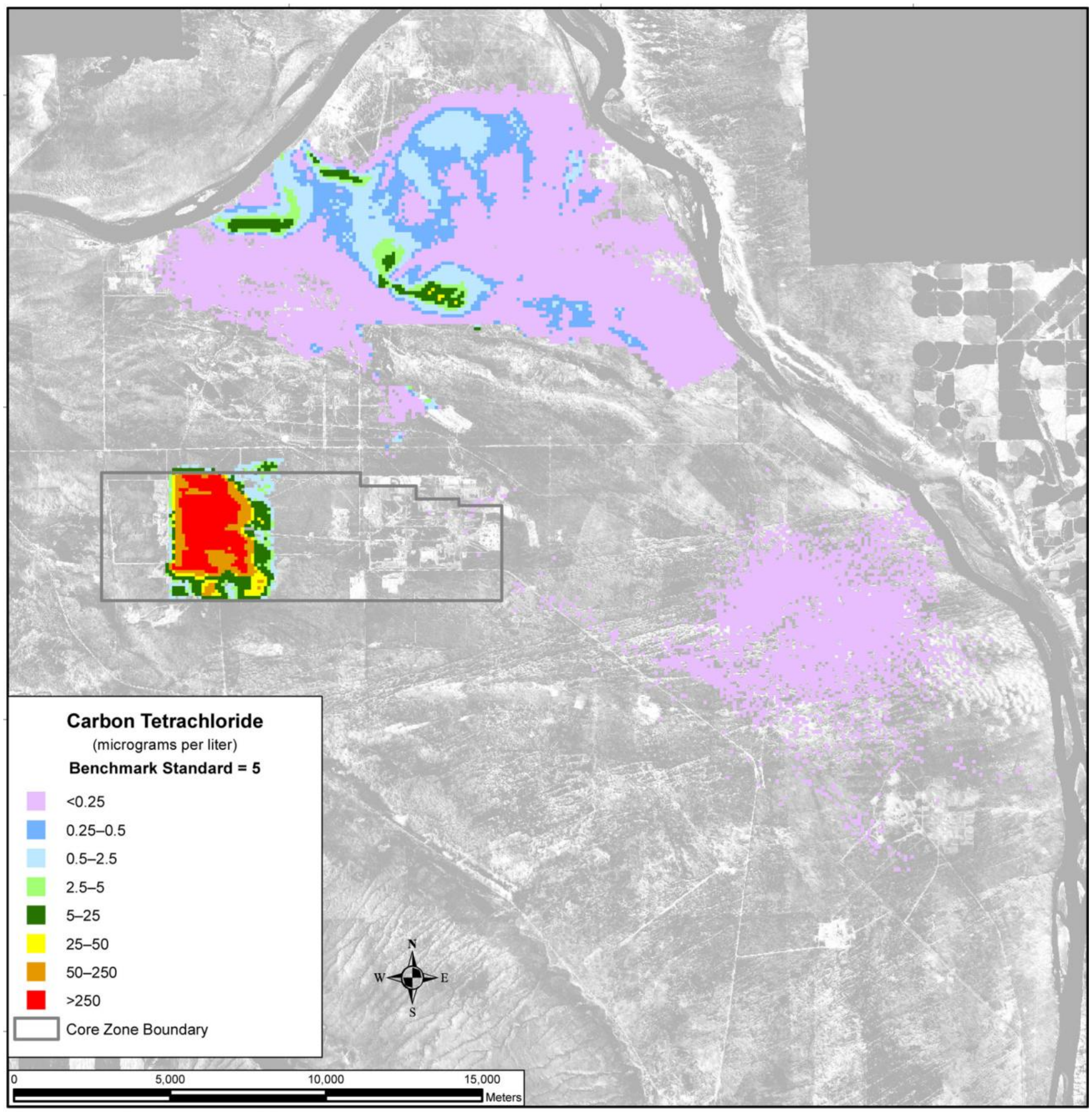


Note: To convert meters to feet, multiply by 3.281.

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

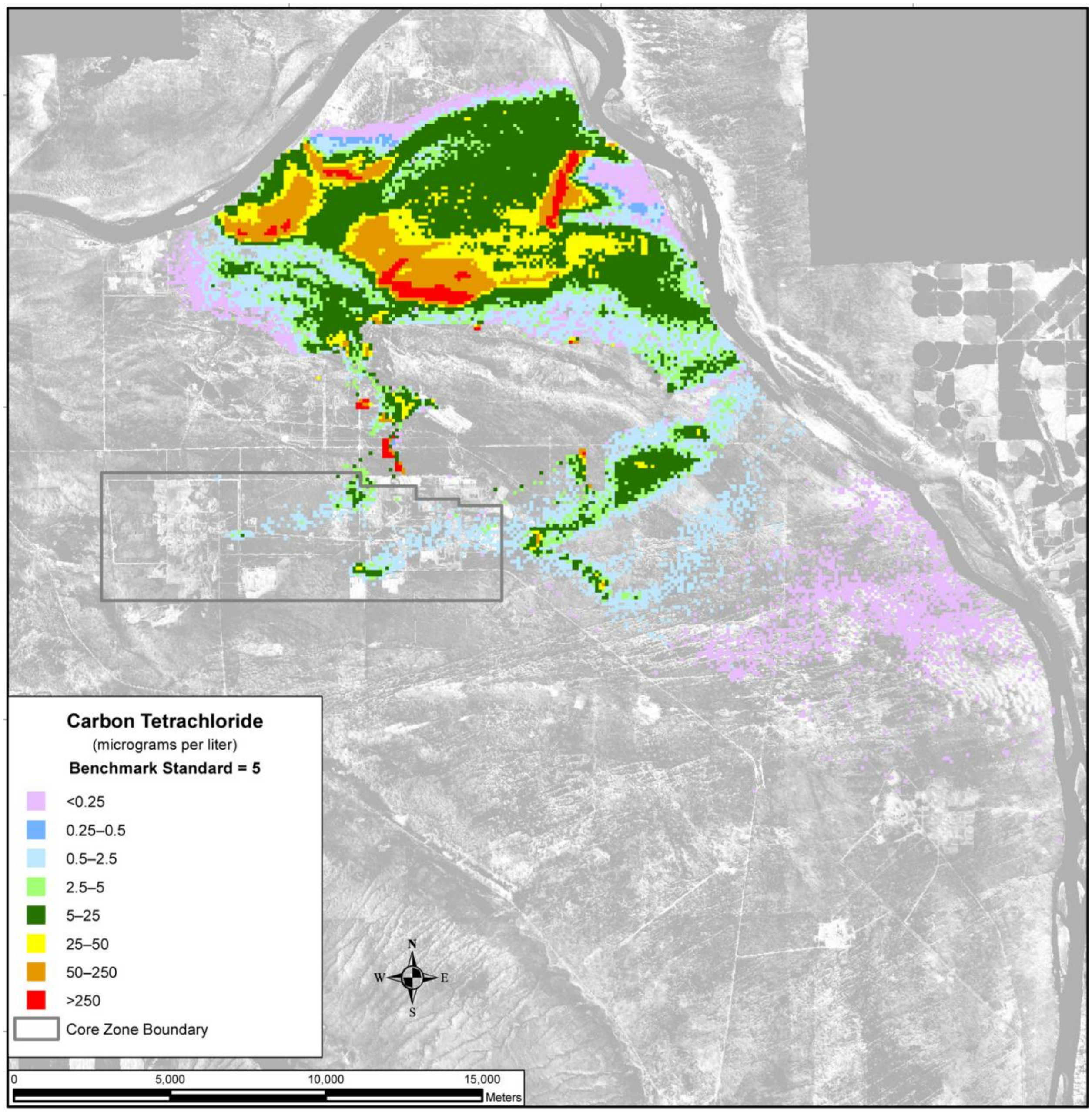
The spatial distribution of carbon tetrachloride concentrations in groundwater is dominated by non–*TC & WM EIS* sources associated with the Z Area within the 200-West Area. The spatial distribution in CY 2010, shown in Figure 6–62, is a large plume covering most of the 200-West Area, with peak concentrations 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.



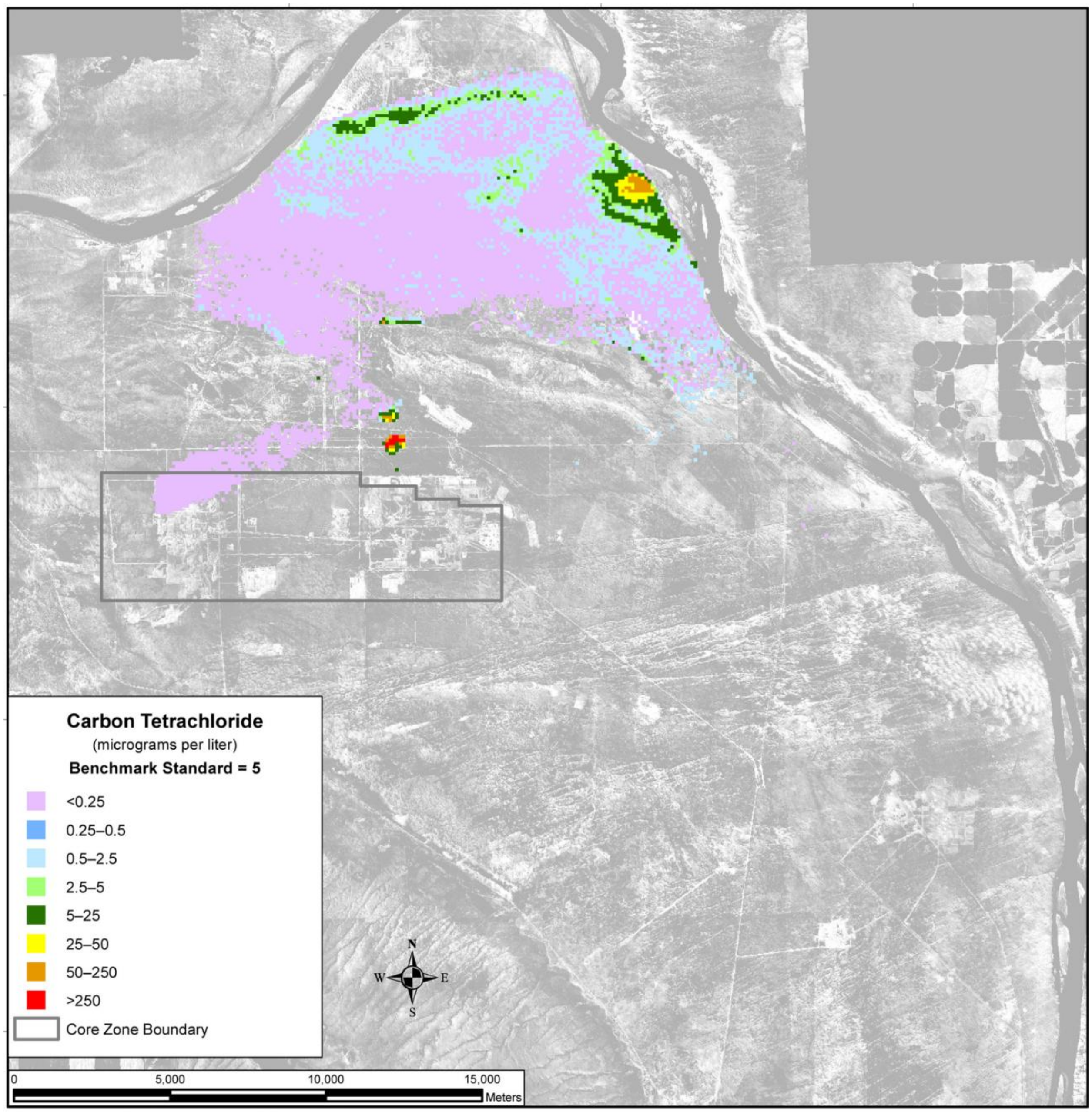
Note: To convert meters to feet, multiply by 3.281.

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



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

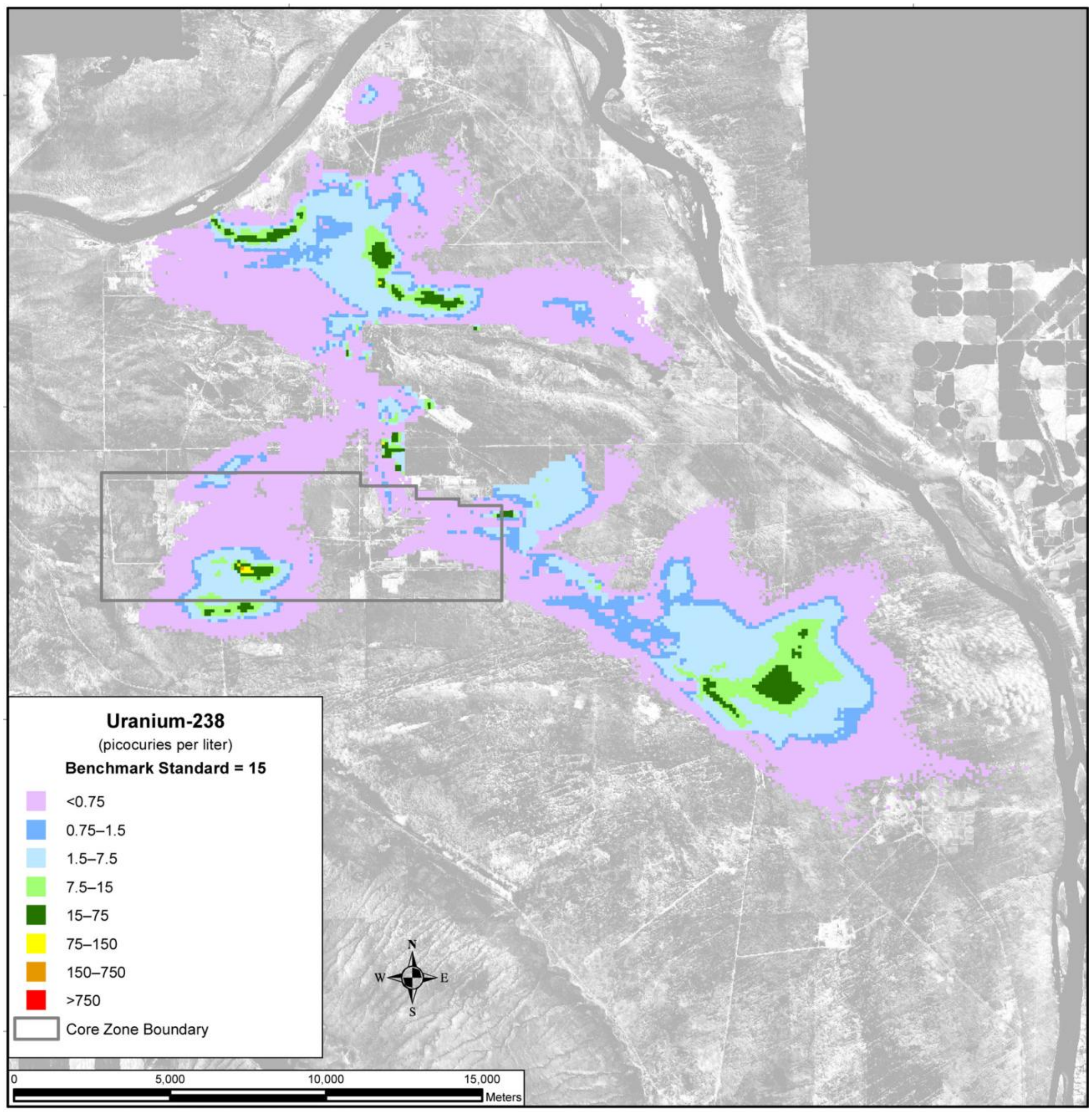
Figure 6–63. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Carbon Tetrachloride Concentration, Calendar Year 2135



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

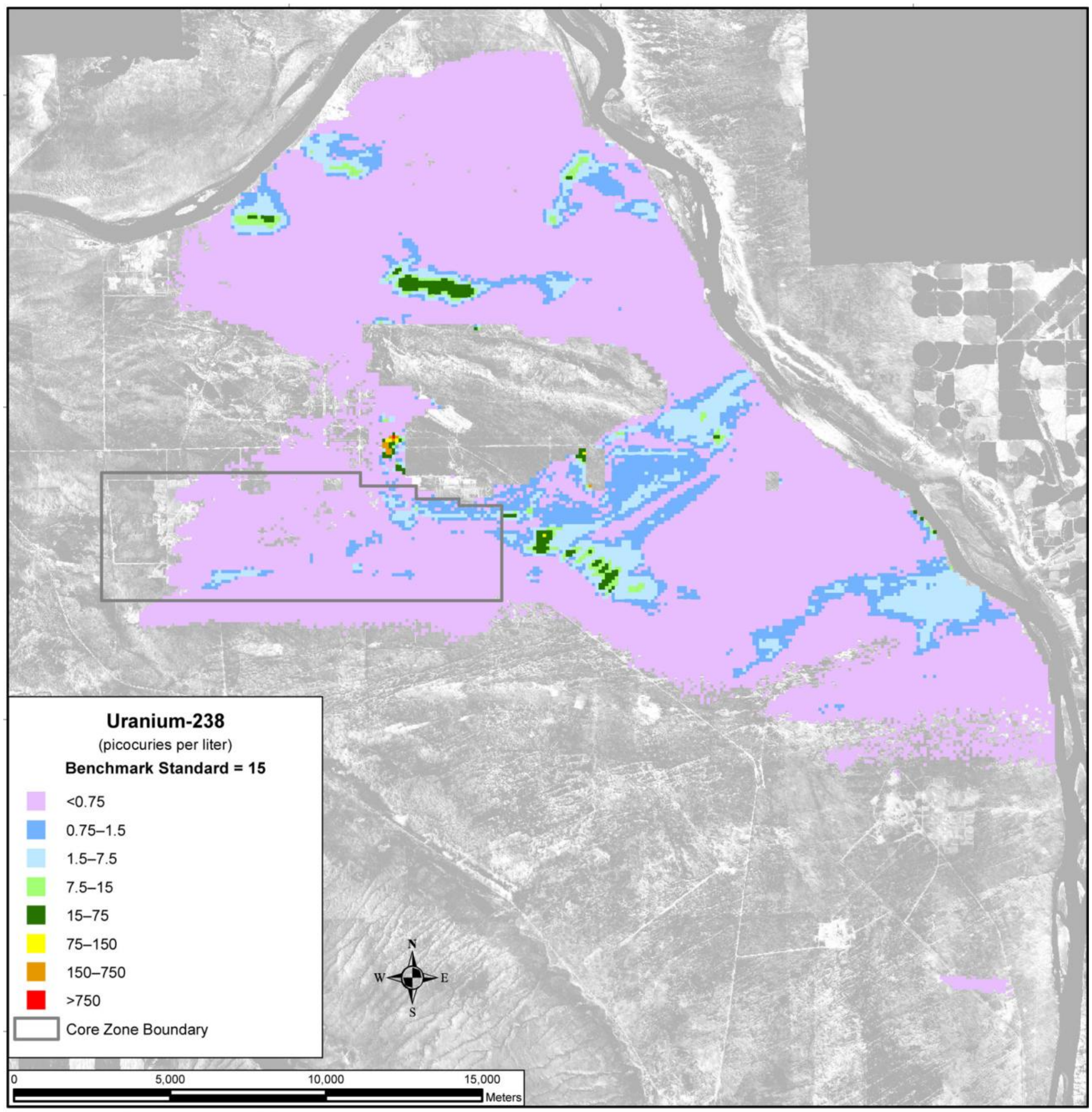
Figure 6–64. Alternative Combination 2 Spatial Distribution of Cumulative Groundwater Carbon Tetrachloride Concentration, Calendar Year 3890

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.



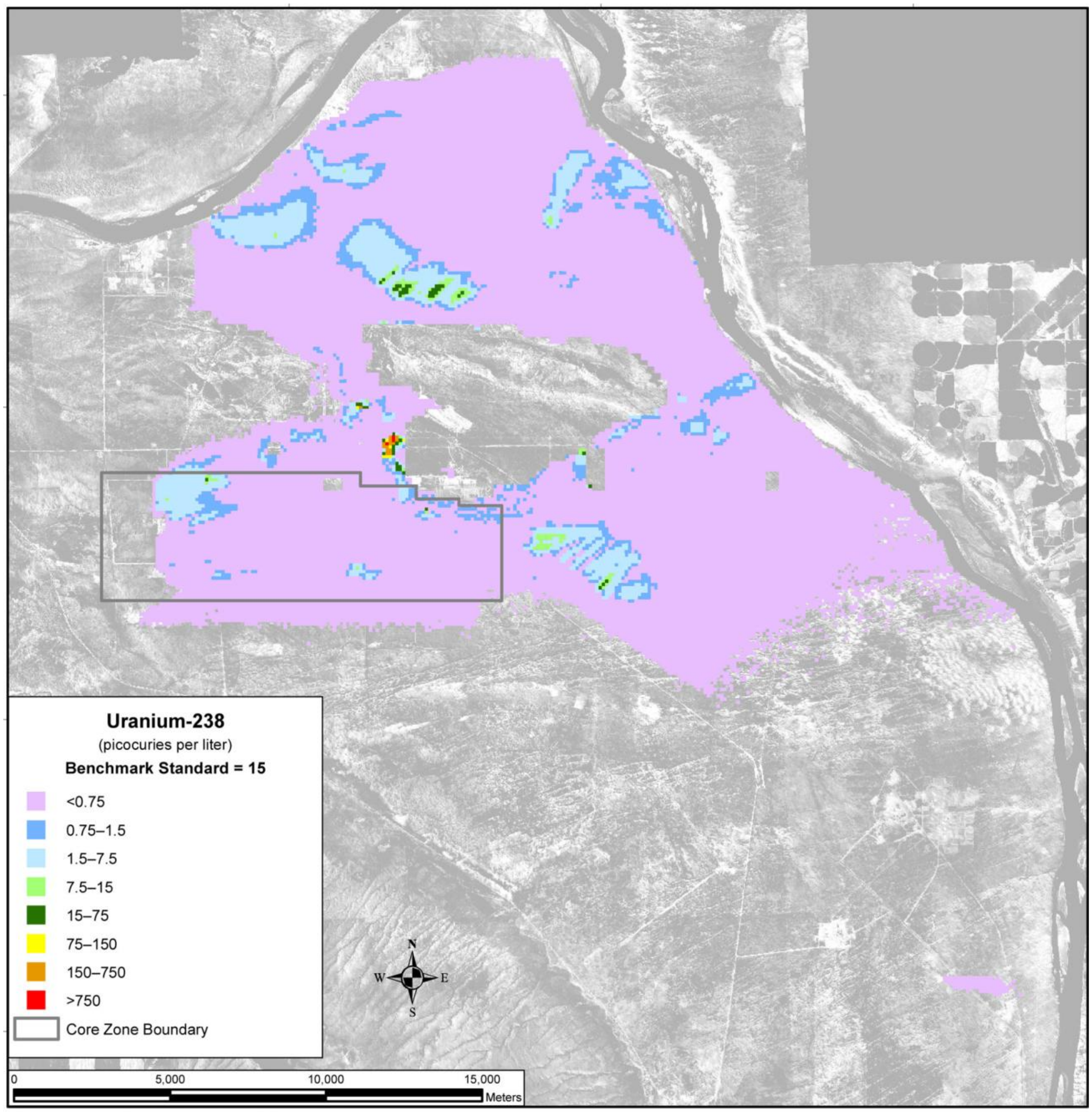
Note: To convert meters to feet, multiply by 3.281.

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



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

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

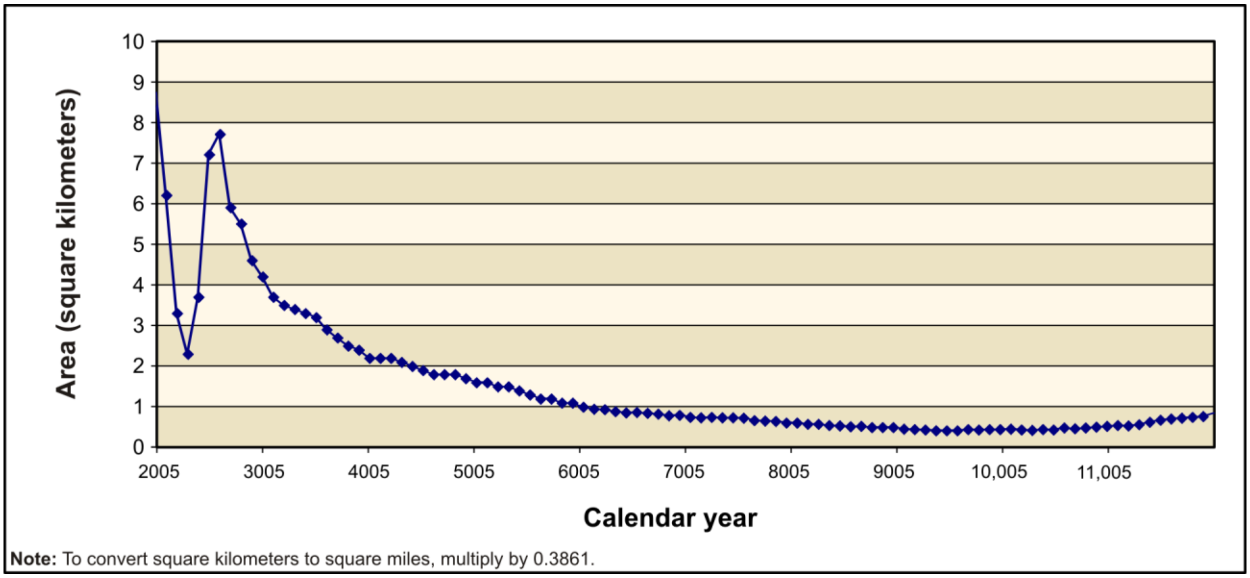
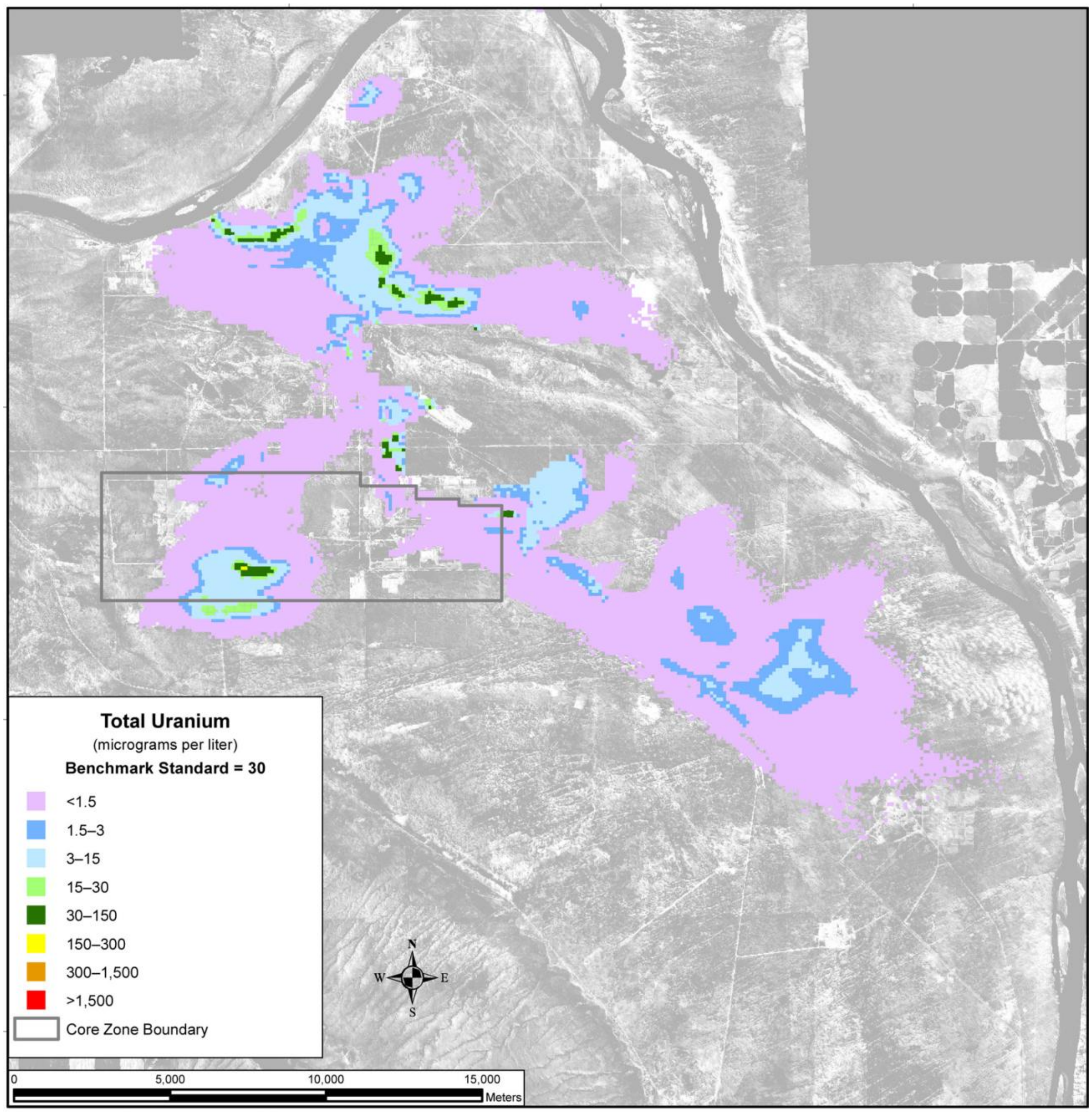
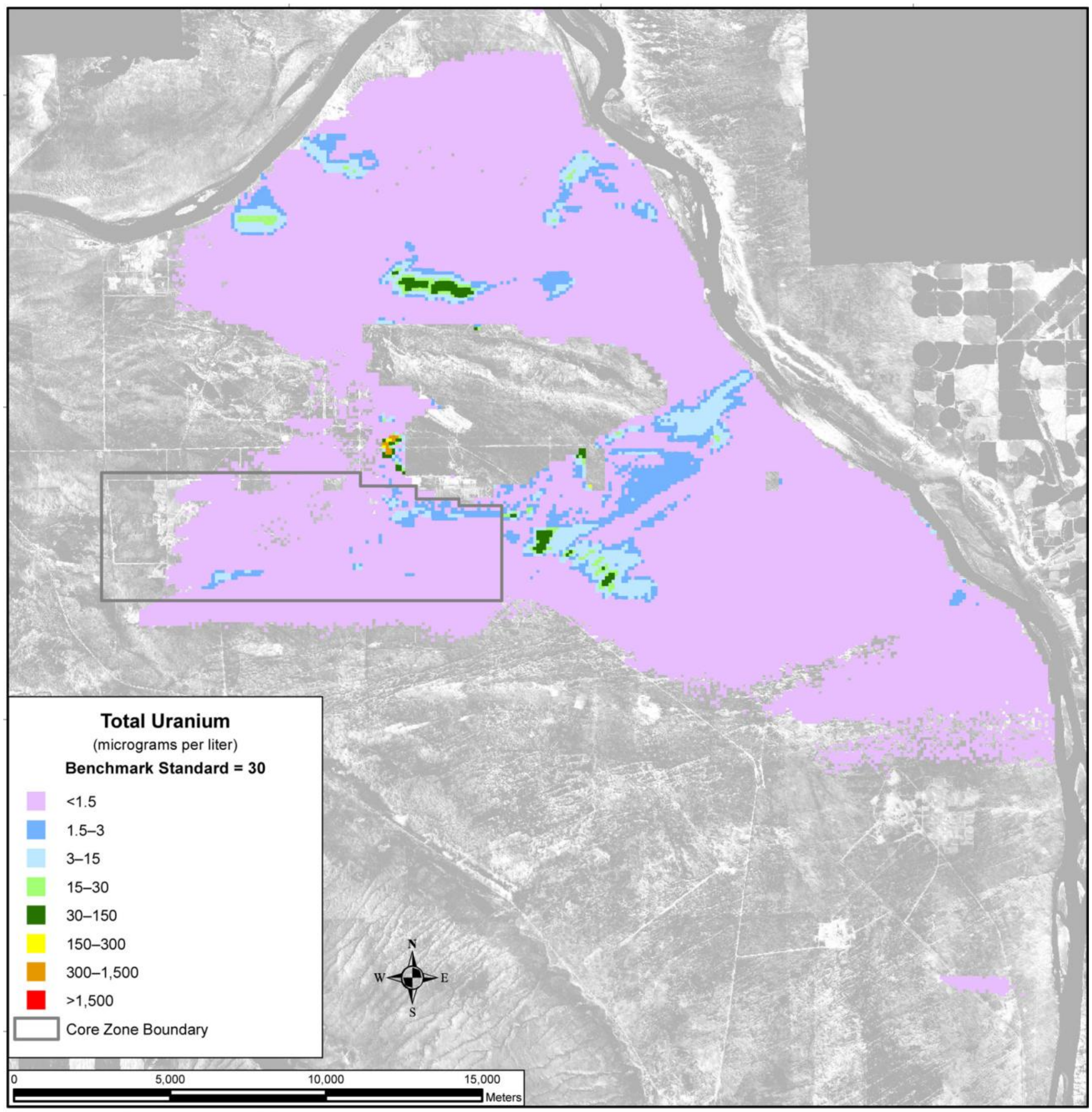


Figure 6–68. Alternative Combination 2 Total Area of Cumulative Groundwater Uranium-238 Concentrations Exceeding the Benchmark Concentration as a Function of Time



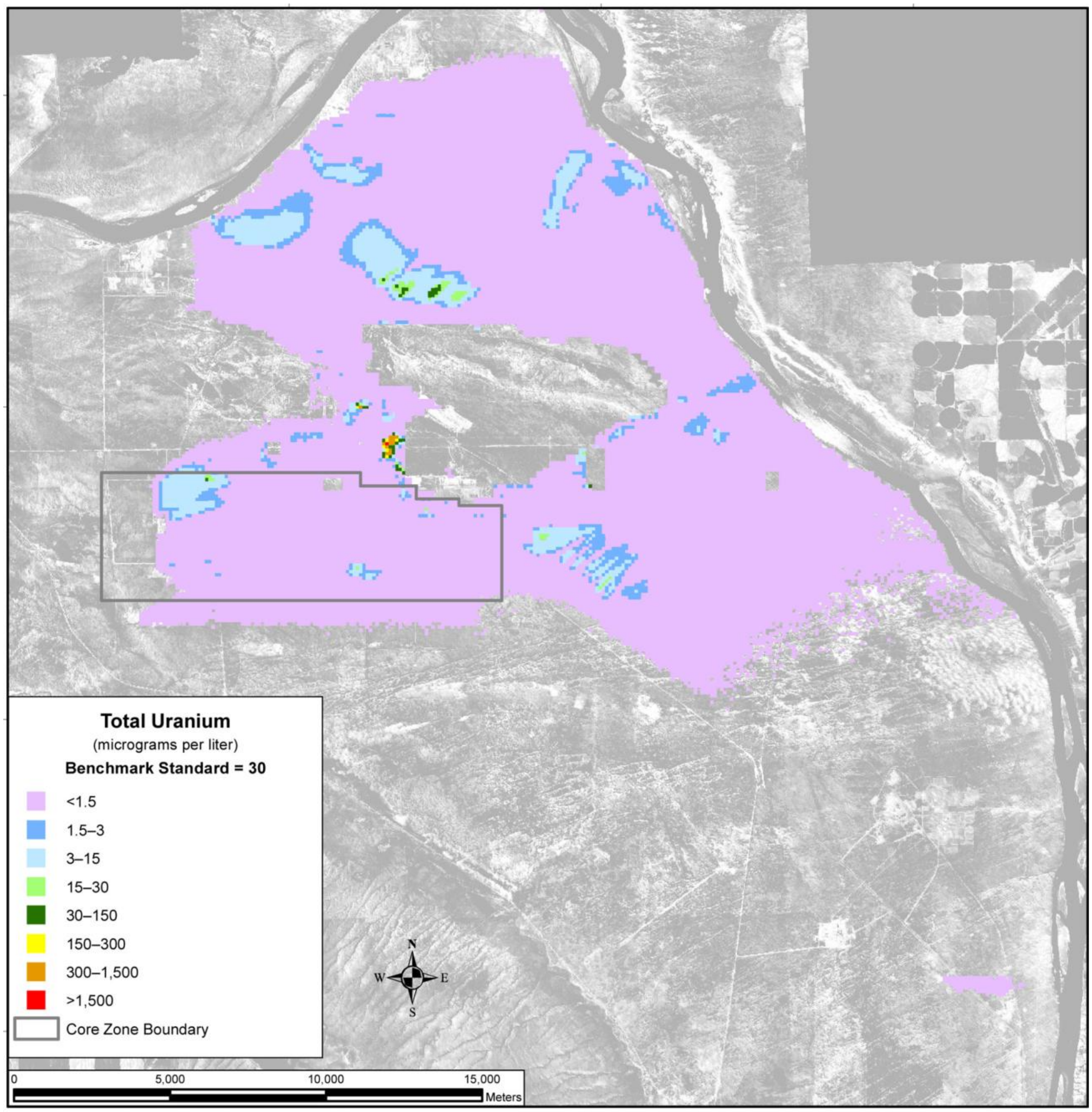
Note: To convert meters to feet, multiply by 3.281.

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



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

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

	Radioactive COPCs (curies)				Chemical COPCs (kilograms)		
Source	**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	$\mathbf{2.48\times10^{6}}$	$\mathbf{3.77\times10^{3}}$	$\mathbf{1.75\times10^{1}}$	$\mathbf{3.98\times10^{3}}$	$\mathbf{4.49\times10^{5}}$	$\mathbf{1.11\times10^{8}}$	$\mathbf{7.11\times10^{6}}$

[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	$\mathbf{2.06 \times 10^{6}}$	$\mathbf{3.44 \times 10^{3}}$	$\mathbf{1.58 \times 10^{1}}$	$\mathbf{2.17 \times 10^{2}}$	$\mathbf{4.56 \times 10^{5}}$	$\mathbf{1.12 \times 10^{8}}$	$\mathbf{1.31 \times 10^{5}}$

[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	$\mathbf{7.25 \times 10^{4}}$	$\mathbf{3.42 \times 10^{3}}$	$\mathbf{1.57 \times 10^{1}}$	$\mathbf{2.13 \times 10^{2}}$	$\mathbf{4.78 \times 10^{5}}$	$\mathbf{1.15 \times 10^{8}}$	$\mathbf{1.15 \times 10^{5}}$

[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.

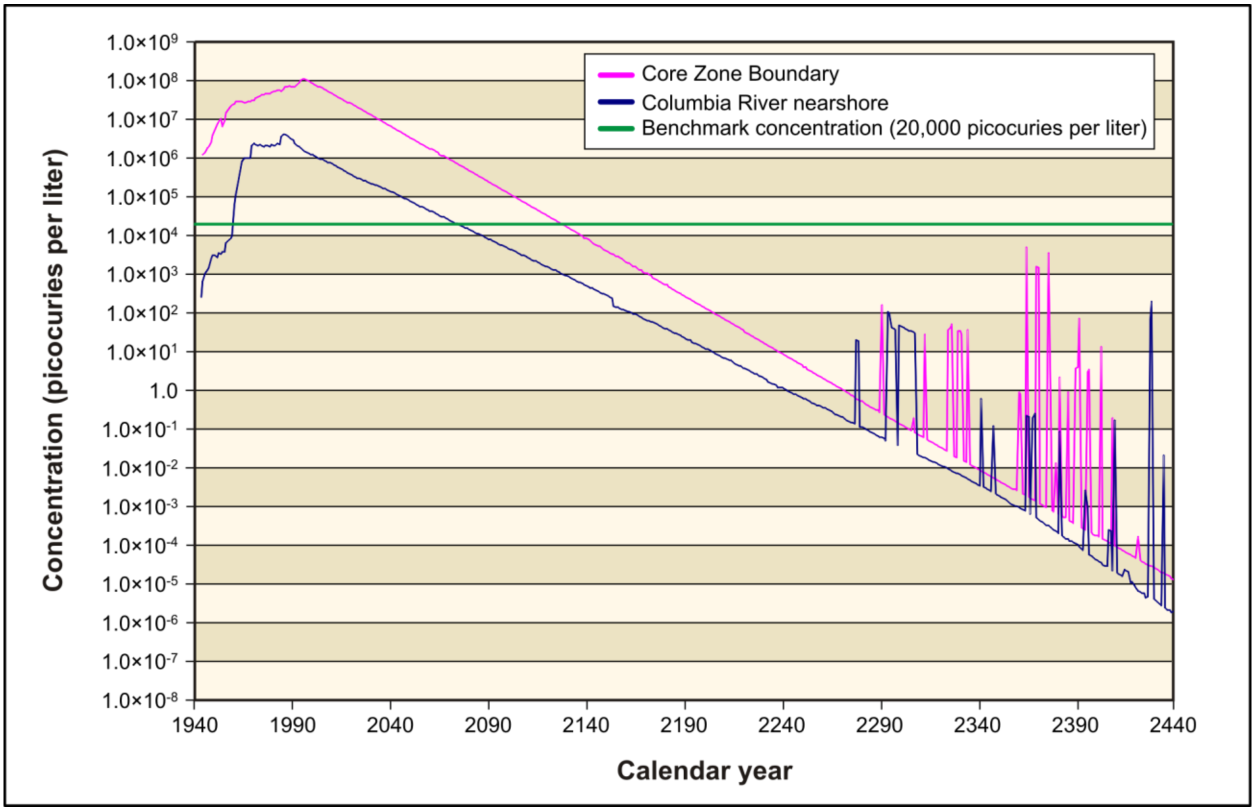


Figure 6–72. Alternative Combination 3 Cumulative Hydrogen-3 (Tritium) Concentration Versus Time

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 & WM EIS* 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.

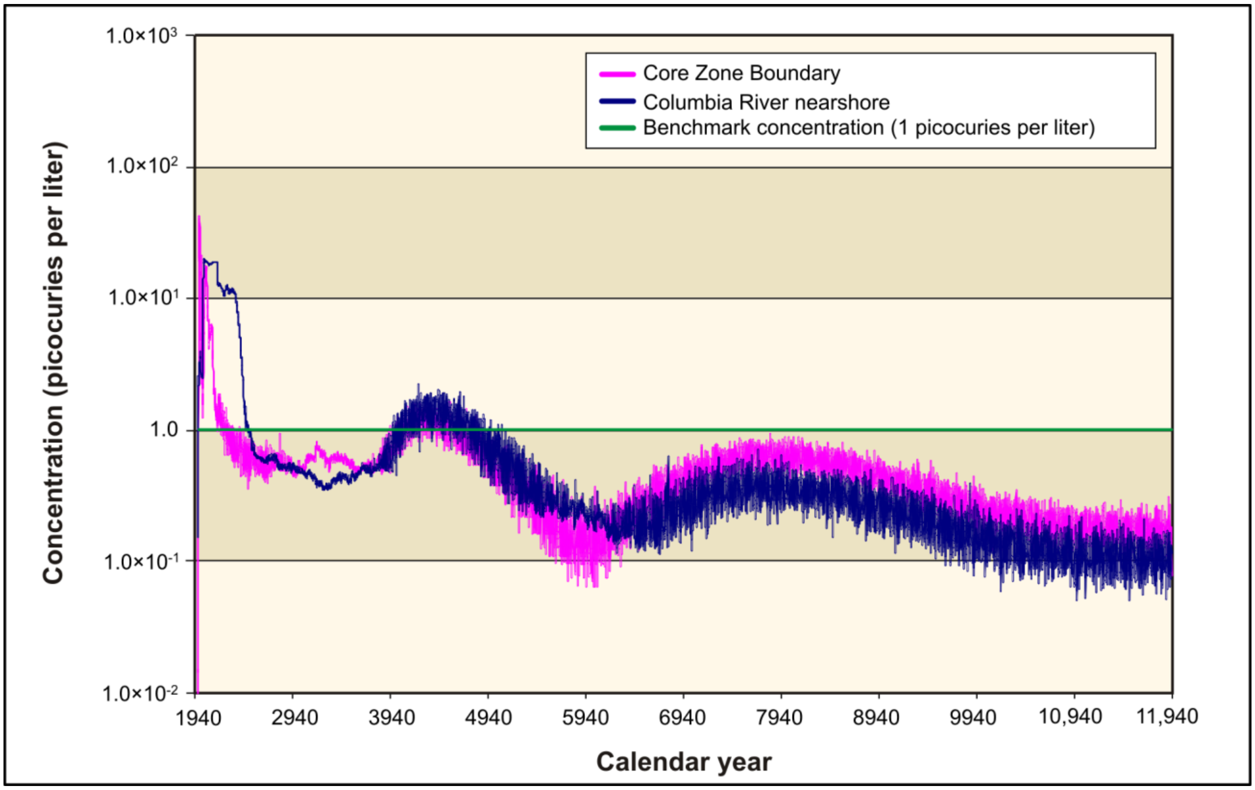


Figure 6–73. Alternative Combination 3 Cumulative Iodine-129 Concentration Versus Time

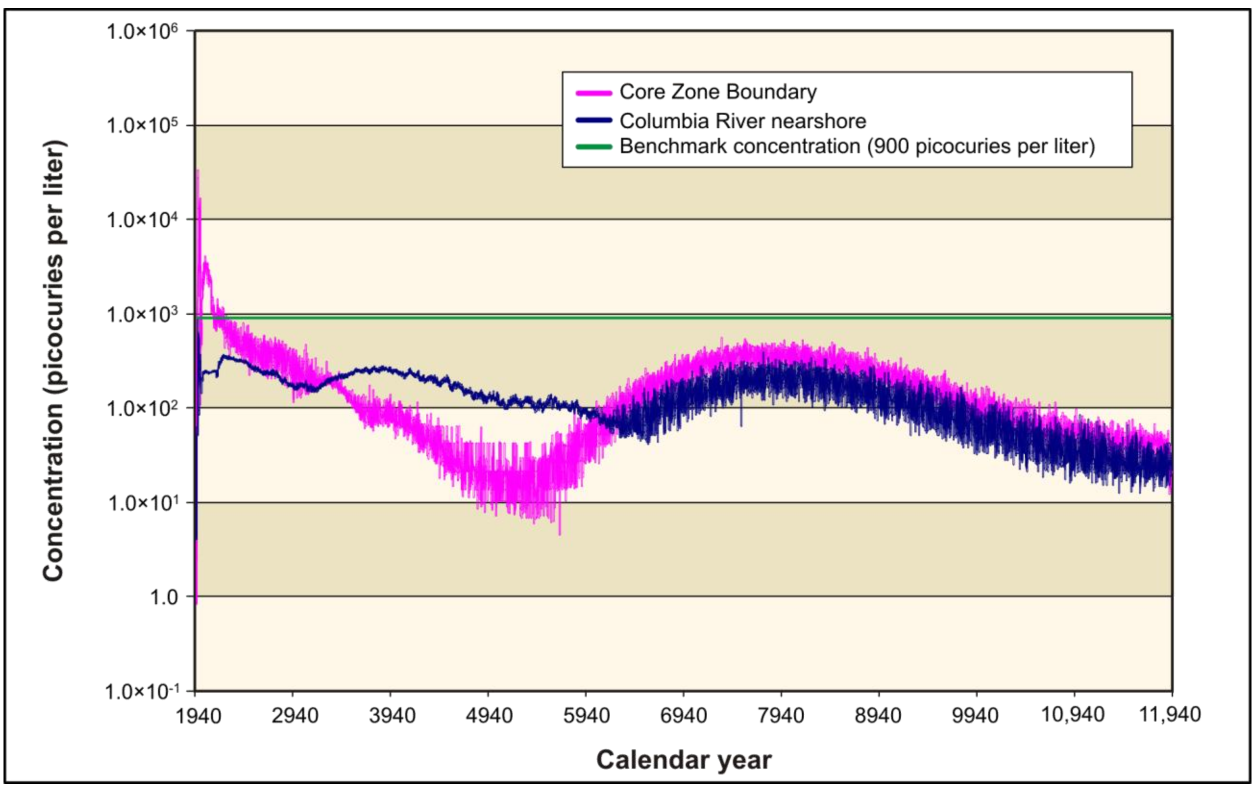


Figure 6–74. Alternative Combination 3 Cumulative Technetium-99 Concentration Versus Time

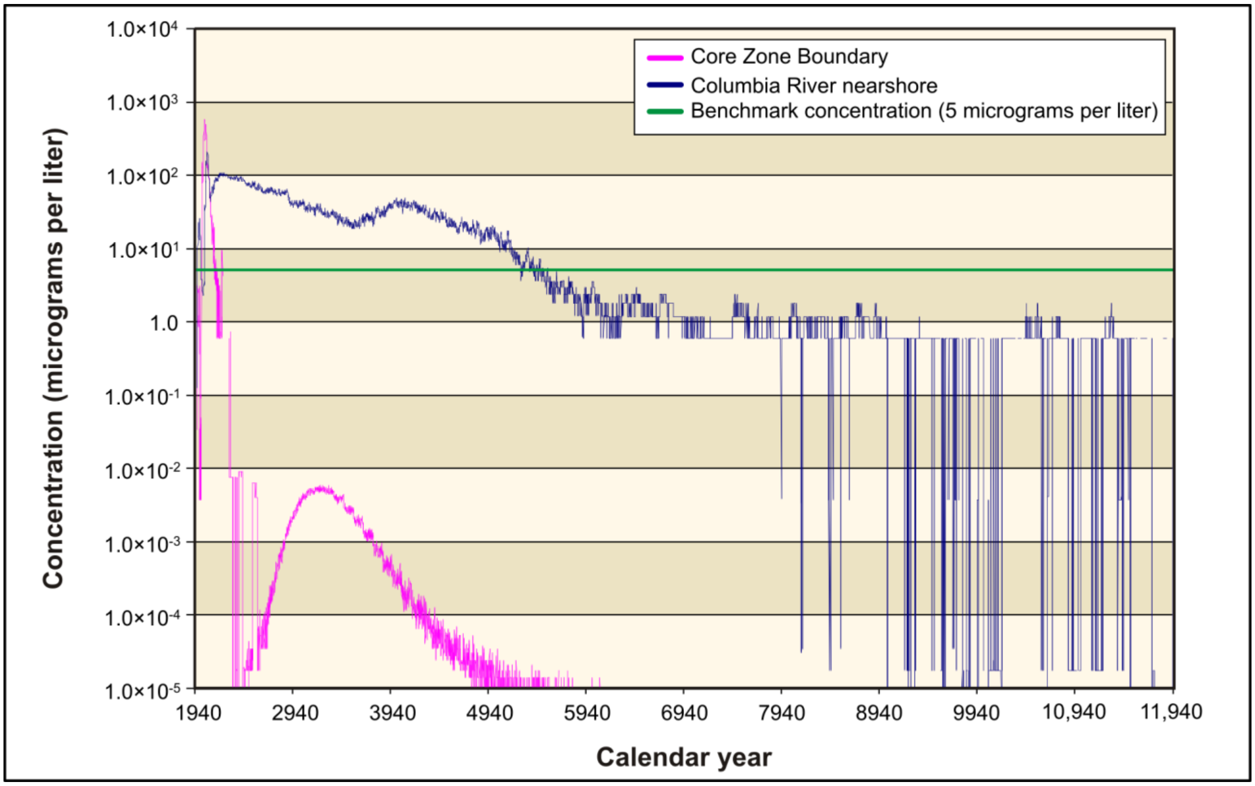


Figure 6–75. Alternative Combination 3 Cumulative Carbon Tetrachloride Concentration Versus Time

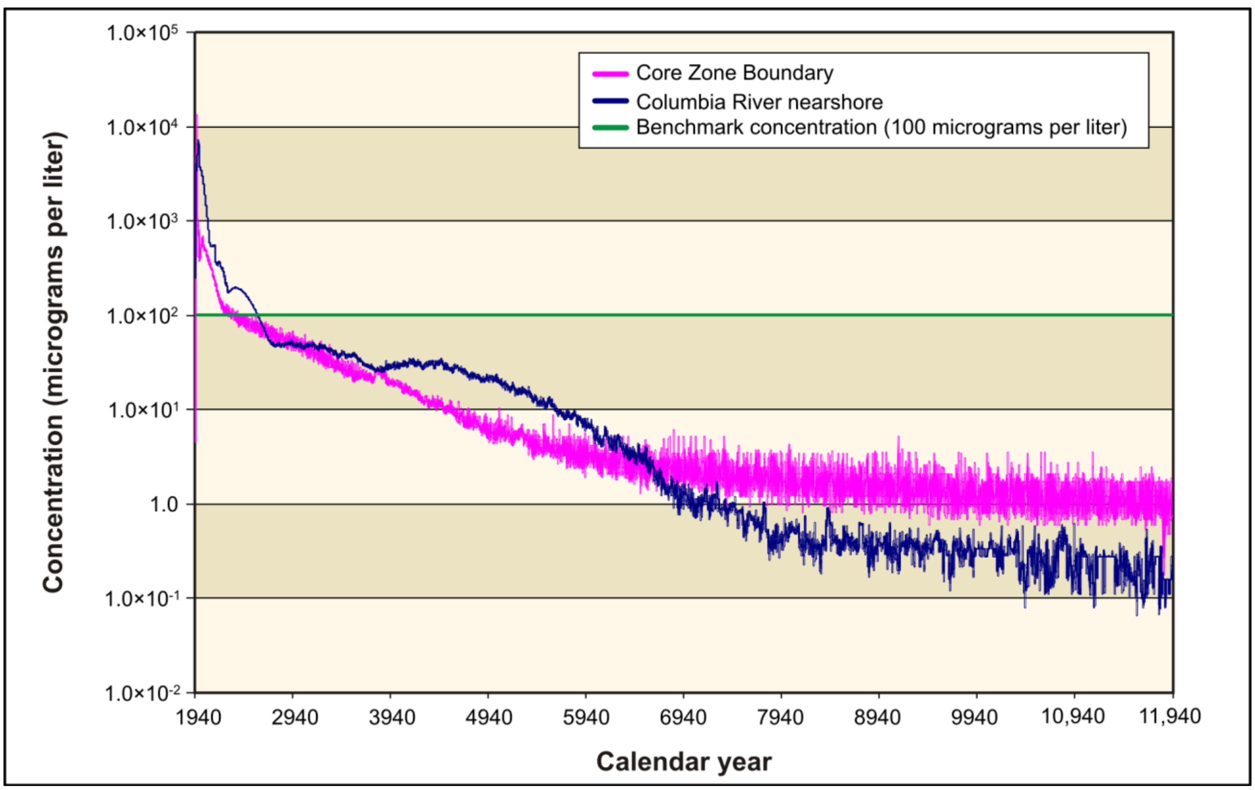


Figure 6–76. Alternative Combination 3 Cumulative Chromium Concentration Versus Time

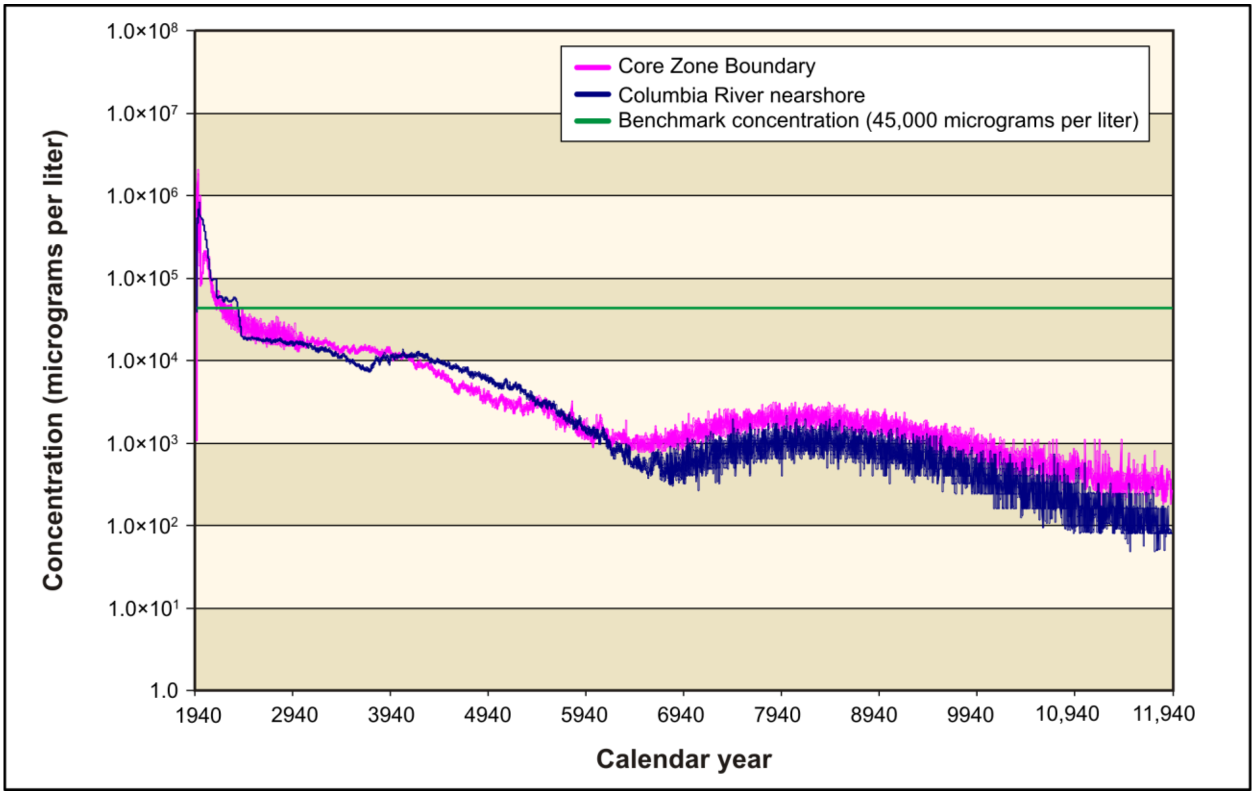


Figure 6–77. Alternative Combination 3 Cumulative Nitrate Concentration Versus Time

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.

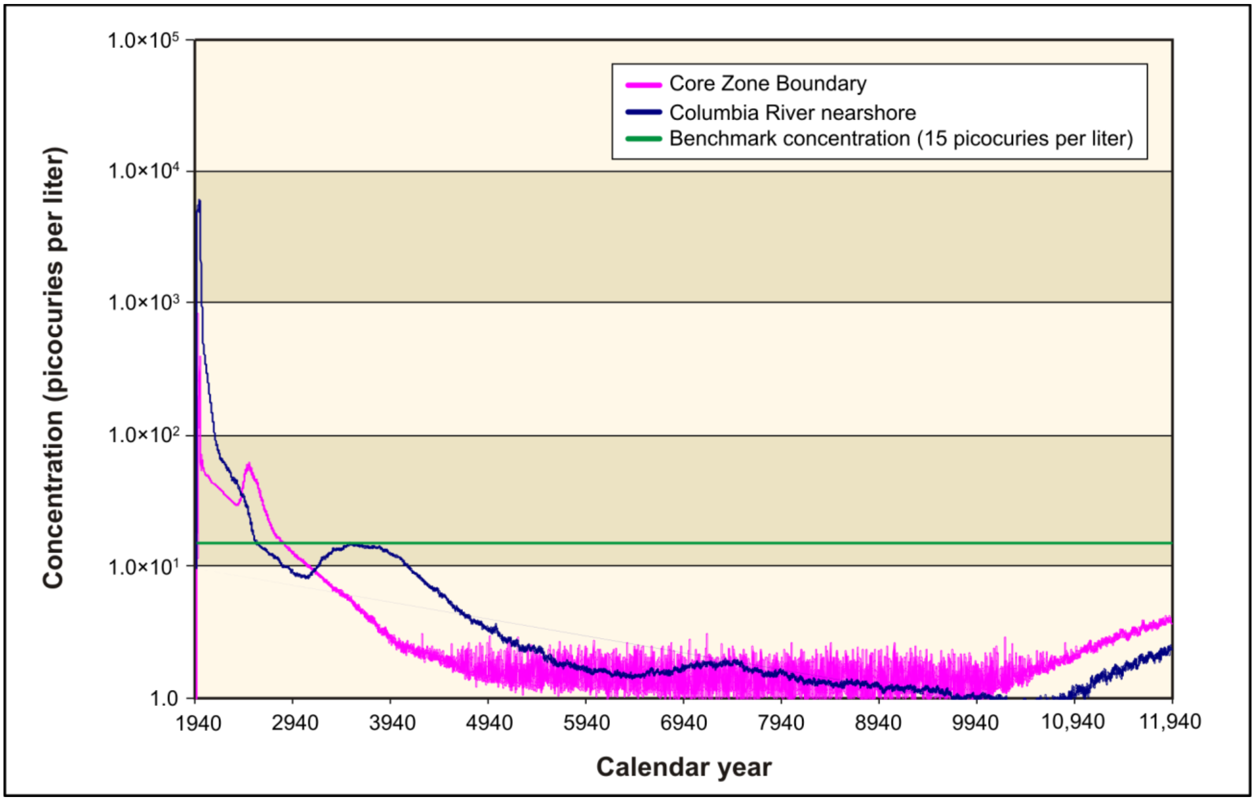


Figure 6–78. Alternative Combination 3 Cumulative Uranium-238 Concentration Versus Time

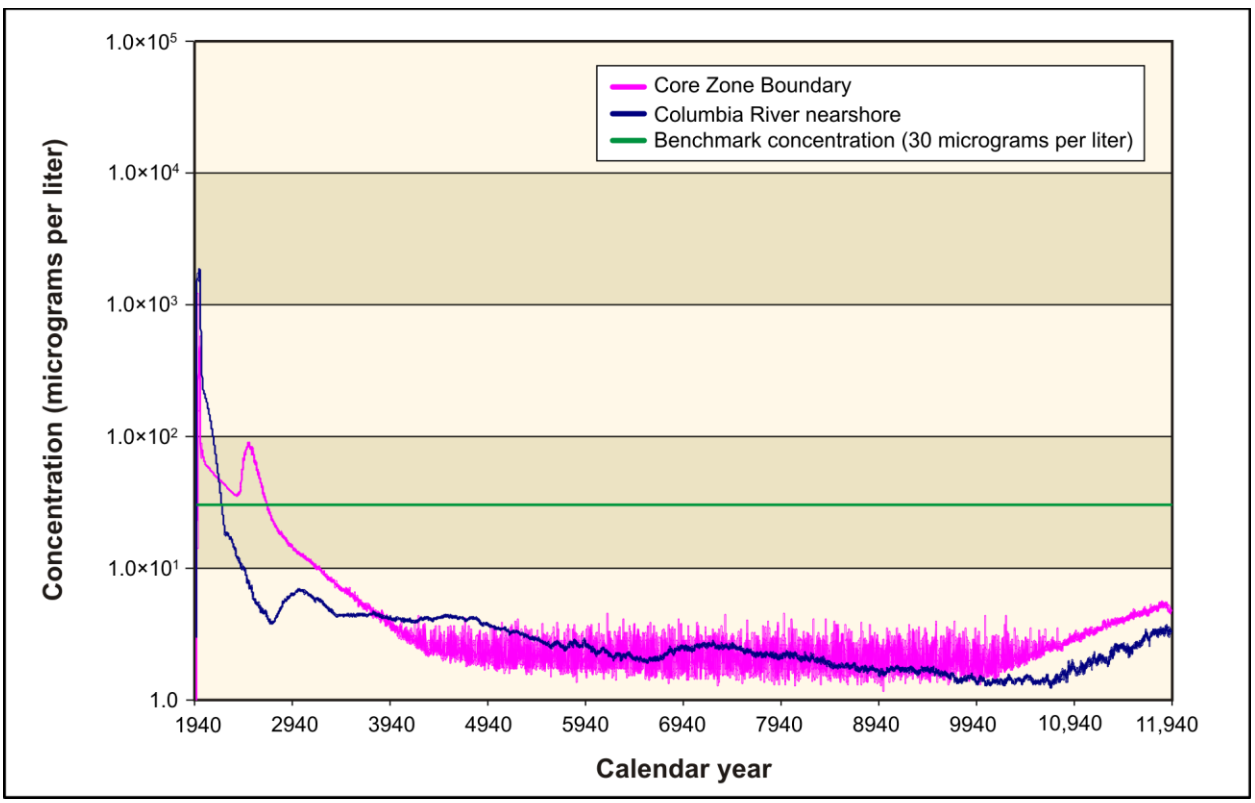
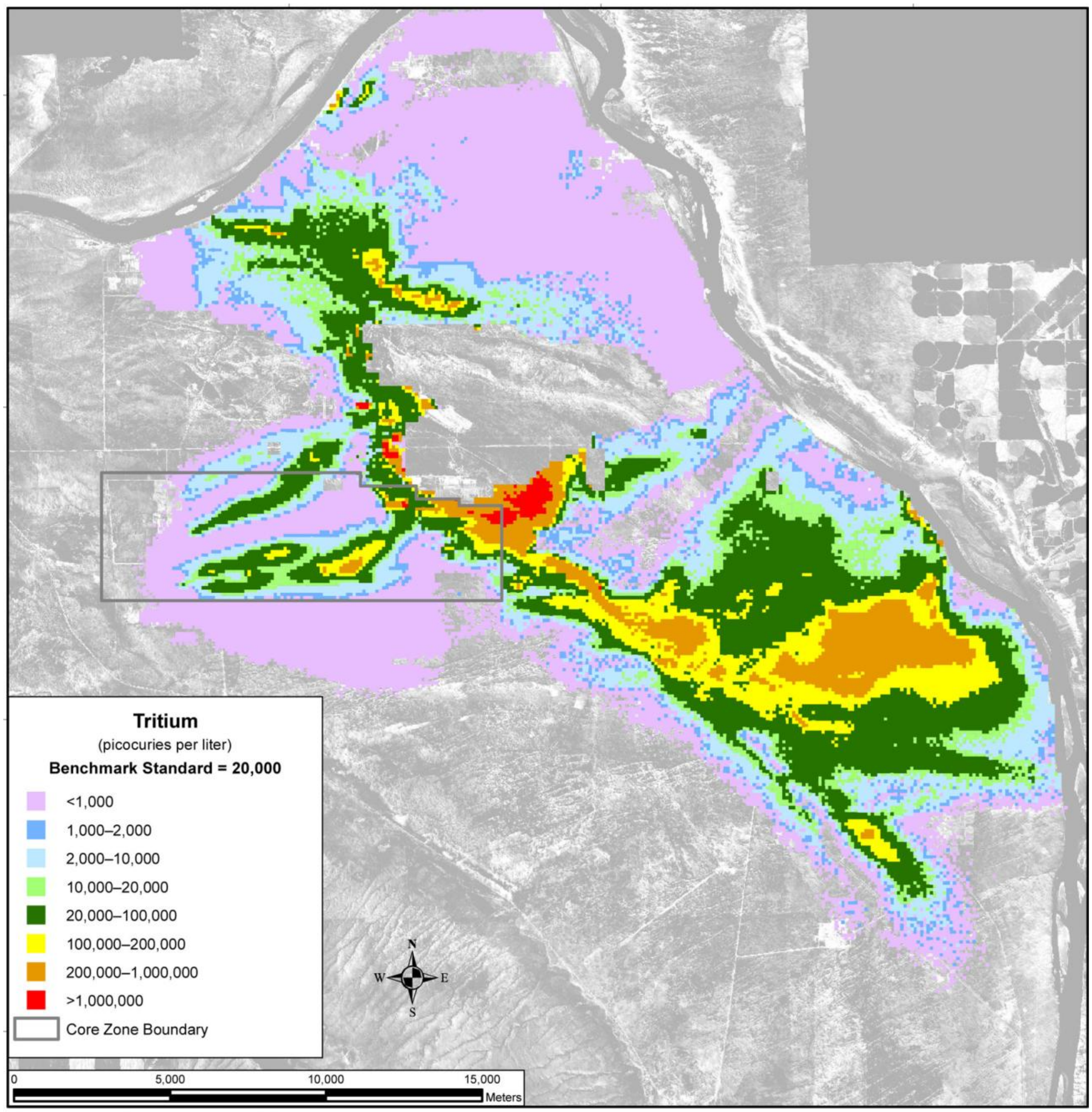


Figure 6–79. Alternative Combination 3 Cumulative Total Uranium Concentration Versus Time

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.

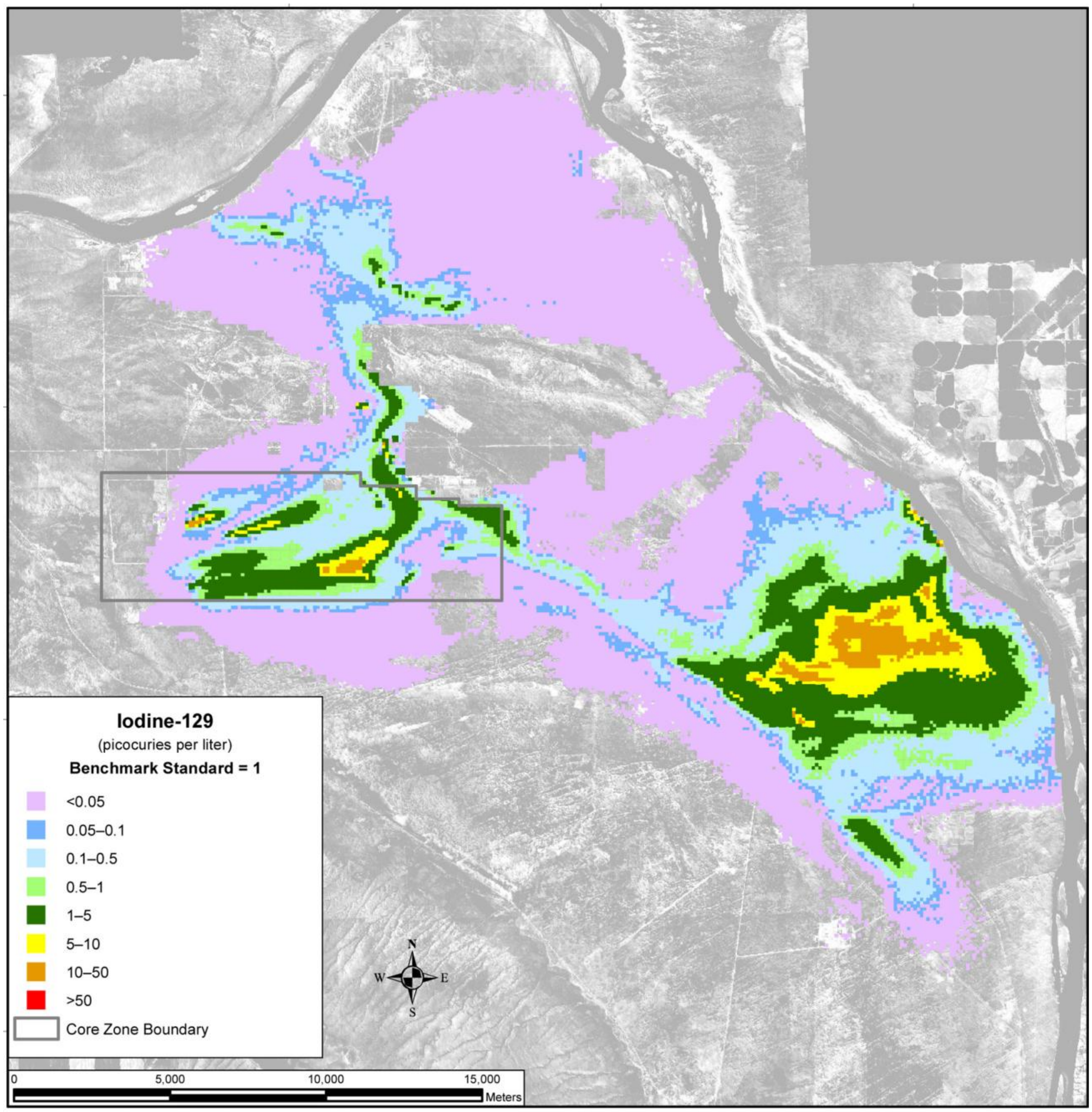
Figure 6–80 shows the spatial distribution of tritium concentrations in groundwater in CY 2010 and contrasts the behavior of the releases from *TC & WM EIS* and non–*TC & WM EIS* sources. The release from *TC & WM EIS* sources results from cribs and trenches (ditches) and past tank leaks and is evident 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.



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

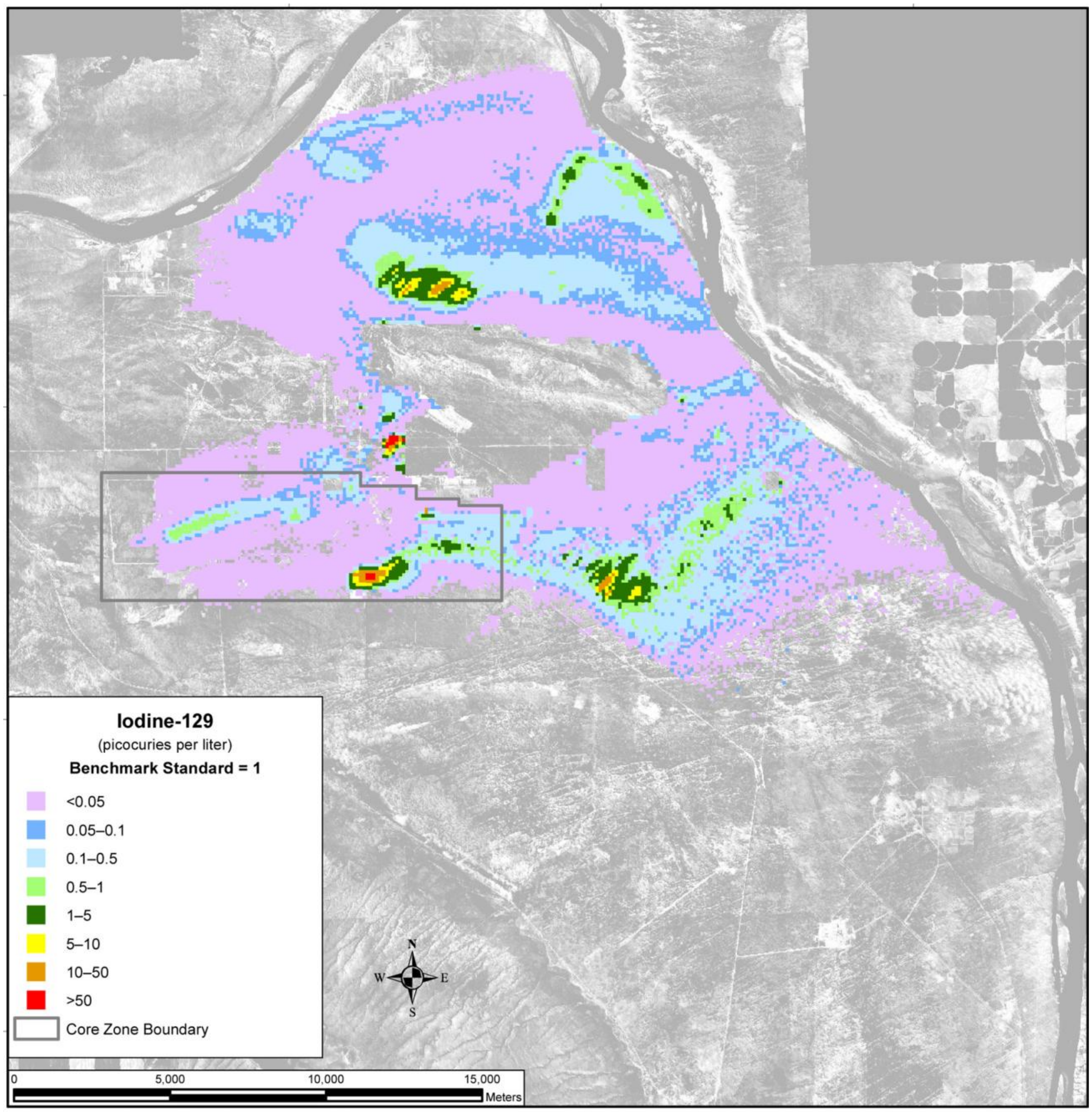
Figure 6–80. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Hydrogen-3 (Tritium) Concentration, Calendar Year 2010

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 & WM EIS* source. Releases from the PUREX Plant area (another non–*TC & WM EIS* 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.



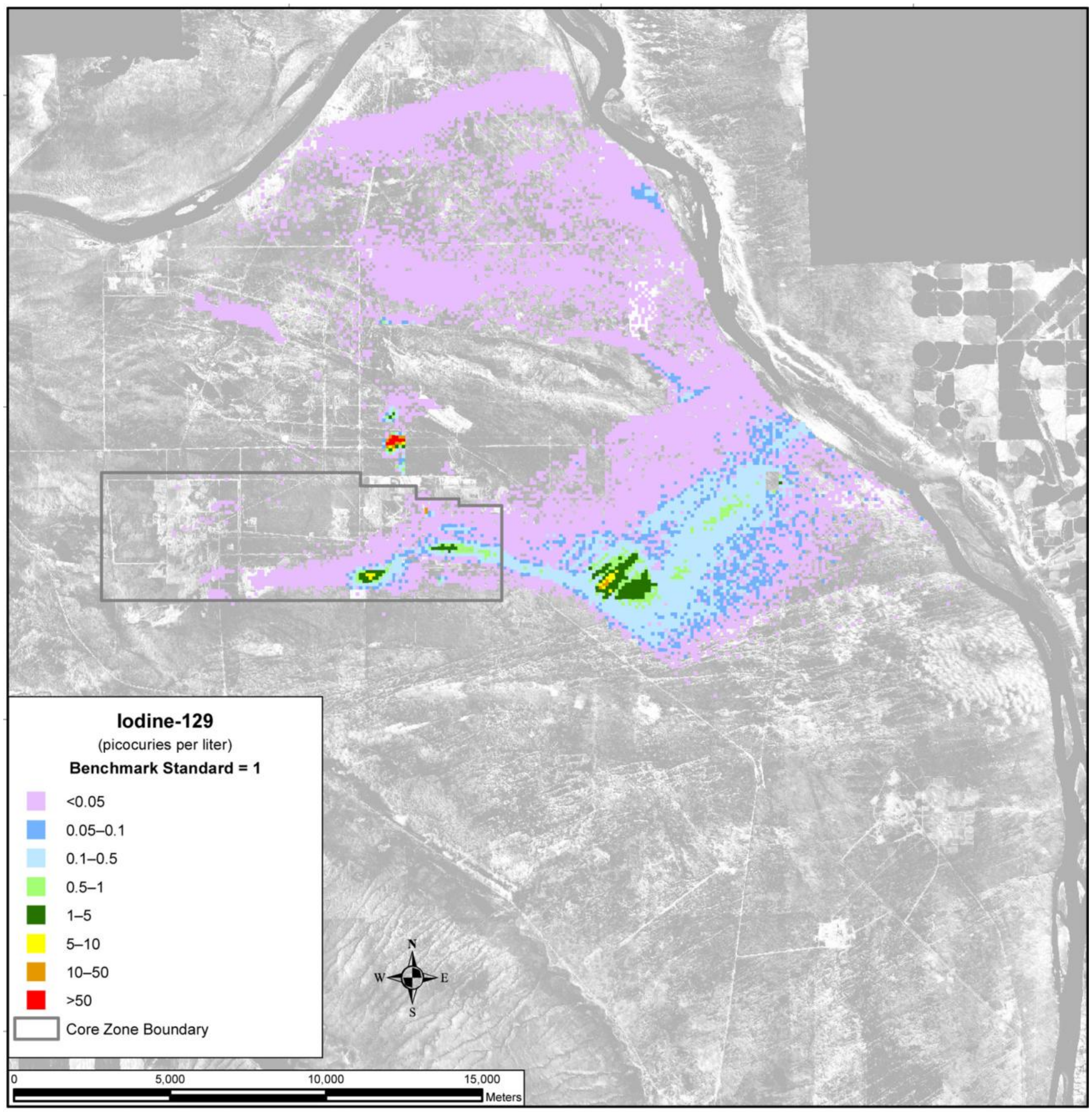
Note: To convert meters to feet, multiply by 3.281.

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



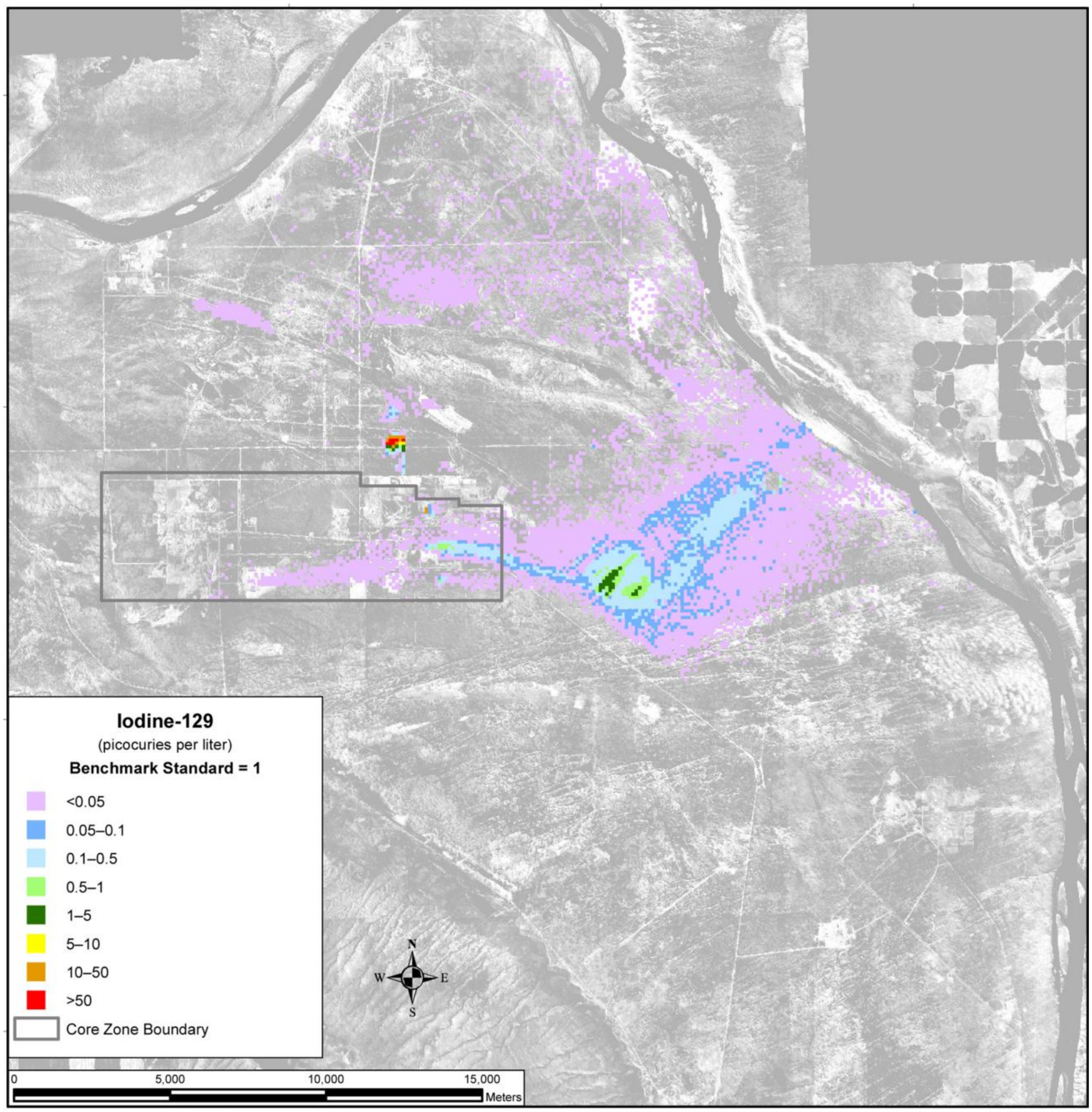
Note: To convert meters to feet, multiply by 3.281.

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



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

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

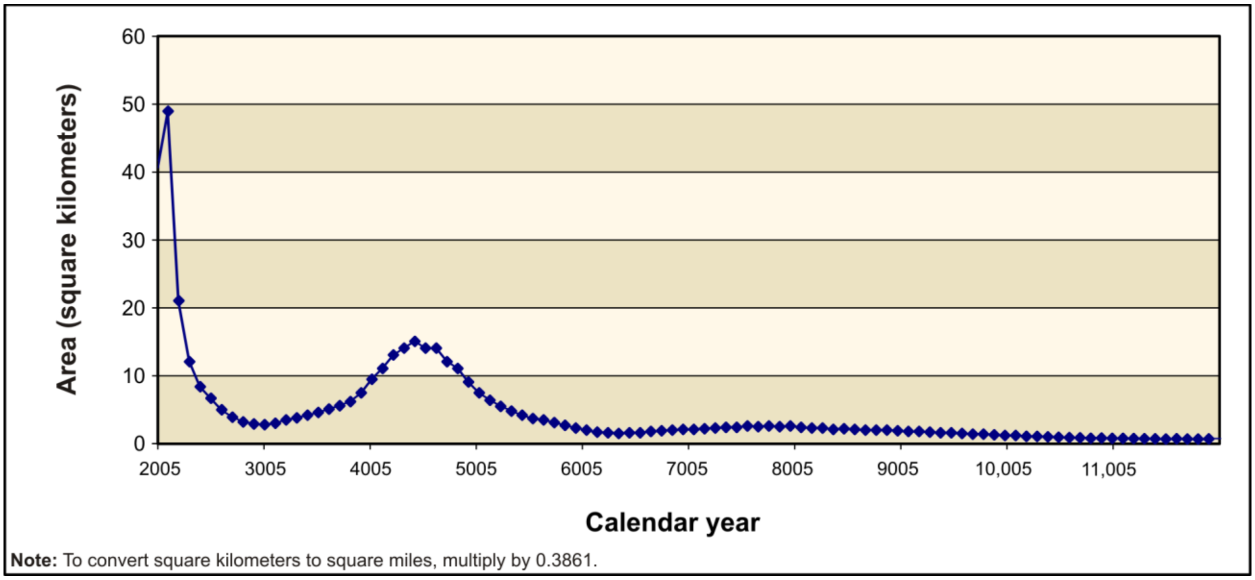
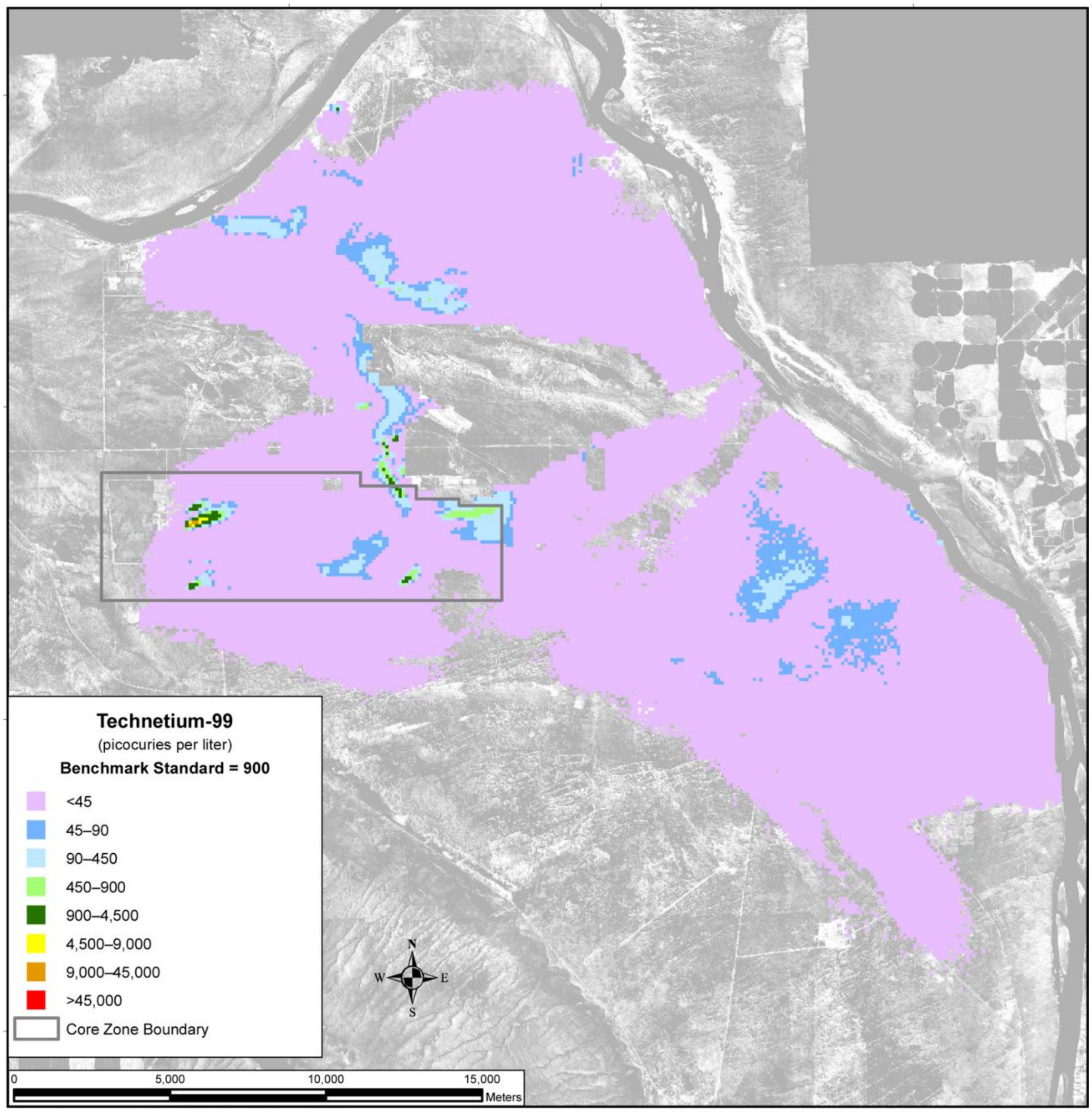


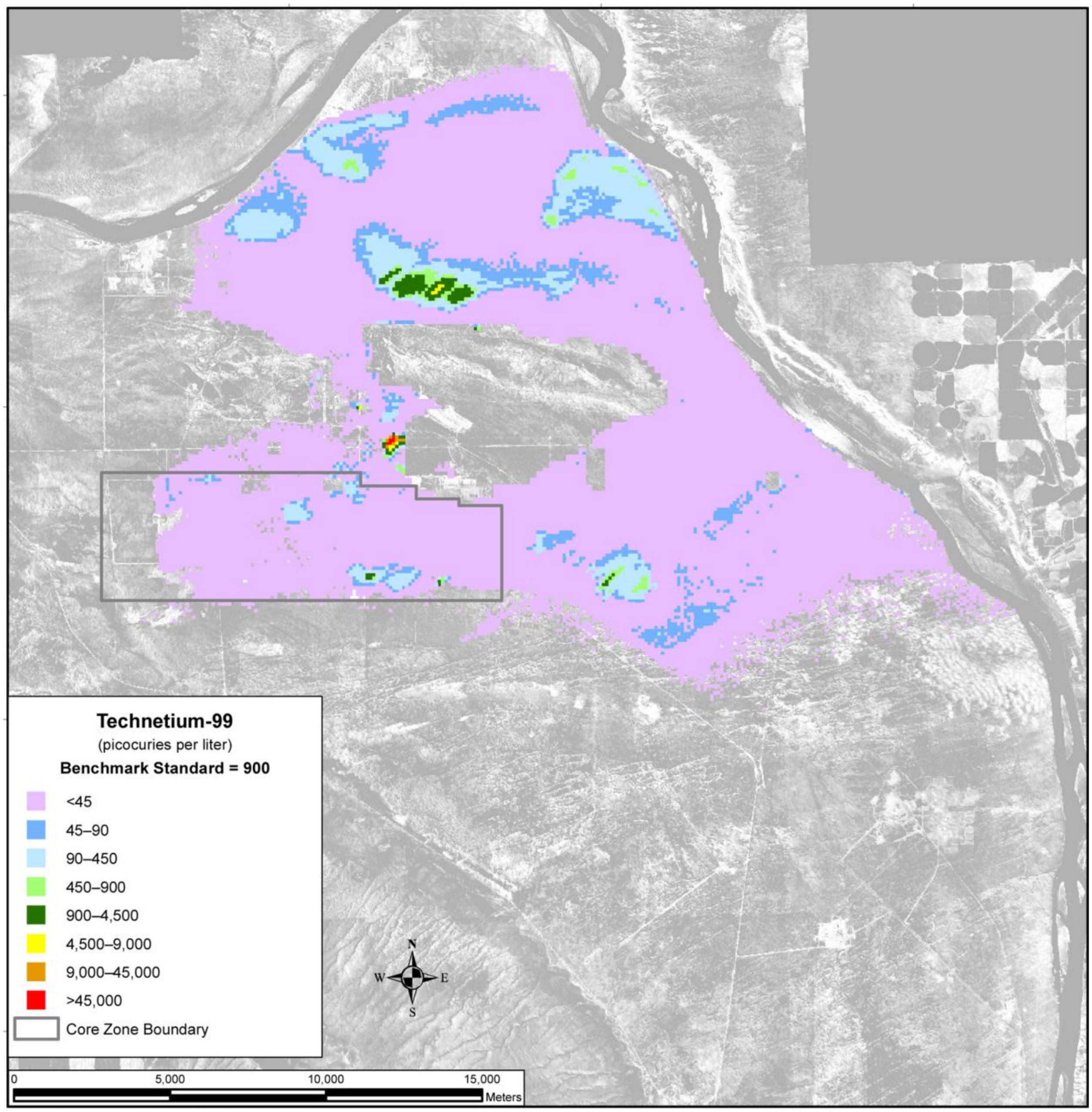
Figure 6–85. Alternative Combination 3 Total Area of Cumulative Groundwater Iodine-129 Concentrations Exceeding the Benchmark Concentration as a Function of Time

Figures 6–86 through 6–89 show the spatial distributions of technetium-99 concentrations in groundwater in CYs 2010, 3890, 7140, and 11,885. Figure 6–90 shows the total area of exceedance versus time for technetium-99. These spatial distributions of technetium-99 do not include major contributions from the PUREX Plant sources (compared with iodine-129 distributions) and are dominated by releases from other tank farm sources and IDF-East. Chromium (see Figures 6–91 through 6–94) and nitrate (see Figures 6–95 through 6–98) show increased spatial distributions relative to technetium-99 because of the additional contributions from non–*TC & WM EIS* sources.



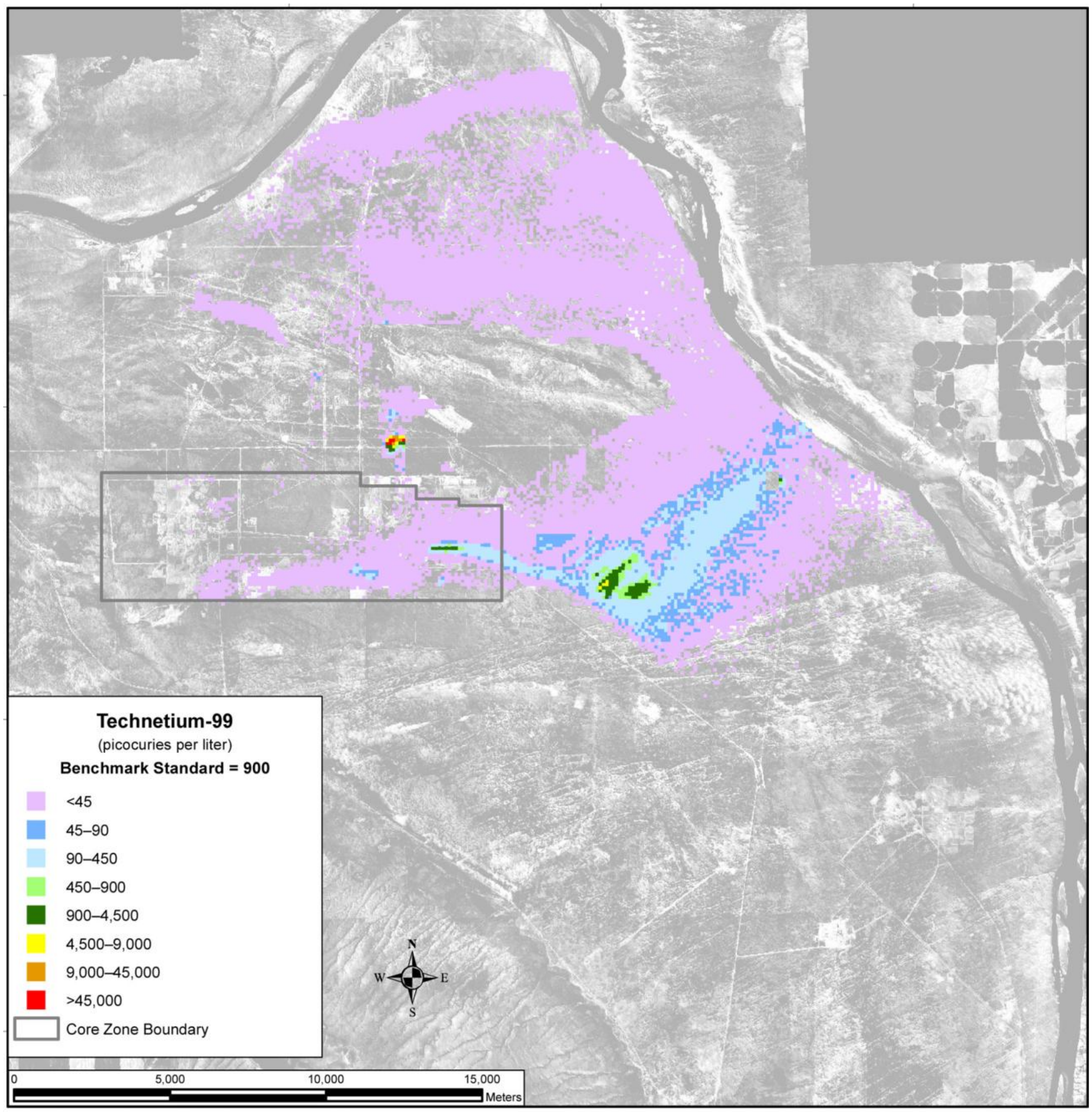
Note: To convert meters to feet, multiply by 3.281.

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



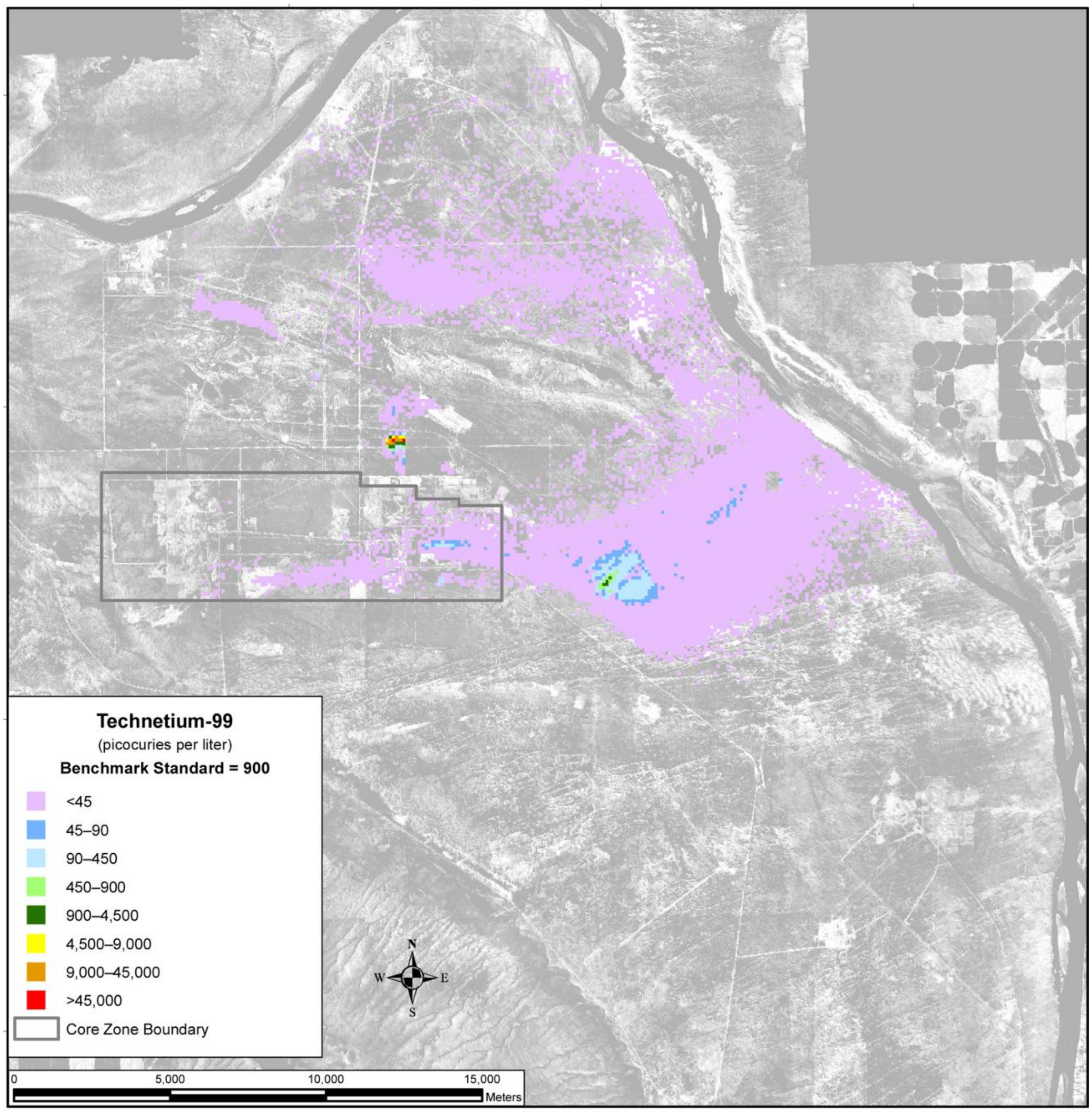
Note: To convert meters to feet, multiply by 3.281.

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



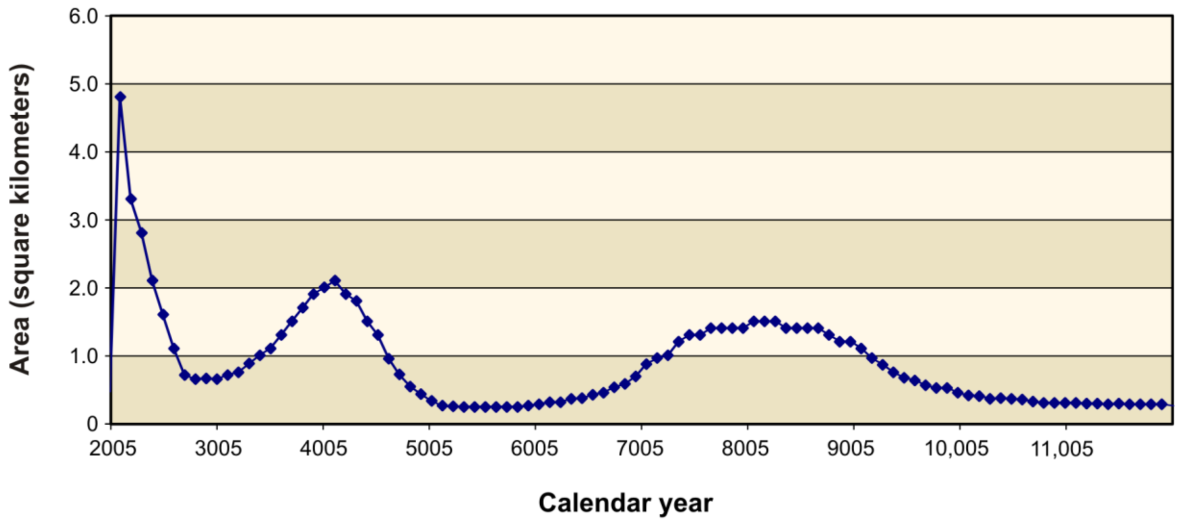
Note: To convert meters to feet, multiply by 3.281.

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



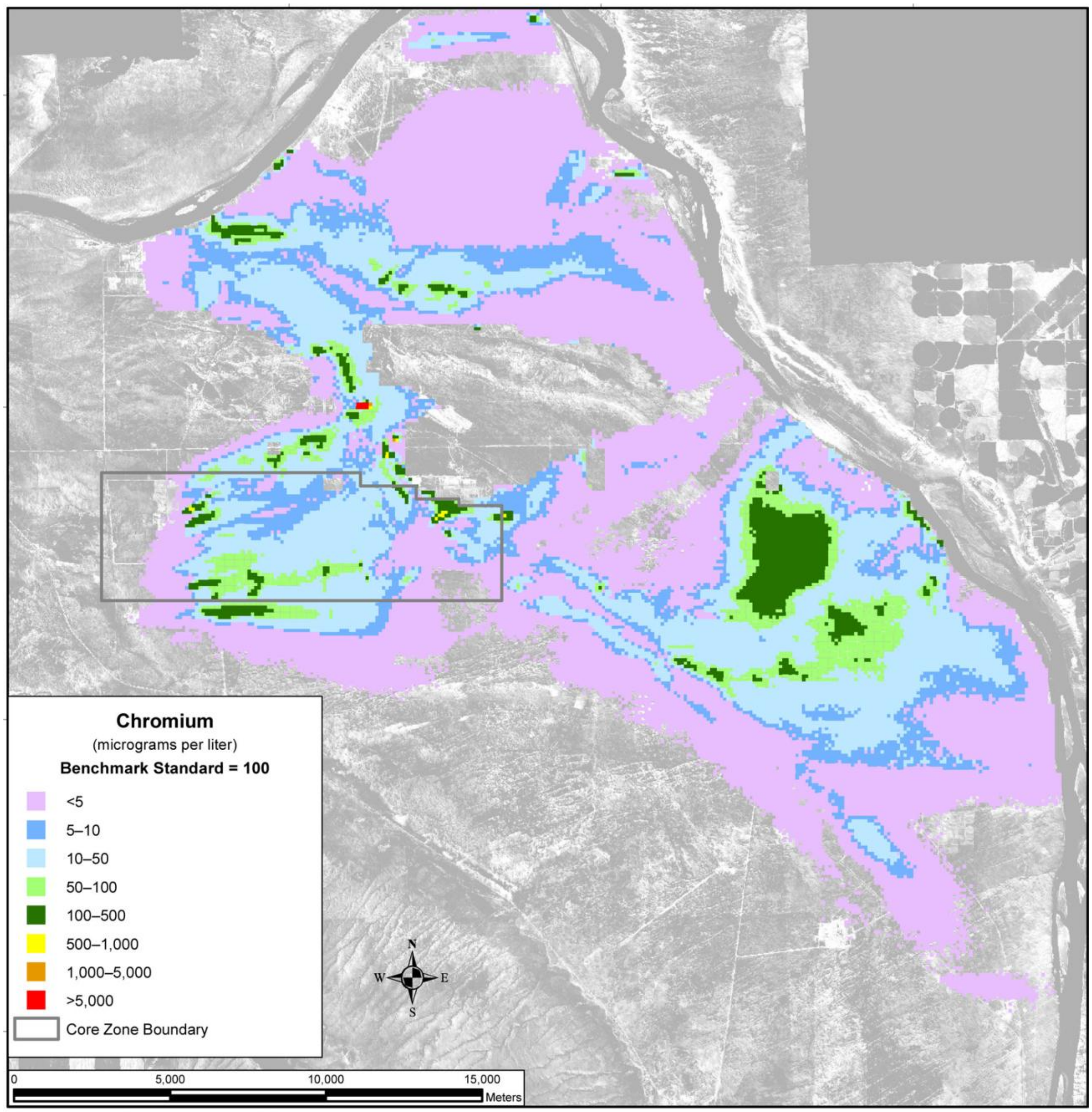
Note: To convert meters to feet, multiply by 3.281.

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



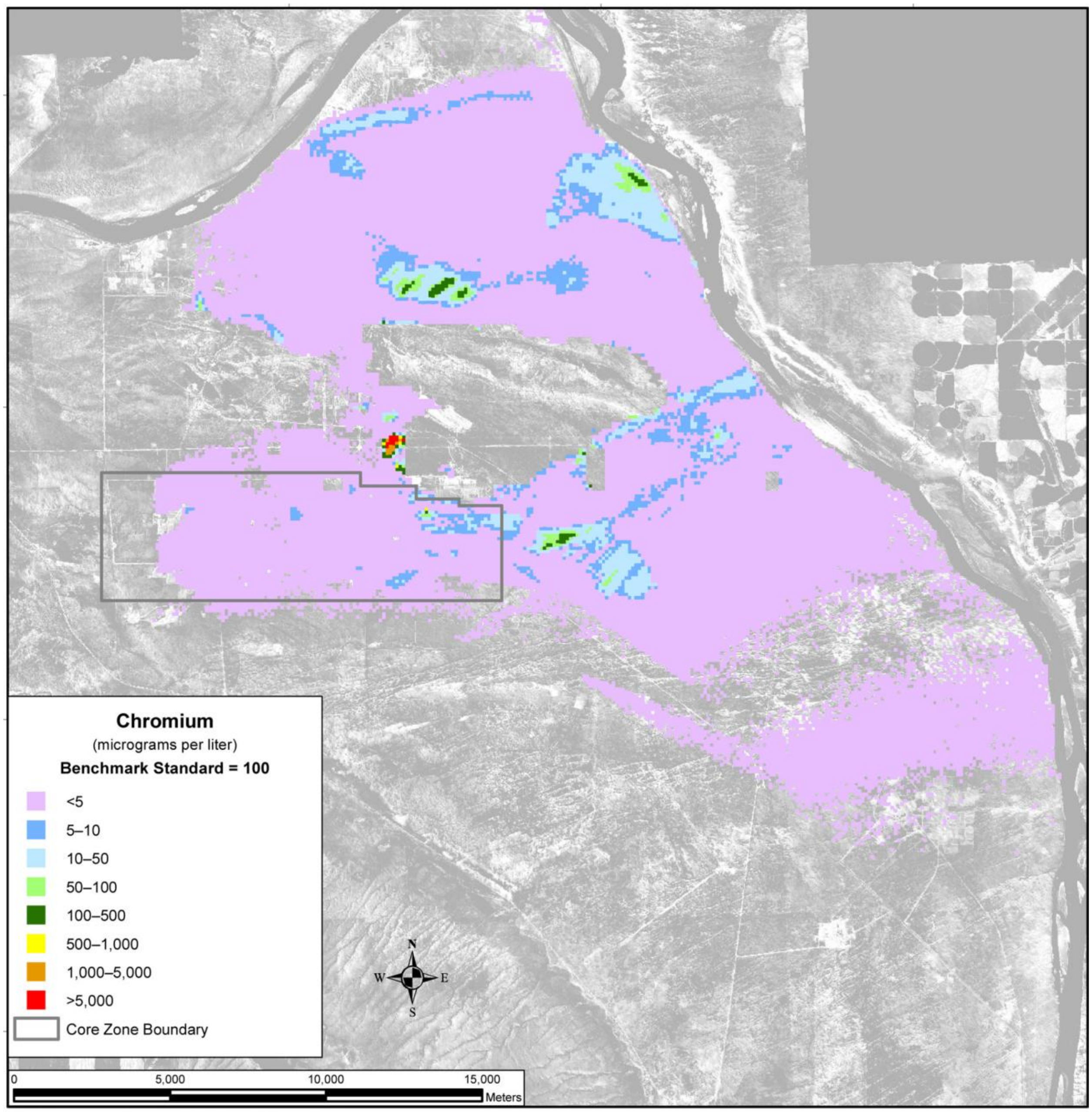
Note: To convert square kilometers to square miles, multiply by 0.3861.

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



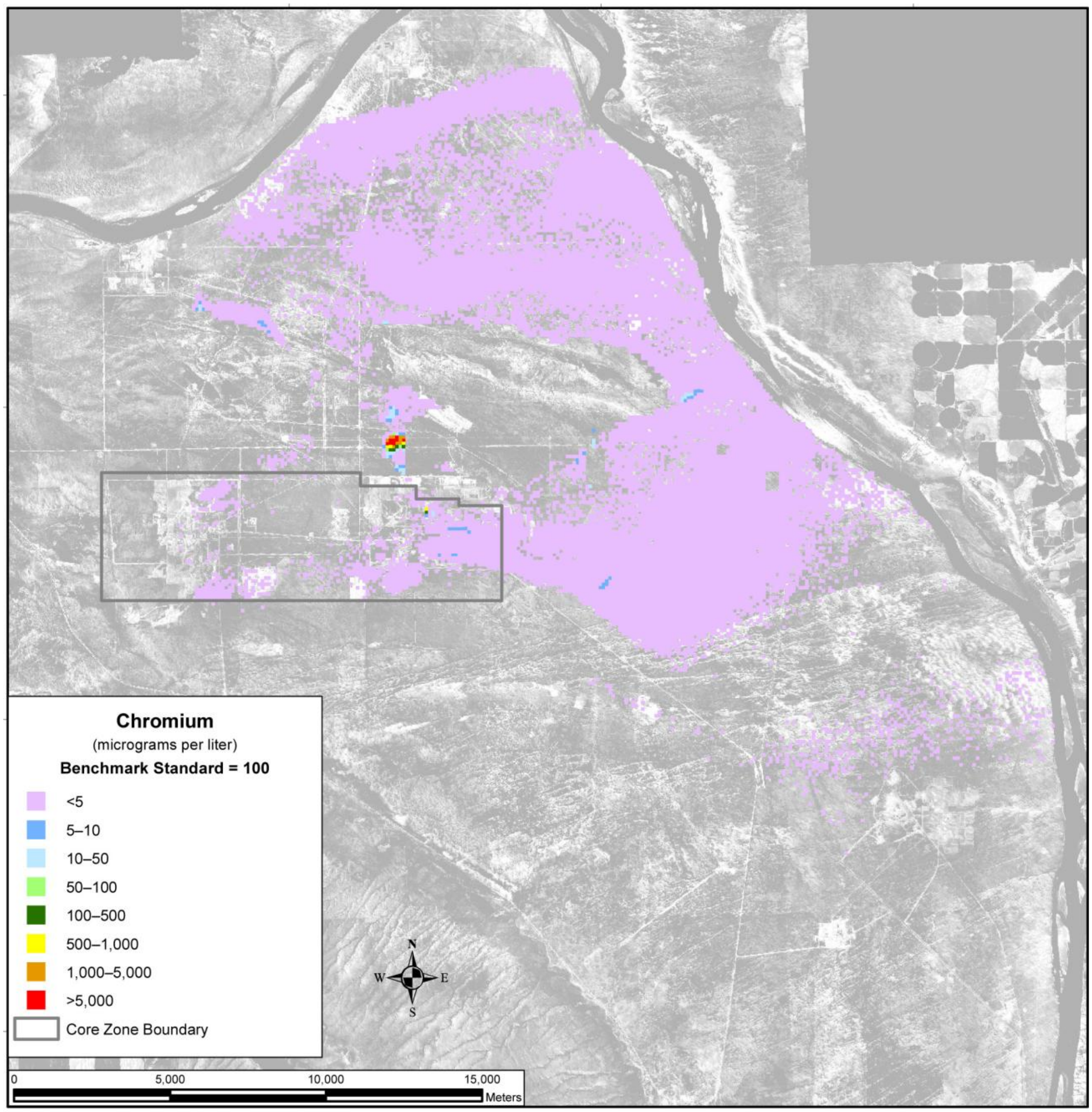
Note: To convert meters to feet, multiply by 3.281.

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



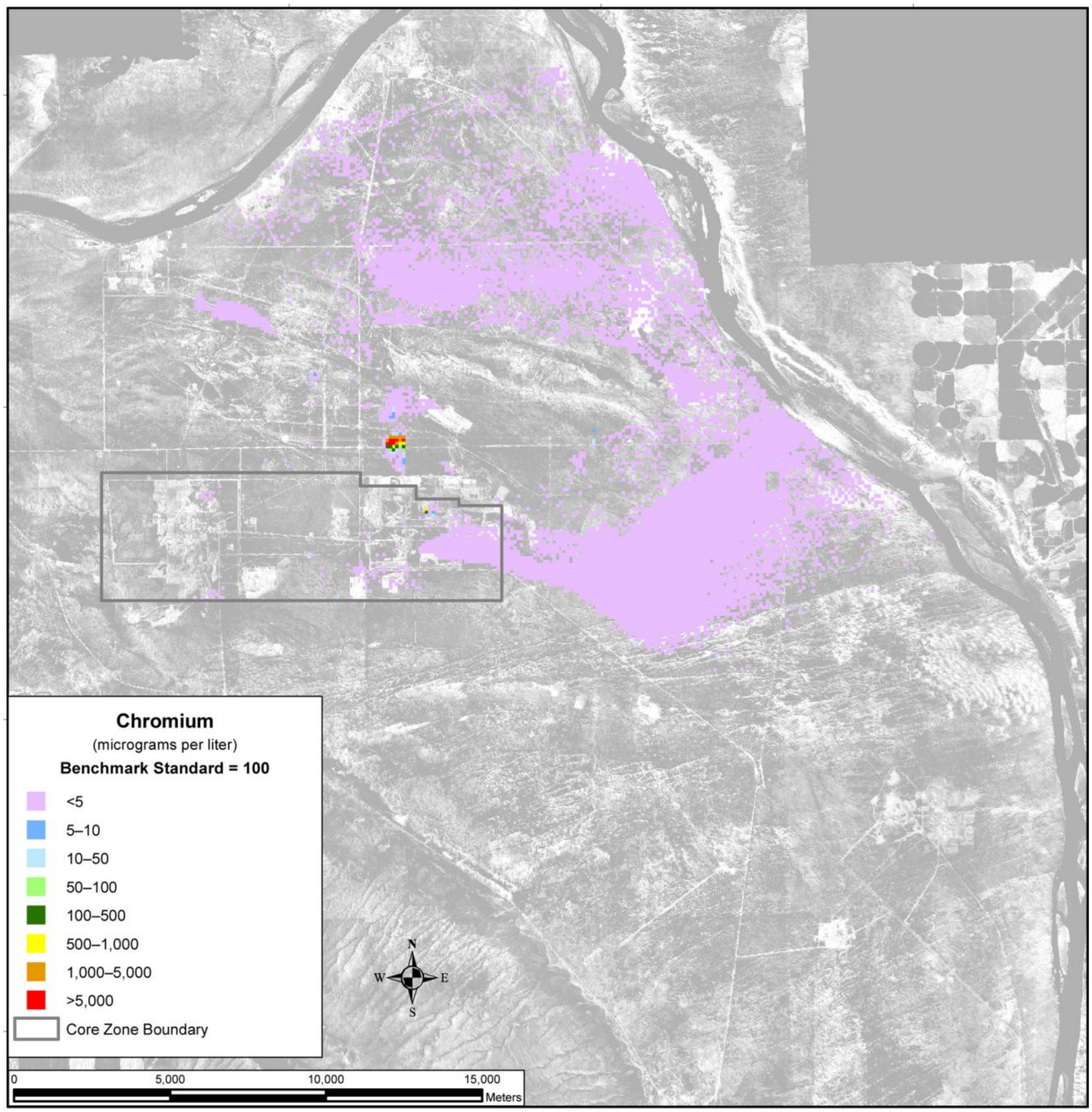
Note: To convert meters to feet, multiply by 3.281.

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



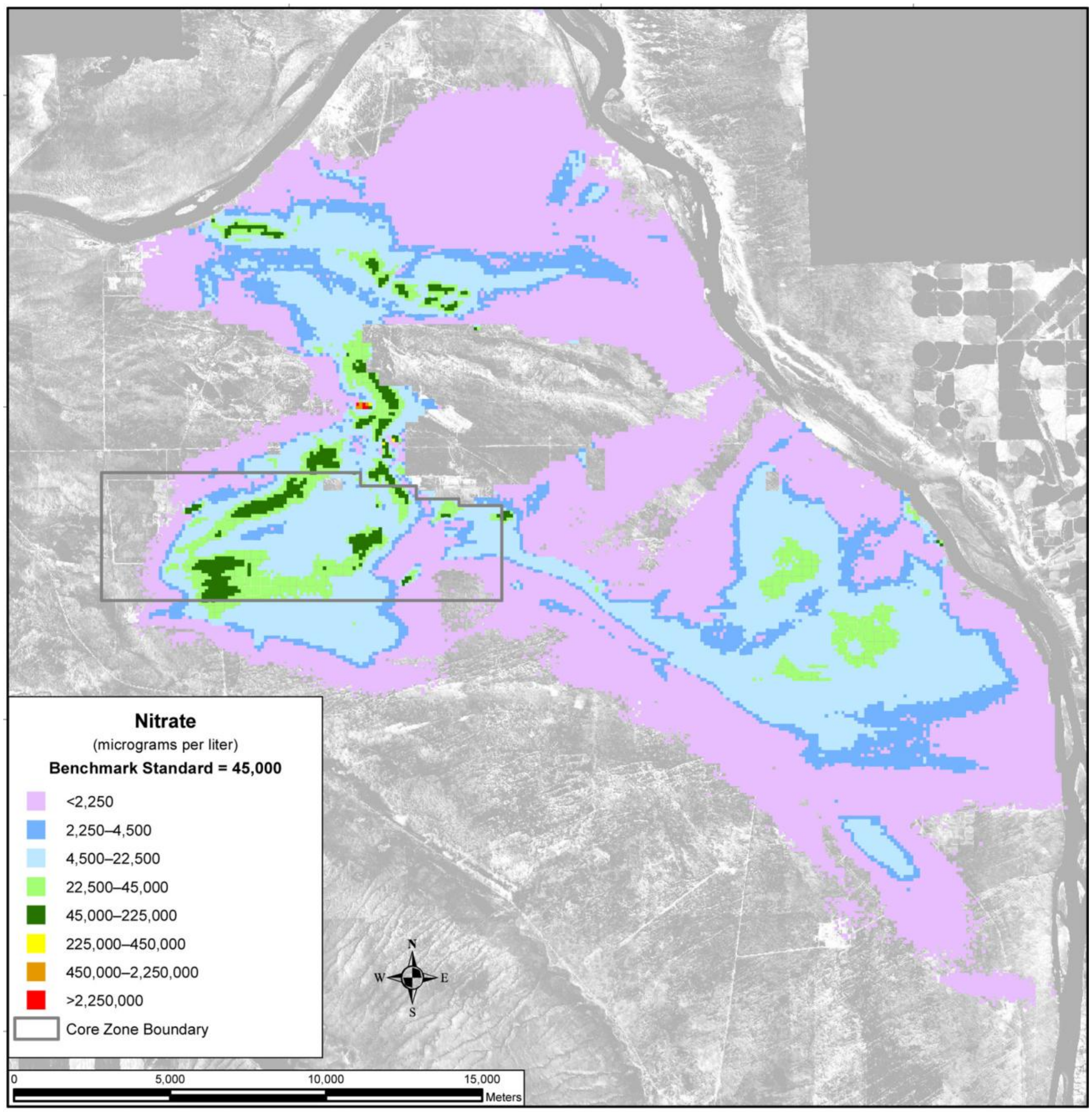
Note: To convert meters to feet, multiply by 3.281.

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



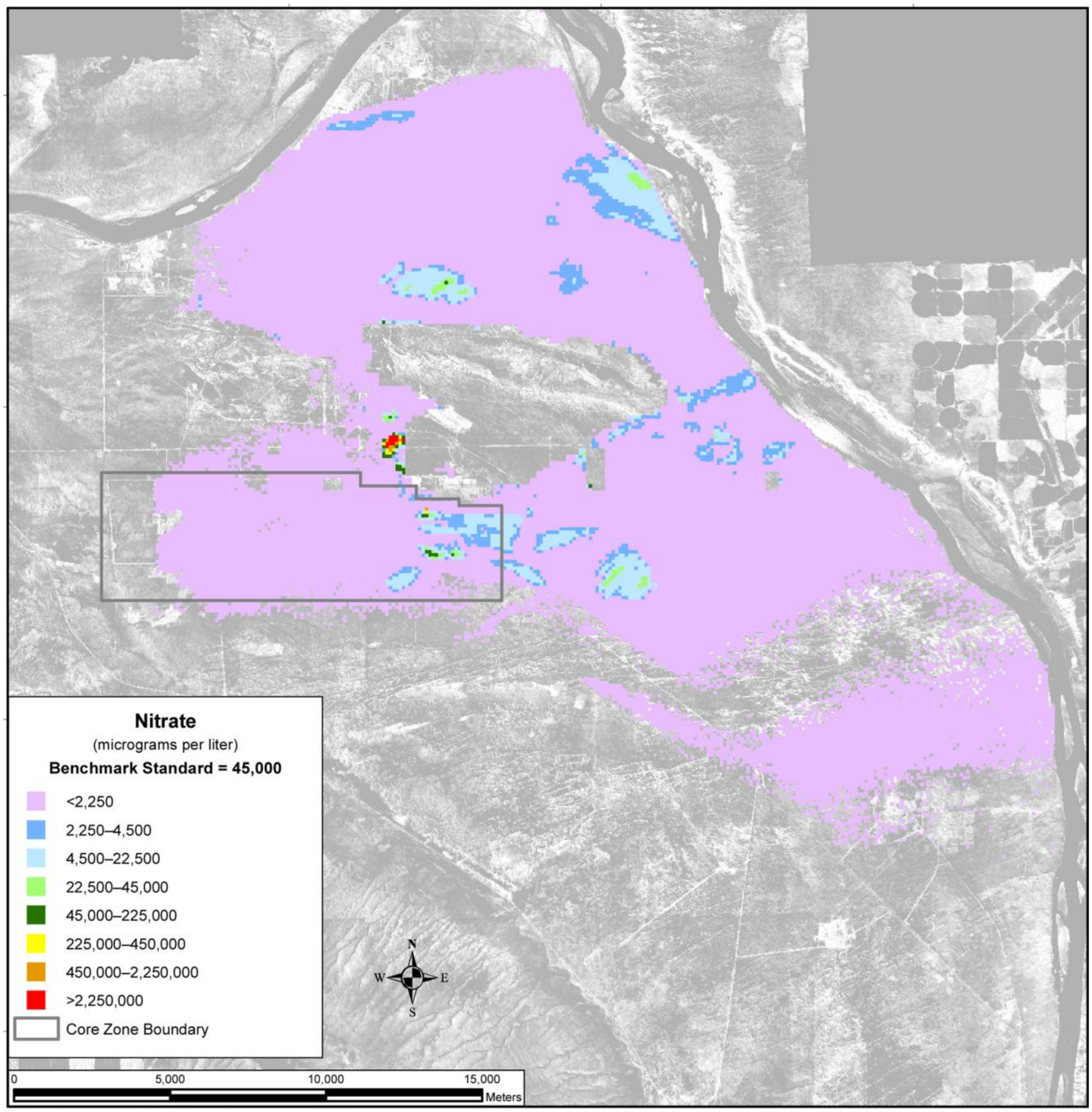
Note: To convert meters to feet, multiply by 3.281.

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



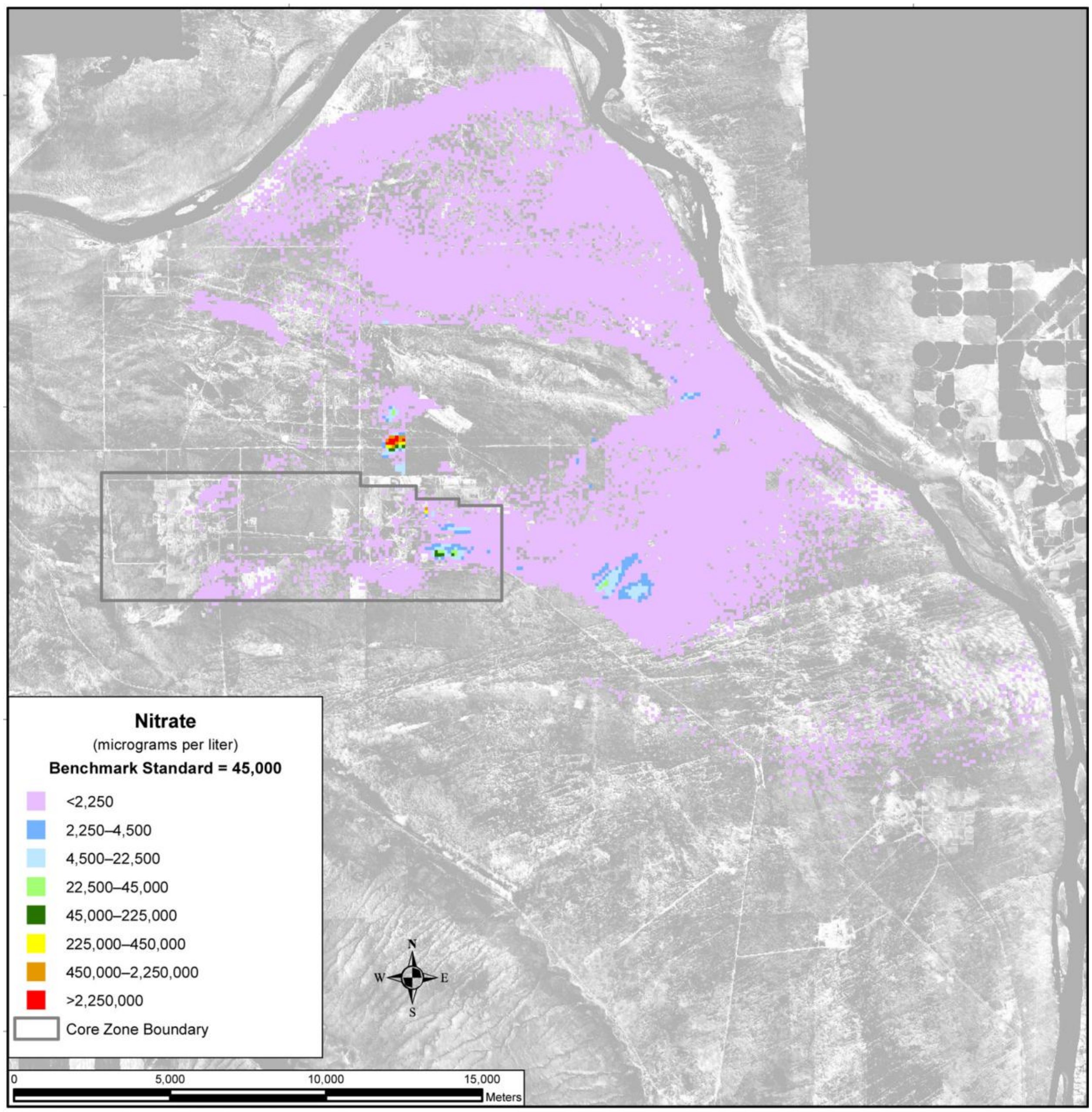
Note: To convert meters to feet, multiply by 3.281.

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



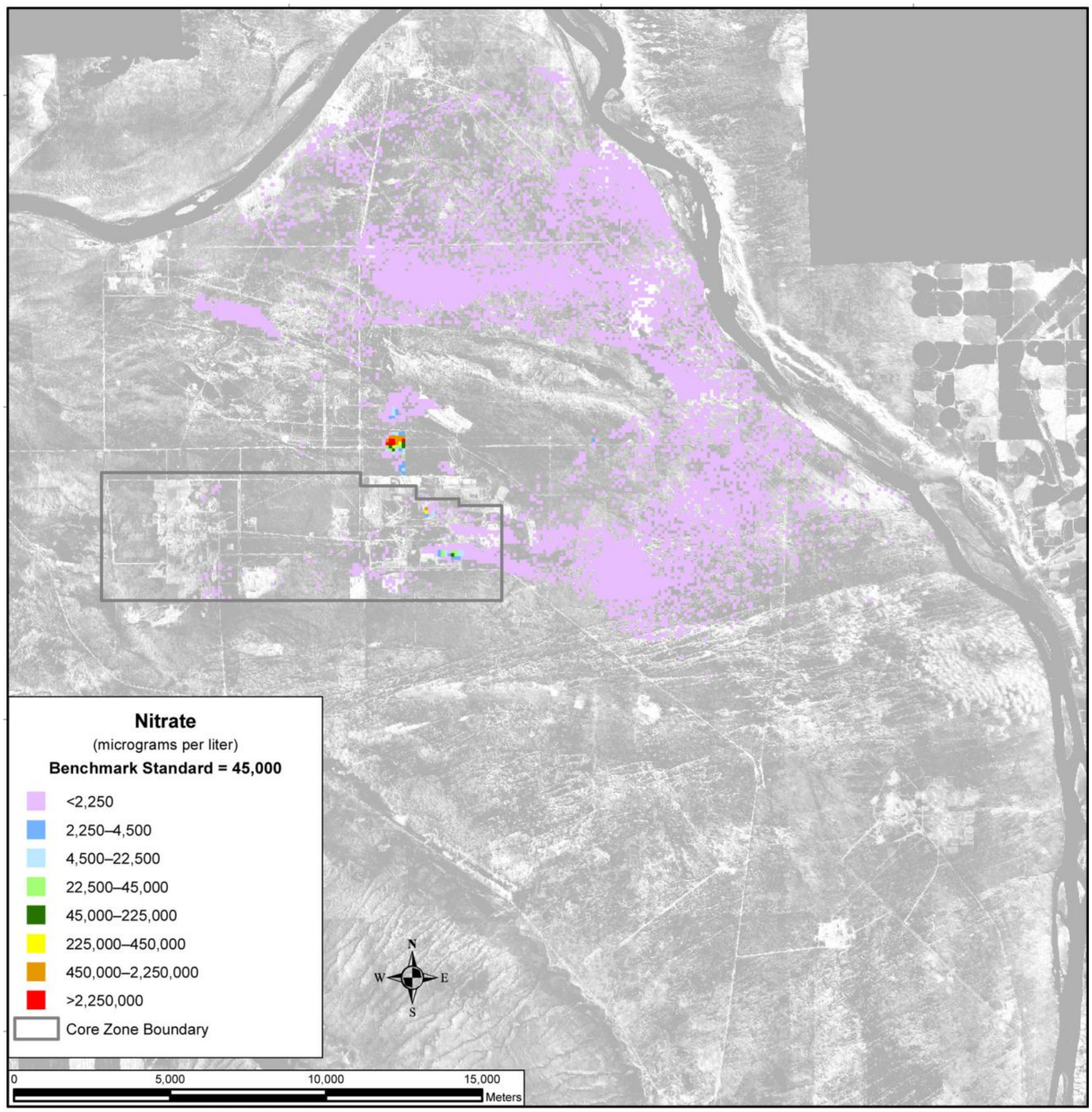
Note: To convert meters to feet, multiply by 3.281.

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



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

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

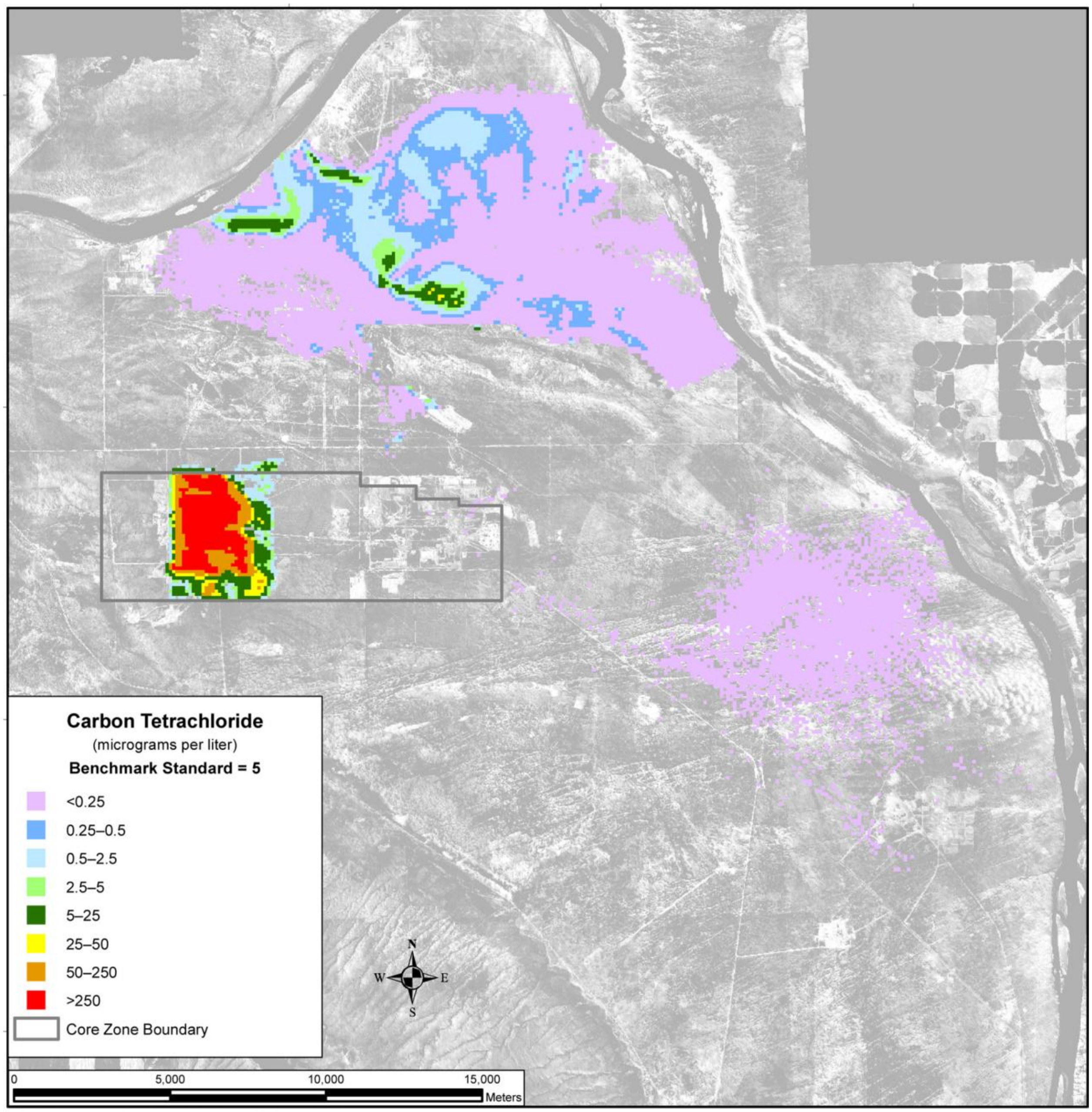


Note: To convert meters to feet, multiply by 3.281.

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

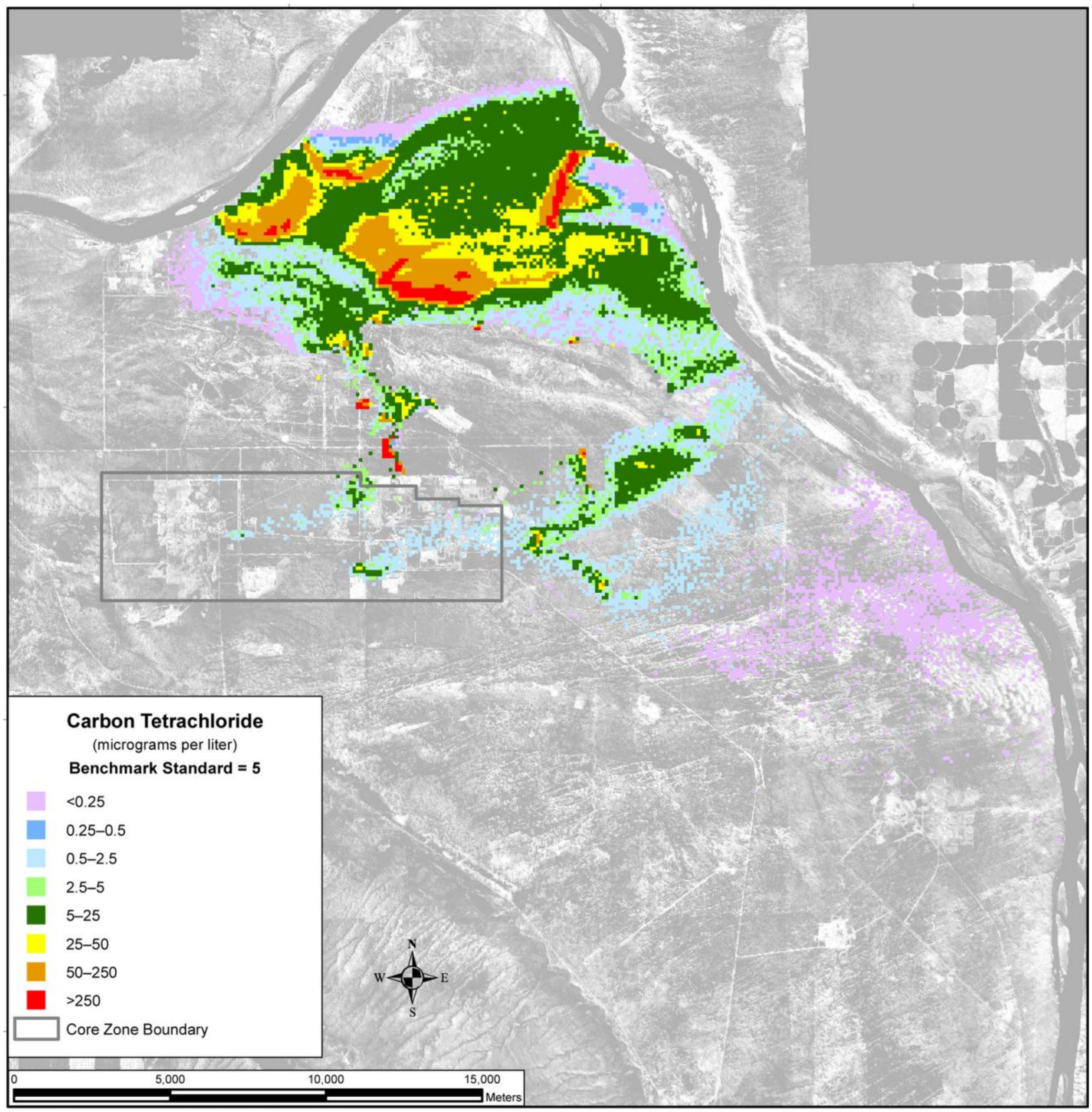
The spatial distribution of carbon tetrachloride concentrations in groundwater is dominated by non–*TC & WM EIS* sources associated with the Z Area within the 200-West Area. The spatial distribution in CY 2010, shown in Figure 6–99, is a large plume covering most of the 200-West Area, with peak concentrations 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.



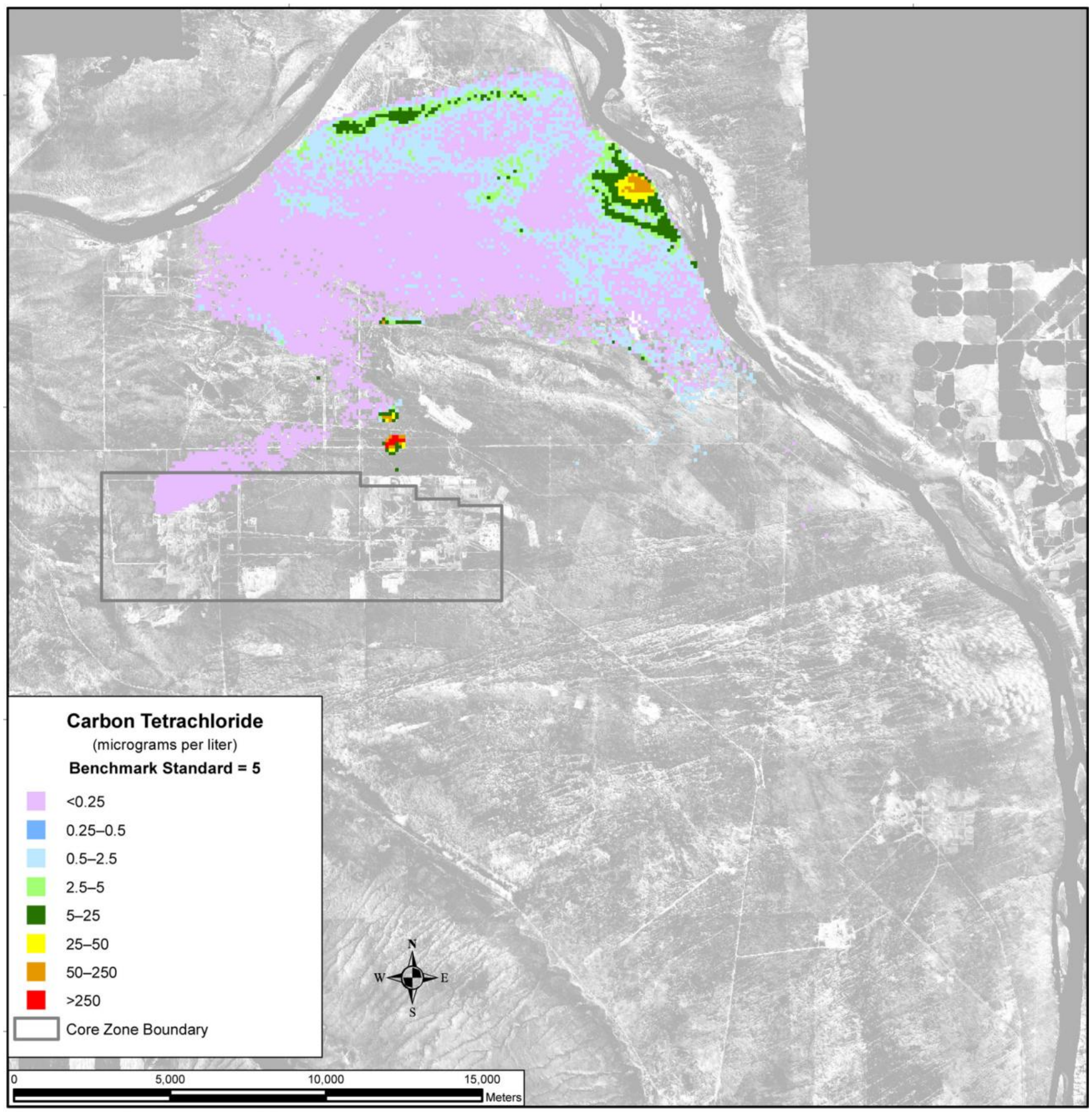
Note: To convert meters to feet, multiply by 3.281.

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



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

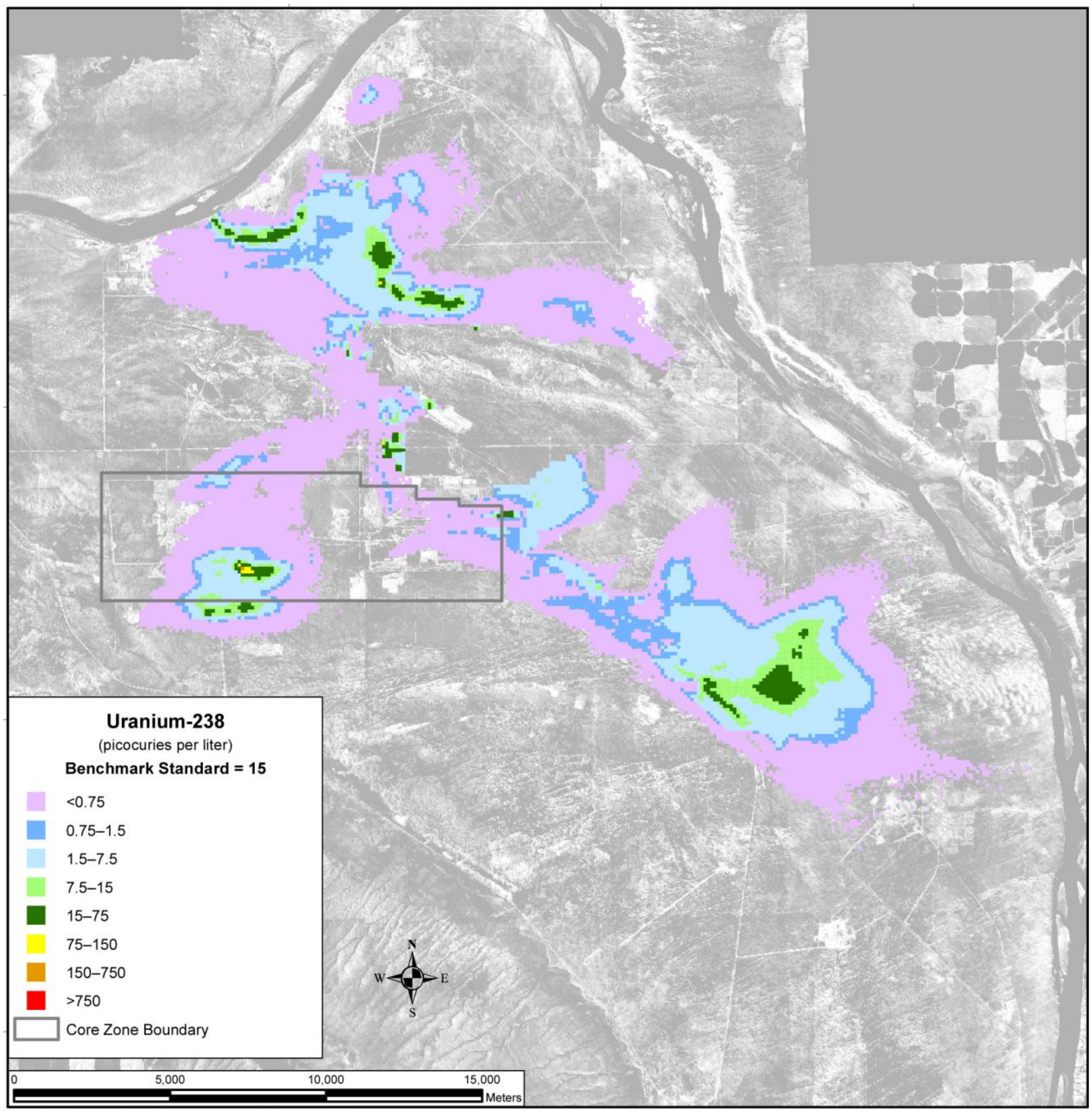
Figure 6–100. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Carbon Tetrachloride Concentration, Calendar Year 2135



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

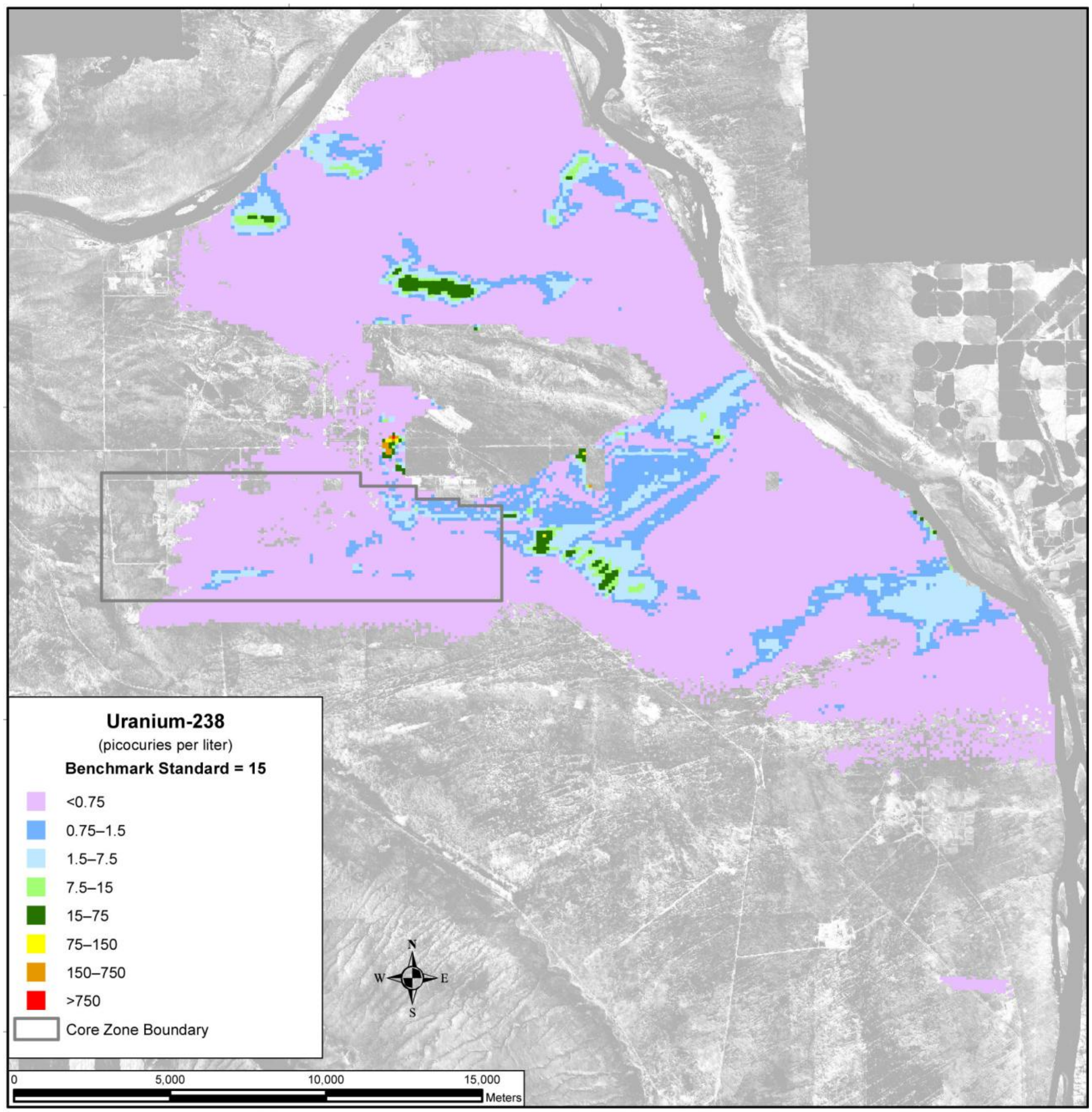
Figure 6–101. Alternative Combination 3 Spatial Distribution of Cumulative Groundwater Carbon Tetrachloride Concentration, Calendar Year 3890

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.



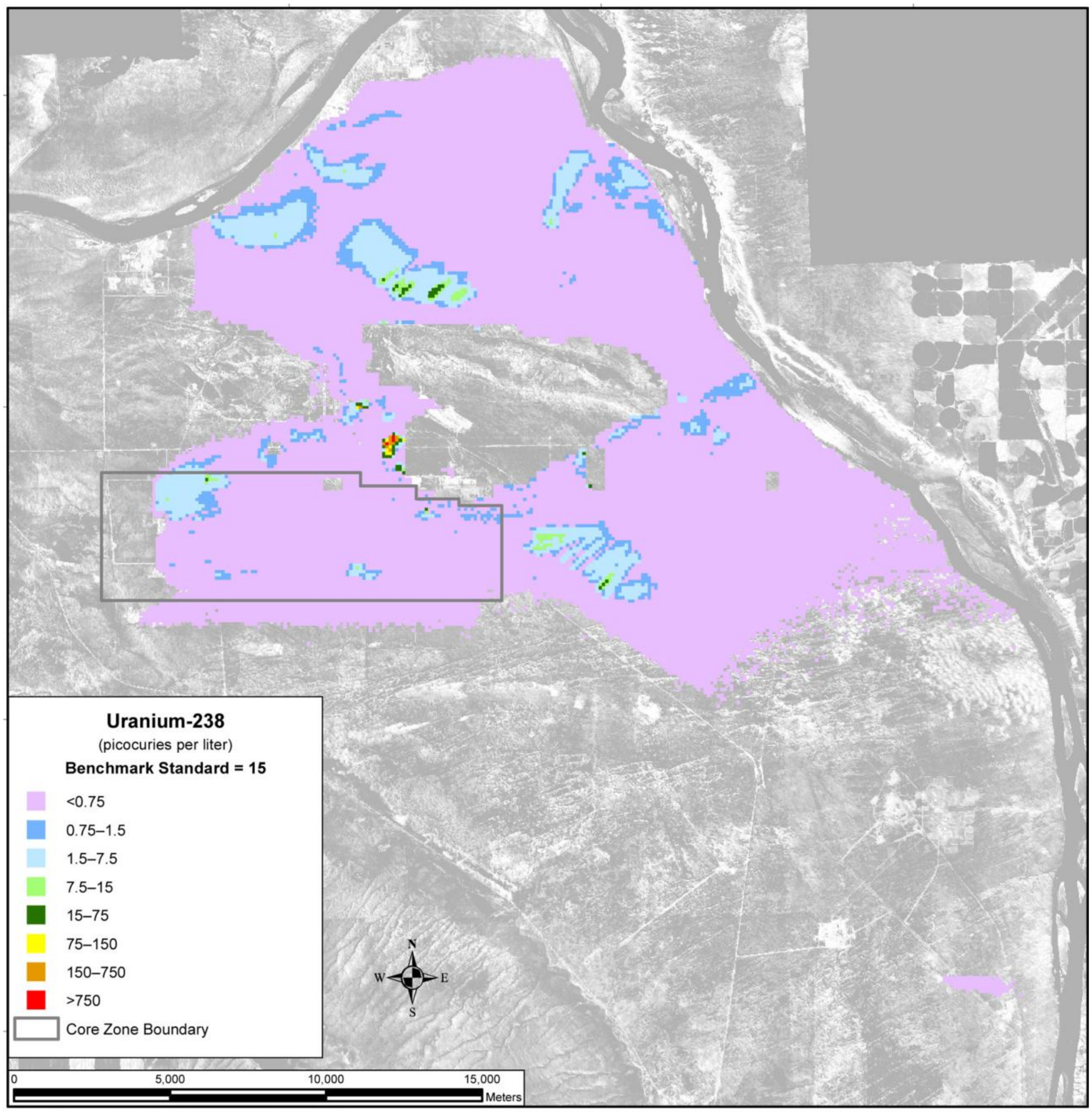
Note: To convert meters to feet, multiply by 3.281.

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



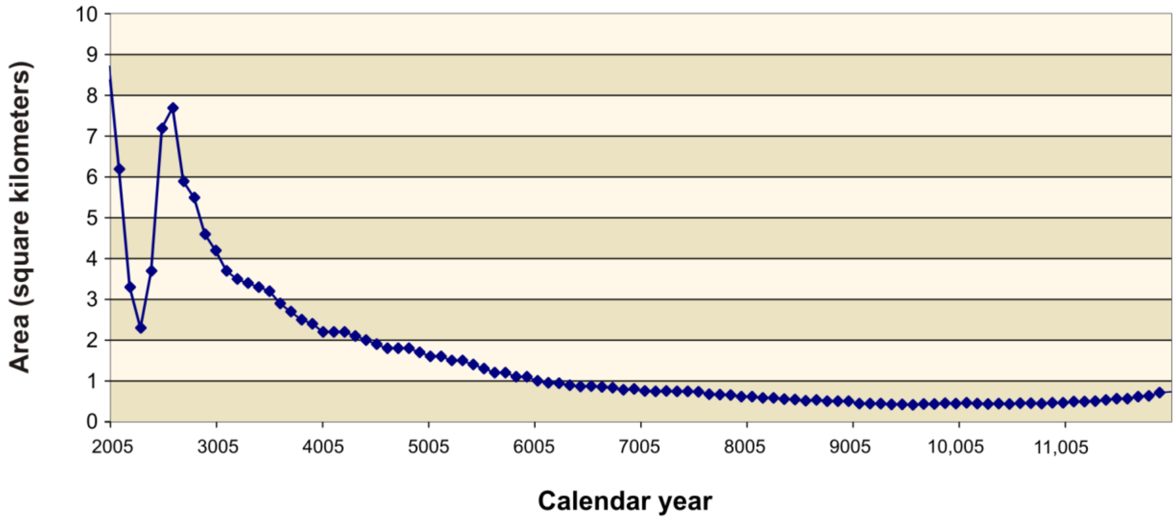
Note: To convert meters to feet, multiply by 3.281.

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



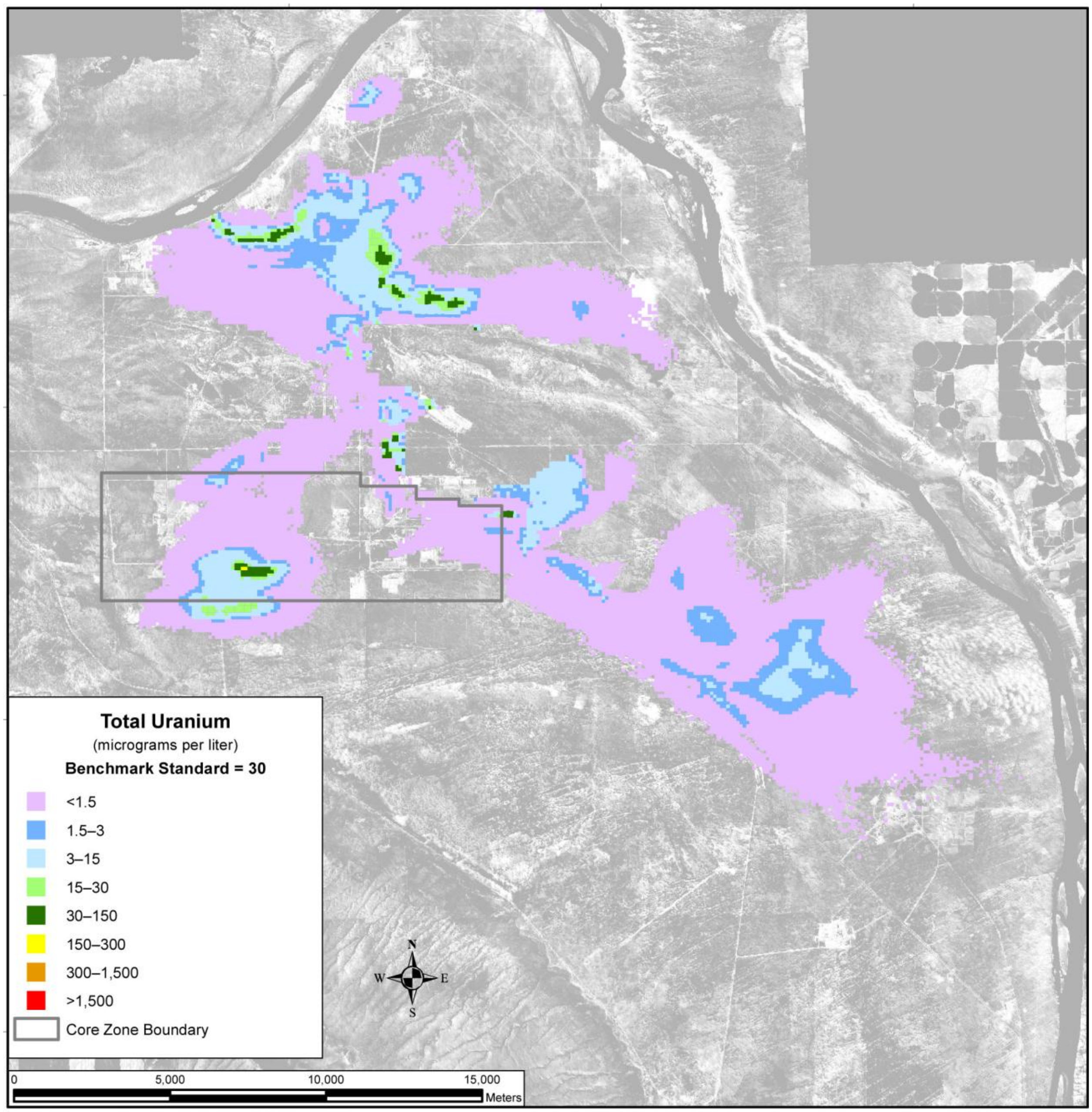
Note: To convert meters to feet, multiply by 3.281.

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



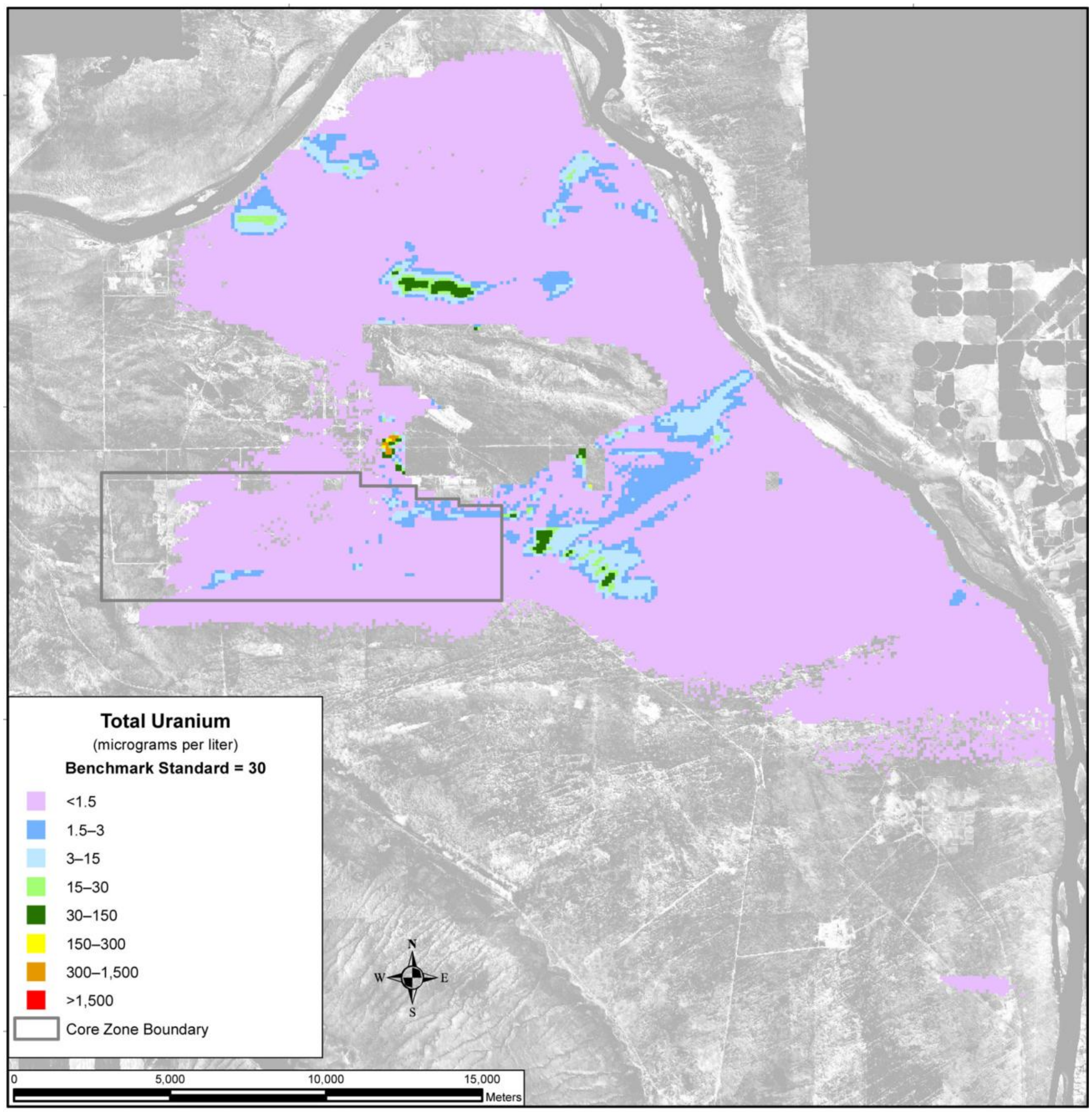
Note: To convert square kilometers to square miles, multiply by 0.3861.

Figure 6–105. Alternative Combination 3 Total Area of Cumulative Groundwater Uranium-238 Concentrations Exceeding the Benchmark Concentration as a Function of Time



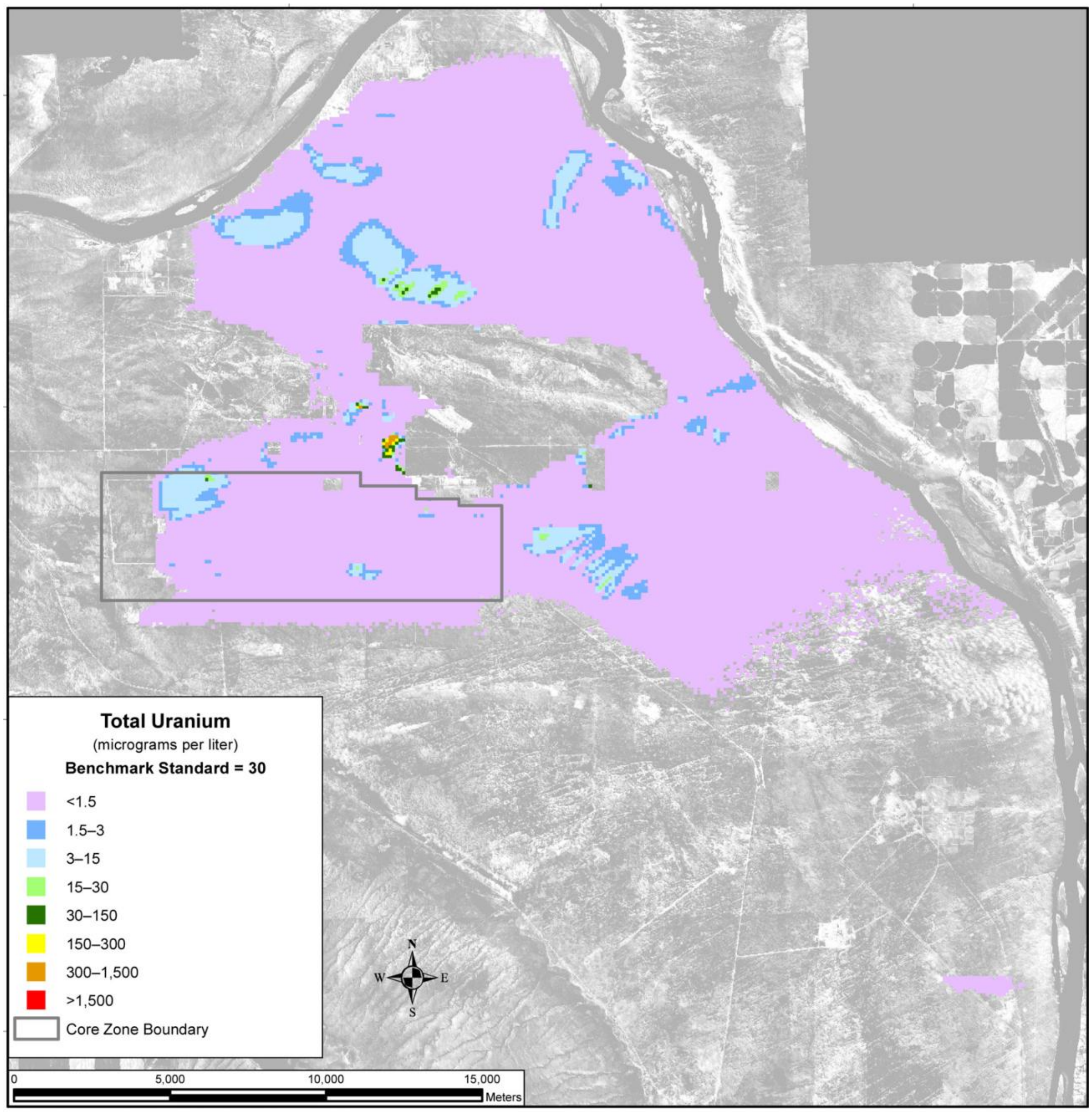
Note: To convert meters to feet, multiply by 3.281.

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



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

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)
***TC & WM EIS* 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}	$\mathbf{6.3 \times 10^{-6}}$	2.0×10^{-1}	$\mathbf{3.0 \times 10^{-4}}$
Other DOE Actions Subtotal	7.0×10^{-3}	$\mathbf{6.3 \times 10^{-6}}$	2.0×10^{-1}	$\mathbf{3.0 \times 10^{-4}}$

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}	$\mathbf{6.3\times10^{-6}}$	2.0×10^{-1}	$\mathbf{3.0\times10^{-4}}$
Alternative Combination 2	**2.47**	$\mathbf{6.3\times10^{-6}}$	$\mathbf{2.1\times10^{-1}}$	$\mathbf{3.0\times10^{-4}}$
Alternative Combination 3	**2.58**	$\mathbf{6.3\times10^{-6}}$	$\mathbf{2.1\times10^{-1}}$	$\mathbf{3.0\times10^{-4}}$
Benchmark Concentration[c]	$\mathbf{1.5\times10^{-2}}$	$\mathbf{2.8\times10^{-6}}$	$\mathbf{2.0\times10^{-1}}$	$\mathbf{3.16\times10^{-4}}$

[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: $C_{soil} = TRV/(IR_{food} \times BAF\text{-}S + IR_{soil})$; 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); $BAF\text{-}S$ = 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 × 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}	**4.32×10^{1}**
Alternative Combination 2	1.67×10^{-1}	1.37×10^{-1}	**1.13**	1.43×10^{-2}	**1.37**	3.69×10^{-2}	**4.31×10^{1}**
Alternative Combination 3	1.67×10^{-1}	1.37×10^{-1}	**1.13**	1.43×10^{-2}	**1.37**	3.69×10^{-2}	**4.31×10^{1}**
Cumulative Impacts Under Alternative Combinations							
	Uranium-238	**Lead**		**Chromium[b]**	**Nitrate**	**Fluoride**	**Chromium[b]**
Alternative Combination 1	**2.14×10^{1}**	**1.31×10^{2}**	**4.59×10^{2}**	2.06×10^{-1}	**2.64**	**2.21**	**2.32×10^{2}**
Alternative Combination 2	**2.14×10^{1}**	**1.31×10^{2}**	**4.59×10^{2}**	2.06×10^{-1}	**2.64**	**2.21**	**2.32×10^{2}**
Alternative Combination 3	**2.14×10^{1}**	**1.31×10^{2}**	**4.59×10^{2}**	2.06×10^{-1}	**2.64**	**2.21**	**2.32×10^{2}**

[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}	**3.58×10^{1}**	**4.33**	4.81×10^{-1}	4.60×10^{-1}	**2.32×10^{2}**
Fluoride	No TRV	9.77×10^{-2}	**3.25×10^{2}**	**3.48×10^{1}**	**2.21**	**1.68**	No TRV
Lead	**9.39×10^{-1}**	**8.62×10^{-2}**	**4.59×10^{2}**	**1.31×10^{2}**	**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}	**2.95×10^{1}**	**6.63×10^{1}**	9.09×10^{-2}	**1.55**	**4.91**
Radioactive Constituents of Potential Concern							
Uranium-238	**2.14×10^{1}**	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)
***TC & WM EIS* 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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CHAPTER 7
ENVIRONMENTAL CONSEQUENCES AND MITIGATION DISCUSSION

Chapter 7 discusses environmental consequences that would occur due to implementation of the reasonable alternatives for each of the following: (1) tank waste retrieval, treatment, and disposal and single-shell tank system closure at the Hanford Site (i.e., tank closure); (2) decommissioning of the Fast Flux Test Facility and auxiliary facilities and disposition of the inventory of radioactively contaminated bulk sodium (i.e., Fast Flux Test Facility decommissioning); and (3) management of waste resulting from other Hanford Site activities and limited volumes from other U.S. Department of Energy sites (i.e., waste management). Chapter 4 presents more-detailed analysis of short-term impacts; Chapter 5, of long-term impacts. As previously discussed in Chapter 4, Section 4.4, three representative scenarios, or combinations of alternatives, were selected to facilitate comparison of the alternatives and discussion of the analyses.

Section 7.1 discusses mitigation measures that could be implemented to reduce or avoid environmental impacts on each resource area or discipline (e.g., geology and soils) and identifies resource areas that could be affected such that consideration of additional mitigation measures may be warranted. Section 7.2 discusses adverse impacts that are unavoidable and would occur even after implementation of all of the reasonable mitigation measures discussed in Section 7.1. Section 7.3 discusses the major irreversible and irretrievable resource commitments that would be made under all alternatives. Section 7.4 discusses the relationship between short-term uses of the environment and the maintenance and enhancement of its long-term productivity. Section 7.5 provides an expanded discussion of the groundwater sensitivity analyses and potential long-term groundwater mitigation strategies.

Detailed analyses and discussions of environmental justice concerns, that is, potential high and disproportionate impacts on minority and low-income populations, are provided in Chapter 4, Sections 4.1.13, 4.2.13, and 4.3.13, and are not repeated in this chapter. The discussion presented in this chapter on public health and occupational safety includes impacts estimated under the alternatives related to normal operations, facility accidents, and waste transportation.

7.1 MITIGATION

This section describes the mitigation measures that could be used to avoid or reduce environmental impacts resulting from implementation of the alternatives described in previous chapters. As specified in Council on Environmental Quality (CEQ) National Environmental Policy Act (NEPA) regulations (40 CFR 1508.20), mitigation includes the following:

- Avoiding the impact altogether by not taking a certain action or parts of an action
- Minimizing the impact by limiting the degree or magnitude of the action and its implementation
- Rectifying the impact by repairing, rehabilitating, or restoring the affected environment
- Reducing or eliminating the impact over time by preserving and maintaining the affected environment during the life of the action
- Compensating for the impact by replacing or providing substitute resources or environments

All of the *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington (TC & WM EIS)* alternatives, including the No Action Alternative, have the potential to impact one or more resource areas or disciplines over the timeframes analyzed in this environmental impact statement (EIS). Resource areas that could be negatively impacted include land 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 (human health), and waste management. To mitigate impacts on resource areas, activities associated with the *TC & WM EIS* proposed action alternatives would follow standard procedures and best management practices for facility construction and would consider incorporating, where applicable, the best demonstrated available technologies for facility operations and closure. The

U.S. Department of Energy (DOE) is already applying best management practices to minimize environmental impacts in association with ongoing Waste Treatment Plant (WTP) construction. These practices are required by Federal and state licensing and permitting requirements, as described in Chapter 8.

The 1996 *Tank Waste Remediation System, Hanford Site, Richland, Washington, Final Environmental Impact Statement (TWRS EIS)* (DOE and Ecology 1996) described possible mitigation measures for the projected short- and long-term impacts of the proposed action alternatives for tank waste retrieval and treatment. DOE committed to these mitigation measures, as documented in the 1997 *TWRS EIS* Record of Decision (ROD) (62 FR 8693).

The 1999 *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement (Hanford Comprehensive Land-Use Plan EIS)* (DOE 1999a) identified specific mitigation measures, policies, and management controls that direct land use at the Hanford Site (Hanford). DOE committed to these mitigation measures, as documented in the 1999 *Hanford Comprehensive Land-Use Plan EIS* ROD (64 FR 61615). These commitments were reaffirmed in the 2008 *Supplement Analysis, Hanford Comprehensive Land-Use Plan Environmental Impact Statement (Hanford Comprehensive Land-Use Plan EIS SA)* (DOE 2008) and in the associated ROD (73 FR 55824).

The mitigation measures associated with the *TWRS EIS*, *Hanford Comprehensive Land-Use Plan EIS*, and *Hanford Comprehensive Land-Use Plan EIS SA* would continue to be implemented, as applicable, in coordination with the tank waste retrieval and treatment activities discussed in this EIS.

Following completion of this *TC & WM EIS* and its associated ROD, DOE would be required to prepare a mitigation action plan that explains mitigation commitments expressed in the ROD (10 CFR 1021.331). This mitigation action plan would be prepared before DOE would implement any *TC & WM EIS* alternative actions that are the subject of a mitigation commitment expressed in the ROD.

Following completion of the mitigation action plan and before implementing any closure actions, DOE will develop a tank farm system closure plan that will be implemented for each of the waste management areas. The State of Washington "Dangerous Waste Regulations" (WAC 173-303) implement the Hazardous Waste Management Act of 1976, as amended. These regulations provide the requirements for decisionmaking regarding the cleanup and permitting of dangerous wastes. The regulations define the state closure standards for the owners and operators of all dangerous waste facilities (WAC 173-303-610(2)) and include references to requirements for tank systems (WAC 173-303-640). Requirements for a response to a leak or spill and unfit-for-use tank systems are also described (WAC 173-303-640(7)). The regulations describe specific requirements for closure of the tank system (WAC 173-303-640(8)(a) and (b)). This part of the regulations provides a requirement for DOE to "remove or decontaminate all waste residues, contaminated soils, and structures and equipment contaminated with waste" for the tank system. If DOE "demonstrates that not all contaminated soils can be practically removed or decontaminated," then closure is required (WAC 173-303-640(8)(b)). The closure plan will include a preliminary performance assessment. The plan will be reviewed to ensure regulatory compliance by the Washington State Department of Ecology and presented for public comment before approval as a modification to the Hanford sitewide permit. This process is described in Appendix I of the Hanford Federal Facility Agreement and Consent Order, also known as the Tri-Party Agreement (TPA). A closure plan will be submitted for each waste management area that meets the compliance schedule and requirements of the TPA, as well as those of the state closure standards (WAC 173-303-610(2)) and the *TC & WM EIS* ROD. The Washington State Department of Ecology will consider all EIS mitigation information and any additional, relevant information when developing the closure plan. As an example of the current process, the TPA has milestones for the completion of a soil investigation for Waste Management Area C (Milestone M-45-61), submittal of a closure plan (Milestone M-45-82), and completion of Waste Management Area C closure (Milestone M-45-83). DOE will complete the soil investigation to determine the nature and extent of the contamination. To inform the decision process for closure, DOE will complete a Waste Management Area C performance assessment and risk assessment. Following completion of the tank waste retrievals and data collection activities for residuals in the pipelines, ancillary equipment, and soil, the performance assessment will be revised to include all data. This revised performance assessment and closure plan will be presented for public review and comment, and the Waste Management Area C closure plan will be modified and incorporated into the Hanford sitewide permit.

DOE has incorporated several mitigation measures into the alternatives proposed in this EIS to prevent or reduce their short- and long-term environmental impacts. Some mitigation measures were incorporated into all of the alternatives, and some represent variations in one or more of the elements or technologies used to construct the alternatives. Table 7–1 summarizes the potential mitigation measures by resource area; these mitigation measures are discussed in more detail in the sections that follow. The table is divided into three groups: the first group presents mitigation measures that would normally be considered regardless of impact severity; the second group presents additional mitigation measures that may be necessary for cases in which specific short-term impacts are projected to approach or exceed existing capacities, regulatory thresholds, or other guidelines; and the third group presents additional mitigation measures for cases in which specific long-term impacts may require special consideration.

While some mitigation measures have already been incorporated into the actions proposed under the *TC & WM EIS* alternatives, some may have not yet been identified; these would be implemented after issuance of the ROD. Furthermore, because of the relatively long timeframes required to conclude each alternative's life cycle, additional and more-effective mitigation measures may become available in the future that could reduce the environmental impacts associated with a proposed action. DOE will continue to identify and incorporate new technologies or practices that could potentially reduce the impacts throughout the life cycle of a selected alternative.

As discussed in Chapter 5 of this *TC & WM EIS*, DOE acknowledges that benchmark standards could be exceeded in groundwater at the Core Zone Boundary and/or the Columbia River nearshore on various dates. In response to comments received on the *Draft TC & WM EIS* concerning these potential long-term impacts on groundwater resources, additional sensitivity analyses were performed and are included in this final EIS. The additional analyses focus on factors perceived to have a substantial influence on the magnitude of long-term groundwater impacts. The factors evaluated in this final EIS include (1) reduction in the availability of constituents of potential concern (COPCs) for discharge into the environment (e.g., flux reduction) that might mimic remedial actions conducted at some of the more-prominent waste sites on the Central Plateau and along the river corridor or restrictions on the receipt and disposal of offsite waste at Hanford; (2) modification of treatment processes (e.g., iodine-129 recycle, technetium-99 removal); and (3) improvements in Integrated Disposal Facility (IDF) performance (e.g., infiltration rates) and in secondary- and supplemental-waste-form performance (e.g., release rates). Section 7.5 was added to this final EIS and provides a more detailed discussion of this topic and summarizes the results of these analyses. The results of these analyses will aid DOE in formulating an appropriate mitigation action plan subsequent to this final EIS and its associated ROD(s) and in prioritizing future Hanford remedial actions that would be protective of human health and the environment and would reduce long-term impacts on groundwater.

Table 7–1. Summary of Potential Mitigation Measures

Resource Area	Mitigation Measures
Potential Mitigation Measures	
Land resources	• Locate facilities in proximity to related activities. • Maintain and coordinate land use as described in the *Hanford Comprehensive Land-Use Plan EIS* (DOE 1999a), the subsequent *Hanford Comprehensive Land-Use Plan EIS SA* (DOE 2008), and their associated RODs (64 FR 61615 and 73 FR 55824). • Use existing buildings or disturbed land. • Use existing permitted facilities to supplement activities. • Use existing infrastructure and rights-of-way. • Expedite restoration of land upon completion of mission, and when appropriate, emphasize long-term reclamation versus interim site stabilization.
Infrastructure	• Incorporate high-efficiency motors, pumps, lights, and other energy conservation measures into the design of new facilities. • Schedule operations during offpeak times. • Sequence operations to minimize peak use of utilities.
Noise and vibration	• Limit construction to daylight hours. • Maintain equipment mufflers. • Restrict use of horns and use appropriately sized heavy equipment. • Plan truck routes and timing of traffic.
Air quality	• Implement dust suppression techniques, such as application of water or surfactants. • Use low-sulfur fuels or alternative fuel vehicles. • Maintain equipment in peak working condition. • Implement zone ambient air monitoring to monitor effectiveness of engineering controls. • Sequence and schedule construction and/or operations of activities. • Limit the amount of disturbed land areas and revegetate land as soon as possible. • Incorporate best available air pollution control technologies into design of new facilities. • Use containment structures for excavation activities, whenever appropriate.
Geology and soils	• Manage borrow materials as described in the *Hanford Comprehensive Land-Use Plan EIS* (DOE 1999a), the subsequent *Hanford Comprehensive Land-Use Plan EIS SA* (DOE 2008), and their associated RODs (64 FR 61615 and 73 FR 55824) to address requirements such as contouring and revegetating the landscape to match the natural surroundings. • Use disturbed land areas whenever possible. • Limit the time disturbed soils are exposed and/or use protective covers over denuded areas and stockpiles. • Adhere to best management practices for erosion and sedimentation control (e.g., dust suppression, soil fixation). • Restore and recontour disturbed areas to preexisting and culturally relevant conditions to the maximum extent possible.

Table 7–1. Summary of Potential Mitigation Measures *(continued)*

Resource Area	Mitigation Measures
Potential Mitigation Measures *(continued)*	
Water resources	• Continue to operate or deploy groundwater remediation technologies such as a pump-and-treat system, temporary or reactive barriers, or other groundwater extraction and treatment methods. • Implement spill prevention and control and stormwater pollution prevention plans. • Incorporate water conservation practices into routine operations. • Adhere to strict waste acceptance criteria for burial at one of the proposed or existing waste disposal facilities. • Consider higher levels of tank waste retrieval to mitigate impacts on groundwater (e.g., 90 percent, 99 percent, 99.9 percent). • Implement groundwater-quality monitoring programs. • Construct engineered surface barriers with liners and leachate collections systems. • Extend duration of postclosure care or administrative control period.
Ecological resources	• Implement mitigation measures similar to those listed for land. • Provide compensatory mitigation of sagebrush habitat or other sensitive plant species encountered. • Demarcate construction and land disturbance zones clearly to limit intrusion into non-work areas. • Avoid special status plant and animal species whenever possible. • Implement spill prevention and control plans. • Avoid interfering with animal breeding or nesting areas or periods.
Cultural and paleontological resources	• Assign an archaeological monitor during construction and other earth-disturbing activities. • Perform surveys to identify prehistoric or cultural resources prior to initiating earth-disturbing activities, and avoid any discovered resources. Visual aspects: • Stockpile borrow material or coordinate the timing of excavation activities (e.g., at night) in Borrow Area C to avoid interfering with tribal ceremonial and religious activities that could be affected visually from Rattlesnake Mountain. • Remove unnecessary facilities or infrastructure when no longer needed. • Consolidate facilities or infrastructure where appropriate. • Restore and/or revegetate disturbed areas in a culturally relevant manner. • Provide minimal maintenance to exterior of buildings, equipment, and roads to reduce disturbed areas.
Socioeconomics	• Construct and operate new facilities in sequence, rather than concurrently, whenever possible, to reduce the demand on employment resources and associated public services. • Upgrade select traffic routes or intersections. • Use alternate work schedules or expand the existing carpool and commuter program in accordance with Washington's commute trip reduction policy. • Coordinate shipment of materials and waste with heavy commute or public traffic timeframes.

Table 7–1. Summary of Potential Mitigation Measures *(continued)*

Resource Area	Mitigation Measures
Potential Mitigation Measures *(continued)*	
Public and occupational health and safety	• Incorporate best available demonstrated technologies for reducing release of radioactive emissions. • Maintain acceptable worker doses by implementing ALARA techniques (e.g., reducing time of exposure, increasing number of workers, using shielding, implementing remote operations). • Prepare shipments of waste in containers certified for the intended purpose, and train and license handlers and transporters.
Waste management	• Implement pollution prevention and waste minimization techniques. • Investigate technologies that have the potential to increase WTP melter life and increase waste loading (e.g., sulfate removal).
Additional Considerations for Short-Term Mitigation Measures	
Infrastructure	WTP operations would place a high demand on Hanford's electrical grid for an extended amount of time and are projected to approach or, under some alternatives, exceed existing peak capacity. To mitigate this impact, the following steps could be taken: (1) prepare an energy consumption plan, (2) supplement electric power supply from alternative sources, and (3) upgrade Hanford's distribution system.
Air quality	Construction activities are projected to exceed ambient air quality standards for particulate matter under most alternatives, and in some cases, for carbon monoxide or nitrogen dioxide as well. However, the projections do not take into account implementation of all reasonable mitigation measures. Mitigation measures may be necessary to ensure applicable standards are met. A more refined analysis, assuming implementation of reasonable engineering controls, would likely result in a substantial reduction in projected emissions of criteria air pollutants.
Geology and soils	The analysis in this *TC & WM EIS* assumes all borrow material would come from Borrow Area C and no excavation soils from waste management disposal facility or new facility construction would be used. To mitigate this impact, the extraction and management of geologic materials would be executed in a manner consistent with the policies and resource management plans as described in the *Hanford Comprehensive Land-Use Plan EIS* (DOE 1999a), the subsequent *Hanford Comprehensive Land-Use Plan EIS SA* (DOE 2008), and their associated RODs (64 FR 61615 and 73 FR 55824).
Public and occupational health and safety	Under *TC & WM EIS* Tank Closure Alternatives 4, 6A, and 6B, which would involve either partial (under Alternative 4) or complete (under Alternatives 6A and 6B) clean closure of the tank farms, the average worker dose would approach and, in some cases, potentially exceed DOE's Administrative Control Level of 500 millirem per year. In these cases, a comprehensive evaluation of worker exposures may be warranted to determine which activities are the largest contributors to worker dose and to implement aggressive ALARA techniques to ensure worker doses remain below the appropriate levels. In addition, public exposure during the peak year of activities, although low, would coincide with the relatively short operation of the cesium and strontium capsule processing campaign in the WTP. The processing of this material could be spread over a longer timeframe, thus mitigating the peak impact on the public.
Waste management	Under *TC & WM EIS* Tank Closure Alternatives 6A, 6B, and 6C, all tank waste would be managed as HLW, representing a significant increase in waste volume managed as HLW by a factor of at least 14 times more than other action alternatives. Under these alternatives, the treated radioactive tank waste would be stored on site. To mitigate potential impacts of storing large quantities of HLW, waste management areas could be modified as necessary.

Table 7–1. Summary of Potential Mitigation Measures *(continued)*

Resource Area	Mitigation Measures
Additional Considerations for Long-Term Mitigation Measures	
Water resources	Several COPCs are predicted to exceed or approach benchmark concentrations in groundwater at the Core Zone Boundary and/or the Columbia River nearshore at various dates. The COPCs resulting in the majority of impacts include the radionuclides hydrogen-3 (tritium), iodine-129, technetium-99, and uranium-238 and the chemicals chromium, nitrate, and total uranium. These COPC drivers are consistent across all *TC & WM EIS* alternatives. Potential mitigation measures that could be considered include the following: • Increase partitioning of COPC drivers into ILAW and/or IHLW forms by recycling secondary-waste streams into primary-waste feeds or adopting pretreatment removal technologies that would target COPCs (e.g., technetium removal). • Continue research and development for more-robust, long-term-performing secondary-waste forms and supplemental-treatment primary-waste forms. • Design and construct more-robust surface barriers or require periodic replacements of engineered barriers. • Restrict the receipt of offsite waste to waste that would have low impacts on groundwater over the long term at Hanford (e.g., limit or restrict receipt of offsite waste containing iodine-129 or technetium-99 at Hanford). Note: For example, DOE evaluated in this final EIS the effect of applying waste acceptance criteria to offsite waste by removing a highly radioactive waste stream (i.e., high inventories of iodine-129 and technetium-99) from the inventory of offsite waste analyzed for disposal at Hanford. • Implement comprehensive groundwater-quality monitoring programs with contingency corrective action plans.
Ecological resources	Long-term impacts on ecological receptors from air emissions and groundwater contamination are expected to be minor; however, because a reduction in impacts on air quality and water resources would result in a corresponding reduction in ecological receptor risk, the mitigation measures discussed under "Air Quality" and "Water Resources" could also reduce impacts on ecological resources. Additionally, periodic monitoring programs for ecological receptors could provide early detection of declining populations and, if necessary, implementation of corrective actions.
Public and occupational health and safety	Impacts on offsite receptors would be negligible when compared with background exposures; however, impacts on onsite receptors that consume groundwater as a drinking water source would exceed dose standards for one or more COPCs. Long-term impacts on human health receptors (e.g., resident farmer) are indirect impacts that would result from long-term impacts on other resources, such as groundwater (e.g., water used for irrigating land, drinking water) or ecological resources (e.g., consumption of animals or fish). As such, any potential mitigation measures that could reduce impacts on water resources and/or ecological resources may also be applicable for mitigation of human health impacts.

Key: ALARA=as low as is reasonably achievable; COPC=constituent of potential concern; DOE=U.S. Department of Energy; EIS=environmental impact statement; Hanford=Hanford Site; *Hanford Comprehensive Land-Use Plan EIS=Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement*; *Hanford Comprehensive Land-Use Plan EIS SA=Supplement Analysis, Hanford Comprehensive Land-Use Plan Environmental Impact Statement*; HLW=high-level radioactive waste; IHLW=immobilized high-level radioactive waste; ILAW=immobilized low-activity waste; ROD=Record of Decision; *TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*; WTP=Waste Treatment Plant.

DOE has prepared or will potentially prepare a number of area and resource management plans, as described in the *Hanford Comprehensive Land-Use Plan EIS* (DOE 1999a), the subsequent *Hanford Comprehensive Land-Use Plan EIS SA* (DOE 2008), and their associated RODs (64 FR 61615 and 73 FR 55824). These plans are either in draft form, have been completed, are being revised, or are waiting on available funds and program prioritization (DOE 2008). These plans and their status are summarized as follows:

- *Hanford Site Ground Water Protection Management Plan*: Final
- *Groundwater Vadose Zone Integration Project Summary Description*: Final
- *Hanford Institutional Control Plan*: Final
- *Ecological Compliance Assessment Management Plan*: Final
- *Hanford Long-Term Stewardship Program and Transition*: *Preparing for Environmental Cleanup Completion*: Final
- *Threatened and Endangered Species Management Plan, Salmon and Steelhead (T&ESMP-SS)*: Final

    Chinook Salmon-Upper Columbia River Spring Run Hanford Management Plan (sub-tier to *T&ESMP-SS*): Final

    Steelhead-Middle Columbia River Run Hanford Management Plan (sub-tier to *T&ESMP-SS*): Final

- *Hanford Cultural Resources Management Plan (HCRMP)*: Final pending revision

    Gable Mountain and Gable Butte Resource Management Plan (sub-tier to *HCRMP*): Final

    Rattlesnake Mountain Cultural Resource Management Plan (sub-tier to *HCRMP*): Draft pending

    Aesthetic and Visual Resources Management Plan (sub-tier to *HCRMP*): Draft pending revision

- *Hanford Site Biological Resources Management Plan (BRMaP)*: Final pending revision

    Hanford Site Biological Resources Mitigation Strategy (sub-tier to *BRMaP*): Final pending revision

    Fire Management Plan (sub-tier to *BRMaP*): Final pending revision

    Noxious Weed Management Plan (sub-tier to *BRMaP*): Final pending revision

- *Hanford Bald Eagle Management Plan*: Final pending revision
- *Facility and Infrastructure Assessment and Strategy*: Draft
- *Industrial Mineral Resources Management Plan*: Draft
- *Fitzner-Eberhardt Arid Lands Ecology Reserve Comprehensive Conservation Plan*: Draft
- *Wahluke Slope Comprehensive Conservation Plan*: Draft
- *Columbia River Corridor Area Management Plan*: Draft
- *Hanford Site Watershed Management Plan*: Pending available funds and program prioritization
- *South 600 Area Management Plan*: Pending available funds and program prioritization

As these management plans become available, special management or mitigation required by the procedures outlined in the plans would be implemented for the proposed *TC & WM EIS* activities, as appropriate.

7.1.1 Land Resources

Land resources would be used to construct facilities for the treatment, storage, or retrieval of tank closure or Fast Flux Test Facility (FFTF) decommissioning and closure waste. The duration and amount of land used would vary depending on the alternative. Land resources would also be used to construct permanent disposal facilities in support of the Waste Management alternatives. Construction of tank waste retrieval, treatment, storage, and permanent disposal facilities would occur primarily within the 200 Areas, which are encompassed by the Central Plateau. In the *Hanford Comprehensive Land-Use Plan EIS* (DOE 1999a) and associated ROD (64 FR 61615), the Central Plateau was designated Industrial-Exclusive, and the 400 Area was designated for industrial use. There are two exceptions in which new facilities would be constructed outside the Central Plateau. The first exception would be construction of the Remote Treatment Project (RTP) under the FFTF Decommissioning action alternatives; this facility would be built in the existing T Plant complex in Hanford's 400 Area under the Hanford Option. The second exception would be construction of additional Immobilized High-Level Radioactive Waste (IHLW) Interim Storage Modules east of the Central Plateau (covering an area of 86.2 hectares [213 acres]) under Tank Closure Alternative 6A. Under this alternative, all tank waste would be managed as high-level radioactive waste (HLW) and treated to become IHLW.

In addition to the construction of new facilities, land resources would be mined for geologic materials necessary for implementation of the alternatives. Borrow Area C is an approximately 926.3-hectare (2,289-acre) borrow area designated to provide all borrow materials, including rock, riprap (basalt), aggregate (gravel and sand), and soil (silt and loam), for facility construction and associated activities described in this EIS. In the *Hanford Comprehensive Land-Use Plan EIS* (DOE 1999a) and associated ROD (64 FR 61615), Borrow Area C is designated as Conservation (Mining).

As described in the *Hanford Comprehensive Land-Use Plan EIS* (DOE 1999a), the subsequent *Hanford Comprehensive Land-Use Plan EIS SA* (DOE 2008), and their associated RODs (64 FR 61615 and 73 FR 55824), to mitigate impacts, representative locations for new facilities to support tank waste retrieval, treatment, storage, and disposal under each of the alternatives may have been chosen based on the following factors or by taking the following steps:

- Location of all facilities, to the maximum extent practical, within the Central Plateau Industrial-Exclusive land use zone (i.e., the 200-East and 200-West Areas and areas in between).

- Proximity to similar facilities (e.g., landfills near landfills), supporting infrastructure, or the tank farms.

- Proximity of Borrow Area C to the Central Plateau.

- Availability of sufficient uncontaminated space not reserved for use by other Hanford projects.

- Maintenance of proposed land use within the Industrial-Exclusive and Conservation (Mining) land use zones.

- Selection and use of existing buildings whenever possible.

- Collocation of related actions and interdependent facilities to reduce the areal extent of land disturbance (e.g., supplemental treatment facilities and Cesium and Strontium Capsule Processing Facility adjacent to the WTP).

- Use of existing infrastructure and rights-of-way.

- Expedient restoration and re-landscaping of open areas upon completion of construction-related activities or upon termination and closure of a facility at the completion of its mission.

- Restoration of Borrow Area C through activities including regrading; contouring the landscape; revegetating to match the natural landscape using native species; and adhering to best management practices for soil erosion and sediment control in accordance with appropriate resource management plans, such as a final adopted version of the *Draft Industrial Mineral Resources Management Plan* (Reidel, Hathaway, and Gano 2001).

Several Tank Closure alternatives would require the construction of more facilities than others; however, such construction would be designed to make use of options that could help mitigate impacts on other resource areas. For example, Tank Closure Alternatives 3A, 3B, 3C, 4, and 5 all analyze the construction of supplemental treatment facilities for treating tank waste. Supplemental treatment would shorten the length of time required to treat tank waste, which may help reduce impacts on other resource areas. In other cases, the treatment of all tank waste through the WTP under Alternative 2A or the clean closure of all single-shell tank (SST) farms under Alternatives 6A and 6B would require long implementation timeframes. This may lead to better-performing waste forms, but, as a consequence of the longer implementation timeframes, replacement facilities or construction of new double-shell tanks (DSTs) may become a necessity.

Land resources located in the Industrial-Exclusive zone and dedicated to permanent waste management or buffer areas in the long term would not be available for unrestricted use. This particular impact cannot be mitigated and would be considered a long-term impact or commitment of land resources, as discussed in Section 7.3.

7.1.2 Infrastructure

Except for electric power required under Tank Closure Alternative 6A, Base and Option Cases, in which all tank waste would be treated as HLW in the WTP, none of the other *TC & WM EIS* alternatives are expected to consume energy, fuel, or water resources exceeding that which can be provided through existing infrastructure. Existing facilities and infrastructure could be utilized whenever possible to mitigate any necessary changes or upgrades. Necessary and new facilities associated with the *TC & WM EIS* action alternatives could be constructed within areas that have existing infrastructure and rights-of-way whenever possible. If needed, new infrastructure would be constructed consistent with the *Hanford Comprehensive Land-Use Plan EIS* (DOE 1999a), the subsequent *Hanford Comprehensive Land-Use Plan EIS SA* (DOE 2008), and their associated RODs (64 FR 61615 and 73 FR 55824).

To satisfy short-lived demands on utilities (such as those typical during construction), portable generators, temporary work lighting, portable water and fuel storage vessels, and portable sanitary facilities could be used to mitigate the need for upgrades to the existing, permanent infrastructure. This would be especially true for those activities that would occur in locations that do not have readily available tie-ins to the existing infrastructure.

The estimated peak electrical usages under the Tank Closure action alternatives range from 28 percent to 113 percent of available capacity, as discussed in Chapter 4, Section 4.1.2. The high demand for electric power would be largely due to WTP operations, particularly operation of the HLW melters. Under Tank Closure Alternative 6A, Base and Option Cases, in which all tank waste would be vitrified in the WTP HLW melters, demand is projected to exceed the peak electrical capacity of Hanford's electric power distribution system. Even though activities under the other Tank Closure alternatives are not projected to exceed the available peak capacity, electrical consumption is expected to remain near Hanford's peak capacity for the duration of WTP operations analyzed under each alternative. The consumption of electric power during WTP operations may require mitigation or the implementation of an energy consumption plan. The following steps could be taken to mitigate electrical consumption:

- Incorporate high-efficiency motors, pumps, lights, and other energy-saving equipment into the design of new facilities.
- Schedule operations during offpeak times.
- Sequence operations to minimize peak use of utilities.
- Use alternative or supplemental methods to supply electricity that would not disrupt or threaten to disrupt the regional supply grid.

Infrastructure demands under the FFTF Decommissioning and Waste Management alternatives are expected to be relatively low and thus would not require implementation of additional mitigation measures. Pursuant to DOE Order 430.2B, *Departmental Energy, Renewable Energy and Transportation Management*, and Executive Order 13514, *Federal Leadership in Environmental, Energy, and Economic Performance*, DOE has established agency-wide goals for energy efficiency and water conservation improvements at DOE sites, including reductions in energy and potable water consumption, use of advanced electric metering systems, use of sustainable building materials and practices, and use of innovative renewable and clean energy sources. Consideration given to implementing policies under the Tank Closure, FFTF Decommissioning, and Waste Management alternatives consistent with Executive Order 13514 could reduce impacts on infrastructure.

7.1.3 Noise and Vibration

Generally, noise impacts on residential developments and other offsite public areas under the proposed *TC & WM EIS* alternatives are expected to be negligible because most activities would take place in the interior portion of Hanford (the Central Plateau) and away from these sensitive locations. The noise impacts projected to occur in the Central Plateau areas would not represent a significant increase over current levels. However, noise impacts would affect wildlife near Borrow Area C the most. Activities in Borrow Area C could be limited to daylight hours. Noise impacts during construction would be minimized by maintaining the equipment to ensure that the mufflers and other components are operating properly, by restricting the use of vehicle horns, and by using appropriately sized equipment. Noise from truck traffic coming and going from work sites could be mitigated by planning the routes and timing of truck traffic.

7.1.4 Air Quality

The *TC & WM EIS* action alternatives would involve construction of (1) new facilities over varying timeframes; (2) large permanent disposal facilities; and (3) surface barriers for tank farms, cribs and trenches (ditches), and disposal facilities. Construction activities would generate criteria and hazardous air pollutants. Emissions would be associated with diesel-fueled construction equipment and other fuel-burning equipment (e.g., generators) and vehicles. Construction equipment emissions can be minimized by using more-refined fuels (e.g., low-sulfur diesel fuel) and by maintaining the equipment to ensure that emissions control systems and other components are functioning at peak efficiency. Most notably, fugitive dust emissions would occur as a result of land disturbance by heavy equipment and vehicles, causing suspension of particulate matter from exposed soil in the air. Ambient monitoring and engineering controls may be necessary to maintain pollutants below acceptable levels. Engineering controls could include watering and/or using surfactants to control dust emissions from exposed areas and storage piles, revegetating exposed areas, sequencing and scheduling work, watering roadways, and minimizing construction activity in dry or windy conditions (during late summer and fall). DOE is currently applying these measures in constructing the WTP. For activities that could disturb contaminated dust (e.g., removal of tank farms), excavation work could take place beneath domed containment structures using negative-pressure systems, air locks, and water sprays.

As discussed in Chapter 4, Sections 4.1.4 and 4.3.4, construction and other earth-disturbing activities associated with all Tank Closure and Waste Management alternatives, including No Action, have the potential to cause particulate matter to exceed standards. The 1-hour average concentrations of carbon monoxide and nitrogen dioxide are also projected to exceed standards under several Tank Closure alternatives. However, the analysis of emissions did not consider the emissions controls described above that could be employed in construction areas to mitigate impacts. Before implementation of any Tank Closure or Waste Management alternative, a more refined analysis of emissions, assuming reasonable control technologies and more-detailed construction activities, would need to be performed; this analysis is expected to result in substantially lower estimates of emissions and ambient concentrations of criteria pollutants under all *TC & WM EIS* alternatives. Concentrations of other hazardous air pollutants are projected to be within acceptable levels under all *TC & WM EIS* alternatives and below any published acceptable source impact levels, except mercury under Tank Closure Alternatives 2B, 6B, and 6C.

New facility process operations (especially operations of the WTP and its supporting facilities) and subsequent deactivation would generate airborne emissions of various pollutants, including radionuclides and nonradioactive organic and inorganic chemicals. Because a variety of air pollutant contributors and processes could be operating under the action alternatives, a variety of air pollutant control technologies could be considered. For example, for removal of airborne particulates and gaseous emissions, the following control technologies could be considered in process design:

- The cyclone precipitator is a common industrial technology used as a precleaning step ahead of more-expensive and -effective control systems for removal of particulates. Because this technology is commonly used at commercial concrete production facilities, it would be a good candidate for precleaning emissions emanating from nonthermal treatment systems, such as the Cast Stone Facility. It would generally not be a useful control technology for thermal waste treatment systems, such as the WTP, and its use in radioactive environments may be limited as well.

- The electrostatic precipitator is another useful technology for control of particulate emissions. The current WTP design calls for installation of wet electrostatic precipitators. This technology would remove particulates and some of the vapor included in the air stream and could provide effective treatment for all of the air emissions generated from all waste treatment systems currently considered in this *TC & WM EIS*.

- Direct filtration can also be effective in controlling particulates. One typical industrial application is a baghouse filter system. Direct filtration via high-efficiency particulate air (HEPA) filters has been shown to be very effective at controlling particulates at Hanford. HEPA filters can be used (and will probably be required) for all of the waste treatment systems analyzed in this EIS as long as the exhaust stream temperature can be properly tempered.

- Scrubber systems are another effective air treatment control technology. Currently, the WTP design includes two kinds of scrubbers: caustic and submerged bed. Scrubbers can be used with all currently planned waste treatment technologies. Submerged bed scrubbers are effective at reducing particulate loading in the airborne emissions stream. They can be used on any of the waste treatment technologies considered in this EIS. Caustic scrubbers are effective in treating acid gases produced as part of the thermal treatment system. They would be an effective control on all of the thermal waste treatment system facilities (e.g., WTP, bulk vitrification) but would not provide any additional reduction to the nonthermal systems (e.g., cast stone).

- Thermal oxidation systems are an important treatment technology for controlling emissions of organic chemicals and vapors because they burn these emissions. The current WTP design calls for inclusion of a thermal catalytic oxidizer.

- Carbon adsorption is another treatment technology that helps remove organics from the air emissions stream. This technology is very effective at removing organics and other vapors with the proper chemical affinity. However, as with HEPA filters, carbon adsorption systems are not very effective with high-temperature or liquid-saturated air streams; therefore, the stream must be properly tempered for this technology to be effective. Current WTP design calls for inclusion of a carbon-bed adsorption unit for removal of mercury vapor from the emissions stream.

- The current WTP plan calls for inclusion of a selective catalytic reduction unit for control of nitrous oxide. This type of system can be designed to treat specific chemicals in the airborne stream by using different catalysts and can help reduce acid gases in the emissions stream. This treatment technology could be an effective addition to most of the waste treatment systems and could be effectively implemented to address specific chemicals of concern.

- Pretreatment of waste streams prior to introduction to the WTP or other supplemental treatment processes could also help reduce airborne contaminants and gaseous emissions. Pretreatment would be employed to remove problematic toxic and radioactive air pollutants from the waste stream prior to treatment, thus eliminating or reducing the potential for emissions of target contaminants from the process stacks.

Executive Order 13514, *Federal Leadership in Environmental, Energy, and Economic Performance*, makes reduction of greenhouse gas emissions a priority for Federal agencies by establishing agency-wide goals to reduce the energy intensity in buildings, increase the use and generation of renewable energy, and reduce the use of fossil fuels in vehicle fleets. Consideration given to implementing policies under the Tank Closure, FFTF Decommissioning, and Waste Management alternatives consistent with Executive Order 13514 could reduce impacts on air quality, particularly those associated with climate change. For example, DOE could consider the use of cleaner-burning fuels such as natural gas in lieu of diesel fuel for WTP and/or other facility operations.

7.1.5 Geology and Soils

Impacts on geology and soils would generally be proportional to the total area of land disturbed by construction of new treatment, storage, and disposal facilities; the depth and lateral extent of excavations of the tank farms and other contaminated soils; and the total amount of geologic resources that would be mined from Borrow Area C. Excavation depths for new facility construction generally would not exceed about 12 meters (40 feet); however, deep soil excavation ranging from depths of 20 meters (65 feet) to as many as 78 meters (255 feet) below the land surface may be required for clean closure of the SST farms under Tank Closure Alternatives 6A and 6B or for clean closure of the BX and SX tank farms under Tank Closure Alternative 4. The majority of impacts on geology and soils would result from (1) mining materials to backfill tank farm excavations and permanent disposal facilities; (2) providing engineered backfill for construction of the WTP and related facilities; and (3) constructing engineered barriers for closure of the tank farms, cribs and trenches (ditches), River Protection Project Disposal Facility (RPPDF), and one or two IDFs. For analysis purposes, it was assumed that all required geologic resources for the *TC & WM EIS* alternatives would come only from Borrow Area C and would potentially involve disturbance of up to 619 hectares (1,530 acres) of land excavated to a depth of approximately 4.6 meters (15 feet). The greatest impact on Borrow Area C would occur under an alternative combination involving Tank Closure Alternative 6A, Option Case; FFTF Decommissioning Alternative 3; and Waste Management Alternative 2, Disposal Group 3. This potential combination of alternatives is not one of the three selected for analysis in this EIS. The following mitigating factors could possibly reduce the overall impact of mining operations from Borrow Area C:

- Extraction and management of geologic materials would be executed in a manner consistent with the policies and resource management plans described in the *Hanford Comprehensive Land-Use Plan EIS* (DOE 1999a), the subsequent *Hanford Comprehensive Land-Use Plan EIS SA* (DOE 2008), and their associated RODs (64 FR 61615 and 73 FR 55824).

- Borrow Area C would be restored through activities including regrading; contouring the landscape; revegetating to match the natural landscape; and adhering to best management practices for soil erosion and sediment control in accordance with appropriate resource management plans, such as a final adopted version of the *Draft Industrial Mineral Resources Management Plan* (Reidel, Hathaway, and Gano 2001).

Regardless of the use of borrow materials sources other than Borrow Area C, geologic resources would still be required in large quantities under some alternatives, and the long-term impacts of mining these materials would be realized.

Surface soils and unconsolidated sediments exposed in excavations and cut slopes during new facility construction would be subject to wind and water erosion if left exposed over an extended period of time. In all cases, adherence to standard best management practices for soil erosion and sediment control during construction would serve to minimize soil erosion and loss. Due to the number of construction projects that would be ongoing during the early years of each of the action alternatives, erosion of exposed soils cannot be completely eliminated during construction, but a number of practices could reduce overall impacts. Temporary soil disturbance outside the eventual footprint of new facilities could be limited by using inactive areas within the building footprints for material laydown, storage, and parking, as well as by using narrow access and egress corridors for construction equipment usage. In general, limiting the amount of time soils are exposed, limiting the area disturbed during any phase of a construction project, and applying protective coverings to denuded areas during construction (e.g., mulch, geotextiles) until the disturbed areas can be revegetated or otherwise covered by facilities could reduce the potential for soil loss. Soil loss and offsite transport could be further reduced by appropriate sedimentation and soil erosion and control devices, including sediment traps, sediment fences, staked hay bales, or other methods that Hanford's arid conditions may dictate. Stockpiles of soil removed during construction could be covered with a geotextile or temporary vegetative covering to protect them from erosion. This soil would normally be reclaimed for reuse on site—as backfill for facility excavations, for example. To reduce the risk from exposing contaminated soils, areas in which new facilities would be constructed would be surveyed prior to any ground disturbance, and any contamination could be remediated as necessary.

Mitigation measures, such as controlling the spread of contaminated soil or preventing the recontamination of remediated areas during decommissioning, could be implemented through the use of work sequencing, soil stabilization measures, temporary covers, and exclusion zones. Impacts on soils could also be mitigated by grading the land to create contours consistent with the surrounding environment.

7.1.6 Water Resources

There would be no direct discharge of effluents to either surface waters or groundwater during new facility construction, operations, or subsequent deactivation, and no appreciable impact on water quality is expected to result from routine activities. Nonhazardous process wastewater would be discharged to the Treated Effluent Disposal Facility in the 200-East Area, while radioactive liquid effluents would be discharged to the 200 Area Liquid Effluent Retention Facility prior to treatment in the Effluent Treatment Facility (ETF). It was assumed that these facilities, or their equivalents, would continue to be available to manage process liquids generated under the action alternatives, and that any necessary life extensions or replacements would be completed as needed.

Surface water and groundwater would be protected from hazardous materials spills by development and implementation of spill prevention and contingency plans for instances in which hazardous materials are being handled. These plans to minimize the potential for hazardous materials spills would include provisions for storage of hazardous materials and refueling of construction equipment within the confines of protective berms, as well as cleanup and recovery plans and emergency response notification plans and procedures. Spills would also be reduced by keeping vehicles and equipment in good working order to prevent oil and fuel leaks. Soil erosion and sediment control plans and stormwater pollution prevention plans would be implemented, as required, for any earth-disturbing activity to minimize the transport of suspended sediment or other deleterious materials to surface-water or groundwater bodies.

Portions of the probable maximum flood zone associated with Cold Creek lie within the confines of Borrow Area C. Mining of geologic materials to support tank closure and waste management activities would include consideration of impacts on the watercourse and associated floodplain. Any changes in the extent and nature of predicted mining that could impact the floodplain would be evaluated, and a floodplain assessment would be prepared, as required by Executive Order 11988, *Floodplain Management*, and other Federal regulations (10 CFR 1022).

Water resources requirements under any of the *TC & WM EIS* alternatives would be well below available resources; therefore, no mitigation would be required to provide alternative supplies. However, whenever possible, water conservation practices could be implemented.

Impacts on groundwater would occur over the long term under all of the alternatives. Contaminants from past SST system leaks and releases and other historic waste discharges in the 200 Areas that are already resident in the vadose zone would continue migrating downgradient to the unconfined aquifer and toward the Columbia River. Any future leaks from the SST or DST system and onsite disposal of waste would add to these impacts. The Tank Closure No Action Alternative would make the largest additional incremental contribution to existing contaminant releases over the long term because no tank waste retrieval and treatment or SST system closure would be performed. Even after implementation of corrective action measures to fill deteriorating tanks with grout or gravel, Hanford SSTs, DSTs, and miscellaneous underground storage tanks would fail over time, resulting in the unmitigated release of their entire contents to the vadose zone and unconfined aquifer system. However, elements of the Tank Closure action alternatives for tank waste storage, retrieval, treatment, and disposal and SST system closure that are analyzed in this *TC & WM EIS* incorporate mitigation measures to varying degrees for attenuating long-term groundwater-quality impacts. Under all of the Tank Closure action alternatives, waste residing in the SSTs and DSTs would be retrieved for treatment, leaving residual waste ranging from 0.1 to 10 percent of the waste volume in place. This *TC & WM EIS* assumed leaks from the SST system would occur during retrieval operations. As the analysis shows, even if the tanks were to leak during retrieval, retrieval and treatment of tank waste would reduce the incremental contribution of tank farm actions over the long term.

Waste forms generated as a result of tank waste treatment and from contaminated soil and debris would be disposed of in an onsite, engineered disposal facility (either an IDF or the RPPDF). Liners and leachate collection systems would be used to control infiltration of surface water, prevent effluent releases to the vadose zone, and actively monitor contaminant release levels so that appropriate corrective actions can be implemented. Corrective actions include installation of additional temporary barriers to halt contaminant migration or exhumation of waste for further treatment before redisposal. Temporary barriers have been placed on tank farms and could be applied to other locations. WTP immobilized low-activity waste (ILAW) forms could be formulated to preferentially retain contaminants to retard their release to the subsurface, or pretreatment steps could be employed to remove problematic constituents prior to treatment and disposal. Similarly, grouting of certain mixed low-level radioactive waste (MLLW) streams could prove successful in delaying release of some contaminants. However, in the long term, contaminants would eventually be released as systems fail and would eventually impact the vadose zone and groundwater.

DOE uses a proactive approach to protecting groundwater through the performance assessment process. Disposal facility performance assessments are routinely reviewed to ensure that facilities meet requirements established in DOE Orders 435.1, *Radioactive Waste Management*, and 458.1, *Radiation Protection of the Public and the Environment*. Changes in disposal facility waste acceptance criteria could be enforced if a review indicates that groundwater contamination might exceed applicable requirements. As a result, some waste could require further treatment prior to disposal, additional confinement (such as disposal in high-integrity containers), or the development and use of better long-term-performing waste forms. Waste that does not meet the waste acceptance criteria for immediate disposal could be stored until another treatment or disposal method is found.

Most Tank Closure alternatives would employ landfill closure of the tank farms, which would include placing an engineered surface barrier (either the modified Resource Conservation and Recovery Act [RCRA] Subtitle C barrier or the Hanford barrier design) over the tank farms to minimize water infiltration through the residual tank waste inventories and its subsequent transport through the vadose zone. The surface barrier would be monitored and maintained during a 100-year postclosure care period to ensure its structural integrity. For the Tank Closure alternatives that would employ clean closure of all tank farms (i.e., Alternatives 6A and 6B), the impacts were analyzed without assessment of such barriers. Tank Closure Alternative 4 represents a partial clean closure alternative; the BX and SX tank farms would be excavated and clean-closed, whereas other tank farms would be left in place. In addition, engineered surface barriers would be constructed for FFTF entombment and closure of waste management disposal facilities, such as one or two IDFs and the RPPDF. The Hanford barrier, a more robust surface barrier analyzed under Tank Closure Alternative 5, is a potential mitigating measure that could be incorporated into all alternatives for closure of tank farms, cribs and trenches (ditches), and waste management disposal facilities, depending on its performance compared with the RCRA Subtitle C barrier.

The engineered surface barriers that would be constructed for in-place closure of the tank farms, FFTF entombment, or closure of the waste management disposal facilities would have an extensive groundwater-quality monitoring network of observation wells to detect contaminant releases. Given that releases of contaminants from the closed disposal facilities or tank farms would occur hundreds or thousands of years into the future, groundwater-quality monitoring systems may need to remain in place far beyond the 30- or 100-year periods assumed under current regulations and incorporated into these alternatives. Should the monitoring system detect releases that could lead to significant deterioration of groundwater quality, DOE could implement one or more of the following mitigation measures:

- The same types of technologies that could be implemented to address existing groundwater contamination could be implemented to remediate potential future groundwater contamination under any *TC & WM EIS* alternative.

- The same technologies and actions described under the clean closure alternatives for tank, ancillary equipment, and contaminated soil removal could be implemented to remove the source(s) of all or a portion of the contaminants from the vadose zone on a location-by-location basis.

- Surface controls (e.g., hydraulic barriers, water run-on and runoff management systems, leachate collection systems) implemented to limit and control infiltration through engineered barriers could be replaced by more-robust and -effective systems and/or subsurface contaminant migration control systems (e.g., grout curtains, chemical barriers, injected sequestering agents).

- Postclosure care, associated administrative controls, and monitoring and maintenance of the closure systems (e.g., groundwater monitoring; restriction of access to the surface of the sites; routine repair of remediation systems, including surface barrier lobes), which were assumed to end after 100 years, could be extended and/or implemented to restrict access to groundwater by future site users.

Of particular interest when considering long-term impacts on groundwater, and as discussed in detail in Chapter 5, are hydrogen-3 (tritium), iodine-129, technetium-99, chromium, nitrate, uranium-238, and total uranium. Collectively, these COPCs account for essentially 100 percent of the risk and hazard drivers when analyzing long-term groundwater impacts of the *TC & WM EIS* alternatives. Tritium is a short-lived radionuclide (with a half-life of 12.7 years) that is projected to decay to below benchmark concentrations before reaching the Columbia River. Iodine-129, technetium-99, chromium, and nitrate are referred to as "conservative tracers" due to their mobility and because they are long-lived or persistent in the environment. Under Tank Closure Alternatives 6A and 6B, in which the SST farms would be clean-closed, the peak concentrations of conservative tracers at the Core Zone Boundary were projected to have occurred during the past-practice period due to past leaks from SST farms and discharges to cribs and trenches (ditches). Under Tank Closure Alternatives 1 and 2A, in which tank farm closure would not be achieved, the peak concentrations at the Core Zone Boundary would occur shortly after the post–administrative control period ends, when any residual waste in the SSTs or DSTs would be released into the vadose zone. The end of the post–administrative control period ranges from calendar year (CY) 2107 under Tank Closure Alternative 1 to CY 2193 under Tank Closure Alternative 2A. Uranium-238 and total uranium are characterized by limited mobility and are projected to reach peak concentrations at the Core Zone Boundary at a much later date than the other, more-mobile COPCs (i.e., after CY 5000).

Under the FFTF Decommissioning alternatives, tritium and technetium-99 are the risk drivers; however, neither of these COPCs is projected to exceed benchmark standards within the 400 Area Property Protected Area or at the Columbia River.

The same COPCs as discussed above in regard to the Tank Closure alternatives are also the risk and hazard drivers under the Waste Management action alternatives. However, the performance of an IDF in the 200-East Area (IDF-East), an IDF in the 200-West Area (IDF-West) under Waste Management Alternative 3, and the RPPDF and their related impacts on groundwater would be largely influenced by waste form performance and the partitioning of COPCs between the various waste forms. Generally, ILAW (e.g., vitrified waste) forms perform better than supplemental- and secondary-waste forms. A major contributing factor to the groundwater-related impacts of the Waste Management alternatives is disposal of offsite waste from other DOE facilities. Under the Waste Management action alternatives, iodine-129 and technetium-99 that leach from an IDF would be the largest contributors to groundwater impacts when compared with other *TC & WM EIS* sources (i.e., Tank Closure and FFTF Decommissioning action alternatives).

This *TC & WM EIS* shows that receipt of offsite waste streams that contain specific amounts of certain isotopes, specifically iodine-129 and technetium-99, could cause an adverse impact on the environment. As evaluated in this EIS, 2.3 curies of iodine-129 from offsite waste streams could cause impacts above benchmark standards, regardless of whether this waste stream is disposed of in the 200-East Area under Waste Management Alternative 2 or in the 200-West Area under Waste Management Alternative 3. The technetium-99 inventory of 1,460 curies from offsite waste streams evaluated in this EIS could cause impacts that are less significant than those of iodine-129. However, considering the combined impacts of technetium-99 from offsite waste streams and from past leaks and cribs and trenches (ditches), DOE believes it may not be prudent to add significant additional technetium-99 to the existing environment. Therefore, one means of mitigating this impact would be for DOE to limit disposal of offsite waste streams containing iodine-129 or technetium-99 at Hanford. For example, DOE evaluated the effect of applying waste acceptance criteria to offsite waste by removing a highly radioactive waste stream (i.e., high inventories of iodine-129 and technetium-99) from the inventory of offsite waste analyzed for disposal at Hanford in this final EIS. The removal of this waste stream from the offsite inventories presented in Appendix D, Section D.3.6, Tables D–86, D–87, and D–88 significantly reduces the radionuclide inventory used in groundwater analyses, particularly for iodine-129 and technetium-99. This *Final TC & WM EIS* considers the receipt of offsite waste containing 2.3 curies of iodine-129 and 1,460 curies of technetium-99, whereas the *Draft TC & WM EIS* evaluated approximately 15 curies of iodine-129 and 1,790 curies of technetium-99.

Appendix D provides detailed discussion and assumptions regarding the partitioning of COPCs between the various waste form products. One of the assumptions of the *TC & WM EIS* analysis is that approximately 20 percent of iodine-129 would be captured in primary-waste forms (e.g., ILAW, bulk vitrification glass, steam reforming waste); the volatilized balance would be recovered in secondary-waste forms. The only exception would be under Tank Closure Alternatives 3B, 4, and 5, in which cast stone would capture a higher percentage of iodine-129 due to the nonthermal nature of this treatment technology. As mentioned above, iodine-129 is a conservative tracer with a half-life of approximately 17 million years and is projected to exceed benchmark concentrations. As such, reasonable mitigation measures could be considered that would recycle secondary-waste streams into the primary-waste-stream feeds within the WTP to increase iodine-129 capture in ILAW and bulk vitrification glass, which are considered more-stable waste forms than those associated with secondary waste. The current WTP design supports the ability to recycle. For example, one method would involve the recycling of iodine within the WTP by capturing it in the submerged bed scrubber and returning it to pretreatment. This recycling could theoretically concentrate the iodine in the feed stream, which, in turn, could put more iodine in a specific volume of glass product. Also, the development of more-robust, longer-performing waste forms, particularly in regard to cast stone waste, steam reforming waste, and other grouted waste (i.e., ETF-generated secondary waste), could be pursued.

Another assumption detailed in Appendix D of this *TC & WM EIS* is partitioning of technetium-99 in IHLW, ILAW, and supplemental treatment primary-waste forms. Without technetium-99 removal as a pretreatment step in the WTP, the analysis assumes that roughly 97 to 98 percent of the technetium-99 from treated tank waste would be captured in ILAW or supplemental-waste products, 1 to 2 percent would be captured in secondary-waste forms, and less than 1 percent would be captured in IHLW. The further partitioning of technetium-99 among ILAW and supplemental-waste forms would be generally proportional to the volume of waste that would be treated in each of the facilities. For example, under Tank Closure Alternative 3A, technetium-99 was assumed to partition in primary-waste forms at 28 percent, 38 percent, and 32 percent between ILAW processed in the WTP, bulk vitrification glass processed in the 200-East Area Bulk Vitrification Facility, and bulk vitrification glass processed in the 200-West Area Bulk Vitrification Facility, respectively. However, under Tank Closure Alternative 2B, in which technetium-99 removal would be incorporated as a pretreatment step in the WTP, 97.5 percent of technetium-99 is expected to be captured in IHLW and only 1 percent in ILAW. In addition, under Tank Closure Alternative 3B, in which technetium-99 removal would be employed in the WTP, 99 percent of the technetium-99 in the waste treated in the 200-East Area would be incorporated in IHLW. Similar to iodine-129 above, technetium-99 is a conservative tracer with a long half-life (211,000 years) and is projected to exceed benchmark standards. Potential mitigation measures that could be considered include technetium-99 removal as a pretreatment option in the WTP. Also, the development of more-robust, longer-performing waste forms, particularly for supplemental treatment technologies and other grouted waste (i.e., ETF-generated secondary waste), could be pursued.

In response to comments received on the *Draft TC & WM EIS* concerning these potential long-term impacts on groundwater resources, additional sensitivity analyses were performed and are included in this final EIS. The additional analyses focus on factors perceived to have a substantial influence on the magnitude of long-term groundwater impacts. Section 7.5 summarizes the results of these analyses and their relative importance to mitigation planning.

7.1.7 Ecological Resources

Short-term impacts on ecological resources could potentially upset terrestrial habitats and compromise threatened and endangered species. The significance of these impacts would largely depend on the amount of new land disturbance that would occur under each *TC & WM EIS* alternative. Disturbance of new land could be minimized by employing the same mitigation measures discussed in Section 7.1.1.

Ecological resources in the Industrial-Exclusive zone of the Central Plateau have been adversely affected from previous disturbances of the area, including the 24 Command and Wautoma Fires (see Chapter 3, Section 3.2.7). However, the fires did not affect the 200-East Area. New facility construction under the Tank Closure and Waste Management alternatives would impact sagebrush habitat to varying degrees, depending on the alternative. Chapter 4, Sections 4.1.7 and 4.3.7, discuss the total area of sagebrush habitat that would be affected under each alternative. This loss may be subject to compensatory mitigation at a ratio of 1:1 to 3:1, as prescribed in the *BRMaP* (DOE 2001) and the *Hanford Site Biological Resources Mitigation Strategy* (DOE 2003a). In addition, some habitats and species that have repopulated the burned areas could also be subject to mitigation under existing biological conditions and current mitigation guidelines. Within the Central Plateau, several state-listed, special status species of plants and wildlife have been observed or have the potential for inhabiting the areas of disturbance. The noted species include two state watch plant species, the stalked-pod milkvetch and crouching milkvetch, which would not require mitigation, although they could be considered in project planning. Other, more-protected species that are considered Level III resources under the *BRMaP* (DOE 2001) would potentially require active mitigation (e.g., Piper's daisy [state sensitive]; loggerhead shrike and northern sagebrush lizard [Federal species of concern and state candidates]; black-tailed jackrabbit, sage sparrow, striped whipsnake, and sage thrasher [state candidates]). No significant ecological impacts, and therefore no mitigation activities, are expected to occur in the 400 Area under any of the FFTF Decommissioning alternatives.

The extent of ecological impacts on Borrow Area C would depend on the amount of geologic materials that would need to be mined to support backfilling needs, construction of new facilities, and construction of engineered surface barriers. The maximum impacts would occur under the Tank Closure alternatives that involve clean closure of the tanks and cribs and trenches (ditches) (i.e., Alternatives 6A and 6B, Option Cases) and under Waste Management Alternatives 2 and 3, Disposal Groups 2 and 3 (in which one or two IDFs and the RPPDF would be sized for the largest capacities). Vegetation communities located within Borrow Area C include cheatgrass/bluegrass and needle-and-thread grass/Indian ricegrass. The latter represents an unusual and relatively pristine community type at Hanford and is more highly valued. In addition to Piper's daisy, stalked-pod milkvetch, and crouching milkvetch, which are also found in the Central Plateau, as discussed above, the long-billed curlew (state monitor) has been identified in Borrow Area C.

Biological surveys of areas potentially affected under the action alternatives have been completed (Sackschewsky 2003a, 2003b). While current biological conditions and mitigation guidelines are appropriate for determining mitigation requirements for near-term impacts, they are not suitable for judging long-term mitigation requirements because habitats and species assemblages may change over time. Consequently, actual mitigation requirements for later activities that would occur under the alternatives considered would depend on the results of field surveys conducted just prior to initiating ground-disturbing activities and the mitigation guidelines in effect at Hanford at that time.

In addition to preparation of a comprehensive mitigation action plan to address the impacts on Level III resources (Piper's daisy, black-tailed jackrabbit, loggerhead shrike, and sage sparrow) and sagebrush habitat, the following mitigation measures could be implemented to minimize short-term impacts on terrestrial resources and threatened and endangered species:

- Conduct proper maintenance of heavy equipment, and clearly mark construction zones to prevent intrusion into sensitive areas or outside work areas.
- Implement noise-reduction measures, as discussed in Section 7.1.3.
- Implement spill prevention and control plans, as discussed in Section 7.1.6.
- Avoid, to the maximum extent possible, disturbance of the needle-and-thread grass/Indian ricegrass communities in Borrow Area C.
- Avoid performing land-disturbing activities during animal breeding and nesting periods.

The long-term impacts of air emissions and groundwater contamination on ecological receptors are correlated with the amount and timing of air emissions and releases of contaminants to the vadose zone and underlying aquifers. As discussed in Chapter 5, radioactive COPCs from air emissions are not projected to be a risk to ecological receptors. Groundwater impacts at the Columbia River associated with nonradioactive and radioactive COPCs are also not projected to be a significant risk; however, chromium would pose a slightly elevated risk to aquatic biota at the Columbia River under most Tank Closure and Waste Management alternatives. In some cases, moderate risks associated with nonradioactive COPCs from air emissions are projected. The majority of impacts are associated with mercury and xylene under the Tank Closure alternatives and with xylene alone under the FFTF Decommissioning and Waste Management alternatives. However, as presented in Appendix D, for conservative analysis, the mercury inventory was assumed both to be captured in waste forms and to be emitted into the air. The assumption under most action alternatives that essentially 100 percent of the mercury inventory should be included in air emission analysis (i.e., almost 100 percent of the mercury inventory was assumed to be captured in waste-form products) suggests that the risk from mercury is conservatively overstated. Implementing any of the mitigation measures discussed in Sections 7.1.4 and 7.1.6, which would reduce air and groundwater impacts, would also serve to reduce impacts on ecological receptors. Other mitigation measures could include performing periodic ecological surveys to monitor trends in terrestrial, riparian, and aquatic populations.

7.1.8 Cultural and Paleontological Resources

Although no alternative is expected to impact any prehistoric or other significant cultural resource, the potential for inadvertent discovery of prehistoric resources exists. Avoidance of identified resources would be the primary form of mitigation, wherever practical. To avoid loss of cultural resources during new facility construction, cultural resource surveys have been and may in the future be conducted in areas of interest. An archaeological monitor could be assigned to oversee any highly sensitive areas during ground-disturbing activities to ensure that, whenever possible, construction impacts are limited to the project area. If any cultural resources are discovered during construction, construction would be halted, and procedures set forth in the *HCRMP* (DOE 2003b) would be implemented.

The construction of new facilities in the Central Plateau would increase the industrial profile of the area from higher elevations. Likewise, excavation of Borrow Area C would alter the view of this area from higher elevations, such as Rattlesnake Mountain, which is of cultural interest to local American Indian tribes. To mitigate potential visual impacts on, or interference with, tribal and religious ceremonies on Rattlesnake Mountain, borrow material could be stockpiled or the timing of excavation activities could be coordinated with the tribes. For example, excavation could be conducted at night to avoid affecting certain ceremonies that might be performed during the day. The consolidation of existing activities or facilities and the removal of unnecessary facilities or infrastructure on Rattlesnake Mountain would tend to improve the visual profile of the mountain, allow restoration of the natural habitat, and enhance tribal religious and cultural experiences. The restoration of land used for *TC & WM EIS* activities, as well as restoration of Borrow Area C in accordance with the appropriate resource management plans, such as a final adopted version of the *Draft Industrial Mineral Resources Management Plan* (Reidel, Hathaway, and Gano 2001), would lessen these visual impacts. DOE will continue its ongoing practice of consulting with American Indian tribes concerning potential impacts that may affect traditional cultural properties, including visual impacts. Where needed, measures to restore disturbed land or to avoid or minimize these impacts would be developed and implemented in coordination with area tribes in a culturally relevant manner consistent with the *BRMaP* (DOE 2001).

7.1.9 Socioeconomics

The potential exists for substantial impacts on regional socioeconomic conditions under all of the *TC & WM EIS* alternatives. Under the Tank Closure No Action Alternative, termination of WTP construction would lead to a noticeable and immediate short-term effect on the regional economy due to loss of employment and revenue. This loss of jobs could not be easily mitigated, as workers with certain skill sets could find it difficult to find comparable employment in the region. In contrast, implementation of any of the action alternatives would significantly increase the demand for professional, skilled, and unskilled labor. This would affect the regional economy, demographic characteristics, and housing and community services in the socioeconomic region of influence for the foreseeable future. Construction activities would cause short-term spikes in employment and demands on the regional economy. These short-term spikes could place a strain on the availability of housing and could cause large upward and downward swings in housing prices. These spikes could also strain local school districts and other public services. Secondary effects on housing and community services would be somewhat mitigated by the fact that the spike in employment would be associated with construction. The long duration of some alternatives during the operations phase would lead to a more stable, long-term demand on regional socioeconomics. Data indicate that vacant permanent housing for sale and rent in the region may be insufficient to meet the demand under some action alternatives (see Chapter 3, Section 3.2.9.3, and Chapter 4, Section 4.1.9). It is anticipated that additional demand would stimulate construction of permanent and other forms of housing to meet the influx of construction workers, thereby producing a positive effect on the regional economy. Similarly, the direct and indirect income associated with procurement of equipment and supplies for completion of the WTP and associated new facility construction would be another economic benefit. Nevertheless, school enrollments associated with the influx of construction and operations workers and their families are expected to increase, and utility, community safety, and police and fire services may need to be expanded to meet demand.

Careful scheduling of activities, particularly during the construction phases, could reduce the severity of short-term spikes. Certain facilities could be built in sequence, rather than concurrently, although this could cause some small delays in initiation or completion of the projects and increases in project cost.

Implementing any action alternative could impact local transportation infrastructure, especially during commuting periods. The local transportation system has additional capacity during noncommuting periods, but has no additional capacity during the morning and evening peaks (see Chapter 4, Sections 4.1.9, 4.2.9, and 4.3.9). As also described in these subsections, employee commuter traffic and truck traffic would peak at various times, depending on the nature and intensity of the activities being conducted under each alternative. This combined effect would decrease the available capacity of site access roads during the morning and evening rush hours. Possible measures that could be used to mitigate traffic volume impacts are physical improvements to local and onsite roads to increase capacity, including construction of additional vehicle lanes throughout road segments; construction of passing lanes in certain locations; or realignment of roadways to reduce points of congestion. Employee programs that provide flexible hours or staggered work shifts to reduce peak traffic volumes also could reduce local transportation impacts. In addition, employee programs and incentives encouraging ridesharing could be established, and existing bus and/or vanpool programs could be expanded. Under Washington State law (Washington State 2006), major employers in Benton and Franklin Counties and the cities of Kennewick, Pasco, Richland, and West Richland must adopt commute trip reduction plans. The intent of the commute trip reduction policy is to reduce commutes by workers from their homes to major work sites during the peak period of 6:00 A.M. to 9:00 A.M. on weekdays. Construction work sites are generally excluded under the law, provided the construction duration is less than 2 years. The ongoing construction of the Hanford WTP would likely not be exempt.

Transport of geologic materials from Borrow Area C across State Route 240 to the 200 Areas presents a particular concern for its potential to cause traffic congestion and accidents and may require specific mitigation measures. Safety measures could include dust control; restrictions on crossings to non-shift-change hours; signs and warning lights along State Route 240 to the north, south, and well in advance of the crossing; and a traffic control light at the crossing itself.

7.1.10 Public and Occupational Health and Safety

Current and anticipated design, construction, and operations of waste treatment and disposal facilities would incorporate the best available technology and engineering controls to limit the discharge of potentially hazardous materials to the environment. The peak annual dose to both the on- and offsite maximally exposed individual through the inhalation pathway is projected to be well below the regulatory limit of 10 millirem per year (40 CFR 61, Subpart H) under all alternatives analyzed.

Although doses are expected to remain below any regulatory limits, the years of peak radiological impacts on the public would coincide with strontium and cesium processing. One option for mitigating this impact could be to alter the treatment strategy by distributing the treatment of strontium and cesium capsules over a longer period of time or by incorporating more-aggressive air pollution control technology designed to target strontium and cesium emissions.

Workers would receive radiation doses under the *TC & WM EIS* alternatives. For all work activities involving radiation, the principle of maintaining doses as low as is reasonably achievable (ALARA) would be followed. This principle would involve formal analysis by workers, supervisors, and radiation and/or chemical protection personnel of the work in a hazardous environment to reduce exposure of workers to the lowest practicable level. Examples of ALARA measures could include minimizing time spent in the field of radiation, maximizing distances from sources of radiation, using shielding whenever possible, and/or reducing the radioactive source. Mitigation measures also would be used to protect workers from radiological and chemical exposure hazards during construction, operations, and demolition activities. These mitigation measures would be derived from formal radiation protection programs and chemical hazards management programs. Examples of specific measures could include using personal protective equipment (e.g., Tyvek suits, face masks), shielding (e.g., earth berms, concrete walls, steel plates, lead bricks), and remotely operated robotic machinery; training workers; and spreading the work across a larger number of workers. All activities that affect the handling, treatment, storage, or disposal of radioactive waste would be performed within the limits of a DOE-approved safety basis. The safety basis would be established by evaluating potential accidents and defining appropriate controls to ensure that accident impacts are below required levels.

The regulatory limit for a worker dose is 5,000 millirem per year (10 CFR 835). The recommended DOE Administrative Control Level for a worker dose is 500 millirem per year (DOE Standard 1098-2008). The analysis of worker dose presented in Chapter 4, Sections 4.1.10, 4.2.10, and 4.3.10, calculated an aggregated average dose for a full-time-equivalent (FTE) worker over all activities included under each alternative. For example, an average annual dose reported to be 500 millirem per year would indicate that, unless mitigation measures were taken, a portion of an alternative's activities would exceed DOE's administrative control level and a portion would be below this level. Under Tank Closure Alternatives 4 and 6B, the average annual dose would exceed 500 millirem per year without mitigation measures. Under Tank Closure Alternative 6A, the average annual dose would approach 500 millirem per year. The high average FTE worker dose incurred in these cases would be primarily due to the exhumation of tank farms and underlying radioactively contaminated soils. In these cases, a comprehensive evaluation of worker exposures may be warranted and, whenever possible, applicable ALARA techniques or other mitigation measures similar to those discussed above may be necessary to ensure the worker dose is reduced and maintained below 500 millirem per year. Under all other *TC & WM EIS* alternatives, the FTE worker dose would be sufficiently low that the probability of any worker dose exceeding 500 millirem per year would be low.

Long-term impacts on human health were analyzed using a variety of receptors and receptor locations, as discussed in Chapter 5 and detailed further in Appendix K. In summary, the offsite receptor locations are the Columbia River itself and downstream population centers. One receptor is an American Indian hunter-gatherer, who, like people living in the downstream population centers, would consume water from the Columbia River. In contrast, the onsite receptors (i.e., the drinking-water well user, resident farmer, and American Indian resident farmer) would directly consume groundwater for drinking water, and, in some cases, would use groundwater to irrigate crops. The exposure scenarios for onsite receptors involve several locations within the Core Zone Boundary and at the Columbia River nearshore. The COPCs that are drivers for groundwater impacts, briefly discussed in Section 7.1.6, are also the drivers for human health impacts.

Because of the substantial dilution that would take place as groundwater seeps into the Columbia River, impacts on downstream population centers and the American Indian hunter-gatherer, both of whom would use surface water as a source of drinking water or might consume fish from the Colombia River, would be negligible compared with background exposures. However, impacts on any receptor that consumes groundwater as a drinking water source and uses groundwater to irrigate crops within the Core Zone Boundary would exceed dose standards and Hazard Indices for either one or multiple COPCs. These impacts on receptors at onsite locations could not be directly mitigable because the underlying assumption is that access to the site and its groundwater resources would be attainable at some future date after all institutional controls are no longer in force. However, implementing any of the mitigation measures discussed in Section 7.1.6, which would reduce groundwater impacts, may also reduce impacts on human health.

All shipments of radioactive or hazardous materials on public roads would be performed within applicable regulatory requirements that address the following:

- Waste packaging in containers certified for use in waste transport
- Training and licensing requirements for transporters
- Notification of potentially affected organizations

Potential mitigation measures to reduce impacts on workers and the public could include packaging the waste to reduce radiation doses below regulatory limits, selecting transportation routes to minimize exposure to populations along the route, and scheduling transport to avoid high-traffic times and locations. The latter could also reduce congestion and transportation delays, thereby reducing radiological exposure and the potential for traffic accidents.

7.1.11 Waste Management

This *TC & WM EIS* analyzes the construction, operations, and closure of permanent disposal facilities to support the disposal of the waste that would be generated under each of the Tank Closure, FFTF Decommissioning, and Waste Management alternatives. These permanent disposal facilities would include IDF-East, IDF-West, and the RPPDF, which would be located in an area between the 200-East and 200-West Areas. A more detailed description of the IDF and RPPDF is provided in Chapter 2 and Appendix E. This *TC & WM EIS* analyzes several configurations of the IDF and RPPDF, depending on the capacity and duration of operations required; these configurations are referred to as "disposal groups." A disposal group is designed to conservatively provide disposal capacity to multiple Tank Closure alternatives; thus, under some Tank Closure alternatives, the full capacity of the disposal facilities, as analyzed in this EIS, may not be used. Chapter 2 provides a more detailed description of the disposal groups, including an explanation of how they were determined and which Tank Closure alternatives would be supported under each disposal group.

Permanent disposal facilities (i.e., one or two IDFs and the RPPDF) would be constructed with an RCRA-compliant liner and leachate collection system to manage infiltration and prevent the release of contaminants into the vadose zone. Each permanent disposal area would be closed and covered with an engineered modified RCRA Subtitle C barrier. The emplacement of a more robust Hanford barrier design, which may further mitigate infiltration of surface water and extend the lifetime of the structural integrity of the barrier, is analyzed under Tank Closure Alternative 5. These engineered surface barriers, constructed for in-place closure of the tank farms, entombment of FFTF, or closure of the waste management disposal facilities, could have an extensive groundwater-quality monitoring network of observation wells to detect contaminant releases.

Except for the Tank Closure No Action Alternative, HLW would be generated under all of the Tank Closure alternatives. Under Tank Closure Alternative 6A, all tank waste would be treated and formed into IHLW in the WTP. Under Tank Closure Alternatives 6A, 6B, and 6C, all treated tank waste would be managed as HLW. In addition to the IHLW, HLW melters, which are used to vitrify HLW as part of WTP operations, would be taken out of service and would require disposal. The amount of treated tank waste managed as HLW under Tank Closure Alternative 6A, 6B, or 6C would be at least 14 times more than that of any other action alternative. Under these alternatives, the treated tank waste would be stored on site. The increase in the volume of waste managed as HLW under Tank Closure Alternatives 6A, 6B, and 6C would also result in a corresponding reduction in the volume of ILAW glass that would require onsite disposal in an IDF.

Sulfate removal is a WTP pretreatment step analyzed under Tank Closure Alternative 5. Sulfate removal has the potential to mitigate impacts on the waste management system (see Appendix E, Section E.1.2.3.9). This technology would remove sulfates from the tank waste stream, thereby reducing corrosivity and potentially extending melter life. This may lead to a reduction in melters taken out of service that would otherwise require disposal. The removal of sulfates may also enable increased waste loading from 14 weight-percent sodium oxide loading to 20 weight-percent sodium oxide loading, thereby potentially reducing the number of IHLW and/or ILAW canisters that would be produced (CEES 2007). However, sulfate grout waste would be generated and would require disposal in an IDF.

DOE has a longstanding policy to minimize waste generation. DOE is implementing Executive Order 13423, *Strengthening Federal Environmental, Energy, and Transportation Management*, by conducting its environmental, transportation, and energy-related activities under the law in an environmentally, economically, and fiscally sound, integrated, continuously improving, efficient, and sustainable manner. Hanford has a pollution prevention program that was formalized in the *Hanford Site Waste Minimization and Pollution Prevention Awareness Program Plan* (DOE 1999b). Program components include waste minimization, recycling, source reduction, and buying practices that give preference to products made from recycled materials. Implementation of the pollution prevention and waste minimization plans could minimize the generation of secondary waste.

7.1.12 Alternative Combinations

Generally, potential mitigation measures for each resource area would remain the same regardless of the selected combination of alternatives; therefore, additional discussion of mitigation measures across the three alternative combinations would be redundant. However, wherever appropriate in the previous subsections of Section 7.1, mitigation measures may be specifically discussed for a particular alternative (e.g., Tank Closure) when analysis suggests that a specific impact of that alternative may need more emphasis. The alternative combinations and their effects on short-term impacts are discussed in more detail in Chapter 4, Section 4.4.

7.2 UNAVOIDABLE, ADVERSE ENVIRONMENTAL IMPACTS

Unavoidable, adverse environmental impacts are those that would occur after implementation of all feasible mitigation measures, including those design elements incorporated in and analyzed under the individual *TC & WM EIS* alternatives. Implementing any of the alternatives considered in this *TC & WM EIS* would result in unavoidable, adverse impacts on the human environment. A summary discussion of these impacts is included in this section; however, a more detailed impacts discussion can be found for each resource area in the appropriate sections in Chapter 4 for short-term impacts and in Chapter 5 for long-term impacts.

Unavoidable, adverse environmental impacts may occur in either the short or long term. For analysis purposes in this EIS, "short-term" denotes the complete project life cycle under each alternative, during which construction, operations, decommissioning, deactivation, and closure activities would take place. All of the *TC & WM EIS* alternatives require either a 100-year administrative control or postclosure care period or storage of HLW for a significant period of time, either of which would contribute very little to impacts. Thus, the most significant unavoidable, adverse environmental impacts would occur in the earlier years of the short-term timeframes of the *TC & WM EIS* alternatives, during which all construction, operations, and deactivation activities would be completed and only postclosure care or storage activities would remain. A Tank Closure, FFTF Decommissioning, and Waste Management alternative would be implemented concurrently as an alternative combination, so while the short-term impacts under one *TC & WM EIS* alternative may end, they may continue under another.

"Long term" denotes the timeframe that extends beyond conclusion of the short-term project life-cycle period of each alternative. Under any viable alternative, it is expected that an increase in short-term adverse impacts would lead to an overall decrease in long-term adverse impacts (see Section 7.4).

7.2.1 Land Resources

Construction, consolidation, operations, maintenance, and deactivation of new or existing facilities would be required to support the action alternatives and would result in short-term adverse impacts on land and visual resources, including the development or use of undisturbed land. Visual impacts of existing structures and maintenance activities on Rattlesnake and Gable Mountains and land use for construction of new facilities are considered short-term impacts because, after a facility's mission has been completed, that facility would be deactivated and demolished, and vegetation and habitat would be reestablished to recreate the natural condition. Many of the facilities currently reside on or would be constructed on land that has been disturbed; thus, while this would be considered a short-term commitment of land, it would not necessarily be considered an adverse impact. Except for facilities associated with the FFTF Decommissioning alternatives, the IHLW Interim Storage Modules constructed under Tank Closure Alternative 6A, and Borrow Area C, new and existing facilities would be situated in the area designated

Industrial-Exclusive in the *Hanford Comprehensive Land-Use Plan EIS*. This area has been set aside for waste management activities. FFTF decommissioning activities at Hanford would take place within the 400 Area Property Protected Area, which is in an industrial use designated area (DOE 1999a). Borrow Area C is located at the end of Beloit Avenue, just south of State Route 240. Other land resource impacts are presented and discussed in Chapter 4, Sections 4.1.1, 4.2.1, and 4.3.1.

The amount of new land disturbance required for construction of facilities to support the Tank Closure alternatives ranges from 3.2 hectares (8 acres) under Alternative 2B to 186 hectares (460 acres) under Alternative 6A, Option Case. Under Tank Closure Alternatives 6A, 6B, and 6C, in which all tank waste would be managed as HLW and would require substantial facility storage space, the disturbance of new land would be very high compared with that of the remainder of the Tank Closure alternatives. Under the Tank Closure No Action Alternative, construction of the WTP and the Canister Storage Building would be terminated, and no new disturbance of land would be required. New land disturbance would not be necessary under any of the FFTF Decommissioning alternatives. Under the Waste Management No Action Alternative, no new land areas would be disturbed; only existing disposal facilities would be used. The amount of new land disturbance under the Waste Management action alternatives ranges from 63 hectares (155 acres) under Alternative 2, Disposal Group 1, to 240 hectares (594 acres) under Alternative 3, Disposal Group 3. All newly disturbed land under the Tank Closure alternatives would be used to construct treatment and storage facilities; because these facilities would eventually be deactivated and demolished, this disturbance would be considered a short-term adverse impact. The vast majority of newly disturbed land under the Waste Management alternatives would be used for construction of permanent disposal facilities, which would be considered a long-term impact. Less than 1 percent of the new land disturbed under the Waste Management alternatives, or 0.4 hectares (1 acre), would be used for construction of new treatment facilities.

Borrow Area C is the designated source of the geologic materials that would be used for construction, operations, deactivation, and closure activities. Geologic materials from Borrow Area C would be used for concrete and grout, backfill, and construction of engineered barriers. The unavoidable, adverse impacts would be the areal extent of land disturbance and the mining of geologic materials to a maximum depth of 4.6 meters (15 feet) in some locations. Despite any restoration efforts, the land contours and visual references would be unavoidably altered for the long term; however, the potential use of the land would remain as Conservation (Mining), as designated by the *Hanford Comprehensive Land-Use Plan EIS* (DOE 1999a). Borrow Area C land disturbance required to support tank closure would range from 2 hectares (5 acres) under the Tank Closure No Action Alternative to 458 hectares (1,131 acres) under Tank Closure Alternative 6A, Option Case. The FFTF Decommissioning No Action Alternative would not require any geologic materials, but FFTF Decommissioning Alternative 3 would require disturbance of up to 3.2 hectares (8 acres) of Borrow Area C. Geologic materials would not be required under the Waste Management No Action Alternative, but Waste Management Alternative 2, Disposal Groups 2 and 3, would require disturbance of up to 159 hectares (392 acres) of Borrow Area C. The areal extent of land disturbance impacts would be commensurate with the total amount of geologic resources consumed, as discussed in more detail in Section 7.2.5.

7.2.2 Infrastructure

Implementation of the *TC & WM EIS* alternatives would not adversely affect the current infrastructure's long-term ability to provide energy, fuel, or water resources to support future actions. In the short term, under Tank Closure Alternative 6A, Base and Option Cases, in which all tank waste would be vitrified in WTP HLW melters, demand is projected to exceed the peak electrical capacity of Hanford's electric power distribution system. Even though the available peak capacity is not projected to be exceeded under other tank closure activities, electrical consumption is expected to remain near Hanford's peak capacity for the duration of the WTP operations analyzed under each alternative. However, this short-term adverse impact on electrical distribution can be mitigated, as discussed in Section 7.1.2.

7.2.3 Noise and Vibration

Increases in noise levels would be relatively low outside the immediate areas of construction; however, the combination of construction noise and associated human activity would likely displace small numbers of animals surrounding the work areas. Heavy diesel equipment used for construction under most of the alternatives is expected to result in the highest noise levels. The most obvious reaction of wildlife would be a startle or fright response resulting from transient, unexpected noise. Such noise could cause animals to flee the area. Lower, more-constant noise levels may cause wildlife to temporarily avoid the construction zone. None of the construction activities are located near residential areas. Noise impacts would be considered short-term impacts that would occur mainly during the construction phases of an alternative. Noise impacts are presented and discussed in Chapter 4, Sections 4.1.3, 4.2.3, and 4.3.3.

7.2.4 Air Quality

Implementation of the *TC & WM EIS* alternatives would cause unavoidable, adverse impacts on air quality resulting from the release of various criteria and toxic chemical constituents. Peak impacts of the release of criteria pollutants are expected to occur during construction activities. Under select Tank Closure alternatives, unmitigated air pollutant emissions could result in exceedance of standards for particulate matter, and in some cases, for carbon monoxide and nitrogen dioxide. The FFTF Decommissioning alternatives are not projected to exceed standards for criteria pollutants. All Waste Management alternatives except the No Action Alternative are projected to exceed standards for particulate matter and 1-hour standards for nitrogen dioxide and carbon monoxide. Under Waste Management Alternatives 2 and 3, Disposal Groups 1 and 2, the 1-hour standard for sulfur dioxide also projected to be exceeded.

All toxic air pollutants are projected to be below acceptable source impact levels, except for mercury under Tank Closure Alternatives 2B; 6B, Base and Option Cases; and 6C.

Even after employing the best available technology and management practices to bring air contaminants down to acceptable levels, complete elimination of criteria and toxic air pollutants would not be possible, and some unavoidable, adverse impacts would still occur. Nonradiological air quality impacts are presented and discussed in Chapter 4, Sections 4.1.4, 4.2.4, and 4.3.4.

In addition to nonradioactive air pollutants, unavoidable, adverse impacts on air quality would occur as a result of radioactive emissions. Unavoidable impacts on ecological receptors and human health due to radioactive air emissions are discussed in Sections 7.2.7 and 7.2.10, respectively.

7.2.5 Geology and Soils

Large volumes of geologic resource materials would be required for constructing facilities, backfilling excavations, constructing engineered barriers for closure of tank systems, entombing facilities, and closing landfill disposal sites. Such geologic resource materials would include rock, gravel, sand, clays, and soil. Under Tank Closure Alternatives 3A, 4, and 5, in which bulk vitrification would be employed as a supplemental treatment option, geologic resources would also be consumed. Section 7.3 and Chapter 4, Sections 4.1.5, 4.2.5, and 4.3.5, discuss impacts on geology and soils in more detail. Borrow Area C is the designated source of geologic materials for all activities discussed in this *TC & WM EIS*. This *TC & WM EIS* assumes that all geologic materials would be supplied from Borrow Area C.

The utilization of geologic materials would be the most significant under Tank Closure Alternatives 6A and 6B, in which the SST farms would be clean-closed, and Waste Management Alternatives 2 and 3, Disposal Groups 2 and 3, in which the disposal facilities would be designed and built to contain the largest disposal capacities.

7.2.6 Water Resources

Adverse impacts on subsurface soils and groundwater, which flow into and thus would subsequently affect the Columbia River, would be unavoidable over the long term under all of the *TC & WM EIS* alternatives due to historical releases of contaminants and the ongoing presence of onsite disposal areas. The greatest impact on water resources would occur under the No Action Alternative for tank closure, FFTF decommissioning, and waste management, in which the following would occur, respectively: (1) the storage tanks would be left to degrade over time, leading to the eventual release of untreated tank waste into the subsurface; (2) the remote-handled special components (RH-SCs) and bulk sodium would not be properly disposed of; and (3) construction of modern landfill facilities would not be completed. All of the action alternatives are designed to enhance waste-form and disposal area performance. Discussions of the long-term performance assessment, the projected impacts, and whether these impacts would exceed existing health- and risk-based standards are found in Chapter 4, Sections 4.1.6, 4.2.6, and 4.3.6, as well as in Chapter 5.

The unavoidable, adverse impacts on groundwater that would result from implementation of any of the *TC & WM EIS* action alternatives would be proportional to the amount of tank waste that would be retrieved for treatment and the performance of the primary- and secondary-waste forms. Even the high-performing ILAW that would be disposed of on site would eventually leach some COPCs into the subsurface. During any post–administrative control period, the eventual failure of engineered barriers, followed by infiltration of water through the permanent disposal facilities or in-place closure of other facilities, would facilitate migration of contaminants into the groundwater.

In addition to waste generated under the *TC & WM EIS* alternatives, the onsite non–Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) waste and any offsite waste that would be received and disposed of in an IDF or the RPPDF would contribute to any unavoidable impacts on groundwater.

7.2.7 Ecological Resources

Unavoidable, adverse impacts on ecological resources would be commensurate with the amount of new land disturbance that would occur as a result of a particular action, as previously discussed in Section 7.2.1. This would cause short-term unavoidable impacts on the natural habitat in these areas, affecting both plant and wildlife ecosystems. Microbiotic crusts, which are expected to occur only on undisturbed sites within the 200 Areas and Borrow Area C, would be destroyed by new construction and excavation activities. Ground disturbance would also result in the loss of less-mobile species, such as small mammals, reptiles, and amphibians. Larger, more-mobile species, including many mammals and birds, would be displaced to similar surrounding habitat. Their ultimate survival would depend on whether the areas into which they move are at their carrying capacity (i.e., whether they already contain the maximum number of individual animals that the habitat is capable of supporting). Over the long term, except for areas used for waste disposal, vegetation and wildlife would be reestablished to re-create the natural condition on land disturbed for construction of treatment facilities, including Borrow Area C.

Federally or state-listed threatened or endangered species have not been observed within or in the immediate vicinity of the 200 Areas or Borrow Area C; therefore, long-term impacts on these groups of plants and animals are not expected. However, there are several state-listed species of interest that may be adversely affected in newly disturbed land areas; these include the stalked-pod milkvetch, crouching milkvetch, Piper's daisy, black-tailed jackrabbit, loggerhead shrike, sage sparrow, and long-billed curlew.

The five ponds associated with the Liquid Effluent Retention Facility and Treated Effluent Disposal Facility, located within and adjacent to the 200-East Area, would receive effluent discharges. Although the Liquid Effluent Retention Facility ponds are covered by a floating membrane constructed of very low-density polyethylene (Poston, Duncan, and Dirkes 2011:6.24), the Treated Effluent Disposal Facility ponds are not covered and, therefore, are accessible to wildlife. Potential long-term indirect impacts on wildlife that depend on Columbia River aquatic resources are discussed in Chapter 4, Sections 4.1.7, 4.2.7, and 4.3.7.

In addition to new land disturbance, air and groundwater impacts over the long term would cause limited unavoidable, adverse impacts on ecological receptors. Even after implementation of air pollution control technologies, radioactive and nonradioactive COPCs would be deposited into area soils and the Columbia River as a result of emissions from facility operations. Furthermore, under all *TC & WM EIS* alternatives, some COPCs would eventually migrate to and seep into the Columbia River. However, as discussed in Chapter 5, most of these impacts are not projected to be a risk to ecological receptors. In a few cases, the impacts would represent a very small risk. Implementing the mitigation measures discussed in Section 7.1.7 would further reduce these impacts.

7.2.8 Cultural and Paleontological Resources

None of the *TC & WM EIS* alternatives or ongoing maintenance and operational activities are expected to significantly impact any prehistoric, historic, cultural, paleontological, or visual resources. Given that ground disturbance would be required under most alternatives, the potential for inadvertent discovery of prehistoric resources exists. If discovered, the mitigation steps described in Section 7.1.8 of this chapter would be implemented. Excavation of Borrow Area C would alter the view of this area from higher elevations, such as Rattlesnake Mountain, which is of cultural interest to local American Indians, even after restoration efforts have been completed. The consolidation of existing activities or facilities, removal of unnecessary facilities or infrastructure on Rattlesnake Mountain, and maintenance of firebreaks and access roads on Rattlesnake and Gable Mountains would constitute unavoidable, adverse short-term impacts, but over the long term would tend to improve the visual profiles on or from these natural features and allow restoration of natural habitat, thus enhancing tribal religious and cultural experiences.

7.2.9 Socioeconomics

The potential exists for substantial impacts on regional socioeconomic conditions under all of the *TC & WM EIS* alternatives. Under the Tank Closure No Action Alternative, termination of WTP construction would lead to a noticeable and immediate short-term effect on the regional economy due to the loss of employment and revenue. In contrast, implementation of any of the action alternatives would result in a significant increase in demand for professional, skilled, and unskilled labor. This would affect the regional economy, demographic characteristics, and housing and community services in the socioeconomic region of influence for the foreseeable future. Construction activities would cause short-term spikes in employment and demands on the regional economy. These short-term spikes could strain the availability of housing and cause large upward and downward swings in housing prices. These spikes could also strain local school districts and other public services. Additionally, the influx of people to the region would strain the local transportation system. These unavoidable impacts could not be easily mitigated; however, implementing the mitigation measures discussed in Section 7.1.9 of this chapter could reduce their effect on the region.

7.2.10 Public and Occupational Health and Safety

Normal facility operations and deactivation, including some closure activities, would result in unavoidable radiological exposure to workers and the general public. The general public would be exposed to radiation from facility air emissions. Impacts on the general population and maximally exposed individuals are discussed in Chapter 4, Sections 4.1.10, 4.2.10, and 4.3.10. Workers would be exposed to radiation from routine operations dealing with the processing of radioactive waste. Workers would have the highest levels of exposure due to proximity and length of exposure, but doses would be administratively controlled to ensure radiological exposure levels would not exceed occupational health and safety standards. In addition to radiological exposures, workers would be exposed to chemical hazards and would also incur injuries, possibly even fatalities, while performing routine work-related tasks. Except for Tank Closure Alternative 6A, Base and Option Cases, in which about three fatalities are projected, projected fatalities for routine work-related accidents were calculated to be less than one under all *TC & WM EIS* alternatives. Work-related accidents are discussed in Sections 4.1.15, 4.2.15, and 4.3.15.

The human health risk from transportation of radioactive materials is categorized as either radiological or nonradiological. Radiological risk is that associated with the release of radioactive materials during an accident or the effects of low levels of radiation emitted during normal, or incident-free, transportation. Nonradiological risk is that associated with transportation itself, regardless of the nature of the cargo being transported, such as accidents resulting in injury or death when there is no release of radioactive material. Shipping packages containing radioactive materials emit low levels of radiation during incident-free transportation. The amount of radiation emitted depends on the kinds and amounts of materials being transported. U.S. Department of Transportation regulations require that shipping packages containing radioactive materials have sufficient radiation shielding to limit the radiation to an acceptable level of 10 millirem per hour at 2 meters (6.6 feet) from the transporter. Incident-free exposure and accident-related fatalities while shipping both radioactive waste and nonradioactive materials are discussed in Chapter 4, Sections 4.1.12, 4.2.12, and 4.3.12.

In addition to the human health risk associated with facilities and transportation, any unavoidable impact on groundwater that occurs (see Section 7.2.6) despite mitigation measures (see Section 7.1.6), even if contamination is below benchmark standards, would affect human health. This human health risk would exist even if impacts are deemed acceptable from a dose perspective or are predicted to be negligible compared with background exposure levels.

7.2.11 Waste Management

Secondary waste, including low-level radioactive waste (LLW), MLLW, and hazardous waste, would be an unavoidable byproduct generated during construction, operations, deactivation, and closure activities. Examples of secondary waste include personal protective equipment, rags, tools, filters, and empty containers. This secondary waste would be in addition to the primary-waste forms produced as a result of tank waste treatment or FFTF decommissioning activities. Secondary-waste generation would be greatest during the operations and deactivation phases of each alternative. Secondary waste would be managed, treated, and/or stored for eventual recycling or disposal in accordance with applicable Federal and State of Washington regulations. Waste management impacts are discussed in Chapter 4, Sections 4.1.14, 4.2.14, and 4.3.14.

Primary waste is generally not considered an unavoidable, adverse environmental impact because this waste already exists in one form or another and, consequently, would require management and disposal. However, depending on the treatment method implemented, the volumes of primary waste may increase. This could result from the addition of binding agents (e.g., glass formers, grout), treatment by acid wash, or WTP and/or Preprocessing Facility (PPF) melters that are taken out of service. The increased volumes of waste would lead to a larger demand for landfill space. The increase in landfill loading would be considered an unavoidable consequence, although not necessarily an adverse consequence, because the overall performance of the final waste form would be enhanced.

7.2.12 Alternative Combinations

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

This section presents a comparison of the unavoidable, adverse environmental impacts that are projected to occur under the three alternative combinations selected for analysis in this EIS. A summary of overall projected unavoidable, adverse impacts under these alternative combinations is presented in Table 7–2. A detailed discussion of short-term impacts under the alternative combinations is presented in Chapter 4, Section 4.4. Long-term impacts under the alternative combinations are presented in Chapter 5, Section 5.4.

Alternative Combination 1, which represents all the No Action Alternatives, would have the least unavoidable impacts on most resource areas in the short term, but conversely would also have the greatest overall adverse impacts on the environment over the long term. Until construction of the WTP and Canister Storage Building could be terminated under the Tank Closure No Action Alternative, some land disturbance and mining of geologic materials would occur in Borrow Area C. This would result in relatively small but unavoidable short-term impacts on land, noise, air, and ecological resources. Approximately 2 hectares (5 acres) of new land disturbance would take place solely in Borrow Area C. Because of the limited disturbance of land in Borrow Area C, it is expected that native vegetation and natural species habitat would reclaim the disturbed areas relatively quickly, especially after restoration efforts are completed. Noise impacts would remain in the general vicinity of construction zones, but are not projected to exceed guidelines at receptor locations. Air quality would be adversely affected, with the possibility that particulate matter and nitrogen dioxide could exceed existing standards. Noise and air impacts would end with the cessation of construction activities. Over the long term, untreated tank waste would eventually be released from all the tank systems, migrate through the subsurface into groundwater, and unavoidably and adversely impact the Columbia River and the Hanford Reach ecosystem.

Alternative Combination 2 represents a midrange set of alternatives. The majority of short-term impacts would occur between 2006 and 2052, after which most activities would have been completed and the 100-year postclosure care and monitoring period for this set of alternatives would collectively begin. In the short term, not including Borrow Area C, 68 hectares (167 acres) of new land would be disturbed at Hanford, disrupting mostly sagebrush habitat and potentially several species of interest. In Borrow Area C, 140 hectares (345 acres) of new land would be permanently disturbed, altering the aesthetic quality of this area from several vantage points. Most of the 6.5 million cubic meters (8.5 million cubic yards) of geologic resources utilized would come from Borrow Area C. Electricity demand for WTP operations would approach site capacities and would need to be sustained for the duration of WTP operations. Noise impacts from construction activities would not necessarily increase in acuteness, but the effects would be distributed over a prolonged period of time, compared with Alternative Combination 1. Particulate matter, nitrogen dioxide, carbon monoxide, sulfur dioxide, and mercury could exceed air quality standards or guidelines at times. Vitrification of tank waste would eliminate the threat of untreated tank waste being released into the subsurface, but subsequent burial in an onsite disposal facility would be an unavoidable consequence of such treatment. Additional waste would be generated as a result of tank waste treatment, including secondary waste and low-activity waste (LAW) melters taken out of service, thereby increasing the need for onsite disposal capacity. The transportation risk assessment projected two fatalities due to accidents that involve fatal radiation doses to workers and three fatalities due to accidents that do not involve radiological exposure (e.g., fatalities resulting from impact of crash). The majority of projected transportation risks are associated with the receipt of offsite LLW and MLLW from other DOE facilities, an activity that is not associated with tank closure.

Alternative Combination 3 represents the set of alternatives that would produce the greatest impacts on most resource areas; therefore, it most closely resembles a scenario in which the maximum reasonably foreseeable unavoidable consequences would occur in the short term. The duration of short-term impacts resulting from construction, operations, and deactivation would extend through 2102. Unavoidable impacts on land and ecological resources would be similar to those under Alternative Combination 2, but would be magnified. Not including Borrow Area C, new land disturbance at Hanford would increase to 350 hectares (865 acres), while disturbance in Borrow Area C would increase to 401 hectares (992 acres). Geologic material consumption would increase to 18.7 million cubic meters (24.5 million cubic yards). Depending on the timing of construction activities, particulate matter, nitrogen dioxide, carbon monoxide, sulfur dioxide, and mercury emissions could exceed air quality standards or guidelines. The management of all treated tank waste as HLW would balance the reduction in the need for onsite LLW disposal capacity with an increase in demand for onsite HLW storage facilities. Secondary waste would be generated in greater quantities due to the significant increase in waste treatment associated with clean closure of the tank systems. WTP LAW melters that are taken out of service would be managed as HLW and would not require onsite disposal, but would be replaced with PPF melters, which would require onsite disposal when taken out of service. Transportation risks would increase for tank closure activities, but the majority of the projected risk would still be from receipt of offsite LLW and MLLW. The transportation risk assessment projected two worker fatalities due to accidents involving radiation doses and four fatalities due to nonradiological accidents.

Table 7–2. Alternative Combinations Unavoidable, Adverse Environmental Impacts

Resource Area	Alternative Combination 1	Alternative Combination 2	Alternative Combination 3
Land resources	2 hectares of new land would be disturbed in Borrow Area C only.	Not including Borrow Area C, 68 hectares of new land would be disturbed at Hanford. 140 hectares would be disturbed in Borrow Area C.	Not including Borrow Area C, 350 hectares of new land would be disturbed at Hanford. 401 hectares would be disturbed in Borrow Area C.
Infrastructure	Demand would remain well below capacities; therefore, no adverse impacts are expected.	Demand would remain well below capacities, except electrical demand would be approximately 68 percent of site capacities during WTP operations. This impact would not be permanent, but would require infrastructure upgrades or supplemental electrical supply to prevent a potential disruption in the local electrical supply grid.	Demand would remain well below capacities, except electrical demand would be approximately 73 percent of site capacities during WTP operations. This impact would not be permanent, but would require infrastructure upgrades or supplemental electrical supply to prevent a potential disruption in the local electrical supply grid.
Noise and vibration	Increases in noise levels would be relatively low outside immediate areas of construction and would be barely discernible at the Hanford site boundaries. Noise levels at these boundaries under all combinations of alternatives are projected to be below the Washington State standard daytime maximum noise level limitation of 60 dBA for industrial sources impacting residential receptors. Noise levels are expected to be the highest during the construction phase. Since the activities undertaken in support of each scoping area of this *TC & WM EIS* (tank closure, FFTF decommissioning, and waste management) would occur in different geographic areas, the impacts on noise levels would not be additive.		
Air quality	Particulate matter and nitrogen dioxide emissions may require additional analysis or engineering controls.	Particulate matter, nitrogen dioxide, carbon monoxide, sulfur dioxide, and mercury emissions may require additional analysis or engineering controls.	Particulate matter, nitrogen dioxide, carbon monoxide, sulfur dioxide, and mercury emissions may require additional analysis or engineering controls.
Geology and soils	99,000 cubic meters of geologic resources would be consumed for partial construction of the WTP and Canister Storage Building until terminated.	6,470,000 cubic meters of geologic resources would be consumed.	18,700,000 cubic meters of geologic resources would be consumed.
Water resources	All tank waste would eventually leak into the subsurface, adversely affecting groundwater quality and the Columbia River. The majority of long-term impacts would be from the eventual release of tank waste. Tank Closure Alternative 1 would account for more than 99 percent of impacts on groundwater under this alternative combination.	All tank waste would be vitrified in the WTP and disposed of in 200 Area disposal facilities or stored on site until disposition decisions are made and implemented. Some leaching of contaminants would occur prior to decay. The majority of long-term impacts would be from tank farm sources of hydrogen-3 (tritium), uranium-238, chromium, nitrate, and total uranium. The largest contributors of iodine-129 and technetium-99 would be waste management sources, particularly offsite waste disposed of in the 200-East Area Integrated Disposal Facility.	All tank waste would be vitrified and managed as HLW, requiring long-term, onsite storage in aboveground storage facilities. PPF glass and deep soil that has been removed would be disposed of in 200 Area disposal facilities. Some leaching of contaminants would occur prior to decay, although less than under Alternative Combination 2, due to aboveground storage of vitrified tank waste. Long-term impacts would be similar to those under Alternative Combination 2.

Table 7–2. Alternative Combinations Unavoidable, Adverse Environmental Impacts *(continued)*

Resource Area	Alternative Combination 1	Alternative Combination 2	Alternative Combination 3
Ecological resources	Negligible ecological impacts on grasslands and state-listed species within Borrow Area C would occur. However, long-term impacts could occur along the Columbia River due to release of untreated tank waste. Negligible long-term ecological impacts would occur from air emissions. Due to unmitigated release of tank waste into the subsurface, impacts on ecological resources in the Columbia River might occur from migration of contaminants through groundwater.	Grassland and sagebrush habitat would be adversely impacted, along with several state-listed species. Some long-term impacts on ecological resources would occur from air emissions associated mainly with WTP operations. Less, but more prolonged, than under Alternative Combination 1, impacts on ecological resources in the Columbia River might occur from releases from tank farm sources and waste management sources into the groundwater. Overall, ecological resource impacts would be the greatest, although very low, under this alternative combination.	Grassland and sagebrush habitat would be adversely impacted along with several state-listed species. This alternative combination's impact on grassland and sagebrush habitat would be greater due to the length of short-term activities and the amount of new land disturbance when compared with Alternative Combination 2. Some long-term impacts on ecological resources would occur from air emissions associated with WTP, PPF, and clean closure operations. Overall, long-term impacts on groundwater would be similar to those under Alternative Combination 2, although somewhat less due to offsite disposal of more treated tank waste, which would be managed as HLW.
Cultural and paleontological resources	No impacts are expected to occur under this alternative combination.	Excavation of Borrow Area C would alter the view of this area from higher elevations, such as Rattlesnake Mountain, which is of cultural interest to local American Indians, even after completion of restoration efforts.	
Socioeconomics	With the termination of WTP construction, the loss of jobs in the short term would negatively impact the local economy and could possibly suppress growth within the ROI. At its peak, and prior to termination of construction, the workforce would be approximately 1,840 FTEs and would represent 1.5 percent of the projected 2008 labor force within the ROI.	Significant growth in the workforce would be necessary and would fuel regional growth. The peak workforce would represent approximately four to five times the peak workforce under Alternative Combination 1, although the peak would occur around 2040. The number of daily commuter vehicles would be correlated with the increase in the workforce and could affect commute times.	Major growth in the workforce would be necessary and would fuel regional growth. The peak workforce would represent approximately seven times the peak workforce under Alternative Combination 1, although the peak would occur around 2021. The number of daily commuter vehicles would be correlated with the increase in the workforce and could affect commute times.

Table 7–2. Alternative Combinations Unavoidable, Adverse Environmental Impacts *(continued)*

Resource Area	Alternative Combination 1	Alternative Combination 2	Alternative Combination 3
Public and occupational health and safety	Normal facility operations and deactivation, including some closure activities, would result in unavoidable radiological exposure to workers and the general public; nevertheless, no latent fatal cancers are expected among the workers or the general public. Any increase in transportation risks would be negligible because they would be limited to continued operation of the low-level radioactive waste burial grounds, and because no tank waste would be treated and/or transported. No transportation-related fatalities are projected. Comparatively, this alternative combination would lead to the maximum potential for long-term impacts on the public due to unmitigated releases of radioactive contaminants from the storage tanks. Impacts on groundwater from releases of tank inventories within the Core Zone Boundary would potentially increase risks to onsite receptors that attempt to use groundwater as a source of drinking water or for irrigation of crops. Negligible impacts on downstream populations are projected.	Normal facility operations and deactivation, including some closure activities, would result in unavoidable radiological exposure to workers and the general public. Nine latent fatal cancers could occur among workers due to radiological exposure, and one is expected among the general public. The majority of transportation risks would be associated with receipt of offsite waste. Impacts on groundwater within the Core Zone Boundary from waste management areas would potentially increase risks to onsite receptors that attempt to use groundwater as a source of drinking water or for irrigation of crops. Negligible impacts on downstream populations are projected.	Normal facility operations and deactivation, including some closure activities, would result in unavoidable radiological exposure to workers and the general public. The number of latent fatal cancers among workers due to radiological exposure could increase to 53 as a result of clean closure activities and one latent fatal cancer is expected among the general public. The majority of transportation risks would be associated with the receipt of offsite waste, with a minor increase due to the local transportation of additional waste associated with clean closure of the tanks. Comparatively, this alternative combination would have a lower potential for long-term impacts on the public due to the management of treated tank waste as HLW. Although less than those under Alternative Combination 2, impacts on groundwater within the Core Zone Boundary and waste management areas would potentially increase risks to onsite receptors that attempt to use groundwater as a source of drinking water or for irrigation of crops. Negligible impacts on downstream populations are projected.
Waste management	Any increase in secondary-waste generation is expected to be negligible during ongoing administrative activities related to maintaining existing tank systems. In time, as efforts to maintain existing tank systems would likely intensify, the rate of secondary-waste generation would also increase.	WTP operations would yield secondary-waste and low-activity-waste melters that would be taken out of service.	All tank waste would be managed as HLW. A possible long-term consequence would be the requirement for long-term care and management of large quantities of HLW in onsite, aboveground storage facilities. PPF operations in support of clean closure activities would yield secondary-waste and PPF melters that would be taken out of service. WTP melters taken out of service would also be managed as HLW.

Note: To convert cubic meters to cubic yards, multiply by 1.308; hectares to acres, by 2.471.

Key: dBA=decibels A-weighted; FFTF=Fast Flux Test Facility; FTE=full-time equivalent; Hanford=Hanford Site; HLW=high-level radioactive waste; PPF=Preprocessing Facility; ROI=region of influence; *TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*; WTP=Waste Treatment Plant.

7.3 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

This section describes the major irreversible and irretrievable commitments of resources that have been identified under each alternative considered in this *TC & WM EIS*. A commitment of resources is irreversible when future options for a resource are limited due to primary or secondary impacts of the commitment. A commitment of resources is irretrievable when a resource is neither renewable nor recoverable for future use once it has been used or consumed under the commitment. In general, the commitments of capital, land, energy, labor, and materials during implementation of the activities in support of the Tank Closure, FFTF Decommissioning, and Waste Management alternatives would be irreversible or irretrievable. This section discusses the commitments of four major categories of resources that would be required to implement the proposed actions and alternatives: land, materials, utilities, and labor.

Implementation of any of the alternatives considered in this *TC & WM EIS*, including the No Action Alternatives, would entail the irreversible and irretrievable commitments of land; construction materials (e.g., steel, concrete), chemicals, and geologic resources; utility resources (electricity, fossil fuels, and water); and labor. These resources would be committed over the entire life cycle of the alternatives described in this *TC & WM EIS* and would essentially be irrecoverable. The life cycle of an alternative includes construction, operations, decommissioning, and closure of facilities used to accomplish the objectives included in the scope of this *TC & WM EIS*.

Based on the analysis in this *Final TC & WM EIS*, some portion of the land, extending to the soil, may not be available for use and may be subject to access or use restrictions. For example, under certain Tank Closure alternatives where landfill closure of tank structures would occur, the land and underlying vadose zone would be covered by an engineered barrier and may be subject to access or use restrictions. A similar situation would exist under FFTF Decommissioning Alternative 2, where below-grade structures, such as the reactor vessel, piping, and other components, would be entombed and covered by an engineered barrier. Under the Waste Management action alternatives, waste that is disposed of (e.g., ILAW glass), would remain in place, and the disposal areas would be covered by an engineered barrier and be subject to access and use restrictions. Potential long-term land use commitments and associated timeframes are discussed in more detail in Section 7.4. The 2010 groundwater monitoring report (DOE 2010a) identifies current exceedances for the following radionuclides: tritium, technetium-99, iodine-129, strontium-90, and uranium. Cesium-137, cobalt-60, and plutonium exceed the standards in a number of wells. Exceedances were also identified for the following chemicals: nitrates, carbon tetrachloride, chromium, and trichloroethylene (DOE 2010a). Corrective actions and remedial activities are ongoing planned for all of the Hanford areas. Appendix U provides the status of remedial activities identified to date. As additional cleanup work still has to be done, the full extent of access or use restrictions will not be known until the scope of *TC & WM EIS* activities and CERCLA cleanup have been completed. Previously, in Section 7.2.6, potential unavoidable adverse impacts on groundwater that would result from implementation of any of the *TC & WM EIS* alternatives are discussed.

7.3.1 Tank Closure Alternatives

Under the Tank Closure No Action Alternative, both ongoing partial construction of new facilities and routine tank operations would continue until these activities are terminated, followed by administrative controls for 100 years. Under Tank Closure Alternatives 2 through 6C, construction, operations, and deactivation of new facilities would be required to support tank waste retrieval, treatment, and disposal and SST system closure. (Tank Closure Alternative 2A does not address SST system closure.) For some facilities, construction of multiple replacements would be necessary because the life cycle of a particular alternative would exceed the design life of the facility.

7.3.1.1 Land Resources

Land use commitments under the Tank Closure alternatives for (1) construction of new facilities on undisturbed land, (2) permanent in-place closure of existing facilities, and (3) borrow areas that would be used to supply geologic materials (e.g., sand, gravel, and soil) would be irreversible and irretrievable (see Table 7–3).

Land use commitments under the Tank Closure No Action Alternative include the area currently occupied by the SST farms and the B and T Area cribs and trenches (ditches) that would not be closed. Under Tank Closure Alternatives 2A through 5 and 6C, land use commitments would include new treatment and storage facilities constructed on undisturbed land. Under Tank Closure Alternative 2A, land use commitments would also include the SST farms and cribs and trenches (ditches), where waste would be left in place. Under Tank Closure Alternatives 2B through 5 and 6C, land use commitments would also include those areas where engineered barriers would be placed over the SST farms and cribs and trenches (ditches). Under Tank Closure Alternatives 6A and 6B, clean closure of the SST farms would be achieved, thereby eliminating the need for engineered barriers. However, management and subsequent storage of all tank waste as IHLW under these alternatives would require a substantial amount of land until permanent waste disposal could be realized. Tank Closure Alternatives 6A and 6B, Base Cases, however, would still require the emplacement of an engineered barrier over the cribs and trenches (ditches). Tank Closure Alternatives 6A and 6B, Option Cases, would achieve clean closure of the SST farms and the B and T Area cribs and trenches (ditches).

Table 7–3. Tank Closure Alternatives Irreversible and Irretrievable Commitments of Land Resources[a]

Alternative	Land Resource (hectares)	
	Permanently Committed and Newly Disturbed Land[b]	**Borrow Area C (Disturbed Land)**
1	17	2
2A	33	29
2B	107	95
3A	110	100
3B	111	92
3C	111	93
4	87	102
5	111	117
6A, Base Case	209	381
6A, Option Case	186	458
6B, Base Case	128	240
6B, Option Case	104	316
6C	153	104

[a] Calculated as total alternative life-cycle requirements, encompassing construction, operations, deactivation, and closure. Does not include land area already committed for construction of the original Waste Treatment Plant.

[b] This includes (1) land area where facilities would be closed in place or where engineered barriers would be constructed; (2) new disturbance of land for facility construction; and (3) new disturbance of land for construction of engineered barriers beyond the boundary of the barrier itself. Does not include Borrow Area C.

Note: To convert hectares to acres, multiply by 2.471.

Source: SAIC 2010a.

New disturbance of land for construction of facilities would be considered an irreversible impact. The in-place closure of SST farms and cribs and trenches (ditches), with or without the emplacement of engineered barriers, would be considered an irreversible and irretrievable commitment of land. Section 7.4 discusses the relationship between short-term uses of the environment and the maintenance and enhancement of its long-term productivity.

Construction of new facilities, emplacement of engineered surface barriers, and/or partial or complete clean closure of the SST system would require relatively large volumes of geologic materials from Borrow Area C for backfilling of excavations. While this land would not be irreversibly or irretrievably committed to some use, the area would be irreversibly altered. The consumption of geologic materials, including soil, gravel, sand, and rock or basalt, is covered in Section 7.3.1.2 below.

The estimated areas of land that may be permanently committed or newly disturbed while supporting the Tank Closure alternatives are presented in Table 7–3. Except for Borrow Area C and the construction of IHLW Interim Storage Modules under Tank Closure Alternative 6A, all land commitments would be within the Central Plateau (200 Areas). This area has been designated Industrial-Exclusive by the *Hanford Comprehensive Land-Use Plan EIS* (DOE 1999a) and has been set aside for *TC & WM EIS* activities. For a detailed discussion of land use impacts of construction of new and existing facilities and Borrow Area C operations under the Tank Closure alternatives, see Chapter 4, Section 4.1.1. Table 7–3 may differ from the presentation of analysis in Section 4.1.1 because Table 7–3 does not include committed land for construction of new facilities where the land is known to have already been disturbed.

7.3.1.2 Material Resources

The irreversible and irretrievable commitment of material resources would include process chemicals used during operations of facilities, materials used for construction that cannot be recovered or recycled, materials that would be rendered radioactive and could not be decontaminated, raw materials consumed or reduced to irrecoverable waste forms, and geologic borrow materials. Projected demands for primary material resources under each of the Tank Closure alternatives are shown in Table 7–4 for construction and in Table 7–5 for nonconstruction-related activities.

Principal construction materials would include steel; asphalt; and concrete and grout constituents such as cement, gravel, and sand. Although other materials, including wood, plastics, and other metals, would be used, these quantities are not considered a primary demand. Concrete, steel, and other materials incorporated into the framework of new facilities, such as the WTP and supplemental treatment facilities, would be irretrievably lost, regardless of whether operations would result in direct contamination of the materials. Cement would be used to formulate concrete for construction of new facilities and in the grouting of SSTs and ancillary equipment in the tank farms. Concrete would be manufactured in batch plants located throughout the 200 Areas. The management of all tank waste as HLW under Tank Closure Alternatives 6A and 6B would require construction of additional IHLW Shipping/Transfer Facilities and Interim Storage Facilities, as well as ILAW Interim Storage Facilities, which would increase the steel, asphalt, and concrete commitments. Significant quantities of grout would be utilized under Tank Closure Alternatives 2B through 6C to fill the SSTs in place or the ancillary equipment associated with the tank system and/or cribs and trenches (ditches). The Tank Closure No Action Alternative and Alternative 2A would not utilize comparable amounts of grout because the SSTs would not be closed under these alternatives.

Geologic materials would include sand, gravel, soil, and rock mined from Borrow Area C for the construction of engineered barriers and for specification and nonspecification backfill (e.g., other borrow materials). Specification backfill has been designated for construction of the WTP due to the sensitivity of the melters to facility settling. Under the appropriate alternatives, nonspecification backfill would be used to replenish voids resulting from excavation and removal of the SST farms and cribs and trenches (ditches). For example, Tank Closure Alternatives 6A and 6B, in which deep soil removal would be required for the tank systems and/or cribs and trenches (ditches), would require a notable increase in soil commitments (shown under "Other Borrow Materials" in Table 7–4) for backfilling the excavation. In addition, construction of shipping/transfer facilities and interim storage facilities under Tank Closure Alternative 6A to manage the additional IHLW that would be produced specifically requires 'rock' as a backfill for facility construction. Except for the Tank Closure No Action Alternative; Alternative 2A; and Alternatives 6A and 6B, Option Cases, engineered barriers would be constructed and emplaced. Tank Closure Alternatives 6A and 6B, Base Cases, would not require engineered barriers for the SST farms; however, these alternatives would still require placement of engineered barriers over the cribs and trenches (ditches).

The consumption of various materials would be necessary to support nonconstruction-related activities under the Tank Closure alternatives. Under the Tank Closure No Action Alternative, there would be no retrieval or treatment of tank waste; therefore, the consumption of materials would be below notable quantities. The WTP, which would be required under Tank Closure Alternatives 2A through 6C, as well as the PPF, which would be required under Tank Closure Alternatives 4, 6A, and 6B, would utilize glass formers for the vitrification of tank waste into a high-performing waste form. Operations of the WTP LAW melters would require the use of ion exchange resins to remove cesium-137 from the waste feed prior to treatment, except under Tank Closure Alternative 6A, in which all tank waste would be treated as HLW. To achieve 99.9 percent tank waste retrieval under Tank Closure Alternatives 4, 6A, and 6B, chemical washing would be employed, requiring the use of miscellaneous retrieval chemicals (e.g., oxalic acid). The consumption of nitric acid (3 percent and 57 percent solution) and caustics (50 percent solution) would support operations of the PPF under Tank Closure Alternatives 4, 6A, and 6B. Under Tank Closure Alternatives 3A through 5, transuranic (TRU) waste would be separated from other tank waste using dedicated Contact-Handled and Remote-Handled Mixed TRU Waste Facilities. The TRU waste processing facilities required under these alternatives would use appreciable quantities of sorbent materials and sodium hydroxide.

The various supplemental treatment technologies (i.e., bulk vitrification, cast stone, steam reforming, and sulfate removal) would all consume additional materials to expedite treatment of tank waste. The bulk vitrification technology, implemented under Tank Closure Alternatives 3A, 4, and 5, would utilize soil and sand as an insulator in the large bulk vitrification containers during the melt process. The cast stone technology, implemented under Tank Closure Alternatives 3B, 4, and 5, would utilize fly ash, slag, and cement to encapsulate the waste feed and produce a solid-waste form. The steam reforming technology, implemented under Tank Closure Alternative 3C, would consume sucrose (sugar), kaolin clay, iron oxide, oxygen, and nitrogen as chemical additives at various stages of the treatment process. Finally, sulfate removal, implemented under Tank Closure Alternative 5, would consume nitric acid (12.2 molar), strontium nitrate (41.5 weight-percent), sodium hydroxide (30 weight-percent), and grout. The chemicals would be used to react and precipitate sulfates from the waste feed, and the grout would be used to stabilize the sulfate precipitate after it is removed from the waste stream. Appendix E provides a more detailed analysis of the operations and chemical uses of each of the tank waste treatment technologies.

Table 7–4. Tank Closure Alternatives Irreversible and Irretrievable Commitments of Construction Materials[a, b]

Resource (× 1,000)	Tank Closure Alternative												
	1	**2A**	**2B**	**3A**	**3B**	**3C**	**4**	**5**	**6A, Base Case**	**6A, Option Case**	**6B, Base Case**	**6B, Option Case**	**6C**
Construction Materials (metric tons)													
Steel	4	88	73	62	61	69	168	63	1,240	1,740	534	1,030	143
Asphalt	0	5	5	4	4	4	5	4	125	125	5	5	5
Concrete (cubic meters)[c]													
Cement	8	162	102	84	83	85	120	88	1,500	1,530	346	374	195
Sand	16	327	206	168	167	172	240	178	3,010	3,070	685	742	388
Gravel	21	427	268	219	218	224	312	233	3,920	4,000	889	965	507
Fly ash	0	0	0	0	0	0	0	0	0	0	0	0	0
Grout (cubic meters)[c]													
Cement	0	0.01	13	13	13	13	20	13	28	93	28	93	13
Sand	0	0.05	774	774	774	774	661	772	116	384	116	384	774
Fly ash	0	0.04	166	166	166	166	182	163	140	463	140	463	166
Bentonite clay	0	0	6	6	6	6	7	6	7	9	7	9	6
Water-reducing agent	0	0	0.22	0.22	0.22	0.22	0.19	0.22	0.04	0.14	0.04	0.14	0.22
Engineered Barrier (cubic meters)													
Sand	0	0	1,060	1,060	1,060	1,060	591	1,760	317	0	317	0	1,060
Gravel	0	0	253	253	253	253	141	421	76	0	76	0	253
Soil	0	0	849	849	849	849	475	1,420	255	0	255	0	849
Asphalt	0	0	138	138	138	138	77	230	41	0	41	0	138
Other Borrow Materials (cubic meters)													
Rock	0	14	14	10	10	10	13	10	350	350	14	14	14
Sand	0.2	1	4	4	4	4	4	4	1	1	1	1	4
Gravel	0.3	6	8	8	8	8	11	8	11	11	9	9	8
Soil	0.2	1	529	529	529	529	1,800	1	8,300	12,100	8,300	12,100	529
Specification backfill	55	549	254	220	220	220	220	220	1,020	1,020	254	254	254

[a] Resources listed were calculated as total life-cycle requirements for construction-related activities.
[b] Values presented in this table are in thousands; multiply by 1,000 to obtain actual value of resource commitment.
[c] Concrete and grout are presented as premixed constituents.
Note: To convert cubic meters to cubic yards, multiply by 1.308.
Source: SAIC 2010a.

Table 7–5. Tank Closure Alternatives Irreversible and Irretrievable Commitments of Nonconstruction Materials[a, b]

Resource (× 1,000)	Tank Closure Alternative												
	1	2A	2B	3A	3B	3C	4	5	6A, Base Case	6A, Option Case	6B, Base Case	6B, Option Case	6C
Materials													
Glass formers (metric tons)[c]	0	195	202	197	197	197	199	181	194	264	206	276	202
Ion exchange resins (liters)[d]	0	1,580	2,440	1,590	1,590	1,590	1,960	1,600	0	0	2,440	2,440	2,440
Retrieval chemicals, (e.g., oxalic acid) (liters)[e]	0	0	0	0	0	0	189,000	0	244,000	244,000	189,000	189,000	0
Nitric acid (3 percent and 57 percent solution) (liters)[e]	0	0	0	0	0	0	5,680	0	1,790	62,700	1,790	62,700	0
Caustic (50 percent solution) (liters)[e]	0	0	0	0	0	0	2,430	0	61	2,120	61	2,120	0
Sorbent (liters)	0	0	0	984	984	984	1,010	894	0	0	0	0	0
Sodium hydroxide (kilograms)	0	0	0	22	22	22	22	22	0	0	0	0	0
Soil (cubic meters)[f]	0	0	0	187	0	0	63	63	0	0	0	0	0
Sand (cubic meters)[f]	0	0	0	148	0	0	50	50	0	0	0	0	0
Fly ash (cubic meters)[g]	0	0	0	0	233	0	149	149	0	0	0	0	0
Slag (cubic meters)[g]	0	0	0	0	233	0	149	149	0	0	0	0	0
Cement (cubic meters)[g]	0	0	0	0	28	0	18	18	0	0	0	0	0
Sucrose (metric tons)[h]	0	0	0	0	0	1,130	0	0	0	0	0	0	0
Kaolin clay (metric tons)[h]	0	0	0	0	0	207	0	0	0	0	0	0	0
Oxygen (metric tons)[h]	0	0	0	0	0	1,070	0	0	0	0	0	0	0
Nitrogen (metric tons)[h]	0	0	0	0	0	460	0	0	0	0	0	0	0
Nitric acid (12.2 molar) (liters)[i]	0	0	0	0	0	0	0	91,600	0	0	0	0	0
Strontium nitrate (41.5 weight-percent) (liters)[i]	0	0	0	0	0	0	0	42,800	0	0	0	0	0
Grout mix (kilograms)[i]	0	0	0	0	0	0	0	28,000	0	0	0	0	0
Sodium hydroxide (30 weight-percent) (liters)	0	0	0	0	0	0	0	3,820	0	0	0	0	0

[a] Resources listed were calculated as total life-cycle requirements for nonconstruction-related activities.
[b] Values presented in this table are in thousands; multiply by 1,000 to obtain actual value of resource commitment.
[c] The Waste Treatment Plant and Preprocessing Facility utilize glass formers for the vitrification process. These values do not include materials for processing cesium and strontium capsules. The values under Tank Closure Alternatives 3A through 5 do not reflect a reduction due to treatment of some tank waste using supplemental treatment.
[d] Cesium removal pretreatment.
[e] Used in chemical washing, which is needed to achieve 99.9 percent retrieval of tank waste.
[f] Bulk vitrification insulating materials.
[g] Cast stone materials.
[h] Steam reforming materials (table does not include small amount of iron oxide that would also be consumed in this process).
[i] Sulfate removal materials.

Note: To convert cubic meters to cubic yards, multiply by 1.308; kilograms to pounds, by 2.2046; liters to gallons, by 0.26417.
Source: SAIC 2010a.

7.3.1.3 Utility Resources

Key utility infrastructure resources include the projected activity demands for water, electricity, and fuel over the life cycle of each Tank Closure alternative. Projected demands for key utility infrastructure resources under each Tank Closure alternative are shown in Table 7–6.

Table 7–6. Tank Closure Alternatives Utility Resource Commitments[a, b]

Alternative	Resource (× 1,000,000)			
	Water (liters)	Electricity (kilowatt-hours)	Fuel (liters)	
			Diesel	Gasoline
1	3,300	115	36	5
2A	208,000	35,600	4,960	221
2B	86,300	17,900	4,040	156
3A	77,000	14,100	1,860	116
3B	77,000	12,100	1,860	116
3C	77,300	20,100	1,980	116
4	82,200	14,800	2,050	133
5	92,500	12,200	4,110	124
6A, Base Case	643,000	186,000	22,900	715
6A, Option Case	643,000	188,000	23,000	711
6B, Base Case	92,600	21,100	4,360	216
6B, Option Case	92,800	23,800	4,440	212
6C	86,300	17,900	4,040	156

[a] Calculated as total alternative life-cycle requirements, encompassing construction, operations, deactivation, and closure.

[b] Values presented in this table are in millions; multiply by 1,000,000 to obtain actual value of resource commitment.

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

Source: SAIC 2010a.

Water would be required during construction for soil compaction, dust control, and possibly for work surface and equipment washdown. Concrete and grout would be produced in onsite batch plants that would require large volumes of water. During operations, water would be required to support process makeup requirements and facility cooling, as well as the potable and sanitary needs of the operations workforce and other uses. Water would also be consumed during facility deactivation activities to stabilize and partially decontaminate waste retrieval, treatment, and disposal facilities.

Energy expended would be in the form of electricity for construction equipment and facility operations and fuel for equipment, vehicles, and process operations. The energy required to support the activities under each alternative would be a large fraction of the total energy used at Hanford. The high demand for electricity under Tank Closure Alternatives 2A through 6C would largely be attributable to operations of the WTP and PPF melters, and the demand under Tank Closure Alternatives 3A, 3C, 4, and 5 would also be attributable to operations of the bulk vitrification or steam reforming supplemental treatment processes. Electricity and fuels would be purchased from commercial sources.

For a detailed discussion of the impacts on the existing infrastructure of implementing the Tank Closure alternatives, see Chapter 4, Section 4.1.2.

7.3.1.4 Labor Resources

Labor resources associated with the Tank Closure alternatives would be required over the entire life cycle of the alternatives, although more would be required during the construction and operations phases. Under Tank Closure Alternative 6A, the treatment and management of all tank waste as HLW and the duration of all life-cycle phases (156 years) would require a substantially larger commitment of labor compared with other Tank Closure action alternatives. The labor requirements of all of the Tank Closure alternatives are shown in Table 7–7. These labor requirements have the potential to generate economic impacts that may affect the need for housing units, public services, and local transportation in the region. For a detailed analysis of the labor impacts associated with the Tank Closure alternatives, see Chapter 4, Section 4.1.9.

Table 7–7. Tank Closure Alternatives Labor Resource Commitments[a]

Alternative	Labor Hours	Labor (FTEs)
1	16,300,000	7,840
2A	708,000,000	340,000
2B	388,000,000	187,000
3A	349,000,000	168,000
3B	344,000,000	165,000
3C	357,000,000	172,000
4	450,000,000	216,000
5	325,000,000	156,000
6A, Base Case	2,060,000,000	990,000
6A, Option Case	2,130,000,000	1,020,000
6B, Base Case	515,000,000	248,000
6B, Option Case	572,000,000	275,000
6C	389,000,000	187,000

[a] Calculated as total alternative life-cycle requirements, encompassing construction, operations, deactivation, and closure.

Note: To convert FTEs to labor hours, multiply by 2,080.

Key: FTE=full-time equivalent.

Source: SAIC 2010a.

7.3.2 FFTF Decommissioning Alternatives

Implementation of the FFTF Decommissioning No Action Alternative would involve completion of deactivation activities and site monitoring under administrative controls for 100 years. The deactivation activities would include removal and storage of the four FFTF RH-SCs and bulk sodium. A complete description of the four FFTF RH-SCs is provided in Appendix E, Section E.2.4.4. FFTF Decommissioning Alternative 2 would involve demolition of structures to grade and in-place entombment. FFTF Decommissioning Alternative 3 would involve complete removal of all above- and below-grade structures. Both FFTF Decommissioning Alternatives 2 and 3 would require disposition of the four RH-SCs in an RTP at either Hanford or the Idaho National Laboratory (INL), as well as bulk sodium processing in a new Sodium Reaction Facility (SRF) at Hanford or in the existing Sodium Processing Facility (SPF) at INL. As a result of the proposed locations of these facilities at either Hanford or INL, FFTF Decommissioning Alternatives 2 and 3 have four different scenarios depending on the potential location combinations.

7.3.2.1 Land Resources

Land use commitments under the FFTF Decommissioning alternatives for (1) construction of new facilities on undisturbed land, (2) permanent in-place closure of existing facilities, and (3) borrow areas that would be used to supply geologic materials (e.g., sand, gravel, and soil) would be irreversible and irretrievable (see Table 7–8).

Table 7–8. FFTF Decommissioning Alternatives Irreversible and Irretrievable Commitments of Land Resources[a]

Alternative (with Options)	Land Resource (hectares)	
	Permanently Committed and Newly Disturbed Land[b]	Borrow Area C (Disturbed Land)
1–No Action	18	0
2–Hanford RTP and SRF	0.7	2.8
2–Hanford RTP and INL SPF	0.7	2.8
2–INL RTP and Hanford SRF	0.7	2.8
2–INL RTP and SPF	0.7	2.8
3–Hanford RTP and SRF	0	3.2
3–Hanford RTP and INL SPF	0	3.2
3–INL RTP and Hanford SRF	0	3.2
3–INL RTP and SPF	0	3.2

[a] Calculated as total alternative life-cycle requirements, encompassing construction, operations, deactivation, and closure.

[b] This includes (1) land area where facilities would be closed in place or where engineered barriers would be constructed; (2) new disturbance of land for facility construction; and (3) new disturbance of land for construction of engineered barriers beyond the boundary of the barrier itself. Does not include Borrow Area C.

Note: To convert hectares to acres, multiply by 2.471.

Key: FFTF=Fast Flux Test Facility; Hanford=Hanford Site; INL=Idaho National Laboratory; RTP=Remote Treatment Project; SPF=Sodium Processing Facility; SRF=Sodium Reaction Facility.

Source: SAIC 2010b.

FFTF is located in Hanford's 400 Area. None of the FFTF Decommissioning alternatives involve new disturbance of land for construction of an RTP at Hanford or INL, construction of an SRF at Hanford, or construction of an SPF at INL. Construction of these facilities would be within existing buildings or on disturbed land. The area where engineered barriers would be placed over the Reactor Containment Building (RCB) and Buildings 491E and 491W would be considered an irreversible and irretrievable commitment of land as a permanent waste management area. Section 7.4 discusses the relationship between short-term uses of the environment and the maintenance and enhancement of its long-term productivity.

The construction of new facilities, backfilling of subgrade void spaces, and emplacement of engineered surface barriers would require relatively large volumes of geologic materials from Borrow Area C. While this land would not be irreversibly or irretrievably committed to some use, the area would be irreversibly altered. The consumption of geologic materials, including soil, gravel, sand, and rock or basalt, is covered in Section 7.3.2.2.

The estimated areas of land that may permanently be committed or newly disturbed while supporting the FFTF Decommissioning alternatives are presented in Table 7–8. Except for Borrow Area C, all land use would occur within the FFTF Property Protected Area (i.e., 400 Area). For a detailed discussion of land use impacts of construction of new and existing facilities and Borrow Area C operations under the FFTF Decommissioning alternatives, see Chapter 4, Section 4.2.1. Table 7–8 may differ from the presentation of analysis in Chapter 4, Section 4.2.1, because Table 7–8 does not include committed land for construction of new facilities where the land is known to have already been disturbed.

7.3.2.2 Material Resources

The irreversible and irretrievable commitment of material resources would include process chemicals used during operations of facilities, construction materials that would not be recovered or recycled, materials that would be rendered radioactive and could not be decontaminated, raw materials consumed or reduced to irrecoverable waste forms, and geologic borrow materials. Projected demands for primary material resources under each FFTF Decommissioning alternative are shown in Table 7–9. The commitment of material resources would be for the entire life cycle of each FFTF Decommissioning alternative, including construction, operations, deactivation, and closure.

Regardless of whether the SRF is built at Hanford or INL's SPF is reactivated, modified, and used, some nitrogen would be necessary for the operations of either bulk sodium processing facility. Principal construction materials would include steel, as well as concrete and grout constituents, such as cement, gravel, and sand. Although other materials, including wood, plastics, and other metals, would be used, the use of these materials would be minor. For practical purposes, concrete, steel, and other materials incorporated into the framework of new facilities, such as the RTP and SRF at Hanford, would be irretrievably lost, regardless of whether operations would result in the direct contamination of the materials. In general, the RTP and SRF would be of comparable size and complexity; therefore, similar quantities of construction materials would be required for their respective construction.

Geologic materials, including sand, gravel, and soil, would be mined from Borrow Area C for the construction of engineered barriers and for nonspecification backfill, as presented in Table 7–9 under "Other Borrow Materials." The amount of nonspecification backfill required for filling subgrade void spaces would be higher under FFTF Decommissioning Alternative 3, in which the structures would be completely removed. Under all of the FFTF Decommissioning Alternative 2 scenarios, entombment would require the construction of an engineered barrier.

Table 7–9. FFTF Decommissioning Alternatives Irreversible and Irretrievable Commitments of Materials[a, b]

Resource (× 1,000)	FFTF Decommissioning Alternative								
	1	2–Entombment (with Options)				3–Removal (with Options)			
	No Action	Hanford RTP and SRF	Hanford RTP and INL SPF	INL RTP and Hanford SRF	INL RTP and SPF	Hanford RTP and SRF	Hanford RTP and INL SPF	INL RTP and Hanford SRF	INL RTP and SPF
Process Chemicals (metric tons)									
Nitrogen	0.14	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045
Construction Materials (metric tons)									
Steel	0	1	1	0.02	0.004	1	1	0.02	0.004
Asphalt	0	0	0	0	0	0	0	0	0
Concrete (cubic meters)[c]									
Cement	0	1	1	0.02	0.006	1	1	0.02	0.006
Sand	0	1	1	0.02	0.04	1	1	0.02	0.04
Gravel	0	2	2	0.05	0.02	2	2	0.05	0.02
Fly ash	0	0	0	0	0	0	0	0	0
Grout (cubic meters)[c]									
Cement	0	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
Sand	0	23	23	23	23	23	23	23	23
Fly ash	0	12	12	12	12	12	12	12	12
Bentonite clay	0	0	0	0	0	0	0	0	0
Water-reducing agent	0	0	0	0	0	0	0	0	0
Engineered Barrier (cubic meters)									
Sand	0	9	9	9	9	0	0	0	0
Gravel	0	2	2	2	2	0	0	0	0
Soil	0	7	7	7	7	0	0	0	0
Asphalt	0	1	1	1	1	0	0	0	0
Other Borrow Materials (cubic meters)									
Rock	0	0	0	0	0	0	0	0	0
Sand	0	0	0	0	0	0	0	0	0
Gravel	0	2	1	0.1	0	0	0	0.1	0
Soil	0	0.04	0.04	0	0	0.04	0.04	0	0
Specification backfill	0	80	80	80	80	120	120	120	120

[a] Values presented in this table are in thousands; multiply by 1,000 to obtain actual value of resource commitment.
[b] Calculated as total alternative life-cycle requirements, encompassing construction, operations, deactivation, and closure.
[c] Concrete and grout are presented as premixed constituents.
Note: To convert cubic meters to cubic yards, multiply by 1.308.
Key: FFTF=Fast Flux Test Facility; Hanford=Hanford Site; INL=Idaho National Laboratory; RTP=Remote Treatment Project; SPF=Sodium Processing Facility; SRF=Sodium Reaction Facility.
Source: SAIC 2010b.

7.3.2.3 Utility Resources

Key utility infrastructure resources would include projected activity demands for water, electricity, and fuel over the life cycle considered under each FFTF Decommissioning alternative. Projected demands for key utility infrastructure resources under each FFTF Decommissioning alternative are shown in Table 7–10.

Table 7–10. FFTF Decommissioning Alternatives Utility Resource Commitments[a, b]

Alternative (with Options)	Resource (× 1,000)			
	Water (liters)	Electricity (kilowatt-hours)	Fuel (liters)	
			Diesel	Gasoline
1–No Action	795,000	600,000	0	114
2–Hanford RTP and SRF	31,100	4,600	5,350	872
2–Hanford RTP and INL SPF	30,900	4,500	4,380	466
2–INL RTP and Hanford SRF	23,600	4,600	5,110	780
2–INL RTP and SPF	23,400	4,500	4,140	372
3–Hanford RTP and SRF	30,400	7,800	5,090	880
3–Hanford RTP and INL SPF	30,200	7,700	4,120	474
3–INL RTP and Hanford SRF	22,900	7,800	5,110	790
3–INL RTP and SPF	22,700	7,700	3,880	382

[a] Calculated as total alternative life-cycle requirements, encompassing construction, operations, deactivation, and closure.

[b] Values presented in this table are in thousands; multiply by 1,000 to obtain actual value of resource commitment.

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

Key: FFTF=Fast Flux Test Facility; Hanford=Hanford Site; INL=Idaho National Laboratory; RTP=Remote Treatment Project; SPF=Sodium Processing Facility; SRF=Sodium Reaction Facility.

Source: SAIC 2010b.

The consumption of water and electricity under the FFTF Decommissioning No Action Alternative would be relatively high compared with that under the action alternatives due to the long-term management requirements of 100 years of administrative controls. Conversely, to effect entombment or complete removal under FFTF Decommissioning Alternatives 2 and 3, fuel consumption would increase. Essentially, the differences in utility consumption between FFTF Decommissioning Alternatives 2 and 3 are negligible.

For a detailed discussion of impacts on the existing infrastructure of implementing the FFTF Decommissioning alternatives, see Chapter 4, Section 4.2.2.

7.3.2.4 Labor Resources

Labor resources associated with the FFTF Decommissioning alternatives would be required over the entire life cycle of each alternative. The FFTF Decommissioning No Action Alternative would require a smaller commitment of labor resources than the action alternatives, but the labor would be needed over an extended period of time. FFTF Decommissioning Alternatives 2 and 3 would require much greater short-term commitments of labor resources to achieve either entombment or removal of the FFTF structures. To achieve removal under FFTF Decommissioning Alternative 3, a slight increase in construction labor would be required compared with FFTF Decommissioning Alternative 2. These labor requirements are shown in Table 7–11. Labor requirements have the potential to generate economic impacts that may affect the need for housing units, public services, and local transportation in the region. For a detailed analysis of the labor impacts associated with the FFTF Decommissioning alternatives, see Chapter 4, Section 4.2.9.

Table 7–11. FFTF Decommissioning Alternatives Labor Resource Commitments[a]

Alternative (with Options)	Labor Hours	Labor (FTEs)
1–No Action	41,600	20
2–Hanford RTP and SRF	1,860,000	894
2–Hanford RTP and INL SPF	1,540,000	740
2–INL RTP and Hanford SRF	1,510,000	726
2–INL RTP and SPF	1,200,000	577
3–Hanford RTP and SRF	2,000,000	962
3–Hanford RTP and INL SPF	1,690,000	813
3–INL RTP and Hanford SRF	1,660,000	798
3–INL RTP and SPF	1,340,000	644

[a] Calculated as total alternative life-cycle requirements, encompassing construction, operations, deactivation, and closure.

Note: To convert FTEs to labor hours, multiply by 2,080.

Key: FFTF=Fast Flux Test Facility; FTE=full-time equivalent; Hanford=Hanford Site; INL=Idaho National Laboratory; RTP=Remote Treatment Project; SPF=Sodium Processing Facility; SRF=Sodium Reaction Facility.

Source: SAIC 2010b.

7.3.3 Waste Management Alternatives

Expansion of Hanford's waste disposal capacity would be necessary to support implementation of the Tank Closure, FFTF Decommissioning, and Waste Management alternatives, as well as to receive and dispose of offsite waste. Under the Waste Management No Action Alternative, the current disposal capacity at Hanford would not be expanded. Burial in low-level radioactive waste burial ground (LLBG) 218-W-5, trenches 31 and 34, would continue until 2035, followed by 100 years of administrative controls. Construction of IDF-East would be terminated; the site would be backfilled with native soils. Under Waste Management Alternatives 2 and 3, disposal groups were developed to support particular Tank Closure alternatives based on needed disposal capacities and operational timeframes. Three disposal groups were developed as a subset of both Waste Management Alternatives 2 and 3; all involve construction, operations, deactivation, closure, and postoperational monitoring of additional disposal facilities (i.e., one or two IDFs and the RPPDF). Additionally, Waste Management Alternatives 2 and 3 would require new facility construction, operations, and deactivation to expand the T Plant and Waste Receiving and Processing Facility (WRAP) and to provide storage capacities for processing and handling TRU waste, LLW, and MLLW.

7.3.3.1 Land Resources

Land use commitments under the Waste Management alternatives for (1) construction of new facilities on undisturbed land, (2) permanent land disposal facilities, and (3) borrow areas that would be used to supply geologic materials would be irreversible and irretrievable (see Table 7–12). Geologic materials (e.g., sand, gravel, soil, rock) would be used to construct disposal areas and to emplace engineered barriers over disposal areas.

The Waste Management No Action Alternative would not require construction of any new facilities or disposal facilities. In addition, construction of IDF-East would cease without burial of waste and the site would be backfilled with native soils. Waste Management Alternatives 2 and 3 would require expansion or new construction of the T Plant, WRAP, and waste processing and storage facilities within the 200-West Area. The only new disturbance of land that would be required under both Waste Management Alternatives 2 and 3 would be the construction of a portion of the WRAP Remote-Handled Mixed

TRU/TRU waste facility in the 200-West Area. Waste Management Alternatives 2 and 3 would also involve construction of additional disposal facilities: IDF-East would be built under Waste Management Alternative 2 and two IDFs, IDF-East and IDF-West, under Waste Management Alternative 3. The RPPDF would be built between the 200-East and 200-West Areas regardless of the alternative selected.

Table 7–12. Waste Management Alternatives Irreversible and Irretrievable Commitments of Land Resources[a]

Alternative (with Disposal Group)	Land Resource (hectares)	
	Permanently Committed and Newly Disturbed Land[b]	Borrow Area C (Disturbed Land)
1–No Action	0	0
2–Disposal Group 1	65	41
2–Disposal Group 2	248	158
2–Disposal Group 3	248	158
3–Disposal Group 1	65	37
3–Disposal Group 2	253	157
3–Disposal Group 3	253	157

[a] Calculated as total alternative life-cycle requirements, encompassing construction, operations, deactivation, and closure.

[b] This includes (1) land area where facilities would be closed in place or where engineered barriers would be constructed; (2) new disturbance of land for facility construction; and (3) new disturbance of land for construction of engineered barriers beyond the boundary of the barrier itself. Does not include Borrow Area C.

Note: To convert hectares to acres, multiply by 2.471.

Source: SAIC 2010c.

New disturbance of land for construction of facilities would be considered an irreversible impact. Land used for permanent disposal facilities would be considered an irreversible and irretrievable commitment of land. Section 7.4 discusses the relationship between short-term uses of the environment and the maintenance and enhancement of its long-term productivity.

The construction of new facilities and emplacement of engineered surface barriers over disposal areas would require relatively large volumes of geologic materials from Borrow Area C. While this land would not be irreversibly or irretrievably committed to some use, the area would be irreversibly altered. The consumption of geologic materials, including soil, gravel, sand, and rock or basalt, is covered in Section 7.3.3.2.

The estimated areas of land that may be permanently committed or newly disturbed while supporting the Waste Management alternatives are presented in Table 7–12. Except for Borrow Area C, all land use would occur within the Central Plateau. For a detailed discussion of land use impacts of construction of new and existing facilities and Borrow Area C operations under the Waste Management alternatives, see Chapter 4, Section 4.3.1. Table 7–12 may differ from the presentation of analysis in Chapter 4, Section 4.3.1, because Table 7–12 does not include committed land for construction of new facilities where the land is known to have already been disturbed.

7.3.3.2 Material Resources

The irreversible and irretrievable commitment of material resources would include process chemicals used during operations of facilities, construction materials that could not be recovered or recycled, materials that would be rendered radioactive and could not be decontaminated, raw materials consumed or reduced to irrecoverable waste forms, and geologic borrow materials. Projected demands for primary material resources under each Waste Management alternative are shown in Table 7–13. The commitment of material resources would be for the entire life cycle of each Waste Management alternative, including construction, operations, deactivation, and closure.

Geologic materials would include sand, gravel, and soil mined from Borrow Area C for the construction of disposal areas and engineered barriers for one or two IDFs and the RPPDF, as presented in Table 7–13 under "Other Borrow Materials." The gravel listed under "Other Borrow Materials" would be used to construct a drain layer as part of the disposal area liners. For Disposal Groups 2 and 3 under both Waste Management action alternatives, the collective size of the IDF(s) and RPPDF would increase significantly to accommodate clean closure of the tank farms and cribs and trenches (ditches), resulting in a proportional increase in the consumption of geologic resources necessary to construct the engineered barriers.

Nitrogen would be used for operations of the expanded WRAP. Principal construction materials would include steel, as well as concrete and grout constituents, such as cement, gravel, and sand. Although other materials, including wood, plastics, and other metals, would be used, the use of these materials would be minor. For practical purposes, concrete, steel, and other materials incorporated into the framework of new facilities, such as the T Plant, WRAP, and waste storage facilities, would be irretrievably lost, regardless of whether operations would result in direct contamination of the materials.

Table 7–13. Waste Management Alternatives Irreversible and Irretrievable Commitments of Materials[a, b]

Resource (× 1,000)	Waste Management Alternative						
	1	2–IDF-East Only			3–IDF-East and IDF-West		
	No Action	Disposal Group 1	Disposal Group 2	Disposal Group 3	Disposal Group 1	Disposal Group 2	Disposal Group 3
Process Chemicals (metric tons)							
Nitrogen	0	1	1	1	1	1	1
Construction Materials (metric tons)							
Steel	2	8	8	8	8	8	8
Asphalt	0	0	0	0	0	0	0
Concrete (cubic meters)[c]							
Cement	1	4	4	4	4	4	4
Sand	3	9	9	9	9	9	9
Gravel	4	11	11	11	11	11	11
Fly ash	0	0	0	0	0	0	0
Grout (cubic meters)[c]							
Cement	0	0	0	0	0	0	0
Sand	0	0	0	0	0	0	0
Gravel	0	0	0	0	0	0	0
Fly ash	0	0	0	0	0	0	0
Bentonite clay	2	5	20	20	5	20	20
Water-reducing agent	0	0	0	0	0	0	0
Engineered Barrier (cubic meters)							
Sand	0	814	3,150	3,150	599	3,070	3,070
Gravel	0	195	755	755	195	755	755
Soil	0	651	2,520	2,520	649	2,520	2,520
Asphalt	0	98	377	377	101	382	382
Other Borrow Materials (cubic meters)							
Rock	0	0	0	0	0	0	0
Sand	0	0	0	0	0	0	0
Gravel	0.034	209	808	808	208	809	809
Soil	0	0	0	0	0	0	0

[a] Values presented in this table are in thousands; multiply by 1,000 to obtain actual value of resource commitment.
[b] Calculated as total alternative life-cycle requirements, encompassing construction, operations, deactivation, and closure.
[c] Concrete and grout are presented as premixed constituents.
Note: To convert cubic meters to cubic yards, multiply by 1.308.
Key: IDF-East=200-East Area Integrated Disposal Facility; IDF-West=200-West Area Integrated Disposal Facility.
Source: SAIC 2010c.

7.3.3.3 Utility Resources

Key utility infrastructure resources include projected activity demands for water, electricity, and fuel over the life cycle considered under each Waste Management alternative and respective disposal group. Projected demands for key utility infrastructure resources under each Waste Management alternative are shown in Table 7–14.

Table 7–14. Waste Management Alternatives Utility Resource Commitments[a, b]

Alternative (with Disposal Group)	Resource (× 1,000)			
	Water (liters)	Electricity (kilowatt-hours)	Fuel (liters)	
			Diesel	Gasoline
1–No Action	35,700	5,630	13,900	1,230
2–Disposal Group 1	3,050,000	559,000	257,000	21,700
2–Disposal Group 2	21,200,000	559,000	1,460,000	83,100
2–Disposal Group 3	37,200,000	559,000	2,220,000	109,000
3–Disposal Group 1	3,040,000	559,000	257,000	21,200
3–Disposal Group 2	21,100,000	569,000	1,450,000	83,100
3–Disposal Group 3	36,900,000	569,000	2,210,000	108,000

[a] Calculated as total alternative life-cycle requirements, encompassing construction, operations, deactivation, and closure.

[b] Values presented in this table are in thousands; multiply by 1,000 to obtain actual value of resource commitment.

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

Source: SAIC 2010c.

The consumption of utility resources under the Waste Management No Action Alternative would be relatively low compared with that under the action alternatives as new waste processing, storage, and disposal facilities would not be constructed. Disposal Group 1 under both Waste Management action alternatives would involve increased consumption of utility resources. Compared with utility demands for Disposal Group 1, consumption of water and fuel would increase significantly under Disposal Groups 2 and 3 in proportion to the large increase in disposal area capacities required. However, electricity consumption would remain constant among the three disposal groups because its use would not correspond to construction and operations of the disposal areas, but rather with operations of the new T Plant, WRAP, and waste storage facilities that would be built and operated regardless of the disposal group selected.

For a detailed discussion of impacts on the existing infrastructure of implementing the Waste Management alternatives, see Chapter 4, Section 4.3.2.

7.3.3.4 Labor Resources

Labor resources associated with the Waste Management alternatives would be required over the entire life cycle of the alternatives. The Waste Management No Action Alternative would require a smaller commitment of labor resources than the action alternatives due to the lack of additional waste processing, storage, and disposal facilities to be constructed and operated. The labor requirements would be proportionally influenced by the size of the disposal areas and the length of operations. The difference in labor requirements between Waste Management Alternatives 2 and 3, which only differ in respective locations of each alternative's disposal areas, would be very minor. The labor requirements of the Waste Management alternatives are shown in Table 7–15. Labor requirements have the potential to generate economic impacts that may affect the need for housing units, public services, and local transportation in the region. For a detailed analysis of the labor impacts associated with the Waste Management alternatives, see Chapter 4, Section 4.3.9.

Table 7–15. Waste Management Alternatives Labor Resource Commitments[a]

Alternative (with Disposal Group)	Labor Hours	Labor (FTEs)
1–No Action	1,010,000	486
2–Disposal Group 1	57,800,000	27,800
2–Disposal Group 2	166,000,000	79,800
2–Disposal Group 3	242,000,000	116,000
3–Disposal Group 1	59,300,000	28,500
3–Disposal Group 2	167,000,000	80,300
3–Disposal Group 3	243,000,000	117,000

[a] Calculated as total alternative life-cycle requirements, encompassing construction, operations, deactivation, and closure.

Note: To convert FTEs to labor hours, multiply by 2,080.

Key: FTE=full-time equivalent.

Source: SAIC 2010c.

7.3.4 Alternative Combinations

This section presents a comparison of the irreversible and irretrievable commitments of resources that are projected under the three alternative combinations selected for analysis in this EIS. The alternative combinations are described in detail in Chapter 4, Section 4.4.

7.3.4.1 Land Resources

Land use commitments under the alternative combinations for construction of new facilities on undisturbed land, permanent land disposal facilities, and borrow areas that would be used to supply geologic materials would be irreversible and irretrievable. The estimated areas of land that may be permanently committed or newly disturbed while supporting the representative alternative combinations are presented in Table 7–16. The values presented in Table 7–16 do not include the commitment of land for construction of new facilities where the land is known to have already been disturbed.

Table 7–16. Alternative Combinations Irreversible and Irretrievable Commitments of Land Resources[a]

Alternative Combination	Land Resource (hectares)	
	Permanently Committed and Newly Disturbed Land[b]	Borrow Area C (Disturbed Land)
1	35	2
2	173	140
3	376	401

[a] Calculated as total alternative life-cycle requirements, encompassing construction, operations, deactivation, and closure.

[b] This includes (1) land area where facilities would be closed in place or where engineered barriers would be constructed; (2) new disturbance of land for facility construction; and (3) new disturbance of land for construction of engineered barriers beyond the boundary of the barrier itself. Does not include Borrow Area C.

Note: To convert hectares to acres, multiply by 2.471.

Source: SAIC 2010a, 2010b, 2010c.

7.3.4.2 Material Resources

The irreversible and irretrievable commitment of material resources would include process chemicals used during operations of facilities, construction materials that cannot be recovered or recycled, materials that would be rendered radioactive and could not be decontaminated, raw materials consumed or reduced to irrecoverable waste forms, and geologic borrow materials. Projected demands for primary material resources under each representative combination of alternatives are presented in Table 7–17.

Table 7–17. Alternative Combinations Irreversible and Irretrievable Commitments of Materials[a, b]

Resource (× 1,000)	Alternative Combination 1	Alternative Combination 2	Alternative Combination 3
Materials			
Glass formers (metric tons)	0	202	206
Ion exchange resins (liters)	0	2,440	2,440
Retrieval chemicals (e.g., oxalic acid) (liters)	0	0	189,000
Nitric acid (3 percent and 57 percent solution) (liters)	0	0	1,790
Caustic (50 percent solution) (liters)	0	0	61
Nitrogen (metric tons)	0.14	1.05	1.05
Construction Materials (metric tons)			
Steel	6	81	538
Asphalt	0	5	5
Concrete (cubic meters)[c]			
Cement	9	106	350
Sand	19	214	694
Gravel	25	280	901
Grout (cubic meters)[c]			
Cement	0	13.4	28.2
Sand	0	797	138
Fly ash	0	178	152
Bentonite clay	2	11	27
Water-reducing agent	0	0.22	0.04
Engineered Barriers (cubic meters)			
Sand	0	1,880	3,470
Gravel	0	450	831
Soil	0	1,510	2,770
Asphalt	0	237	419
Other Borrow Materials (cubic meters)			
Rock	0	14	14
Sand	0.19	4	1
Gravel	0.28	218	817
Soil	0.17	529	8,300
Specification backfill	55	334	374

[a] Calculated as total alternative life-cycle requirements, encompassing construction, operations, deactivation, and closure.

[b] Values presented in this table are in thousands; multiply by 1,000 to obtain actual value of resource commitment.

[c] Concrete and grout are presented as premixed constituents.

Note: To convert cubic meters to cubic yards, multiply by 1.308; liters to gallons, by 0.26417.

Source: SAIC 2010a, 2010b, 2010c.

7.3.4.3 Utility Resources

Key utility infrastructure resources would include projected activity demands for water, electricity, and fuel over the life cycle considered under each alternative combination. The irreversible and irretrievable commitments of utility resources under each representative alternative combination are presented in Table 7–18.

Table 7–18. Alternative Combinations Utility Resource Commitments[a, b]

Alternative Combination	Resource (× 1,000,000)			
			Fuel	
	Water (liters)	Electricity (kilowatt-hours)	Diesel (liters)	Gasoline (liters)
1	11,300	721	50	6
2	89,400	18,500	4,300	179
3	114,000	21,700	5,820	300

[a] Calculated as total alternative life-cycle requirements, encompassing construction, operations, deactivation, and closure.
[b] Values presented in this table are in millions; multiply by 1,000,000 to obtain actual value of resource commitment.
Note: To convert liters to gallons, multiply by 0.26417.
Source: SAIC 2010a, 2010b, 2010c.

7.3.4.4 Labor Resources

Labor resources associated with the alternative combinations would be required over the entire life cycle of each combination, although more labor resources would be required during the construction and operations phases. Labor requirements have the potential to generate economic impacts that may affect the need for housing units, public services, and local transportation in the region. The labor requirements of the representative alternative combinations are shown in Table 7–19.

Table 7–19. Alternative Combinations Labor Resource Commitments[a]

Alternative Combination	Labor Hours	Labor (FTEs)
1	17,400,000	8,370
2	447,000,000	215,000
3	683,000,000	328,000

[a] Calculated as total alternative life-cycle requirements, encompassing construction, operations, deactivation, and closure.
Note: To convert FTEs to labor hours, multiply by 2,080.
Key: FTE=full-time equivalent.
Source: SAIC 2010a, 2010b, 2010c.

7.4 RELATIONSHIP BETWEEN SHORT-TERM USE OF THE ENVIRONMENT AND LONG-TERM PRODUCTIVITY

Pursuant to NEPA regulations (40 CFR 1502.16), an EIS must consider the relationship between local short-term uses of the environment and the maintenance and enhancement of its long-term productivity. Potential short-term impacts related to the Tank Closure, FFTF Decommissioning, and Waste Management alternatives are presented in Chapter 4. For analysis purposes, "short term" encompasses the active project phases of each alternative, during which construction, operations, deactivation, and closure activities would take place. Short-term timeframes include any administrative control, postclosure care, or onsite storage activities for treated waste pending final disposition. "Long term" is defined as the timeframe that extends beyond conclusion of the short-term activities proposed under each alternative. Long-term impacts are discussed in Chapter 5.

In making a decision regarding various alternatives for accomplishing a proposed action, an agency's objective is to demonstrate and implement the alternative(s) that, on balance, would result in the least overall adverse impact on the environment. Under the evaluated *TC & WM EIS* action alternatives, an increase in worker and public exposure under controlled circumstances (i.e., tank waste retrieval, treatment, and disposal) and in compliance with applicable legal requirements over the short term would lead to a decrease in exposure of the unprotected public to unmitigated releases of contaminants into the environment over the long term.

Under certain *TC & WM EIS* alternatives, in addition to short-term use of the environment, the emplacement of engineered barriers over tank farm systems, cribs and trenches (ditches), the FFTF RCB, and/or permanent waste disposal sites would be considered a long-term use of the environment, and thus would decrease the long-term productivity of these locations. Short- and long-term uses of the environment in the broader context would include elements of unavoidable, adverse impacts and irreversible and irretrievable commitments of resources to enhance the long-term productivity of the environment. Unavoidable, adverse environmental impacts are discussed in Section 7.2; irreversible and irretrievable commitments of resources are discussed in Section 7.3.

7.4.1 Tank Closure Alternatives

The short-term duration of each Tank Closure alternative is presented in Table 7–20. The short-term durations are broken into two groups: (1) the construction, operations, and deactivation phase, when most activities would take place, and (2) the closure phase, when administrative controls or postclosure care would be performed and/or long-term storage would continue. Most impacts and short-term uses of the environment would occur during the construction, operations, and deactivation phase. Under the Tank Closure No Action Alternative and Tank Closure Alternative 2A, administrative controls would be required because tank farm closure would not be achieved. Under Tank Closure Alternatives 2B through 5, the SST farms would be closed and covered with an engineered barrier, followed by postclosure care. Under Tank Closure Alternatives 6A and 6B, Base Cases, an engineered barrier would be emplaced over the cribs and trenches (ditches). Under Tank Closure Alternatives 6A and 6B, Option Cases, all tank farms and cribs and trenches (ditches) would be clean-closed and, therefore, would not require construction of an engineered barrier or postclosure care. In contrast, Tank Closure Alternative 6C would require an engineered barrier over the tank farms and cribs and trenches (ditches) and, as a result, would require postclosure care. Under Tank Closure Alternatives 6A through 6C, all tank waste would be managed as HLW, which would require construction and operations of long-term, onsite storage facilities.

Table 7–20. Tank Closure Alternatives Short-Term Life Cycles

Alternative	Construction, Operations, and Deactivation Phase	Closure Phase (Activity Type)[a]
1	2006–2008	2008–2107 (AC)
2A	2006–2094	2094–2193 (AC)
2B	2006–2046	2046–2145 (PM)
3A	2006–2043	2042–2141 (PM)
3B	2006–2043	2042–2141 (PM)
3C	2006–2043	2042–2141 (PM)
4	2006–2046	2045–2144 (PM)
5	2006–2039	2040–2139 (PM)
6A, Base Case	2006–2168	2151–2250 (PM) Until 2262 (ST)
6A, Option Case	2006–2168	Until 2262 (ST)
6B, Base Case	2006–2101	2102–2201 (PM) Until 2199 (ST)
6B, Option Case	2006–2101	Until 2199 (ST)
6C	2006–2046	2046–2145 (PM) Until 2145 (ST)

[a] Activity types: AC=administrative controls; PM=postclosure care and monitoring; ST=onsite storage.

Source: SAIC 2010a.

Short-term commitments of resources would include the space and materials required for construction of new facilities and support facilities; for transportation infrastructure; and for waste storage, retrieval, treatment, and disposal, as well as tank closure. Certain resource commitments would be substantially greater under Tank Closure Alternatives 2B through 6C than under the Tank Closure No Action Alternative or Tank Closure Alternative 2A because construction of an engineered surface barrier for landfill closure and/or partial or complete clean closure of the SST system would be required. Tank Closure Alternative 2A would involve a commitment of resources to treat and stabilize the tank waste, but would not follow through with closure of the SST farms. Depending on the alternative, workers, the public, and the environment would be exposed to various amounts of hazardous and radioactive materials over the short term from tank waste retrieval, treatment, and disposal activities and from SST system closure operations.

Table 7–21 presents the amounts of land that would be committed in the short term to accomplish the objectives of each Tank Closure alternative. The areas given include land for existing facilities and new facilities that would be constructed to support a particular alternative. The land use amounts are presented as aggregate values over the entire short-term life cycles of the alternatives; however, in practice, most facilities would operate during various timeframes. Table 7–21 also presents the long-term land commitments that would continue indefinitely under each alternative, including all permanent disposition areas where engineered barriers would preclude the use of the site for other productive purposes and all areas where tank farms and cribs and trenches (ditches) would not be closed under certain alternatives. Borrow Area C is not included in the short-term commitments of land. While excavation activities conducted in Borrow Area C would take place in the short term, they could be terminated at any time. The amount of land disturbance required in Borrow Area C to support each Tank Closure alternative was previously discussed in Section 7.3.1.1.

Table 7–21. Tank Closure Alternatives Short- and Long-Term Commitments of Land

Alternative	Land Commitment (hectares)	
	Short-Term Use[a]	Long-Term Use[b]
1	0	17
2A	33	17
2B	17	84
3A	16	84
3B	17	84
3C	17	84
4	20	61
5	20	84
6A, Base Case	210	25
6A, Option Case	212	0
6B, Base Case	119	25
6B, Option Case	121	0
6C	62	84

[a] Land use commitments over the short term encompass the total alternative life cycle, including construction, operations, deactivation, and closure. Short-term land use under Alternative 1 does not include partial construction of the Waste Treatment Plant because this action has already been initiated.

[b] Land use commitments over the long term encompass the period following completion of each alternative's scheduled activities. Long-term land use under Alternatives 1 through 3C, 5, and 6C comprises the footprints of the single-shell tank farms and B and T Area cribs and trenches (ditches), with or without engineered barriers, as applicable; that under Alternative 4 does not include the BX and SX tank farms, which would be clean-closed; that under Alternatives 6A and 6B, Base Cases, comprises only the footprints of the B and T Area cribs and trenches (ditches); and that under Alternatives 6A and 6B, Option Cases, does not include any tank farms or cribs and trenches (ditches), which would be clean-closed.

Note: To convert hectares to acres, multiply by 2.471.

Source: SAIC 2010a.

Although this EIS considers only facility deactivation and not decontamination and decommissioning of waste treatment, storage, and disposal facilities, DOE could decontaminate and decommission major facilities at the end of their life cycles and restore adjacent area brownfield sites, which would then be available for future industrial use. However, it is unlikely that any of the facility sites would be restored to their original predevelopment states or natural, terrestrial habitats.

The Tank Closure No Action Alternative would likely incur additional and indefinite commitments of land over the long term, when degradation of tank farms would lead to eventual release of unmitigated contaminants into the subsurface environment, potentially impacting the Columbia River. Except for Tank Closure Alternatives 6A and 6B, under which clean closure of all SST farms would occur, as well as Tank Closure Alternative 4, under which clean closure of the BX and SX tank farms would occur, the remaining action alternatives would leave SST system components and residual tank waste (ranging from 0.01 to 10 percent by volume) in place. Any land areas where tank farms would be left in place would represent a long-term commitment of land and terrestrial resources for waste management. In addition, except for Tank Closure Alternatives 6A and 6B, Option Cases, the areas occupied by the cribs and trenches (ditches) would represent a long-term commitment of land. Therefore, these areas would be removed from long-term productivity considerations. However, these areas would likely be reclaimed by native vegetation and wildlife in the absence of human intervention over the very long term following the end of any administrative control or postclosure care period.

Air emissions associated with waste retrieval, treatment, and disposal and SST system closure would introduce radioactive and nonradioactive constituents into the regional airshed around Hanford. Over time, these emissions would result in additional loading and exposure, but would not impair the long-term productivity of the environment at Hanford.

Chemical and radioactive contamination of the vadose zone and groundwater below and downgradient of the 200 Areas would occur over time under all of the Tank Closure alternatives due to the release of residual tank contaminants and the disposal of treated tank waste and contaminated soil. The long-term performance of waste forms and their impacts on the vadose zone and groundwater receptors are discussed in detail in Chapter 5. Depending on the extent and magnitude of resultant groundwater contaminant plumes, it may be necessary to place land use or other institutional controls on the overlying land areas for an indefinite period, thereby reducing the overall long-term productivity of the affected areas.

Radiation and chemical doses to aquatic and terrestrial receptors at seeps along the Columbia River and in the receiving water were evaluated as part of the ecological risk portion of the analysis. Under all scenarios and alternatives, results indicated that calculated absorbed doses to referenced organisms would be below regulatory limits and/or reference standards and, therefore, would likely have no impact on the long-term productivity of the Columbia River ecosystem.

Continued employment, expenditures, and tax revenues generated during implementation of any of the action alternatives would directly benefit local, regional, and state economies over the short term. Local governments investing project-generated tax revenues into infrastructure and other required services could facilitate economic productivity. Nearby townships and geographic provinces have experienced a recent surge in growth, and the availability of employment opportunities would further sustain and foster regional development.

Management and disposal of LLW, MLLW, mixed TRU waste, IHLW, ILAW, and secondary waste generated as a result of waste retrieval, treatment, and disposal and SST system closure would increase energy demand and consume space at treatment, storage, and disposal facilities. Regardless of the location, a longer-term commitment of terrestrial resources would be required to meet waste management needs. Primary waste (e.g., IHLW canisters) and HLW melters taken out of service would be stored on site. All treated tank waste under Tank Closure Alternatives 6A, 6B, and 6C would be managed as HLW and would require storage at Hanford until disposition decisions are made and implemented.

The short-term use of the environment would be evaluated against the maintenance and enhancement of its long-term productivity, as demonstrated by the performance assessment for untreated and treated tank waste forms. This relationship between short-term uses of the environment and its long-term productivity under the Tank Closure alternatives corresponds to the relationship between commitments of resources now to their use in the future under the Waste Management alternatives (see Section 7.3.3). In a simple sense, the Tank Closure alternatives represent most of the short-term uses of the environment, while the Waste Management alternatives represent most of the resultant long-term commitments of tank closure. These two proposed actions are mutually dependent.

7.4.2 FFTF Decommissioning Alternatives

The short-term duration of each FFTF Decommissioning alternative is presented in Table 7–22. The short-term durations are broken into two groups: (1) the construction, operations, and deactivation phase, when most activities would take place, and (2) the closure phase, when administrative controls or postclosure care would be performed. Most impacts and short-term uses of the environment would occur during the construction, operations, and deactivation phase. Under the FFTF Decommissioning No Action Alternative, administrative controls would be required to maintain the facility in its existing state for 100 years. FFTF Decommissioning Alternatives 2 and 3 would require 100 years of postclosure care, although fewer activities would be required during this period under FFTF Decommissioning Alternative 3 because it does not require emplacement of an engineered barrier.

Table 7–22. FFTF Decommissioning Alternatives Short-Term Life Cycles

Alternative	Construction, Operations, and Deactivation Phase	Closure Phase (Activity Type)[a]
1	Not applicable	2008–2107 (AC)
2[b]	2013–2021	2022–2121 (PM)
3[b, c]	2012–2021	2022–2121 (PM)

[a] Activity types: AC=administrative controls; PM=postclosure care and monitoring.

[b] Life-cycle durations are the same for all Hanford Site and Idaho options.

[c] Alternative 3 includes a 100-year postclosure care period even though this alternative does not have an engineered barrier.

Key: FFTF=Fast Flux Test Facility.

Source: SAIC 2010b.

Short-term commitments of resources would include the space and materials required to expand or construct facilities for treatment of the four FFTF RH-SCs and processing of bulk sodium at Hanford or INL. The only facility under the FFTF Decommissioning alternatives that would require new construction is the SRF at Hanford, although construction would occur within disturbed areas. The RTP at either Hanford or INL and the SPF at INL would be located within or adjacent to existing facilities. Depending on the alternative, workers, the public, and the environment would be exposed to various amounts of hazardous and radioactive materials over the short term due to FFTF decommissioning activities such as decontamination, demolition, and excavation.

Table 7–23 presents the amounts of land that would be committed in the short term to accomplish the objectives of each of the FFTF Decommissioning alternatives, including land use at both Hanford and INL. The SPF at INL is an existing facility and is not included as a short-term commitment under FFTF Decommissioning Alternative 2 or 3. Table 7–23 also presents the long-term land commitments that would continue indefinitely under each alternative, including (1) all permanent disposition areas where engineered barriers would preclude the use of the site for other productive purposes, (2) all areas where buildings would not be decommissioned, and (3) all bulk sodium storage areas. Borrow Area C is not included in the short-term commitments of land. While excavation activities conducted in Borrow Area C would take place in the short term, they could be terminated at any time. The amount of land disturbance required in Borrow Area C to support each FFTF Decommissioning alternative was previously discussed in Section 7.3.2.1.

The FFTF Decommissioning No Action Alternative would likely incur additional and indefinite long-term commitments of land because, after the end of the 100-year administrative control period, contaminants would be released into the environment. Under FFTF Decommissioning Alternative 2, some facilities would be completely removed and others would be entombed (e.g., the RCB, Buildings 491E and 491W). Long-term commitments of land under FFTF Decommissioning Alternative 2 represent an engineered barrier that would be placed over the RCB and Buildings 491E and 491W. Therefore, the FFTF Decommissioning No Action Alternative, and, to a lesser extent, FFTF Decommissioning Alternative 2, would remove land areas within the 400 Area from consideration for long-term productivity. However, these areas would likely be reclaimed by native vegetation and wildlife in the absence of human intervention over the very long term following the end of any administrative control or postclosure care period. FFTF Decommissioning Alternative 3 represents removal of all buildings, including the RCB and Buildings 491E and 491W, except for the RCB's subgrade concrete shell. In this case, an engineered barrier would not be constructed; however, a limited-scope postclosure care period would still be necessary, after which the land could be returned to productive use.

Table 7–23. FFTF Decommissioning Alternatives Short- and Long-Term Commitments of Land

Alternative (with Options)	Land Commitment (hectares)	
	Short-Term Use[a]	Long-Term Use[b]
1–No Action	0	18
2–Hanford RTP and SRF	0.2	0.7
2–Hanford RTP and INL SPF	0.1	0.7
2–INL RTP and Hanford SRF	0.2	0.7
2–INL RTP and SPF	0.1	0.7
3–Hanford RTP and SRF	0.2	0
3–Hanford RTP and INL SPF	0.1	0
3–INL RTP and Hanford SRF	0.2	0
3–INL RTP and SPF	0.1	0

[a] Land use commitments over the short term encompass the total alternative life cycle, including construction, operations, deactivation, and closure.

[b] Land use commitments over the long term encompass the period following completion of each alternative's scheduled activities. Long-term land use under Alternative 1: No Action comprises the footprint of the existing FFTF Property Protected Area; that under Alternative 2, the engineered barrier over the FFTF Reactor Containment Building and Buildings 491E and 491W; and that under Alternative 3, removal of FFTF and all associated support structures.

Note: To convert hectares to acres, multiply by 2.471.

Key: FFTF=Fast Flux Test Facility; Hanford=Hanford Site; INL=Idaho National Laboratory; RTP=Remote Treatment Project; SPF=Sodium Processing Facility; SRF=Sodium Reaction Facility.

Source: SAIC 2010b.

Air emissions associated with building demolition, closure, and site restoration activities, as well as emissions associated with construction, operations, and deactivation of an RTP and SRF or SPF would introduce small amounts of radioactive and nonradioactive constituents to the regional airshed around Hanford. If the RTP is constructed at INL and INL's SPF is reactivated and modified for bulk sodium processing, air emissions from these two facilities would contribute to cumulative impacts, along with air emissions from other sources at INL. Over time, these emissions would result in additional loading and exposure, but would not impact air quality or radiological exposure standards to the extent that long-term productivity of the environment would be impaired at either Hanford or INL.

Chemical and radioactive contamination of the vadose zone and groundwater below and downgradient from the 400 Area would occur over time under FFTF Decommissioning Alternatives 1 and 2; this contamination would not occur under FFTF Decommissioning Alternative 3, in which removal of all of the structures would take place. Impacts would be the most significant under FFTF Decommissioning Alternative 1. Under FFTF Decommissioning Alternative 2, in which the four FFTF RH-SCs and bulk sodium would be removed, long-term impacts on the vadose zone and groundwater would be reduced. The long-term performance of waste forms and their impacts on the vadose zone and groundwater receptors are discussed in detail in Chapter 5. Depending on the extent and magnitude of resultant groundwater contaminant plumes, it may become necessary for land use or other institutional controls to be placed on the overlying land areas for an indefinite period, thereby reducing overall long-term productivity of the affected areas.

No additional short- or long-term impacts on ecological receptors are projected to occur as a result of implementing any of the FFTF Decommissioning alternatives.

Any impacts on socioeconomic factors are expected to be negligible in the context of activities occurring across Hanford and would be confined within the short-term construction, operations, and deactivation phase, ending no later than 2021 under all alternatives.

Management and disposal of LLW, MLLW, and secondary waste would be required under all FFTF Decommissioning alternatives. The FFTF Decommissioning No Action Alternative would require indefinite storage of the four FFTF RH-SCs within the 400 Area and of bulk sodium within the 200-West and 400 Areas, removing these areas from consideration for other long-term productive uses. Under both action alternatives, the specialized components would be decontaminated and repackaged for disposal in an IDF, and the bulk sodium would be processed to produce a caustic sodium hydroxide solution for treating tank waste in the WTP, thereby eliminating the requirement for long-term operations and maintenance of storage facilities. FFTF Decommissioning Alternative 2 would result in the entombment of LLW and MLLW within the subgrade void spaces of the RCB, which would essentially constitute a land use commitment of the RCB and Buildings 491E and 491W over the long term. Comparatively, under FFTF Decommissioning Alternative 3, all internal reactor core components would be extricated, all buildings would be demolished, and all decommissioning debris would be disposed of as LLW or MLLW in an IDF, potentially enabling future productive use of land in the 400 Area.

Short-term use of the environment for removing and processing the four FFTF RH-SCs and the bulk sodium would be evaluated against the potential adverse impacts on long-term productivity that could result from the eventual release of contaminants into the environment. Under the action alternatives, the increase in short-term impacts of removal of all FFTF structures would be evaluated against the emplacement of an engineered barrier and long-term lost productivity of the FFTF land areas. An additional long-term consideration is assessment of waste-form performance and the effect of additional waste loading on an IDF resulting from the generation of decommissioning waste and secondary waste under the action alternatives.

7.4.3 Waste Management Alternatives

The short-term duration of each Waste Management alternative is presented in Table 7–24. The short-term durations are broken into two groups: (1) the construction, operations, and deactivation phase, when most activities would take place, and (2) the closure phase, when administrative controls or postclosure care would be performed. Most impacts and short-term uses of the environment would occur during the construction, operations, and deactivation phase. The Waste Management No Action Alternative would not include construction or operations of any new disposal facilities; however, it would require a 100-year administrative control period. Under the remaining Waste Management alternatives and their associated disposal groups, permanent disposal facilities would be constructed in the 200 Areas that would ultimately be closed under engineered barriers followed by postclosure care.

Short-term commitments of resources under the Waste Management action alternatives would include the space and materials required to construct facility expansions for processing high-dose LLW and MLLW in the T Plant; processing, packaging, and certifying TRU waste in WRAP; and storing waste in the Central Waste Complex. Other short-term uses of resources would be limited to those required for constructing and operating the disposal facilities.

Table 7–24. Waste Management Alternatives Short-Term Life Cycles

Alternative (with Disposal Group)	Construction, Operations, and Deactivation Phase	Closure Phase (Activity Type)[a]
1–No Action	2007–2035	2036–2135 (AC)
2–Disposal Group 1	2006–2052	2053–2152 (PM)
2–Disposal Group 2	2006–2102	2103–2202 (PM)
2–Disposal Group 3	2006–2167	2168–2267 (PM)
3–Disposal Group 1	2006–2052	2053–2152 (PM)
3–Disposal Group 2	2006–2102	2103–2202 (PM)
3–Disposal Group 3	2006–2167	2168–2267 (PM)

[a] Activity types: AC=administrative controls; PM=postclosure care and monitoring.

Source: SAIC 2010c.

Table 7–25 presents the amounts of land that would be committed in the short term to accomplish the objectives of each of the Waste Management alternatives. This short-term use of land would be for expansion of the T Plant, WRAP, and Central Waste Complex facilities under the action alternatives. Table 7–25 also presents the long-term land commitments that would occur indefinitely under each of the action alternative's disposal groups. All areas where permanent disposal facilities would be located would be indefinitely removed from consideration for long-term productive use. Under the Waste Management action alternatives, engineered barriers would be constructed over the RPPDF and IDF(s). Trenches 31 and 34 in LLBG 218-W-5 are not included in long-term commitments of land in this *TC & WM EIS* due to previous long-term commitments consistent with an existing permit. Borrow Area C is not included in the short-term commitments of land. While excavation activities in Borrow Area C would be conducted in the short term, they could be terminated at any time. The amount of land disturbance required in Borrow Area C to support each Waste Management alternative was previously discussed in Section 7.3.3.1.

Table 7–25. Waste Management Alternatives Short- and Long-Term Commitments of Land

Alternative (with Disposal Group)	Land Commitment (hectares)	
	Short-Term Use[a]	Long-Term Use[b]
1–No Action	0	0
2–Disposal Group 1	2.7	65
2–Disposal Group 2	2.7	248
2–Disposal Group 3	2.7	248
3–Disposal Group 1	2.7	65
3–Disposal Group 2	2.7	253
3–Disposal Group 3	2.7	253

[a] Land use commitments over the short term encompass the total alternative life cycle, including construction, operations, deactivation, and closure. Under Alternatives 2 and 3, the land use requirements for the Waste Receiving and Processing Facility, T Plant, and Central Waste Complex construction and operations would be equivalent; under Alternative 1, short-term use does not include partial construction of the 200-East Area Integrated Disposal Facility because this action has already been initiated.

[b] Land use commitments over the long term include the permanent disposal sites (e.g., one or both of the Integrated Disposal Facilities and the River Protection Project Disposal Facility) after closure by emplacement of engineered barriers.

Note: To convert hectares to acres, multiply by 2.471.

Source: SAIC 2010c.

The waste management disposal groups were developed and the waste disposal facilities (the RPPDF and IDF[s]) were sized to primarily support the Tank Closure alternatives and to accept some offsite waste for disposal. The Waste Management No Action Alternative would only be implemented if the corresponding Tank Closure No Action Alternative is selected for implementation. Under Waste Management Alternative 2, only IDF-East would be constructed. Under Waste Management Alternative 3, disposal capacity would be divided between IDF-East and -West. The RPPDF would be constructed between the 200-East and -West Areas, regardless of the action alternative selected. Closure of the RPPDF and IDF(s) would be accomplished with the emplacement of an engineered barrier. Therefore, the land areas associated with each of the permanent waste disposal facilities would be removed from consideration for long-term productivity. However, these areas would likely be reclaimed by native vegetation and wildlife in the absence of human intervention over the very long term following the end of any administrative control or postclosure care period.

Air emissions associated with the Waste Management alternatives would introduce small amounts of radioactive and nonradioactive constituents to the regional airshed around Hanford. Radioactive air emissions would result from expanded operations of the T Plant and WRAP. Nonradioactive air emissions would be the greatest during initial construction of the waste disposal facilities, and then again during closure of the facilities and the construction of engineered barriers. Over time, these emissions would result in additional loading and exposure, but would not impact air quality or radiological exposure standards at Hanford to the extent that long-term productivity of the environment would be impaired.

Chemical and radioactive contamination of the vadose zone and groundwater below and downgradient of the 200 Areas would occur over time under all of the alternatives due to release of contaminants from tank closure waste; FFTF decommissioning waste; and offsite waste disposed of in the LLBGs, IDF(s), and the RPPDF. The amounts and timing of contaminants that would leach from the waste disposal sites would largely depend on long-term waste form performance, as dictated by the waste treatment methodologies analyzed under the Tank Closure alternatives. Long-term performance of waste forms and their impacts on the vadose zone and groundwater receptors are discussed in detail in Chapter 5. Depending on the extent and magnitude of resultant groundwater contaminant plumes, it may become necessary for land use or other institutional controls to be placed on the overlying land areas for an indefinite period, thereby reducing the overall long-term productivity of the affected areas.

Radiation and chemical doses to aquatic and terrestrial receptors at seeps along the Columbia River and in the receiving water were evaluated as part of the ecological risk portion of the analysis. Under all scenarios and alternatives, results indicated that calculated absorbed doses to referenced organisms would be below regulatory limits and/or reference standards and, therefore, would have no impact on the long-term productivity of the Columbia River ecosystem.

Continued employment, expenditures, and tax revenues generated during implementation of any of the action alternatives would directly benefit local, regional, and state economies over the short term. Local governments investing project-generated tax revenues into infrastructure and other required services could facilitate economic productivity. Nearby townships and geographic provinces have experienced a recent surge in growth, and the availability of employment opportunities would further sustain and foster regional development.

In addition to the waste generated under the Tank Closure and FFTF Decommissioning alternatives, some quantities of LLW and MLLW would be generated from expanded T Plant operations and would be disposed of in an IDF. TRU waste processed at the expanded WRAP would be stored on site until it could be transported off site for disposal at the Waste Isolation Pilot Plant near Carlsbad, New Mexico. A certain amount of offsite waste would be received under Waste Management Alternatives 2 and 3 and disposed of in an IDF, a long-term commitment at Hanford that would result in comparable enhancement of long-term productivity at other DOE facilities.

The short-term use of the environment for treating waste would be evaluated against the maintenance and enhancement of the long-term productivity of the environment, as demonstrated by the performance assessment for the final waste forms that would be disposed of in an IDF and the RPPDF.

7.4.4 Alternative Combinations

This section presents a comparison of the relationship between short-term uses of the environment and maintenance and enhancement of its long-term productivity under the three alternative combinations selected for analysis in this EIS. The alternative combinations are described in detail in Chapter 4, Section 4.4.

The short-term durations of the three alternative combinations analyzed in this EIS are presented in Table 7–26. The short-term durations are broken into two groups: (1) the construction, operations, and deactivation phase, when most activities would take place, and (2) the closure phase, when administrative controls or postclosure care would be performed and/or long-term storage would continue. Under Alternative Combination 1, construction of the WTP, Canister Storage Building, and IDF-East would be terminated. The only activity that would continue would be disposal of waste in LLBG 218-W-5, trenches 31 and 34, until 2035, followed by a 100-year administrative control period. Expanded WTP vitrification under Alternative Combination 2 would significantly reduce the duration of short-term actions, which would end in 2052. Short-term activities would be extended until 2102 under Alternative Combination 3 to accommodate clean closure of the SST farms, followed by a 100-year postclosure care and monitoring period.

Table 7–26. Alternative Combinations Short-Term Life Cycles

Alternative Combination	Alternative	Construction, Operations, and Deactivation Phase	Closure Phase (Activity Type)[a]
1	Tank Closure Alternative 1	2006–2008	2008–2107 (AC)
	FFTF Decommissioning Alternative 1	Not applicable	2008–2107 (AC)
	Waste Management Alternative 1	2007–2035	2036–2135 (AC)
2	Tank Closure Alternative 2B	2006–2046	2046–2145 (PM)
	FFTF Decommissioning Alternative 2	2013–2021	2022–2121 (PM)
	Waste Management Alternative 2, Disposal Group 1	2006–2052	2053–2152 (PM)
3	Tank Closure Alternative 6B, Base Case	2006–2101	2102–2201 (PM) Until 2199 (ST)
	FFTF Decommissioning Alternative 3	2012–2021	2022–2121 (PM)
	Waste Management Alternative 2, Disposal Group 2	2006–2102	2103–2202 (PM)

[a] Activity types: AC=administrative controls; PM=postclosure care and monitoring; ST=onsite storage.
Key: FFTF=Fast Flux Test Facility.
Source: SAIC 2010a, 2010b, 2010c.

Table 7–27 presents the amounts of land that would be committed in the short term under each of the three representative alternative combinations, including the land area required for existing facilities and construction of new facilities to support a particular alternative combination. The land use amounts are presented as aggregate values over the entire short-term life cycles of the alternatives; however, in practice, most facilities would operate during various timeframes. Borrow Area C is not included in the short-term commitments of land. While excavation activities conducted in Borrow Area C would take place in the short term, they could be terminated at any time. The amount of land disturbance required in Borrow Area C to support each alternative combination was previously discussed in Section 7.3.4.1.

Table 7–27 also presents the long-term land commitments that would continue indefinitely under the alternatives, including all permanent disposition areas where engineered barriers would preclude the use of the site for other productive purposes and all areas where the tank farms and cribs and trenches (ditches) or facilities within the FFTF Property Protected Area would not be closed under certain alternatives. No new facilities would be constructed or operated in the short term under Alternative Combination 1; however, a commitment of 35 hectares (86.5 acres) of land would be made to provide waste management areas for the SST farms, cribs and trenches (ditches), and FFTF Property Protected Area. Under Alternative Combination 2, short- and long-term land commitments would be greater due to construction of new disposal facilities and emplacement of engineered barriers over the SST farms and cribs and trenches (ditches). The increase in the long-term commitment of land under Alternative Combination 2 over that under Alternative Combination 1 would occur due to retrieval, treatment, and disposal of all tank waste under Alternative Combination 2. Treating the tank waste and disposing of it in an engineered disposal facility would reduce the long-term effects of radioactive and chemical contaminants leaching into the subsurface and groundwater. Under Alternative Combination 3, short- and long-term land commitments would increase even further. In this case, the increase in short- and long-term land use would be due to SST clean closure activities and requirements for deep soil excavation and disposition. Treated tank waste under Alternative Combination 3 would be managed as HLW and stored on site until disposition decisions are made and implemented.

Table 7–27. Alternative Combinations Short- and Long-Term Commitments of Land

Alternative Combination	Land Commitment (hectares)		
	Alternative	**Short-Term Use[a]**	**Long-Term Use[b]**
1	Tank Closure Alternative 1	0	17
	FFTF Decommissioning Alternative 1	0	18
	Waste Management Alternative 1	0	0
	Total Combined	**0**	**35**
2	Tank Closure Alternative 2B	17	84
	FFTF Decommissioning Alternative 2	0.2	0.7
	Waste Management Alternative 2, Disposal Group 1	2.7	65
	Total Combined	**20**	**150**
3	Tank Closure Alternative 6B, Base Case	119	25
	FFTF Decommissioning Alternative 3	0.2	0
	Waste Management Alternative 2, Disposal Group 2	2.7	248
	Total Combined	**122**	**273**

[a] Land use commitments over the short term encompass the total alternative life cycle, including construction, operations, deactivation, and closure.

[b] Land use commitments over the long term encompass the period following completion of each alternative's scheduled activities.

Note: To convert hectares to acres, multiply by 2.471.

Key: FFTF=Fast Flux Test Facility.

Source: SAIC 2010a, 2010b, 2010c.

Long-term impacts of the alternative combinations would be associated with water resources, ecological resources, and human health. Long-term impacts on ecological resources would result from air emissions and groundwater contamination. A number of onsite and offsite receptors would be affected by human health impacts; these impacts would depend on the acuteness and duration of groundwater contamination due to linkage of exposure pathways to consumption of surface water or the use of groundwater for drinking water or crop irrigation. Thus, impacts on ecological resources and human health would correlate strongly with groundwater impacts. Water resources would be impacted the most under Alternative Combination 1, in which unmitigated releases from tank inventories would occur and would cause the majority of long-term impacts. Inevitable releases from tank inventories would overcome past-practice groundwater impacts and tank system leaks. Conversely, impacts on air quality would be least under Alternative Combination 1 because no new facilities would be constructed or operated.

Under Alternative Combination 2, retrieval and treatment of tank waste in the WTP would have short-term impacts on air quality. Air emissions would not be sufficient to produce significant long-term impacts on ecological resources. By the time groundwater reaches and is diluted by the Columbia River, impacts on ecological resources would also be negligible. The majority of impacts on groundwater resources would no longer be from tank inventories, as most of this waste would be immobilized through WTP operations, but rather from past discharges to the cribs and trenches (ditches), past leaks from tank systems, and new waste management areas. Ultimately, Alternative Combination 2 is projected to result in a reduction in concentrations of conservative tracers by one or two orders of magnitude at the Core Zone Boundary versus those that would occur under Alternative Combination 1. However, Alternative Combination 2 would require construction of IDF-East and the RPPDF in new locations. The receipt and disposal of offsite waste in IDF-East would also contribute to eventual groundwater impacts in this area, particularly associated with iodine-129 and technetium-99.

Under Alternative Combination 3, air quality impacts similar to those described above under Alternative Combination 2 would occur from treatment of tank waste; however, to accomplish excavation and clean closure of the tank farms, air quality impacts would increase significantly. Still, long-term impacts on ecological resources due to air emissions would be minor. Conversely, long-term impacts on ecological resources due to groundwater contamination would decrease when compared with those impacts under Alternative Combination 2. Under Alternative Combination 3, the SST farms would be clean-closed, and any future releases and contributions of residual tank inventories to groundwater would be eliminated. Similar to Alternative Combination 2, past discharges to the cribs and trenches (ditches) and past leaks from tank systems would still be the major source of impacts on groundwater. Under Alternative Combination 3, all treated tank waste would be managed as HLW and stored in onsite storage facilities. As a result, long-term groundwater impacts would be slightly lower under Alternative Combination 3, but generally similar to those under Alternative Combination 2. Treated tank waste requiring disposal in IDF-East would be reduced; however, there would be an increase in need for onsite storage capacity and in disposal requirements for clean closure waste in IDF-East and tank debris in the RPPDF. As under Alternative Combination 2, receipt and disposal of offsite waste in IDF-East would contribute to eventual groundwater impacts in this area, particularly related to iodine-129 and technetium-99.

Under all of the alternative combinations, the human health dose standards for one or more COPCs within the Core Zone Boundary would be exceeded if groundwater is used as a source of drinking water and crop irrigation. The impacts on the health of human receptors within the Core Zone Boundary are predicated on each receptor's ability to access groundwater; this ability would be delayed or made more difficult under Alternative Combinations 2 and 3, in which engineered barriers would be constructed in various locations. These engineered barriers would be constructed over the tank farms, cribs and trenches (ditches), or permanent disposal areas, as applicable under Alternative Combination 2 or 3.

7.5 LONG-TERM MITIGATION STRATEGIES

This *Final TC & WM EIS* discussed potential long-term mitigation measures for reducing impacts on groundwater resources in Section 7.1.6; this section presents a more indepth discussion on this topic. DOE acknowledges that several COPCs are predicted to approach or exceed benchmark standards at the Core Zone Boundary and/or Columbia River nearshore at various dates, although such predictions carry a degree of uncertainty. Several commentors on the *Draft TC & WM EIS* expressed concerns about the predicted magnitude of impacts on groundwater under various closure scenarios. DOE conducted a series of sensitivity analyses to help identify additional long-term mitigation actions that may have the potential to reduce long-term groundwater impacts. The sensitivity analyses conducted as part of this *Final TC & WM EIS* are examples of those areas that could be investigated; there may be other areas that might warrant further study. More than one mitigation action may be warranted in the near, mid-, and long term depending on the details of a particular waste management area unit or concern. This section attempts to clarify and discuss some of the uncertainties associated with groundwater impact analyses and to summarize the approach and results of the additional sensitivity analyses that were conducted and incorporated in various sections of this *Final TC & WM EIS*.

DOE intends to select a combination of Tank Closure, FFTF Decommissioning, and Waste Management alternatives and to develop and implement a Mitigation Action Plan that addresses mitigation commitments expressed in the ROD.

Recently, the CEQ issued final guidance on the *Appropriate Use of Mitigation and Monitoring and Clarifying the Appropriate Use of Mitigated Findings of No Significant Impact* (Sutley 2011). DOE's approach to mitigation strategies, as discussed in this *Final TC & WM EIS*, is consistent with the CEQ's new guidance. The new guidance clarifies the appropriate use of performance-based mitigation. The new guidance encourages the use of internal processes for postdecision monitoring to ensure the implementation and effectiveness of mitigation actions and stresses that mitigation is an ongoing and ever-evolving process that should continue well after an action is selected and implemented to ensure mitigation commitments are fully met. A conceptual model of the CEQ's mitigation and adaptive management process is illustrated in Figure 7–1.

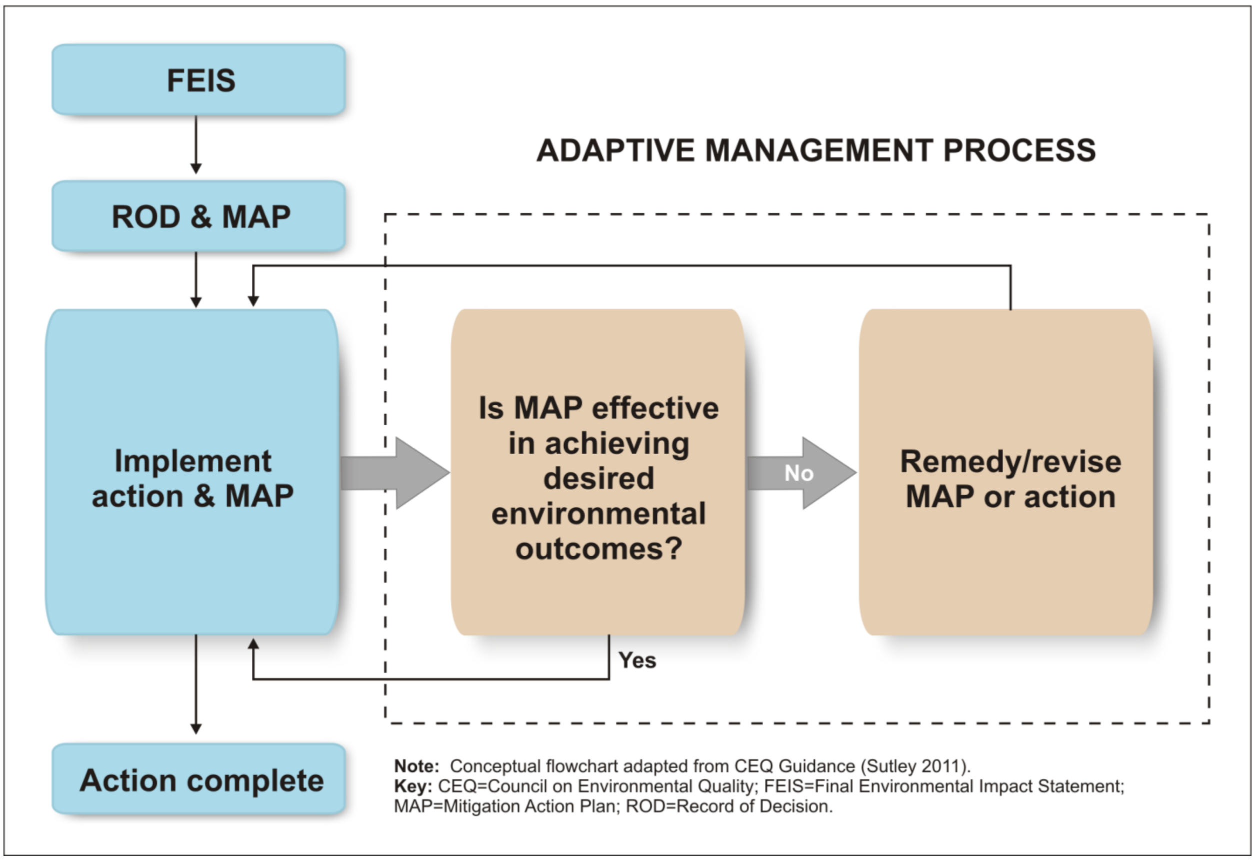


Figure 7–1. Mitigation and Adaptive Management Processes

7.5.1 Effects of Uncertainty on Long-Term Groundwater Predictions

As stated above, there is a degree of uncertainty associated with the prediction of long-term groundwater impacts. This is in part due to the limitations of the vadose zone and groundwater flow models, the technical data used as inputs to the models, or the difficulty predicting the fate and transport of COPCs over large geographical areas and for very long periods of time. The following section introduces some general information related to uncertainty and its relationship to long-term groundwater performance. Specific ways in which issues or concerns identified in this *Final TC & WM EIS* are or could be mitigated are discussed.

As shown in Figure 7–2, groundwater impacts may be plotted as concentration versus time at a specific receptor location (e.g., the Core Zone Boundary, Columbia River nearshore). As explained in Appendix O, Section O.2, these concentration plots can exhibit large fluctuations and appear erratic due to the stochastic nature of the model, resolution factors, and use of tracking objects for receptors. The best way to view these plots is to look for overall trends. Uncertainty causes potential variance in predicting the concentrations of COPCs at a receptor location. This variance could result in the actual concentration at some future date being more or less than that predicted. Furthermore, uncertainty, or variance, can also be magnified the further into the future a prediction is made. As we are evaluating impacts over considerable timeframes (e.g., 10,000 years), the resultant range of potential concentrations (predicted plus or minus variances) that could actually occur at a particular receptor location could be rather wide. Figure 7–3 illustrates the concept of a range of potential concentrations, also known as a variance band.

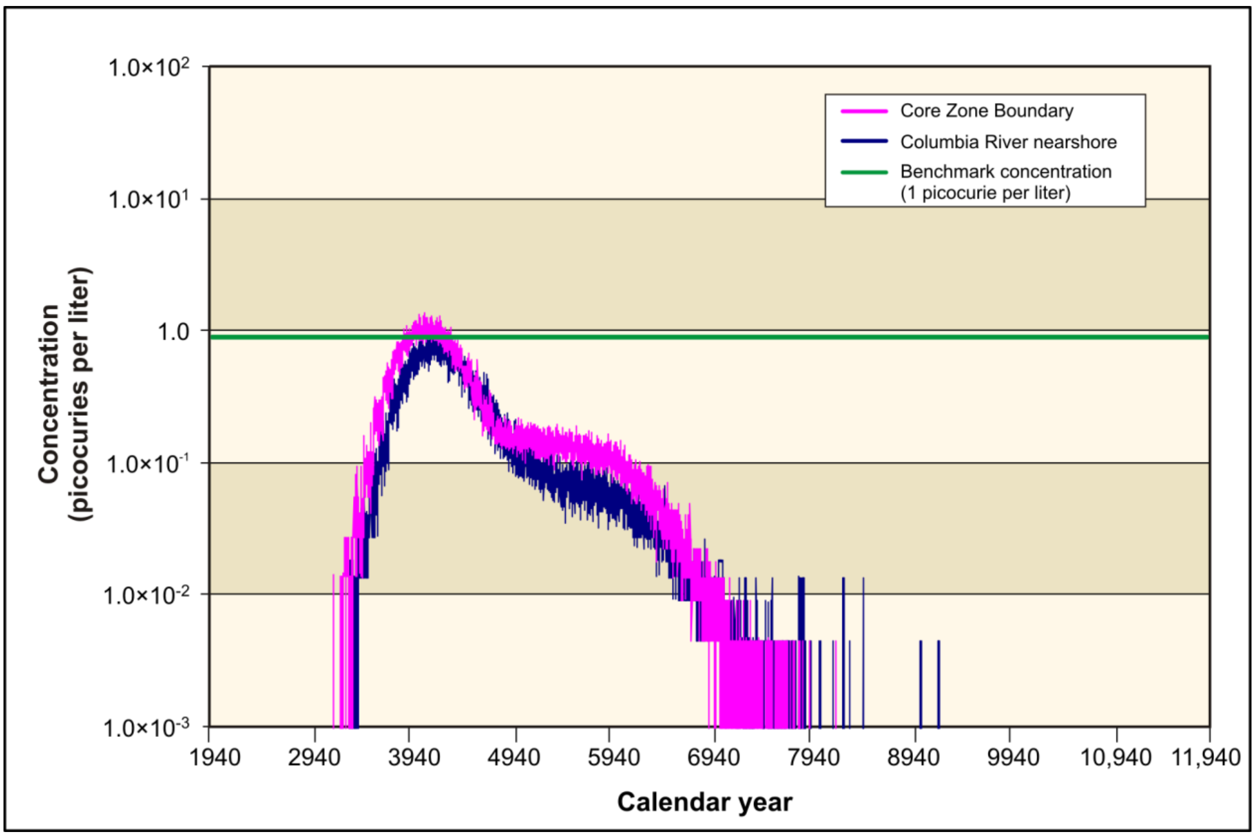


Figure 7–2. Typical Concentration-Versus-Time Plot

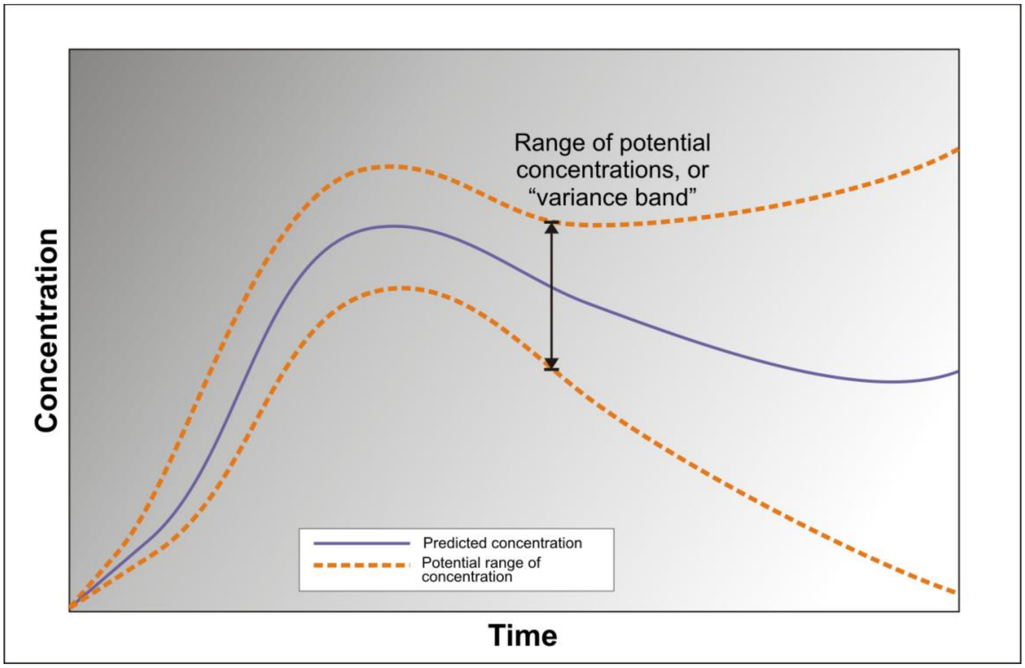


Figure 7–3. Conceptual Range of Potential Concentrations with Variance Band

This discussion might lead someone to ask the question "How can we reduce uncertainty?" This is relevant because reducing uncertainty is important to developing and implementing an effective mitigation strategy. By reducing uncertainty in the analysis, we can more precisely predict groundwater impacts and, thus, how these impacts compare to benchmark standards and how aggressive mitigation strategies need to be to meet those benchmark standards. There are two types of uncertainties: those that can be influenced (e.g., waste forms used, acceptance criteria for offsite waste) and those that generally cannot be influenced (e.g., geology and hydrogeology, infiltration rates, inventories of COPCs). Some uncertainties can be influenced by setting performance standards (e.g., allowable release rates for waste forms, waste acceptance criteria, cleanup standards), resulting in predicted long-term groundwater impacts that would remain below benchmark standards. The uncertainties that cannot be influenced are typically related to physical or chemical data, where little or disputed information is available. While these uncertainties cannot be influenced, they can be understood better by understanding their importance. By reducing uncertainties associated with environmental impacts analysis or implementation of mitigation strategies, the predicted concentrations of COPCs over time at a receptor location can be affected in the following three general ways (also illustrated in Figure 7–4):

1. Narrowing the overall variance band by reducing the uncertainties associated with the physical and chemical data or assumptions. For example, if more-precise and -accepted information on IDF infiltration were known, this would result in less magnification of the variance band over time.
2. Horizontally shifting the concentration plot to the right (later release of COPCs) or left (earlier release of COPCs). For example, barrier failure later than 500 years would shift the plot to the right, and an earlier barrier failure might shift the plot to the left.
3. Vertically shifting the concentration plot up (increase in COPCs) or down (decrease in COPCs). For example, if the Best-Basis Inventory were revised upward (or downward), the receipt and disposal of offsite waste at Hanford were restricted, or waste were shipped from Hanford to an offsite disposal facility, then the amounts of COPCs available for release would be higher (or lower), resulting in a corresponding vertical shift in the concentration plot or a decrease in the predicted peak concentration.

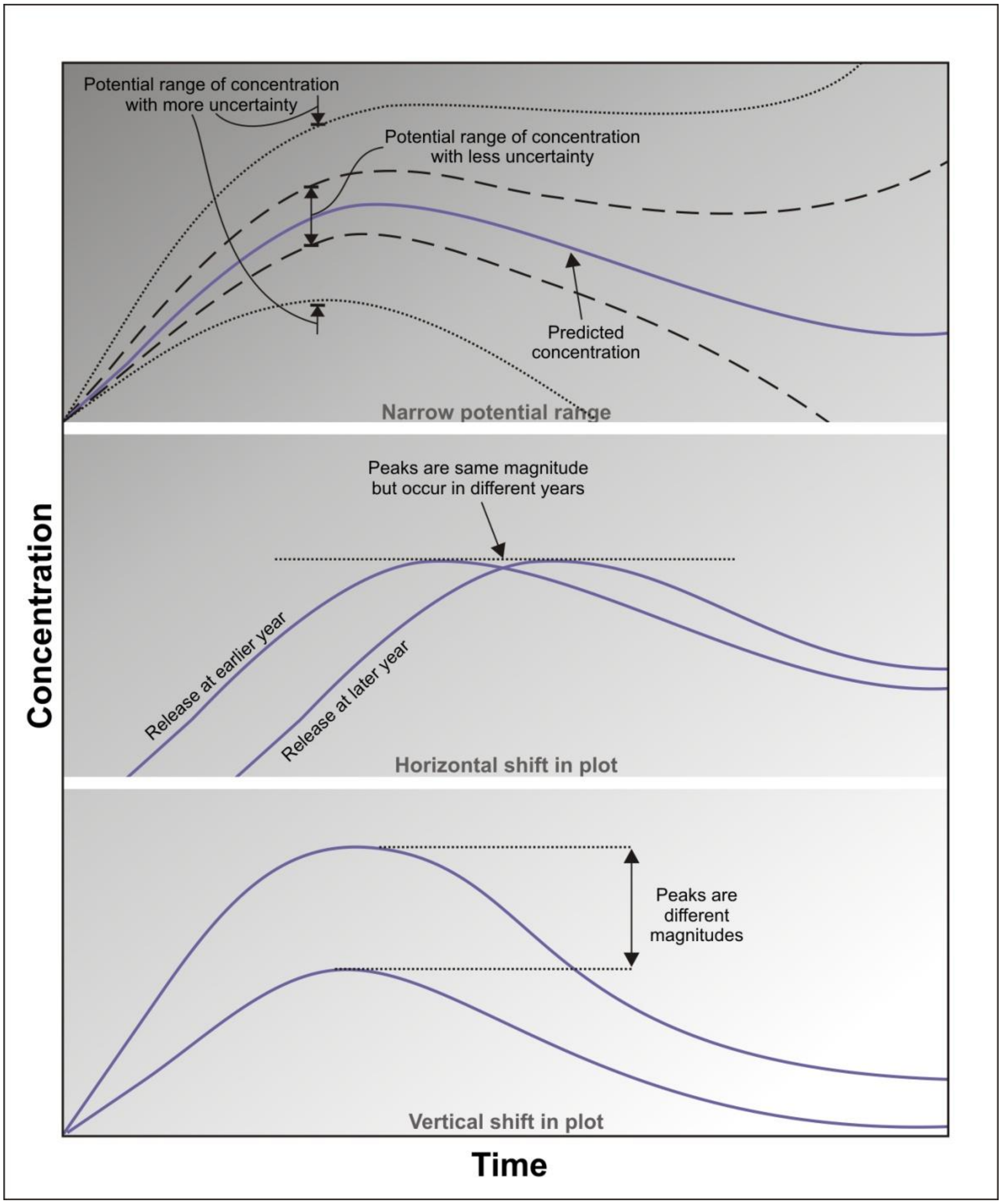


Figure 7–4. Effects of Reducing Uncertainty on Concentration Plots

Another example would be vadose zone remediation at one or more of the prominent waste sites in the Central Plateau, where COPCs could be treated and placed into a more stable waste form and subsequently disposed of in an IDF or in the RPPDF, the Environmental Restoration Disposal Facility, or another onsite permitted disposal facility. This scenario might affect the concentration plot simultaneously in two ways: (1) by delaying the release of COPCs and shifting the peak horizontally and (2) by changing the waste form that contains the COPCs and flattening the peak vertically.

An important note is that the groundwater impacts on a receptor presented in this final EIS as a concentration plot are actually an aggregation of impacts of many potential sources. Figure 7–5 provides an example concentration plot of the individual sources and the final aggregated plot after combining the effects of all the potential sources considered. Thus, reducing the uncertainty associated with a single source may or may not have an appreciable effect on the aggregated concentration plot for many sources. For example, vadose zone remediation at one site out of many across the Central Plateau may or may not reduce the flux of COPCs such that the concentration at the receptor location changes in a meaningful way. Another example might be that improvements in the performance of one waste form would not likely have an effect on the aggregated concentration unless that particular waste form is a major contributor to, or "driver" of, groundwater impacts. As mentioned above, waste form performance is one of many uncertainties. The key to determining which uncertainties, or to what extent changes to an uncertainty, might have more potential for mitigating groundwater impacts is the subject of the sensitivity analyses discussed in the following sections.

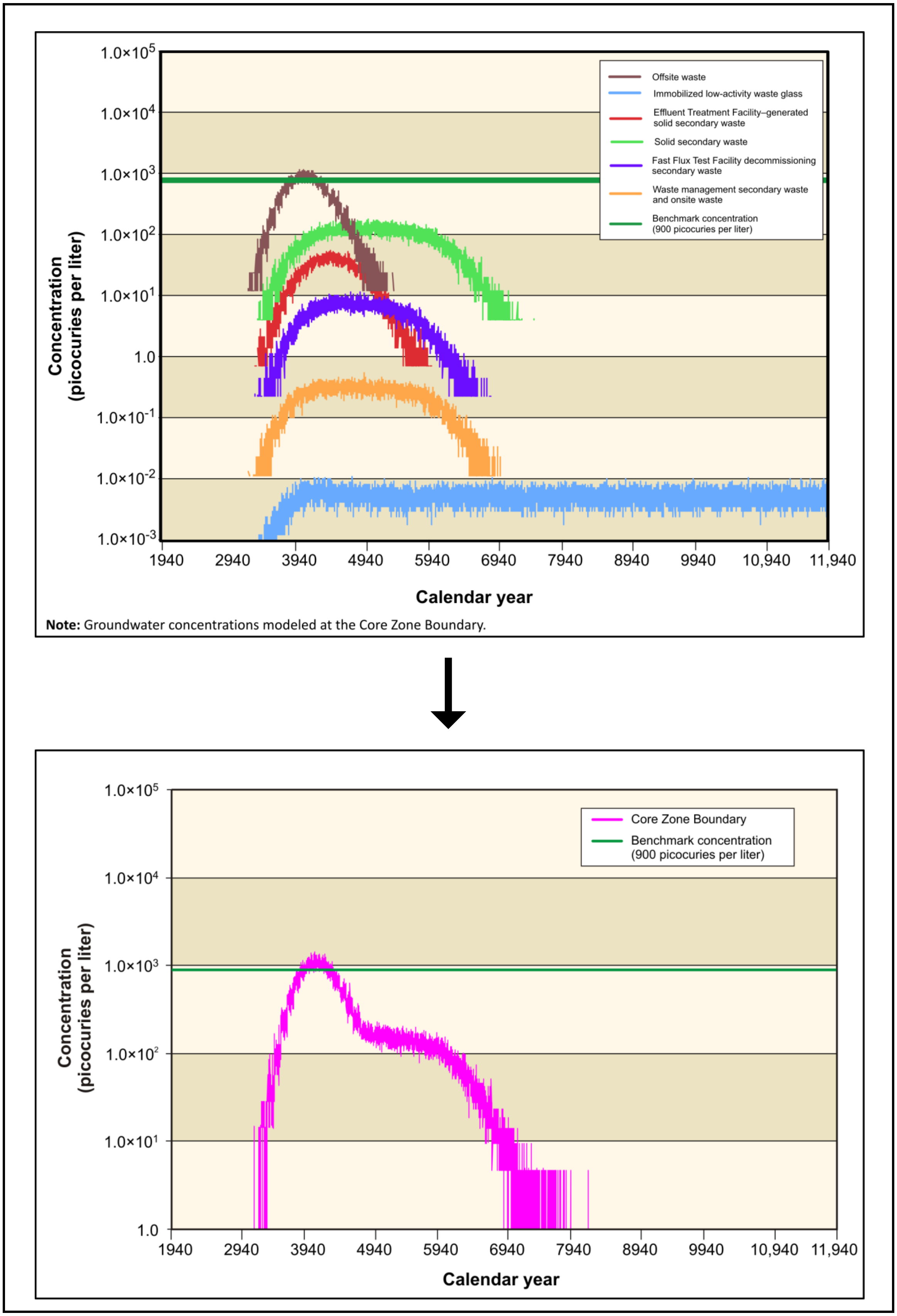


Figure 7–5. Example of Individual Contributors and Aggregation of Multiple Sources

7.5.2 Sensitivity Analyses Discussion

The sensitivity analyses conducted as part of this *Final TC & WM EIS* were used to determine which factors may contribute the most to groundwater impacts and where mitigation strategies might yield the most benefit. These sensitivity analyses are examples of factors that could be investigated.

In considering strategies for mitigating groundwater impacts in this EIS, various sensitivity analyses were conducted under the three following general areas:

- Reduce the inventory of COPCs available for discharge into the environment.
  - Flux reduction
  - Offsite-waste acceptance
  - Capture-and-removal scenario
  - Cribs and trenches (ditches) partial clean closure
- Modify processes for retrieval and treatment of tank waste.
  - Iodine recycle
  - Technetium removal
  - Leak loss of 15,142 liters (4,000 gallons) per tank
- Understand and manage the fate and transport of COPCs.
  - Waste form performance (e.g., ILAW glass, bulk vitrification glass, steam reforming waste, grouted waste)
  - Infiltration rates
  - Climate change and recharge assumptions

The sensitivity analyses were conducted on several COPCs that are considered hazard drivers (e.g., iodine-129, technetium-99, uranium-238); however, the same general principles and conclusions discussed in this section could apply to most COPCs, as would any mitigation planning and monitoring. The results of the sensitivity analyses are summarized in this section and presented in detail in various appendices of this final EIS, as indicated in Section 7.5.3. The results are also discussed in the context of what it means to the development of successful mitigation strategies for activities that will take place several years in the future.

7.5.2.1 Sensitivity Analysis: Flux Reduction

The purpose of the flux-reduction sensitivity analysis was to evaluate the effect on predicted long-term groundwater impacts if certain remediation activities were conducted at some of the more prominent waste sites on the Central Plateau and along the river corridor. A portion of the analysis results is summarized in this section, and additional details and analysis can be found in Appendix U, Section U.1.3.4.1. When conducting the flux-reduction analysis, the following parameters were defined:

- Flux reductions of 50, 75, and 99 percent were applied to cumulative and tank closure sources (e.g., sites) included in the sensitivity analyses, as described below.
- Flux reductions were applied at CY 2035, representing an assumed date when remediation might be completed at a particular site.

- The sources evaluated ranged between low-, moderate-, and heavy-discharge sites.

- Iodine-129 (high mobility) and uranium-238 (low mobility) were modeled.

The flux-reduction sensitivity analysis evaluated cumulative impact sites in the Central Plateau and along the river corridor, as well as tank farm sources from Tank Closure Alternative 2B (landfill closure). The following cumulative impacts sites were included in the analysis:

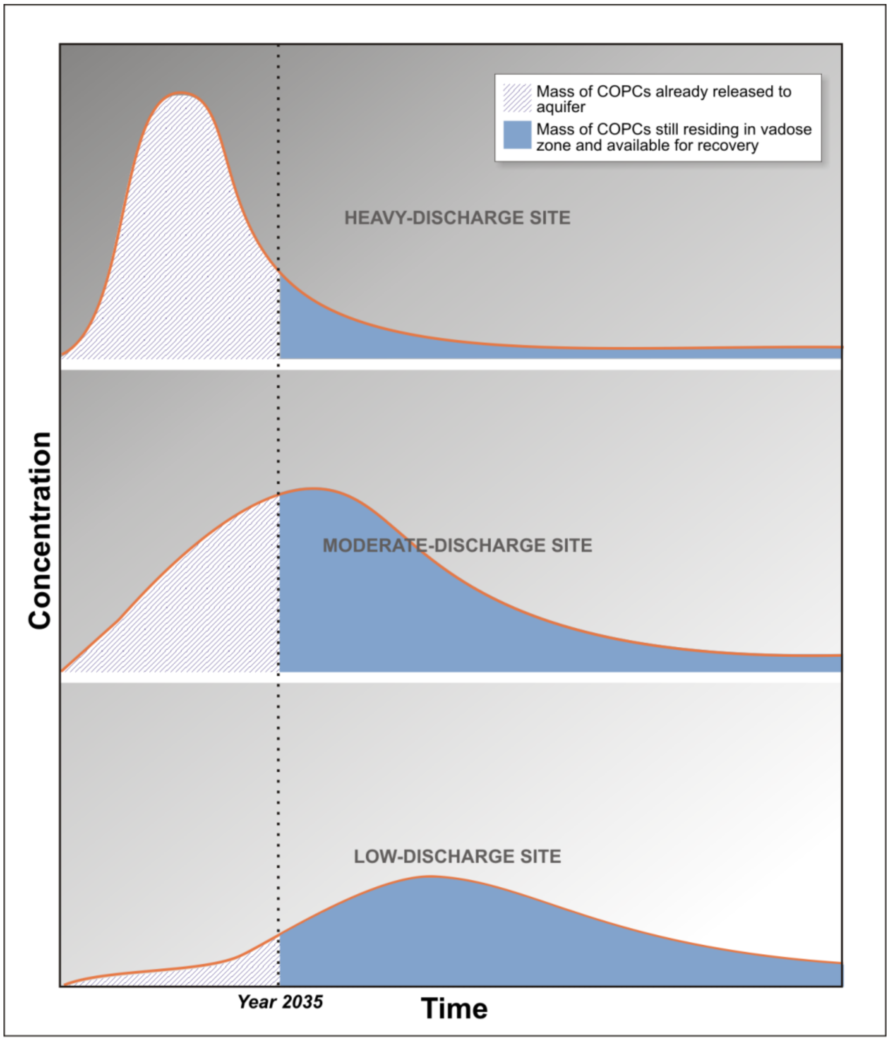
- Ponds (B, S, T, U, and Gable Mountain)
- River corridor sources (1301-N, 100-K Mile Long Trench, and 300 Area Process Ponds)
- BC Cribs (and trenches)
- REDOX [reduction-oxidation] sources (216-U-8, 216-S-7, 216-S-8)
- PUREX [plutonium-uranium extraction] sources (216-A-9, 216-A-10, 216-A-30, 216-B-12)

Tank Closure Alternative 2B (landfill closure) was the basis for the alternative sources that were analyzed in the flux-reduction sensitivity analysis. Those sources included the following:

- Tank farm past leaks (A, AX, B, BX, BY, C, S, SX, T, TX, TY, and U)
- Ancillary equipment (A, AN, AP, AW, AX, AY, AZ, B, BY, C, S, SY, T, TX, TY, and U)
- Retrieval leaks (A, AX, B, BX, BY, C, S, SX, T, TX, TY, and U)
- Tank residuals (A, AN, AP, AW, AX, AY, AZ, B, BX, BY, C, S, SX, SY, T, TX, TY, and U)
- Cribs and trenches (ditches) (B, BX, BY, T, TX, and TY)

For analysis purposes in this *TC & WM EIS*, aqueous sources of contamination were examined based on the amount of discharge. Sources with an aqueous discharge of less than 1 meter (3 feet) per year were categorized as moderate-discharge sources. Sources with aqueous releases of greater than 1 meter (3 feet) per year were categorized as heavy-discharge sources. Solid sources were categorized as low-discharge sources. The sources along the Columbia River primarily fall within the heavy- and moderate-discharge categories and include releases associated with the nuclear reactors. The sources in the central portion of the site include heavy-, moderate-, and low-discharge sites and were associated with plutonium processing and storage of waste generated from plutonium production. The sources in the 300 Area include heavy-, moderate-, and low-discharge sites and are associated with manufacturing work and experiments that were carried out during operations.

The concept behind flux reduction is to recognize the benefits of vadose zone remediation before COPCs are released into the underlying aquifers. Vadose zone remediation can only be effective if a majority of COPCs are recoverable before they can impact the groundwater and if the mass of COPCs available for removal is significant in terms of the overall mass of COPCs from the multitude of sites across the Central Plateau. Once COPCs have been released into the underlying aquifer, vadose zone remediation will have only a limited benefit in reducing the long-term impacts on groundwater concentrations because very little of the COPC mass would remain in the vadose zone where it would be available for remediation. By the time the majority of COPCs have impacted groundwater, remediation actions such as using reactive barriers or pump-and-treat systems would be the only options remaining. Figure 7–6 conceptually illustrates the proportion of COPCs that might be available for remediation for heavy-, moderate-, and low-discharge sites, as discussed below, and assuming remediation would be completed in CY 2035.



Key: COPC=constituent of potential concern.

Figure 7–6. Availability of COPCs for Recovery from Vadose Zone

Heavy-discharge sites are characterized by high volumes of liquid disposal occurring on site for short periods of time. Examples of heavy-discharge sites include the 216-A-9 crib and TY cribs. Concentration plots for heavy-discharge sites typically exhibit a sharp high peak, followed by a tapering shoulder.

For most heavy-discharge sites, flux reduction applied in CY 2035 would occur on the downward side of the peak after a majority of the COPCs have already been released into the groundwater system. Flux reduction as a mitigating measure would generally lower only the shoulder. Consequently, a small portion of the overall COPC mass would be remediated, and long-term concentration reductions at receptor locations would be minimal.

Moderate-discharge sites experience less liquid disposal than a heavy-discharge site, but also for relatively shorter periods of time. Examples of moderate-discharge sites include past tank leaks such as those that occurred at the C and U tank farms. Concentration plots for moderate-discharge sites typically exhibit a rounded peak, followed by a tapering shoulder.

For most moderate-discharge sites, flux reduction applied in CY 2035 would occur somewhere within the peak of COPC release to the groundwater system. Flux reduction as a mitigating measure would generally lower both the rounded peak and the shoulder of the concentration plot. Therefore, vadose zone remediation would generally be more effective for moderate-discharge sites than for heavy-discharge sites; however, depending on the site, the percentage of COPC mass available for remediation may not be large enough for such remediation to result in a corresponding reduction in long-term concentrations at receptor locations. Moderate-discharge sites have a more finite time in which actions need to occur in the vadose zone before the beneficial impact would be realized.

Low-discharge sites experience much less liquid disposal than other heavy- or moderate-discharge sites and might also experience discharge over longer periods of time. An example of a low-discharge site could be the longer-term release from tank residuals, such as that from the C and U tank farms after in situ closure. Typical concentration plots for these sites might exhibit little to no peak with a long, steady, but gradually increasing or decreasing shoulder.

For low-discharge sites, flux reduction applied in CY 2035 might occur prior to the peak of COPC release to the groundwater system. Flux reduction as a mitigating measure would affect the entire duration of release. Low-discharge sites are more likely to have a high percentage of COPC mass still available for remediation in the vadose zone. Therefore, vadose zone remediation would generally be effective in recovering a large percentage of COPC mass and, thus, result in a corresponding reduction in long-term concentrations in the groundwater system. Low-discharge sites may have a longer window of opportunity in which vadose zone actions would be effective, if needed at all.

In summary, flux reduction is more likely to be effective in reducing predicted long-term impacts on groundwater for moderate- to low-discharge sites. However, the specific target COPC is equally important when determining whether flux reduction might be effective. For example, iodine-129 is a COPC that will migrate into the groundwater system more quickly than uranium-238, which migrates comparatively slowly. In most cases, iodine-129 may be available for remediation at most low- and some moderate-discharge sites; however, uranium-238 may be available for remediation at most low- to moderate-discharge sites and potentially at some heavy-discharge sites. Generally, flux reduction at heavy-discharge sites is not likely to be favorable. Flux reduction at moderate-discharge sites might be considered in the near term (e.g., before the peak dissipates), and flux reduction at low-discharge sites might be considered in the near to mid-term as an effective strategy. Additional sensitivity analyses might be needed to determine the overall impact of potential vadose zone remediation for a site at a particular receptor location; this information could subsequently assist DOE in prioritizing the remediation of sites across the Central Plateau. In circumstances where COPCs have already "fluxed" to the groundwater system, remediation strategies might include interceptor, pump-and-treat, or other groundwater extraction and remediation technologies, but would not include technologies that target the vadose zone.

Tank Closure Alternative 4 includes clean closure of the BX and SX tank farms as part of the EIS base case analysis for this alternative, which represents a very specific example of the flux-reduction concept. This example of flux reduction is limited in scope to two source areas, versus a blanket flux reduction for all sources, as was done for the flux-reduction sensitivity analysis, and is limited to remediation by excavation. Appendix U, Section U.1.3.4.1.4, discusses the relative difference in flux reduction in terms of curies of technetium-99, iodine-129, and uranium-238 analyzed under Tank Closure Alternative 4 compared with the analysis performed for the 50 percent, 75 percent, and 99 percent sensitivity cases. On the surface, flux reduction offers some interesting and potentially beneficial outcomes. The prospect of achieving results similar to those of Tank Closure Alternative 4 without the issues of worker exposure, waste generation, technical issues associated with tank exhumation, and increased accidents is certainly worth consideration. Flux reduction is not an easy or simple solution and presents a different set of technical challenges, as discussed below.

An important caveat to the flux-reduction sensitivity analysis is that "hot spot" remediation, partial clean closure analyzed under Tank Closure Alternative 4, or clean closure analyzed under Tank Closure

Alternatives 6A and 6B are complicated remediation activities that require more than simple flux reduction. In most of these cases, the COPCs that could be remediated from the "hot spots" would simply be moved to another location at Hanford (i.e., an IDF, the RPPDF, or the Environmental Restoration Disposal Facility) and may or may not be treated. The risk associated with these COPCs would not necessarily be eliminated, but rather may only be moved to another location or changed in some way. Therefore, flux reduction in one area of Hanford could mean a flux increase in another area of Hanford. Remediation of "hot spots" also might involve increased risk and exposure to workers, which ultimately would need to be evaluated against the potential benefits associated with any flux-reduction action.

DOE published the *Long-Range Deep Vadose Zone Program Plan* in October 2010 (DOE 2010a). This program plan summarizes the current knowledge regarding deep vadose zone remediation challenges beneath the Central Plateau of Hanford and DOE's approach to solving those challenges. The challenges faced are the result of contaminant depth and spread; the presence of multiple contaminants and comingled waste chemistries; the physical, chemical, and biological fate and transport mechanisms; uncertain contaminant behavior; unknown limited availability and effectiveness of cleanup remedies; and the efficacy of remediation performance over the periods and spatial scales needed to make decisions. Remediation of the deep vadose zone is central to Hanford cleanup because the vadose zone provides an ongoing source of contamination to the underlying aquifer and the Columbia River unless permanent solutions are developed and implemented (DOE 2010a). The sensitivity analysis related to flux reduction that was conducted for this final EIS could be expanded and integrated with DOE vadose zone remediation programs to coordinate and prioritize the near-term remediation of some sites while providing for the timely development and availability of technologies for remediating and treating waste from candidate sites in the mid-term.

7.5.2.2 Sensitivity Analysis: Offsite-Waste Acceptance

Previously, in Section 7.1.6, the mitigating measure limiting the receipt of offsite waste for disposal at Hanford was discussed, particularly for those waste streams that contain higher concentrations of iodine-129 and technetium-99. For example, DOE evaluated the effect of applying waste acceptance criteria to offsite waste by removing a highly radioactive waste stream (i.e., high inventories of iodine-129 and technetium-99) from the inventory of offsite waste analyzed for disposal at Hanford in this final EIS. Elimination of this single waste stream removes approximately 13 curies of iodine-129 (a reduction of almost 85 percent) and 338 curies of technetium-99 (a reduction of almost 20 percent) from the offsite inventories that were considered for disposal at Hanford in the *Draft TC & WM EIS*. This *Final TC & WM EIS* considers the receipt of offsite waste containing 2.3 curies of iodine-129 and 1,460 curies of technetium-99.

The purpose of this sensitivity analysis was to evaluate the potential contribution to predicted long-term groundwater impacts resulting from accepting offsite-waste disposal at Hanford. A portion of the results are summarized in this section, and additional details and analysis can be found in Appendix M, Section M.5.7.6. After removing the waste stream mentioned above, the offsite-waste sensitivity analysis applied the following additional parameters:

- Zero to 3 curies of iodine-129 and 0 to 1,500 curies of technetium-99 were established as offsite waste inventories that could be disposed of in IDF-East and representing a potential range of offsite-waste disposal at Hanford.

- IDF-East's configuration was consistent with Waste Management Alternative 2 and Tank Closure Alternative 2B.

- Offsite waste would be received "as is" for disposal with no pretreatment or stabilization steps taken; thus, the waste form performance was assumed to be convective flow with partition-limited release.

- Iodine-129 and technetium-99 were modeled with a background IDF-East infiltration rate of 0.9 millimeters per year.

Figure 7–7 shows the predicted concentration of iodine-129 at the Core Zone Boundary and Columbia River receptor locations if no offsite waste is accepted for disposal at Hanford (i.e., 0 curies). Figure 7–8 shows the predicted concentrations of iodine-129 if 3 curies were disposed of in IDF-East at Hanford. As shown, the disposal of offsite waste with 3 curies of iodine-129 in IDF-East at Hanford results in a peak groundwater concentration at the Core Zone Boundary and Columbia River in approximately CY 8000; this peak is 10 times greater than the concentration predicted for no importation of offsite waste.

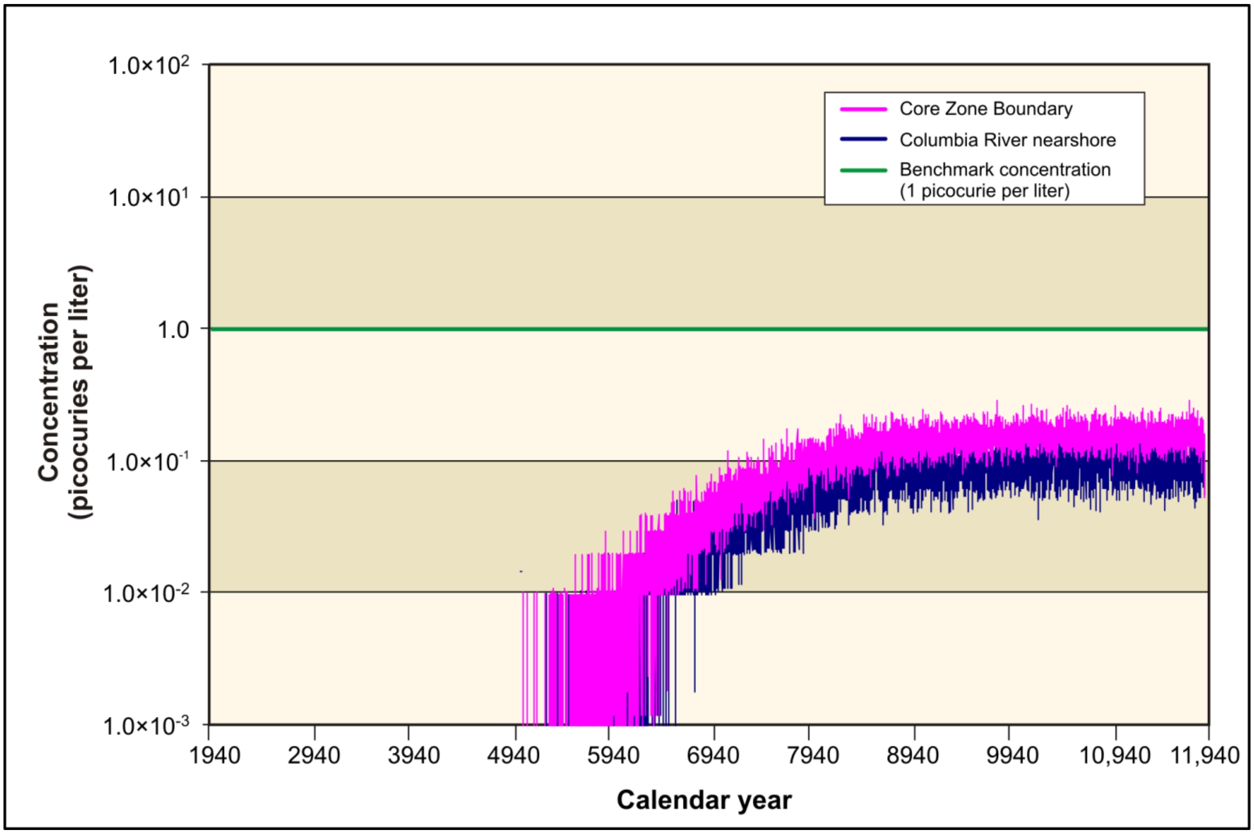


Figure 7–7. Tank Closure Alternative 2B Groundwater Iodine-129 Concentration Without Offsite Waste

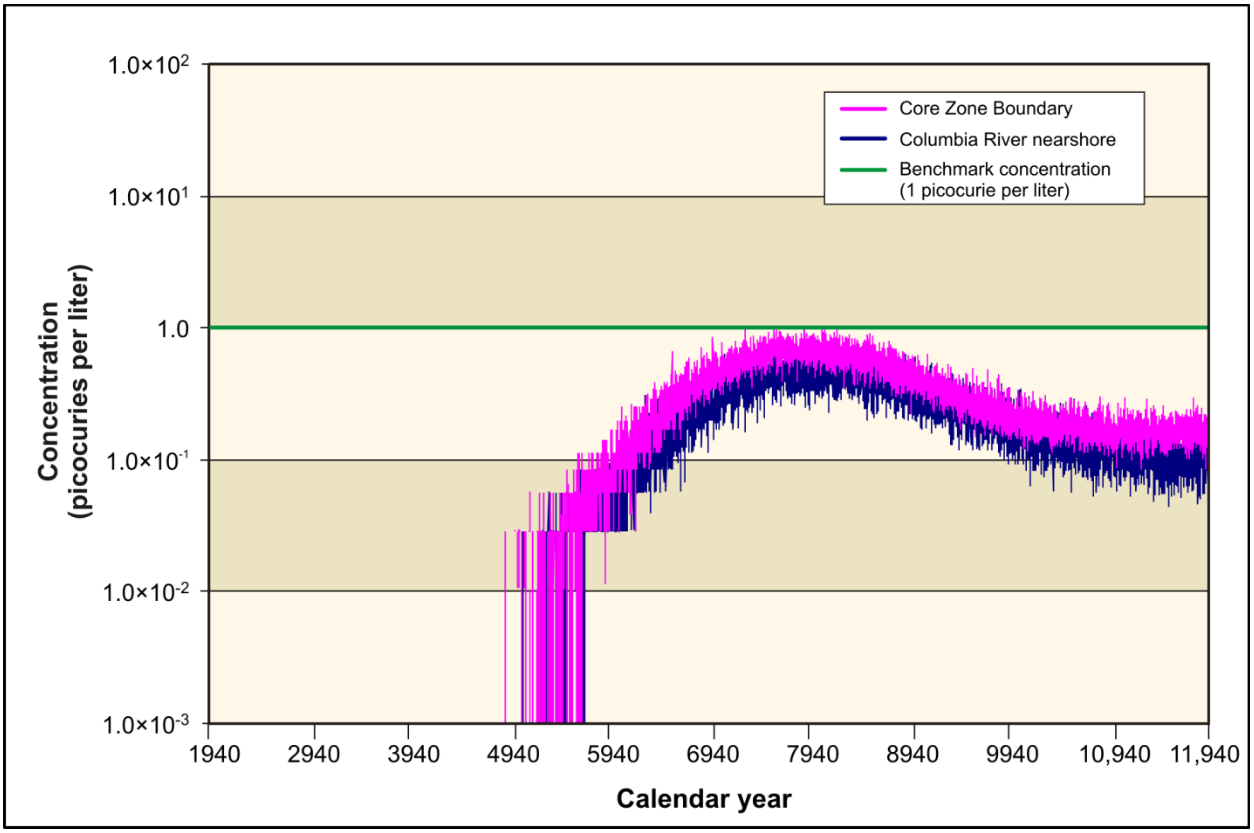


Figure 7–8. Tank Closure Alternative 2B Groundwater Iodine-129 Concentration with 3 Curies of Iodine-129 in Offsite Waste

Figure 7–9 shows the predicted concentrations of technetium-99 at the Core Zone Boundary and Columbia River receptor locations if no offsite waste is accepted for disposal at Hanford (i.e., 0 curies). Figure 7–10 shows the predicted concentrations of technetium-99 if 1,500 curies were disposed of in IDF-East at Hanford. As shown, the disposal of offsite waste with 1,500 curies of technetium-99 in IDF-East at Hanford results in a peak in groundwater concentration at the Core Zone Boundary and Columbia River in approximately CY 8000; this peak is 10 times greater than the concentrations predicted for no importation of offsite waste.

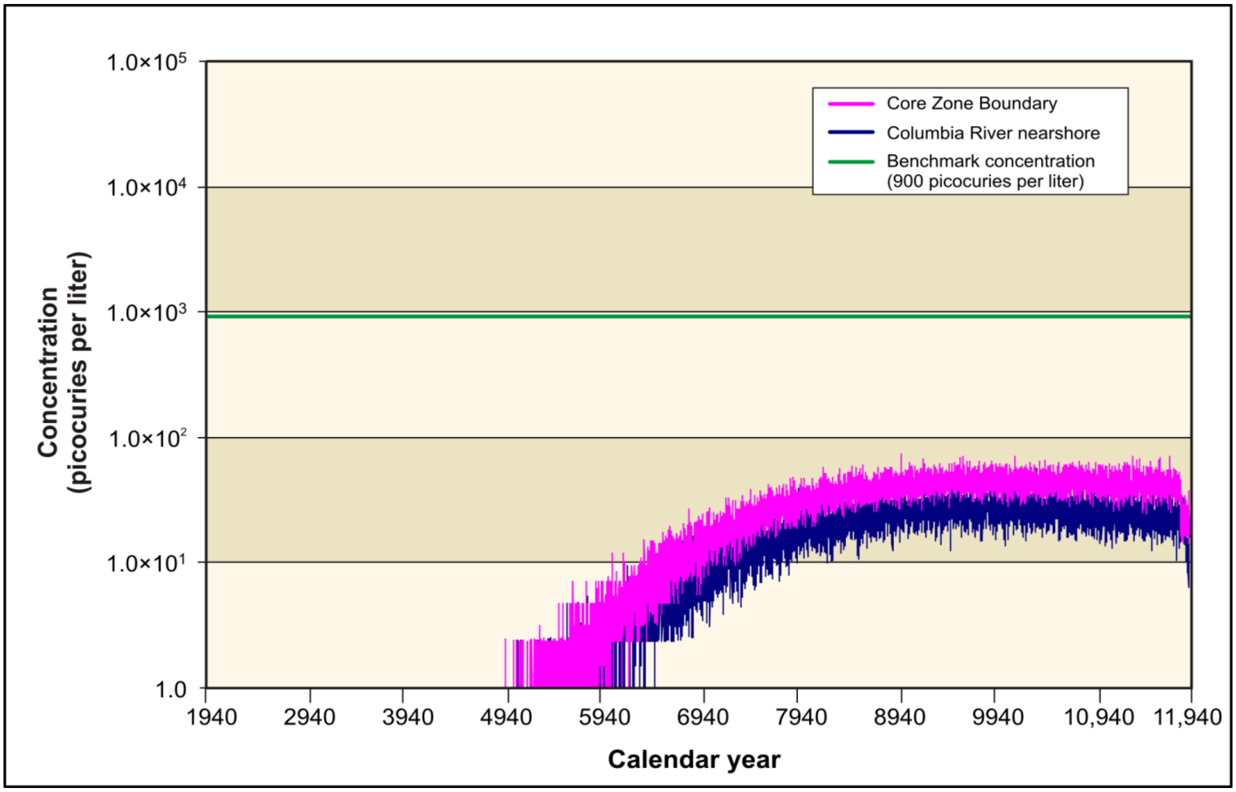


Figure 7–9. Tank Closure Alternative 2B Groundwater Technetium-99 Concentration Without Offsite Waste

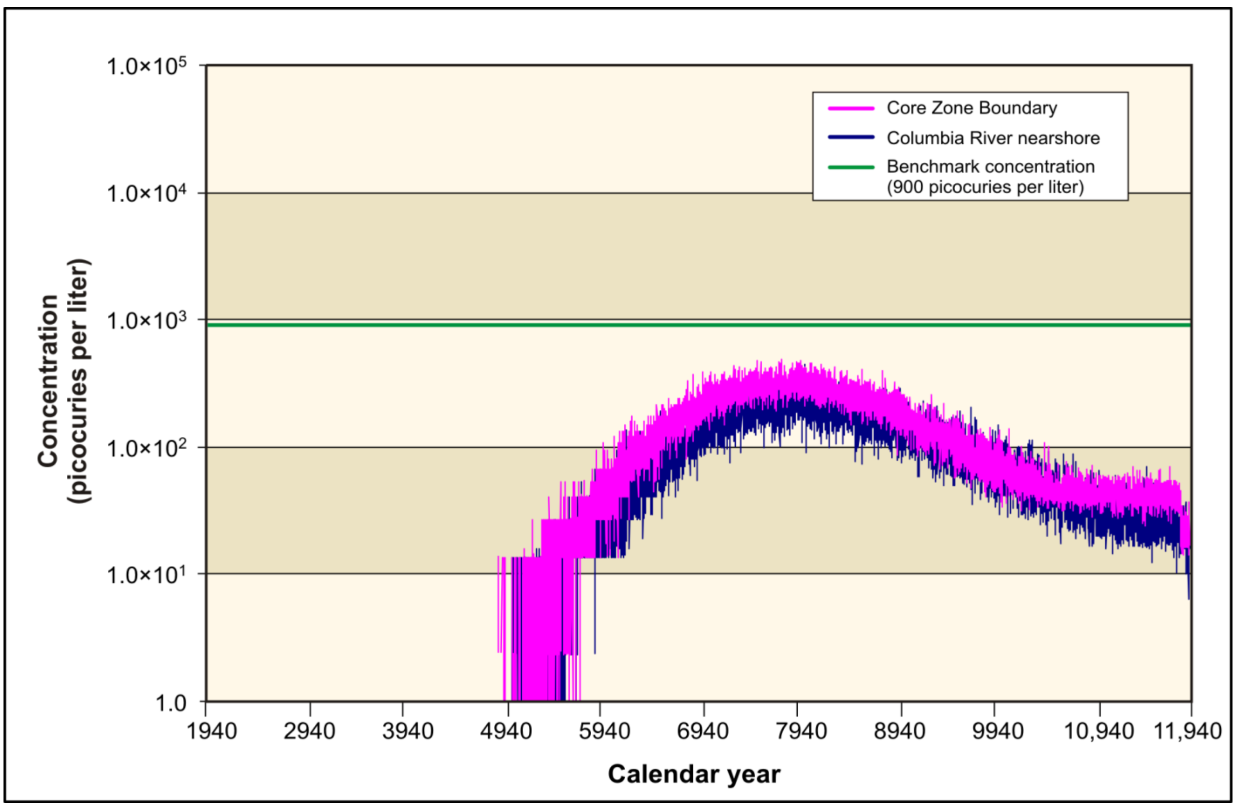


Figure 7–10. Tank Closure Alternative 2B Groundwater Technetium-99 Concentration with 1,500 Curies of Technetium-99 in Offsite Waste

Appendix M, Section M.5.7.6, presents similar concentration plots for intermediate concentrations of iodine-129 (e.g., 1 and 2 curies) and technetium-99 (e.g., 500 and 1,000 curies) in offsite waste. The data suggest a strong, proportional relationship between inventories of iodine-129 and technetium-99 in offsite waste disposed of in an IDF and long-term groundwater impacts at the Core Zone Boundary and the Columbia River.

In addition to mitigating measures such as restricting the acceptance of offsite waste or eliminating specific waste streams from consideration for disposal at Hanford, DOE could require pretreatment of offsite waste (e.g., grout, packaging) into better-performing waste forms prior to disposal in an IDF at Hanford. This might improve the release characteristics of offsite-waste forms, and thus downgrade the status of offsite waste as a dominating contributor to long-term groundwater impacts.

7.5.2.3 Sensitivity Analysis: Capture and Removal

The purpose of this sensitivity analysis was to evaluate the effect a planned pump-and-treat groundwater remediation system would have on a plume of carbon tetrachloride in the western portion of the Central Plateau. The plume is approximately 65,000 kilograms (143,000 pounds) of carbon tetrachloride that originated from the Plutonium Finishing Plant and was disposed of in three of the 216-Z cribs and trenches (ditches) (DOE 2010b). In addition to carbon tetrachloride, other COPCs such as chromium, nitrate, iodine-129, tritium, technetium-99, and uranium, also reside in this portion of the aquifer and would be affected by a pump-and-treat system. The Base Case for this *Final TC & WM EIS* does not take any credit for any planned remediation of this plume in the cumulative impacts analysis for long-term impacts on groundwater. This sensitivity analysis simulates two remedial end states for the plume at 95 and 99 percent removal and evaluates the predicted concentrations at the Core Zone Boundary and Columbia River for carbon tetrachloride, chromium, and technetium-99. The results for carbon tetrachloride are summarized in this section, and additional details and analysis for chromium and technetium-99 can be found in Appendix U, Section U.1.3.4.2. As a basis for the capture-and-removal sensitivity analysis, the following parameters were defined:

- Capture and removal of 0, 95, and 99 percent of COPC plume mass. For carbon tetrachloride, this corresponds to 0 percent removal (65,000 kilograms [143,000 pounds] released in CY 2005), 95 percent removal (3,250 kilograms [7,170 pounds] released in the year 2040), and 99 percent removal (650 kilograms [1,430 pounds] released in CY 2040).

- CY 2040 as an approximate date when remediation might be completed. This is based on a start date for full-scale remediation in approximately 2012 and an active pump-and-treat period of 25 years for the Operable Unit 200-ZP-1 groundwater system (EPA 2008).

A comparison of predicted concentrations of carbon tetrachloride at the Core Zone Boundary and Columbia River receptor locations for the 0, 95, and 99 percent mass removal scenarios is presented in Figures 7–11 and 7–12, respectively.

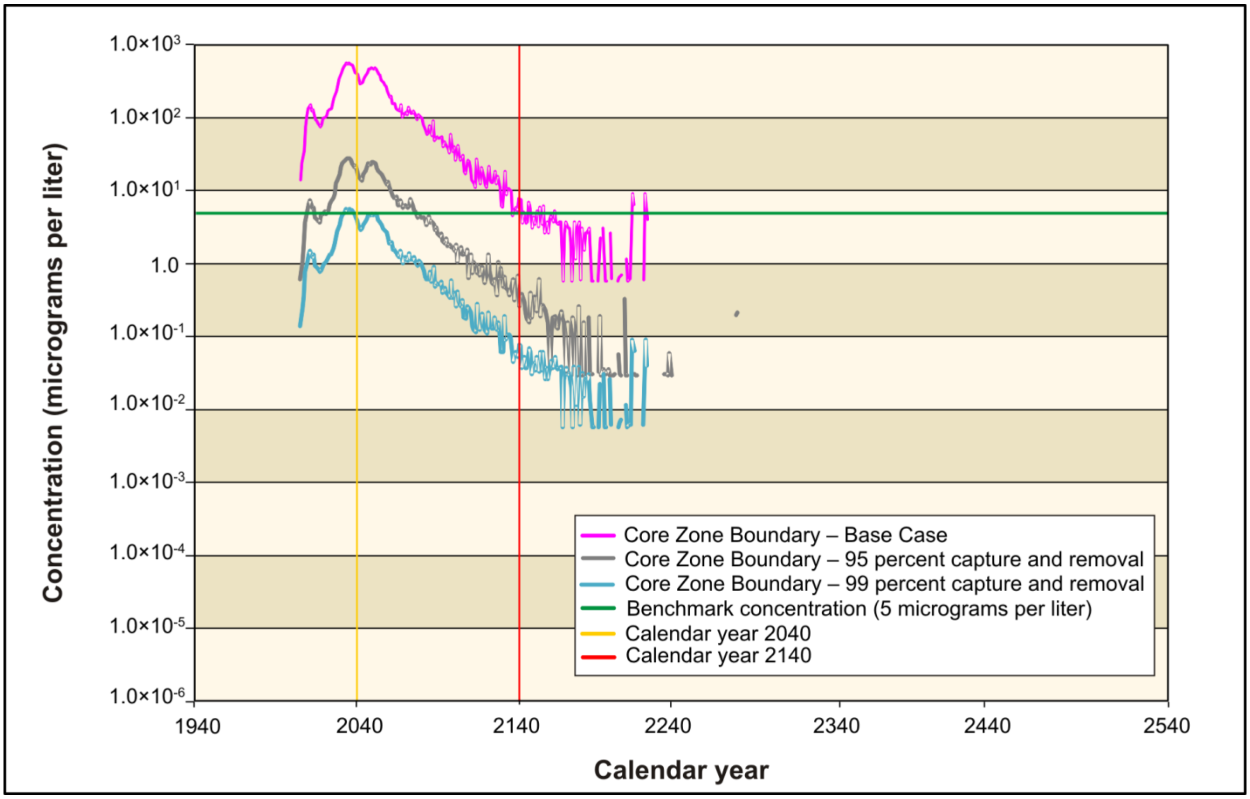


Figure 7–11. Carbon Tetrachloride Concentration Versus Time at the Core Zone Boundary, Capture-and-Removal Scenario Comparison

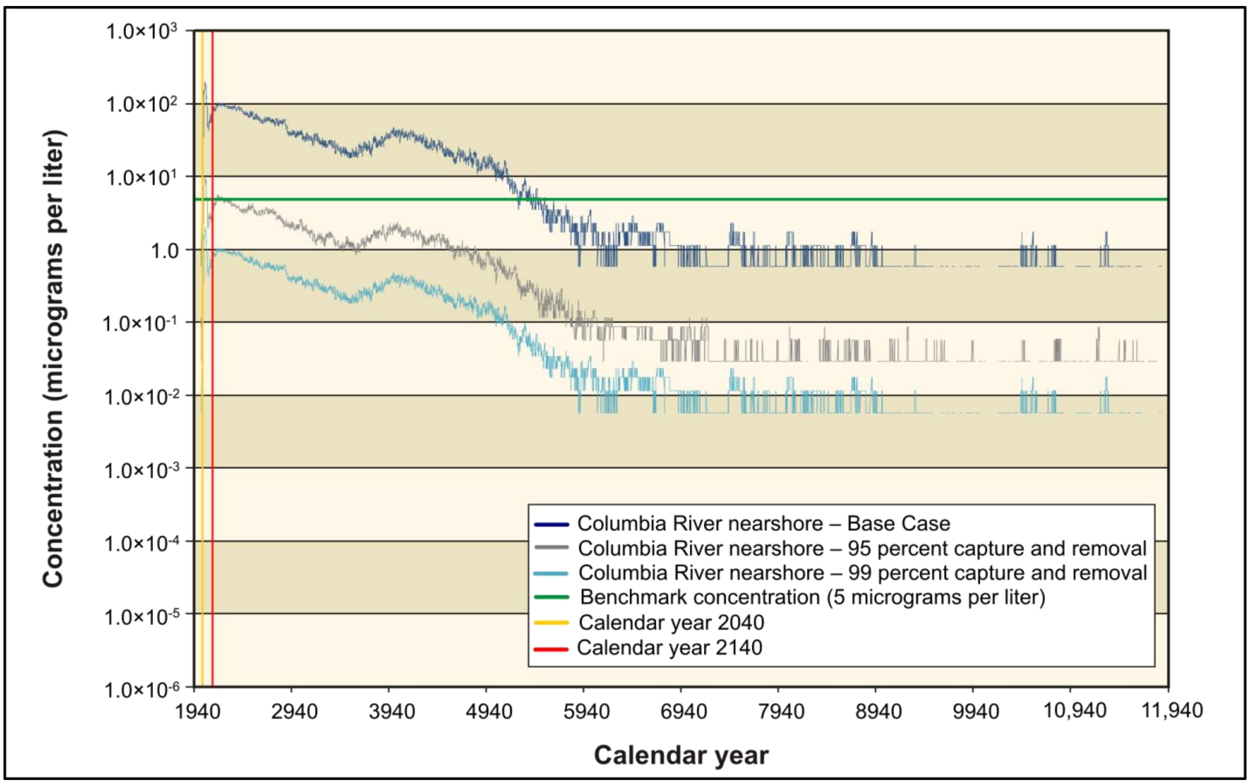


Figure 7–12. Carbon Tetrachloride Concentration Versus Time at the Columbia River, Capture-and-Removal Scenario Comparison

The results shown in both figures suggest that removal of the carbon tetrachloride in the upper 15 meters (49.2 feet) of the unconfined aquifer would result in a proportional decrease in concentrations predicted to occur at both the Columbia River nearshore and Core Zone Boundary receptor locations. There is some uncertainty associated with the technical limitations of the model. For instance, any plume remediation would take place over time; however, the model recognizes 95 and 99 percent mass removal in a single year, which was assumed to be CY 2040. Note that the timescale for Figure 7–11 is 600 years, whereas the timescale for Figure 7–12 is 10,000 years; this was done to provide a higher degree of resolution when evaluating impacts at the Core Zone Boundary. With the 0-percent-mass-removal case (i.e., the EIS case), concentrations are predicted to remain above benchmark standards at the Core Zone Boundary until approximately CY 2140 and at the Columbia River until approximately CY 5500. For the 95-percent-removal case, exceedances are predicted at both receptor locations from approximately CY 2050 to CY 2150, a much shorter duration than those predicted for the EIS case. For the 99-percent-removal case, concentrations are predicted to approach, but not exceed, benchmark standards at the Core Zone Boundary; concentrations at the Columbia River are predicted to remain at least one order of magnitude below benchmark standards during the period of analysis. The data suggest that remediation of the carbon tetrachloride plume in the western portion of the Central Plateau might be effective in significantly reducing groundwater concentrations that could occur at the Core Zone Boundary and Columbia River. On a larger scale, the data suggest that groundwater remediation systems may be an effective mitigation strategy at certain locations and for certain COPCs within the Central Plateau.

As discussed in Appendix U, Section U.1.3.4.2, concentrations of chromium and technetium-99 at the Columbia River nearshore and Core Zone Boundary receptor locations are not projected to exceed benchmark standards due to the mass of these COPCs residing within this portion of the aquifer, even for the 0-percent-removal case. However, similar to the carbon tetrachloride analysis, removal (both 95 percent and 99 percent) of the chromium or technetium-99 plume mass is also predicted to reduce predicted concentrations at the Columbia River nearshore and Core Zone Boundary receptor locations.

7.5.2.4 Sensitivity Analysis: Cribs and Trenches (Ditches) Partial Clean Closure

The purpose of this sensitivity analysis was to evaluate the predicted long-term groundwater impacts of proposed activities on concentration plots without the masking effect of the cribs and trenches (ditches). Past disposal practices in the cribs and trenches (ditches) impact groundwater early in the modeling timeframe, making it difficult to discern differences amongst the activities associated with Tank Closure alternatives (i.e., a masking effect). In other words, the analysis was conducted to determine the long-term groundwater impacts under Tank Closure Alternative 2B only if the contribution to groundwater impacts of the cribs and trenches (ditches) were removed. This analysis offered a higher degree of resolution in assessing the groundwater impacts. When conducting the analysis of crib and trench (ditch) partial clean closure, the following parameters were defined:

- The cribs and trenches (ditches) were removed from the sources of the COPCs analyzed under Tank Closure Alternative 2B long-term groundwater impacts.
- The radionuclides tritium, technetium-99, iodine-129, and uranium isotopes, as well as the chemicals chromium, nitrate, and total uranium, were evaluated.

In summary, the analysis indicates that groundwater impacts of past releases from cribs and trenches (ditches) occur early in the modeling timeframe (i.e., from approximately 1944 for 100 years) and that these impacts are significant when compared with impacts predicted to occur from activities associated with the Tank Closure alternatives. The contributions to groundwater impacts of past releases from cribs and trenches (ditches) are predicted to exceed benchmark standards under all Tank Closure alternatives, including the No Action Alternative.

Additional details and analysis can be found in Appendix O, Section O.6.6. From a mitigation perspective, this analysis does not directly lead to potential mitigation strategies; however, understanding the relative importance of tank closure activities when evaluating groundwater impacts may focus future mitigation planning.

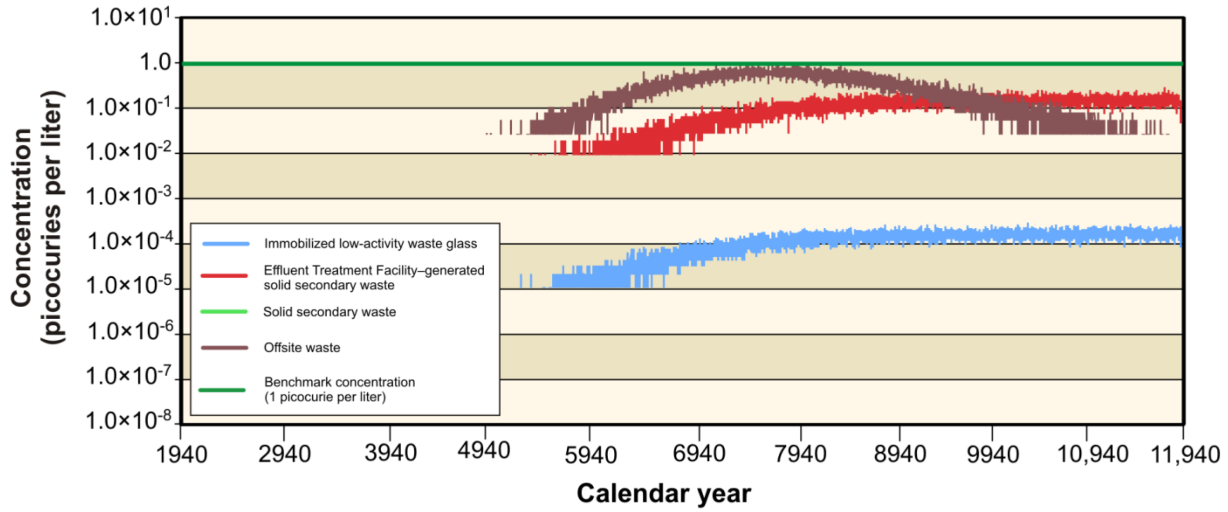
7.5.2.5 Sensitivity Analysis: Iodine Recycle

The purpose of this sensitivity analysis was to evaluate the effect on predicted long-term groundwater impacts if treatment technologies were able to increase the amount of iodine-129 captured in ILAW glass waste forms instead of grouted secondary-waste forms. Under Tank Closure Alternative 2B, this *Final TC & WM EIS* assumes that iodine-129 would partition as 20 percent in ILAW glass and 80 percent in grouted secondary-waste forms. A portion of these results is summarized in this section, and additional details and analysis can be found in Appendix M, Section M.5.7.2. As a basis for the iodine-recycle analysis, the following parameters were defined:

- Partitioning of iodine-129 would increase to 70 percent in ILAW glass and decrease to 30 percent in grouted secondary waste, representing more capture of iodine-129 in primary-waste forms.
- Iodine-129 was modeled with a background IDF-East infiltration rate of 0.9 millimeters per year.

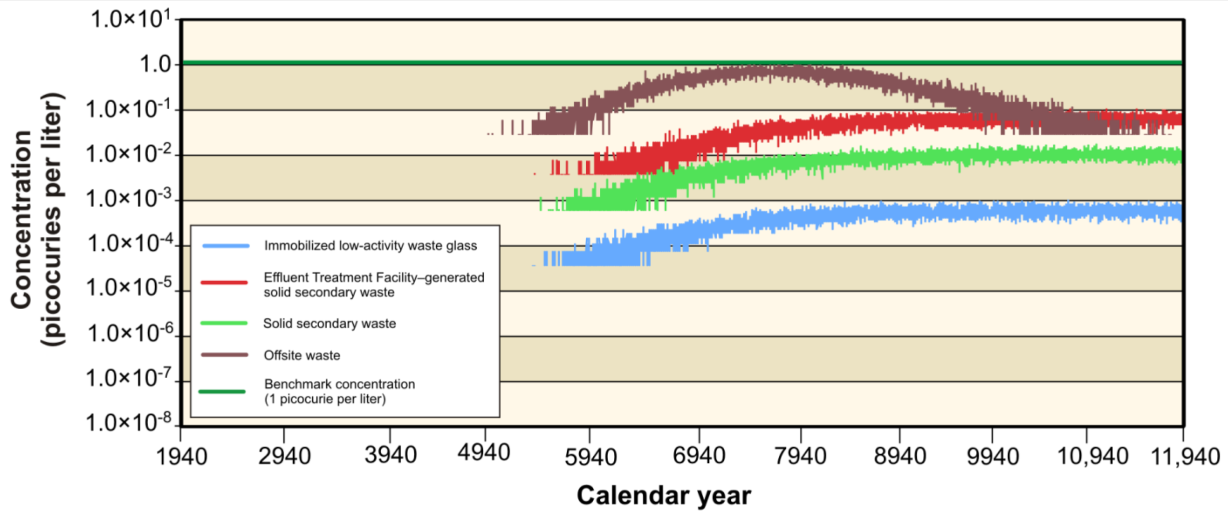
Figure 7–13 illustrates the predicted concentration for each contributing source of iodine-129 at the Core Zone Boundary, assuming that 20 percent of iodine-129 is captured in ILAW glass and 80 percent is captured in grouted secondary-waste forms (i.e., the EIS case). Offsite waste is the largest contributor to long-term groundwater impacts; ETF-generated secondary waste and solid secondary waste are the next-largest contributors, respectively. (Restriction of offsite waste as a potential mitigation measure is discussed in Section 7.5.2.2.) In this case, the grouted, ETF-generated secondary-waste contribution at the Core Zone Boundary is almost 1,000 times the secondary-waste contribution of WTP ILAW glass. Figure 7–14 illustrates the predicted concentrations for each contributing source at the Core Zone Boundary if less iodine-129 (30 percent) were captured in grouted ETF-generated and solid secondary-waste forms (i.e., the iodine recycle sensitivity case). In this second case, where more iodine-129 would be recycled and captured in the primary-waste form ILAW glass (70 percent), the predicted contribution from grouted ETF-generated and solid secondary waste decreases and the predicted contribution from ILAW glass increases accordingly. However, the grouted ETF-generated secondary-waste contribution at the Core Zone Boundary is still approximately 100 times that for WTP ILAW glass. Because grouted secondary-waste forms are the key drivers of long-term groundwater impacts, this reduction would have a significant beneficial effect on the overall predicted concentrations of iodine-129 at receptor locations.

The results indicate that iodine recycle, or an increase in the percentage capture of iodine-129 in the primary-waste form ILAW glass instead of grouted secondary-waste forms, would be an effective mitigation technique in reducing long-term groundwater impacts. However, iodine-129 is very volatile, and achieving greater partitioning of iodine-129 in ILAW glass, which involves a thermal treatment process, may be technologically challenging. Despite this challenge, the data suggest that even incremental increases in the capture of iodine-129 in ILAW glass could have an appreciable mitigating effect on long-term groundwater impacts.



Note: Groundwater concentrations modeled at the Core Zone Boundary.

Figure 7–13. Waste Management Alternative 2, Tank Closure Alternative 2B, Groundwater Iodine-129 Concentrations at the Core Zone Boundary, *TC & WM EIS* Case



Note: Groundwater concentrations modeled at the Core Zone Boundary.

Figure 7–14. Waste Management Alternative 2, Tank Closure Alternative 2B, Groundwater Iodine-129 Concentrations at the Core Zone Boundary, Iodine Recycle Sensitivity Case

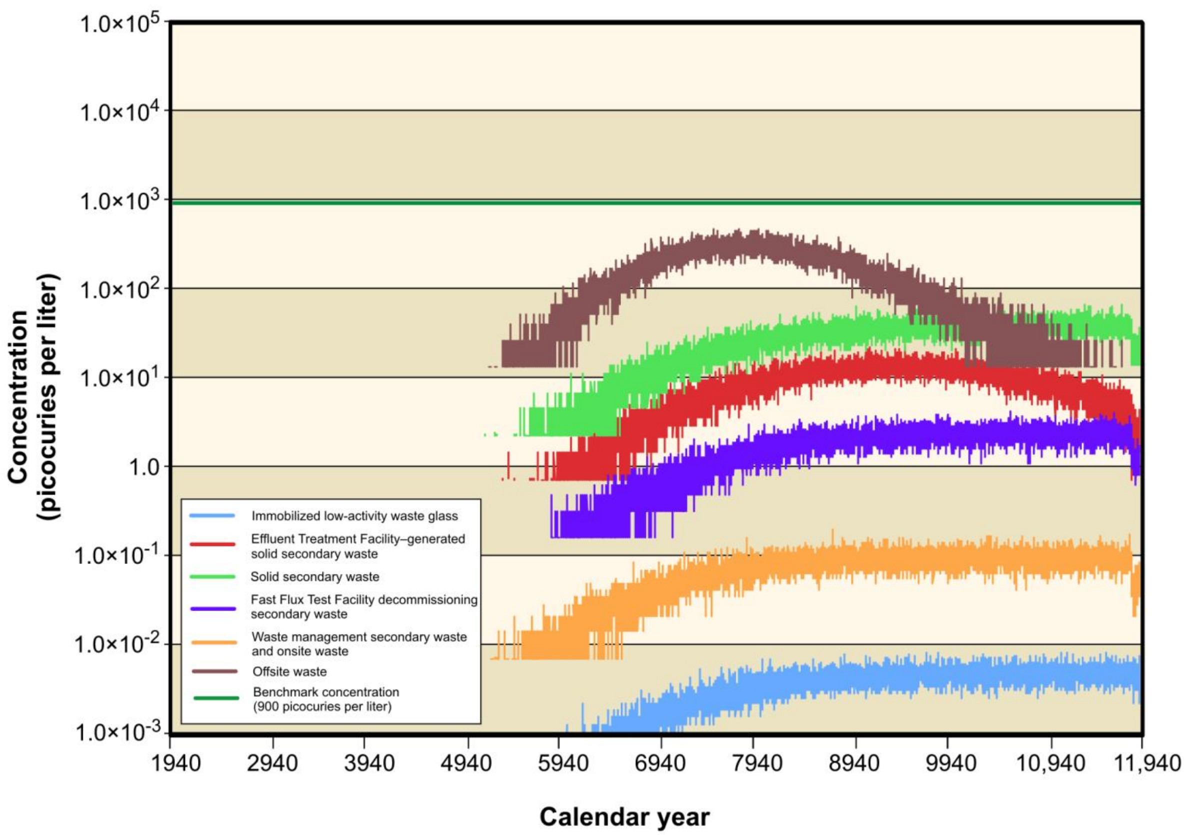
7.5.2.6 Sensitivity Analysis: No Technetium-99 Removal

The purpose of this sensitivity analysis was to evaluate the effect on predicted long-term groundwater impacts if technetium-99 were not selectively removed and partitioned in IHLW glass, which would be disposed of off site. This *Final TC & WM EIS* assumes that, under Tank Closure Alternative 2B, technetium-99 would be selectively removed from the LAW stream as a pretreatment step to WTP treatment and captured in IHLW glass. In this case, approximately 29,000 curies would be partitioned in IHLW glass; approximately 288 curies, in ILAW glass; and approximately 578 curies, in grouted secondary-waste forms. A portion of the results are summarized in this section, and additional details and analysis can be found in Appendix M, Section M.5.7.3. As a basis for the no-technetium-removal analysis, the following parameters were defined:

- Partitioning of technetium-99 would decrease to 247 curies in IHLW glass, increase to 28,800 curies in ILAW glass, and decrease to 517 curies in grouted secondary-waste forms. Sites analyzed included waste sources associated with Tank Closure Alternative 2B.

- Technetium-99 was modeled with a background IDF-East infiltration rate of 0.9 millimeters per year.

Figure 7–15 illustrates the predicted concentration of technetium-99 for each contributing source at the Core Zone Boundary assuming its selective removal and partitioning in IHLW glass. After offsite waste, grouted secondary-waste forms are the next-largest contributors to long-term groundwater impacts, as was predicted for iodine-129; however, the two types are reversed. This is due to the inventory of technetium-99 associated with solid secondary waste from WTP melter operations and spent resins. Figure 7–16 illustrates the predicted concentrations at the Core Zone Boundary without selective technetium-99 removal. In this second case, where more technetium-99 would be partitioned in ILAW glass and disposed of in an IDF, the predicted contribution from grouted ETF-generated and solid secondary waste slightly decreases and the predicted contribution from ILAW glass increases significantly. The slight reduction in technetium-99 in grouted secondary-waste forms appears to have a very small impact on overall predicted concentrations of technetium-99 at receptor locations and is somewhat offset by the significant increase in technetium-99 inventory that would be disposed of in an IDF as ILAW glass.



Note: Groundwater concentrations modeled at the Core Zone Boundary.

Figure 7–15. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Groundwater Technetium-99 Concentrations at the Core Zone Boundary

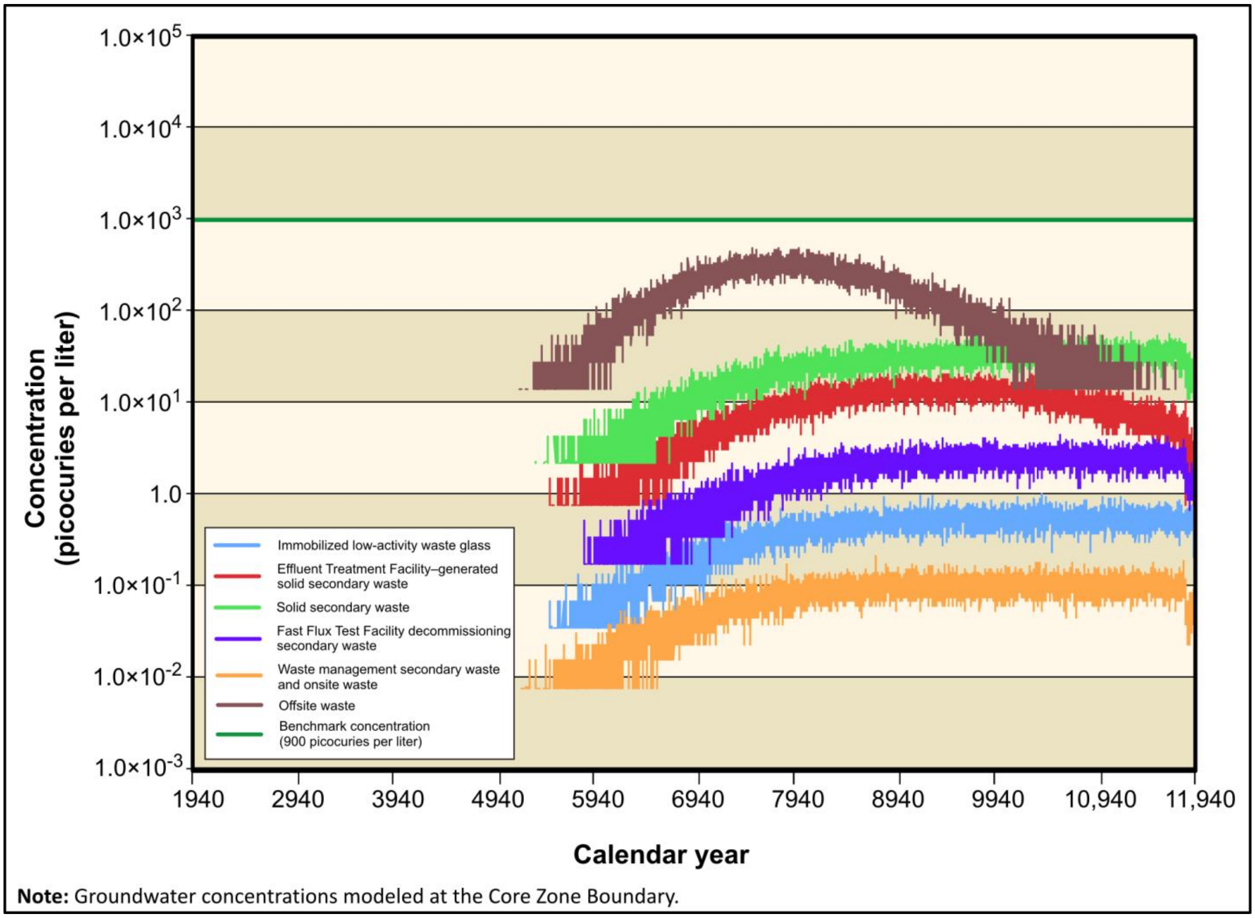


Figure 7–16. Groundwater Technetium-99 Concentration at the Core Zone Boundary, No-Technetium-99-Removal Case

The results suggest that selectively removing technetium-99 from the ILAW stream and partitioning it in IHLW glass has a limited overall effect on long-term groundwater impacts. This can be attributed to the determination that grouted secondary-waste forms (i.e., ETF-generated secondary waste and solid secondary waste) are still major contributors to long-term groundwater impacts. Selective removal of technetium-99 would not significantly alter the combined inventory that is partitioned in these waste forms. Therefore, data suggest that selectively removing technetium-99 from the ILAW stream and partitioning it into IHLW glass is not an effective strategy for mitigating long-term groundwater impacts. However, the data also suggest that a strategy to reduce the amount of technetium-99 found in all types of grouted secondary-waste forms could be effective in reducing long-term groundwater impacts, similar to the discussion for the iodine-129 recycle sensitivity analysis. Since ILAW glass is assumed to be a much better performing waste form than those generated from supplemental treatment technologies, it could be anticipated that, if supplemental treatment under Tank Closure Alternatives 3A, 3B, or 3C were pursued, selectively removing technetium-99 from supplemental treatment waste streams and incorporating it into IHLW or ILAW glass might yield more-positive results.

7.5.2.7 Sensitivity Analysis: Tank Waste Retrieval Losses

The purpose of this sensitivity analysis was to evaluate the relative predicted contributions of tank waste retrieval losses on long-term groundwater impacts compared with those from other sources after in situ tank closure (e.g., grouted ancillary equipment and tank residuals). This *Final TC & WM EIS* assumes retrieval losses of 15,142 liters (4,000 gallons) would occur from each SST, and the amount lost during retrieval operations would be approximately 25 percent of the original tank waste concentration. Both of these assumptions are perceived as conservative. Additional details and analysis can be found in Appendix M, Section M.5.6. As a basis for the tank waste retrieval loss sensitivity analysis, the following parameters were defined:

- Tank Closure Alternative 2B tank farm sources were evaluated, including retrieval losses, ancillary equipment, and tank residuals.
- Retrieval losses were assumed to be 15,142 liters (4,000 gallons), equal to 25 percent of original tank waste concentrations.
- Ancillary equipment and tank residuals would be grouted. The grouted waste forms would fail in 500 years, releasing their inventories of COPCs.
- Technetium-99 was modeled.

Tank waste retrieval losses are those leaks that could occur during tank waste retrieval operations; some tank waste retrieval technologies could result in more or less losses than other technologies, depending on the nature and aggressiveness of the technology during deployment (e.g., the amount of tank waste disturbance). Ancillary equipment includes subsurface piping to and from the tank farms systems, miscellaneous underground storage tanks, pump pits, diversion boxes, valve pits, and other miscellaneous facilities (see Appendix E, Section E.1.2.5.2) that would be grouted in place. Tank residuals are the 0.1, 1, or 10 percent residual tank waste that would remain in the tanks, depending on whether 99.9, 99, or 90 percent tank waste removal was selected by DOE. The peak release of COPCs from tank waste retrieval losses (i.e., 15,142 liters [4,000 gallons]) to the vadose zone is predicted to be at least one order of magnitude higher than those for other tank farm sources, although the releases from other tank farm sources would occur for a short period of time. Tank waste retrieval losses would occur during tank closure operations. Grouted waste forms for ancillary equipment and tank residuals would fail after 500 years, releasing their inventories of COPCs.

Figures 7–17 and 7–18 illustrate the predicted concentration of technetium-99 at the Core Zone Boundary and the Columbia River with and without the contribution of retrieval losses, respectively. Comparison of these concentration plots suggests that retrieval losses are not a major contributor to long-term groundwater impacts. The analysis also suggests that the amount of waste retrieved for treatment is important, regardless of whether retrieval losses occur. Mitigation strategies would include those that have the potential for reducing tank waste retrieval losses and could include using less-aggressive retrieval methods or developing and selecting more-effective retrieval technologies. As discussed previously, there is uncertainty associated with the assumption that 15,142 liters (4,000 gallons) of tank waste would leak during retrieval operations or that the concentration of COPCs that would be contained in these losses would have long-term groundwater impacts. It is possible that, during retrieval operations, less than 15,142 liters (4,000 gallons) of liquid would be released to the vadose zone.

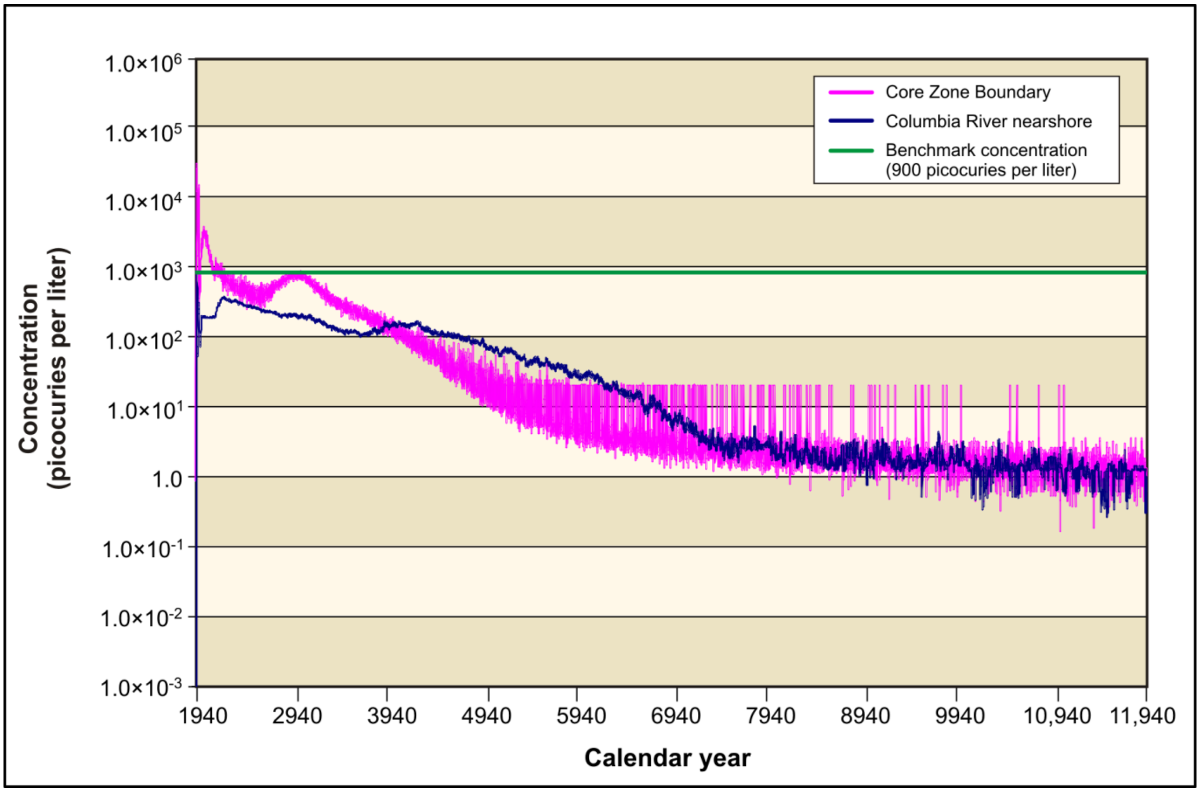


Figure 7–17. Tank Closure Alternative 2B Groundwater Technetium-99 Concentration at the Core Zone Boundary and the Columbia River, Retrieval Loss Sensitivity Case

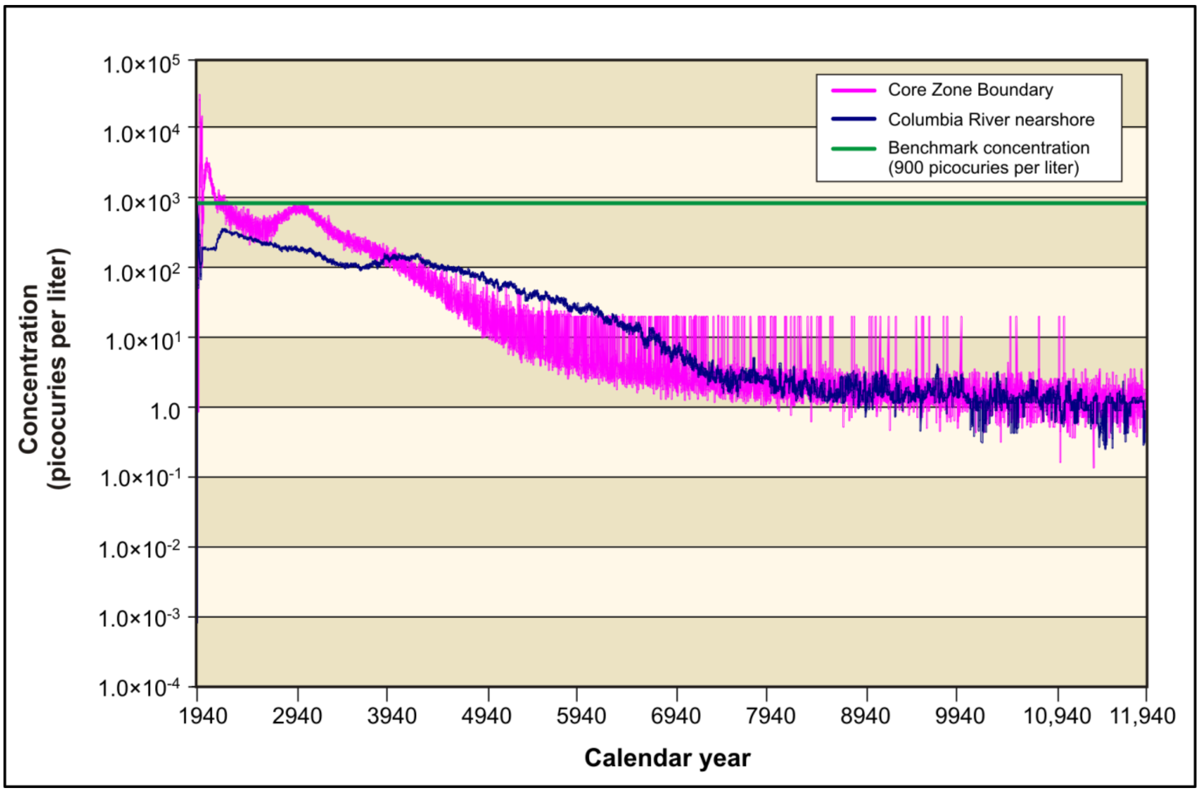


Figure 7–18. Tank Closure Alternative 2B Groundwater Technetium-99 Concentration at the Core Zone Boundary and the Columbia River, No-Retrieval-Losses Sensitivity Case

7.5.2.8 Sensitivity Analysis: Waste Form Performance

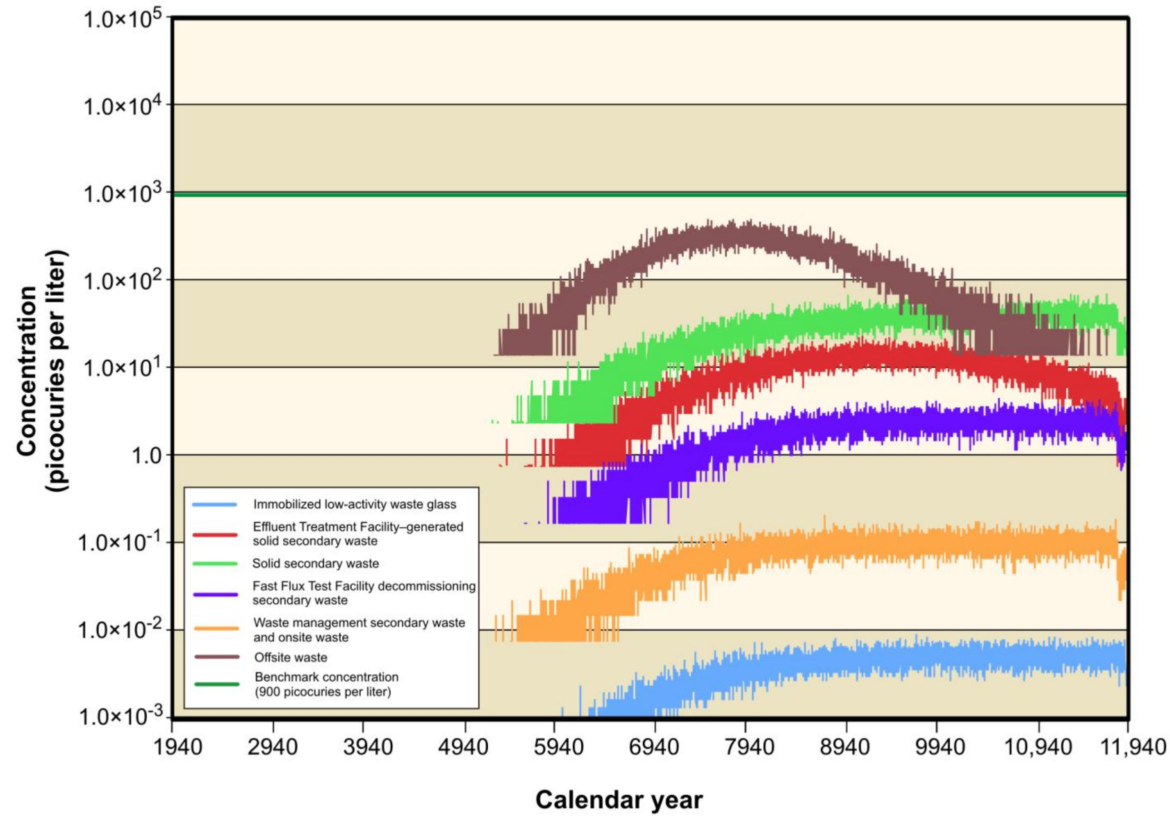
Under the Waste Management action alternatives, where an IDF would be constructed and operated in the 200-East and/or 200-West Areas, COPCs that would leach from the IDF(s) would result in the majority of long-term groundwater impacts when compared with other *TC & WM EIS* sources (i.e., the Tank Closure and FFTF Decommissioning action alternatives). As such, the performance of waste forms that would be disposed of in an IDF becomes very important when predicting long-term groundwater impacts. WTP ILAW glass, onsite non-CERCLA waste, offsite waste, FFTF closure waste, secondary waste, and, potentially, supplemental treatment waste would be disposed of in an IDF. As discussed in Section 7.5.2.5 and shown in Figures 7–13 and 7–14, offsite waste is predicted to be the largest contributor to long-term groundwater impacts for sources disposed of in an IDF, followed by grouted waste forms. As previously discussed in Section 7.5.2.2, this *Final TC & WM EIS* analysis assumes that offsite waste would be disposed of in an IDF as it is received, with no pretreatment or additional stabilization steps taken. In the evaluation of long-term groundwater impacts of an IDF, the remaining waste forms that can be considered are from onsite sources. As has been discussed, there is a level of uncertainty regarding waste form performance in an IDF. There are very limited data to support long-term performance assessments for some of the waste forms analyzed in this EIS, particularly those associated with the supplemental treatment technologies, bulk vitrification, and steam reforming, as analyzed under Tank Closure Alternatives 3B and 3C. Bulk vitrification waste forms are discussed in more detail in Appendix M, Section M.5.7.4. Steam reforming waste forms are discussed in more detail in Appendix M, Section M.5.5. The sensitivity analyses discussed below address four specific areas of waste form performance: ILAW glass from WTP treatment, bulk vitrification glass from supplemental treatment under Tank Closure Alternative 3A, steam reforming waste from supplemental treatment under Tank Closure Alternative 3C, and grouted waste.

ILAW Glass Waste Form Performance

The purpose of this sensitivity analysis was to determine the effect if the ILAW glass primary-waste form from the WTP performed better or worse than expected in an IDF. The performance of ILAW glass assumes a fractional release model for COPCs. A portion of the results are summarized in this section, and additional details and analysis can be found in Appendix M, Section M.5.7.1. As a basis for the ILAW glass waste form performance sensitivity analysis, the following parameters were defined:

- The IDF-East configuration was assumed to be consistent with Tank Closure Alternative 2B, Waste Management Alternative 2.
- The performance of ILAW glass was evaluated and compared, assuming three different fractional release rates: (1) 2.80×10^{-8} grams per gram per year (i.e., the EIS case); (2) 2.80×10^{-7} grams per gram per year, representing a decrease in waste form performance; and (3) 2.80×10^{-9} grams per gram per year, representing an improvement in waste form performance.
- Technetium-99 was modeled with a background IDF-East infiltration rate of 0.9 millimeters per year.

Figure 7–19 illustrates the predicted concentration of technetium-99 at the Core Zone Boundary for individual waste forms that might be disposed of in an IDF under Tank Closure Alternative 2B for the EIS case (e.g., fractional release equivalent to 2.80×10^{-8} grams per gram per year). Of several contributors, ILAW glass contributes the least to long-term groundwater impacts. For the sensitivity cases, where the fractional release of COPCs increases or decreases by an order of magnitude, the contribution from ILAW glass likewise increases or decreases one order of magnitude accordingly. However, even for the sensitivity case where ILAW glass performance decreases by an order of magnitude, it is predicted that ILAW glass would still contribute the least to groundwater impacts. Since the contribution from ILAW glass represents only a small fraction of the cumulative long-term groundwater impacts, improvements in the performance of this primary-waste form would not likely yield any observable reductions in concentrations of COPCs at the Core Zone Boundary or the Columbia River.



Note: Groundwater concentrations modeled at the Core Zone Boundary.

Figure 7–19. Tank Closure Alternative 2B Groundwater Technetium-99 Concentration at the Core Zone Boundary

<u>Bulk Vitrification Waste Glass Performance</u>

The purpose of this sensitivity analysis was to determine the effect if the bulk vitrification supplemental treatment process could be improved. The performance of bulk vitrification glass assumes a fractional release model for COPCs in the primary-waste form and a convection-limited release for the castable refractory block. Furthermore, the EIS analysis assumes that COPCs will partition between the primary-waste form and the castable refractory block. The castable refractory block is a thermal insulating layer that envelops the primary-waste form along the edges of the bulk vitrification container. As discussed in Appendix E, Section E.1.2.3.6.5, there is uncertainty regarding the amount of COPCs that will partition between the primary-waste form and the castable refractory block. This sensitivity analysis evaluates improvement in the fractional release of the primary-waste form and improvement in the partitioning of COPCs. A portion of the results are summarized in this section, and additional details and analysis can be found in Appendix M, Section M.5.7.4. As a basis for this sensitivity analysis, the following parameters were defined:

- The IDF-East configuration was assumed to be consistent with Tank Closure Alternative 3A, Waste Management Alternative 2.

- The performance of bulk vitrification glass was evaluated and compared, assuming a higher percentage of COPCs is captured in the primary-waste form: (1) 93.5 percent in bulk vitrification glass and 6.5 percent in the castable refractory block (i.e., the EIS case), and (2) 99.7 percent in bulk vitrification glass and 0.3 percent in the castable refractory block (i.e., the sensitivity case).
- The performance of bulk vitrification glass was evaluated and compared, assuming a lower fractional release rate from the primary-waste form: (1) 1.00×10^{-8} grams per gram per year (i.e., the EIS case), and (2) 1.00×10^{-9} grams per gram per year (i.e., the sensitivity case, which assumes better-performing waste forms).
- Technetium-99 was modeled with a background IDF-East infiltration rate of 0.9 millimeters per year.

Figure 7–20 illustrates the predicted concentration of technetium-99 at the Core Zone Boundary for individual waste forms that might be disposed of in an IDF under Tank Closure Alternative 3A for the EIS case (i.e., 93.5 percent partitioned in bulk vitrification glass and a fractional release equivalent to 1.00×10^{-8} grams per gram per year). The two largest contributors are offsite waste and bulk vitrification glass. (Note: "Bulk vitrification glass," as shown in the figures, includes the contribution to impacts from both the bulk vitrification primary-waste form and the castable refractory block added together.) Figure 7–21 illustrates the predicted concentration if more technetium-99 is partitioned in the primary waste (e.g., increase to 99.7 percent from 93.5 percent) and less in the castable refractory block (e.g., decrease to 0.3 percent from 6.5 percent). The results suggest that an increase in the amount of technetium-99 partitioned in the primary-waste form yields a corresponding reduction in the contribution to impacts from bulk vitrification glass. The sensitivity case predicts that the contribution to impacts from bulk vitrification glass would decrease to the level of other grouted secondary-waste forms and would no longer contribute as much as offsite waste.

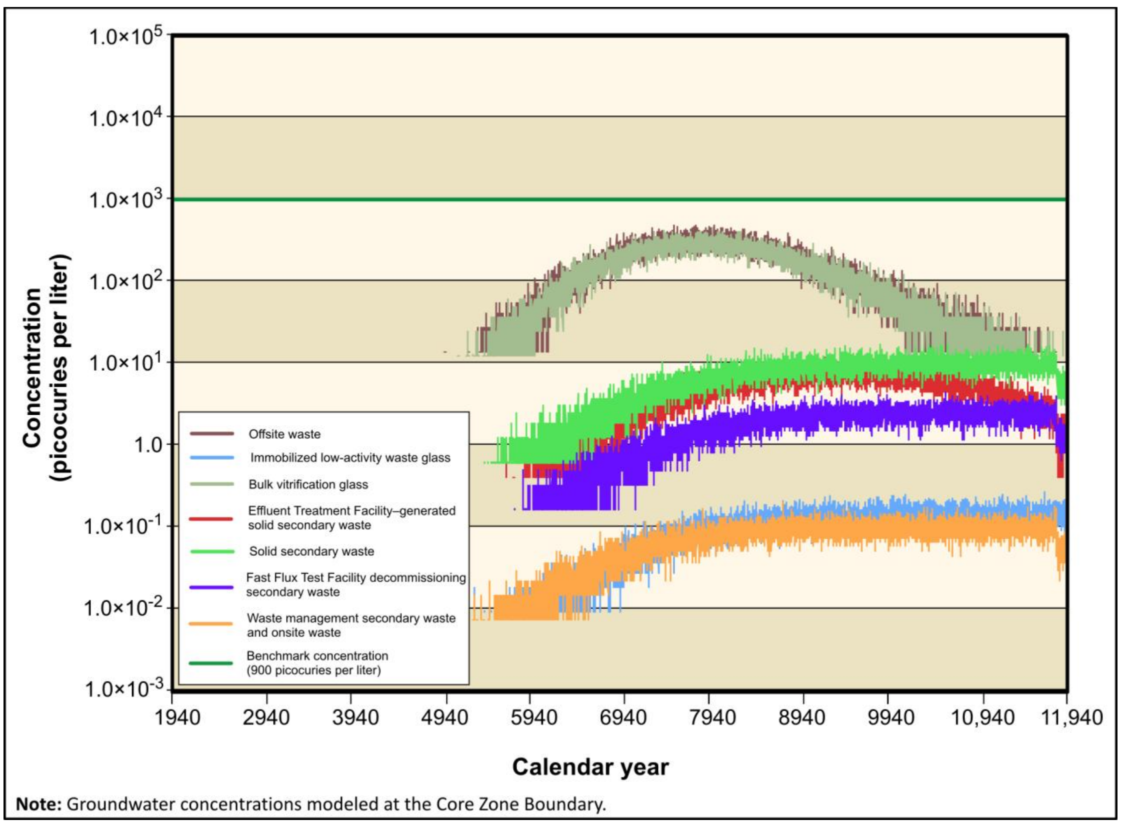


Figure 7–20. Groundwater Technetium-99 Concentrations at the Core Zone Boundary, Bulk Vitrification EIS Case

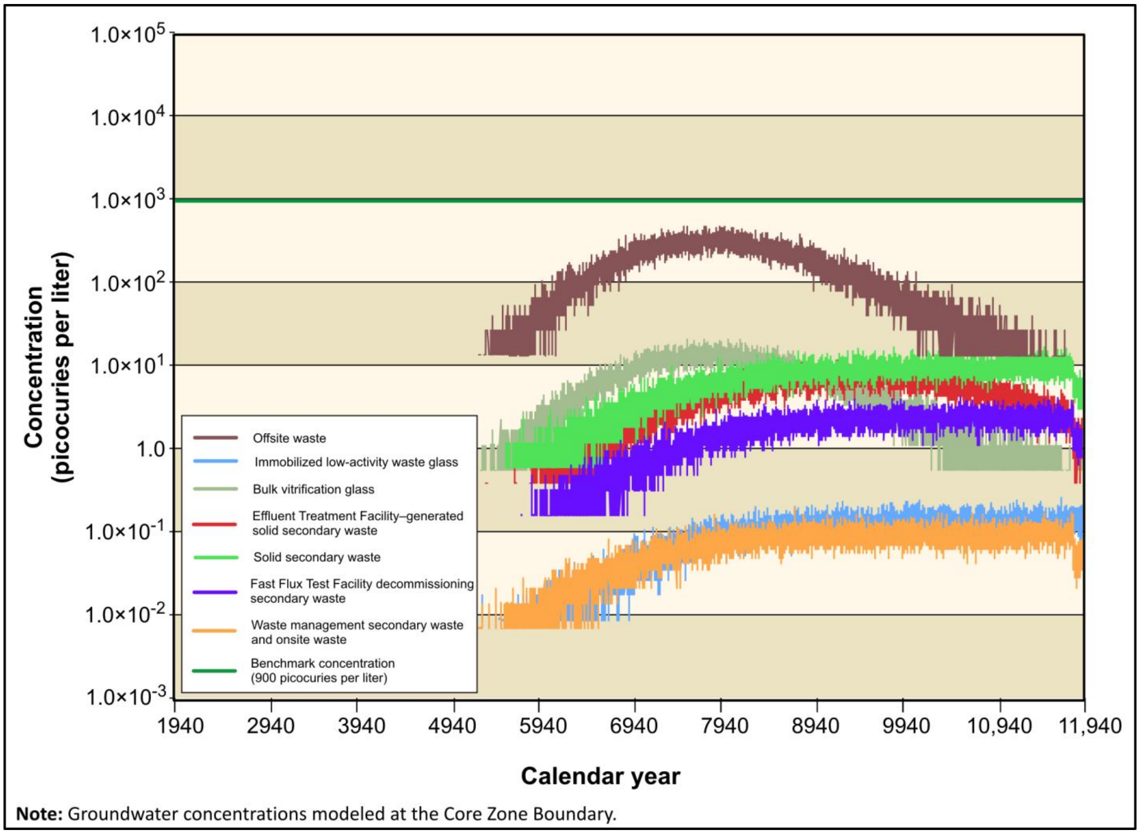
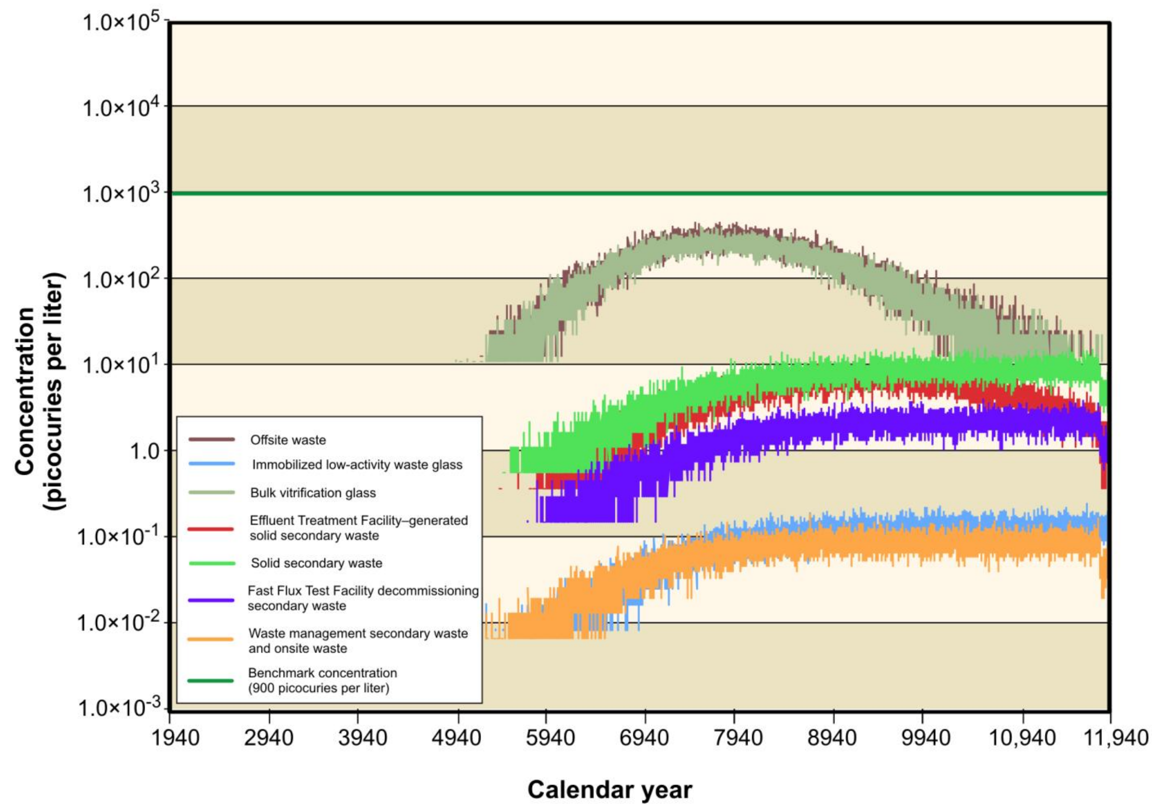


Figure 7–21. Groundwater Technetium-99 Concentrations at the Core Zone Boundary, Bulk Vitrification Sensitivity Case 1

Figure 7–22 illustrates the predicted concentration of technetium-99 at the Core Zone Boundary for the sensitivity case where the release rate of the primary-waste form for bulk vitrification is reduced by an order of magnitude. Unlike the ILAW glass sensitivity case analyzed and discussed above, there does not appear to be a corresponding reduction in the predicted contribution to impacts when comparing these results with the EIS case shown in Figure 7–20. The reason for an apparent lack of response to the groundwater system is that bulk vitrification glass consists of two components: the primary-waste form and the castable refractory block. The castable refractory block, which is modeled assuming a convective release of COPCs, contributes more than the primary-waste form to long-term groundwater impacts for bulk vitrification glass; therefore, changes to the fractional release of the primary-waste form have an imperceptible effect on the predicted concentrations for bulk vitrification glass as a whole.

The sensitivity analysis of bulk vitrification waste glass performance suggests that mitigation measures designed either to increase the partitioning of COPCs in the primary-waste form or to improve the release mechanisms in the castable refractory block could reduce the predicted concentrations in groundwater. However, there is a high degree of uncertainty associated with how COPCs partition between bulk vitrification components or which release mechanisms prevail for the castable refractory block. The data also suggest that, because the castable refractory block is the largest contributor to impacts from bulk vitrification glass, a reduction in the fractional release rate of the primary-waste form would not likely result in noticeable improvements in groundwater concentrations.



Note: Groundwater concentrations modeled at the Core Zone Boundary.

Figure 7–22. Groundwater Technetium-99 Concentrations at the Core Zone Boundary, Bulk Vitrification Sensitivity Case 2

<u>Steam Reforming Waste Performance</u>

The purpose of this sensitivity analysis was to determine the effect of variation in the release model concept on the estimates of rate of release from steam reforming waste. A fluidized-bed steam reformer contacts a waste stream containing organics, nitrates, and dissolved solids with a carbonaceous or clay co-reactant in a reducing steam environment to produce a mineralized waste form product (i.e., steam reforming waste). Depending on the fluidized-bed steam reforming operating conditions and the nature of the co-reactant, the solid product may adopt amorphous, glassy, or crystalline structures exhibiting a range of matrix solubility and constituent retention properties. Release models considered in this *TC & WM EIS* include a reactant (water)-limited release model supported by surface-reaction-rate data and a chemical reaction equilibrium–limited release model (i.e., solubility-limited release model) based on certain assumptions. Preliminary test data suggest that the primary matrix of the fluidized-bed steam reforming product is nepheline, an aluminosilicate mineral. A summary of results is provided in this section, and additional details and analysis can be found in Appendix M, Section M.5.5. As a basis for the steam reforming waste sensitivity analysis, the following conditions were defined:

- The IDF-East configuration was assumed to be consistent with Tank Closure Alternative 3C and Waste Management Alternative 2.

- The rate of release of steam reforming waste was evaluated and compared for three solubility cases for nepheline: (1) 2.01×10^6 grams per cubic meter based on the reactant-limited release model; (2) 1.75×10^5 grams per cubic meter (i.e., the EIS case), representing an upper limit based on the chemical reaction equilibrium–limited release model; and (3) 220 grams per cubic meter, representing a lower limit based on the chemical reaction equilibrium–limited release model.

- Technetium-99 was modeled.

Consistent with the values of solubility, the peak release rate to the vadose zone for the reactant-limited release model is a factor of approximately 10 higher than that for the EIS case, the upper-limit chemical reaction equilibrium–limited release model. The peak release rate to the vadose zone for the lower-limit solubility case is a factor of approximately 1,000 lower than that for the EIS case. Model evaluation in this final EIS requires knowledge of product particle and alteration-product structure, as well as parameters such as mass transfer coefficients and effective diffusivities, which have not been investigated for the current fluidized-bed steam reforming waste forms; therefore, some uncertainty exists regarding waste form performance for steam reforming waste under disposal conditions.

Grouted Waste Performance

The purpose of this sensitivity analysis was to determine the effect if grouted waste forms performed better. Grouted waste forms may include ETF-generated secondary waste, solid secondary waste, FFTF decommissioning or waste management secondary waste, onsite non-CERCLA waste, and cast stone from supplemental treatment under Tank Closure Alternative 3B. A portion of the results are summarized in this section, and additional details and analysis can be found in Appendix M, Section M.5.7.5. As a basis for this analysis, the following parameters were defined:

- The IDF-East configuration was assumed to be consistent with Tank Closure Alternatives 2B, 3A, 3B, and 3C and Waste Management Alternative 2.

- The performance of grouted waste forms was evaluated and compared under two environmental conditions: (1) when the grouted waste form is saturated (i.e., the EIS case), and (2) when the moisture content is 7 percent (i.e., the grout sensitivity case). Effective diffusion coefficients depend on the soil moisture content in contact with the grouted waste forms.

- Iodine-129 was modeled with a background IDF-East infiltration rate of 0.9 millimeters per year.

Figure 7–23 illustrates the predicted concentration of iodine-129 at the Core Zone Boundary for individual waste forms that might be disposed of in IDF-East under Tank Closure Alternative 2B for the EIS case (i.e., saturated waste form). Offsite waste is the largest contributor to long-term groundwater impacts, followed by ETF-generated secondary waste, solid secondary waste, and ILAW glass. In this case, the grouted ETF-generated secondary-waste contribution at the Core Zone Boundary is almost 1,000 times that of ILAW glass, and the secondary-waste contribution of grouted solid secondary waste at the Core Zone Boundary is almost 100 times that of ILAW glass. Excluding offsite waste, this suggests that an increase or decrease in the performance of grouted secondary-waste forms would have a corresponding proportional effect on long-term groundwater impacts from onsite sources of waste disposed of in an IDF.

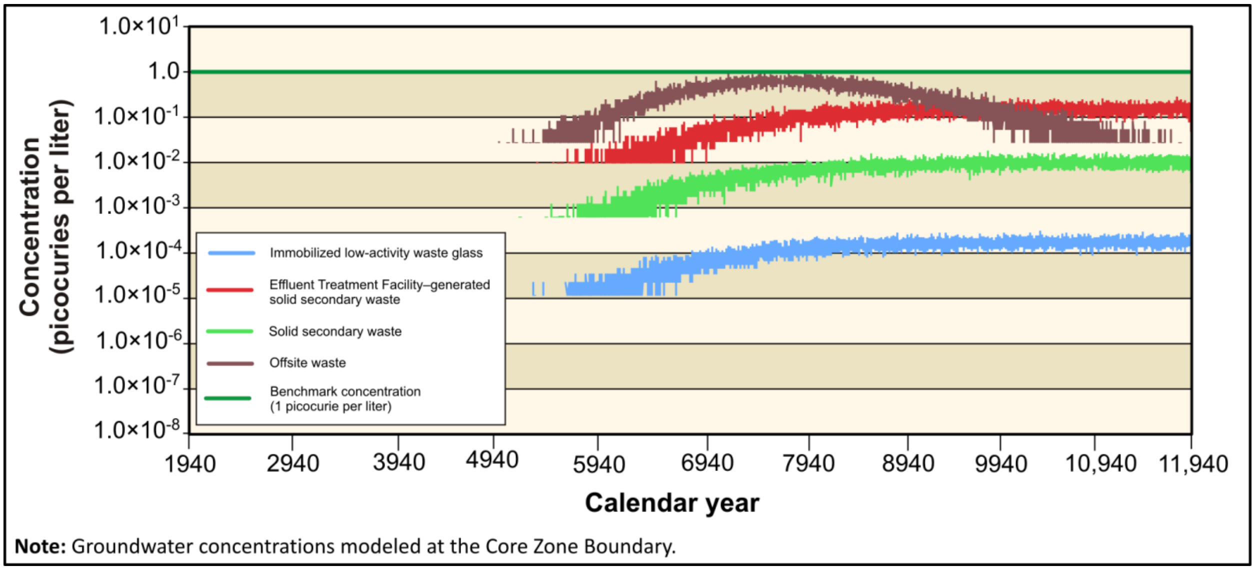


Figure 7–23. Waste Management Alternative 2, Tank Closure Alternative 2B, Groundwater Iodine-129 Concentrations at the Core Zone Boundary, EIS Performance Case

Data suggest that grout surrounded by soil with a lower moisture content would lead to a corresponding decrease in the diffusivity of concrete for grouted waste forms, and thus a better-performing waste form with slower release rates (Mattigod et al. 2001). Figure 7–24 reanalyzes the data for the grout sensitivity case (i.e., 7 percent moisture content). The results suggest that the sensitivity grout would perform substantially better—almost two orders of magnitude better for all grouted waste forms—and thus would likely lead to much lower concentrations in groundwater at the Core Zone Boundary for onsite sources of waste disposed of in an IDF. At an infiltration rate of 3.5 millimeters per year, lowering the diffusivity for grout by two orders of magnitude (i.e., from 1.00×10^{-10} to 1.00×10^{-12} square centimeters per second) would decrease the contribution of ETF-generated secondary waste by a factor of 100, thus deleting this waste from the list of dominant contributors to risk. Similar results were predicted for simulations under Tank Closure Alternatives 3A, 3B, and 3C, as discussed in Appendix M, Section M.5.7.5.

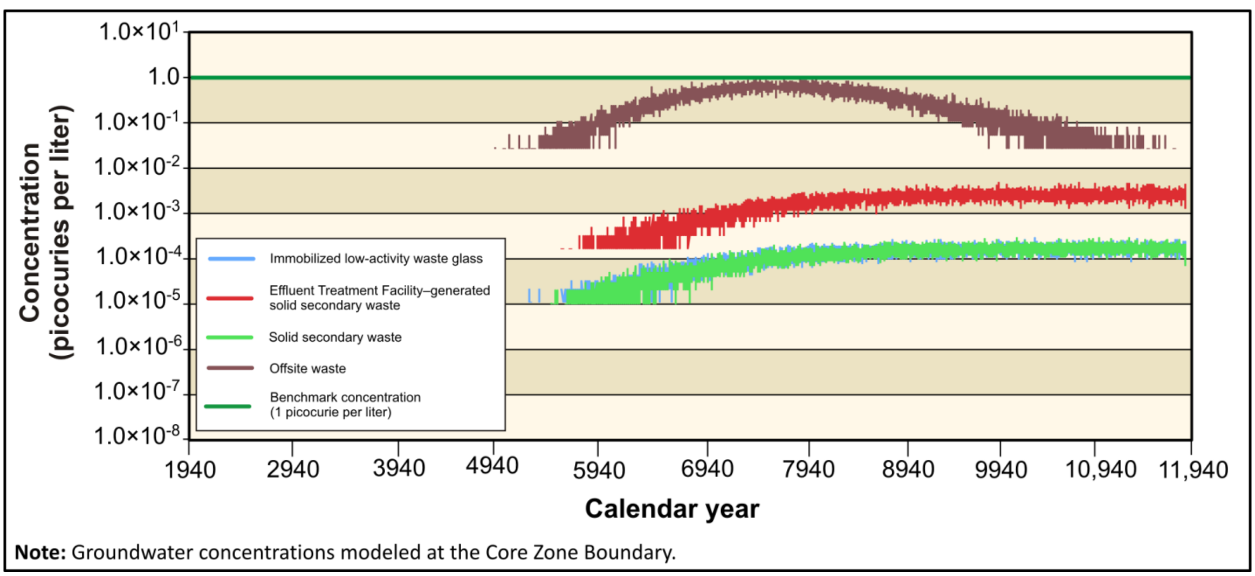


Figure 7–24. Waste Management Alternative 2, Tank Closure Alternative 2B, Groundwater Iodine-129 Concentrations at the Core Zone Boundary, Sensitivity Grout Case

Sensitivity Analysis: Waste Form Performance Conclusions

Mitigation strategies could involve the development of test methods for assessing the long-term performance of primary- and secondary-waste forms, thereby reducing the associated uncertainty. However, the data also suggest that a very promising mitigation measure would be to develop better-performing grout for the disposal of secondary waste in an IDF, which could lead to significant improvements in the overall performance of an IDF. As discussed above, when offsite waste is considered for disposal in an IDF, this waste stream becomes the largest contributor, even more so if the performance of grouted ETF-generated secondary waste is improved. However, the assumption for offsite waste is that it would be accepted for disposal because it would be received with no additional stabilization steps taken. Waste form performance for offsite waste would likewise be improved if it is grouted prior to disposal, therefore improving its long-term performance

Operation of an IDF would be permitted and regulated by the Washington State Department of Ecology. The permit is likely to contain specific performance-based stipulations (e.g., groundwater concentrations at a receptor location may not exceed a certain value). These permit conditions can be used to determine which waste form performance standards would be required to meet these conditions before accepting a supplemental-treatment-, secondary-, or offsite-waste form for disposal in an IDF.

DOE recognizes the importance of improving secondary-waste-form performance and has already taken steps to address this need. On July 21 through July 23, 2008, DOE held a workshop to identify the risks and uncertainties associated with treatment and disposal of secondary waste and to develop a roadmap for addressing those risks and uncertainties. Attending the workshop were representatives from DOE, the U.S. Environmental Protection Agency, the Washington State Department of Ecology, the Oregon State Department of Energy, and the U.S. Nuclear Regulatory Commission, as well as technical experts from DOE national laboratories, academia, and private industry. As a result of the individual contributions to the workshop, DOE published the *Hanford Site Secondary Waste Roadmap* in January 2009 (PNNL 2009). This secondary-waste roadmap includes elements addressing regulatory and performance requirements, waste composition, preliminary waste form screening, waste form development, process design and support, and validation. The regulatory and performance requirements activity will provide the secondary-waste-form performance requirements. The waste-composition activity will provide workable ranges of secondary-waste compositions and formulations for stimulants and surrogates. Preliminary waste form screening will identify candidate waste forms for immobilizing the secondary waste. The waste form development activity will mature the waste forms, leading to one or more selected waste forms and providing a defensible understanding of the long-term release rate and input into the critical decision process for a secondary-waste treatment process/facility. The process and design support activity will provide a reliable process flowsheet and input to support a robust facility design. The validation effort will confirm that the selected waste form meets regulatory requirements. Implementation of the secondary-waste roadmap will ensure compliant, effective, timely, and cost-effective disposal of the secondary waste (PNNL 2009).

Improvement in the performance of primary-waste forms may also reduce long-term groundwater impacts, although it is expected these improvements would be small and incremental compared with improvements in the performance of secondary-waste forms. The results of the sensitivity analysis for grouted secondary-waste forms where environmental conditions are drier (i.e., the grouted waste form is not saturated) indicate that significant improvements in grouted-waste-form performance might be achievable if these conditions could be controlled in some manner. However, improvements in primary-waste forms that would increase partitioning of COPCs in primary- rather than secondary-waste forms would lead to more-significant and proportional reductions in long-term groundwater impacts.

7.5.2.9 Sensitivity Analysis: Infiltration Rates

Another parameter that can significantly affect the fate and transport of COPCs is infiltration rates. The infiltration rate is the rate in which moisture moves vertically through the vadose zone. Background (i.e., natural) infiltration rates at Hanford have been a subject of debate. This *Final TC & WM EIS* relies on the *Technical Guidance Document for Tank Closure Environmental Impact Statement Vadose Zone and Groundwater Revised Analyses* (*Technical Guidance Document*) (DOE 2005) when defining infiltration rates in long-term groundwater modeling. The *Technical Guidance Document* specifies background infiltration rates of 0.9 millimeters per year for IDF-East and 3.5 millimeters per year for other Hanford sites. The *Technical Guidance Document* also specifies a range of 0.9 to 5.0 millimeters per year for analyzing sensitivity cases. Infiltration rates can be temporarily influenced by constructing barriers over waste sites. This *Final TC & WM EIS* assumes that an engineered barrier would temporarily depress the infiltration rate to 0.5 millimeters per year for its design life. An RCRA barrier has an assumed design life of 500 years before failure, whereas the Hanford barrier analyzed under Tank Closure Alternative 5 has an assumed design life of 1,000 years before failure. Because decisions must be made to support WTP operations and to close tank farms prior to knowing for certain what the long-term postclosure infiltration rate is, a sensitivity analysis was performed to show how this uncertainty should be viewed when establishing permit conditions associated with an IDF. The results are summarized in this section, and additional details and analysis can be found in Appendix N, Section N.5.9. As a basis for this sensitivity analysis, the following parameters were defined:

- Background infiltration rates for IDF-East were assumed to be 0.9, 1.75, 2.5, 3.5, 4.25, and 5.0 millimeters per year, representing the full range of sensitivity analysis. These infiltration rates apply to pre-Hanford (i.e., background) and post–barrier failure periods at IDF-East. Background infiltration rates were assumed to remain at 3.5 millimeters per year for all other sites at Hanford, including IDF-West under Waste Management Alternative 3. The EIS case assumes a background infiltration rate of 0.9 millimeters per year.
- The configuration of IDF-East was assumed to be consistent with Waste Management Alternative 2 under Tank Closure Alternatives 2B, 3A, 3B, and 3C.
- Technetium-99 was modeled.

Figures 7–25, 7–26, and 7–27 illustrate the predicted concentration of technetium-99 at the Core Zone Boundary for background infiltration rates at IDF-East of 0.9 millimeters per year, 3.5 millimeters per year, and 5.0 millimeters per year, respectively, under Tank Closure Alternative 2B. Each of these plots assumes infiltration of 0.5 millimeters per year until the RCRA barrier fails in approximately CY 2500. For a background infiltration rate of 0.9 millimeters per year (i.e., the EIS case), the concentrations of technetium-99 at the Core Zone Boundary and Columbia River approach, but do not exceed, benchmark standards. The peak occurs in approximately CY 7800. Increasing the background infiltration rate to 3.5 millimeters per year causes the predicted concentrations of technetium-99 to exceed benchmark standards at the Core Zone Boundary and to very nearly exceed technical standards at the Columbia River. The peak concentration occurs in approximately CY 4000, then decreases rapidly thereafter. Increasing the background infiltration rate to 5.0 millimeters per year causes the predicted concentrations of technetium-99 to exceed benchmark standards at both the Core Zone Boundary and the Columbia River. The peak concentration occurs in approximately CY 3800, then decreases rapidly thereafter. Additional figures illustrating the full range of sensitivity cases for background infiltration rates under Tank Closure Alternative 2B, as well as under Tank Closure Alternatives 3A, 3B, and 3C, are provided in Appendix N, Section N.5.9. Generally, similar observations could be made with regard to the results found for all Tank Closure alternatives analyzed. As infiltration rates increase, the peak occurs sooner and with greater magnitude. The tradeoff is that the concentrations at receptor locations would decrease more quickly beyond the peak year. A closer examination of other infiltration rates, as presented in Appendix N, Section N.5.9, suggests that concentrations of COPCs are most sensitive to changes in infiltration from 0.9 to approximately 2.0 millimeters per year, after which sensitivity to changes in infiltration rates are not as noticeable.

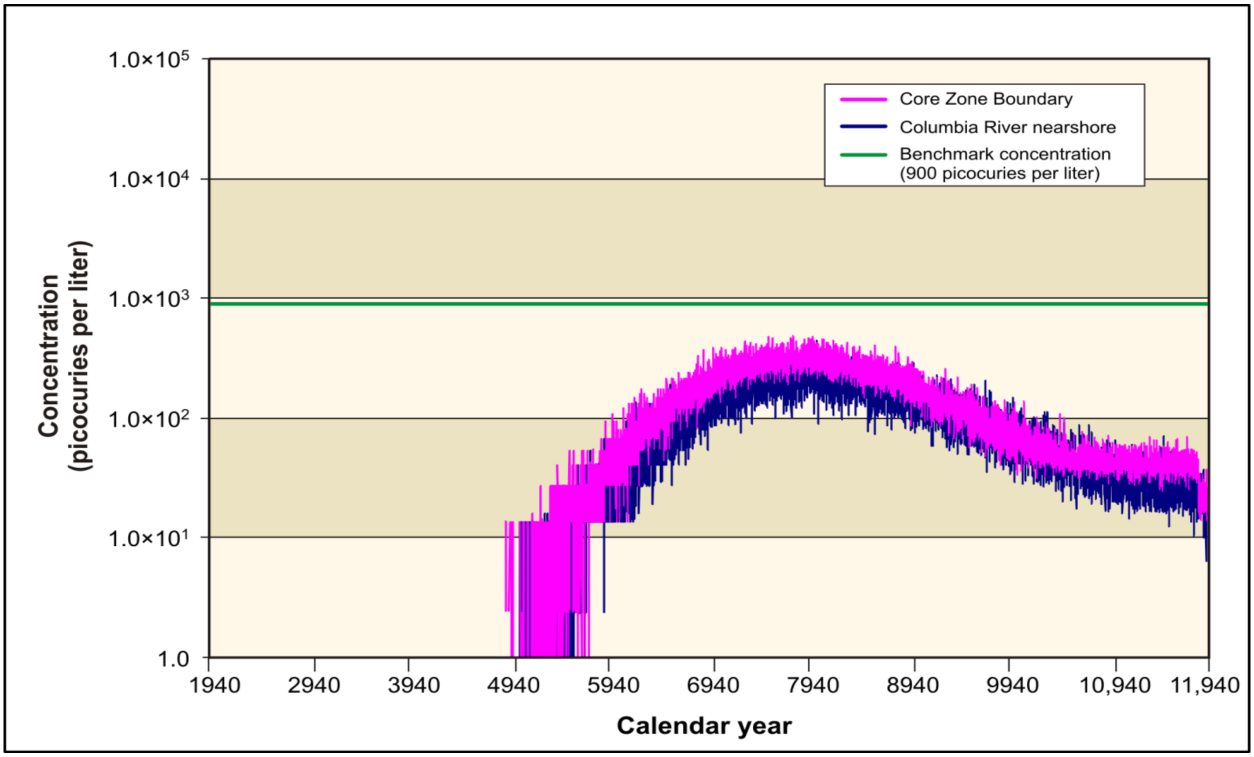


Figure 7–25. Waste Management Alternative 2, Tank Closure Alternative 2B, Groundwater Technetium-99 Concentrations at a Background Infiltration Rate of 0.9 Millimeters per Year

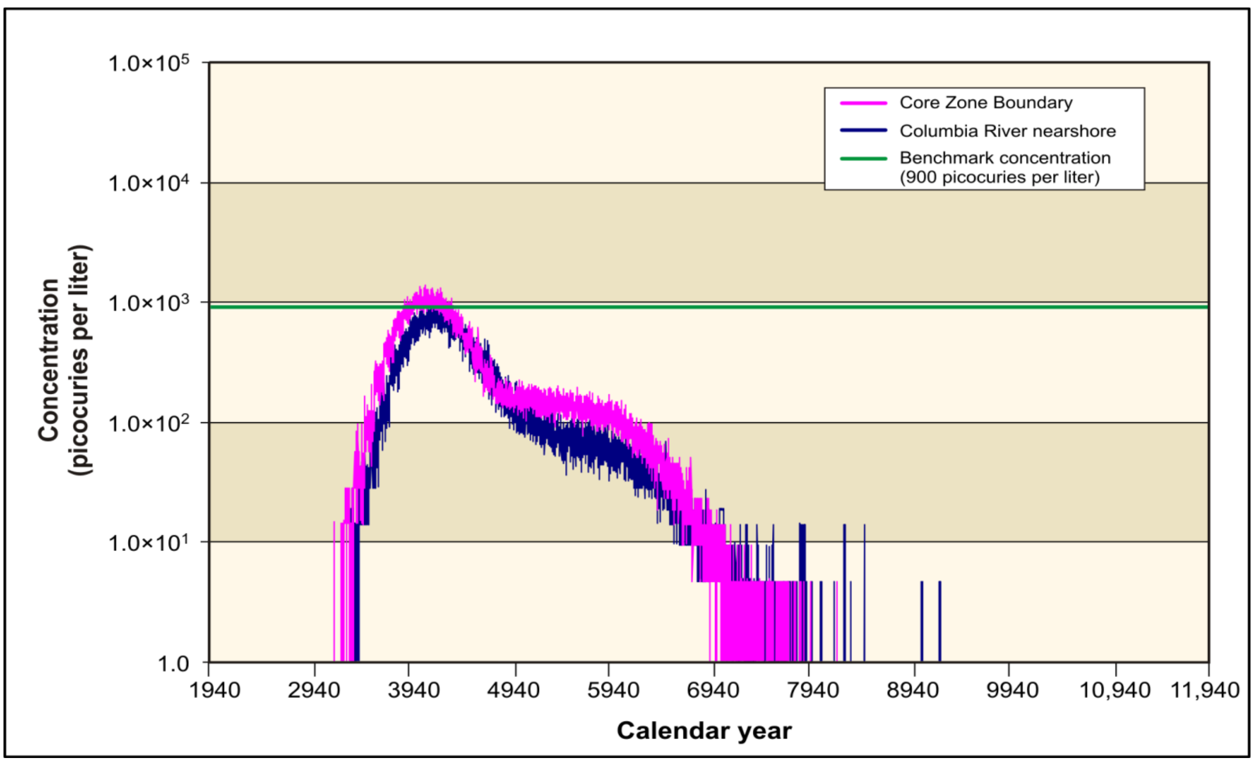


Figure 7–26. Waste Management Alternative 2, Tank Closure Alternative 2B, Groundwater Technetium-99 Concentrations at a Background Infiltration Rate of 3.5 Millimeters per Year

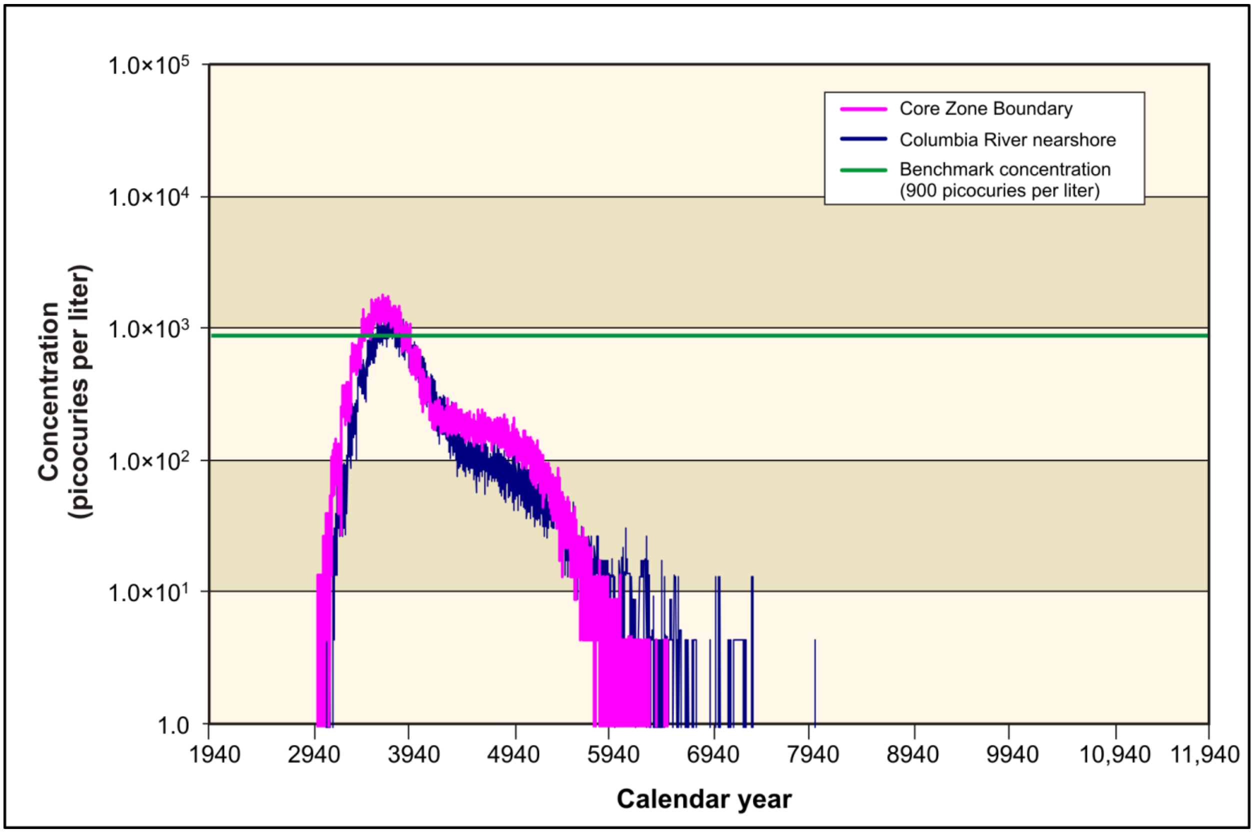


Figure 7–27. Waste Management Alternative 2, Tank Closure Alternative 2B, Groundwater Technetium-99 Concentrations at a Background Infiltration Rate of 5.0 Millimeters per Year

From a mitigation perspective, background infiltration is not a parameter that can be controlled. However, the range of infiltration rates associated with Hanford that is used in modeling might be narrowed with continued research and analysis. Additionally, as mentioned above, infiltration rates can be artificially influenced by the construction of engineered barriers that might last between 500 and 1,000 years before failure.

7.5.2.10 Sensitivity Analysis: Climate Change

The purpose of this sensitivity analysis is to evaluate the effect if the climate or natural environment were to change in a significant manner over time. This is worth considering given that long-term impacts on groundwater are considered over a 10,000-year period, where even small changes in the climate or natural environment could influence the groundwater system. As a basis for this analysis, the following parameters were defined:

- A 10-fold increase in regional rainfall was assumed, from 3.5 millimeters per year to 35 millimeters per year (i.e., background recharge sensitivity case).
- An increase of 10 meters (32.8 feet) head in surface-water flow from the west was assumed to simulate a sustained increase in mountain water runoff (i.e., Generalized Head Boundary sensitivity case).
- An increase of 5 meters (16.4 feet) head in the Columbia River was assumed (i.e., Columbia River recharge sensitivity case).

- Technetium-99 was modeled under Tank Closure Alternative 2B and Waste Management Alternative 2.

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 toward the north through the Gable Mountain–Gable Butte 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 within the context of the selected *TC & WM EIS* alternatives.

A detailed discussion and the results of this analysis can be found in Appendix V. From a mitigation perspective, this analysis does not directly lead to potential mitigation strategies; however, understanding how climate change might influence the behavior of the groundwater system in the future may lead to a change in the timing and aggressiveness of future mitigation planning.

7.5.3 Sensitivity Analyses Summary and Mitigation Strategies

The sensitivity analyses conducted for this *Final TC & WM EIS* are a few examples of the parameters that could be modeled to better understand the uncertainties associated with certain assumptions and what changes those assumptions might have on the predicted long-term impacts on groundwater. Table 7–28 provides the location in this *Final TC & WM EIS* where additional details can be found regarding each area of the sensitivity analyses summarized in this chapter. Such analyses may assist DOE in determining where to focus mitigation efforts that might yield the most benefit in reducing impacts. The overall purpose of conducting these sensitivity analyses is to understand the major impact drivers and the magnitude and timing of impacts.

Table 7–28. Locations of Details Regarding Sensitivity Analyses in This *Final TC & WM EIS*

Area of Sensitivity Analysis	Location
Flux reduction	Appendix U, Section U.1.3.4.1
Offsite-waste acceptance	Appendix M, Section M.5.7.6
Capture-and-removal scenario (200-West Area carbon tetrachloride plume)	Appendix U, Section U.1.3.4.2
Cribs and trenches (ditches) partial clean closure	Appendix O, Section O.6.6
Iodine recycle	Appendix M, Section M.5.7.2
Technetium removal	Appendix M, Section M.5.7.3
Tank waste retrieval losses	Appendix M, Section M.5.6
Waste form performance	
ILAW glass	Appendix M, Section M.5.7.1
Bulk vitrification waste glass	Appendix M, Section M.5.7.4
Steam reforming waste	Appendix M, Section M.5.5
Grouted waste	Appendix M, Section M.5.7.5
Infiltration rates	Appendix N, Section N.5.9
Climate change	Appendix V

Key: ILAW=immobilized low-activity waste; *TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*.

Table 7–29 lists potential mitigation strategies that have been identified and could be implemented, as previously discussed in this section under each area of sensitivity analysis.

Table 7–29. Other Potential Long-Term Mitigation Strategies

Flux reduction	Perform additional sensitivity analyses in the area of flux reduction and integrate the results into cleanup programs for the Central Plateau by using the data to prioritize the remediation of sites.
	Target remediation on more-mobile COPCs (e.g., iodine-129, technetium-99) at low-discharge and some moderate-discharge sites.
	Target remediation on less-mobile COPCs (e.g., uranium-238, chromium) at moderate-discharge sites.
	Deploy groundwater remediation technologies such as pump-and-treat, reactive barrier, or other groundwater extraction methods for heavy-discharge sites where COPCs are predicted to have been released to the underlying aquifer.
Offsite-waste acceptance	Restrict, through waste acceptance criteria, certain waste streams or waste streams with high concentrations of certain COPCs from disposal at Hanford.
	Require pretreatment (i.e., stabilization) of offsite waste prior to disposal in an IDF.
Iodine recycle	Reduce the mass percentage of iodine-129 partitioned in grouted secondary-waste forms.
Technetium removal	Reduce the mass percentage of technetium-99 partitioned in grouted secondary waste.
Tank waste retrieval losses	Develop and implement retrieval technologies that would reduce the amount of potential tank waste leaked during retrieval operations.
Waste form performance	Develop improvements in secondary-waste-form performance by either improving grouted formulations or developing other stabilization methods (e.g., ceramics).
	Implemented the *Hanford Site Secondary Waste Roadmap* in January 2009, which addressed regulatory and performance requirements, waste composition, preliminary waste form screening, waste form development, process design and support, and validation (PNNL 2009).
	Improve grouted-waste-form performance by investigating methods to maintain drier conditions within and surrounding the grouted waste form.
	Continue research and development on supplemental-waste forms (e.g., bulk vitrification glass, steam reforming waste) and their associated release characteristics to reduce uncertainties about how these waste forms might impact groundwater in the long term.
	Develop primary-waste forms that would allow an increase in waste loading and, thus, a reduction in the mass percentage of COPCs that would partition in secondary-waste forms.
	Develop pretreatment and waste acceptance criteria for offsite waste prior to disposal in an IDF.
	Develop a set of performance criteria (release rates, etc.) for primary- and secondary-waste forms that would be emplaced in an IDF as part of the permit conditions for an IDF.
Infiltration rates	Perform research and data collection to better understand prevailing background infiltration rates at Hanford.
	Artificially reduce infiltration rates through the use of engineered barriers or replace barriers at the onset of original barrier failure.

Key: COPC=constituent of potential concern; Hanford=Hanford Site; IDF=Integrated Disposal Facility.

Following completion of this *TC & WM EIS* and its associated ROD, DOE would be required to prepare a mitigation action plan that explains the mitigation commitments expressed in the ROD (10 CFR 1021.331). This mitigation action plan would be prepared before DOE would implement any *TC & WM EIS* alternative actions that are the subject of a mitigation commitment expressed in the ROD. The mitigation action plan will address both short-term and long-term actions designed to mitigate adverse environmental impacts that are appropriate for the tank closure, FFTF decommissioning, and waste management actions selected for implementation. After implementation, DOE will periodically evaluate the efficacy of mitigation actions, and if necessary, will change or revise these mitigation actions to maintain the ability to achieve desired environmental outcomes.

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CHAPTER 8
POTENTIALLY APPLICABLE LAWS, REGULATIONS, AND OTHER REQUIREMENTS

Chapter 8 presents the laws, regulations, and other requirements that apply to the alternatives. Federal, state, and U.S. Department of Energy environmental, safety, and health requirements are summarized in Section 8.1. Permits or licenses that may be required to implement the alternatives are discussed in Section 8.2. Consultations with Federal, state, and local agencies and federally recognized American Indian groups are discussed in Section 8.3.

8.1 ENVIRONMENTAL, SAFETY, AND HEALTH LAWS, REGULATIONS, ORDERS, AND OTHER REQUIREMENTS

Operations at the Hanford Site (Hanford) and Idaho National Laboratory (INL) are affected and, in many cases, regulated by numerous Federal and state legal requirements addressing environmental compliance, remediation, planning, preservation, and waste management. In some cases, the U.S. Department of Energy (DOE) has sole authority to take action, e.g., under the Atomic Energy Act (AEA). In other cases, the U.S. Environmental Protection Agency (EPA) has authority to regulate; in others, EPA has delegated its authority to regulate to the State of Washington and the State of Idaho, e.g., under the Resource Conservation and Recovery Act (RCRA). In still other cases, state laws apply. Under DOE Order 436.1, *Departmental Sustainability*, it is DOE policy to carry out its mission in a sustainable manner to maximize energy and water efficiency; minimize chemical toxicity and harmful environmental releases; promote renewable and other clean energy development; and conserve natural resources while sustaining assigned mission activities. The major Federal and state laws and regulations, Executive orders, DOE orders, and other requirements that may currently or in the future apply to the various alternatives analyzed in this *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington (TC & WM EIS)* are identified in Table 8–1. These compliance requirements are briefly described in Sections 8.1.1 through 8.1.12.

The various action alternatives analyzed in this *TC & WM EIS* involve the construction of new DOE facilities; the operation, deactivation/demobilization, closure/decontamination and decommissioning of new and existing DOE facilities; and the transportation, treatment, and disposal of waste. Chapter 2 provides a discussion of these alternatives.

Table 8–1. Potentially Applicable Environmental, Safety, and Health Laws, Regulations, Orders, and Other Requirements

Law, Regulation, Order, or Other Requirement	Citation/Date
Environmental Quality	
National Environmental Policy Act of 1969, as amended	42 U.S.C. 4321 et seq.
Council on Environmental Quality Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act	40 CFR 1500 through 1508
"National Environmental Policy Act Implementing Procedures"	10 CFR 1021
National Environmental Policy Act Compliance Program	DOE Order 451.1B (October 26, 2000; Change 1, September 28, 2001; Change 2, June 25, 2010; Admin Change 3, January 19, 2012)
State Environmental Policy Act	RCW 43.21C

Table 8–1. Potentially Applicable Environmental, Safety, and Health Laws, Regulations, Orders, and Other Requirements *(continued)*

Law, Regulation, Order, or Other Requirement	Citation/Date
Environmental Quality *(continued)*	
Settlement Agreement in re *State of Washington v. Bodman*	Civil No. 2:03-cv-05018-AAM, January 6, 2006
Protection and Enhancement of Environmental Quality, as amended by Executive Order 11991	Executive Order 11514
Departmental Sustainability	DOE Order 436.1 (May 2, 2011)
Air Quality and Noise	
Clean Air Act of 1970, as amended	42 U.S.C. 7401 et seq.
"National Emission Standards for Hazardous Air Pollutants"	40 CFR 61
"National Emission Standards for Hazardous Air Pollutants for Source Categories"	40 CFR 63
Washington Clean Air Act	RCW 70.94
Washington State Air Pollution Control Regulations	WAC 173-400 through 173-495
"Ambient Air Quality Standards and Emission Limits for Radionuclides"	WAC 173-480
"Radiation Protection – Air Emissions"	WAC 246-247
Idaho Environmental Protection and Health Act	IC 39-100
Noise Control Act of 1972, as amended	42 U.S.C. 4901 et seq.
Water Resources	
Clean Water Act of 1972, as amended	33 U.S.C. 1251 et seq.
"EPA Administered Permit Programs: The National Pollutant Discharge Elimination System"	40 CFR 122 et seq.
Washington Water Pollution Control Act of 1945	RCW 90.48
"State Waste Discharge Permit Program"	WAC 173-216
"Underground Injection Control Program"	WAC 173-218
"Water Quality Standards for Ground Waters of the State of Washington"	WAC 173-200
"Water Quality Standards for Surface Waters of the State of Washington"	WAC 173-201A
Idaho Water Pollution Control Act of 1983	IC 39-3600 et seq.
"On-site Sewage Systems"	WAC 246-272
Safe Drinking Water Act of 1974, as amended	42 U.S.C. 300(f) et seq.
Drinking Water Regulations	40 CFR 141 through 149
Hanford Reach Study Act of 1988	P.L. 100-605
Floodplain Management	Executive Order 11988
"Compliance with Floodplain and Wetland Environmental Review Requirements"	10 CFR 1022
Hazardous Waste and Materials Management	
Resource Conservation and Recovery Act of 1976, as amended	42 U.S.C. 6901 et seq.
Washington State Hazardous Waste Management Act	RCW 70.105
"Dangerous Waste Regulations"	WAC 173-303

Table 8–1. Potentially Applicable Environmental, Safety, and Health Laws, Regulations, Orders, and Other Requirements *(continued)*

Law, Regulation, Order, or Other Requirement	Citation/Date
Hazardous Waste and Materials Management *(continued)*	
Model Toxics Control Act	RCW 70.105D
"Model Toxics Control Act – Cleanup"	WAC 173-340
Hanford Federal Facility Agreement and Consent Order (also known as the Tri-Party Agreement)	May 15, 1989, as amended
Federal Facility Compliance Act of 1992	P.L. 102-386
Interim Stabilization Consent Decree (No. CT-99-5076-EFS)	September 30, 1999, as amended (terminated March 8, 2011)
Idaho Site Treatment Plan and Consent Order for Federal Facility Compliance Act	November 1, 1995
State of Washington v. Chu Consent Decree (Civil No. 2:08-cv-05085-FVS)	October 25, 2010
Idaho Hazardous Waste Management Act of 1983	IC 39-4400 et seq.
Spent Fuel Settlement Agreement (also known as the Governor's Agreement)	October 16, 1995
Toxic Substances Control Act of 1976	15 U.S.C. 2601 et seq.
Framework Agreement for Management of Polychlorinated Biphenyls in Hanford Tank Waste	August 31, 2000
Radioactive Waste and Materials Management	
Atomic Energy Act of 1954	42 U.S.C. 2011 et seq.
Low-Level Radioactive Waste Policy Act of 1980, as amended	42 U.S.C. 2021 et seq.
"Licensing Requirements for Land Disposal of Radioactive Waste"	10 CFR 61
Nuclear Waste Policy Act of 1982, as amended	42 U.S.C. 10101 et seq.
Waste Isolation Pilot Plant Land Withdrawal Act, as amended	P.L. 102-579, as amended by P.L. 104-201
"Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes"	40 CFR 191
Radioactive Waste Management	DOE Order 435.1 (July 9, 1999; Change 1, August 28, 2001)
Real Property Asset Management	DOE Order 430.1B (September 24, 2003; Change 1, February 8, 2008; Change 2, April 25, 2011)
Ecological Resources	
Bald and Golden Eagle Protection Act of 1973, as amended	16 U.S.C. 668 through 668d
Endangered Species Act of 1973, as amended	16 U.S.C. 1531 et seq.
Natural Area Preserves Act	RCW 79.70
U.S. Fish and Wildlife Coordination Act	16 U.S.C. 661 et seq.
Migratory Bird Treaty Act of 1918, as amended	16 U.S.C. 703 et seq.
Protection of Wetlands	Executive Order 11990
Cultural and Paleontological Resources	
American Indian Religious Freedom Act of 1978	42 U.S.C. 1996
Antiquities Act of 1906, as amended	16 U.S.C. 431 through 433

Table 8–1. Potentially Applicable Environmental, Safety, and Health Laws, Regulations, Orders, and Other Requirements *(continued)*

Law, Regulation, Order, or Other Requirement	Citation/Date
Cultural and Paleontological Resources *(continued)*	
Archaeological and Historic Preservation Act of 1960, as amended	16 U.S.C. 469 through 469c-2
Archaeological Resources Protection Act of 1979, as amended	16 U.S.C. 470aa et seq.
National Historic Preservation Act of 1966, as amended	16 U.S.C. 470 et seq.
"Protection of Historic Properties"	36 CFR 800
Programmatic Agreement Among the U.S. Department of Energy Richland Operations Office, the Advisory Council on Historic Preservation, and the Washington State Historic Preservation Office for the Maintenance, Deactivation, Alteration, and Demolition of the Built Environment on the Hanford Site, Washington	August 21, 1996
Native American Graves Protection and Repatriation Act of 1990	25 U.S.C. 3001 et seq.
Protection and Enhancement of the Cultural Environment	Executive Order 11593
Indian Sacred Sites	Executive Order 13007
Consultation and Coordination with Indian Tribal Governments	Executive Order 13175
Trails for America in the 21st Century	Executive Order 13195
Preserve America	Executive Order 13287
American Indian Tribal Government Interactions and Policy	DOE Order 144.1 (January 16, 2009; Admin Change 1, November 6, 2009)
Department of Energy Management of Cultural Resources	DOE Policy 141.1 (May 2, 2001; Certified January 28, 2011)
Worker Safety and Health	
Occupational Safety and Health Act of 1970	29 U.S.C. 651 et seq.
"Occupational Radiation Protection"	10 CFR 835
"Worker Safety and Health Program"	10 CFR 851
Worker Protection Program for DOE (Including the National Nuclear Security Administration) Federal Employees	DOE Order 440.1B (May 17, 2007)
Seismic Safety of Federal and Federally Assisted or Regulated New Building Construction, as amended by Executive Order 13286	Executive Order 12699
Radiological Safety Oversight and Radiation Protection	
"Nuclear Safety Management"	10 CFR 830
Facility Safety	DOE Order 420.1B (December 22, 2005; Change 1, April 19, 2010)
Conduct of Operations	DOE Order 422.1 (June 29, 2010)
Verification of Readiness to Start Up or Restart Nuclear Facilities	DOE Order 425.1D (April 16, 2010)
Integrated Safety Management Policy	DOE Policy 450.4A (April 25, 2011)
Radiation Protection of the Public and the Environment	DOE Order 458.1 (February 11, 2011; Change 1, March 8, 2011; Change 2, June 6, 2011)

Table 8–1. Potentially Applicable Environmental, Safety, and Health Laws, Regulations, Orders, and Other Requirements *(continued)*

Law, Regulation, Order, or Other Requirement	Citation/Date
Radiological Safety Oversight and Radiation Protection *(continued)*	
Personnel Selection, Training, Qualification, and Certification Requirements for DOE Nuclear Facilities	DOE Order 426.2 (April 21, 2010)
Maintenance Management Program for DOE Nuclear Facilities	DOE Order 433.1B (April 21, 2010)
Transportation	
Hazardous Materials Transportation Act of 1975, as amended	49 U.S.C. 5101 et seq.
"Packaging and Transportation of Radioactive Material"	10 CFR 71
Packaging and Transportation Safety	DOE Order 460.1C (May 14, 2010)
Departmental Materials Transportation and Packaging Management	DOE Order 460.2A (December 22, 2004)
Emergency Planning, Pollution Prevention, and Conservation	
Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (also known as Superfund)	42 U.S.C. 9601 et seq.
Emergency Planning and Community Right-to-Know Act of 1986	42 U.S.C. 11001 et seq.
Pollution Prevention Act of 1990	42 U.S.C. 13101 et seq.
Federal Compliance with Pollution Control Standards, as amended by Executive Order 12580, *Superfund Implementation*	Executive Order 12088
Strengthening Federal Environmental, Energy, and Transportation Management	Executive Order 13423
Federal Leadership in Environmental, Energy, and Economic Performance	Executive Order 13514
Environmental Justice and Protection of Children	
Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations	Executive Order 12898
Protection of Children from Environmental Health Risks and Safety Risks	Executive Order 13045

Key: CFR=*Code of Federal Regulations*; DOE=U.S. Department of Energy; EPA=U.S. Environmental Protection Agency; IC=*Idaho Code*; P.L.=Public Law; RCW=*Revised Code of Washington*; U.S.C.=*United States Code*; WAC=*Washington Administrative Code*.

8.1.1 Environmental Quality

National Environmental Policy Act (NEPA) of 1969, as amended (42 U.S.C. 4321 et seq.). The purposes of NEPA of 1969, as amended, are to (1) declare a national policy that will encourage productive and enjoyable harmony between man and his environment; (2) promote efforts that will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man; (3) enrich the understanding of the ecological systems and natural resources important to the Nation; and (4) establish a Council on Environmental Quality (CEQ). NEPA establishes a national policy requiring that Federal agencies consider the environmental impacts of major Federal actions significantly affecting the quality of the human environment before making decisions and taking actions to implement those decisions. Implementation of NEPA requirements in accordance with CEQ regulations

(40 CFR 1500–1508) may result in a categorical exclusion, an environmental assessment and Finding of No Significant Impact, or an environmental impact statement (EIS). This *Final TC & WM EIS* has been prepared in accordance with NEPA requirements, CEQ regulations (40 CFR 1500–1508), and DOE provisions for implementing the procedural requirements of NEPA (10 CFR 1021; DOE Order 451.1B, Admin Change 3). It discusses reasonable alternatives to meet DOE's purpose and need for action and their potential environmental consequences.

State Environmental Policy Act (SEPA) (RCW 43.21C). The purposes of SEPA are to (1) declare a Washington State policy that will encourage productive and enjoyable harmony between man and his environment; (2) promote efforts that will prevent or eliminate damage to the environment and biosphere; (3) stimulate the health and welfare of man; and (4) enrich the understanding of the ecological systems and natural resources important to the state and Nation.

SEPA also specifies that an EIS shall be prepared on proposals for legislation and other major actions having a probable significant adverse environmental impact. SEPA does not legally apply to Federal agencies. Some states with similar laws generally require state agencies to perform a NEPA-like analysis before issuing permits. *Washington Administrative Code* (WAC) 197-11, which specifies the rules promulgated under SEPA, states that an agency (e.g., Washington State Department of Ecology [Ecology]) may adopt a Federal NEPA EIS as a substitute for preparing a SEPA EIS if (1) the requirements of WAC 197-11-600 and 197-11-630 are met and (2) the Federal NEPA EIS is not found inadequate.

The DOE Office of River Protection and Ecology both signed a Memorandum of Understanding (MOU) on March 25, 2003 (DOE and Ecology 2003), for the "Environmental Impact Statement for Retrieval, Treatment, and Disposal of Tank Waste and Closure of Single-Shell Tanks at the Hanford Site, Richland, Washington" ("Tank Closure EIS"). The purpose of this MOU was to clearly set out the responsibilities of each agency in cooperative preparation of the "Tank Closure EIS," consistent with CEQ cooperating agency requirements (40 CFR 1501.6) and guidance. This MOU was revised in January 2006 to more effectively carry out the agencies' respective responsibilities in complying with the applicable provisions of NEPA and SEPA (DOE and Ecology 2006). Under this revised MOU, the Office of River Protection continued as the lead agency, with overall responsibility to produce this *TC & WM EIS*, and Ecology continued as the cooperating agency. Ecology will separately review this *Final TC & WM EIS* and determine whether it can be adopted to fulfill its own responsibilities under SEPA.

Settlement Agreement in re *State of Washington v. Bodman*, Civil No. 2:03-cv-05018-AAM, January 6, 2006. In March 2003, prior to the issuance of the *Final Hanford Site Solid (Radioactive and Hazardous) Waste Program Environmental Impact Statement, Richland, Washington (HSW EIS)* (DOE 2004) and Record of Decision (69 FR 39449), Ecology initiated litigation on issues related to the importation, treatment, and disposal of radioactive and hazardous waste generated off site as a result of nuclear defense and research activities. The court enjoined shipment of offsite transuranic (TRU) waste to Hanford for processing and storage pending shipment to the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico.

Ecology amended its March 2003 complaint in 2004, challenging the adequacy of the *HSW EIS* analysis of offsite waste importation. In May 2005, the court granted a limited discovery period, continuing the injunction against shipping offsite wastes to Hanford, including low-level radioactive waste (LLW) and mixed low-level radioactive waste (MLLW) (*State of Washington v. Bodman* [Civil No. 2:03-cv-05018-AAM]). In July 2005, while preparing responses to discovery requests from Ecology, Battelle Memorial Institute, DOE's contractor who assisted in preparing the *HSW EIS*, advised DOE of several differences in groundwater analyses between the *HSW EIS* and its underlying data.

DOE promptly notified the court and the state and, in September 2005, convened a team of DOE experts in quality assurance and groundwater analysis, as well as transportation and human health and safety impacts analysis, to conduct a quality assurance review of the *HSW EIS*. In January 2006, the team completed its *Report of the Review of the "Hanford Solid Waste Environmental Impact Statement (EIS)" Data Quality, Control and Management Issues (Quality Review)* (DOE 2006a). Because both Ecology and DOE have a shared interest in the effective cleanup of Hanford, DOE, Ecology, the Washington State Attorney General's Office, and the U.S. Department of Justice signed a Settlement Agreement ending the NEPA litigation on January 6, 2006 (subsequently amended on June 5, 2008). The agreement is intended to resolve Ecology's concerns about *HSW EIS* (DOE 2004) groundwater analyses and to address other concerns about the *HSW EIS* that were identified in the *Quality Review* (DOE 2006a).

The agreement called for expanding the "Tank Closure EIS" to provide a single, integrated set of analyses that includes all waste types analyzed in the *HSW EIS* (LLW, MLLW, and TRU waste), which is now this *TC & WM EIS*. Under the agreement, pending issuance of a Record of Decision for this *Final TC & WM EIS*, the *HSW EIS* remains in effect to support ongoing waste management activities at Hanford (including transportation of TRU waste to WIPP) in accordance with applicable regulatory requirements. The agreement also stipulates that, when this *TC & WM EIS* has been completed, it will supersede the *HSW EIS*. Until that time, DOE will not rely on *HSW EIS* groundwater analyses for decisionmaking and will not import offsite waste to Hanford, apart from certain limited exemptions specified in the agreement, pending finalization of this *TC & WM EIS*.

Executive Order 11514, *Protection and Enhancement of Environmental Quality* (March 5, 1970), as amended by Executive Order 11991 (May 24, 1977). This Executive order requires Federal agencies to continually monitor and control their activities to (1) protect and enhance the quality of the environment and (2) develop procedures to ensure the fullest practicable provision of timely public information and understanding of Federal plans and programs that may have potential environmental impact so that interested parties can submit their views. DOE has issued regulations (10 CFR 1021) and DOE Order 451.1B, *National Environmental Policy Act Compliance Program*, for compliance with this Executive order.

DOE Order 436.1, Departmental Sustainability (May 2, 2011). This order canceled DOE Order 450.1A, *Environmental Protection Program*, dated June 4, 2008. It provides requirements and responsibilities for managing sustainability within DOE to (1) ensure that DOE carries out its missions in a sustainable manner that addresses national energy security and global environmental challenges and advances sustainable, efficient, and reliable energy for the future; (2) institute wholesale cultural change to factor sustainability and greenhouse gas reductions into all DOE corporate management decisions, and (3) ensure that DOE achieves the sustainability goals established in its *Strategic Sustainability Performance Plan* pursuant to applicable laws, regulations, and Executive Orders; related performance scorecards; and sustainability. For purposes of this order, "sustainability" is broadly defined as those actions taken to maximize energy and water efficiency; minimize chemical toxicity and harmful environmental releases; promote renewable and other clean energy development; and conserve natural resources while sustaining assigned mission activities.

8.1.2 Air Quality and Noise

Federal, state, and local agencies enforce the standards and requirements of the Clean Air Act to regulate air emissions and the requirements of the Noise Control Act to regulate noise at facilities such as Hanford and INL. DOE must comply with these standards and requirements for any of the activities being considered under this *TC & WM EIS*. These standards and requirements are summarized below.

Clean Air Act of 1970, as amended (42 U.S.C. 7401 et seq.). The Clean Air Act is intended to "protect and enhance the quality of the Nation's air resources so as to promote the public health and welfare and the productive capacity of its population." Section 118 of the Clean Air Act (42 U.S.C. 7418) requires each Federal agency with jurisdiction over any property or facility engaged in any activity that might result in the discharge of air pollutants to comply with "all Federal, state, interstate, and local requirements" with regard to the control and abatement of air pollution.

Section 109 of the Clean Air Act (42 U.S.C. 7409 et seq.) directs EPA to set National Ambient Air Quality Standards (NAAQS) for criteria pollutants. EPA has identified and set national ambient air quality standards under Title 40 of the *Code of Federal Regulations* (CFR), Part 50 (40 CFR 50) for the following criteria pollutants: particulate matter, sulfur dioxide, carbon monoxide, ozone, nitrogen dioxide, and lead. Section 111 of the Clean Air Act (42 U.S.C. 7411) requires establishment of national standards of performance for new or modified stationary sources of atmospheric pollutants. Section 160 of the Clean Air Act (42 U.S.C. 7470 et seq.) requires specific emission increases to be evaluated prior to permit approval to prevent significant deterioration of air quality. Section 112 of the Clean Air Act (42 U.S.C. 7412) requires specific standards for releases of hazardous air pollutants (including radionuclides). These standards are implemented through state implementation plans.

Emissions of air pollutants from DOE facilities are regulated by EPA under 40 CFR 50–99. Emissions of radionuclides from DOE facilities and other hazardous air pollutants, including a release of asbestos during demolition and renovation activities, are regulated under the National Emission Standards for Hazardous Air Pollutants (NESHAPs) program (40 CFR 61 and 40 CFR 63, respectively). EPA initially granted interim delegation of authority to the State of Washington to implement and enforce two NESHAPs for radionuclides, specifically, "Emissions of Radionuclides Other than Radon from DOE Facilities" (40 CFR 61, Subpart H) and "National Emission Standards for Radionuclide Emissions from Federal Facilities Other Than Nuclear Regulatory Commission Licensees and Not Covered by Subpart H" (40 CFR 61, Subpart I). Additional delegations to local air agencies in Washington occurred in 1998 (63 FR 66054); delegation to Ecology and four local air pollution control agencies, including the Benton Clean Air Authority, now called the Benton Clean Air Agency, occurred in 2001 (66 FR 48211). Previous delegations of authority were updated in 2002 (67 FR 11417), and partial approval to implement and enforce specific subparts of the NESHAPs for radionuclide air emissions (i.e., Subparts A, B, H, I, K, Q, R, T, and W, as in effect on July 1, 2004, with a few specific exclusions) was granted to the Washington State Department of Health in 2006 (71 FR 32276).

Washington Clean Air Act (RCW 70.94) and Associated Regulations. Most of the provisions of the Washington Clean Air Act mirror the requirements of the Federal Clean Air Act. The Federal Clean Air Act establishes a minimum, or "floor," for Washington air quality programs. The Washington Clean Air Act authorizes Ecology; the Department of Health; and the Benton County Clean Air Agency (where Hanford is located), to implement provisions and programs consistent with the Federal Clean Air Act. For example, the Washington Clean Air Act authorizes an operating permit program, enhanced civil penalties, administrative enforcement provisions, motor vehicle inspections, and provisions addressing ozone and acid rain.

Washington State also has an extensive set of regulations governing toxic air pollutants (WAC 173-460 through 173-495). These regulations are similar to the programs for regulating hazardous air pollutants under the Federal Clean Air Act. In contrast to the Federal Clean Air Act program, which applies to new and existing emission sources, the toxic air pollutant rules apply only to new sources and any modification of an existing source where the modification will increase emissions of toxic air pollutants. Ecology's toxic air pollutant rules are implemented under the New Source Review Program. Ecology's Nuclear Waste Program regulates air toxic and criteria pollutant emissions from Hanford. Ecology's implementing requirements (e.g., WAC 173-400, WAC 17-401, WAC 17-460) specify a review of new source emissions, permitting, applicable controls, reporting, notifications, and provisions of compliance with the general standards for applicable sources of Hanford emissions.

The Washington State Department of Health regulations, "Radiation Protection – Air Emissions" (WAC 246-247), contain standards and permit requirements for the emission of radionuclides to the atmosphere from DOE facilities based on Ecology standards, "Ambient Air Quality Standards and Emission Limits for Radionuclides" (WAC 173-480). Prior to beginning any work that would result in creating a new or modified source of radioactive airborne emissions, a Notice of Construction application must be submitted to the Washington State Department of Health for review and approval. Ensuring adequate emission controls, emissions monitoring/sampling, and/or annual reporting of air emissions is a typical requirement for radioactive air emission sources. Hanford operates under state license No. FF-01 for such emissions. This license was incorporated into the Hanford air operating permit renewal, which was reissued by Ecology (Poston, Duncan, and Dirkes 2011:5.22).

The local air authority, Benton Clean Air Agency, enforces state regulations pertaining to detrimental effects, fugitive dust, incineration products, odor, opacity (e.g., haze), asbestos, and sulfur oxide emissions. The agency also has been delegated authority to enforce the EPA asbestos regulations.

Compliance with the Clean Air Act requires both facility and sitewide compliance. The *Hanford Site Environmental Report for Calendar Year 2010 (Including Some Early 2011 Information)* (Poston, Duncan, and Dirkes 2011) identifies existing facility-specific and sitewide compliance activities and requirements. The air operating permit for Hanford was renewed, effective from January 2007 through January 2012 (permit No. 00-05-006 renewal), and another renewal is pending (Poston, Duncan, and Dirkes 2011:D.2). Activities conducted under all of the alternatives must be in compliance with the Hanford Air Operating Permit and applicable Federal, state, and local regulations. The air quality sections of Chapter 4 of this *TC & WM EIS* provide information on the assessment of compliance with applicable standards and appropriate air quality criteria and standards for each of the alternatives.

Several of the activities under the alternatives would involve construction of a source of air emissions. For new or modified nonradioactive air emissions, DOE would need to obtain a permit to construct from Ecology and would need to conduct a NESHAPs review prior to commencing construction. Prior to construction of any new or modified source of radioactive airborne emissions, DOE would need to submit a Notice of Construction application to the Washington State Department of Health for review and approval. New facilities would also be required to be included in the air operating permit through a permit modification after construction and startup.

Idaho Environmental Protection Health Act (IC 39-100). This act provides for development of air pollution control permitting regulations in the State of Idaho. Under EPA regulations, the State of Idaho has been delegated authority under the Clean Air Act to maintain the Primary and Secondary NAAQS (40 CFR 52) to issue permits under the Prevention of Significant Deterioration regulations (40 CFR 52.683), to enforce performance standards of new stationary sources, and to issue permits to operate. The Idaho State air pollution control permitting regulations are found under "Rules for the Control of Air Pollution in Idaho," Idaho Administrative Procedures Act (IDAPA) (IDAPA 58.01.01). The State of Idaho also administers a permit program that regulates sources that are too small to qualify as a major source under Prevention of Significant Deterioration regulations. To date, the State of Idaho does not have authority delegated from EPA to administer the NESHAPs program regulating emissions of radionuclides at DOE facilities, so that authority remains with EPA. The air quality sections of Chapter 4 of this *TC & WM EIS* provide information on the assessment of compliance with applicable standards and appropriate air quality criteria and standards for each of the alternatives.

Noise Control Act of 1972, as amended (42 U.S.C. 4901 et seq.). Section 4 of the Noise Control Act of 1972, as amended, directs all Federal agencies to carry out "to the fullest extent within their authority" programs within their jurisdictions in a manner that furthers a national policy of promoting an environment free from noise jeopardizing health and welfare. Chapter 4 of this EIS addresses the impacts associated with the construction, operations, deactivation, or closure activities analyzed for each of the alternatives.

8.1.3 Water Resources

There are several statutes, orders, and regulations that DOE must comply with to protect the waters at Hanford and INL; these are briefly discussed below, along with potential implication to this *TC & WM EIS*.

Clean Water Act of 1972, as amended (33 U.S.C. 1251 et seq.). The Clean Water Act, which amended the Federal Water Pollution Control Act, was enacted to "restore and maintain the chemical, physical, and biological integrity of the Nation's water." The Clean Water Act prohibits the "discharge of toxic pollutants in toxic amounts" to navigable waters of the United States. Section 313 of the Clean Water Act requires all branches of the Federal Government engaged in any activity that might result in a discharge or runoff of pollutants to surface waters to comply with Federal, state, interstate, and local requirements.

Section 404 of the Clean Water Act gives the U.S. Army Corps of Engineers permitting authority over activities that discharge dredge or fill materials into waters of the United States, including wetlands.

The Clean Water Act also provides guidelines and limitations for effluent discharges from point-source discharges and establishes the National Pollutant Discharge Elimination System (NPDES) permit program. The NPDES program is administered by EPA, pursuant to regulations in 40 CFR 122 et seq., and may be delegated to states. Sections 401 through 405 of the Water Quality Act of 1987 added Section 402(p) to the Clean Water Act, requiring that EPA establish regulations for permits for stormwater discharges associated with industrial activities, including construction activities disturbing 2 hectares (5 acres) or more. After March 2003, the threshold for obtaining a permit was lowered to 0.4 hectares (1 acre). Stormwater provisions of the NPDES program are set forth at 40 CFR 122.26. This program is administered by EPA in both Washington and Idaho. Permit modifications are required if discharge effluent is altered.

Hanford has one NPDES permit (No. WA-002591-7). This permit covers two active outfalls: outfalls 003 and 004 in the 100-K Area to the Columbia River. The outfall for the 300 Area Treated Effluent Disposal Facility was removed from the permit in 2009 because the facility was shut down. EPA's NPDES Storm Water Multi-Sector General Permit No. WAR05A57F established the terms and conditions under which stormwater discharges associated with industrial activity are authorized for Hanford. This permit was issued in 2000 by EPA and terminated on June 22, 2009. These industrial activities were then covered under an NPDES Construction General Permit (No. WAR10B90F) that took effect on June 3, 2009 (Poston, Duncan, and Dirkes 2010:5.23). This permit was terminated on March 18, 2010, and has not been renewed (Poston, Duncan, and Dirkes 2011:D.2). For the construction of new facilities or modifications to existing facilities, DOE is required to develop written stormwater discharge plans that conform to requirements of the existing stormwater discharge permit. Hanford stormwater discharge permits would then need to be appended to include the additional or modified facility.

Washington Water Pollution Control Act of 1945 (RCW 90.48). This act applies to surface waters and groundwaters of the State of Washington and implements, at the state level, provisions of the Federal Clean Water Act and Federal Safe Drinking Water Act (42 U.S.C. 300(f) et seq.). The Washington Water Pollution Control Act requires the development of state waste discharge permits and onsite sewage disposal system approvals and is administered by Ecology and the Washington State Department of Health. Regulations relating to water pollution and water quality include the following:

- "State Waste Discharge Permit Program" (WAC 173-216)
- "Water Quality Standards for Ground Waters of the State of Washington" (WAC 173-200)
- "Water Quality Standards for Surface Waters of the State of Washington" (WAC 173-201A)
- "On-Site Sewage System" (WAC 246-272)

Discharges from the 200 Area Treated Effluent Disposal Facility and Liquid Effluent Retention Facility, Waste Treatment Plant (WTP), and the Fast Flux Test Facility (FFTF) Ponds in the 400 Area are covered by state wastewater discharge permits issued by Ecology (Poston, Duncan, and Dirkes 2010:5.25, D.2). The state derives its authority to administer the Underground Injection Control Program from *Revised Code of Washington* (RCW) 43.21A.445, whose intent is to satisfy the Federal Safe Drinking Water Act. DOE complies with State of Washington programs and applies for discharge permits or injection control permits as a matter of comity. Activities conducted under all of the alternatives must be in compliance with the applicable standards specified under the requirements listed above. The water resources sections of Chapter 4 provide information on compliance with these standards. If the selected action results in new or modified point-source discharges, DOE would need to modify its current permit.

Idaho Water Pollution Control Act (IC 39-3600). This act establishes a program to enhance and preserve the quality and value of water resources. The "Water Quality Standards" (IDAPA 58.01.02) and "Rules for the Reclamation and Reuse of Municipal and Industrial Wastewater" (IDAPA 58.01.17) require protection of designated water uses and establishment of water quality standards that will protect those uses. The State of Idaho has established groundwater quality standards and enforces them under state authority.

Safe Drinking Water Act of 1974, as amended (42 U.S.C. 300(f) et seq.). The primary objective of the Safe Drinking Water Act is to protect the quality of public drinking water supplies and sources of drinking water. The implementing regulations, administered by EPA unless delegated to states, establish standards applicable to public water systems. These regulations include maximum contaminant levels (including those for radioactivity) in public water systems, which are defined as water systems that have at least 15 service connections used by year-round residents or regularly serve at least 25 year-round residents. These standards apply to Columbia River water at community water supply intakes downstream of Hanford. The EPA regulations implementing the Safe Drinking Water Act are found in 40 CFR 141–149. For radioactive material, the regulations specify that the average annual concentration of manmade radionuclides in drinking water, as delivered to the user by such a system, shall not produce a dose equivalent to the total body or an internal organ greater than 4 millirem per year beta-gamma activity (40 CFR 141.16(a)). They further specify a concentration limit for gross alpha particle activity (excluding radon and uranium) of 15 picocuries per liter and for uranium of 0.03 milligrams per liter (40 CFR 141.66). Other programs established by the Safe Drinking Water Act include the Sole Source Aquifer Program, the Wellhead Protection Program, and the Underground Injection Control Program.

The groundwater analysis conducted for this *TC & WM EIS* consists of a comparison of the projected water quality with relevant regulatory standards, including standards established under the Safe Drinking Water Act that apply at the point of delivery. Results of this analysis are summarized in the groundwater resources sections of Chapter 5 and Appendix O of this EIS.

Executive Order 11988, *Floodplain Management* (May 24, 1977). This order (implemented by DOE in 10 CFR 1022) requires Federal agencies to establish procedures to ensure that the potential effects of flood hazards and floodplain management are considered for any action undertaken in a floodplain, and that floodplain impacts be avoided to the extent practicable. As discussed in Chapter 3 of this EIS, the areas of Hanford and INL being considered for this EIS are not located in a floodplain.

8.1.4 Hazardous Waste and Materials Management

All the alternatives analyzed for this EIS involve the management of hazardous and mixed wastes. These waste types must be managed in compliance with the applicable requirements. For all alternatives, hazardous waste and nonradioactive hazardous components of mixed waste would be stored at Hanford in accordance with applicable EPA and Ecology regulations. Ultimate treatment and disposal would be conducted in accordance with applicable standards and regulations at Hanford or offsite locations. The waste management sections of Chapter 4 provide information on the generation and management of hazardous and mixed wastes under each of the alternatives. The following are brief summaries of potentially applicable hazardous waste and materials management requirements.

Resource Conservation and Recovery Act of 1976, as amended (42 U.S.C. 6901 et seq.). The transportation and treatment, storage, and disposal (TSD) of solid and hazardous wastes are regulated by EPA under the authority of RCRA of 1976, as amended. The EPA regulations implementing RCRA (40 CFR 260–282) define and identify hazardous waste; establish standards for waste transportation and TSD; and require permits for persons engaged in hazardous waste activities.

EPA defines waste that exhibits the characteristics of ignitability, corrosivity, reactivity, or toxicity as "characteristic" hazardous waste. EPA has also identified certain materials as hazardous waste by listing them in RCRA regulations. These materials are referred to as "listed" hazardous waste. "Mixed waste" is waste that contains both a hazardous waste component regulated under Subtitle C of RCRA and a radioactive component consisting of source, special nuclear, or byproduct material regulated under the AEA. The definition of "solid waste" in RCRA specifically excludes the radioactive component (i.e., source, special nuclear, or byproduct materials as defined by the AEA). As a result, mixed waste is regulated under multiple authorities: by RCRA, as implemented by EPA or authorized states for the hazardous waste components, and by the AEA, as implemented by either DOE or the U.S. Nuclear Regulatory Commission (NRC) for the radioactive components.

RCRA applies mainly to owners and operators of facilities that generate and manage hazardous waste. This act imposed management requirements on generators and transporters of hazardous waste and upon owners and operators of TSD facilities. EPA has established a comprehensive set of regulations governing all aspects of TSD facilities, including location, design, operations, and closure.

Any state that seeks to administer and enforce a hazardous waste program pursuant to RCRA may apply to EPA for authorization to administer its state program in lieu of the Federal program. EPA has authorized the State of Washington to implement the state hazardous waste management program in lieu of the Federal RCRA program, except for delisting authority. EPA has authorized the State of Idaho to implement the state hazardous waste management program in lieu of the Federal RCRA program, including the authority to delist wastes within the state's jurisdiction. Neither state is authorized for national treatability variances under the Land Disposal Restriction Program, since EPA has determined that the authority for national treatability variances cannot be delegated to states. Both states, however, have received authorization to issue site-specific treatability variances within their respective jurisdictions.

***Land-Disposal-Restriction Requirements*.** The Hazardous and Solid Waste Amendments of 1984 added provisions to RCRA to prohibit the land disposal of hazardous waste that does not meet specific treatment standards. RCRA land disposal restrictions require that hazardous waste be treated to meet applicable standards set forth in 40 CFR 268 prior to disposal. The standards may consist of required treatment technologies or concentration levels that must be achieved for hazardous constituents. Once hazardous waste is treated in accordance with the applicable treatment standards, it may be disposed of under applicable requirements. The tank waste is considered to be mixed waste (i.e., contains both RCRA hazardous waste and radioactive constituents regulated under the AEA). Therefore, the tank waste must be treated to meet the applicable treatment standards. Under each of the action alternatives, DOE would need to determine whether the treatment proposed meets the applicable treatment standards for that waste stream. If a specified treatment standard cannot be met, then DOE would need to apply for a treatment variance from that treatment standard or demonstrate equivalent treatment. DOE is preparing a treatability variance for the tank waste to allow vitrification as the treatment method for all the hazardous waste codes that apply to the tank waste. Currently, vitrification is the treatment standard for high-level radioactive waste (HLW) that exhibits the characteristic of toxicity for metals and corrosivity. Hanford's HLW also exhibits the characteristic of corrosivity and toxicity for organics and contains listed hazardous waste. While HLW would be treated by vitrification, low-activity waste and secondary waste would still need to meet the applicable treatment standards.

Washington State Hazardous Waste Management Act (RCW 70.105). The Washington State Hazardous Waste Management Act gives Ecology authority to regulate the disposal of hazardous waste in Washington and to implement waste reduction and prevention programs. Ecology has adopted regulations that are found in "Dangerous Waste Regulations" (WAC 173-303). Except as noted above, Washington State has been authorized to implement the state RCRA program within the state's borders in lieu of the Federal program. Ecology's regulations are consistent with, and cover a larger universe of materials than, the Federal hazardous waste program. The waste categories defined in Ecology's regulations (WAC 173-303) are *dangerous waste, acutely hazardous waste, extremely hazardous waste*, and *special waste*. The following discussions focus on two specific areas of compliance with the State of Washington's hazardous waste management program (i.e., permits and closure) and their relation to the activities considered in this *TC & WM EIS*.

Hazardous/Dangerous Waste Permit. The owner/operator of a dangerous waste facility that treats, stores, disposes of, or recycles dangerous waste must obtain a permit in accordance with WAC 173-303-800 through 173-303-840 covering the active life, closure period, groundwater protection compliance period, completion of corrective action for releases from solid waste management units, and, for any regulated unit (as defined in WAC 173-303-040) or for any facility that at closure does not meet the removal or decontamination limits of WAC 173-303-610(2)(b), the postclosure care period, unless they demonstrate closure by removal or decontamination as provided under WAC 173-303-800(9) and (10). If a postclosure permit is required, the permit must address applicable groundwater monitoring, unsaturated zone monitoring, corrective action, and postclosure care requirements of WAC 173-303.

Hanford is considered a single facility for purposes of RCRA and the Washington State Hazardous Waste Management Act. Hanford's RCRA permit (No. WA7890008967) was originally issued in two portions, one by EPA Region 10 and the other by Ecology for which Ecology was not authorized at the time. The EPA portion of the Hanford RCRA permit covered the Hazardous and Solid Waste Amendments. The Ecology portion of the permit, which covered the dangerous waste provisions, was issued on September 27, 1994, and is periodically updated. The permit is the foundation for RCRA permitting on Hanford in accordance with provisions set forth in WAC 173-303-800 through -840, and those portions of the Hanford Federal Facility Agreement and Consent Order (also known as the Tri-Party Agreement [TPA]) (Ecology, EPA, and DOE 1989). Ecology is now fully authorized to implement the dangerous waste program in lieu of the Federal RCRA program; therefore, there is no need or authority for EPA to separately issue a hazardous solid waste amendment component of the Hanford permit (Bartus 2008). Ecology is currently working on a draft of the revised permit (Poston, Duncan, and Dirkes 2011:D.2).

This *TC & WM EIS* analyzes new facilities that will be permitted under RCRA and existing facilities that are operating under interim status requirements. The double-shell tank (DST) farm continues to operate under interim status. The single-shell tanks (SSTs) are expected to be closed in accordance with WAC 173-303 and the TPA. A final RCRA Part B permit is being obtained for the WTP on an incremental basis as the facility design matures. Any new TSD units would require a modification of the Hanford RCRA permit. An RCRA Part B permit application for the 200-East Area Integrated Disposal Facility was submitted to Ecology in 2005.

Treatment or disposal activities at other sites may require RCRA permits or approvals. The State of New Mexico carries out programs similar to the State of Washington's in which the Federal requirements are enforced under state law. Therefore, any hazardous waste management activities taking place in other states as a result of implementing one of the alternatives would be subject to the hazardous waste requirements of that particular state.

***RCRA Closure*.** When hazardous waste management facilities cease operations, they must be closed in a manner that ensures they will not pose a future threat to human health and the environment. RCRA provides for two types of closure for hazardous waste tanks: (1) closure by removal, or decontamination (referred to as "clean closure"), and (2) closure with waste in place, or "landfill closure." The premise of clean closure is that all the hazardous waste has been removed from the RCRA-regulated unit, and any releases at or from the unit have been remediated so that further regulatory control under RCRA Subtitle C is not necessary to protect human health and the environment. The Action Plan (Attachment II to the TPA) (Ecology, EPA, and DOE 1989) presents specific requirements and milestones that are applicable to tank system closure and generally requires that the process to close any unit be carried out in accordance with the applicable requirements of WAC 173-303 and 40 CFR 270.1.

For closure of a tank system, the owner or operator must remove or decontaminate all waste residues, contaminated containment system components (liners, etc.), contaminated soils, and structures and equipment contaminated with waste and manage them as dangerous waste (WAC 173-303-640).

If the owner or operator demonstrates that all contaminated soils cannot practicably be removed or decontaminated, then the owner or operator must close the tank system and perform postclosure care in accordance with closure and postclosure care requirements that apply to a hazardous waste landfill (WAC 173-303-640(8)(b)). A postclosure care permit covering maintenance, monitoring, and corrective action provisions would be issued.

Ecology's regulations for closure (WAC 173-303-610) state that when the removal or decontamination of dangerous waste, waste residues, or equipment, bases, liners, soils, or other materials containing or contaminated with dangerous waste or waste residue is required, then such removal or decontamination must ensure that the levels of dangerous waste or dangerous waste constituents or residues do not exceed the following:

- For soils, groundwater, surface water, and air, the numeric cleanup levels calculated using residential exposure assumptions according to the Model Toxics Control Act regulations (WAC 173-340) as incorporated by the dangerous waste regulations. Primarily, these will be numeric cleanup levels.

- For all structures, equipment, bases, liners, etc., clean closure standards that will be set by Ecology on a case-by-case basis in accordance with the closure performance standards of WAC 173-303-610(2)(a)(ii) and in a manner that minimizes or eliminates postclosure escape of dangerous waste constituents.

The state has the ability to use alternative closure requirements in WAC 173-303-610(1)(e). The Tank Closure No Action Alternative and Tank Closure Alternative 2A of this *TC & WM EIS* do not address SST system closure, which is not consistent with the commitments for tank closure in the TPA. Tank Closure Alternatives 2B, 3A, 3B, 3C, 5, and 6C address SST system closure as landfills. Tank Closure Alternative 4 addresses SST system closure as a combination of a landfill and clean closure of certain tank farms. Tank Closure Alternatives 6A and 6B address SST system closure under the clean closure scenario.

Model Toxics Control Act (RCW 70.105D). The Model Toxics Control Act is implemented through the Hazardous Waste Cleanup – Model Toxics Control Act regulations found under WAC 173-340. The primary goal of these regulations is to provide a workable process to accomplish effective and expeditious cleanups that are not being conducted under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (42 U.S.C. 9601) in a manner that protects human health and the environment. It is primarily intended to address releases of hazardous substances caused by past activities, although its provisions may be applied to potential and ongoing releases of hazardous substances from current activities. They are also applicable under the state corrective action authority (WAC 173-303-64620). These regulations provide methodologies for calculating numeric cleanup levels for soils, groundwater, surface water, and air.

Washington State Initiative 297, the Cleanup Priority Act. Initiative 297, known as the Cleanup Priority Act, was passed by Washington State voters in November 2004. The Cleanup Priority Act was intended to add a new chapter to the Mixed Radioactive and Hazardous Waste law (RCW 70.105E) and would have, among other things, restricted importing offsite waste to Hanford, set cleanup standards for radioactive releases, and required DOE to pay a new mixed-waste surcharge. The U.S. Department of Justice challenged the initiative, arguing it violated the U.S. Constitution. The Federal District Court agreed and ruled the initiative "invalid in its entirety" because it was preempted by Federal law, violated the Commerce Clause, and violated the principle of sovereign immunity. The State of Washington appealed the ruling, but the Ninth Circuit Court of Appeals affirmed the lower court, declaring the initiative was preempted by the AEA.

Hanford Federal Facility Agreement and Consent Order, May 15, 1989, as amended (Ecology, EPA, and DOE 1989). The TPA is an enforceable agreement among Ecology, EPA, and DOE for achieving compliance at Hanford with RCRA (42 U.S.C. 6901 et seq.); CERCLA (42 U.S.C. 9601 et seq.); and the Washington State Hazardous Waste Management Act (RCW 70.105). This agreement (1) defines RCRA and CERCLA cleanup commitments; (2) establishes responsibilities; (3) provides a basis for budgeting; and (4) reflects a concerted goal to achieve regulatory compliance and remediation with enforceable milestones (Poston, Duncan, and Dirkes 2011:3.1).

The milestones governing the FFTF deactivation activities are defined in the TPA Milestone M-81-00 series and related M-20-29B milestones. A three-phased process is delineated in the TPA for decontamination and decommissioning of key facilities: Phase 1 is Transition or Deactivation, Phase 2 is Surveillance and Maintenance, and Phase 3 is Disposition.

For the SSTs, the TPA (as supplemented by the Interim Stabilization Consent Decree) lays out a process and schedule to remove pumpable liquids, retrieve solids, and close the SST system in lieu of achieving full compliance with RCRA requirements. The TPA milestones applicable to tank farms are provided in the following series: M-20 (immobilized low-activity waste [ILAW] and immobilized HLW [IHLW] facility RCRA permitting); M-23 (SST leak detection and integrity); M-43 (DST upgrades); M-45 (SST retrieval and closure); M-46 (DST space); M-47 (waste feed delivery); M-48 (DST integrity); and M-90 (ILAW and IHLW facility design, construction, and operations). The TPA also lays out the process for submittal, review, and approval of RCRA permit applications and closure plans (CH2M HILL 2003:B-2). In addition, the TPA lays out the process and authority to operate non-RCRA-compliant SSTs pending closure and identifies the process and procedures for SST system closure under RCRA.

It is assumed that closure activities would be integrated with nearby CERCLA waste sites. Because of the number and location of waste sites surrounding the SST farms, there is a need to integrate decisions on remediation and closure (including surface barrier design). The TPA provides a means to integrate RCRA/CERCLA decisions to prevent conflicting requirements and resolve disputes. This is also a consideration for DST farm closure decisions. However, decisions on disposition of the DST farms are governed by WAC 173-303. This *TC & WM EIS* does not address existing-DST closure decisions or remediation of contaminated groundwater. Decisions on DST closure would be addressed at a later date, subject to appropriate NEPA review. Groundwater contamination in the 200 Areas will be remediated under CERCLA.

Federal Facility Compliance Act of 1992 (P.L. 102-386). The Federal Facility Compliance Act, enacted on October 6, 1992, amended RCRA Section 6961 and other sections and requires DOE to prepare plans that develop treatment capacity for mixed waste stored or generated at each facility, except for those facilities subject to a permit that establishes a schedule for treatment of such waste or an existing agreement or order governing the treatment of such waste to which the state is a party. The host state and/or EPA must approve each plan.

The State of Washington, EPA, and DOE had an existing plan (the TPA) that addressed compliance with the storage prohibition for mixed waste at the time this law was enacted. Therefore, Hanford was not required to develop a new plan. A violation of the TPA may concurrently be a violation of the Federal Facility Compliance Act (i.e., the State of Washington may seek judicial enforcement under Title 42 of the *United States Code* (U.S.C.), Section 6901 et seq. [42 U.S.C. 6901 et seq.]).

DOE and the State of Idaho have an approved plan, known as the "Site Treatment Plan," and an associated consent order for INL. The INL Site Treatment Plan, Section 4.5, identifies the process for pretreatment and post-treatment storage at INL of offsite mixed waste. The process identified in the INL Site Treatment Plan, Section 4.5, requires approval of the treatment plan by the State of Idaho Department of Environmental Quality (IDEQ). Approval of the plan would allow for up to 6 months pre- and post-treatment storage of the offsite mixed waste. The process also requires notification of IDEQ regarding (1) the proposed schedule subsequent to approval of the treatment plan and addition of the offsite waste stream to the list contained in Section 4.5, Table 4-5, as well as (2) actual receipt of offsite radioactive sodium and remote-handled special components; completion of the primary treatment step; and offsite shipment of product, waste, and treatment residue.

Interim Stabilization Consent Decree (No. CT-99-5076-EFS, September 30, 1999, as amended). This Consent Decree established a court-enforceable, technically sound schedule for pumping liquid nuclear waste from the remaining 29 unstabilized SSTs. All 29 SSTs have now been interim stabilized, and all work required to be performed under this Consent Decree has been completed and confirmed. As a result, the court granted the joint motion to terminate the Consent Decree on March 8, 2011.

***State of Washington v. Chu* Consent Decree (Civil No. 2:08-cv-5085-FVS, October 25, 2010).** In late 2008, the State of Washington and the State of Oregon sued DOE to enforce deadlines for Hanford's cleanup (*State of Washington v. Chu*, Civil Action No. 2:08-cv-05085-FVS). On October 25, 2010, the parties reached a settlement, resulting in a Consent Decree that covers certain near-term (2010 to 2022) tank waste retrieval; WTP construction and operation requirements, including a 2022 deadline for initial operations of the WTP (currently under construction); and certain new TPA milestones. The Consent Decree adds its own new milestones, more enforcement, and a higher level of court oversight. It also allows state regulators to weigh in every 3 years on the cleanup plan and to propose accelerating final deadlines every 6 years. Thus, the Consent Decree provides accountability, enforcement, and regulatory oversight for completion of the WTP.

Idaho Hazardous Waste Management Act of 1983 (IC 39-4400 et seq.). The State of Idaho has been given authority by EPA to enact and carry out a hazardous waste program that enables the state to assume primacy over hazardous waste management in the State of Idaho. This includes authority to issue permits for hazardous waste TSD. The Idaho regulations include requirements for hazardous waste generators, transporters, and management facilities, as well as detailed procedures for permitting these activities. Under the state's law (IC 39-4404), regulations may not be promulgated that impose conditions or requirements more stringent or broader in scope than RCRA or the RCRA regulations of EPA.

Spent Fuel Settlement Agreement (also known as the Governor's Agreement) (October 16, 1995). This agreement allows INL to receive spent nuclear fuel (SNF) and mixed waste from off site and establishes schedules for the treatment of existing HLW, TRU waste, mixed waste, and removal of SNF from the state. This agreement states that any and all treatable waste shipped into the State of Idaho for treatment at INL shall be treated within 6 months of receipt at the facility and shipped off site within 6 months of treatment. DOE may request an exception to the 6-month time period on a case-by-case basis, considering factors at the shipping site such as health and safety concerns, insufficient permitted storage capacity, and base or site closures. This agreement further states that DOE shall continue to use the Federal Facility Compliance Act process, as facilitated by the National Governors Association, to determine what locations are suitable for MLLW treatment and storage.

Toxic Substances Control Act of 1976 (15 U.S.C. 2601 et seq.). The Toxic Substances Control Act provides EPA with the authority to require testing of chemical substances entering the environment and to regulate them as necessary. EPA is also authorized to impose strict limitations on the use and disposal of polychlorinated biphenyls (PCBs), chlorofluorocarbons, asbestos, dioxins, certain metal-working fluids, and hexavalent chromium. The EPA regulations that establish prohibitions of and requirements for PCBs and PCB items are found in 40 CFR 761, "Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions." Removal of the two PCB transformers remaining at FFTF would require disposition in compliance with this act.

Framework Agreement for Management of Polychlorinated Biphenyls in Hanford Tank Waste (August 31, 2000). Some Hanford DSTs contain PCB remediation waste, which is waste containing PCBs as a result of a spill, release, or other unauthorized disposal and is regulated under the Toxic Substances Control Act. Therefore, the waste feed to the vitrification plant will also contain PCB remediation waste. On August 31, 2000, DOE, EPA Region 10, and Ecology signed the Framework Agreement for Management of Polychlorinated Biphenyls in Hanford Tank Waste (EPA, DOE, and Ecology 2000). The agreement states that, "DOE, EPA and Ecology will pursue a rational path based on a risk-based disposal approval option per Title 40 of the *Code of Federal Regulations* 761.61(c) for the management of PCBs remediation waste." Since that time, DOE has submitted two risk-based disposal applications to EPA Region 10 for their approval. The first application, titled "Transmittal of Toxic Substance Control Act (TSCA) Risk-Based Disposal Application for the Double Shell Tank (DST) System for 2001," was submitted on January 15, 2002. The second application, titled "Application for Risk-Based Disposal Approval for PCBs Hanford 200 Area Liquid Waste Processing Facilities," was submitted on February 28, 2002. The various action alternatives analyzed in this *TC & WM EIS* will require compliance with the Framework Agreement for PCBs and the resulting PCB remediation waste program.

8.1.5 Radioactive Waste and Materials Management

All the alternatives analyzed for this *TC & WM EIS* involve the management of radioactive waste and materials. Radioactive waste and materials must be managed in compliance with the applicable requirements. Under all alternatives, the radioactive waste and the radioactive components of mixed waste would be stored at Hanford in accordance with applicable DOE requirements. Ultimate treatment and disposal would be conducted in accordance with applicable standards and regulations at Hanford or offsite locations. The waste management sections of Chapter 4 of this EIS provide information on the generation and management of radioactive and mixed wastes under each of the alternatives. The following are brief summaries of potentially applicable radioactive waste and materials management requirements.

Atomic Energy Act of 1954 (42 U.S.C. 2011 et seq.). The AEA provides fundamental jurisdictional authority to DOE and NRC over governmental and commercial use of nuclear materials. The AEA authorizes DOE to establish standards to protect health and minimize dangers to life or property for activities under DOE's jurisdiction. DOE has issued a series of departmental orders to establish an extensive system of standards and requirements to ensure safe operation of DOE facilities. DOE regulations are found in Title 10 of the CFR. The DOE regulations that are the most relevant to radioactive waste and materials management include:

- "Nuclear Safety Management" (10 CFR 830)
- "Occupational Radiation Protection" (10 CFR 835)
- "Byproduct Material" (10 CFR 962)

The AEA also gives EPA the authority to develop generally applicable standards for protection of the general environment from radioactive materials. EPA has promulgated several regulations under this authority. The EPA regulation that is the most relevant to radioactive waste and materials management activities addressed by this EIS is "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes" (40 CFR 191).

Low-Level Radioactive Waste Policy Act of 1980, as amended (42 U.S.C. 2021 et seq.). This act amended the AEA to specify that the Federal Government (i.e., DOE and NRC) is responsible for disposal of LLW. If authorized by NRC under interstate compacts, states may regulate disposal of LLW from commercial sources. DOE remains responsible for the disposition of defense (DOE and U.S. Navy origin) LLW that will require management under any of the alternatives analyzed in this *TC & WM EIS*.

"Licensing Requirements for Land Disposal of Radioactive Waste" (10 CFR 61). The regulations in 10 CFR 61 establish, for land disposal of LLW, the procedures, criteria, and terms and conditions upon which NRC issues licenses for the disposal of radioactive waste containing byproduct, source, and special nuclear material. These regulations do not apply to HLW, or DOE-managed LLW, but do apply to LLW, including waste designated as Class A, B, or C radioactive waste managed in commercial facilities. Disposal facilities for radioactive waste other than DOE-regulated facilities would have to obtain an NRC or agreement state license and comply with these regulations.

Nuclear Waste Policy Act of 1982, as amended (42 U.S.C. 10101 et seq.). The Nuclear Waste Policy Act directed DOE to characterize and evaluate the Yucca Mountain, Nevada, site for suitability as a potential repository for disposal of commercial SNF and HLW. The act also directed the President to evaluate the need for a separate repository for HLW resulting from atomic energy defense activities. On April 30, 1985, President Reagan found "no basis to conclude that a defense only repository is required…" (DOE 1985). As a result of this finding, HLW from atomic energy defense activities may be disposed of in the proposed repository along with SNF. After passage by the U.S. House of Representatives and U.S. Senate, on July 23, 2002, President Bush signed House Joint Resolution 87 approving the site at Yucca Mountain for the development of a repository for the disposal of HLW and SNF, pursuant to the Nuclear Waste Policy Act.

The Secretary of Energy has determined that a Yucca Mountain repository is not a workable option for permanent disposal of SNF and HLW. However, DOE remains committed to meeting its obligations to manage and ultimately dispose of these materials. The Administration has convened the Blue Ribbon Commission on America's Nuclear Future (BRC) to conduct a comprehensive review of policies for managing the back end of the nuclear fuel cycle, including all alternatives for the storage, processing, and disposal of SNF and HLW. The BRC's final recommendations will form the basis of a new solution to managing and disposing of SNF and HLW.

Waste Isolation Pilot Plant Land Withdrawal Act, as amended (P.L. 102-579). The Waste Isolation Pilot Plant Land Withdrawal Act withdrew land from the public domain for the purposes of creating and operating WIPP, the geologic repository in New Mexico designated as the national disposal site for defense TRU waste. In addition to establishing the location for the facility, the Land Withdrawal Act also defines the characteristics and amount of waste that will be disposed of at the facility. The amendments to the Waste Isolation Pilot Plant Land Withdrawal Act exempt waste designated by the Secretary of

Energy for disposal at WIPP from the RCRA land disposal restrictions. However, these amendments do not exempt mixed TRU waste from other RCRA requirements. WIPP does have an RCRA permit and can accept mixed TRU waste. On May 15, 2003, EPA Region 6 approved DOE's request to dispose of TRU waste and mixed TRU waste containing PCBs at WIPP subject to certain "conditions of approval." A decision for disposal at WIPP will not be made until the waste meets the (1) WIPP Waste Acceptance Criteria (DOE 2002), with special emphasis on the waste determination as delineated in the WIPP recertification decision by EPA in March 2006; and (2) regulatory eligibility requirements for disposal as described in the WIPP hazardous waste facility permit.

"Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes" (40 CFR 191). The regulations in 40 CFR 191 establish radiation protection standards for the management and storage of SNF, HLW, and TRU waste at (1) facilities regulated by NRC or agreement states and (2) disposal facilities operated by DOE that are not regulated by NRC or agreement states. The regulations also establish limitations on radiation doses, which may occur after closure of the disposal system. These standards include both individual protection requirements and groundwater protection standards.

Under Tank Closure Alternatives 2B, 3A, 3B, 3C, 4, 5, and 6C, some portion of the tank waste would remain in the tanks after retrieval and be subjected to closure activities as landfills. If the residual waste in some SSTs is defined as TRU waste, the closure of these tanks as landfills could potentially be considered TRU waste disposal as defined by 40 CFR 191. The options that would be available to DOE include (1) managing the closed tanks as a TRU waste disposal site according to 40 CFR 191 requirements or (2) developing alternative disposal criteria through DOE and EPA rulemaking.

DOE Order 435.1, *Radioactive Waste Management* (July 9, 1999; Change 1, August 28, 2001). This order and its associated manual and guidance establish responsibilities and requirements for the management of DOE HLW, TRU waste, LLW, and the radioactive component of mixed waste. These documents provided detailed radioactive waste management requirements, including waste incidental to reprocessing determinations; waste characterization, certification, and TSD; and radioactive waste facility design and closure.

The terms "incidental waste" and "waste incidental to reprocessing" refer to a process for identifying waste streams that are incidental to SNF reprocessing, and are subsequently managed as LLW or TRU waste, if the waste incidental to reprocessing requirements contained in DOE Manual 435.1-1 are met. Thus, it is a process by which DOE can make a determination that, for example, waste residues remaining in tanks, equipment, or transfer lines can be managed as LLW or TRU waste if the requirements in Section II.B of DOE Manual 435.1-1 have been or will be met. These requirements are divided into two processes, the "citation" process and the "evaluation" process.

Waste resulting from processing SNF that is determined to be incidental to reprocessing is not HLW and shall be managed under DOE's regulatory authority in accordance with the requirements for LLW or TRU waste, as appropriate. When determining whether SNF processing plant wastes are another waste type or HLW, either the citation or evaluation process shall be used. In July 2003, parts of DOE Order 435.1 dealing with the procedures for determining waste incidental to reprocessing were declared invalid by the U.S. District Court for the District of Idaho in *Natural Resources Defense Council v. Abraham,* 271 F. Supp.2d 1260 (D. Id. 2003). On November 5, 2004, the court's decision was reversed on appeal by the U.S. Court of Appeals for the Ninth Circuit and remanded to the District Court with instructions to dismiss the case, *Natural Resources Defense Council v. Abraham,* 388 F.3d 701 (9th Cir. 2004). On March 6, 2006, the District Court dismissed the case. Some alternatives analyzed in this *TC & WM EIS* evaluate SST system closure, as well as the disposal, at Hanford, of ILAW, ancillary equipment, WTP melters, and other supplemental-waste streams meeting *Hanford Site Solid Waste Acceptance Criteria* (Fluor Hanford 2005). DOE would proceed with SST system closure and disposal of these wastes only if closure and disposal activities comply with applicable laws. LLW and MLLW disposal facilities that would be sited, constructed, and operated under the alternatives analyzed in this EIS would be subject to the appropriate DOE Manual 435.1-1 requirements. Additionally, closure of HLW facilities, including the tank farms, would also be subject to the DOE Manual 435.1-1 requirements.

DOE Order 430.1B, *Real Property Asset Management* (September 24, 2003; Change 1, February 8, 2008; Change 2, April 25, 2011). This order establishes a corporate, holistic, and performance-based approach to real property life-cycle asset management that links real property asset planning, programming, budgeting, and evaluation to program mission projections and performance outcomes. This order also identifies requirements and establishes reporting mechanisms and responsibilities for real property asset management. Planning for disposition must be initiated when real property assets are identified as no longer required for current or future programs. Disposition includes stabilizing, preparing for reuse, deactivating, decommissioning, decontaminating, dismantling, demolishing, and/or disposing of real property assets. DOE must ensure compliance with this order during the decontamination and closure phases of the activities being considered under Tank Closure Alternatives 2B, 3A, 3B, 3C, 4, 5, 6A, 6B, and 6C; FFTF Decommissioning Alternatives 2 and 3; and Waste Management Alternatives 2 and 3 (see Chapter 2 of this EIS for discussions of alternatives).

8.1.6 Ecological Resources

The action alternatives analyzed for this EIS require new facilities to be constructed and borrow materials to be excavated, which would result in ground disturbances. As a result of potential ground-disturbing activities, DOE is required by certain statutes and other requirements to ensure that proposed activities will not adversely impact the ecological resources located in those areas. The following are summaries of these legal requirements, which also require consultations with the appropriate agency prior to initiation of such actions. Section 8.3 of this chapter discusses DOE activities regarding consultations with the appropriate agency. The specific results of these consultations are provided in the ecological resources sections of Chapter 4.

Bald and Golden Eagle Protection Act of 1973, as amended (16 U.S.C. 668–668d). The Bald and Golden Eagle Protection Act, as amended, makes it unlawful to take, pursue, molest, or disturb bald (American) and golden eagles, their nests, or their eggs anywhere in the United States. A permit must be obtained from the U.S. Department of Interior (DOI) to relocate a nest that interferes with resource development or recovery operations.

Endangered Species Act of 1973, as amended (16 U.S.C. 1531 et seq.). The Endangered Species Act is intended to prevent the further decline of endangered and threatened species and to restore these species and habitats. Section 7 of the act requires Federal agencies having reason to believe that a prospective action may affect an endangered or threatened species or its habitat to consult with the U.S. Fish and Wildlife Service (USFWS) of DOI or the National Marine Fisheries Service of the U.S. Department of Commerce to ensure that the action does not jeopardize the species or destroy its habitat (50 CFR 17). If, despite reasonable and prudent measures to avoid or minimize such impacts, the species or its habitat would be jeopardized by the action, a review process is specified to determine whether the action may proceed as an incidental taking.

U.S. Fish and Wildlife Coordination Act (16 U.S.C. 661 et seq.). The U.S. Fish and Wildlife Coordination Act promotes effective planning and cooperation between Federal, state, public, and private agencies for the conservation and rehabilitation of the Nation's fish and wildlife and authorizes DOI to provide assistance. This act requires consultation with USFWS on the possible effects on wildlife if there is construction, modification, or control of bodies of water in excess of 4 hectares (10 acres) in surface area. This act also requires consultation with the head of the state agency that administers wildlife resources in the affected state.

Migratory Bird Treaty Act of 1918, as amended (16 U.S.C. 703 et seq.). The Migratory Bird Treaty Act, as amended, is intended to protect birds that have common migration patterns between the United States and Canada, Mexico, Japan, and Russia. It regulates the harvest of migratory birds by specifying conditions such as mode of harvest, hunting seasons, and bag limits. The act stipulates that it is unlawful, unless permitted by regulations, to "pursue, hunt, take, capture, kill, attempt to take, capture or kill, possess…any migratory bird…or any part, nest, or egg of any such bird." Although no permit for this project is required under the act, DOE is required to consult with USFWS regarding impacts on migratory birds and to avoid or minimize these effects in accordance with USFWS mitigation policy.

Executive Order 11990, *Protection of Wetlands* (May 24, 1977). This order (implemented by DOE in 10 CFR 1022) requires Federal agencies to avoid any short- or long-term adverse impacts on wetlands wherever there is a practicable alternative. Each agency must also provide opportunity for early public review of any plans or proposals for new construction in wetlands. As discussed in Chapter 4 of this *TC & WM EIS*, because no wetlands exist in the proposed locations, no impact on wetlands is expected under any of the alternatives being considered in this EIS.

8.1.7 Cultural and Paleontological Resources

The action alternatives analyzed for this EIS require new facilities to be constructed and borrow materials to be excavated, which would result in ground disturbances. As a result of potential ground-disturbing activities or the location of these new facilities, DOE is required by certain statutes and other requirements to ensure that proposed activities will not adversely impact the cultural resources located in those areas or to limit access to these culturally important areas. The following are summaries of these legal requirements, some of which require consultations with the appropriate agency and American Indian tribes prior to initiation of such actions. Section 8.3 of this chapter discusses DOE activities regarding consultations with the appropriate agency and American Indian tribes. The specific results of these consultations are provided in the cultural resources sections of Chapter 4.

American Indian Religious Freedom Act of 1978 (42 U.S.C. 1996). This act reaffirms American Indian religious freedom under the First Amendment and sets the United States policy to protect and preserve the inherent and constitutional right of American Indians to believe, express, and exercise their traditional religions. The act requires Federal actions to avoid interfering with access to sacred locations and traditional resources that are integral to the practice of religions.

Antiquities Act of 1906, as amended (16 U.S.C. 431–433). This act protects historic and prehistoric ruins, monuments, and antiquities, including paleontological resources, on federally controlled lands from appropriation, excavation, injury, and destruction without permission. On June 9, 2000 (65 FR 37253), the Hanford Reach was designated as a national monument through Presidential Proclamation No. 7319 under this act. The cultural resources section of Chapter 3 of this EIS provides more information on the Hanford Reach.

Archaeological and Historic Preservation Act of 1960, as amended (16 U.S.C. 469–469c-2). The purpose of this act is to provide for the preservation of historical and archaeological data (including relics and specimens) that might otherwise be irreparably lost or destroyed as a result of Federal actions.

Archaeological Resources Protection Act of 1979, as amended (16 U.S.C. 470aa et seq.). This act requires a permit for any excavation or removal of archaeological resources from Federal or American Indian lands. Excavation must be undertaken for the purpose of furthering archaeological knowledge in the public interest, and resources that are removed are to remain the property of the United States. The law requires that, whenever any Federal agency finds that its activities may cause irreparable loss or destruction of significant scientific, prehistoric, or archaeological data, the agency must notify DOI and may request that DOI undertake the recovery, protection, and preservation of such data. Consent must be obtained from the American Indian tribe or the Federal agency having authority over the land on which a resource is located before issuance of a permit; the permit must contain terms and conditions requested by the tribe or Federal agency.

National Historic Preservation Act of 1966, as amended (16 U.S.C. 470 et seq.). This act states that sites with significant national historic value are to be placed on the National Register of Historic Places (National Register), which is maintained by the Secretary of the Interior. The implementing regulations for this act are located in “Protection of Historic Properties” (36 CFR 800). The major provisions of the act that affect DOE are Sections 106 and 110. Both sections aim to ensure that historic properties are appropriately considered and preserved in planning Federal initiatives and actions. No permits or certifications are required under the act; however, consultation with the State Historic Preservation Officer, Advisory Council on Historic Preservation, American Indian tribes, and the public is required if a Federal undertaking might impact a historic resource. This consultation might result in a memorandum of agreement that includes stipulations to minimize adverse impacts on the historic resource. Coordination with the State Historic Preservation Office is undertaken to ensure that potentially significant sites are properly identified and appropriate mitigation measures are implemented. DOE has submitted documentation to the State Historic Preservation Officer regarding the determination of eligibility for the portion of the *Laliik* traditional cultural property (including Rattlesnake Mountain) that is under DOE’s ownership and management responsibility. In addition, DOE has started consultations under Section 106 with the State Historic Preservation Officer, Advisory Council on Historic Preservation, and American Indian tribes on the possible adverse effects of the use of Borrow Area C for the proposed actions being evaluated in this *TC & WM EIS*. DOE anticipates continuing discussions and consultations with American Indian tribes to address the adverse effects of the proposed actions and alternatives based on the analyses in this *TC & WM EIS*. Copies of the correspondence between DOE and the State Historic Preservation Officer are provided in Appendix C of this EIS.

Programmatic Agreement Among the U.S. Department of Energy Richland Operations Office, the Advisory Council on Historic Preservation, and the Washington State Historic Preservation Office for the Maintenance, Deactivation, Alteration, and Demolition of the Built Environment on the Hanford Site, Washington (August 21, 1996). Among other things, this agreement identified five buildings (405, 436, 4621-W, 4703, and 4710) inside the 400 Area Property Protected Area, which includes FFTF, as eligible for inclusion in the National Register under criterion A as contributing properties recommended for individual documentation (mitigation) within the Hanford Site Manhattan Project and Cold War Era Historic District. Sixteen other buildings also are eligible for inclusion in the National Register as contributing properties within the Cold War Era Historic District, with no individual documentation required.

As a result of this agreement and the implementing sitewide treatment plan, the DOE Richland Operations Office took numerous actions. For instance, the DOE Richland Operations Office completed walkthroughs of the 5 historic buildings that were required to have individual documentation (mitigation) to locate and identify any artifacts that may have interpretive or educational value as potential exhibits within local, state, or national museums. Because of the potential of locating significant artifacts in these facilities, walkthroughs were also conducted in each of the 16 contributing properties that did not require individual documentation. These walkthroughs were completed, and artifacts were identified and tagged in 8 of the buildings. Tagged artifacts will be documented in place or retrieved for delivery to the Columbia River Exhibition of History, Science, and Technology Museum, as appropriate, prior to building demolition. By its own terms, the agreement was in effect until September 30, 2000, and has not been renewed. However, some activities undertaken to comply with the agreement are still ongoing. Unless new actions are proposed that would disturb previously undisturbed areas, these activities completed DOE’s National Historic Preservation Act responsibilities for the 400 Area Property Protected Area, including FFTF.

Native American Graves Protection and Repatriation Act of 1990 (25 U.S.C. 3001 et seq.). The Native American Graves Protection and Repatriation Act directs the Secretary of the Interior to guide Federal agencies in the repatriation of Federal archaeological collections and collections affiliated culturally to American Indian tribes that are currently held by museums receiving Federal funding. This act establishes provisions for the treatment of inadvertent discoveries of American Indian remains and cultural objects. When discoveries are made during ground-disturbing activities, the following steps are to occur: (1) activity in the area of the discovery is to cease immediately; (2) reasonable efforts are to be made to protect the items discovered; (3) notice of discovery is to be given to the Federal agency and the appropriate tribes; and (4) a period of 30 days is to be set aside following notification for negotiations regarding the appropriate disposition of the discovered item(s).

Executive Order 11593, *Protection and Enhancement of the Cultural Environment* (May 13, 1971). This order directs Federal agencies to locate, inventory, and nominate properties under their jurisdiction or control to the National Register, if those properties qualify. This process requires DOE to provide the Advisory Council on Historic Preservation the opportunity to comment on the possible impacts of the proposed activity on any potential eligible or listed resources.

Executive Order 13007, *Indian Sacred Sites* (May 24, 1996). This order directs Federal agencies, to the extent practicable, permitted by law, and not clearly inconsistent with essential agency functions, to (1) accommodate access to and ceremonial use of American Indian sacred sites by their religious practitioners and (2) avoid adversely affecting the physical integrity of such sacred sites. Where appropriate, agencies are to maintain the confidentiality of sacred sites.

Executive Order 13175, *Consultation and Coordination with Indian Tribal Governments* (November 6, 2000). This order supplements the Executive Memorandum (dated April 29, 1994) entitled "Government-to-Government Relations with Native American Tribal Governments" and states that each executive department and agency shall consult, to the greatest extent practicable and to the extent permitted by law, with tribal governments prior to taking actions that affect federally recognized tribal governments. This order also states that each executive department and agency shall assess the impact of Federal Government plans, projects, programs, and activities on tribal trust resources and ensure that tribal government rights and concerns are considered during the development of such plans, projects, programs, and activities.

Executive Order 13195, *Trails for America in the 21st Century* (January 18, 2001). This order states that Federal agencies will, to the extent permitted by law and where practicable—and in cooperation with tribes, states, local governments, and interested citizen groups—protect, connect, promote, and assist trails of all types throughout the United States.

Executive Order 13287, *Preserve America* (March 3, 2003). The goals of the initiative addressed by this order include a greater shared knowledge about the Nation's past, strengthened regional identities and local pride, increased local participation in preserving cultural and natural heritage assets, and support for the economic vitality of our communities. This order establishes Federal policy to provide leadership in preserving America's heritage by actively advancing the protection, enhancement, and contemporary use of the historic properties owned by the Federal Government and by promoting intergovernmental cooperation and partnerships for the preservation and use of historic properties.

DOE Order 144.1, *American Indian Tribal Government Interactions and Policy* (January 16, 2009; Admin Change 1, November 6, 2009). This order communicates responsibilities for interacting with American Indian tribal governments and transmits the DOE *American Indian & Alaska Native Tribal Government Policy*, including its guiding principles. The policy outlines the requirements to be followed by DOE in its interactions with federally recognized American Indian tribes. It is based on the U.S. Constitution, treaties, Supreme Court decisions, Executive orders, statutes, existing Federal policies, tribal laws, and the dynamic political relationship between American Indian nations and the Federal Government. Included in the policy principles is DOE's responsibility to implement a proactive outreach effort of notice and consultation regarding current and proposed actions affecting tribes and to ensure integration of American Indian nations into decisionmaking processes.

DOE Policy 141.1, *Department of Energy Management of Cultural Resources* (May 2, 2001; Certified January 28, 2011). The purpose of this policy is to ensure that DOE programs and field elements integrate cultural resource management into their missions and activities and to raise the level of awareness and accountability among DOE contractors concerning the importance of DOE's cultural resource–related legal and trust responsibilities.

Treaties with American Indian Tribes of the Hanford Region. DOE's relationship with American Indians is based on treaties, statutes, and DOE directives. Representatives of the United States negotiated treaties with leaders of various Columbia Plateau American Indian tribes and bands in June 1855 at Camp Stevens in the Walla Walla Valley. The negotiations resulted in three treaties, one with the 14 tribes and bands of the group that would become the Confederated Tribes and Bands of the Yakama Nation, one with the 3 tribes that would become the Confederated Tribes of the Umatilla Indian Reservation, and one with the Nez Perce Tribe. The U.S. Senate ratified the treaties in 1859. The negotiated treaties are as follows:

- Treaty with the Walla Walla, Cayuse, etc., Tribes (June 9, 1855; 12 Stats. 945)
- Treaty with the Yakama Nation (June 9, 1855; 12 Stats. 951)
- Treaty with the Nez Perce Tribe (June 11, 1855; 12 Stats. 957)

The Confederated Tribes and Bands of the Yakama Nation of the Yakama Reservation, the Confederated Tribes of the Umatilla Indian Reservation, and the Nez Perce Tribe of Idaho are federally recognized tribes that are eligible for funding and services from the U.S. Bureau of Indian Affairs by virtue of their status as Indian tribes (68 FR 68180, December 5, 2003).

The terms of the three preceding treaties are similar. Each of the three tribal organizations agreed to cede large blocks of land to the United States. Hanford is within the ceded lands. The treaties reserved to the tribes certain lands for their exclusive use (the three reservations). The treaties also secured to the tribes certain rights and privileges to continue traditional activities outside the reservations. These included (1) the right to fish at usual and accustomed places in common with citizens of the United States and (2) the privileges of hunting, gathering roots and berries, and pasturing horses and cattle on open and unclaimed lands. No portion of the Hanford Site constitutes open and unclaimed land.

8.1.8 Worker Safety and Health

DOE emphasizes compliance with requirements to ensure worker safety at DOE facilities, which would include the new and existing facilities being addressed by this *TC & WM EIS*. Through DOE regulations and orders, DOE prescribes that contractors meet U.S. Department of Labor Occupational Safety and Health Administration (OSHA) standards applicable to work at Government-owned, contractor-operated facilities and AEA standards to ensure safety of workers from radiation exposure. A summary of worker safety and health requirements is provided below.

Occupational Safety and Health Act of 1970 (29 U.S.C. 651 et seq.). Section 4(b)(1) of the Occupational Safety and Health Act exempts DOE and its contractors from the occupational safety requirements of OSHA. However, 29 U.S.C. 668 requires Federal agencies to establish their own occupational safety and health programs for their places of employment, consistent with OSHA standards. DOE Order 440.1A, *Worker Protection Management for DOE Federal and Contractor Employees*, states that DOE will implement a written worker protection program that (1) provides a place of employment free from recognized hazards that are causing or are likely to cause death or serious physical harm to their employees and (2) integrates all requirements contained in paragraphs 4a to 4l of DOE Order 440.1A; 29 CFR 1960, "Basic Program Elements for Federal Employee Occupational Safety and Health Programs and Related Matters"; and other related site-specific worker protection activities.

"Occupational Radiation Protection" (10 CFR 835). This regulation establishes radiation protection standards, limits, and program requirements for protecting occupational workers and visitors from ionizing radiation resulting from the conduct of DOE activities. These requirements are applicable to general employees involved in activities being considered in this *TC & WM EIS* that have the potential to result in the occupational exposure of an individual to radiation or radioactive materials.

"Worker Safety and Health Program" (10 CFR 851). This regulation establishes requirements for a worker safety and health program that prevents or reduces occupational injuries, illnesses, and accidental losses by providing DOE contractors and their workers with safe and healthful workplaces at DOE sites. This regulation also establishes procedures for investigating whether a violation has occurred, determining the nature and extent of any such violation, and imposing an appropriate remedy.

DOE Order 440.1B, *Worker Protection Program for DOE (Including the National Nuclear Security Administration) Federal Employees* (May 17, 2007). This order establishes the framework for an effective worker protection program that will reduce or prevent injuries, illnesses, and accidental losses by providing safe and healthful DOE Federal and contractor workplaces.

Executive Order 12699, *Seismic Safety of Federal and Federally Assisted or Regulated New Building Construction* (January 5, 1990), as amended by Executive Order 13286 (February 28, 2003). This order requires Federal agencies to (1) reduce risks to occupants of buildings owned, leased, or purchased by the Federal Government or buildings constructed with Federal assistance and to persons who would be affected by failures of Federal buildings in earthquakes; (2) improve the capability of existing Federal buildings to function during or after an earthquake; and (3) reduce earthquake losses of public buildings, all in a cost-effective manner. Each Federal agency responsible for the design and construction of a Federal building shall ensure that the building is designed and constructed in accordance with appropriate seismic design and construction standards.

8.1.9 Radiological Safety Oversight and Radiation Protection

DOE has specific regulations and directives that affect radiological safety during construction, operations, deactivation, and closure of new and existing facilities being addressed by this *TC & WM EIS*. The DOE regulations and directives affecting radiological safety are summarized below.

"Nuclear Safety Management" (10 CFR 830). Specific requirements in these regulations apply to DOE contractors, DOE personnel, and other persons conducting activities (including providing items and services) that affect, or may affect, the safety of DOE nuclear facilities. These regulations include quality assurance (10 CFR 830, Subpart A) and safety-basis (10 CFR 830, Subpart B) requirements. The latter require the contractor responsible for a DOE nuclear facility to analyze the facility, work to be performed and associated hazards, and to identify the conditions, safe boundaries, and hazard controls necessary to protect workers, the public, and the environment from adverse consequences. DOE relies on these analyses and hazard controls to operate facilities safely.

DOE Order 420.1B, *Facility Safety* (December 22, 2005; Change 1, April 19, 2010). This order establishes facility safety requirements related to nuclear and explosives safety design criteria; a comprehensive fire protection program for DOE sites, facilities, and emergency service organizations; nuclear criticality safety (i.e., a criticality safety program applicable to DOE nuclear facilities and activities, including transportation activities, with potential for criticality hazards); natural phenomena hazards mitigation; and a systems engineer program for hazard category 1, 2, and 3 nuclear facilities to ensure continued operational readiness of the systems within its scope. This order requires that all DOE facilities and sites be designed, constructed, and operated so that the public, workers, and environment are protected from impacts of natural phenomena hazards (e.g., earthquake, wind, flood, and lightning). This order applies to design and construction of new DOE hazard category 1, 2, and 3 nuclear facilities, as well as major modifications to such nuclear facilities that could substantially change the approved facility safety analysis.

DOE Order 422.1, *Conduct of Operations* (June 29, 2010). The purpose of this order is to provide requirements and guidelines for DOE to use in developing directives, plans, and/or procedures relating to the conduct of operations at DOE facilities to result in improved quality and uniformity of operations.

DOE Order 425.1D, *Verification of Readiness to Start Up or Restart Nuclear Facilities* (April 16, 2010; Cancels DOE Order 425.1C, March 13, 2003). This order establishes DOE requirements for verifying readiness for the startup of new hazard category 1, 2, and 3 nuclear facilities, activities, and operations and the restart of existing hazard category 1, 2, and 3 nuclear facilities, activities, and operations that have been shut down. The requirements specify a readiness review process (e.g., operational readiness reviews or readiness assessments) that provides an independent verification of readiness to start or restart operations.

DOE Order 458.1, *Radiation Protection of the Public and the Environment* (February 11, 2011; Change 2, June 6, 2011). This order establishes requirements to protect the public and the environment against undue risk from radiation associated with radiological activities conducted under the control of DOE, pursuant to the AEA, as amended.

DOE Order 426.2, *Personnel Selection, Training, Qualification, and Certification Requirements for DOE Nuclear Facilities* (April 21, 2010). This order establishes the selection, training, qualification, and certification requirements for DOE contractor personnel involved in the operation, maintenance, and technical support of DOE nuclear reactors and nonreactor nuclear facilities. DOE objectives under this order are to ensure the development and implementation of contractor-administered training programs that provide consistent and effective training for personnel at DOE nuclear facilities. The order contains minimum requirements that must be included in training and qualification programs.

DOE Order 433.1B, *Maintenance Management Program for DOE Nuclear Facilities* (April 21, 2010). This order defines the safety management program required by 10 CFR 830.204(b)(5) for maintenance and the reliable performance of structures, systems, and components that are part of the safety basis required by 10 CFR 830.202 at hazard category 1, 2, and 3 DOE nuclear facilities. Radiological facilities (e.g., facilities with quantities of hazardous radioactive materials that fall below the hazard category 3 threshold per DOE Standard 1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*) are excluded from the provisions of this order; however, the maintenance management program requirements of DOE Order 430.1B, *Real Property Asset Management*, are applicable to radiological facilities. Radiological facilities that warrant additional controls may apply appropriate requirements of this order until further guidance is issued. A single maintenance program may be used to address the requirements of this order and the requirements of DOE Order 430.1B (discussed in Section 8.1.5 of this chapter).

8.1.10 Transportation

The transportation of all radioactive and other hazardous materials associated with any alternative selected for implementation would need to comply with the applicable DOE directives and EPA, U.S. Department of Transportation (DOT), and Ecology regulations. It is DOE policy (DOE Order 460.2A) that all DOE operations shall be conducted in compliance with all applicable international, Federal, state, local, and tribal laws, rules, and regulations governing materials transportation that are consistent with Federal regulations, unless exemptions or alternatives are approved in accordance with DOE Order 460.2A. The following are summaries of those transportation requirements that are relevant to the transportation of radioactive and other hazardous materials, including mixed TRU waste and TRU waste that would be transported to WIPP under each of the action alternatives and remote-handled special components and bulk sodium that would be transported to the Materials and Fuels Complex at INL for processing or storage under some of the action alternatives.

Hazardous Materials Transportation Act of 1975, as amended (49 U.S.C. 5101 et seq.). The Hazardous Materials Transportation Act of 1975, as amended, requires DOT to prescribe uniform national regulations for transportation of hazardous materials (including radioactive materials). Most state and local regulations regarding such transportation that are not substantively the same as the DOT regulations are preempted (i.e., rendered void) (49 U.S.C. 5125). This, in effect, allows state and local governments only to enforce the Federal regulations, not to change or expand upon them.

This program is administered by the Research and Special Programs Administration of DOT, which, when covering the same activities, coordinates its regulations with NRC (under the AEA) and EPA (under RCRA). DOT regulations, which may be found under 49 CFR 171–178 and 49 CFR 383–397, contain requirements for identifying a material as hazardous or radioactive. These regulations interface with the NRC regulations for identifying material, but DOT hazardous material regulations govern the hazard communication (such as marking, labeling, vehicle placarding, and emergency response information) and shipping requirements. Requirements for transport by rail, air, and public highway are included. EPA regulations (40 CFR 262) govern offsite transportation of hazardous waste. States also have established regulations consistent with DOT regulations. The Ecology regulations applicable to transportation of hazardous waste in Washington State are found in WAC 173-303-240 through 270, for packaging and transporting radioactive materials in WAC 246-231, and for transportation of hazardous materials in WAC 446-50. The State of Idaho regulations for transportation of hazardous materials/waste on highways are found in *Idaho Code* (IC) 49-2200 and *Idaho Code* 18-3900.

Transportation of waste products and contaminated equipment that is conducted entirely on DOE property (i.e., on site), to which public access is controlled at all times through the use of gates and guards, is subject to applicable DOE directives and transportation safety requirements set forth in 10 CFR 830, Subpart B, but is not directly subject to the DOT requirements. DOE transport of these materials over highways to which the public has access would be subject to applicable DOT, EPA, and Ecology regulations, as well as to applicable DOE directives.

"Packaging and Transportation of Radioactive Material" (10 CFR 71). These NRC regulations include detailed packaging design requirements and package certification testing requirements. Complete documentation of design and safety analysis and the results of the required testing are submitted to NRC to certify the package for use. This certification testing involves the following components: heat, physical drop onto an unyielding surface, water submersion, puncture by dropping the package onto a steel bar, and gas tightness.

DOE Order 460.1C, *Packaging and Transportation Safety* (May 14, 2010). This order sets forth DOE policy and assigns responsibilities for the proper packaging and transportation of DOE offsite shipments and onsite transfers of hazardous materials and for modal transport.

DOE Order 460.2A, *Departmental Materials Transportation and Packaging Management* (December 22, 2004). This order states that DOE operations shall be conducted in compliance with all applicable international, Federal, state, local, and tribal laws, rules, and regulations governing materials transportation that are consistent with Federal regulations, unless exemptions or alternatives are approved in accordance with DOE Order 460.1C. This order also states that it is DOE policy that shipments will comply with the DOT 49 CFR 100–185 requirements, except those that infringe upon maintenance of classified information.

8.1.11 Emergency Planning, Pollution Prevention, and Conservation

There are several statutes and Executive orders that require Federal agencies to have in place programs or plans to respond to an emergency resulting from the release of hazardous substances and also to have in place programs that allow for conservation and pollution prevention. DOE is required to implement these programs at its facilities and would be required to ensure that these plans and programs are in place to address activities being considered under any of the alternatives. The following are summaries of these statutes and Executive orders related to emergency planning, pollution prevention, and conservation requirements.

Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (42 U.S.C. 9601 et seq.) (also known as Superfund). CERCLA provides a statutory framework for the remediation of waste sites, including Federal facilities, containing hazardous substances and, as amended by the Superfund Amendments and Reauthorization Act, an emergency response program in the event a release (or threat of a release) of a hazardous substance to the environment occurs. Releases of hazardous substances exceeding reportable quantities must be reported on a timely basis to the National Response Center. Using a hazard-ranking system, Federal and private contaminated sites are ranked and may be included on the National Priorities List. CERCLA requires Federal facilities with contaminated sites to undertake investigations, remediation, and natural resource restoration, as necessary.

Emergency Planning and Community Right-to-Know Act of 1986 (42 U.S.C. 11001 et seq.). Federal facilities are required under Subtitle A of the Emergency Planning and Community-Right-to-Know Act to provide information to EPA and the state and local emergency response offices regarding the inventories of chemicals used or stored at a site and releases from that site. The goal of providing this information is to ensure that emergency plans are sufficient to respond to unplanned releases of hazardous substances. The required information includes inventories of specific chemicals used or stored and descriptions of releases that occur from sites.

Pollution Prevention Act of 1990 (42 U.S.C. 13101 et seq.). The Pollution Prevention Act establishes a national policy for waste management and pollution control. Source reduction is given first preference, followed by environmentally safe recycling, with disposal or releases to the environment as a last resort.

Executive Order 12088, *Federal Compliance with Pollution Control Standards* (October 13, 1978), as amended by Executive Order 12580, *Superfund Implementation* (January 23, 1987). This order directs Federal agencies to comply with applicable administrative and procedural pollution control standards established by, but not limited to, the Clean Air Act, the Noise Control Act, the Clean Water Act, the Safe Drinking Water Act, the Toxic Substances Control Act, and RCRA.

Executive Order 13423, *Strengthening Federal Environmental, Energy, and Transportation Management* (January 24, 2007). This order sets goals for Federal agencies to conduct their environmental, transportation, and energy-related activities under the law in support of their respective missions in an environmentally, economically, and fiscally sound, integrated, continuously improving, efficient, and sustainable manner.

Executive Order 13514, *Federal Leadership in Environmental, Energy, and Economic Performance* (October 5, 2009). This order focuses on improving and strengthening the overall sustainability of the Federal Government. All Federal agencies are required to inventory their greenhouse gas emissions; set targets to reduce their emissions by 2020; and develop a plan for meeting a wide range of goals for improving sustainability, such as water efficiency, waste reduction, sustainable community development planning, high-performance buildings, sustainable acquisition, electronics stewardship, and environmental management.

In accordance with Executive Order 13514, DOE published the *Strategic Sustainability Performance Plan–Discovering Sustainable Solutions to Power and Secure America's Future* (DOE 2010) in September 2010. The Strategic Sustainability Performance Plan, to be updated annually and progress towards its goals reported, includes the following: (1) sustainability goals and targets, including greenhouse gas reduction targets; (2) integration with overall strategic planning and budgeting processes within the DOE; (3) activities, policies, plans, procedures, goals, schedules, and milestones needed to implement Executive Order 13514; (4) performance metrics and evaluation of projects based on lifecycle return on investment; (5) involvement of DOE employees in achieving the sustainability goals; and (6) climate change adaptation planning.

8.1.12 Environmental Justice and Protection of Children

There are two Executive orders that require Federal agencies to identify and address environmental risks to certain populations when planning a major Federal action such as those activities being considered in this *TC & WM EIS*. The following are summaries of these two orders.

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations* (February 11, 1994). This order requires each Federal agency to identify and address disproportionately high and adverse human health and environmental effects of its programs, policies, and activities on minority and low-income populations.

The CEQ, which oversees the Federal Government's compliance with Executive Order 12898 and NEPA, has developed guidelines to assist Federal agencies in incorporating the goals of Executive Order 12898 in the NEPA process. This guidance, published in 1997, was intended to "…assist Federal agencies with their NEPA procedures so that environmental justice concerns are effectively identified and addressed." As part of this process, DOE has performed an analysis to determine whether implementing any of the proposed alternatives would result in disproportionately high or adverse impacts on minority or low-income populations. The results of this analysis are discussed in the environmental justice sections of Chapter 4 of this EIS for each of the alternatives under consideration.

Executive Order 13045, *Protection of Children from Environmental Health Risks and Safety Risks* (April 21, 1997), as amended by Executive Order 13229 (October 9, 2001). This order requires each Federal agency to make it a high priority to identify and assess environmental health risks and safety risks that may disproportionately affect children and to ensure that its policies, programs, activities, and standards address disproportionate risks to children that result from environmental health risks or safety risks.

8.2 PERMITS

Information on the status of existing environmental permits at Hanford is discussed in the *Hanford Site Environmental Report for Calendar Year 2010 (Including Some Early 2011 Information)* (Poston, Duncan, and Dirkes 2011). Included is information on environmental permitting for DOE activities at Hanford required by environmental laws and regulations, such as RCRA; the Toxic Substances Control Act; the Clean Air Act; the Clean Water Act; the state wastewater discharge permit; the onsite sewage system permit; and the NPDES permits, including stormwater permits. In compliance with applicable laws and regulations, the following is a summary of key environmental permits currently held at Hanford and INL.

Hanford is considered a single facility for purposes of RCRA and the Washington State Hazardous Waste Management Act. The site has been issued EPA/state identification No. WA7890008967. The Hanford

RCRA permit governs all final-status TSD activities at Hanford (Duncan 2007). The Hanford RCRA permit was originally issued in two portions, one issued by EPA Region 10 and the other by Ecology. The EPA portion of the Hanford RCRA permit covered the Hazardous and Solid Waste Amendments. The Ecology portion of the permit covered compliance with Ecology's dangerous waste regulations, as well as standard conditions, general facility conditions, and specific conditions for the individual TSD units and TSD units undergoing corrective action or closure (Duncan 2007). The 10-year period for the permit, as specified by the regulations, ended on September 27, 2004, and DOE continues to operate under the old permit until a revised permit is issued by Ecology. Ecology is now fully authorized to implement the dangerous waste program in lieu of the Federal RCRA program; therefore, there is no need or authority for EPA to separately issue a hazardous solid waste amendment component of the Hanford permit (Bartus 2008).

The DST farms continue to operate under interim status requirements. A Part B permit application for the DSTs was submitted to Ecology in 2005. The TPA lays out the process and authority to operate non-RCRA-compliant SSTs pending closure and identifies the process and procedures for SST system closure. A final RCRA Part B permit is being obtained for the WTP on an incremental basis as the design matures. A Part B permit application for the 200-East Area Integrated Disposal Facility was submitted to Ecology in 2005. Any new or modified TSD units would require a modification of the Hanford RCRA permit. An RCRA Part B permit application for the 200-East Area Integrated Disposal Facility was submitted to Ecology in 2005.

DOE has submitted two risk-based disposal applications to EPA Region 10 for their approval. The first application, titled "Transmittal of Toxic Substance Control Act (TSCA) Risk-Based Disposal Application for the Double Shell Tank (DST) System for 2001," was submitted on January 15, 2002. The second application, titled "Application for Risk-Based Disposal Approval for PCBs Hanford 200 Area Liquid Waste Processing Facilities," was submitted on February 28, 2002.

The 400 Area waste management unit is currently permitted under the Hanford RCRA permit. The 400 Area waste management unit stores mixed waste (i.e., sodium residuals-contaminated waste) generated from FFTF deactivation activities in the FFTF Fuel Storage Facility and the 400 Area Interim Storage Area. Once this waste is treated, removed, and disposed of, appropriate closure of the 400 Area waste management unit facilities would be done under applicable regulations.

IDEQ administers the requirements of RCRA through the Idaho Hazardous Waste Management Act. The Idaho hazardous waste regulations are found in IDAPA 58.01.05 (ANL-W and Fluor Hanford 2002).

The Sodium Processing Facility (SPF) at Idaho obtained an Idaho Hazardous Waste Management Act/RCRA hazardous waste treatment and storage permit in January 1997. The SPF is permitted in accordance with IDAPA 58.01.05.008/40 CFR 264 for tank and container treatment and storage. This hazardous waste operating permit allows for the treatment and storage of sodium, sodium potassium, and caustic (sodium and potassium hydroxide). No SPF Idaho Hazardous Waste Management Act/RCRA permit modifications are anticipated that would be required for treatment and storage of FFTF sodium in the SPF whether the sodium is classified as product or hazardous waste (ANL-W and Fluor Hanford 2002).

Hanford Site Air Operating Permit No. 00-05-006, Renewal 1, covers operations at Hanford having a potential to emit airborne emissions. This permit became effective on January 1, 2007, and expired on January 1, 2012. Another renewal is pending. The permit is intended to provide a compilation of applicable Clean Air Act requirements for both radioactive and nonradioactive emissions at Hanford. It is implemented through Federal and state programs (Poston, Duncan, and Dirkes 2011:D.2).

DOE holds a license (No. FF-01), issued by the Washington State Department of Health, covering airborne radioactive emissions from Hanford operations. The license is incorporated as Attachment 2 in the Hanford Site Air Operating Permit (Poston, Duncan, and Dirkes 2011:D.2).

The State of Idaho issued to INL a Tier I operating permit under Title V of the Clean Air Act, with an effective date of June 28, 2005 (DOE 2006b:2.1). A Notice of Construction was prepared according to requirements of WAC 246-247, "Radiation Protection – Air Emissions," and 40 CFR 61 Subpart H, for the Sodium Storage Facility and submitted to EPA and the Washington State Department of Health. The final Notice of Construction was approved on February 24, 1995. A Notice of Construction would be required for the Sodium Reaction Facility, if it is constructed at Hanford (ANL-W and Fluor Hanford 2002).

A NESHAPs application (40 CFR 61) for the SPF was submitted to EPA Region 10 on December 19, 1995; approval for construction was granted in February 1996. EPA Region 10 granted approval for construction on February 5, 1996 (ANL-W and Fluor Hanford 2002). DOE-Chicago received an approved permit from IDEQ to construct the SPF on September 29, 1995, with subsequent amendments and approval on September 26, 2000. IDEQ found the SPF treatment and storage operations met the provisions of IDAPA 58.01.01 "Rules for the Control of Air Pollution in Idaho" (ANL-W and Fluor Hanford 2002).

Assuming that the radionuclide concentrations for Hanford sodium would not exceed the permitted radionuclide emissions from the SPF, no modification for the NESHAPs application would be necessary. Additionally, no modification is expected for the SPF permit to construct, as no other air contaminants, other than those currently specified in the permit to construct, are identified in FFTF sodium.

There is one NPDES permit (No. WA-002591-7) issued by EPA for Hanford. The permit covers two active outfalls: outfalls 003 and 004 in the 100-K Area. The outfall for the 300 Area Treated Effluent Disposal Facility was removed from the permit in 2009 because the facility was shut down (Poston, Duncan, and Dirkes 2010:D.2; 2011:D.2).

EPA's NPDES Storm Water Multi-Sector General Permit No. WAR05A57F established the terms and conditions under which stormwater discharges associated with industrial activity are authorized. The permit was issued in 2000 and expired on October 30, 2005. Facilities that obtained coverage under the 2000 Multi-Sector General Permit prior to its expiration were automatically granted an administrative continuance of permit coverage. CH2M HILL Plateau Remediation Company terminated coverage under this permit on June 22, 2009. A new permit (No. WAR10B90F) took effect on June 3, 2009, that governed stormwater discharges (Poston, Duncan, and Dirkes 2010:D.2). This permit was terminated on March 18, 2010, and has not been renewed (Poston, Duncan, and Dirkes 2011:D.2).

Hanford has five state wastewater discharge permits for the discharge or disposal of wastewater to groundwater (Permit Nos. ST 4500, ST 4501, ST 4502, ST 4507, and ST 4511), issued by Ecology (Poston, Duncan, and Dirkes 2011:D.2).

DOE has asserted a federally reserved water withdrawal right with respect to its Hanford operations. Current Hanford activities use water withdrawn under DOE's federally reserved water rights (Duncan 2007).

The INL site complies with four Clean Water Act permits through implementation of procedures, policies, and best management practices. These four permits are: Section 404 Permit for dredge and fill activities; discharges from Idaho Falls facilities to the City of Idaho Falls publicly owned treatment works; NPDES General Permit for Storm Water Discharges from Industrial Activities; and NPDES General Permit for Storm Water Discharges from Construction Activities (DOE 2006b:2.12).

DOE would obtain the required permits or permit modifications for any new or modified facility associated with proposed *TC & WM EIS* activities. In particular, DOE would need to obtain permits and approvals for (1) construction and operation of new treatment facilities (i.e., supplemental treatment facilities); (2) modifications to currently planned or existing treatment facilities (e.g., the WTP, 200 Area Effluent Treatment Facility, Liquid Effluent Retention Facility, T Plant complex, Waste Receiving and Processing Facility); (3) construction and operation of new or modified waste storage facilities (e.g., canister storage modules, WTP melter pads, the Central Waste Complex); (4) construction, operation, and closure of disposal facilities (i.e., one or two Integrated Disposal Facilities and the River Protection Project Disposal Facility); and (5) closure of storage facilities (i.e., the SST system, including ancillary equipment). Table 8–2 provides a list of potential future permits, permit modifications, or approvals that may be required at Hanford as a result of activities discussed under the action alternatives in this *TC & WM EIS*.

Table 8–2. Potential Permits and Approvals Needed for *TC & WM EIS* Activities

Activity	Regulatory Action	Requirement	Regulatory Agency
Air emissions (nonradioactive)	Notice of Construction (approval) and sitewide air operating permit (permit modification)	40 CFR 61 WAC 173-400 WAC 173-460 IDAPA 58.01.01	Ecology and EPA; Idaho Department of Environmental Quality
Air emissions (radioactive)	Notice of Construction (approval) and sitewide air operating permit (permit modification)	40 CFR 61 WAC 173-400 WAC 246-247	Washington State Departments of Health and Ecology; EPA; Idaho Department of Environmental Quality
Dangerous (including mixed) waste generation, treatment, storage and disposal	Dangerous waste and RCRA permit (permit modification)	40 CFR 260–280 WAC 173-303 IDAPA 58.01.05	Ecology; Idaho Department of Environmental Quality
Dangerous (including mixed) waste facility closure	Dangerous waste permit, RCRA permit (permit modification) and closure plan/postclosure plan (approvals)	40 CFR 260–280 WAC 173-303 IDAPA 58.01.05	Ecology; Idaho Department of Environmental Quality
Radiological	Disposal authorization statement, waste incidental to reprocessing determination, and authorization to proceed with closure activities statement (approvals)	DOE Manual 435.1-1	DOE
Water effluents	NPDES (permit modification) and stormwater discharge (permit modification)	40 CFR 122	EPA
Water quality	Public water system (permit modification); Sanitary wastewater – onsite sewage system (permit modification)	40 CFR 141–149; WAC 246-272	Washington State Board of Health and Washington State Department of Health; Washington State Department of Health

Key: CFR=*Code of Federal Regulations*; DOE=U.S. Department of Energy; Ecology=Washington State Department of Ecology; EPA=U.S. Environmental Protection Agency; IDAPA=Idaho Administrative Procedures Act; NPDES=National Pollutant Discharge Elimination System; RCRA=Resource Conservation and Recovery Act; *TC & WM EIS*=*Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*; WAC=*Washington Administrative Code*.

8.3 CONSULTATIONS

Certain laws, such as the Endangered Species Act, U.S. Fish and Wildlife Coordination Act, and National Historic Preservation Act, require consultation and coordination by DOE with other governmental entities, including other Federal agencies, state and local agencies, and federally recognized American Indian governments. In addition, the *American Indian Tribal Government Interactions and Policy* (DOE Order 144.1) requires consultation, including, but not limited to (1) providing for mutually agreed-upon protocols for timely communication, coordination, and collaboration prior to taking actions that could impact American Indian and Alaska Native nations to determine the impact on traditional and cultural ways of life, natural resources, and treaty and other federally reserved rights, and (2) involving appropriate tribal officials and representatives throughout the decisionmaking process (including final decisionmaking and action implementation as allowed by law), consistent with a government-to-government relationship. Most of these consultations are related to biotic resources, cultural resources, and American Indian rights.

The biotic resource consultations generally pertain to the potential for activities to disturb sensitive species or habitats. Cultural resource consultations relate to the potential for disruption of important cultural resources and archaeological sites. American Indian consultations are concerned with the potential for impacts on any rights and interests, including disturbance of ancestral American Indian sites, traditional practices of American Indians, and natural resources of importance to American Indians.

DOE has performed consultations with the appropriate State Historic Preservation Officers, as required by NEPA and Section 106 of the National Historic Preservation Act; USFWS, as required by the Endangered Species Act of 1973, the Bald and Golden Eagle Protection Act, and the Migratory Bird Treaty Act; the National Oceanic and Atmospheric Administration, as required by the Endangered Species Act; and the appropriate state regulators, as required by Washington State laws or regulations. These consultations began in 2002 during the initial preparation of the "Tank Closure EIS" and continued with the newly scoped *TC & WM EIS*. A list of those organizations consulted for the "Tank Closure EIS" consultation process is provided in Table 8–3 and for this *TC & WM EIS*, in Table 8–4. The specific results of the consultation process are presented in Chapter 4 of this EIS. Copies of the correspondence to these agencies and responses received are provided in Appendix C of this EIS. DOE also initiated consultations with the appropriate American Indian tribal governments for the "Tank Closure EIS," which continued with the newly scoped *TC & WM EIS*, as required by the Executive Memorandum (dated September 23, 2004) entitled, "Government-to-Government Relationship with Tribal Governments" (White House 2004) and DOE Order 144.1, *American Indian Tribal Government Interactions and Policy*.

Table 8–3. Organizations Contacted During the Consultation Process for the "Tank Closure EIS"

Subject	Addressee (Date of Letter)
Ecological resources	Mr. Mark Miller U.S. Fish and Wildlife Service (June 16, 2003)
	Mr. Dennis Carlson National Oceanic and Atmospheric Administration (June 16, 2003)
	Mr. Jeff Tayer Washington State Department of Fish and Wildlife (June 16, 2003)
	Ms. Sandy Swope Moody Washington State Department of Natural Resources (June 16, 2003)
Cultural resources	Dr. Allyson Brooks Washington State Department of Archaeology and Historic Preservation (August 12, 2003, and September 3, 2003)

Key: "Tank Closure EIS"="Environmental Impact Statement for Retrieval, Treatment, and Disposal of Tank Waste and Closure of Single-Shell Tanks at the Hanford Site, Richland, Washington."

Table 8–4. Organizations Contacted During the Consultation Process for This *TC & WM EIS*

Subject	Addressee (Date of Letter)
Ecological resources	Mr. Mark Miller U.S. Fish and Wildlife Service (June 12, 2008)
	Mr. Dennis Carlson National Oceanic and Atmospheric Administration (June 12, 2008)
	Mr. Jeff Tayer Washington State Department of Fish and Wildlife (June 12, 2008)
	Ms. Sandy Swope Moody Washington State Department of Natural Resources (June 12, 2008)
Cultural resources	Dr. Allyson Brooks Washington State Department of Archaeology and Historic Preservation (April 6, 2007)
	Mr. John M. Fowler Advisory Council on Historic Preservation (April 10, 2007)
	Dr. Allyson Brooks Washington State Department of Archaeology and Historic Preservation (July 30, 2007)
	Mr. John M. Fowler Advisory Council on Historic Preservation (September 5, 2007)
	Dr. Allyson Brooks Washington State Department of Archaeology and Historic Preservation (September 25, 2007)
	Mr. John M. Fowler Advisory Council on Historic Preservation (November 2, 2007)

Key: *TC & WM EIS=Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*.

In addition to the formal consultation process, DOE initiated many staff-to-staff discussions during the development of this EIS. Many communications occurred during quarterly meetings during the development of the *Draft TC & WM EIS*. A chronology of the consultation process and communications with the American Indian tribal governments for the "Tank Closure EIS" and for this *TC & WM EIS* is provided in Appendix C of this EIS. Information in Appendix C is separated into sections that cover formal correspondence, as well as staff-to-staff dialogue. Developments since the *Draft TC & WM EIS* was issued in October 2009 are listed in this *Final TC & WM EIS*. The following is a summary that represents interactions related to the entire *TC & WM EIS* development.

Representatives from five of the area tribes were offered an opportunity to participate in the cultural surveys done for the alternatives in August 2003 and again in April 2007, when the scope of this *TC & WM EIS* was expanded. In November 2004, the tribes were approached by DOE regarding the tribal scenario to be presented in this *TC & WM EIS*. The goal was to run one scenario to allow the analysis to focus on differences between potential impacts of a tribal scenario in comparison to other human health scenarios. There were discussions from November 2004 through January 2005 between DOE and tribal staff on the details of the representative tribal scenario. The Confederated Tribes of the Umatilla Indian Reservation's scenario was selected as the starting point. In January 2005, an agreement was reached on the specifics, resulting in a few modifications to this scenario (a copy of which is provided in Appendix W of this EIS). During this time, information on tribal scenarios continued to evolve. On September 11, 2007, the Confederated Tribes and Bands of the Yakama Nation submitted its tribal scenario to DOE. Between October 2007 and December 2007, efforts were made by DOE and the Yakama Nation to meet on questions related to the Yakama Nation's tribal scenario. In addition, in October 2007, the Yakama Nation indicated its desire for no additional consultation prior to release of the

Draft TC & WM EIS. Due to this request and the unresolved questions regarding the scenario, the *Draft TC & WM EIS* evaluated the one tribal scenario agreed to in January 2005. During the public comment process, requests were made to present the Yakama and Umatilla tribal scenarios independently. DOE understands the concerns expressed regarding the American Indian scenarios evaluated in the *Draft TC & WM EIS*. DOE believes that both the resident farmer and hunter-gatherer scenarios consider the reasonable range of exposure pathways. However, in response to this comment, DOE has reviewed regulatory guidance and tribal recommendations regarding this scenario and has increased the fish intake for the American Indian hunter-gatherer. DOE has provided more information and the technical basis for intake rates for all receptors in Appendix Q of this EIS.

The January 6, 2006, Settlement Agreement in re *State of Washington v. Bodman* (subsequently amended on June 5, 2008) called for an expansion of the existing "Tank Closure EIS," which is this *TC & WM EIS*. The purpose of this expansion was to provide an integrated set of groundwater analyses. In addition, DOE decided to use a commercially available modeling code and additional outreach activities were planned relating to the modeling and expanded scope. The Technical Review Group, made up of modeling experts from academia and industry, was established to provide an independent perspective (Appendix C, Section C.3, of this *TC & WM EIS* describes this in more detail). The tribal members were asked to identify potential representatives for the Technical Review Group. Several members were identified by the tribes but were not selected either because they had conflicting commitments during the needed timeframe or they did not meet the panel criteria. The tribal staff indicated they were not going to participate in the model development. On January 17, 2007, DOE and tribal representatives met and reached agreement on a Public Information Outreach Plan (see Appendix C, Table C–1 of this *TC & WM EIS*). DOE and tribal representatives agreed to a schedule and participation expectations for a series of workshops. Tribal representatives or their consultants were offered an opportunity to present information related to their views at workshops where applicable. This information was evaluated in development of the *Draft TC & WM EIS*. Details of those activities are identified in Appendix C, Table C–3 of this *TC & WM EIS*.

On February 27, 2007, a list of all the reference documents reviewed to support the cumulative impacts analysis was sent to the tribes, along with a request for any additional information or documents they would like DOE to consider. No additional information was received by DOE.

On April 6, 2007, DOE initiated the National Historic Preservation Act Section 106 process related to the use of Borrow Area C, including Rattlesnake Mountain. As a result, a draft MOU was prepared and shared with the tribes on September 18, 2007. The tribes had requested that information be available in the draft EIS before providing feedback on the potential mitigation methods. The tribes indicated that they would prefer seeing the draft EIS prior to development of the MOU so more-accurate comments could be provided. DOE agreed to allow the tribes to wait until after the draft EIS was published to develop the MOU. Since the draft was issued, DOE has continued consultation with the tribal nations on the possible adverse effects of the proposed actions and alternatives evaluated in this *TC & WM EIS*.

On November 7, 2007, letters were sent to the tribes requesting they provide their unique tribal perspective on the *Draft TC & WM EIS*. Although no information was provided in time to support the preparation of the *Draft TC & WM EIS*, three tribes (i.e., Confederated Tribes and Bands of the Yakama Nation, Confederated Tribes of the Umatilla Indian Reservation, and Nez Perce) provided this information for inclusion in this *Final TC & WM EIS*. These American Indian tribal governments' perspectives on the cleanup of Hanford are provided in Appendix W of this *TC & WM EIS*.

In addition to tribal consultation and communication, DOE used other forums for outreach during the development of this *TC & WM EIS*. A summary of the interactions with the Hanford Advisory Board and Oregon Hanford Cleanup Board is provided in Appendix C.

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CHAPTER 9
GLOSSARY

absorbed dose – The energy imparted to matter by ionizing radiation per unit mass of the irradiated material (e.g., biological tissue). The units of absorbed dose are the rad and the gray. (One rad equals 0.01 grays, which equals 100 ergs per gram of material.) (See *erg*, *gray*, *ionizing radiation*, *irradiated*, and *radiation absorbed dose [rad]*.)

accelerator (particle) – An apparatus for imparting high velocities by electromagnetic or electrostatic means to charged particles (as electrons) that are generated in the apparatus, accelerated in controlled paths to a state of high energy, and focused continuously until they emerge as a stream of high-speed projectiles. (See *electron*.)

accident – In the context of this environmental impact statement, a specific, identifiable, unexpected, unusual, and unintended event or sequence of events that results in undesirable consequences.

accident sequence – In regard to nuclear facilities, an initiating event followed by system failures or operator errors that could result in significant core damage, confinement system failure, and/or radionuclide releases.

acid – A chemical compound with a pH value lower than 7.0. (See *pH*.)

actinide – Any member of the group of elements with atomic numbers 89 (actinium) to 103 (lawrencium), including uranium and plutonium. All members of this group are radioactive. (See *atomic number* and *radioactivity*.)

activation energy – The minimum amount of energy required to initiate a chemical reaction.

activation product – An element that is formed by absorption of neutrons, protons, or other nuclear particles and thus may be radioactive. (See *neutron* and *proton*.)

active fault – A fault where another earthquake is likely sometime in the future. Faults are commonly considered to be active if they have moved one or more times in the last 10,000 years. (See *fault*.)

activity – (1) A measure of the amount of radiation emitted from a radioactive material, expressed in either becquerels or curies. (See *becquerel* and *curie*.) (2) An action, operation, or effort.

Acute Exposure Guideline Levels (AEGLs) – Threshold values published by the National Research Council and National Academy of Sciences for use in chemical emergency planning, prevention, and response programs. AEGLs represent threshold exposure limits for the general population, including susceptible individuals, and are developed for exposure periods of 10 minutes, 30 minutes, 1 hour, 4 hours, and 8 hours. AEGL values are defined for varying degrees of severity of toxic effects, as follows:

> **AEGL-1:** The airborne level of concentration of a substance above which the exposed population could experience notable discomfort, irritation, or certain asymptomatic nonsensory effects. However, the effects would not be disabling and would be transient and reversible upon cessation of exposure.
>
> **AEGL-2:** The airborne level of concentration of a substance above which the exposed population could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.
>
> **AEGL-3:** The airborne level of concentration of a substance above which the exposed population could experience life-threatening health effects or death.

additive – The property whereby the total effect of multiple agents is the sum of effects of the agents acting separately under the same conditions.

administrative control – Provisions related to organization and management, procedures, record-keeping, assessment, and reporting that are necessary to ensure safe operation of a facility.

adsorption – A "taking up" by physical or chemical forces of the molecules of gases, dissolved substances, or liquids by the surfaces of solids or liquids with which they are in contact.

AEGL-1, -2, and -3 – See *Acute Exposure Guideline Levels*.

affected environment – The existing biological, physical, social, and economic conditions of an area that are subject to direct and/or indirect changes as a result of a proposed human action.

air pollutant – Generally, an airborne substance that, in sufficiently high concentrations, could harm living things or cause damage to materials. From a regulatory perspective, air pollutants are substances for which emissions or atmospheric concentrations are regulated or for which maximum guideline levels have been established to enable assessment of their potential for harmful effects on human health and welfare.

air quality – The cleanliness of the air as measured by the levels of pollutants relative to the standards or guideline levels established to protect human health and welfare.

air quality control region – Geographic subdivisions of the United States that were established to deal with pollution on a regional or local level. Some regions span more than one state.

ALARA – See *as low as is reasonably achievable*.

alkaline – Having the properties of a soluble mineral salt capable of neutralizing acids.

alluvium (alluvial) – Unconsolidated, poorly sorted detrital sediments deposited by streams and ranging in size from clay to gravel.

alpha activity – The emission of alpha particles by radioactive materials. (See *alpha particle*.)

alpha particle – A positively charged particle ejected spontaneously from the nuclei of some radioactive elements. It is identical to a helium nucleus and has a mass number of 4 and an electrostatic charge of +2. It has low penetrating power and a short range (a few centimeters in air). (See *alpha radiation*.)

alpha radiation – A strongly ionizing, but weakly penetrating, form of radiation consisting of positively charged alpha particles emitted spontaneously from the nuclei of certain elements during radioactive decay. Alpha radiation is the least penetrating of the three common types of ionizing radiation (alpha, beta, and gamma). Even the most energetic alpha particle generally fails to penetrate the dead layers of cells covering the skin and can be easily stopped by a sheet of paper. Alpha radiation is most hazardous when an alpha-emitting source resides inside an organism. (See *alpha particle*, *ionizing radiation*, and *radioactive decay*.)

alternative – One of two or more actions, processes, or propositions from which a decisionmaker will determine the course to be followed. The National Environmental Policy Act (NEPA) of 1969, as amended, states that in preparing an environmental impact statement (EIS), an agency "shall ... study, develop, and describe appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources" (Title 42 of the *United States Code*, Section 4322(2)(E)). Council on Environmental Quality NEPA-implementing regulations indicate that the alternatives section in an EIS is "the heart of the environmental impact statement" (Title 40 of the *Code of Federal Regulations*, Section 1502.14) and include rules for presenting the alternatives, including no action, and their estimated impacts.

ambient – Surrounding.

ambient air – The atmosphere surrounding people, plants, and structures.

ambient air quality standards – As prescribed by regulations, the level of pollutants in the air that may not be exceeded during a specified time in a defined area. Air quality standards are used to provide a measure of the health-related and visual characteristics of the air.

amphibian – Class of cold-blooded, scaleless vertebrates that usually begin life with gills and then develop lungs.

anadromous – Fish (such as salmon) that ascend freshwater streams from saltwater bodies of water to spawn.

ancillary equipment – Structures associated with tank operations, including miscellaneous underground storage tanks; the waste transfer system (diversion boxes, valve pits, and transfer piping); tank pits; tank risers; in-tank equipment; and miscellaneous facilities used in the treatment, transfer, or storage of tank waste. (See *miscellaneous underground storage tanks*.)

anion – A negatively charged ion. (See *ion*.)

annulus – The space between the inner and outer shells of a double-shell tank. (See *double-shell tank*.)

antagonistic – Opposing or counteracting the effects of something else.

aquatic – Living or growing in, on, or near water.

aquatic biota – The sum total of living organisms within any designated aquatic area.

aquifer – An underground geologic formation, group of formations, or part of a formation that is capable of yielding a significant amount of water to wells or springs.

aquitard – A semipermeable geologic unit that inhibits the flow of water.

archaeological sites – Any location where humans have discarded artifacts or otherwise altered the terrain during prehistoric or historic times.

area use factor – The ratio of the size of an organism's home, breeding, or feeding/foraging range to the size of a contamination area; if the home range is larger than the contamination area, then the area use factor is unity (1).

artifact – An object produced or shaped by human workmanship that is of archaeological or historical interest.

as low as is reasonably achievable (ALARA) – An approach to radiation protection used to manage and control worker and public exposures (individual and collective) and releases of radioactive material to the environment to as far below applicable limits as social, technical, economic, practical, and public policy considerations permit. ALARA is not a dose limit; it is instead a process for minimizing doses to as far below limits as is practicable.

atmospheric dispersion – The distribution of pollutants from their source into the atmosphere by wind, turbulent air motion attributable to solar heating of Earth's surface, or air movement over rough terrain and variable land and water surfaces.

Atomic Energy Act – A law enacted in 1946 and amended in 1954 (Title 42 of the *United States Code*, Part 2011 et seq.) that placed nuclear production and control of nuclear materials under the oversight of a civilian agency, originally the Atomic Energy Commission. (See *Atomic Energy Commission*.)

Atomic Energy Commission (AEC) – A five-member commission established by the Atomic Energy Act of 1946 (Title 42 of the *United States Code*, Part 2011 et seq.) to supervise nuclear weapons design, development, manufacturing, maintenance, modification, and dismantlement. In 1974 AEC was abolished, and all its functions were transferred to the U.S. Nuclear Regulatory Commission and the Administrator of the Energy Research and Development Administration (ERDA). ERDA was later terminated, and functions vested by law in the Administrator were transferred to the Secretary of Energy. (See *Atomic Energy Act* and *U.S. Nuclear Regulatory Commission*.)

atomic number – The number of positively charged protons in the nucleus of an atom or the number of electrons on an electrically neutral atom. (See *electron* and *proton*.)

attainment area – An area that the U.S. Environmental Protection Agency has designated as in compliance with one or more of the National Ambient Air Quality Standards for sulfur dioxide, nitrogen dioxide, carbon monoxide, ozone, lead, and particulate matter. An area may be in attainment for some pollutants but not for others. (See *National Ambient Air Quality Standards*, *nonattainment area*, and *particulate matter*.)

attenuate – In the context of this environmental impact statement: (1) To reduce the concentration over time of a chemical (usually through adsorption, degradation, dilution, and/or transformation) or radionuclide (through radioactive decay). (See *adsorption* and *radioactive decay*.) (2) To dissipate, e.g., certain geologic strata tend to dissipate (attenuate) seismic energy.

backfill – Excavated earth or other material transferred into an open trench, cavity, or other opening in the earth.

background radiation – Radiation from cosmic sources; naturally occurring radioactive materials, including radon (except as a decay product of source or special nuclear material); and atmospheric fallout (e.g., from the testing of nuclear explosive devices).

barrier – Any material or structure that prevents or substantially delays movement of constituents toward the accessible environment, especially an engineered structure used to isolate contaminants from the environment in accordance with appropriate regulations. (See *cap*, *Hanford barrier*, and *modified RCRA Subtitle C barrier*.)

basalt – The most common volcanic rock, dark gray to black in color, high in iron and magnesium, low in silica, and typically found in lava flows.

base – A chemical compound with a pH value higher than 7.0. (See *pH*.)

baseline – The existing environmental conditions against which the impacts of the proposed actions and their alternatives can be compared.

basin – Geologically, a circular or elliptical downwarp or depression in Earth's surface that collects sediment. Younger sedimentary beds occur in the center of basins. Topographically, a depression into which water from the surrounding area drains.

becquerel – A unit of radioactivity equal to one disintegration per second. Thirty-seven billion becquerels equal 1 curie. (See *curie* and *radioactivity*.)

bedrock – The solid rock that lies beneath soil and other loose surface materials.

BEIR V – The fifth in a series of committee reports from the National Research Council on the biological effects of ionizing radiation, published in 1990. (See *BEIR VII* and *ionizing radiation*.)

BEIR VII – The seventh in a series of committee reports from the National Research Council on the biological effects of ionizing radiation, published in 2006. BEIR VII updates BEIR V, using epidemiologic and experimental research information accumulated since the BEIR V report to develop the best possible risk estimate for exposure experienced by radiation workers and members of the general public. (See *BEIR V* and *ionizing radiation*.)

benchmark – Dose or concentration known or accepted to be associated with a specific level of effect. Thus, Federal drinking water standards (Title 40 of the *Code of Federal Regulations*, Parts 141 and 143) are used as benchmarks against which potential contamination can be compared. Drinking water standards for Washington State are found in *Washington Administrative Code* 246-290. (See *benchmark standards*, *dose*, *drinking water standards*, and *Washington Administrative Code*.)

benchmark standards – The "benchmark standards" used in this environmental impact statement represent dose or concentration levels that correspond to known or established human health effects. For groundwater, the benchmark is the maximum contaminant level (MCL) if an MCL is available. For constituents with no available MCL, additional sources for benchmark standards include Washington State guidance and relevant regulatory standards, e.g., Clean Water Act, Safe Drinking Water Act. For example, the benchmark for iodine-129 is 1 picocurie per liter; for technetium-99, it is 900 picocuries per liter. These benchmark standards for groundwater impacts analysis were agreed upon by both the U.S. Department of Energy and the Washington State Department of Ecology as the basis for comparing the alternatives and representing potential groundwater impacts. (See *alternative*, *benchmark*, *dose*, and *maximum contaminant level*.)

benthic – Relating to plants and animals dwelling at the bottom of oceans, lakes, rivers, and other surface waters.

beryllium – An extremely lightweight element with the atomic number 4. It is metallic and is used in nuclear reactors as a neutron reflector. (See *atomic number*, *neutron*, and *nuclear reactor*.)

best available technology (BAT) – (1) Economically achievable pollution control methods that allow point sources to comply with the effluent limitations required by the Clean Water Act (Title 33 of the *United States Code* [U.S.C.], Part 1251 et seq.). Taken into account in identifying the BAT are the age of the equipment and facilities involved; process employed; engineering aspects of various control techniques; process changes; cost of achieving such effluent reduction; non-water-quality environmental impacts (including energy requirements); and other factors deemed appropriate by the U.S. Environmental Protection Agency (EPA) Administrator. (See *Clean Water Act of 1972, 1987*.) (2) Available techniques, processes, or knowledge the EPA Administrator finds are available to comply with the provisions of the Safe Drinking Water Act (42 U.S.C., Section 300(f) et seq.) after examining their efficacy under field and laboratory conditions and considering the costs. For the purpose of setting maximum contaminant levels for synthetic organic chemicals, any BAT must be at least as effective as granular activated carbon. (See *maximum contaminant level* and *Safe Drinking Water Act*.)

best management practices (BMPs) – Structural, nonstructural, and managerial techniques, other than techniques for effluent limitations, used to prevent or reduce pollution of surface water. They are the most effective and practical means to control pollutants that are compatible with the productive use of the resource to which they are applied. BMPs are used in both urban and agricultural areas. BMPs can include activity schedules; practice prohibitions; maintenance procedures; treatment requirements; operating procedures; and practices to control plant site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage. (See *surface water*.)

beta emitter – A radioactive substance that decays by releasing a beta particle. (See *beta particle*.)

beta particle – A particle emitted in the radioactive decay of many radionuclides. A beta particle is identical to an electron. It has a short range in air and a limited ability to penetrate other materials; it can be stopped by clothing or a thin sheet of metal. (See *electron* and *radioactive decay*.)

beyond-design-basis accident – An accident postulated for the purpose of generating large consequences by exceeding the functional and performance requirements for safety structures, systems, and components. (See *design-basis accident*.)

beyond-design-basis events – Postulated disturbances in process variables resulting from external events or multiple component or system failures that can potentially lead to beyond-design-basis accidents. (See *design-basis events*.)

bioaccumulation factor – The ratio of the concentration of a chemical in an organism to its concentration in a medium to which the organism is exposed.

bioconcentration factor – The ratio of the concentration of a chemical in an aquatic organism to the concentration of the chemical in the surface water, sediment, or soil to which that organism is exposed.

biodiversity – The diversity of life forms and their levels of organization.

biomagnification – The process by which the concentration of some chemicals increases with the increasing trophic level; thus, the concentration in a predator exceeds the concentration in its prey. (See *trophic level*.)

biota (biotic) – The plant and animal life of a region.

biotransfer factor – The ratio of the concentration of a substance in an organism to the concentration of that substance in food that is ingested per unit time.

blanket assembly – The material in an accelerator wherein the generated neutrons are moderated to permit their absorption (capture) in the target material to produce a new isotope. (See *isotope* and *neutron*.)

block – U.S. Census Bureau term for small areas bounded on all sides by visible features or political boundaries; used in tabulation of census data.

body burden – The total amount of a substance in the cells and tissues of an organism.

boron-10 – An isotope of the element boron that has a high-capture cross section for neutrons. It is used in nuclear reactor absorber rods for reactor control. (See *isotope* and *nuclear reactor*.)

borrow – Excavated material that has been taken from one area to be used as raw material or fill at another location.

borrow area (pit, site) – An area designated as the excavation site for geologic resources such as rock/basalt, sand, gravel, or soil to be used elsewhere for fill. (See *basalt*, *sand*, and *soils*.)

bound – To use simplifying assumptions and analytical methods in an analysis of impacts or risks such that the result overestimates or describes an upper limit on (i.e., "bounds") potential impacts or risks.

A *bounding analysis* is an analysis designed to overestimate, or determine the upper limit on, potential impacts or risks.

A *bounding accident* is a hypothetical accident, the calculated consequences of which equal or exceed the consequences of all other potential accidents for a particular activity or facility.

bounded – Having the greatest consequences of any assessment of impacts associated with normal or abnormal operations.

buffering capacity – The ability of chemicals in solution (usually a weak acid or base and its salt) to minimize changes in the hydrogen ion concentration upon addition of an acid or base. (See *ion*.)

bulk vitrification – A supplemental thermal treatment process that converts low-activity waste into a solid glass form by mixing the waste with soil or other glass formers, drying the mixture, mixing it with additional soil additives, and applying electrical current to the mix within a large steel container. (See *low-activity waste*.)

burial ground – A place for burying low-level radioactive waste and mixed low-level radioactive waste so as to prevent the escape of hazardous chemicals or radiation, and the dispersion thereof, into the environment. (See *hazardous chemical*, *low-level radioactive waste*, and *mixed low-level radioactive waste*.)

byproduct material – (1) Any radioactive material (except special nuclear material [SNM]) yielded in, or any material made radioactive by exposure to radiation during, the process of producing or utilizing SNM. (See *special nuclear material*.) (2) The tailings or waste produced by the extraction or concentration of uranium or thorium from any ore that is processed primarily for its source material content. (See *source material*.)

Byproduct material is exempt from regulation under the Resource Conservation and Recovery Act (RCRA) (Title 42 of the *United States Code*, Part 6901 et seq.). However, the exemption applies only to the actual radionuclides dispersed or suspended in the waste substance. Any nonradioactive hazardous waste component of the waste is subject to regulation under RCRA. (See *radioisotope or radionuclide* and *Resource Conservation and Recovery Act*.)

caisson – Any of the cylindrical, steel-reinforced concrete underground vaults that are designed to store remote-handled waste in the low-level radioactive waste burial grounds. (See *burial ground* and *remote-handled waste*.)

calcination – A process that uses heat to evaporate water from radioactive waste and de-nitrate fission products to assist in stabilizing the waste form produced. (See *fission* and *radioactive waste*.)

cancer – The name given to a group of diseases characterized by uncontrolled cellular growth where the cells have invasive characteristics that enable the disease to transfer from one organ to another.

candidate species – *Federal:* Species native to the United States for which the U.S. Fish and Wildlife Service or the National Marine Fisheries Service has sufficient information on biological vulnerability and threats to justify proposing to add them to the threatened or endangered species list, but cannot do so immediately because other species have a higher priority for listing. The Services determine the listing priority of candidate taxa in accordance with general guidelines published in the *Federal Register*. (See *taxa*.)

Washington State: Species for which current information indicates the probable appropriateness of listing as endangered or threatened (*Washington Administrative Code* 232-12-297). (See *endangered species* and *threatened species*.)

canister – A general term for a container, usually cylindrical, used in the handling, storage, transportation, or disposal of waste.

canyon – In the nuclear industry, a large, heavily shielded concrete building that contains a remotely operated nuclear materials processing facility.

cap – A cap used to cover a waste burial ground with soil, rock, vegetation, or other materials as part of the facility closure process. The cap is designed to reduce migration of radioactive and hazardous materials in the waste caused by infiltration of water or intrusion of humans, plants, or animals from the surface. In this environmental impact statement, the modified Resource Conservation and Recovery Act Subtitle C barrier was selected as a cap for low-level radioactive waste and mixed low-level radioactive waste disposal grounds. Also called a cover cap or barrier. (See *barrier*, *burial ground*, *low-level radioactive waste*, *mixed low-level radioactive waste*, and *modified RCRA Subtitle C barrier*.)

capable fault – A fault that has exhibited one or more of the following characteristics: (1) movement at or near the ground surface at least once within the past 35,000 years or movement of a recurring nature within the past 500,000 years; (2) macroseismicity as determined instrumentally and as reflected in records of sufficient precision to demonstrate a direct relationship with the fault; and (3) a structural relationship with another capable fault according to characteristic 1 or 2 above such that movement on one could reasonably be expected to be accompanied by movement on the other. (See *fault* and *macroseismicity*.)

capacity (electric) – An electric power plant's maximum power output.

capacity factor – The ratio of the annual average power production of a power plant to its rated capacity.

capping – As applied to radioactive and mixed-waste disposal facilities, the process of covering a burial ground with soil, rock, vegetation, or other materials as part of the facility closure process. (See *burial ground*.)

carbonate – A salt or ester of carbonic acid. (See *ester*.)

carbon dioxide – A colorless, odorless gas that is a normal component of ambient air and a product of fossil fuel combustion, animal expiration, and the decay or combustion of animal or vegetable matter.

carbon monoxide – A colorless, odorless, poisonous gas produced by incomplete fossil fuel combustion.

carcinogen – A substance or agent that produces or incites cancerous growth. (See *cancer*.)

cask – A heavily shielded container used to store or ship radioactive materials.

cast stone – A nonthermal waste stabilization process that may be performed at ambient temperatures and pressures and involves mixing the waste with grout formers (e.g., Portland cement, fly ash, slag) and conditioners to produce a solid waste form.

Category 1 low-level radioactive waste (LLW) – LLW containing radionuclide concentrations within the maximum limits defined for this waste type in the *Hanford Site Solid Waste Acceptance Criteria*. These limits are site specific and define the lowest activity category of LLW. Category 1 waste typically does not require special packaging or treatment for disposal by shallow land burial. (See *low-level radioactive waste*.)

Category 3 low-level radioactive waste (LLW) – LLW containing radionuclide concentrations greater than those defined for Category 1 waste, but within the maximum limits defined for Category 3 waste in the *Hanford Site Solid Waste Acceptance Criteria*. These limits are site specific and are established using the performance assessment for a particular disposal facility. Category 3 waste typically requires special packaging or treatment for disposal by shallow land burial. (See *low-level radioactive waste*.)

cation – A positively charged ion. (See *ion*.)

cell – See *hot cell*.

Central Plateau – The elevated area in the center of the Hanford Site where the 200-East and 200-West Areas are located.

chain reaction – A reaction that initiates its own repetition. In nuclear fission, a chain reaction occurs when a neutron induces a nucleus to fission and the fissioning nucleus releases one or more neutrons, which induce other nuclei to fission. (See *fission*, *neutron*, and *nucleus*.)

Chalfont container 9975 – A shielded Type B container with primary- and secondary-containment features that is used to store or ship radioactive materials. (See *cask* and *Type B packaging*.)

characteristic waste – Solid waste that is classified as hazardous waste because it exhibits any of the following properties or characteristics: ignitability, corrosivity, reactivity, or toxicity, as described in Title 40 of the *Code of Federal Regulations*, Sections 261.20 through 261.24. (See *hazardous waste*, *solid waste*, and *waste characterization*.)

characterization – See *waste characterization.*

chemical oxidation – A chemical reaction in which a molecule or atom loses electrons, thereby increasing its oxidation state, often by adding oxygen. Typical oxidizing agents include ozone, peroxides, persulfates, and permanganates and are commonly used for oxidation of organic constituents. (See *electron* and *oxidation.*)

chemical reduction – A chemical reaction in which a molecule or atom gains electrons, thereby decreasing its oxidation state. Typical reducing agents include chemicals such as sulfites, polyethylene glycol, hydrosulfide, or ferrous salts. In general, the reduced forms of the contaminant are much less mobile in the environment because of their low solubility and high adsorption to soils. Microbiological reduction of these waste constituents also has been found to occur naturally in sediment and aquifer environments. With the addition of chemical food sources to enhance microbe growth rates, reductive biological remediation is becoming more economical. (See *adsorption*, *electron*, and *oxidation*.)

chronic exposure – A continuous or intermittent exposure of an organism to a stressor (e.g., a toxic substance or ionizing radiation) over an extended period of time or significant fraction (often 10 percent or more) of the organism's lifespan. Generally, chronic exposure is considered to produce effects that can be observed only after a time following initial exposure. These may include impaired reproduction or growth, genetic effects, congenital defects, cancer, precancerous lesions, benign tumors, cataracts, and skin changes.

cladding – The outer metal jacket of a nuclear fuel element or target. It prevents fuel corrosion and retains fission products during nuclear reactor operation and subsequent storage, as well as providing structural support. Zirconium alloys, stainless steel, and aluminum are common cladding materials. In general, a metal coating bonded onto another metal. (See *fission products*, *nuclear reactor*, and *target*.)

Class I area – A specifically designated area where the degradation of air quality is stringently restricted (e.g., many national parks, wilderness areas). (See *Prevention of Significant Deterioration*.)

Class II area – Most of the country that is not designated as Class I is designated as Class II. Class II areas are generally cleaner than air quality standards require, and moderate increases in new pollution are allowed after an impacts review, mandated by regulations.

clastic – Refers to rock or sediment made up primarily of broken fragments of preexisting rocks or minerals. (See *sediment*.)

clay – (1) The name for a family of finely crystalline sheet silicate minerals that commonly form as a product of rock weathering. (2) Any particle smaller than or equal to about 0.002 millimeters (0.00008 inches) in diameter.

Clean Air Act – This act (Title 42 of the *United States Code*, Part 7401 et seq.) mandates, and provides for enforcement of, regulations to control air pollution from various sources.

Clean Air Act Amendments of 1990 – Amendments expanding the U.S. Environmental Protection Agency's enforcement powers and adding restrictions on air toxics, ozone-depleting chemicals, stationary and mobile emission sources, and emissions implicated in acid rain and global warming. (See *ozone*.)

clean closure – The premise of clean closure is that all hazardous waste has been removed from a given Resource Conservation and Recovery Act (RCRA)-regulated unit and any releases at or from the unit have been remediated so that further regulatory control under RCRA Subtitle C is not necessary to protect human health and the environment. Under State of Washington requirements (*Washington Administrative Code* 173-303-64) for closure of a tank system, the owner or operator must remove or decontaminate all waste residues, contaminated containment system components (e.g., liners), contaminated soils, and structures and equipment contaminated with waste and must manage them as dangerous waste as required. (See *dangerous waste* and *Resource Conservation and Recovery Act*.)

Clean Water Act of 1972, 1987 – This act (Title 33 of the *United States Code*, Part 1251 et seq.) regulates the discharge of pollutants from a point source into navigable waters of the United States in compliance with a National Pollutant Discharge Elimination System permit and regulates discharges to or dredging of wetlands. (See *National Pollutant Discharge Elimination System* and *wetlands*.)

cleanup – Refers to the full range of projects and activities undertaken to address environmental and legacy waste issues associated with the Hanford Site.

closure – Refers to the deactivation and stabilization of a waste treatment, storage, or disposal unit (such as a waste treatment tank, waste storage building, or landfill) or hazardous materials storage unit (such as an underground storage tank). For storage units, closure typically includes removal of all residues, contaminated system components, and contaminated soil. For radioactive and hazardous waste disposal units (i.e., where waste is left in place), closure typically includes site stabilization and emplacement of surface barriers. Specific requirements for the closure process are found in the regulations applicable to many types of waste management units and hazardous material storage facilities. For the State of Washington, hazardous waste disposal unit closure regulations are found at *Washington Administrative Code* 173-303-610.

***Code of Federal Regulations* (CFR)** – The publication, in codified form, of all Federal regulations that are in effect.

collective dose – The sum of the individual doses received in a given period of time by a specified population from exposure to a specified source of radiation. Collective dose is expressed in units of person-rem or person-sieverts. (See *dose*, *ionizing radiation*, *person-rem*, and *person-sievert*.)

commercial light-water reactor – The term used to describe commercially operated power-producing U.S. nuclear reactors that use "light" (as opposed to heavy) water for cooling and neutron moderation. (See *light water*, *light-water reactor*, *neutron*, and *nuclear reactor*.)

committed dose equivalent – The dose equivalent received by an individual's organs or tissues during the 50 years following an intake of radioactive material. It does not include contributions from radiation sources external to the body. Committed dose equivalent is expressed in units of rem or sieverts. (See *ionizing radiation*, *roentgen equivalent man [rem]*, and *sievert*.)

committed effective dose equivalent – The dose value obtained by multiplying the committed dose equivalents for the organs or tissues that are irradiated and the weighting factors applicable to those organs or tissues and summing all the resulting products. Committed effective dose equivalent is expressed in units of rem or sieverts. (See *committed dose equivalent*, *irradiated*, *roentgen equivalent man [rem]*, *sievert*, and *weighting factor*.)

community – *(biotic definition)* All plants and animals occupying a specific area under relatively similar conditions.

(environmental justice definition) A group of people or a site within a spatial scope exposed to risks that potentially threaten health, ecology, or land values or exposed to industry that stimulates unwanted noise, smell, industrial traffic, particulate matter, or other nonaesthetic impacts.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 – A Federal law (also known as Superfund) enacted in 1980 and reauthorized in 1986 (Title 42 of the *United States Code*, Part 9601 et seq.) that provides the legal authority for emergency response and cleanup of hazardous substances released into the environment and for the cleanup of inactive waste sites.

conformity – Conformity is defined in the Clean Air Act (Title 42 of the *United States Code*, Part 7401 et seq.) as the action's compliance with an implementation plan's purpose of eliminating or reducing the severity and number of violations of the National Ambient Air Quality Standards and achieving expeditious attainment of such standards. Such activities will not cause or contribute to any new violation of any standard in any area; increase the frequency or severity of any existing violation of any standard in any area; or delay timely attainment of any standard, any required interim emission reduction, or other milestones in any area. (See *Clean Air Act* and *National Ambient Air Quality Standards*.)

constituent of potential concern (COPC) – A chemical or radionuclide, present in a source material or environmental media, whose quantity and concentrations are significant enough to warrant analysis via one or more receptor pathways.

contact-handled waste – Radioactive waste or waste packages whose external dose rate is low enough to permit contact-handling by humans during normal waste management activities (e.g., waste with a surface dose rate not exceeding 200 millirem per hour). (See *remote-handled waste*.)

container – In regard to radioactive waste, the outside envelope in the waste package that provides the primary-containment function of the waste package, which is designed to meet the containment requirements of Title 10 of the *Code of Federal Regulations*, Part 60.

containment design basis – For a nuclear reactor, those bounding conditions for the design of the containment, including temperature, pressure, and leakage rate. Because the containment is provided as an additional barrier to mitigate the consequences of accidents involving the release of radioactive materials, the containment design basis may include an additional specified margin above those conditions expected to result from the plant design-basis accidents to ensure that the containment design can mitigate unlikely or unforeseen events. (See *bound*, *design basis*, *design-basis accident*, *nuclear reactor*, and *reactor containment*.)

contamination – The deposition of undesirable material in air, soils, water, or ecological resources or on the surfaces of structures, areas, objects, or personnel.

control rod – A rod containing material such as boron that is used to control the power of a nuclear reactor. By absorbing excess neutrons, a control rod prevents the neutrons from causing further fissions, i.e., increasing power. (See *boron-10*, *fission*, *neutron*, and *nuclear reactor*.)

coolant – A substance, either gas or liquid, circulated through a nuclear reactor or processing plant to remove heat. (See *nuclear reactor*.)

cooperating agency – "Any Federal agency (other than a lead agency) that has jurisdiction by law or special expertise with respect to any environmental impact involved in a proposal (or a reasonable alternative) for legislation or other major Federal action significantly affecting the quality of the human environment. A state or local agency of similar qualification or, when the effects are on a reservation, an Indian tribe, may, by agreement with the lead agency, become a cooperating agency" (Title 40 of the *Code of Federal Regulations*, Section 1508.5).

Core Zone – A portion of the Central Plateau within the Hanford Site, encompassing the 200-East and 200-West Areas, that lies within the Industrial-Exclusive land use designation established under the 1999 *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement*. (See *Central Plateau*.)

Core Zone Boundary – The perimeter of the Core Zone that is used as a line of analysis for groundwater transport calculations. (See *Core Zone*.)

credible accident – An accident with a probability of occurrence greater than or equal to once in 1 million years.

crib – An underground structure designed to distribute liquid waste, usually through a perforated pipe, to the soil directly or to a connected tile field. Cribs use the filtration and ion exchange properties of the soil to contain radionuclides. A crib is operated only if radionuclide contamination observed in the groundwater beneath the crib is below a prescribed limit. (See *ion* and *radioisotope or radionuclide*.)

criteria pollutant – An air pollutant that is regulated by National Ambient Air Quality Standards. The U.S. Environmental Protection Agency must describe the characteristics and potential health and welfare effects that form the basis for setting or revising the standard for each regulated pollutant. Criteria pollutants include sulfur dioxide, nitrogen dioxide, carbon monoxide, ozone, lead, and two size classes of particulate matter: less than or equal to 2.5 and 10 micrometers (0.0001 and 0.0004 inches) in diameter. New pollutants may be added to or removed from the list of criteria pollutants as more information becomes available. (See *National Ambient Air Quality Standards*, *nitrogen oxides*, *ozone*, *particulate matter*, and *sulfur oxides*.)

critical habitat – Habitat essential to the conservation of an endangered or threatened species that has been designated as critical by the U.S. Fish and Wildlife Service or the National Marine Fisheries Service following the procedures outlined in the Endangered Species Act (Title 16 of the *United States Code*, Part 1531 et seq.) and its implementing regulations (Title 50 of the *Code of Federal Regulations* [CFR], Part 424). The lists of critical habitats can be found in 50 CFR, Sections 17.95 (fish and wildlife) and 17.96 (plants) and Part 226 (marine species). (See *endangered species* and *threatened species*.)

critical mass – The smallest mass of fissionable material that will support a self-sustaining nuclear chain reaction. (See *chain reaction*, *criticality*, and *fission*.)

critical organ – The body organ receiving a radionuclide or radiation dose that would result in the greatest overall damage to the body. Specifically, that organ in which the dose equivalent would be most significant due to a combination of the organ's radiological sensitivity and the dose distribution throughout the body. (See *dose*, *dose equivalent*, *ionizing radiation*, and *radioisotope or radionuclide*.)

criticality – The condition in which a system is capable of sustaining a nuclear chain reaction (a reaction that initiates its own repetition). (See *chain reaction*, *fission*, and *neutron*.)

cryptogamic (microbiotic) crusts – Earth crusts that generally occur in the top 1 to 4 millimeters (0.039 to 0.157 inches) of soil and are formed by living organisms and their byproducts, creating a crust of soil particles bound together by organic materials.

cullet – Small (pea-sized) pieces of glass formed when hot molten glass is quenched in a water bath.

cultural resources – Archaeological sites, historical sites, architectural features, traditional use areas, and American Indian sacred sites. (See *archaeological sites* and *historic resources*.)

cumulative impacts – Impacts on the environment that result from incremental impacts of the action when added to other past, present, and reasonably foreseeable future actions, regardless of the agency or person undertaking such other actions. Cumulative impacts can result from individually minor, but collectively significant, actions that take place over a period of time (Title 40 of the *Code of Federal Regulations*, Section 1508.7).

curie – (1) A unit of radioactivity equal to 37 billion disintegrations per second (i.e., 37 billion becquerels). (See *becquerel*.) (2) A quantity of any radionuclide or mixture of radionuclides having 1 curie of radioactivity. (See *radioactivity*.)

dangerous waste – Solid waste designated in *Washington Administrative Code* 173-303-070 through 173-303-100 as dangerous, extremely hazardous, or mixed waste. (See *mixed waste*.)

daphnid – A group of simple animals related to insects, nearly microscopic in size and found in freshwater habitats.

day-night average sound level – The 24-hour, A-weighted equivalent sound level expressed in decibels. A 10-decibel penalty is added to sound levels between 10:00 P.M. and 7:00 A.M. to account for increased annoyance due to noise during night hours. (See *decibel*, *A-weighted*.)

deactivation – Placing a facility in a stable and known condition, including removal of hazardous and radioactive materials, to ensure adequate protection of workers, public health and safety, and the environment, thereby limiting the long-term cost of surveillance and maintenance. Actions include the removal of fuel, draining and/or de-energizing of nonessential systems, removal of stored radioactive and hazardous materials, and related actions. Deactivation does not include all decontamination necessary for the dismantlement and demolition phase of decommissioning (e.g., removing contamination remaining in fixed structures and equipment after deactivation).

As applied to waste treatment, removal of the hazardous characteristics of a waste due to its ignitability, corrosivity, and/or reactivity. (See *decontamination* and *reactivity*.)

decay (radioactive) – See *radioactive decay.*

decay heat (radioactivity) – The heat produced by the decay of radionuclides. (See *radioisotope or radionuclide*.)

decibel (dB) – A unit for expressing the relative intensity of sounds on a logarithmic scale where zero is below human perception and 130 is above the threshold of pain to humans. For traffic and industrial noise measurements, the A-weighted decibel, a frequency-weighted noise unit, is widely used. (See *decibel, A-weighted*.)

decibel, A-weighted (dBA) – A unit of frequency-weighted sound pressure level, measured by the use of a metering characteristic and the "A" weighting specified by the American National Standards Institute in ANSI S1.4-1983 (R1594), which accounts for the frequency of the human ear.

deciduous – Trees that shed leaves at a certain season.

decommissioning – The process of closing and securing a nuclear facility or nuclear material storage facility to provide adequate protection from radiological exposure and to isolate radioactive contamination from the human environment. It takes place after deactivation and includes surveillance, maintenance, decontamination, and/or dismantlement. These actions are taken at the end of the facility's life to retire it from service with adequate regard for the health and safety of workers and the public and protection of the environment. The ultimate goal of decommissioning is unrestricted release or restricted use of the site. (See *deactivation*, *decontamination*, and *ionizing radiation*.)

decontamination – The removal or reduction of residual chemical, biological, or radioactive contaminants and hazardous materials by mechanical, chemical, or other techniques to achieve a stated objective or end condition.

depleted uranium – Uranium whose content of the fissile isotope uranium-235 is less than the 0.7 percent (by weight) found in natural uranium, so that it contains more uranium-238 than natural uranium. (See *natural uranium* and *uranium-238*.)

deposition – In geology, the laying down of potential rock-forming materials; sedimentation. In atmospheric transport, the settling out on ground and building surfaces of atmospheric aerosols and particles ("dry deposition") or their removal from the air to the ground by precipitation ("wet deposition" or "rainout").

derived concentration guide – The concentration of a radionuclide in air or water that, under conditions of continuous exposure for 1 year by one exposure mode (i.e., ingestion of water, submersion in air, or inhalation), would result in an effective dose equivalent of 100 millirem. (See *effective dose equivalent*, *millirem*, and *radioisotope or radionuclide*.)

dermal – Of or pertaining to the skin or other external body covering.

design basis – For nuclear facilities, information that identifies the specific functions to be performed by a structure, system, or component and the specific values (or ranges of values) chosen for controlling parameters for reference bounds for design. These values may be (1) restraints derived from generally accepted state-of-the-art practices for achieving functional goals; (2) requirements derived from analysis (based on calculation and/or experiments) of the effects of a postulated accident for which a structure, system, or component must meet its functional goals; or (3) requirements derived from Federal safety objectives, principles, goals, or requirements. (See *bound*.)

design-basis accident – An accident postulated for the purpose of establishing functional and performance requirements for safety structures, systems, and components. (See *beyond-design-basis accident*.)

design-basis events – Postulated disturbances in process variables that can potentially lead to design-basis accidents. (See *beyond-design-basis events*.)

detector – A device used to convert the energy of incident radiation into another form (such as light, an electrical signal, or a trace in a chemical emulsion) to observe or measure radiation.

A *particle detector* is any device used to sense the passage of atomic or subatomic particles or to measure their properties. For many particle detectors, this involves observing and measuring the electromagnetic or ionizing radiation released as particles interact with a gaseous, liquid, or solid medium or an electromagnetic field. The term also may refer to a collection of particle detection devices designed to allow physicists to reconstruct particle events. (See *ionizing radiation*.)

deterministic analysis – A single calculation using only a single value for each of the model parameters. A deterministic system is governed by definite rules of system behavior leading to cause-and-effect relationships and predictability. Deterministic calculations do not account for uncertainty in the physical relationships or parameter values. Typically, deterministic calculations are based on best estimates of the involved parameters. (See *stochastic analysis*.)

dewatering – The removal of water. Saturated soils are "dewatered" to make construction of building foundations easier.

dip – A measure of the angle between the flat horizon and the slope of a sedimentary layer, fault plane, metamorphic foliation, or other geologic structure.

direct jobs – The number of workers required at a site to implement an alternative.

disassociation – The action of becoming separated.

discharge – In surface-water hydrology, the amount of water issuing from a spring or in a stream that passes a specific point in a given period of time. (See *surface water*.)

disintegration – Any transformation of a nucleus, whether spontaneous or induced by irradiation, in which the nucleus emits one or more particles or photons. (See *nucleus* and *photon*.)

disposal – As generally used in this environmental impact statement, the placement of waste with no intent to retrieve. Statutory or regulatory definitions of disposal may differ.

disposal groups – Specific combinations of waste capacities allocated to the River Protection Project Disposal Facility and 200-East (or both 200-East and 200-West) Area Integrated Disposal Facility(ies) over varying operational timeframes, based on the different types and amounts of waste generated under the three sets of alternatives analyzed in this environmental impact statement.

disposition – The ultimate "fate" or end use of a surplus U.S. Department of Energy facility following transfer of the facility to the Office of the Assistant Secretary for Environmental Management.

DOE orders – Requirements internal to the U.S. Department of Energy that establish policy and procedures, including those for compliance with applicable laws.

dose – The accumulated radiation or hazardous substance delivered to the whole body or a specified tissue or organ within a specified time and originating from an external or internal source. (See *absorbed dose*, *dose [chemical]*, *dose [radiation]*, *exposure*, and *ionizing radiation*.)

dose (chemical) – The amount of a substance administered to, taken up by, or assimilated by an organism. It is often expressed in terms of the amount of substance per unit mass of the organism, tissue, or organ of concern.

dose (radiation) – A generic term that means absorbed dose, effective dose equivalent, committed effective dose equivalent, or total effective dose equivalent, as defined elsewhere in this glossary.

dose commitment – The total dose equivalent a body, organ, or tissue would receive during a specified period of time (e.g., 50 years) as a result of intake (as by ingestion or inhalation) of one or more radionuclides from a defined release. (See *dose equivalent* and *radioisotope or radionuclide*.)

dose equivalent – A measure of radiation dose that correlates with biological effect on a common scale for all types of ionizing radiation. Defined as a quantity equal to the absorbed dose in tissue multiplied by a quality factor (the biological effectiveness of a given type of radiation) and all other necessary modifying factors at the location of interest. The units of dose equivalent are the rem and the sievert. (See *dose*, *ionizing radiation*, *roentgen equivalent man [rem]*, and *sievert*.)

dose rate – The radiation dose delivered per unit of time (e.g., rem per year). (See *dose*, *ionizing radiation*, and *roentgen equivalent man [rem]*.)

double-shell tank – A large reinforced-concrete underground container with two steel liners to provide containment and backup containment of liquid waste. The space between the liners has instruments that detect leaks from the inner liner.

drinking water standards – The maximum permissible levels of constituents or characteristics in a drinking water supply as specified by the Safe Drinking Water Act (Title 42 of the *United States Code*, Section 300(f) et seq.). (See *Safe Drinking Water Act*.)

dynamic time-varying model – A representation of a system with state variables that change in value over time due to changes in parameters or inputs.

easting – The difference in longitude between two positions as a result of movement to the east.

ecological risk assessment – Evaluation of the likelihood of adverse effects on animals and plants as a result of actual or potential stressors in the environment.

ecology – A branch of science dealing with the interrelationships of living organisms with one another and with their nonliving environment.

ecosystem – A community of organisms and their physical environment that interact as an ecological unit.

edaphic – Of or relating to the soil.

effective dose equivalent – The dose value obtained by multiplying the dose equivalents received by specified tissues or organs of the body by the appropriate weighting factors applicable to the tissues or organs irradiated, and then summing all of the resulting products. It includes the dose from radiation sources internal and external to the body. The effective dose equivalent is expressed in units of rem or sieverts. (See *committed dose equivalent*, *committed effective dose equivalent*, *dose*, *ionizing radiation*, *irradiated*, *roentgen equivalent man [rem]*, and *sievert*.)

effervescent – Giving off gas bubbles.

efficacy – A measure of the probability and intensity of beneficial effects.

effluent – A waste stream flowing into the atmosphere, surface water, groundwater, or soil; frequently applied to waste discharged to surface water. (See *surface water*.)

electrometallurgical treatment – A technique for collecting, concentrating, and immobilizing fission products and transuranic elements from metallic spent nuclear fuel by removing the uranium in the spent fuel with an electrochemical cell. The treatment alters the chemical and physical nature of spent nuclear fuel to reduce its toxicity, volume, and mobility and render it suitable for transport, storage, or disposal. (See *fission products*, *hot cell*, *spent nuclear fuel*, and *transuranic*.)

electron – An elementary particle with a mass of 9.107×10^{-28} grams (or 1/1,837 of a proton) and a negative charge. Electrons surround the positively charged nucleus and determine the chemical properties of the atom. (See *nucleus*.)

element occurrence – An element occurrence of a plant community is one that meets minimum standards set by the Washington State Natural Heritage Program, established by the Natural Area Preserves Act (*Revised Code of Washington*, Chapter 79.70), for ecological condition, size, and surrounding landscape. Element occurrences are generally considered to be of significant conservation value from a state and/or regional perspective.

eluate – An adsorbed substance that has been removed from an adsorbent solution. (See *adsorption*.)

Emergency Response Planning Guidelines (ERPGs) – Values developed by the American Industrial Hygiene Association to assist emergency response personnel in planning for catastrophic releases to the community. ERPG values are defined for varying degrees of severity of toxic effects, as follows:

ERPG-1: The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined, objectionable odor.

ERPG-2: The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair an individual's ability to take protective action.

ERPG-3: The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.

emission – A material discharged into the atmosphere from a source operation or activity.

emission standard – A requirement established by the state or the U.S. Environmental Protection Agency that limits the quantity, rate, or concentration of air pollutant emissions on a continuous basis, including any requirement relating to (1) operation or maintenance of a source to ensure continuous emission reduction and (2) any design, equipment, work practice, or operational standard.

endangered species – *Federal:* Species that are in danger of extinction throughout all or a significant portion of their ranges and that have been listed as endangered by the U.S. Fish and Wildlife Service or the National Marine Fisheries Service following procedures outlined in the Endangered Species Act (Title 16 of the *United States Code*, Part 1531 et seq.) and its implementing regulations (Title 50 of the *Code of Federal Regulations* [CFR], Part 424). The lists of endangered species can be found in 50 CFR, Sections 17.11 (wildlife), 17.12 (plants), and 222.23(a) (marine organisms).

Washington State: Any wildlife species native to the state of Washington that is seriously threatened with extinction throughout all or a significant portion of its range within the state within the foreseeable future if factors contributing to its decline continue (*Washington Administrative Code* 232-12-297; Washington State Natural Heritage Program, established by the Natural Area Preserves Act [*Revised Code of Washington*, Chapter 79.70]). (See *candidate species* and *threatened species*.)

engineered safety features – For a nuclear facility, features that prevent, limit, or mitigate the release of radioactive material from its primary containment. (See *radioactivity* and *reactor containment*.)

enriched uranium – Uranium with a content of the fissile isotope uranium-235 greater than the 0.7 percent (by weight) found in natural uranium. (See *highly enriched uranium*, *natural uranium*, and *uranium*.)

entombment – A process whereby aboveground structures are decontaminated and dismantled, belowground structures are grouted and left in place, and an infiltration barrier is placed over the contaminated material.

entrainment – The involuntary capture and inclusion of organisms in streams of flowing water; a term often applied to the cooling water systems of power plants and nuclear reactors. The organisms involved may include phyto- and zooplankton, fish eggs and larvae (*ichthyoplankton*), shellfish larvae, and other forms of aquatic life. (See *nuclear reactor*.)

Environment, Safety, and Health Program – In the context of the U.S. Department of Energy (DOE), encompasses those requirements, activities, and functions in the conduct of all DOE and DOE-controlled operations that are concerned with: impacts on the biosphere; compliance with environmental laws, regulations, and standards controlling air, water, and soil pollution; limiting the risks to the well-being of both the operating personnel and the general public; and protecting property against accidental loss and damage. Typical activities and functions related to this program include, but are not limited to, environmental protection, occupational safety, fire protection, industrial hygiene, health physics, occupational medicine, process and facility safety, nuclear safety, emergency preparedness, quality assurance, and radioactive and hazardous waste management.

environmental assessment (EA) – A concise public document that a Federal agency prepares under the National Environmental Policy Act (NEPA) (Title 42 of the *United States Code*, Part 4321 et seq.) to provide sufficient evidence and analysis to determine whether a proposed agency action would require preparation of an environmental impact statement (EIS) or a Finding of No Significant Impact. A Federal agency may also prepare an EA to aid its compliance with NEPA when no EIS is necessary or to facilitate its preparation of an EIS when one is necessary.

An EA must include brief discussions of the (1) need for the proposal, (2) alternatives, (3) environmental impacts of the proposed actions and alternatives, and (4) a list of agencies and persons consulted. (See *environmental impact statement*, *Finding of No Significant Impact*, and *National Environmental Policy Act of 1969*.)

environmental impact statement (EIS) – The detailed written statement that is required by Section 102(2)(C) of the National Environmental Policy Act (NEPA) (Title 42 of the *United States Code*, Part 4321 et seq.) for a proposed major Federal action that could significantly affect the quality of the human environment. A U.S. Department of Energy (DOE) EIS is prepared in accordance with applicable requirements of the Council on Environmental Quality's NEPA regulations (Title 40 of the *Code of Federal Regulations* [CFR], Parts 1500–1508) and the DOE NEPA regulations found in 10 CFR, Part 1021. The statement includes, among other information, discussions of the environmental impacts of the proposed actions and the range of reasonable alternatives; the adverse environmental effects that cannot be avoided should the proposal be implemented; the relationship between short-term use of the environment and long-term productivity; and any irreversible and irretrievable commitments of resources.

environmental justice – The fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Fair treatment means that no group of people, including racial, ethnic, and socioeconomic groups, should bear a disproportionate share of the negative environmental consequences resulting from industrial, municipal, or commercial operations or the execution of Federal, state, local, or tribal programs or policies. Executive Order 12898 directs Federal agencies to make achieving environmental justice part of their missions by identifying and addressing disproportionately high and adverse effects of agency programs, policies, and activities on low-income and minority populations. (See *low-income population* and *minority population*.)

eolian – Pertaining to, caused by, or carried by the wind.

ephemeral stream – A stream that flows only after a period of heavy precipitation.

epicenter – The point on Earth's surface directly above the focus of an earthquake.

epidemiology – Study of the occurrence, causes, and distribution of disease or other health-related states and events in human populations, often as related to age, sex, occupation, ethnicity, and economic status, to identify and alleviate health problems and promote better health.

equilibrium partitioning – Process of achieving a steady state between the activity of chemicals (usually approximated as concentration) in the various component phases—water, sediment, and organisms.

equivalent sound (pressure) level – The equivalent, steady sound level that, if continuous during a specified time period, would contain the same total energy as the actual time-varying sound. L_{eq} (1-h) and L_{eq} (24-h) are the 1-hour and 24-hour equivalent sound levels, respectively.

erg – An absolute unit of work representing the work done by a force of 1 dyne acting through a displacement of 1 centimeter in the direction of the force. (A dyne is a unit of force equal to the force that would accelerate a free mass of 1 gram 1 centimeter per second squared.)

erosion – Removal of material by water, wind, or ice.

ERPG-1, -2, and -3 – See *Emergency Response Planning Guidelines*.

ester – Any of a class of chemical compounds that, when hydrolyzed, yield an organic or inorganic acid and an alcohol or phenol and hence may be classified by either their acid constituent or their alcohol or phenol constituent.

Evolutionarily Significant Unit – A distinctive group of Pacific salmon, steelhead, or sea-run cutthroat trout.

excavation – A cavity in the earth formed by cutting, digging, or scooping using heavy construction equipment.

experimental, nonessential population (Federal) – The term "experimental population" means any population (including any offspring arising solely therefrom) authorized, per procedures outlined in the Endangered Species Act (Title 16 of the *United States Code*, Part 1531 et seq.), for release outside the current range of such species, but only when, and at such times as, the population is wholly separate geographically from nonexperimental populations of the same species. An experimental population determined to be not essential to the continued existence of a species shall be treated, except when it occurs in an area within the National Wildlife Refuge System or the National Park System, as a species proposed to be listed as an endangered species or a threatened species.

exposure – The condition of being subject to the effects of, or acquiring a dose of, a potential stressor such as a hazardous chemical agent or ionizing radiation; also, the process by which an organism acquires a dose of a chemical such as mercury or a physical agent such as ionizing radiation. Exposure can be quantified as the amount of the agent available at various boundaries of the organism (e.g., skin, lungs, gut) and available for absorption. (See *ionizing radiation*.)

exposure limit – The level of exposure to a hazardous chemical (set by law or a standard) at which or below which adverse human health effects are not expected to occur. (See *reference concentration* and *reference dose*.)

exposure pathway – The course a chemical or physical agent takes from the source to the exposed organism. An exposure pathway describes a mechanism by which chemicals or physical agents at or originating from a release site reach an individual or population. Each exposure pathway includes a source or release from a source, an exposure route, and an exposure point. If the exposure point differs from the source, a transport/exposure medium such as air or water is also included. (See *exposure*.)

external dose or exposure – The portion of the dose equivalent received from radiation sources outside the body (i.e., "external sources"). (See *dose equivalent* and *ionizing radiation*.)

extrusion – A type of process in which a material (e.g., metal, plastic) is forced through a die, or very small hole, to give it a certain shape.

Fast Flux Test Facility (FFTF) – A liquid-metal (sodium)-cooled and -moderated nuclear test reactor at the Hanford Site. It was fueled with a mixture of plutonium-uranium dioxide and had a 400-megawatt power level. It is presently being deactivated. (See *nuclear reactor*.)

fault – A fracture or a zone of fractures within a rock formation along which vertical, horizontal, or transverse slippage has occurred. A normal fault occurs when the hanging wall has been depressed in relation to the footwall. A reverse fault occurs when the hanging wall has been raised in relation to the footwall.

fill material – Soil, rock, gravel, or other matter that is placed at a specified location to bring the ground surface up to a desired elevation.

Finding of No Significant Impact (FONSI) – A document by a Federal agency that briefly presents the reasons why an action will not have a significant effect on the human environment and for which an environmental impact statement therefore will not be prepared (Title 40 of the *Code of Federal Regulations*, Section 1508.13). (See *environmental impact statement*.)

fissile material – Although sometimes used as a synonym for fissionable material, this term has acquired a more restricted meaning, namely, any material fissionable by thermal (slow) neutrons. The three primary fissile materials are uranium-233, uranium-235, and plutonium-239. (See *fission* and *neutron*.)

fission – A nuclear transformation that is typically characterized by the splitting of a heavy atomic nucleus into at least two other nuclei, the emission of one or more neutrons, and the release of a large amount of energy. Fission of heavy atomic nuclei can occur spontaneously or be induced by neutron bombardment. (See *neutron*.)

fission products – Radioactive elements or compounds formed by the fission of heavy elements, plus the nuclides formed by the radioactive decay of those elements or compounds. (See *fission*, *nuclide*, and *radioactive decay*.)

fissionable material – Commonly used as a synonym for fissile material, the meaning of this term has been extended to include material that can be fissioned by fast neutrons, such as uranium-238. (See *neutron.*)

floodplain – The lowlands and relatively flat areas adjoining inland and coastal waters and the flood-prone areas of offshore islands. Floodplains include, at minimum, that area with at least a 1 percent chance of being inundated by a flood in any given year.

The *probable maximum flood* is the hypothetical flood considered to be the most severe reasonably possible flood, based on comprehensive hydrometeorological application of maximum precipitation and other hydrological factors favorable for maximum flood runoff (e.g., sequential storms, snowmelts). It is usually several times larger than the maximum recorded flood.

fluvial – Produced by the action of flowing water.

flux – Rate of flow through a unit area; in nuclear reactor operation, the apparent flow of neutrons in a defined energy range. (See *neutron flux* and *nuclear reactor*.)

food chain multiplier – A numerical factor quantifying the increase in concentration of a substance in an organism resulting from the accumulation and biomagnification of the substance through the food web. (See *biomagnification*.)

food web – The network of feeding relationships in an ecosystem. (See *ecosystem*.)

formation – In geology, the primary unit of formal stratigraphic mapping or description. Most formations possess certain distinctive features.

French drain – A rock-filled encasement with an open bottom to allow seepage of liquid waste into the ground.

fuel assembly – A cluster of fuel rods or plates; also called a fuel element. Approximately 200 fuel assemblies make up a nuclear reactor core. (See *nuclear reactor*.)

fuel rod – A nuclear reactor component that includes the fissile material. (See *fissile material* and *nuclear reactor*.)

fugitive emissions – (1) Emissions that do not pass through a stack, vent, chimney, or similar opening where they could be captured by a control device. (2) Any air pollutant emitted to the atmosphere other than from a stack. Sources of fugitive emissions include pumps; valves; flanges; seals; area sources such as ponds, lagoons, landfills, and piles of stored material (e.g., coal); and road construction areas or other areas where earthwork occurs.

fusion – The combining of two light atomic nuclei (such as hydrogen isotopes or lithium) to form a heavier atomic nucleus. Fusion is accompanied by the release of large amounts of energy. (See *nucleus*.)

g – In measuring earthquake ground motion, the acceleration (the rate of change in velocity) experienced relative to that due to Earth's gravity (i.e., approximately equal to 980 centimeters per second squared).

gamma radiation – High-energy, short-wavelength electromagnetic radiation emitted from the nucleus of an atom during radioactive decay. Gamma radiation frequently accompanies alpha and beta emissions and always accompanies fission. Gamma rays are very penetrating and are best stopped or shielded by dense materials, such as lead or depleted uranium. Gamma rays are similar to x-rays, but are usually more energetic. (See *alpha radiation*, *beta particle*, *fission*, *ionizing radiation*, *nucleus*, *radioactive decay*, and *x-rays*.)

generator – Within the context of this environmental impact statement, generators refer to organizations within the U.S. Department of Energy (DOE) or managed by DOE whose act or process produces low-level radioactive waste (LLW), mixed LLW, hazardous waste, or transuranic waste, as defined elsewhere in this glossary.

genetic effects – Inheritable changes (chiefly mutations), produced by exposure to ionizing radiation or other chemical or physical agents, of the parts of cells that control biological reproduction and inheritance. (See *ionizing radiation*.)

GENII – A computer code used to predict the radiological impacts on individuals and populations associated with the release of radioactive material into the environment during normal operations and postulated accidents.

geologic repository – A place to dispose of radioactive waste deep beneath Earth's surface.

geology – The science concerned with the materials, processes, environments, and history of Earth, including rocks and their formation and structure.

gigaelectron volts – One thousand million electron volts (MeV). (See *MeV*.)

glovebox – A large enclosure that separates workers from equipment used to process hazardous material while allowing the workers to be in physical contact with the equipment. Gloveboxes are normally constructed of stainless steel, with large acrylic/lead glass windows. Workers access equipment using heavy-duty, lead-impregnated rubber gloves, the cuffs of which are sealed in portholes in the glovebox windows.

graded approach – A process by which the level of analysis, documentation, and actions necessary to comply with a requirement are commensurate with (1) the relative importance to safety, safeguards, and security; (2) the magnitude of any hazard involved; (3) the life-cycle stage of a facility; (4) the programmatic mission of a facility; (5) the particular characteristics of a facility; and (6) any other relevant factor.

grading – Any stripping, cutting, filling, stockpiling, or combination thereof that modifies the land surface.

gravel pit No. 30 – This gravel pit, located between the 200-East and 200-West Areas, is an approximately 54-hectare (134-acre) borrow site containing a large quantity of aggregate (sand and gravel) suitable for multiple uses. Gravel pit No. 30 provides aggregate for onsite concrete batch plants in support of the construction of new facilities, including those at the Waste Treatment Plant adjacent to the 200-East Area. (See *borrow area [pit, site]*.)

gray – The International System of Units (SI) unit of absorbed dose. One gray is equal to an absorbed dose of 1 joule per kilogram (1 gray is equal to 100 rad). The joule is the SI unit of energy and is equivalent to 10 million ergs. (See *absorbed dose*, *erg*, *joule*, and *radiation absorbed dose [rad]*.)

greater-than-Category 3 (GTC3) low-level radioactive waste (LLW) – LLW that exceeds the maximum radionuclide concentration limits as defined for Category 3 LLW. (See *Category 3 low-level radioactive waste*.)

greater-than-Class C (GTCC)-like waste – As used in this environmental impact statement, GTCC-like waste refers to radioactive waste that is owned or generated by the U.S. Department of Energy (DOE) and has characteristics similar to those of GTCC low-level radioactive waste (LLW) such that a common disposal approach may be appropriate. GTCC-like waste consists of LLW and potential non-defense-generated transuranic waste that has no identified path for disposal. The term is not intended to, and does not, create a new DOE classification of radioactive waste.

greater-than-Class C (GTCC) low-level radioactive waste (LLW) – LLW generated by U.S. Nuclear Regulatory Commission (NRC) or agreement state licensees that contains radionuclide concentrations that exceed NRC limits for Class C LLW as defined in "Licensing Requirements for Land Disposal of Radioactive Waste" (Title 10 of the *Code of Federal Regulations*, Part 61). It is the most radioactive of the categories of LLW.

In addition to the GTCC LLW generated as a result of NRC- or agreement-state-licensed activities, the U.S. Department of Energy (DOE) generates waste containing concentrations of radionuclides that are similar to GTCC LLW. This waste is referred to as "DOE GTCC-like waste."

ground shine – The radiation dose received from an area on the ground where radioactivity has been deposited by a radioactive plume or cloud. (See *dose* and *ionizing radiation*.)

groundwater – Water below the ground surface in a zone of saturation.

grout – A fluid mixture of cement-like materials and liquid waste that sets up as a solid mass and is used for waste fixation, immobilization, and stabilization.

habitat – The environment occupied by individuals of a particular species, population, or community.

half-life (radiological) – The time in which one-half of the atoms of a particular radioactive isotope disintegrate to another nuclear form. Half-lives vary from millionths of a second to billions of years. (See *radioisotope or radionuclide*.)

Hanford barrier – A horizontal, multilayered, above-grade soil structure used as a representative surface barrier (cap) for closure at a Hanford Site landfill. The barrier's function is to isolate the waste site from the environment by preventing or reducing the likelihood of wind erosion; water infiltration; or plant, animal, or human intrusion. (See *barrier* and *cap*.)

Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) – An agreement signed in 1989 by the U.S. Department of Energy, the U.S. Environmental Protection Agency, and the Washington State Department of Ecology that identifies milestones for key environmental restoration and waste management actions.

hazard driver – A chemical constituent of potential concern evaluated in this environmental impact statement to be a major contributor to chemical hazard (i.e., non-cancer-associated toxic effects) during the year of peak hazard at locations of analysis during the 10,000-year period of analysis. (See *risk driver* and *10,000-year period of analysis*.)

Hazard Index – *(ecological definition)* The sum of the individual Hazard Quotients of constituents within a class that exert effects with the same toxicological mechanism or endpoint and are additive in effect. (See *additive* and *Hazard Quotient*.)

(human health definition) A summation of the Hazard Quotients for all chemicals now being used at a site, as well as those proposed to be added, to yield the cumulative levels for the site. A Hazard Index value of 1 or less means that no adverse human health effects (noncancer) are expected to occur. (See *Hazard Quotient*.)

Hazard Quotient – The value used as an assessment of non-cancer-associated toxic effects of chemicals, e.g., kidney or liver dysfunction. It is a ratio of the estimated exposure to that level of exposure at which it is expected that adverse health effects would begin to be produced. It is independent of a cancer risk, which is calculated for only those chemicals identified as carcinogens. (See *cancer* and *carcinogen*.)

hazardous air pollutants – Air pollutants that are not covered by ambient air quality standards, but may present a threat of adverse human health or environmental effects. Those specifically listed in Title 40 of the *Code of Federal Regulations,* Section 61.01, are asbestos, benzene, beryllium, coke oven emissions, inorganic arsenic, mercury, radionuclides, and vinyl chloride. More broadly, hazardous air pollutants include any of the 189 pollutants listed in or pursuant to Section 112(b) of the Clean Air Act (Title 42 of the *United States Code*, Part 7412). (See *ambient air quality standards*, *beryllium*, and *Clean Air Act*.)

hazardous chemical – Under Title 29 of the *Code of Federal Regulations,* Part 1910, Subpart Z, hazardous chemicals are defined as "any chemical that is a physical hazard or a health hazard." Physical hazards include combustible liquids, compressed gases, explosives, flammables, organic peroxides, oxidizers, pyrophorics, and reactives. A health hazard is any chemical for which there is good evidence that acute or chronic health effects occur in exposed employees. Hazardous chemicals include carcinogens; toxic or highly toxic agents; reproductive toxins; irritants; corrosives; sensitizers; hepatotoxins; nephrotoxins; agents that act on the hematopoietic system; and agents that damage the lungs, skin, eyes, or mucous membranes. (See *carcinogen*.)

hazardous material – A material, including a hazardous substance, as defined by Title 49 of the *Code of Federal Regulations,* Section 171.8, that poses a risk to health, safety, or property when transported or handled.

hazardous substance – Any substance subject to the reporting and possible response provisions of the Clean Water Act (Title 33 of the *United States Code* [U.S.C.], Part 1251 et seq.) and the Comprehensive Environmental Response, Compensation, and Liability Act (42 U.S.C., Part 9601 et seq.). (See *Clean Water Act of 1972, 1987* and *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*.)

hazardous waste – A category of waste regulated under the Resource Conservation and Recovery Act (RCRA). To be considered hazardous, a waste must be a solid waste under RCRA and must exhibit at least one of four characteristics described in Title 40 of the *Code of Federal Regulations* (CFR), Sections 261.20 through 261.24 (i.e., ignitability, corrosivity, reactivity, or toxicity), or it must be specifically listed by the U.S. Environmental Protection Agency in 40 CFR, Sections 261.31 through 261.33. Hazardous waste may also include solid waste designated by Washington State in *Washington Administrative Code* 173-303-070 through 173-303-100 as dangerous or extremely hazardous waste. (See *Resource Conservation and Recovery Act*.)

heavy-haul truck – A truck that exceeds normally applicable vehicle weight limits for highway travel. State authorities may issue special permits allowing trucks to exceed weight limits to carry "nondivisible loads," such as spent nuclear fuel casks, on public highways. Roadways and bridges may need to be upgraded to carry such vehicles. (See *legal-weight truck* and *spent nuclear fuel*.)

As used in this environmental impact statement, "heavy-haul truck" means a truck with a gross vehicle weight (truck and cargo weight) of more than 58,500 kilograms (129,000 pounds).

heavy metal – In the context of nuclear technology, "heavy metal" means all uranium, plutonium, or thorium placed into a nuclear reactor. (See *nuclear reactor*.)

heavy metals – Metallic and semimetallic elements that are generally highly toxic to plants and animals and tend to accumulate in food chains are referred to collectively as "heavy metals." Heavy metals include lead, mercury, cadmium, chromium, and arsenic.

hexavalent – Having a valence of six. (See *hexavalent chromium* and *valence*.)

hexavalent chromium – Hexavalent chromium compounds are a group of chemical substances that contain the metallic element chromium in its positive-6 valence (hexavalent) state. (See *hexavalent* and *valence*.)

high-efficiency particulate air filter – An air filter capable of removing at least 99.97 percent of particles 0.3 micrometers (about 0.00001 inches) in diameter. These filters include a pleated fibrous medium (typically fiberglass) that is capable of capturing very small particles.

high-integrity container – A container that provides additional confinement for remote-handled Category 3 low-level radioactive waste (LLW) and some contact-handled Category 3 LLW and is typically constructed of concrete or other durable material. (See *Category 3 low-level radioactive waste*, *contact-handled waste*, and *remote-handled waste*.)

high-level radioactive waste – As defined in the *Radioactive Waste Management Manual* (U.S. Department of Energy Manual 435.1-1), highly radioactive waste material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations; and other highly radioactive material that is determined, consistent with existing law, to require permanent isolation. (See *fission products*, *radioactive waste*, and *spent nuclear fuel*.)

highly enriched uranium – Uranium whose content of the fissile isotope uranium-235 has been increased through enrichment to 20 percent or more (by weight). (See *depleted uranium*, *enriched uranium*, and *natural uranium*.)

historic resources – (1) Archaeological sites, architectural structures, and objects produced after the advent of written history or dating to the time of the first European-American contact in an area. (See *archaeological sites*.)

(2) As defined by the National Historic Preservation Act of 1966, as amended (Title 16 of the *United States Code*, Part 470 et seq.), any prehistoric or historic district, site, building, structure, or object included in, or eligible for inclusion on, the National Register of Historic Places, including artifacts, records, and material remains related to such a property or resource. (See *National Historic Preservation Act* and *National Register of Historic Places*.)

Holocene – An epoch of the Quaternary period that began at the end of the Pleistocene, or the "Ice Age," about 10,000 years ago and continues to the present. It is named from the Greek words "holos" (entire) and "ceno" (new). (See *Pleistocene* and *Quaternary*.)

hot cell – A shielded facility that requires the use of remote manipulators for handling radioactive materials.

hydraulic head – A specific measurement of the potential for water to flow, expressed in units of length relative to a vertical datum. For an unconfined aquifer (as modeled in this environmental impact statement [EIS]), the hydraulic head is nearly equivalent to the water table elevation. In this EIS, hydraulic head is expressed in meters relative to the North American Vertical Datum of 1988 (NAVD88).

hydrology – The science dealing with the properties, distribution, and circulation of natural water systems.

hydrophobic – Lacking an affinity for water.

immobilization – Placement of waste within a material such as concrete or glass to reduce (immobilize) the dispensability and leachability of the radioactive or hazardous components within the waste. (See *vitrification*.)

immobilized low-activity waste (ILAW) – (1) Waste immobilized by the Waste Treatment Plant or processed by supplemental treatment (i.e., bulk vitrification, cast stone, or steam reforming). After receiving the necessary approvals, ILAW could be managed as low-level radioactive waste incidental to reprocessing, as defined in the *Radioactive Waste Management Manual* (U.S. Department of Energy Manual 435.1-1). Because it is produced from treatment of Hanford Site tank waste, it also could be managed as a mixed waste. (See *cast stone*, *low-activity waste*, *mixed waste*, *vitrification*, and *Waste Treatment Plant*.) (2) Waste that contains mostly nonradioactive chemical constituents.

incident-free risk – The radiological or chemical impacts resulting from emissions during normal operations and normal transportation of packages aboard vehicles. This includes the radiation or hazardous chemical exposure of specific population groups and workers. (See *exposure*, *hazardous chemical*, and *ionizing radiation*.)

indirect jobs – Within a regional economic area, jobs generated or lost in related industries as a result of a change in direct employment.

infrastructure – The basic facilities, services, and utilities needed for the functioning of an industrial facility. Transportation and electrical systems are part of the infrastructure.

ingestion – The action of taking solids or liquids into the digestive system.

inhalation – The action of taking airborne material into the respiratory system.

injection well – A well that takes water from the surface into the ground, either through gravity or by mechanical means.

injector – A device that provides protons for an accelerator by heating hydrogen gas to a plasma state in which the hydrogen atoms lose their electrons, thereby giving the hydrogen nuclei a positive charge. An electric voltage removes the protons from the injector. (See *electron* and *proton*.)

inorganic – Of or pertaining to chemical substances that do not contain carbon except for compounds such as carbonates, carbides, cyanides, carbon dioxide, and carbon monoxide.

institutional control – The period of time when a site is under active governmental controls. Institutional controls may include administrative or legal controls, physical barriers or markers, and methods to preserve information and data and to inform current and future generations of hazards and risks.

Integrated Disposal Facility – A permitted landfill on the Hanford Site with two separate, expandable cells—one for the disposal of low-level radioactive waste and another for the disposal of mixed low-level radioactive waste. (See *low-level radioactive waste* and *mixed low-level radioactive waste*.)

intensity (of an earthquake) – A measure of the effects (due to ground shaking) of an earthquake at a particular location, based on observed damage to structures built by humans, changes in Earth's surface, and reports of how people felt the earthquake. Earthquake intensity is measured in numerical units on the Modified Mercalli Intensity Scale. (See *magnitude [of an earthquake]* and *Modified Mercalli Intensity Scale*.)

interbedded (geological) – Occurring between beds (layers) or lying in a bed parallel to other beds of a different material.

interim status facility (under the Resource Conservation and Recovery Act [RCRA]) – A hazardous waste management (treatment, storage, or disposal) facility that is subject to RCRA permit requirements and was in existence on the effective date of the law or its implementing regulations. Such facilities are considered to have been issued a permit on an interim basis if they met the requirements for notification and submitted a permit application. Such facilities are required to meet the interim status standards described in Title 40 of the *Code of Federal Regulations*, Part 265, until they have been issued a final permit or until their interim status is withdrawn. (See *Resource Conservation and Recovery Act*.)

internal dose – That portion of the dose equivalent received from radioactive material taken into the body (i.e., "internal sources"). (See *dose equivalent*.)

in-trench grouting – Involves placing the waste on a cement pad or on spacers, installing reinforcement steel and forms around the waste, and covering the waste with fresh concrete to encapsulate the waste within a concrete barrier.

invertebrate – Of or pertaining to animals that do not have a backbone.

involved worker – A worker participating in a proposed action. (See *noninvolved worker*.)

ion – An atom that has too many or too few electrons, causing it to be electrically charged. (See *electron*.)

ion exchange – A unit physiochemical process that removes anions and cations, including radionuclides, from liquid streams (usually water) for the purpose of purification or decontamination. (See *anion*, *cation*, and *radioisotope or radionuclide*.)

ion exchange resin – An organic polymer that functions as an acid or base. These resins are used to remove ionic material from a solution. Cation exchange resins are used to remove positively charged particles (cations); anion exchange resins, to remove negatively charged particles (anions). (See *acid*, *base*, and *polymer*.)

ionizing radiation – Alpha particles, beta particles, gamma rays, high-speed electrons, high-speed protons, and other particles or electromagnetic radiation that can displace electrons from atoms or molecules, thereby producing ions. (See *alpha radiation*, *beta particle*, *electron*, *gamma radiation*, *ion*, and *proton*.)

irradiated – Exposed to ionizing radiation. The condition of nuclear reactor fuel elements and other materials in which atoms bombarded with nuclear particles have undergone nuclear changes. (See *ionizing radiation*.)

isotope – Any of two or more variations of an element in which the nuclei have the same number of protons (i.e., the same atomic number) but different numbers of neutrons so that their atomic masses differ. Isotopes of a single element possess almost identical chemical properties, but often different physical properties (e.g., carbon-12 and -13 are stable; carbon-14 is radioactive). (See *neutron*, *nucleus*, and *proton*.)

joule – A metric unit of energy, work, or heat, equivalent to 1 watt-second, 0.737 foot-pounds, or 0.239 calories.

joule-heated melter – See *melter*.

lacustrine – Of or pertaining to lakes.

land disposal restrictions – The restrictions and requirements for land disposal of hazardous or dangerous waste as specified in Title 40 of the *Code of Federal Regulations*, Part 268 (U.S. Environmental Protection Agency "Land Disposal Restrictions"), and *Washington Administrative Code* 173-303-140 (Washington State "Dangerous Waste Regulations: Land Disposal Restrictions").

landfill closure – Following tank waste retrieval, the single-shell tank system would be closed in accordance with state, Federal, and/or U.S. Department of Energy requirements for closure of a landfill. Landfill closure typically includes site stabilization and emplacement of a surface barrier, followed by a postclosure care period. (See *barrier*, *postclosure care*, and *single-shell tank [SST] system*.)

landscape character – The arrangement of a particular landscape as formed by the variety and intensity of the landscape features (land, water, vegetation, and structures) and the four basic elements (form, line, color, and texture). These factors give an area a distinctive quality that distinguishes it from its immediate surroundings.

land use designations – Land use designations at the Hanford Site were established by the U.S. Department of Energy under the 1999 *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement* Record of Decision, amended in September 2008. Changes to land use are subject to procedures identified in that environmental impact statement.

Industrial: An area that is suitable and desirable for activities such as reactor operations; rail and barge transport facilities; mining; manufacturing; food processing; assembly, warehouse, and distribution operations; and other industrial uses.

Industrial-Exclusive: An area that is suitable and desirable for treatment, storage, and disposal of hazardous, dangerous, radioactive, and nonradioactive wastes and related activities.

Conservation (Mining): An area reserved for management and protection of archaeological, cultural, ecological, and natural resources. Limited and managed mining (e.g., quarrying for sand, gravel, basalt, and topsoil for governmental purposes only) could occur as a special use within appropriate areas (a permit would be required). Limited public access would be consistent with resource conservation. This designation includes related activities.

larval – Of or pertaining to the juvenile form of certain kinds of animals.

latent cancer fatality – Death from cancer occurring sometime after, and postulated to be due to, exposure to ionizing radiation or other carcinogens. (See *cancer*, *carcinogen*, and *ionizing radiation*.)

leachate – As applied to mixed low-level radioactive waste trenches, any liquid, including any suspended components in the liquid, that has percolated through, or drained from, hazardous waste. (See *mixed low-level radioactive waste*.)

legal-weight truck – A truck that meets vehicle weight limits for U.S. interstate highways. Under Federal regulations (Title 23 of the *Code of Federal Regulations*, Section 658.17), the total loaded weight of a tractor-trailer combination is limited to 34,874 kilograms (80,000 pounds). Some states allow heavier vehicles on highways within the state.

license amendment – Changes to an existing reactor's operating license that are approved by the U.S. Nuclear Regulatory Commission. (See *U.S. Nuclear Regulatory Commission*.)

light water – The common form of water (a molecule with two hydrogen atoms and one oxygen atom, H_2O), in which the hydrogen atoms consist completely of the normal hydrogen isotope (one proton), with no additional neutrons. (See *isotope* and *proton*.)

light-water reactor – A nuclear reactor in which circulating light water is used to cool the reactor core and to moderate (reduce the energy of) the neutrons created in the core by the fission reactions. (See *fission*, *neutron*, and *nuclear reactor*.)

loam – Soil material that is composed of 7 to 27 percent clay particles, 28 to 50 percent silt particles, and less than 52 percent sand particles. (See *clay*, *sand*, and *silt*.)

lobe – A lobe is a section of a barrier that covers a tank farm or an area of contiguous tank farms. Three barrier lobes are anticipated in the 200-West Area, and two much larger lobes are anticipated in the 200-East Area.

long-lived radionuclide – A radioactive isotope with a half-life of generally greater than 30 years. (See *half-life [radiological]*, *isotope*, and *radioisotope or radionuclide*.)

loss-of-coolant accident – An accident that results from a loss of reactor coolant because of a break in the reactor coolant system. (See *nuclear reactor*.)

lost workdays – The total number of workdays (consecutive or not) during which employees were away from work or limited to restricted work activity because of an occupational injury or illness.

low-activity waste (LAW) – Waste that remains after as much radioactivity as technically and economically practical has been separated from high-level radioactive waste that, when solidified, may be disposed of as low-level radioactive waste in a near-surface facility. In its final form, such solid LAW would not exceed Title 10 of the *Code of Federal Regulations* (CFR), Section 61.55, Class C radioisotope limits and would meet performance objectives comparable to those in 10 CFR, Part 61, Subpart C. (See *high-level radioactive waste* and *low-level radioactive waste*.)

low-enriched uranium – Uranium whose content of the fissile isotope uranium-235 has been increased through enrichment to more than 0.7 percent, but less than 20 percent, by weight. Most nuclear-power reactor fuel contains low-enriched uranium containing 3 to 5 percent uranium-235.

low-income person – A person living in a household that reports an annual income less than the United States official poverty level, as reported by the U.S. Census Bureau.

low-income population – Low-income populations, as defined in terms of U.S. Census Bureau annual statistical poverty levels (Current Population Reports, Series P60 on Consumer Income), may consist of groups or individuals who either live in geographic proximity to one another or are geographically dispersed or transient (such as migrant workers or American Indians), where either type of group experiences common conditions of environmental exposure or effect. (See *environmental justice* and *minority population*.)

low-level radioactive waste – Radioactive waste that is not high-level radioactive waste, spent nuclear fuel, transuranic waste, byproduct material (as defined in Section 11e(2) of the Atomic Energy Act of 1954, as amended [Title 42 of the *United States Code*, Part 2014]), or naturally occurring radioactive material.

macroencapsulation – Treatment method applicable to debris waste as defined by the Resource Conservation and Recovery Act (Title 42 of the *United States Code*, Part 6901 et seq.). Refers to application of surface-coating materials such as polymeric organics (e.g., resins, plastics) or of a jacket of inert material to reduce surface exposure to potential leaching media.

macroseismicity – Seismicity at a level that implies significant, coherent, sustained tectonic activity, as defined by the International Atomic Energy Agency. Associated earthquakes are generally of magnitude 3.5 or greater and instrumentally determined with records of sufficient precision to demonstrate a direct relationship with the causative fault. (See *fault* and *magnitude [of an earthquake]*.)

magnitude (of an earthquake) – A term used to quantify the total energy released by an earthquake, in contrast to "intensity," which describes its effects at a particular place. Magnitude is determined by taking the common logarithm (base 10) of the largest ground motion recorded on a seismograph during the arrival of a seismic wave and applying a standard correction factor for distance to the epicenter. The three common types of magnitude are Richter (or local) (M_L), P body wave (m_b), and surface wave (M_s). Additional magnitude scales, notably the moment magnitude (M_w), have been introduced to increase uniformity in the representation of an earthquake's size.

Moment magnitude is defined as the rigidity of the rock multiplied by the area of faulting, multiplied by the amount of slip. A one-unit increase in magnitude (for example, from magnitude 6 to magnitude 7) represents a 30-fold increase in the amount of energy released. (See *intensity [of an earthquake]*.)

mammal – Warm-blooded, hairy vertebrates whose offspring are fed by milk secreted by the female.

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

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

maximally exposed individual (MEI) – A hypothetical individual whose location and habits result in the highest total radiological or chemical exposure (and thus dose) from a particular source for all exposure routes (e.g., inhalation, ingestion, direct exposure). As used in this environmental impact statement, the MEI refers to an individual located off site, unless characterized otherwise in terms of time or location. (See *exposure*.)

maximum contaminant level (MCL) – The U.S. Environmental Protection Agency (EPA) standards for drinking water quality under the Safe Drinking Water Act (Title 42 of the *United States Code*, Section 300(f) et seq.). The MCL for a given substance is the maximum permissible concentration of that substance in water delivered by a public water system, i.e., the "drinking water standard." The primary MCLs (Title 40 of the *Code of Federal Regulations* [CFR], Part 141) are intended to protect public health and are federally enforceable. They are based on health factors, but are also required by law to reflect the technological and economic feasibility of removing the contaminant from the water supply. Secondary MCLs (40 CFR, Part 143) are set by EPA to protect the public welfare. These secondary drinking water regulations control substances in drinking water that primarily affect aesthetic qualities (such as taste, odor, and color), which are related to public acceptance of water. These secondary regulations are not federally enforceable, but are intended as guidelines for the states.

mayflies – An insect that spends its larval stage on the bottom of a lake or stream and emerges into the terrestrial environment as a flying adult.

megawatt – A unit of power equal to 1 million watts. *Megawatt-thermal* is commonly used to describe heat produced, while *megawatt-electric* describes electricity produced.

melter – A term for the type of joule-heated melters used in the Waste Treatment Plant (WTP) to treat tank waste. Joule heating involves placing electrodes into a material (a slurry of tank waste mixed with glass-forming materials) and applying electrical potential. This results in an electrical current and resistance heating. WTP melters include (1) high-level radioactive waste (HLW) melters used to treat the HLW stream, producing a theoretical maximum capacity (TMC) of 3 metric tons of glass (MTG) per day, and (2) low-activity waste (LAW) melters used to treat the LAW stream, producing a TMC of 15 MTG per day. (See *high-level radioactive waste*, *low-activity waste*, and *Waste Treatment Plant*.)

meteorology – The science dealing with the atmosphere and its phenomena, especially as related to weather.

MeV (million electron volts) – A unit used to quantify energy. In this environmental impact statement, it describes a particle's kinetic energy, which is an indicator of particle speed.

microbial crust – A surface layer of microbes that becomes harder than the underlying soil horizon.

microbiotic crusts – See *cryptogamic (microbiotic) crusts*.

microencapsulation – Encapsulation of waste components in the atomic structure of compounds or materials such as glass, cement, or polymer waste forms. (See *polymer*.)

migration – (1) The natural movement of a material through the air, soil, or groundwater. (2) Seasonal movement of animals from one area to another.

Migratory Bird Treaty Act – This act (Title 16 of the *United States Code*, Part 703 et seq.) states that it is unlawful to pursue, take, attempt to take, capture, possess, or kill any migratory bird or any part, nest, or egg of any such bird unless permitted by regulations.

millirem – One-thousandth of 1 rem. (See *roentgen equivalent man [rem]*.)

minority – Individuals who are members of the following population groups: American Indian or Alaska Native; Asian or Pacific Islander; Black, not of Hispanic origin; or Hispanic.

minority population – Minority populations exist where either (1) the minority population of the affected area exceeds 50 percent or (2) the minority population percentage of the affected area is meaningfully greater than that in the general population or in some other appropriate unit of geographic analysis (such as a governing body's jurisdiction, a neighborhood, census tract, or other similar unit). "Minority populations" include either a single minority group or the total of all minority persons in the affected area. They may consist of groups of individuals living in geographic proximity to one another or a geographically dispersed/transient set of individuals (such as migrant workers or American Indians), where either type of group experiences common conditions of environmental exposure or effect. (See *environmental justice*, *low-income population*, and *minority*.)

Miocene – A geologic epoch of the upper Tertiary period, spanning between about 24 million and 5 million years ago. (See *Tertiary*.)

miscellaneous underground storage tanks – These tanks were used for waste storage in the past, and some are currently being used for a variety of purposes. The tanks vary in capacity from 3,407 to 189,270 liters (900 to 50,000 gallons) and are considered part of the Hanford Site tank waste system.

mitigation – Mitigation includes (1) avoiding an impact altogether by not taking a certain action or parts of an action; (2) minimizing impacts by limiting the degree or magnitude of an action and its implementation; (3) rectifying an impact by repairing, rehabilitating, or restoring the affected environment; (4) reducing or eliminating the impact over time by preservation and maintenance operations during the life of an action; or (5) compensating for an impact by replacing or providing substitute resources or environments. (See *affected environment*.)

mixed low-level radioactive waste – Low-level radioactive waste determined to contain source, special nuclear, or byproduct material that is subject to the Atomic Energy Act of 1954, as amended (Title 42 of the *United States Code* [U.S.C.], Part 2011 et seq.), as well as a hazardous component subject to the Resource Conservation and Recovery Act, as amended (42 U.S.C., Part 6901 et seq.), or *Washington Administrative Code* 173-303-140. (See *byproduct material*, *dangerous waste*, *hazardous waste*, *low-level radioactive waste*, *source material*, and *special nuclear material*.)

mixed oxide fuel – Nuclear reactor fuel made with a physical blend of different fissionable materials, such as uranium dioxide and plutonium dioxide. (See *nuclear reactor*.)

mixed waste – Waste that contains source, special nuclear, or byproduct material that is subject to the Atomic Energy Act of 1954, as amended (Title 42 of the *United States Code* [U.S.C.], Part 2011 et seq.), as well as a hazardous component subject to the Resource Conservation and Recovery Act (42 U.S.C., Part 6901 et seq.). (See *byproduct material*, *source material*, and *special nuclear material*.)

moderator – A material used to decelerate neutrons in a nuclear reactor from high energies to low energies. (See *neutron* and *nuclear reactor*.)

Modified Mercalli Intensity – A level on the Modified Mercalli Intensity Scale that expresses observed effects. A measure of the perceived intensity of earthquake ground shaking, with 12 divisions from I (not felt except by a very few people) to XII (damage total). (See *Modified Mercalli Intensity Scale*.)

Modified Mercalli Intensity Scale – A standard of relative measurement of earthquake intensity, developed to fit construction conditions in most of the United States. It is a 12-step scale, with values from I (not felt except by a very few people) to XII (damage total).

modified RCRA Subtitle C barrier – Landfill cover described by Resource Conservation and Recovery Act (Title 42 of the *United States Code*, Part 6901 et seq.) regulations that also accounts for the unique climatic conditions at the Hanford Site. The design includes layers for foundation and slope, gas collection, and drainage, as well as a low-permeability barrier and cover soil.

modular facility – As used in this environmental impact statement, a modular disposal facility would consist of a number of expandable segments or areas within an overall master facility. Each module would be designed to handle certain waste types or forms. For example, remote-handled waste might be in a different area or "module" than standard packages of contact-handled low-level radioactive waste (LLW) or mixed LLW.

molar – A chemical term relating to the mole, or gram-molecular weight. A 1-molar solution would have 1 mole of solute per liter of solution.

mole ratio (molar ratio) – The mole ratio is the fraction created when a mole of one element is measured against a molar gram of carbon (e.g., 1 mole of nitrogen/1 mole of carbon). A mole is the amount of a substance that contains as many atoms, molecules, ions, or other elementary units as the number of atoms in 0.012 kilograms of carbon-12. The number is 6.0225×10^{23}, or Avogadro's number. Also called *gram molecule*.

monitor species – *Idaho State:* Plant taxa that are common within a limited range or taxa that are uncommon but have no identifiable threats. (See *taxa*.)

Washington State: Animal species that are not considered species of concern, but are monitored for status and distribution. They require management, survey, or data emphasis because they (1) were classified as endangered, threatened, or sensitive within the last 5 years; (2) require habitat that is of limited availability during some of their life cycle; (3) are indicators of environmental quality; or (4) have unresolved taxonomic questions. They are managed by the Washington Department of Fish and Wildlife, as needed, to prevent them from becoming endangered, threatened, or sensitive (*Washington Administrative Code* 232-12-297). (See *endangered species*, *sensitive species*, and *threatened species*.)

mud – A general field term for sedimentary strata or rock composed predominantly of clay-sized particles. Specific lithofacies (rock or sediment characteristics) of geologic members within the Ringold Formation at the Hanford Site have been named "mud" units by members of the geologic community and are formally recognized as such. (See *clay* and *sediment*.)

National Ambient Air Quality Standards – Standards defining the highest allowable levels of certain pollutants in the ambient air (outdoor air to which the public has access). Because the U.S. Environmental Protection Agency must establish the criteria for setting these standards, the regulated pollutants are called criteria pollutants. Criteria pollutants include sulfur dioxide, nitrogen dioxide, carbon monoxide, ozone, lead, and two size classes of particulate matter: less than or equal to 2.5 and 10 micrometers (0.0001 and 0.0004 inches, respectively) in diameter. Primary standards are established to protect public health; secondary standards are established to protect public welfare (e.g., visibility, crops, animals, buildings). (See *criteria pollutant*.)

National Emission Standards for Hazardous Air Pollutants (NESHAPs) – Emission standards set by the U.S. Environmental Protection Agency for air pollutants that are not covered by National Ambient Air Quality Standards and may, at sufficiently high levels, cause increased fatalities, irreversible health effects, or incapacitating illness. These standards are given in Title 40 of the *Code of Federal Regulations*, Parts 61 and 63. NESHAPs are given for many specific categories of sources (e.g., equipment leaks, industrial process cooling towers, drycleaning facilities, petroleum refineries). (See *hazardous air pollutants* and *National Ambient Air Quality Standards*.)

National Environmental Policy Act (NEPA) of 1969 – This act (Title 42 of the *United States Code*, Part 4321 et seq.) is the basic national charter for protection of the environment. It establishes policy, sets goals (Section 101), and provides means for carrying out policy (Section 102). Section 102(2) contains "action-forcing" provisions to ensure that Federal agencies follow the letter and spirit of the act. For major Federal actions significantly affecting the quality of the human environment, Section 102(2)(C) of NEPA requires Federal agencies to prepare a detailed statement that analyzes the environmental impacts of the proposed actions and other specified information. (See *environmental impact statement*.)

National Historic Preservation Act – This act (Title 16 of the *United States Code*, Part 470 et seq.) provides for placement of property resources with significant national historic value on the National Register of Historic Places. It does not require any permits; however, pursuant to Federal code, if a proposed action might impact a historic property resource, it mandates consultation with the proper agencies.

National Pollutant Discharge Elimination System (NPDES) – A provision of the Clean Water Act (Title 33 of the *United States Code*, Part 1251 et seq.) that prohibits discharge of pollutants into waters of the United States unless a special permit is issued by the U.S. Environmental Protection Agency; a state;

or, where delegated, a tribal government on an American Indian reservation. The NPDES permit lists either permissible discharges, the level of cleanup technology required for wastewater, or both. (See *Clean Water Act of 1972*, *1987*.)

National Priorities List (NPL) – The U.S. Environmental Protection Agency's (EPA's) list of the most serious uncontrolled or abandoned hazardous waste sites identified for possible long-term remedial action under the Comprehensive Environmental Response, Compensation, and Liability Act (Title 42 of the *United States Code*, Part 9601 et seq.). The list is based primarily on the score a site receives from the Hazard Ranking System described in Title 40 of the *Code of Federal Regulations*, Part 300, Appendix A. EPA must update the NPL at least once a year. (See *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*.)

National Register of Historic Places – The official list of the Nation's historic resources that are worthy of preservation. The National Park Service maintains the list under direction of the Secretary of the Interior. Buildings, structures, objects, sites, and districts are included in the National Register for their importance in American history, architecture, archaeology, culture, or engineering. Properties included in the National Register range from large-scale, monumentally proportioned buildings to smaller-scale, regionally distinctive buildings. Listed properties are not just of nationwide importance; most are primarily significant at the state or local level. Procedures for listing properties in the National Register are found in Title 36 of the *Code of Federal Regulations*, Part 60.

natural uranium – Uranium with the naturally occurring distribution of uranium isotopes (about 0.7 weight-percent uranium-235, with the remainder essentially uranium-238). (See *depleted uranium*, *enriched uranium*, *highly enriched uranium*, *low-enriched uranium*, and *uranium*.)

neptunium – A mostly manmade element with the atomic number 93. Pure neptunium is a silvery metal. The neptunium-237 isotope has a half-life of 2.14 million years. When neptunium-237 is bombarded by neutrons, it is transformed to neptunium-238, which in turn undergoes radioactive decay to become plutonium-238. When neptunium-237 undergoes radioactive decay, it emits alpha particles and gamma rays. (See *alpha particle*, *atomic number*, *beta particle*, *gamma radiation*, *neutron*, and *radioactive decay*.)

neutralization – Changing the pH of a solution to near 7 by adding an acidic or basic material. (See *pH*.)

neutron – An uncharged elementary particle with a mass slightly greater than that of the proton. Neutrons are found in the nucleus of every atom heavier than hydrogen-1. (See *nucleus* and *proton*.)

neutron flux – The product of neutron number density and velocity (energy), giving an apparent number of neutrons flowing through a unit area per unit time. (See *neutron*.)

nitrate – A compound containing nitrogen, typically seen as a negative anion composed of one nitrogen and three oxygen atoms. (See *anion*.)

nitrogen – A natural element with the atomic number 7. It is a diatomic, colorless, odorless gas that constitutes about four-fifths of the volume of the atmosphere. (See *atomic number*.)

nitrogen oxides – The oxides of nitrogen, primarily nitrogen oxide and nitrogen dioxide. These are produced by the combustion of fossil fuels and can constitute an air pollution problem. Nitrogen dioxide emissions contribute to acid deposition and formation of atmospheric ozone. (See *acid*, *oxide*, and *ozone*.)

noise – Any sound that is undesirable because it interferes with speech and hearing, is intense enough to damage hearing, or is otherwise annoying or undesirable.

nonattainment area – An area that the U.S. Environmental Protection Agency has determined does not meet one or more of the National Ambient Air Quality Standards for sulfur dioxide, nitrogen dioxide, carbon monoxide, ozone, lead, and particulate matter. An area may meet the standards for some pollutants, but not for others. (See *carbon monoxide*, *National Ambient Air Quality Standards*, *nitrogen oxides*, *ozone*, *particulate matter*, and *sulfur oxides*.)

noninvolved worker – A worker on the site of an action, but not participating in the action. (See *involved worker*.)

nonstandard (waste packaging) – Specially designed waste containers or packages used for large or odd-shaped low-level radioactive waste (LLW), mixed LLW, transuranic waste, or items with high dose rates or other unique conditions. (See *standard [waste packaging]*.)

nonvegetated blowout – An area that forms when a patch of protective vegetation is lost, allowing strong winds to "blow out" sand and form a depression.

normal operations – All normal (incident-free) conditions, as well as those abnormal conditions that frequency estimation techniques indicate typically occur with a frequency greater than 0.1 events per year. As used in this environmental impact statement, normal operations refers to routine waste management activities (excluding accident conditions, except for minor process upsets), e.g., waste treatment activities (including processing), packaging and repackaging, storage, final disposal of waste.

northing – The difference in latitude between two positions as a result of movement to the north.

Notice of Intent – An announcement of the initiation of an environmental impact scoping process. The Notice of Intent is usually published in both the *Federal Register* and a local newspaper. The scoping process includes holding at least one public meeting and requesting comments on issues and environmental concerns that an environmental impact statement should address. (See *environmental impact statement*.)

nuclear criticality – See *criticality*.

nuclear facility – A facility that is subject to requirements intended to control potential nuclear hazards. Defined in U.S. Department of Energy directives as "any nuclear reactor or any other facility whose operations involve radioactive materials in such form and quantity that a significant nuclear hazard potentially exists to the employees or the general public."

nuclear fuel cycle – The path followed by nuclear fuel in its various states from mined ore to waste disposal. The basic fuel materials for the generation of nuclear power are the elements uranium and thorium.

nuclear grade – Material of a quality that is adequate for use in a nuclear application.

nuclear material – Composite term applied to (1) special nuclear material; (2) source material such as uranium or thorium or ores containing uranium or thorium; and (3) byproduct material, which is any radioactive material that is made radioactive by exposure to the radiation incident to the process of producing or using special nuclear material. (See *byproduct material*, *source material*, and *special nuclear material*.)

nuclear radiation – Particles (alpha, beta, neutrons) or photons (gamma) emitted from the nucleus of unstable radioactive atoms as a result of radioactive decay. (See *alpha particle*, *beta particle*, *gamma radiation*, *neutron*, *nucleus*, and *radioactive decay*.)

nuclear reactor – A device that sustains a controlled nuclear-fission chain reaction that releases energy in the form of heat. (See *chain reaction.*)

nucleus – The positively charged central portion of an atom that composes nearly all of the atomic mass and consists of protons and neutrons, except in hydrogen, in which it consists of one proton only. (See *neutron* and *proton*.)

nuclide – A species of atom characterized by the constitution of its nucleus (the number of protons and neutrons and the energy content). (See *neutron*, *nucleus*, and *proton*.)

occlusion – A blocking or obstruction of something.

Occupational Safety and Health Administration – An agency of the U.S. Department of Labor that oversees and regulates workplace health and safety. The agency was created by the Occupational Safety and Health Act of 1970 (Title 29 of the *United States Code*, Part 651 et seq.).

offsite/off site – Outside the site boundary.

omnivore – An animal that eats both plant and animal matter.

onsite/on site – Within the site boundary.

operable unit – A term for each of a number of separate activities undertaken as part of a Superfund site cleanup. A typical operable unit would be removal of drums and tanks from the surface of a site. (See *Comprehensive Environmental Response*, *Compensation*, *and Liability Act of 1980*.)

operational waste – Solid waste that is generated to support cleanup activities, including contaminated personal protective clothing, disposable laboratory supplies, and failed tools and equipment.

order of magnitude – As used in this environmental impact statement, an order of magnitude is taken as a power (or factor) of 10.

outfall – The discharge point of a drain, sewer, or pipe as it empties into a body of water.

overpack – Any container into which another container (usually a waste container) is placed. An overpack might be used to provide shielding and structural support (e.g., during transportation), provide additional physical containment for the contents of the inner container, or enclose a damaged container.

oxidation – The combination of a substance with oxygen or the loss of electrons by an oxidized species in a reaction.

oxide – A compound of oxygen and another element.

ozone – The triatomic form of oxygen. In the stratosphere, ozone protects Earth from the Sun's ultraviolet rays, but in lower levels of the atmosphere, ozone is considered an air pollutant.

package – For radioactive materials, the packaging and its radioactive contents.

packaging – In regard to hazardous or radioactive materials, the assembly of components necessary to ensure compliance with Federal regulations for storage and transport. It may consist of one or more receptacles, absorbent materials, spacing structures, thermal insulation, radiation shielding, and devices for cooling or absorbing mechanical shocks. The vehicle tie-down system and auxiliary equipment may be designated part of the packaging.

parameter – A term in a model or equation representing a measurable property or quantity of fixed or variable value.

particulate matter (PM) – Any finely divided solid or liquid material other than uncombined (i.e., pure) water. A subscript denotes the upper limit of the diameter of the particles included. Thus, $PM_{2.5}$ includes only particulate matter with an aerodynamic diameter less than or equal to 2.5 micrometers (0.0001 inches); PM_{10}, less than or equal to 10 micrometers (0.0004 inches).

partitioning or distribution coefficient – A quantity relating the amount or concentration of a substance in a unit of soil or sediment to the amount or concentration in the overlying or pore water in contact with the solid medium. (See *pore water*.)

past-practice unit – The Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) defines past-practice unit as a waste management unit where wastes or substances have been disposed of (intentionally or unintentionally) that is not subject to regulation as a treatment, storage, or disposal unit. Due to the relatively large number of past-practice units at the Hanford Site, these units have been organized into groups called operable units for investigation and response action to prioritize the cleanup work to be done at the site. (See *Hanford Federal Facility Agreement and Consent Order*.)

pathways (exposure) – The means by which a substance moves from an environmental source to an organism.

peak ground acceleration – A measure of the maximum horizontal acceleration (as a percentage of the acceleration due to Earth's gravity) experienced by a particle on the surface of Earth during the course of earthquake motion.

perched aquifer/groundwater – A body of groundwater of small lateral dimensions separated from an underlying body of groundwater by an unsaturated zone.

performance assessment – A systematic analysis of the potential risks posed by waste management systems to the public and the environment and a comparison of those risks to established performance objectives.

periphyton – Total assemblage of attached (sessile) organisms on any substrate that are capable of fixing carbon by photosynthesis or chemosynthesis.

permeability – In geology, the ability of rock or soil to transmit a fluid.

person-rem – A unit of collective radiation dose applied to populations or groups of individuals; that is, a unit for expressing the dose when summed across all persons in a specified population or group. One person-rem equals 0.01 person-sieverts. (See *collective dose*, *dose*, *ionizing radiation*, and *person-sievert*.)

person-sievert – A unit of collective radiation dose applied to populations or groups of individuals; that is, a unit for expressing the dose when summed across all persons in specified population or group. One person-sievert equals 100 person-rem.

pH – A measure of the relative acidity or alkalinity of a solution, expressed on a scale from 0 to 14, with the neutral point at 7.0. Acid solutions have pH values lower than 7.0, and basic (alkaline) solutions have pH values higher than 7.0.

Because pH is the negative logarithm of the hydrogen ion (H+) concentration, each unit increase in pH value expresses a change of state of 10 times the preceding state. Thus, pH 5 is 10 times more acidic than pH 6, and pH 9 is 10 times more alkaline than pH 8.

phenolic protective coating – A coating material made from the chemical phenol.

photon – A unit of electromagnetic energy exhibiting behavior like that of a particle.

physical extraction – Separation or removal of materials or components based on size or material characteristic.

phytoplankton – Microscopic plants floating in a body of water that are incapable of countering water movements.

picocurie – One trillionth (10^{-12}) of a curie. (See *curie*.)

Pleistocene – The geologic period of the earliest epoch of the Quaternary period, spanning between about 1.6 million years ago and the beginning of the Holocene epoch at 10,000 years ago. It is characterized by the succession of northern glaciations; also called the "Ice Age." (See *Holocene* and *Quaternary*.)

Pliocene – The latest geologic epoch of the Tertiary period, beginning about 5.3 million years ago and ending 1.6 million years ago. (See *Tertiary*.)

plume – The elongated volume of contaminated water or air originating at a pollutant source, such as an outlet pipe or a smokestack. A plume eventually diffuses into a larger volume of less-contaminated material as it is transported away from the source.

plutonium – A heavy, radioactive metallic element with the atomic number 94. It is produced artificially by neutron bombardment of uranium. Plutonium has 15 isotopes, with atomic masses ranging from 232 to 246 and half-lives ranging from 20 minutes to 76 million years. (See *atomic number, half-life [radiological], isotope,* and *neutron*.)

plutonium-238 – An isotope with a half-life of 87.74 years, used as the heat source for radioisotope power systems. When plutonium-238 undergoes radioactive decay, it emits alpha particles and gamma rays. (See *alpha particle*, *beta particle*, *gamma radiation*, *half-life [radiological]*, *isotope*, and *radioactive decay*.)

plutonium-239 – An isotope with a half-life of 24,110 years, it is the primary radionuclide in weapons-grade plutonium. When plutonium-239 decays, it emits alpha particles. (See *alpha particle*, *half-life [radiological]*, *isotope*, *radioactive decay*, and *radioisotope or radionuclide*.)

$PM_{2.5}$ and **PM_{10}** – See *particulate matter.*

pollution prevention – The use of materials, processes, and practices that reduce or eliminate the generation and release of pollutants, contaminants, hazardous substances, and waste into land, water, and air. For the U.S. Department of Energy, this includes recycling activities. (See *waste minimization and pollution prevention*.)

polychlorinated biphenyl (PCB) – Any compound or mixture of compounds of a family of chlorinated organic chemicals that were formerly manufactured for use as coolants and lubricants in transformers, capacitors, and other electrical equipment. The manufacture of PCBs stopped in the United States in 1977 because of evidence that they build up in the environment and cause harmful effects. PCBs in water, for example, build up in fish and marine mammals and can reach levels thousands of times higher than the levels in water. It is not known whether PCBs cause cancer in people, but the U.S. Department of Health and Human Services has determined that PCBs may reasonably be anticipated to be carcinogens. The U.S. Environmental Protection Agency has classified all PCBs as Group B2, possible human carcinogens. (See *carcinogen*.)

polymer – A natural or synthetic chemical compound or mixture of compounds formed by a chemical reaction in which two or more small molecules combine to form larger molecules that contain repeating structural units of the original molecules.

population dose – See *collective dose*.

pore water – The water present between particles of soil or sediment.

postclosure care – The period following closure of a hazardous waste disposal system (e.g., a landfill) during which monitoring and maintenance activities must be conducted to preserve the integrity of the disposal system and continue preventing or controlling releases from the disposal unit.

pounds per square inch – A measure of pressure; atmospheric pressure is about 14.7 pounds per square inch.

predator – An animal that eats another animal.

Prevention of Significant Deterioration (PSD) (of air quality) – Regulations established to prevent significant deterioration of air quality in areas that already meet National Ambient Air Quality Standards. Specific details of PSD are found in Title 40 of the *Code of Federal Regulations* (CFR), Section 51.166. Among other provisions, cumulative increases in sulfur dioxide, nitrogen dioxide, and PM_{10} (particulate matter with an aerodynamic diameter less than or equal to 10 micrometers) levels after specified baseline dates must not exceed specified maximum allowable amounts. These allowable increases, also known as increments, are especially stringent in areas designated as Class I areas (e.g., national parks, wilderness areas), where the preservation of clean air is particularly important. All areas not designated as Class I are currently designated as Class II. Maximum increments in pollutant levels are also given in 40 CFR, Section 51.166, for Class III areas, if any such areas should be so designated by the U.S. Environmental Protection Agency. Class III increments are less stringent than those for Class I or II areas. (See *National Ambient Air Quality Standards*.)

prey – An animal that is eaten by another animal.

primary system – In regard to nuclear reactors, the system that circulates a coolant (e.g., water) through the reactor core to remove the heat of reaction. (See *nuclear reactor*.)

prime farmland – Land that has the best combination of physical and chemical characteristics for producing food, feed, fiber, forage, oilseed, and other agricultural crops with minimum inputs of fuel, fertilizer, pesticides, and labor and without intolerable soil erosion, as determined by the Secretary of Agriculture (Farmland Protection Policy Act of 1981 [Title 7 of the *United States Code*, Part 4201 et seq.]).

Priority 1 species (Idaho State) – A taxon in danger of becoming extinct in Idaho in the foreseeable future if identifiable factors contributing to its decline continue to operate; these are taxa whose populations are present only at a critically low level or whose habitats have been degraded or depleted to a significant degree. (See *taxon*.)

Priority 2 species (Idaho State) – A taxon likely to be classified as Priority 1 within the foreseeable future in Idaho if factors contributing to its population decline or habitat degradation or loss continue. (See *taxon*.)

priority habitat – A habitat type with unique or significant value to many species that may be described by a (1) unique vegetation type or dominant plant species of primary importance to fish and wildlife (e.g., oak woodlands, eelgrass meadows) or (2) successional stage (e.g., old growth, mature forests). Alternatively, a priority habitat may consist of a specific habitat element (e.g., consolidated marine/estuarine shorelines, talus slopes, caves, snags) of key value to fish and wildlife.

probabilistic risk assessment – A comprehensive, logical, and structured methodology that accounts for population dynamics and human activity patterns at various levels of sophistication, considering time-space distributions and sensitive subpopulations. The probabilistic method results in a more complete characterization of the exposure information available, which is defined by probability distribution functions. This approach offers the possibility of an associated quantitative measure of the uncertainty around the value of interest.

process – Any method or technique designed to change the physical or chemical character of a product.

processing – As used in this environmental impact statement, any activity necessary to prepare waste for disposal. Processing waste may consist of repackaging, removal, or stabilization of nonconforming waste or treatment of physically or chemically hazardous constituents in compliance with state or Federal regulations.

protactinium – An element produced by the radioactive decay of neptunium-237. This pure metal has a bright metallic luster. The protactinium-233 isotope has a half-life of 27 days and emits beta particles and gamma rays during radioactive decay. (See *beta particle*, *gamma radiation*, *half-life [radiological]*, *isotope*, and *radioactive decay*.)

proton – An elementary nuclear particle with a positive charge equal in magnitude to the negative charge of the electron; it is a constituent of all atomic nuclei. The atomic number of an element indicates the number of protons in the nucleus of each atom of that element. (See *electron* and *nucleus*.)

PUREX – An acronym for plutonium-uranium extraction, the name of the chemical process usually used to remove plutonium and uranium from spent nuclear fuel, irradiated targets, and other nuclear materials. (See *plutonium*, *spent nuclear fuel*, *target*, and *uranium*.)

purpose-built vessel – A vessel specifically designed to carry nuclear fuel casks.

pyrolysis – Chemical decomposition or other chemical change brought about by the action of heat, regardless of the temperature involved.

quality factor – A multiplying factor applied to an absorbed dose to express the biological effectiveness of the radiation producing it. The numerical values of the quality factor are given as a function of the linear energy transfer in water for the radiation producing the absorbed dose. (See *absorbed dose*.)

Quaternary – The second geologic time period of the Cenozoic era, dating from about 1.6 million years ago to the present. It contains two epochs: the Pleistocene and the Holocene, and is characterized by the first appearance of human beings on Earth. (See *Holocene* and *Pleistocene*.)

rad – See *radiation absorbed dose*.

radiation absorbed dose (rad) – The basic unit of absorbed dose equal to the absorption of 0.01 joules per kilogram (100 ergs per gram) of absorbing material (such as body tissue). One rad equals 0.01 grays. (See *erg*, *gray*, and *joule*.)

radiation (ionizing) – See *ionizing radiation*.

radioactive decay – The decrease in the amount of any radioactive material with the passage of time due to spontaneous nuclear disintegration (i.e., emission from atomic nuclei of charged particles, photons, or both). (See *nucleus*.)

radioactive waste – In general, waste that is managed for its radioactive content. Waste material that contains source, special nuclear, or byproduct material is subject to regulation as radioactive waste under the Atomic Energy Act (Title 42 of the *United States Code*, Part 2011 et seq.). Also, waste material that contains accelerator-produced radioactive material or a high concentration of naturally occurring radioactive material may be considered radioactive waste. (See *byproduct material*, *source material*, and *special nuclear material*.)

radioactivity – *(process definition)* The spontaneous transformation of unstable atomic nuclei, usually accompanied by the emission of ionizing radiation.

(property definition) The property of unstable nuclei in certain atoms to spontaneously emit ionizing radiation during nuclear transformations. (See *ionizing radiation* and *neutron*.)

radioisotope or radionuclide – An unstable isotope that undergoes spontaneous transformation, emitting radiation. (See *isotope*.)

radiological risk – In general, a measure of potential harm to populations or individuals due to the presence or occurrence of an environmental or manmade radiological hazard. In terms of human health, risk comprises three components: a sequence of events leading to an adverse impact, the probability of occurrence of that sequence of events, and the severity of the impact. For the release of radionuclides affecting a population, the impact is occurrence of a fatal cancer; risk is expressed as the expected number of latent cancer fatalities (i.e., the product of probability of occurrence and the magnitude of impact). For the release of radionuclides affecting individuals, the impact is incidence of cancer; risk is expressed as the probability over a lifetime of developing cancer. (See *cancer* and *latent cancer fatality*.)

radon – A gaseous, radioactive element with the atomic number 86 resulting from the radioactive decay of radium. Radon occurs naturally in the environment and can collect in unventilated enclosed areas, such as basements. Large concentrations of radon can cause lung cancer in humans. (See *atomic number* and *radioactive decay*.)

RADTRAN – A computer code combining user-determined meteorological, demographic, transportation, packaging, and material factors with health physics data to calculate the expected radiological consequences and accident risk of transporting radioactive material.

reactivity – The rate of nuclear disintegration in a nuclear reactor. (See *nuclear reactor*.)

reactor accident – See *design-basis accident* and *severe accident*.

reactor containment – A steel-reinforced concrete dome built over a nuclear reactor to trap radioactive vapors that might otherwise be released into the environment during a nuclear accident. (See *nuclear reactor*.)

reactor coolant system – The system used to transfer energy from the reactor core either directly or indirectly to the heat rejection system. (See *nuclear reactor*.)

reactor core – The fuel assemblies, fuel and target rods, control rods, blanket assemblies, and coolant/moderator. Fissioning takes place in this part of the reactor. (See *fission*.)

reactor facility – Unless it is modified by words such as *containment*, *vessel*, or *core*, this term includes the housing, equipment, and associated areas devoted to the operation and maintenance of one or more reactor cores. Any apparatus that is designed or used to sustain nuclear chain reactions in a controlled manner, including critical and pulsed assemblies and research, test, and power reactors, is defined as a reactor. All assemblies designed to perform subcritical experiments that could potentially reach criticality are also considered reactors. (See *chain reaction*, *criticality*, and *reactor core*.)

receptor – An organism that is exposed to chemicals or radionuclides in the environment. (See *radioisotope or radionuclide*.)

Record of Decision (ROD) – *(National Environmental Policy Act [NEPA] definition)* A concise public document that records a Federal agency's decision(s) concerning proposed actions for which the agency has prepared an environmental impact statement. The ROD is prepared in accordance with Council on Environmental Quality NEPA regulations (Title 40 of the *Code of Federal Regulations*, Section 1505.2). A ROD identifies the alternatives considered in reaching the decision, the environmentally preferred alternative(s), the factors balanced by the agency in making the decision, and whether all practicable means to avoid or minimize environmental harm were adopted, and if not, why they were not. (See *alternative* and *environmental impact statement*.)

(Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA] definition) A document that records the selection of remedial actions, facts, analyses, public participation, and site-specific policy determinations considered in the course of carrying out CERCLA cleanup activities.

redd – The nest of gravel or small cobble that a fish makes in a river to lay its eggs.

reductant – A chemical used to reduce the oxidation state (ionic charge) of another chemical.

reference concentration – The chronic-exposure concentration (milligrams per cubic meter) for a given hazardous chemical at which or below which adverse human noncancer health effects are not expected to occur. (See *exposure limit* and *reference dose*.)

reference dose – The chronic-exposure dose (milligrams or kilograms per day) for a given hazardous chemical at which or below which adverse human noncancer health effects are not expected to occur. (See *exposure limit* and *reference concentration*.)

refractory block – A solid object composed of a nonmetallic material that maintains its strength and integrity when exposed to extreme heat. Refractory blocks are used in the construction of structures or system components that are exposed to extremely high temperatures.

refueling outage – The period of time that a reactor is shut down for refueling operations. (See *nuclear reactor*.)

region of influence – A site-specific geographic area in which the principal direct and indirect effects of actions are likely to occur and are expected to be of consequence for local jurisdictions.

regional economic area – A geographic area consisting of an economic node, including surrounding counties that are economically related because they include the locations of the places of work and residences of the labor force. Each regional economic area is defined by the U.S. Bureau of Economic Analysis.

regulated substances – A general term used to refer to materials other than radionuclides that may be regulated by other applicable Federal, state, or local requirements.

release – Any spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of a material into the environment. Statutory or regulatory definitions of release may differ.

rem – See *roentgen equivalent man*.

remedial action – Activities conducted to reduce potential risks to people and/or harm to the environment from radioactive and/or hazardous substance contamination. (See *cleanup*.)

remediation – The process, or a phase in the process, of rendering radioactive, hazardous, or mixed waste environmentally safe, whether through entombment, processing, or other methods. (See *entombment* and *processing*.)

remote-handled waste – In general, radioactive waste that must be handled at a distance (remotely) to protect workers from unnecessary exposure (e.g., waste with a dose rate of 200 millirem per hour or more at the surface of the waste package). (See *contact-handled waste*.)

resin – See *ion exchange resin*.

resource – Valued attribute of a system.

Resource Conservation and Recovery Act (RCRA), as amended – This law (Title 42 of the *United States Code*, Part 6901 et seq.) gives the U.S. Environmental Protection Agency the authority to control hazardous waste from "cradle to grave" (i.e., from the point of generation to the point of ultimate disposal), including its minimization, generation, transportation, treatment, storage, and disposal. RCRA also sets forth a framework for management of nonhazardous solid waste. (See *hazardous waste*.)

respiration – Processes by which a living organism takes in oxygen from the air or water, distributes and utilizes it in oxidation, and gives off products of oxidation. (See *oxidation*.)

retrievably stored waste – Waste stored in a manner intended to permit retrieval at a future time.

Review Group 1 species (Washington State) – A plant taxon of potential concern for which additional fieldwork is needed before a status can be assigned (Washington State Natural Heritage Program, established by the Natural Area Preserves Act [*Revised Code of Washington*, Chapter 79.70]). (See *taxon*.)

Review Group 2 species (Washington State) – A plant taxon of potential concern for which taxonomic questions are unresolved (Washington State Natural Heritage Program, established by the Natural Area Preserves Act [*Revised Code of Washington*, Chapter 79.70]). (See *taxon*.)

***Revised Code of Washington* (RCW)** – The compilation of all permanent laws now in force in the State of Washington. It is a collection of session laws (enacted by the legislature and signed by the governor or enacted via the initiative process), arranged by topic, with amendments added and repealed laws removed. It does not include temporary laws such as appropriations acts.

riparian – Of or pertaining to the banks of a river or stream.

risk – In general, a measure of potential harm to populations or individuals due to the presence or occurrence of an environmental or manmade hazard. Risk is calculated as the product of the probability of an occurrence of an impact and the magnitude of the impact. The probability can be interpreted as a relative frequency of occurrence, a quantity with no assigned units.

In terms of human health, risk comprises three components: a sequence of events leading to an adverse impact, the probability of occurrence of that sequence of events, and the severity of the impact. For the release of radionuclides affecting a population, the impact is occurrence of a fatal cancer; risk is expressed as the expected number of latent cancer fatalities (i.e., the product of probability of occurrence and the magnitude of impact). For the release of radionuclides affecting individuals, the impact is incidence of cancer; risk is expressed as the probability over a lifetime of developing cancer. (See *cancer* and *latent cancer fatality*.)

risk assessment (chemical or radiological) – The qualitative and quantitative evaluation performed to define the risk posed to human health and/or the environment by the presence or potential presence and/or use of specific chemical or radioactive materials.

risk driver – A radioactive constituent of potential concern evaluated in this environmental impact statement to be a major contributor to radiological risk during the year of peak risk at locations of analysis during the 10,000-year period of analysis. (See *hazard driver* and *10,000-year period of analysis*.)

River Protection Project (RPP) – The Hanford Site's U.S. Department of Energy RPP mission is to retrieve and treat the site's tank waste and to close the tank farms to protect the Columbia River.

roentgen – A unit of exposure to ionizing x or gamma radiation equal to or producing one electrostatic unit of charge per cubic centimeter of air. (See *gamma radiation* and *x-rays*.)

roentgen equivalent man (rem) – A unit of dose equivalent. The dose equivalent in rem equals the absorbed dose in rad in tissue multiplied by the appropriate quality factor and possibly other modifying factors. Rem refers to the dosage of ionizing radiation that will cause the same biological effect as 1 roentgen of x-ray or gamma-ray exposure. One rem equals 0.01 sieverts. (See *absorbed dose*, *dose equivalent*, *gamma radiation*, *ionizing radiation*, *radiation absorbed dose [rad]*, *roentgen*, *sievert*, and *x-rays*.)

runoff – The portion of rainfall, melted snow, or irrigation water that flows across the ground surface and eventually enters streams.

Safe Drinking Water Act – This act (Title 42 of the *United States Code*, Section 300(f) et seq.) protects the quality of public water supplies, water supply and distribution systems, and all sources of drinking water.

safe, secure trailer (also "safeguarded trailer") – A specially modified semitrailer pulled by an armored tractor truck and used by the U.S. Department of Energy to transport nuclear weapons, nuclear weapon components, or special nuclear material over public highways. (See *special nuclear material*.)

safeguarded trailer – See *safe, secure trailer*.

safeguards – An integrated system of physical protection, material accounting, and material control measures designed to deter, prevent, detect, and respond to unauthorized access, possession, use, or sabotage of nuclear materials.

safety analysis report (SAR) – A report that systematically identifies potential hazards within a nuclear facility, describes and analyzes the adequacy of measures to eliminate or control identified hazards, and analyzes potential accidents and their associated risks. SARs are used to ensure that a nuclear facility can be constructed, operated, maintained, shut down, and decommissioned safely and in compliance with applicable laws and regulations. SARs are required for U.S. Department of Energy (DOE) nuclear facilities and as a part of applications for U.S. Nuclear Regulatory Commission (NRC) licenses. NRC regulations or DOE orders and technical standards that apply to the facility type provide specific requirements for the content of SARs. (See *nuclear facility* and *U.S. Nuclear Regulatory Commission*.)

safety evaluation report – A document prepared by the U.S. Nuclear Regulatory Commission that evaluates documentation (technical specifications, safety analysis reports, and special safety reviews and studies) submitted by a reactor licensee for approval. This ensures that all of the safety aspects of part or all of the activities conducted at a reactor are formally and thoroughly analyzed, evaluated, and recorded. (See *U.S. Nuclear Regulatory Commission*.)

saline – Of or pertaining to salt.

sand – Loose grains of rock or mineral sediment formed by weathering that range in size from 0.0625 to 2.0 millimeters (0.0025 to 0.08 inches) in diameter and often consist of quartz particles.

sanitary waste – Liquid or solid waste generated by normal housekeeping activities (includes sludge) that is not hazardous or radioactive.

scope – The range of actions, alternatives, and impacts to be considered in a document prepared pursuant to the National Environmental Policy Act of 1969 (Title 42 of the *United States Code*, Part 4321 et seq.).

scoping – An early and open process for determining the scope of issues to be addressed in an environmental impact statement (EIS) and for identifying significant issues related to proposed actions. The scoping period begins upon publication in the *Federal Register* of a Notice of Intent to prepare an EIS. The public scoping process is that portion of the process where the public is invited to participate. The U.S. Department of Energy (DOE) also conducts an early internal scoping process for environmental assessments and EISs. For EISs, this internal scoping process precedes the public scoping process. DOE's scoping procedures are found in Title 10 of the *Code of Federal Regulations*, Section 1021.311.

screening – Type of assessment that allows some receptors, pathways, or stressors to be removed from further consideration with a high degree of confidence by using conservative assumptions.

secondary waste – Waste generated as a result of other activities, e.g., waste retrieval or waste treatment, that is not further treated by the Waste Treatment Plant or supplemental treatment facilities and includes liquid and solid wastes. Liquid-waste sources could include process condensates, scrubber wastes, spent reagents from resins, offgas and vessel vent wastes, vessel washes, floor drain and sump wastes, and decontamination solutions. Solid-waste sources could include worn filter membranes, spent ion exchange resins, failed or worn equipment, debris, analytical laboratory waste, high-efficiency particulate air filters, spent carbon adsorbent, and other process-related wastes. Secondary waste can be characterized as low-level radioactive waste, mixed low-level radioactive waste, transuranic waste, or hazardous waste.

security – An integrated system of activities, systems, programs, facilities, and policies for the protection of restricted data and other classified information or matter; nuclear materials, weapons, and components; and/or U.S. Department of Energy contractor facilities, property, and equipment.

sediment – Soil, sand, and minerals washed from land into water and deposited on the bottom of a water body.

sediment-dwelling biota – Animals and plants that live in or on the soft substrate in aquatic environments.

seep – A spot where water contained in the ground oozes slowly to the surface and often forms a pool; a small spring. On the Columbia River, seepage occurs below the river surface and exposed riverbank and is particularly noticeable at the low-river stage. The seeps flow intermittently, apparently influenced primarily by changes in the river level.

seismic – Pertaining to any Earth vibration, especially an earthquake.

seismicity – The frequency and distribution of earthquakes.

selective clean closure – This hybrid closure approach would implement clean closure of a representative tank farm in each of the 200-East and 200-West Areas (i.e., the BX and SX tank farms), while implementing landfill closure for the balance of the single-shell tank system. (See *clean closure*, *landfill closure*, and *single-shell tank [SST] system*.)

sensitive species – *Idaho State:* A taxon with small populations or localized distributions within Idaho that presently do not meet the criteria for classification as Priority 1 or 2, but whose populations and habitats may be jeopardized without active management or removal of threats. (See *Priority 1 species [Idaho State]*, *Priority 2 species [Idaho State]*, and *taxon*.)

Washington State: A taxon that is vulnerable or declining and could become endangered or threatened without active management or removal of threats (*Washington Administrative Code* 232-12-297; Washington State Natural Heritage Program, established by the Natural Area Preserves Act [*Revised Code of Washington*, Chapter 79.70]). (See *endangered species*, *taxon*, and *threatened species*.)

severe accident – An accident with a frequency rate of less than 10^{-6} per year that would have more-severe consequences than a design-basis accident in terms of damage to the facility, offsite consequences, or both. Also referred to as "beyond-design-basis reactor accidents" in this environmental impact statement. (See *design-basis accident*.)

sewage – The total organic waste and wastewater generated by an industrial establishment or a community's municipal wastewater.

shielding – In regard to radiation, any material of obstruction (bulkheads, walls, or other construction) that absorbs radiation to protect personnel or equipment.

short-lived activation product – An element formed from neutron interaction that has a relatively short half-life and is not produced from a fission reaction (e.g., a cobalt isotope formed from impurities in the metal of the reactor piping). (See *fission*, *half-life [radiological]*, *neutron*, and *nuclear reactor*.)

shrub steppe – Plant community consisting of short-statured, widely spaced, small-leaved shrubs, sometimes aromatic, with brittle stems and an understory dominated by perennial bunchgrasses.

shutdown – Facility condition wherein operations and/or construction activities have ceased.

sievert – The International System of Units (SI) unit of radiation dose equivalent. The dose equivalent in sieverts equals the absorbed dose in grays multiplied by the appropriate quality factor (1 sievert equals 100 rem). (See *absorbed dose*, *dose equivalent*, *gray*, and *roentgen equivalent man [rem]*.)

silica gel – An amorphous, highly adsorbent form of silicon dioxide.

silt – Loose particles of rock or mineral sediment ranging in size from about 0.002 to 0.0625 millimeters (0.00008 to 0.0025 inches) in diameter. Silt is finer than sand, but coarser than clay. (See *clay* and *sand*.)

single-shell tank (SST) – Underground reinforced-concrete containers with one carbon steel liner that are covered with 2 to 3 meters (6.6 to 9.8 feet) of earth. Capacity ranges from 208,175 to 3.79 million liters (55,000 to 1 million gallons). SSTs have been used to store radioactive and mixed waste.

single-shell tank (SST) system – An area of the Hanford Site high-level radioactive waste tank farm system that includes 149 SSTs, ancillary equipment, and soils (from surface soils to the interface with groundwater) within SST farms and/or waste management area boundaries used to support Hanford Site waste retrieval and storage activities. (See *ancillary equipment*, *high-level radioactive waste*, *single-shell tank*, and *soils*.)

sinter – A process in which particles are bonded together by pressure and heating without melting.

site – A geographic entity comprising leased or owned land, buildings, and other structures required to perform program activities.

soil profile – A two-dimensional cross section extending vertically from Earth's surface and exposing all the soil horizons and a part of the relatively unaltered underlying material.

soils – All unconsolidated materials above bedrock; natural earthy materials on Earth's surface, in places modified or even made by human activity, that contain living matter and either support or are capable of supporting plants out of doors. (See *bedrock*.)

solid waste – In general, nonliquid, nonsoluble discarded materials, ranging from municipal garbage to industrial waste, that contain complex and sometimes hazardous substances, including sewage sludge, agricultural refuse, demolition waste, and mining residues. For purposes of regulation under the Resource Conservation and Recovery Act, solid waste is "any garbage; refuse; sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility; and other discarded material" (Title 42 of the *United States Code* [U.S.C.], Part 6903). Solid waste includes solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations and from community activities. Solid waste does not include solid or dissolved material in domestic sewage or irrigation return flows or industrial discharges, which are point sources subject to permits under Section 402 of the Clean Water Act (33 U.S.C., Part 1342). Finally, solid waste does not include source, special nuclear, or byproduct material as defined by the Atomic Energy Act (42 U.S.C., Part 2011 et seq.). A more detailed regulatory definition of solid waste can be found in Title 40 of the *Code of Federal Regulations*, Section 261.2. (See *hazardous waste* and *Resource Conservation and Recovery Act*.)

source material – In general, material from which special nuclear material can be derived. Under the Atomic Energy Act (Title 42 of the *United States Code*, Part 2011 et seq.) and U.S. Nuclear Regulatory Commission regulations, "source material" is uranium and thorium in any physical or chemical form, including ores, containing one-twentieth of 1 percent (0.05 percent) or more by weight of uranium or thorium. (See *special nuclear material*.)

source term – The amount of a specific pollutant (e.g., chemical, radionuclide) emitted or discharged to a particular environmental medium (e.g., air, water) from a source or group of sources. It is usually expressed as a rate (i.e., amount per unit time).

spallation – A nuclear reaction in which light particles are ejected as the result of bombardment (as by high-energy protons). (See *proton*.)

special nuclear material – As defined in Section 11 of the Atomic Energy Act of 1954 (Title 42 of the *United States Code*, Part 2014), special nuclear material includes (1) plutonium, uranium enriched in the isotope 233 or 235, and any other material that the U.S. Nuclear Regulatory Commission determines to be special nuclear material; or (2) any material artificially enriched by any of the above. Hydrogen-3 (tritium) is not a special nuclear material. (See *isotope* and *U.S. Nuclear Regulatory Commission*.)

species of concern (Federal) – Species whose conservation standing is of concern to the U.S. Fish and Wildlife Service, but for which status information is still needed.

spectral (response) acceleration – An approximate measure of the acceleration (as a percentage of the acceleration due to Earth's gravity) experienced by a building, as modeled by a particle on a massless vertical rod that has the same natural period of vibration as the building.

spent nuclear fuel – Fuel that has been withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been separated. (See *nuclear reactor*.)

stability class – A category characterizing the degree of stability (absence of turbulence) in the atmosphere. The classification used for regulatory models and methods for estimating the appropriate stability category from other meteorological data are given by the U.S. Environmental Protection Agency.

stabilization – Mixing of an agent such as Portland cement with waste to increase the mechanical strength of the resulting waste form and decrease its leachability.

stable isotope – Variation of an element that has the same atomic number but a different weight (because of the number of neutrons in its nucleus) and does not undergo radioactive decay. (See *atomic number*, *neutron*, *nucleus*, and *radioactive decay*.)

standard (waste packaging) – The common forms of waste packages (such as drums and boxes) used for low-level radioactive waste (LLW) and mixed LLW. (See *nonstandard [waste packaging]*.)

State Environmental Policy Act (SEPA) – The State of Washington's environmental law enacted in 1971 as Chapter 43.12C of the *Revised Code of Washington*. The purposes of this law are to (1) declare a state policy that will encourage productive and enjoyable harmony between man and his environment, (2) promote efforts that will prevent or eliminate damage to the environment and biosphere, (3) stimulate the health and welfare of man, and (4) enrich the understanding of the ecological systems and natural resources important to the state and Nation.

steady state model – A representation of a system with state variables that do not change in value over time; the parameters and inputs are constant.

steam reforming – A thermal process that immobilizes waste by converting (1) low-activity waste solutions (tank waste) to granular minerals and volatilizing water and (2) the decomposing organic compounds, nitrate, and nitrite present in the tank waste to carbon dioxide, water, and nitrogen. (See *low-activity waste* and *nitrate*.)

stochastic analysis – A set of calculations performed using values randomly selected from a range of reasonable values for one or more parameters. In this environmental impact statement, the median value is reported (in contrast, see *deterministic analysis*).

stochastic variability – Natural variation of a measured quantity. For example, in a room full of people, there is an average height, with some being taller and some shorter; the stochastic variability of that group is described by the differences between the individuals' heights and the average.

storage – Holding waste for a temporary period, at the end of which the waste is treated, disposed of, or stored elsewhere.

stratigraphy – The science of the description, correlation, and classification of strata in sedimentary rocks, including interpretation of the depositional environments of those strata.

sulfate removal – Sulfate, a significant component in the supernatant fractions of tank waste at the Hanford Site, poses serious economic impacts (creating more glass) and risks for the low-activity waste (LAW) vitrification process. Sulfate tends to phase-separate in the melter, forming a corrosive molten sulfate salt layer on top of the glass melt that will damage the melter if allowed to accumulate. Removal of the sulfate from the LAW before vitrifying can mitigate these problems. The sulfate removal approach comprises sulfate precipitation using strontium nitrate addition, filtration, and solidification with grout-forming additives for immobilized waste. (See *immobilization*, *low-activity waste*, *melter*, and *vitrification*.)

sulfur oxides – Common air pollutants, primarily sulfur dioxide, a heavy, pungent, colorless gas formed in the combustion of fossil fuels and considered a major air pollutant, and sulfur trioxide. Sulfur dioxide is involved in the formation of acid rain. It can also irritate the upper respiratory tract and cause lung damage.

supernatant – The liquid that stands over a precipitated material.

supplemental treatment – As used in this environmental impact statement, a waste treatment process used to solidify or immobilize the low-activity waste fraction of tank waste in addition to the Waste Treatment Plant vitrification process. (See *immobilization*, *low-activity waste*, and *vitrification*.)

surface water – All bodies of water on the surface of Earth that are open to the atmosphere, such as rivers, lakes, reservoirs, ponds, seas, and estuaries.

surficial material (deposit) – Any loose, unconsolidated sedimentary deposit lying on or above bedrock. (See *bedrock*.)

suspect transuranic (TRU) waste – Radioactive waste that is thought to be TRU waste, but for which adequate characterization data are not yet available to confirm the classification. (See *radioactive waste*.)

tank systems – *Single-shell tank (SST) system:* All 149 SSTs, ancillary equipment (e.g., pipes, pits), and soils (from the surface to the interface with groundwater) within SST farms and/or waste management area boundaries. (See *ancillary equipment*, *single-shell tank*, and *soils*.)

Double-shell tank (DST) system: All 28 existing DSTs, ancillary equipment, and soils within the DST farms, as well as new retrieval and delivery systems that are currently under construction and (potentially) any new DSTs. (See *ancillary equipment*, *double-shell tank*, and *soils*.)

target – A tube, rod, or other form containing material that, on being irradiated in a nuclear reactor or an accelerator, would produce a desired end product. (See *irradiated* and *nuclear reactor*.)

taxa – Plural of taxon. (See *taxon*.)

taxon – A group of organisms sharing common characteristics in varying degrees of distinction that constitute one of the categories of taxonomic classification, such as a phylum, class, order, family, genus, or species.

technical specifications – In regard to U.S. Nuclear Regulatory Commission (NRC) regulations, part of an NRC license authorizing the operation of a nuclear reactor facility. A technical specification establishes requirements for items such as safety limits and limits on safety system settings, control settings, and conditions for operation, as well as surveillance requirements, design features, and administrative controls. (See *administrative control*, *reactor facility*, and *U.S. Nuclear Regulatory Commission*.)

tectonic – Of or relating to motion in Earth's crust and occurring along geologic faults. (See *fault*.)

TEEL-0, -1, -2, and -3 – See *Temporary Emergency Exposure Limits.*

teleost fish – Of or belonging to the Teleostei or Teleostomi, a large group of fish with bony skeletons, including most common fish. The teleosts are distinct from cartilaginous fish such as sharks, rays, and skates.

temporal use factor – The ratio of the amount of time that an organism uses an area of contamination per unit time.

Temporary Emergency Exposure Limits (TEELs) – Values developed by the U.S. Department of Energy (DOE) for use in DOE facility hazard analyses and emergency planning and response for chemicals lacking Acute Exposure Guideline Levels or Emergency Response Planning Guidelines. TEEL values are applied to the peak 15-minute time-weighted average concentration at the point of interest and are defined for varying degrees of severity of toxic effects, as follows:

TEEL-0: The threshold concentration below which most people will experience no appreciable risk of health effects.

TEEL-1: The maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor.

TEEL-2: The maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.

TEEL-3: The maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing or developing life-threatening health effects.

10,000-year period of analysis – The period of analysis used in this environmental impact statement for the long-term impacts analysis for groundwater, human health, and ecological risks.

terrestrial – Of or pertaining to life on land.

Tertiary – The first geologic time period of the Cenozoic era (after the Mesozoic era and before the Quaternary period), spanning between about 66 million and 1.6 million years ago. During this period, mammals became the dominant life form on Earth. (See *Quaternary*.)

thermal treatment – Treatment of waste in a device that uses elevated temperature to change the chemical, physical, or biological character of the waste. Examples include, but are not limited to, vitrification, pyrolysis, steam reforming, and calcination.

threatened species – *Federal:* Species that are likely to become endangered species within the foreseeable future throughout all or a significant portion of their ranges and have been listed as threatened by the U.S. Fish and Wildlife Service or the National Marine Fisheries Service following the procedures set out in the Endangered Species Act (Title 16 of the *United States Code*, Part 1531 et seq.) and its implementing regulations (Title 50 of the *Code of Federal Regulations* [CFR], Part 424).

The lists of threatened species can be found at 50 CFR, Sections 17.11 (wildlife), 17.12 (plants), and 227.4 (marine organisms).

Idaho State: Any wildlife species native to the state that is likely to become an endangered species within the foreseeable future throughout a significant portion of its range within the state if factors contributing to its decline continue. (See *endangered species*.)

Washington State: Any wildlife species native to the state that is likely to become an endangered species within the foreseeable future throughout a significant portion of its range within the state if factors contributing to its decline continue (*Washington Administrative Code* 232-12-297; Washington State Natural Heritage Program, established by the Natural Area Preserves Act [*Revised Code of Washington*, Chapter 79.70]). (See *candidate species* and *endangered species*.)

threshold limit values – The recommended highest concentrations of contaminants to which workers may be exposed according to the American Conference of Governmental Industrial Hygienists.

total effective dose equivalent (TEDE) – The sum of the effective dose equivalent from external exposures and the committed effective dose equivalent from internal exposures. TEDE is expressed in units of rem (or sieverts). (See *committed effective dose equivalent*, *effective dose equivalent*, *external dose or exposure*, *internal dose*, *roentgen equivalent man [rem]*, and *sievert*.)

total recordable cases – The total number of cases recorded of work-related (1) deaths or (2) illnesses or injuries resulting in loss of consciousness, restriction of work or motion, transfer to another job, or required medical treatment beyond first aid.

total uranium – As used in this environmental impact statement, the total concentration of all of the 14 isotopes of uranium used for calculating *nonradiological* human health and ecological risk. (See *uranium* and *uranium-238*.)

Toxic Substances Control Act of 1976 – This law (Title 15 of the *United States Code*, Part 2601 et seq.) requires that the health and environmental effects of all new chemicals be reviewed by the U.S. Environmental Protection Agency before such chemicals are manufactured for commercial purposes. This act also imposes strict limitations on the use and disposal of polychlorinated biphenyls, chlorofluorocarbons, asbestos, dioxins, certain metal-working fluids, and hexavalent chromium. (See *hexavalent chromium* and *polychlorinated biphenyl*.)

Toxic Substances Control Act (TSCA) waste – Any waste, including polychlorinated biphenyl–commingled waste, regulated under TSCA requirements as codified in Title 40 of the *Code of Federal Regulations*, Part 761. (See *polychlorinated biphenyl*.)

toxicity reference value – An exposure level from a valid scientific study that represents a threshold for some level of ecological effect.

toxicity test – An experiment to measure the adverse physiological effect in living organisms resulting from exposure to a chemical substance.

toxicological – Of or pertaining to a poison.

toxicological impact – Impact on human health due to exposure to, or intake of, chemical materials. These impacts are typically described in terms of damage to affected organs.

traditional cultural property – A property or place that is eligible for inclusion on the National Register of Historic Places because of its association with cultural practices and beliefs that are (1) rooted in the history of a community and (2) important to maintaining the continuity of that community's traditional beliefs and practices. (See *National Register of Historic Places*.)

transients – Events that could cause a change or disruption of plant thermal, hydraulic, or neutronic behavior.

transportation index (of the package or packages) – Defined as the highest package dose rate (millirem per hour) that would be received by an individual located at a distance of 1 meter (3.3 feet) from the external surface of the package. (See *dose* and *millirem*.)

transuranic – Refers to any element with an atomic number higher than uranium (atomic number 92), including neptunium, plutonium, americium, and curium. All transuranic elements are produced artificially and are radioactive. (See *atomic number*.)

transuranic isotope – Isotopes of any element having an atomic number greater than 92 (the atomic number of uranium). (See *atomic number* and *isotope*.)

transuranic (TRU) waste – Radioactive waste containing more than 100 nanocuries (3,700 becquerels) of alpha-emitting TRU isotopes per gram of waste, with half-lives greater than 20 years, except for: (1) high-level radioactive waste; (2) waste that the Secretary of Energy has determined, with the concurrence of the Administrator of the U.S. Environmental Protection Agency, does not need the degree of isolation required by Title 40 of the *Code of Federal Regulations* (CFR), Part 191, disposal regulations; or (3) waste that the U.S. Nuclear Regulatory Commission has approved for disposal on a case-by-case basis in accordance with 10 CFR, Part 61. (See *alpha particle*, *half-life [radiological]*, and *high-level radioactive waste*.)

treatment – The physical, chemical, or biological processing of dangerous waste to make such waste nondangerous or less dangerous, safer for transport, amenable for energy or material resource recovery, amenable for storage, or lower in volume, with the exception of compacting, repackaging, and sorting, as allowed under *Washington Administrative Code* 173-303-400(b) and 173-303-600. For radioactive waste, treatment is any method, technique, or process designed to change the physical or chemical character of waste to render it less hazardous; safer to transport, store, or dispose of; or lower in volume. (See *dangerous waste* and *radioactive waste*.)

treatment, storage, and disposal facility – A facility engaged in the treatment, storage, and/or disposal of hazardous waste. These facilities are the last link in the cradle-to-grave hazardous waste management system. (See *hazardous waste* and *Resource Conservation and Recovery Act (RCRA), as amended*.)

trench (ditch) – A depression dug in the ground, open to the atmosphere, and designed for disposal of low-level or intermediate-level radioactive waste. It uses the moisture retention capability of the relatively dry soils above the groundwater.

Tri-Party Agreement (TPA) – See *Hanford Federal Facility Agreement and Consent Order*.

tritiated – Containing hydrogen-3 (tritium).

trivalent – Having a valence of three. (See *valence*.)

trophic level – The number of feeding relations between an organism and an abiotic energy source.

Type A packaging – A regulatory category of packaging for transportation of radioactive materials. Type A packaging must be designed and demonstrated to retain its containment and shielding integrity under normal conditions of transport. Examples of Type A packaging include 0.21-cubic-meter (55-gallon) drums and standard waste boxes. Type A packaging is used to transport materials with low radioactivity levels and usually does not require special handling, packaging, or transportation equipment. (See *Type B packaging*.)

Type B packaging – A regulatory category of packaging for transportation of radioactive material. The U.S. Department of Transportation and U.S. Nuclear Regulatory Commission (NRC) require Type B packaging for shipping highly radioactive material. Type B packages must be designed and demonstrated to retain their containment and shielding integrity under severe accident conditions, as well as under the normal conditions of transport. The current NRC testing criteria for Type B package designs (Title 10 of the *Code of Federal Regulations*, Part 71) are intended to simulate severe accident conditions, including impact, puncture, fire, and immersion in water. The most widely recognized Type B packages are the massive casks used for transporting spent nuclear fuel. Large-capacity cranes and mechanical lifting equipment are usually needed to handle Type B packages. (See *severe accident* and *U.S. Nuclear Regulatory Commission*.)

Type B shipping cask – A U.S. Nuclear Regulatory Commission–certified cask with a protective covering that contains and shields radioactive materials, dissipates heat, prevents damage to the contents, and prevents criticality during normal shipment and accident conditions. It is used for transport of highly radioactive materials and is tested under severe, hypothetical accident conditions that demonstrate resistance to impact, puncture, fire, and submersion in water. (See *criticality*, *severe accident*, and *U.S. Nuclear Regulatory Commission*.)

unit cancer risk – A quantitative measure of the likelihood that a substance is a human carcinogen that estimates risk from oral or inhalation exposure. This estimate can be in terms of either risk per microgram per liter of drinking water or risk per microgram per cubic meter of inhaled air. (See *carcinogen* and *exposure*.)

untilled – Not plowed for cultivation.

uptake mechanisms (routes) – Means by which a chemical enters an organism from the environment (e.g., ingestion, inhalation, dermal absorption).

uranium – A radioactive, metallic element with the atomic number 92; one of the heaviest naturally occurring elements. Uranium has 14 known isotopes, of which uranium-238 is the most abundant in nature. Uranium-235 is commonly used as a fuel for nuclear fission. (See *atomic number*, *depleted uranium*, *enriched uranium*, *highly enriched uranium*, *isotope*, *natural uranium*, and *uranium-238*.)

uranium-238 – As used in this environmental impact statement, the total concentration of all of the 14 isotopes of uranium used for calculating *radiological* human health and ecological risk. (See *isotope*, *total uranium*, and *uranium*.)

U.S. Nuclear Regulatory Commission (NRC) – The Federal agency that regulates the civilian nuclear power industry in the United States. (See *Atomic Energy Commission*.)

vadose zone – The region of soil and rock between the ground surface and the top of the water table in which pore spaces are only partially filled with water. Over time, contaminants in the vadose zone often migrate downward to the underlying aquifer. (See *aquifer*.)

valence – The combining capacity of an atom or radical determined by the number of electrons that it will lose, add, or share when it reacts with other atoms. (See *electron*, *hexavalent*, *hexavalent chromium*, and *trivalent*.)

viewshed – The extent of an area that may be viewed from a particular location. Viewsheds are generally bounded by topographic features such as hills or mountains.

Visual Resource Management class – Any of the classifications of visual resources established through application of the Visual Resources Management process of the U.S. Bureau of Land Management. Four classifications are employed to describe different degrees of modification to landscape elements: Class I, areas where the natural landscape is preserved, including national wilderness areas and the wild sections of national wild and scenic rivers; Class II, areas with very limited land development activity, resulting in visual contrasts that are seen, but do not attract attention; Class III, areas in which development may attract attention, but the natural landscape still dominates; and Class IV, areas in which development activities may dominate the view and may be the major focus in the landscape.

vitrification – A method used to immobilize waste (radioactive, hazardous, and mixed). This involves adding glass formers and waste to a vessel and melting the mixture into a glass. The purpose of this process is to permanently immobilize the waste and isolate it from the environment. (See *immobilization*.)

volatile organic compound – Any of a broad range of organic compounds, often halogenated, that vaporize at ambient or relatively low temperatures, such as benzene, chloroform, and methyl alcohol. In regard to air pollution, any organic compound that participates in atmospheric photochemical reaction, except for those determined by the U.S. Environmental Protection Agency Administrator to have negligible photochemical reactivity.

***Washington Administrative Code* (WAC)** – Regulations of the Executive branch agencies in the State of Washington as issued by the authority of statutes. In the WAC, the regulations of the State of Washington are codified and arranged by subject or responsible agency. The WAC, which is a source of primary law, also states how agencies shall organize and adopt rules and regulations.

waste acceptance criteria – The technical and administrative requirements that a waste must meet for it to be accepted at a treatment, storage, and disposal facility. (See *treatment, storage, and disposal facility*.)

waste certification – A process by which a waste generator certifies that a given waste or waste stream meets the waste acceptance criteria of the facility to which the generator intends to transfer waste for treatment, storage, or disposal. (See *waste acceptance criteria*.)

waste characterization – Identification of waste composition and properties to determine appropriate storage, treatment, handling, transportation, and disposal requirements by (1) review of process knowledge, (2) nondestructive examination, (3) nondestructive assay, or (4) sampling and analysis.

waste classification – Wastes are classified according to the *Radioactive Waste Management Manual* (U.S. Department of Energy Manual 435.1-1) and include high-level radioactive, transuranic, and low-level radioactive wastes. (See *high-level radioactive waste*, *low-level radioactive waste*, and *transuranic (TRU) waste*.)

waste container – Any portable device in which a material is stored, transported, treated, disposed of, or otherwise handled (*Washington Administrative Code* 173-303-400). A waste container may include any liner or shielding material that is intended to accompany the waste in disposal. At the Hanford Site, waste containers typically consist of 208- or 320-liter (55- or 85-gallon) drums and standard waste boxes. Other sizes and styles of containers may also be employed, depending on the physical, radiological, and chemical characteristics of the waste.

waste disposal – See *disposal*.

Waste Isolation Pilot Plant (WIPP) – A U.S. Department of Energy facility designed and authorized to permanently dispose of transuranic radioactive waste in a mined underground facility in deep geologic salt beds. WIPP is located in southeastern New Mexico, 42 kilometers (26 miles) east of the city of Carlsbad.

waste life cycle – The life of a waste from generation through storage, treatment, transportation, and disposal.

waste management – The planning, coordination, and direction of those functions related to the generation, handling, treatment, storage, transportation, and disposal of waste, as well as associated surveillance and maintenance activities.

waste minimization and pollution prevention – An action that economically avoids or reduces the production of waste and pollution by reducing waste generation at the source, reducing the toxicity of hazardous waste and pollution, improving the efficiency of energy usage, or recycling. These actions will be consistent with the general goal of minimizing present and future threats to human health, safety, and the environment.

waste stream – A waste or group of wastes from a process or a facility with similar physical, chemical, or radiological properties. In the context of this environmental impact statement, a waste stream is defined as a collection of wastes with physical and chemical characteristics that will generally require the same management approach (i.e., use of the same treatment, storage, and disposal capabilities).

waste treatment facilities – Existing and new facilities that are required to complete waste treatment.

Waste Treatment Plant (WTP) – The facility that is being designed and built to thermally treat and immobilize tank waste at the U.S. Department of Energy's Hanford Site. (See *immobilization*.)

watch list species (Washington State) – A category of plant species, as identified by the Washington State Natural Heritage Program, established by the Natural Area Preserves Act (*Revised Code of Washington*, Chapter 79.70).

Watch list species consist of those plant taxa of concern that are more abundant and/or less threatened than previously assumed. (See *taxa*.)

water table – The boundary between the unsaturated zone and the deeper, saturated zone. The upper surface of an unconfined aquifer. (See *aquifer*.)

weighting factor – Generally, a method of attaching different importance values to different items or characteristics. In the context of radiation protection, the proportion of the risk of effects resulting from irradiation of a particular organ or tissue to the total risk of effects when the whole body is irradiated uniformly (e.g., the organ dose weighting factor for the lung is 0.12, compared with 1.0 for the whole body). Weighting factors are used to calculate the effective dose equivalent. (See *effective dose equivalent* and *irradiated*.)

wetlands – Those areas that are inundated by surface water or groundwater with a frequency that is sufficient to support, and under normal circumstances do or would support, a prevalence of vegetative or aquatic life that requires saturated or seasonally saturated soil conditions for growth and reproduction. Wetlands generally include swamps, marshes, bogs, and similar areas (e.g., sloughs, potholes, wet meadows, river overflow areas, mudflats, natural ponds). (See *groundwater* and *surface water*.)

Jurisdictional wetlands are those wetlands protected by the Clean Water Act (Title 33 of the *United States Code*, Part 1251 et seq.). They must have a minimum of one positive wetland indicator from each parameter (i.e., vegetation, soil, and hydrology). The U.S. Army Corps of Engineers requires a permit to fill or dredge jurisdictional wetlands.

whole-body dose – In regard to radiation, a dose of radiation resulting from the uniform exposure of all organs and tissues in a human body. (See *effective dose equivalent*.)

wind rose – A circular diagram showing, for a specific location, the percentage of time the wind is from each compass direction. A wind rose for use in assessing consequences of airborne releases also shows the frequency of different windspeeds for each compass direction.

x-rays – Penetrating electromagnetic radiation with a wavelength much shorter than that of visible light. X-rays are identical to gamma rays, but originate outside the nucleus, either when the inner orbital electrons of an excited atom return to their normal state or when a metal target is bombarded with high-speed electrons. (See *electron*, *gamma radiation*, and *nucleus*.)

zircaloy – An alloy of zirconium containing tin, iron, chromium, and nickel.

zooplankton – Microscopic animals floating in a body of water that are incapable of countering water movements.

CHAPTER 10
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Education: Ph.D., Chemical Engineering, University of Maryland
M.S., Chemical Engineering, University of Maryland
B.Ch.E., Chemical Engineering, University of Dayton
Experience: 34 years

Prindiville, Kerry
EIS Responsibilities: *Groundwater Modeling and Analysis; Quality Assurance; Co-Manager*–Appendix O, "Groundwater Transport Analysis"
Education: M.S., Environmental Engineering, Washington State University
B.S., Environmental Science, Washington State University
Experience: 16 years

Rhone, Jacquelyn
EIS Responsibilities: *Manager, Document Production; Quality Assurance; Manager*–Chapter 12, "Index," and Appendix B, "Contractor and Subcontractor National Environmental Policy Act Disclosure Statements"
Education: A.Sc., Radiological Health Technology, Central Florida Community College
Experience: 40 years

Richardson, John
EIS Responsibilities: *Industrial Safety; Groundwater Model Development; Co-Manager*–Appendix I, "Workforce Estimates," and Appendix K, "Short-Term Human Health Risk Analysis"
Education: B.S., General Science, Washington State University
Experience: 17 years

Robinson, Linda
EIS Responsibilities: *Project Quality Advisor*
Education: Executive M.B.A., Loyola College
B.S. Ed., Earth Sciences, Texas Christian University
Experience: 39 years

Roeser, Steven
EIS Responsibilities: *Responsible Corporate Manager, SAIC*
Experience: 24 years

Rooths, Bruce
EIS Responsibilities: *Cost Impacts Analysis; Scheduling*
Education: B.S., Economics, University of Pittsburgh
Experience: 34 years

Russell, Perry
EIS Responsibilities: *Geology and Soils*
Education: M.S., Geological Sciences, California State University, Northridge
B.A., Geological Sciences, University of California, Santa Barbara
Experience: 24 years

Schatzel, Sean
EIS Responsibilities: *Environmental Justice; Quality Assurance; Vadose Zone and Groundwater Modeling; Co-Manager*–Appendix J, "Environmental Justice"
Education: B.A., Political Economics/Public Administration, Bloomsburg University
Experience: 5 years

Schinner, James
EIS Responsibilities: *Cumulative Impacts; Ecological Resources; Cultural and Paleontological Resources; Land Use and Visual Resources; Co-Manager*–Chapter 3, "Affected Environment," Chapter 6, "Cumulative Impacts," Appendix R, "Cumulative Impacts: Assessment Methodology," and Appendix T, "Supporting Information for the Short-Term Cumulative Impact Analyses"
Education: Ph.D., Wildlife Management, Michigan State University
M.S., Zoology, University of Cincinnati
B.S., Zoology, University of Cincinnati
Experience: 40 years

Smith, Alison
EIS Responsibilities: *Technical Editor/Writer; Manager*–Chapter 10, "List of Preparers," and *Assistant Manager*–Chapter 5, "Long-Term Environmental Consequences"
Education: B.A., English Language and Literature, University of Maryland
Experience: 5 years

Spivey, Mary Alice

EIS Responsibilities:	*Deputy Project Manager; Data Development; Manager*–Chapter 1, "Proposed Actions: Background, Purpose and Need," Chapter 5, "Long-Term Environmental Consequences," and Chapter 8, "Potentially Applicable Laws, Regulations, and Other Requirements"; *Co-Manager*–Appendix C, "Cooperating Agency, Consultation, and Other Interaction Documentation," and Appendix S, "Waste Inventories for Cumulative Impact Analyses"
Education:	B.S., Environmental Sciences, Florida Institute of Technology
Experience:	29 years

Stork, Allison

EIS Responsibilities:	*Overall EIS Review*
Education:	M.S., Geography, University of Tennessee at Knoxville B.A., Geography, English, State University of New York at Geneseo
Experience:	5 years

Upchurch, Audra

EIS Responsibilities:	*Air Quality; Socioeconomics; Water Quality*
Education:	M.N.R., Natural Resources, Virginia Polytechnic Institute and State University Graduate Certificate, Natural Resources, Virginia Polytechnic Institute and State University B.S., Forestry; Minor: Environmental Science, Virginia Polytechnic Institute and State University
Experience:	10 years

Vance, Jenny

EIS Responsibilities:	*Quality Assurance; Microsoft Access and Excel Programming; Ecological Resources Risk Analysis Support*
Education:	Graduate Certificate, Computing, University of Cincinnati B.A., Biology, Maryville College
Experience:	30 years

Voorhies, Nathan

EIS Responsibilities:	*Groundwater Flow Field Development*
Education:	M.A., Philosophy of Science, Ohio State University B.S., Chemical Engineering, University of Notre Dame
Experience:	19 years

Waldman, Gilbert

EIS Responsibilities:	*Accident and Human Health Impacts Risk Analysis*
Education:	M.S., Engineering Management, Johns Hopkins University B.S., Nuclear Engineering, University of Florida
Experience:	21 years

Wells, Diane

EIS Responsibilities:	*Manager, Comment-Response Document Production*
Experience:	30 years

Werth, Robert
EIS Responsibilities: *Noise; Air Quality; Manager*–Chapter 4, “Short-Term Environmental Consequences”; *Co-Manager*–Appendix G, “Air Quality Analysis”
Education: B.A., Physics, Gordon College
Experience: 38 years

COLUMBIA ENERGY & ENVIRONMENTAL SERVICES (CEES)

Hendersen, Colin
EIS Responsibilities: *Data Development Lead*
Education: M.S., Environmental Engineering, Washington State University
B.S., Mechanical Engineering, Washington State University
Experience: 25 years

Nichols, David
EIS Responsibilities: *CEES Manager*
Education: B.A., Political Science, History, Communications, University of Iowa
Experience: 30 years

Reich, Fred
EIS Responsibilities: *Vadose Zone and Groundwater Flow and Transport Modeling and Analysis*–Draft EIS
Education: M.S., Electrical Engineering, South Dakota School of Mines
B.S., Electrical Engineering, South Dakota School of Mines
Experience 45 years

Shields, Keith
EIS Responsibilities: *Vadose Zone and Groundwater Flow and Transport Modeling and Analysis*–Draft EIS
Education: M.S. Environmental Science, Washington State University
B.S., Physics, Whitman College
Experience: 23 years

Walker, Brian
EIS Responsibilities: *Vadose Zone and Groundwater Flow and Transport Modeling and Analysis*–Draft EIS
Education: B.S., Environmental Science, Washington State University
Experience: 14 years

Wilson, Robert
EIS Responsibilities: *Flowsheet Development*
Education: M.S., Environmental Systems Engineering, Clemson University
B.S., Chemical Engineering, Vanderbilt University
Experience: 14 years

Columbia Environmental Sciences, Inc.

Erikson, Robert L.

EIS Responsibilities:	*Professional Geologist and Hydrologist, Vadose Zone and Groundwater Flow and Transport Modeling and Analysis*
Education:	M.S., Geochemistry and Mineralogy, Pennsylvania State University B.A., Geology, State University of New York, Brockport
Experience:	35 years

Mateyka, Danielle

EIS Responsibilities:	*Vadose Zone and Groundwater Flow and Transport Modeling and Analysis*
Education:	B.S., Environmental Science; Minor: Geology, Eastern Washington University B.S., Biology; Minor: Urban and Regional Planning, Eastern Washington University
Experience:	2 years

Phipps, Deborah

EIS Responsibilities:	*Vadose Zone and Groundwater Flow and Transport Modeling and Analysis*
Education:	B.S., Biology, Texas A&M University A.A., General Studies, Southwestern College
Experience:	12 years

Siping, Elizabeth

EIS Responsibilities:	*Vadose Zone and Groundwater Flow and Transport Modeling and Analysis*
Education:	B.S., Biology, Eastern Washington University
Experience:	10 years

Stengle, Ryan

EIS Responsibilities:	*Computer Support and Networking, Vadose Zone and Groundwater Flow and Transport Modeling and Analysis*
Education:	B.S., Biology, Central Washington State University B.S., Anthropology, Central Washington State University
Experience:	7 years

Yates, Ryan

EIS Responsibilities:	*Vadose Zone and Groundwater Flow and Transport Modeling and Analysis*
Education:	B.S., Environmental Science, Washington State University
Experience:	5 years

CHAPTER 11
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The U.S. Department of Energy (DOE) is committed to communicating with the public to ensure that potentially affected communities and other interested parties are given opportunities to receive information on the project and notice of public meetings and to comment. In 2003, the environmental impact statement database used existing site mailing information. Over time, the database has evolved through additions from scoping meetings held in 2003, 2004, and 2006 and draft hearings held in 2010. For example, participants completed and returned registration forms at scoping meetings and hearings on the *Draft Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington (TC & WM EIS)*, and individuals or groups submitted comments (containing complete contact information) during the scoping process and comment period for the *Draft TC & WM EIS*; if a record already existed, it was updated. The database was also updated based on feedback from an informational mailer that was sent to stakeholders in October 2008 and October 2011. DOE provided different forums and media for feedback on the distribution list.

DOE provided copies of this *Final TC & WM EIS* to members of Congress; Federal, state, and local elected and appointed government officials; American Indian tribal representatives; environmental and public interest groups; and other organizations and individuals listed in this chapter, including those stakeholders added to the distribution list as a result of the activities listed above.

Approximately 80 copies of the complete *Final TC & WM EIS*, 2,500 copies of the *Final TC & WM EIS* Summary, and 260 compact discs containing the complete *Final TC & WM EIS* were sent to interested parties. Copies will be provided to others upon request and have also been made available on the *TC & WM EIS* website, DOE National Environmental Policy Act website, and DOE Office of River Protection website and in regional DOE public reading rooms and public libraries.

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Rex Buck, Leader

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Idaho Falls, ID 83402
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1000 Independence Avenue, SW, 1G-033
Washington, DC 20585
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2770 University Drive, Room 101L
Richland, WA 99352
(509) 372-7443

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Carlsbad, NM 88220
(575) 234-7348

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American Nuclear Society
Carl Holder
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Greenpeace
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Institute for Energy and Environmental Research
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National Nuclear Workers for Justice
Gai Oglesbee

Natural Resources Defense Council
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Nuclear Information and Research Service
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Physicians for Social Responsibility
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