5.3.3 Ecological Risk

This section presents the results of the evaluation of long-term impacts on ecological resources of releases to air and groundwater under the Waste Management alternatives. Risk indices—Hazard Quotient and Hazard Index—were calculated by comparing the predicted dose to the benchmark dose (see Appendix P). Risk indices could not be calculated for soil-dwelling invertebrates, lizards, toads, or birds exposed to organic compound COPCs released under the Waste Management alternatives because there are no toxicity reference values for such receptors for these COPCs. Calculated risk indices for the COPC with the highest Hazard Quotient or Hazard Index are presented for each receptor.

Releases to air and groundwater are expected under all Waste Management alternatives and all disposal group variants under Waste Management Alternatives 2 and 3. The long-term impacts on terrestrial ecological resources of releases to air at Hanford were evaluated at the onsite maximum-exposure location (Core Zone Boundary) and on terrestrial, riparian, and aquatic resources at the offsite maximum-exposure location (Columbia River nearshore). Impacts on ecological resources of releases to groundwater were evaluated at the Columbia River.

5.3.3.1 Waste Management Alternative 1: No Action

Predicted emissions of COPCs in air from disposal in LLBG 218-W-5, trenches 31 and 34, under Waste Management Alternative 1: No Action do not pose a risk to ecological receptors. This No Action Alternative is not expected to result in releases of radionuclides to air. Releases of chemicals to air are expected from ongoing waste management activities (see Section 5.3 and Chapter 2, Section 2.4). The chemical COPC with the largest calculated Hazard Quotient (1.65) is xylene released to air for the mouse at the onsite maximum-exposure location (see Table 5–172). There would be no risk to terrestrial, riparian, or aquatic ecological receptors from releases to air under Waste Management Alternative 1 at the offsite maximum-exposure location (Columbia River nearshore). The uncertainty about the risk to terrestrial receptors from chemical COPCs in air releases under *TC & WM EIS* alternatives is discussed in Appendix P (see Section P.2.2)

Predicted emissions of chemical and radioactive COPCs in groundwater discharging at the Columbia River nearshore do not pose a risk to ecological receptors. The largest risk index (a Hazard Quotient of 0.003) for groundwater releases under Waste Management Alternative 1 (see Table 5–173) is that calculated for aquatic biota, including salmonids, exposed to chromium in surface water at the Columbia River nearshore. This indicates no risk to ecological receptors from chemical or radioactive COPCs released to groundwater at Hanford under Waste Management Alternative 1.

Table 5–172. Waste Management Alternatives – Long-Term Impacts of Chemical COPC Releases to Air on Terrestrial Resources at the Onsite Maximum-Exposure Location

Waste Management Alternative	Maximum Hazard Quotient of Chemical COPC by Receptor			
	Plants	Great Basin Pocket Mouse	Coyote	Mule Deer
	Toluene	Xylene	Xylene	Formaldehyde
1	3.29×10^{-2}	**1.65**	2.09×10^{-1}	3.71×10^{-1}
2, Disposal Group 1	1.77	**8.70×10^{1}**	1.11×10^{1}	1.70×10^{1}
2, Disposal Group 2	6.98	**3.44×10^{2}**	4.37×10^{1}	6.70×10^{1}
2, Disposal Group 3	9.43	**4.67×10^{2}**	5.93×10^{1}	9.97×10^{1}
3, Disposal Group 1	1.71	**8.36×10^{1}**	1.06×10^{1}	1.65×10^{1}
3, Disposal Group 2	6.92	**3.41×10^{2}**	4.33×10^{1}	6.64×10^{1}
3, Disposal Group 3	9.30	**4.63×10^{2}**	5.88×10^{1}	9.87×10^{1}

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

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

Predicted emissions of COPCs in air under Waste Management Alternative 2 pose little risk to plants and a moderate risk to mammals at the onsite maximum-exposure location (see Table 5–172). The largest calculated risk indices are for mammals exposed to organic chemicals released in air: formaldehyde for the deer and xylene, toluene, formaldehyde, and benzene for the mouse, mule deer, and coyote, all at the onsite maximum-exposure location. These are summarized below. There would be no risk to terrestrial, riparian, or aquatic ecological receptors from releases to air under Waste Management Alternative 2 at the offsite maximum-exposure location (Columbia River nearshore).

Releases to air and resulting long-term impacts on ecological resources would be similar under Waste Management Alternative 2, Disposal Groups 2 and 3. There would be a slight difference in peak air emissions between Disposal Groups 2 and 3 for operation of IDF-East and the RPPDF. IDF-East and the RPPDF, while the same size, would operate for a longer period of time under Disposal Group 3. This would result in higher cumulative emissions of all COPCs under Disposal Group 3 compared with Disposal Group 2, with a somewhat greater long-term impact on ecological resources of air releases under Disposal Group 3.

5.3.3.2.1 Waste Management Alternative 2, Disposal Group 1

Predicted emissions of COPCs in air under Waste Management Alternative 2, Disposal Group 1 (Subgroups 1-A through 1-G), pose a small probability of adverse impact on ecological receptors at the onsite maximum-exposure location only. The calculated Hazard Quotient for deer is 17 for formaldehyde under Waste Management Alternative 2, Disposal Group 1 (see Table 5–172). The chemical COPCs with the largest calculated Hazard Quotients for air releases are xylene (87) and formaldehyde (28) for the mouse at the onsite maximum-exposure location. Risk indices were not calculated separately for the air emissions under the different subgroups of Waste Management Alternative 2, Disposal Group 1 (i.e., Subgroups 1-A through 1-G).

Table 5–173. Waste Management Alternatives – Long-Term Impacts of Contaminant Releases to Groundwater on Aquatic and Riparian Receptors at the Columbia River Nearshore

Waste Management Alternative	Maximum Hazard Quotient or Hazard Index of Chemical or Radioactive COPC by Receptor						
	Benthic Invertebrate	Muskrat	Spotted Sandpiper	Raccoon	Least Weasel	Bald Eagle	Aquatic Biota/Salmonids
	Chromium	Nitrate	Chromium	Chromium	Nitrate	Chromium	Chromium
1	1.15×10^{-4}	6.24×10^{-7}	7.82×10^{-4}	9.47×10^{-5}	7.73×10^{-6}	9.34×10^{-6}	**3.14×10^{-3}**
2, DG1, SG1-A	3.10×10^{-4}	4.01×10^{-4}	2.10×10^{-3}	2.55×10^{-4}	1.10×10^{-2}	3.24×10^{-5}	**2.05×10^{-2}**
2, DG1, SG1-B	2.06×10^{-4}	4.35×10^{-4}	1.40×10^{-3}	1.69×10^{-4}	1.00×10^{-2}	2.33×10^{-5}	**1.66×10^{-2}**
2, DG1, SG1-C	5.73×10^{-2}	2.41×10^{-3}	3.89×10^{-1}	4.71×10^{-2}	5.66×10^{-2}	5.46×10^{-3}	**2.90**
2, DG1, SG1-D	3.40×10^{-3}	4.74×10^{-4}	2.31×10^{-2}	2.79×10^{-3}	1.15×10^{-2}	3.30×10^{-4}	**1.83×10^{-1}**
2, DG1, SG1-E	2.91×10^{-2}	1.34×10^{-3}	1.97×10^{-1}	2.39×10^{-2}	3.42×10^{-2}	2.87×10^{-3}	**1.63**
2, DG1, SG1-F	4.35×10^{-2}	8.16×10^{-4}	2.95×10^{-1}	3.58×10^{-2}	2.32×10^{-2}	4.35×10^{-3}	**2.55**
2, DG1, SG1-G	3.03×10^{-4}	4.01×10^{-4}	2.05×10^{-3}	2.49×10^{-4}	1.10×10^{-2}	3.21×10^{-5}	**2.07×10^{-2}**
2, DG2, SG2-A	3.29×10^{-4}	3.68×10^{-4}	2.23×10^{-3}	2.70×10^{-4}	1.04×10^{-2}	3.36×10^{-5}	**2.04×10^{-2}**
2, DG2, SG2-B, Base Case	1.49×10^{-3}	4.22×10^{-4}	1.01×10^{-2}	1.23×10^{-3}	1.05×10^{-2}	1.59×10^{-4}	**1.03×10^{-1}**
2, DG2, SG2-B, Option Case	1.39×10^{-2}	8.56×10^{-4}	9.45×10^{-2}	1.14×10^{-2}	3.20×10^{-2}	1.49×10^{-3}	**9.72×10^{-1}**
2, DG3, Base Case	1.39×10^{-3}	4.22×10^{-4}	9.40×10^{-3}	1.14×10^{-3}	1.05×10^{-2}	1.52×10^{-4}	**1.04×10^{-1}**
2, DG3, Option Case	1.52×10^{-2}	1.02×10^{-3}	1.03×10^{-1}	1.25×10^{-2}	3.20×10^{-2}	1.56×10^{-3}	**9.60×10^{-1}**
3, DG1, SG1-A	3.48×10^{-4}	4.01×10^{-4}	2.36×10^{-3}	2.86×10^{-4}	1.10×10^{-2}	3.61×10^{-5}	**2.25×10^{-2}**
3, DG1, SG1-B	3.48×10^{-4}	4.35×10^{-4}	2.36×10^{-3}	2.86×10^{-4}	1.00×10^{-2}	3.61×10^{-5}	**2.25×10^{-2}**
3, DG1, SG1-C	5.73×10^{-2}	2.41×10^{-3}	3.89×10^{-1}	4.71×10^{-2}	5.66×10^{-2}	5.45×10^{-3}	**2.90**
3, DG1, SG1-D	3.40×10^{-3}	4.74×10^{-4}	2.31×10^{-2}	2.79×10^{-3}	1.15×10^{-2}	3.30×10^{-3}	**1.83×10^{-1}**
3, DG1, SG1-E	2.91×10^{-2}	1.34×10^{-3}	1.97×10^{-1}	2.39×10^{-2}	3.42×10^{-2}	2.86×10^{-3}	**1.63**
3, DG1, SG1-F	4.35×10^{-2}	8.16×10^{-4}	2.95×10^{-1}	3.57×10^{-2}	2.32×10^{-2}	4.35×10^{-3}	**2.54**
3, DG1, SG1-G	3.48×10^{-4}	4.01×10^{-4}	2.36×10^{-3}	2.86×10^{-4}	1.10×10^{-2}	3.61×10^{-5}	**2.25×10^{-2}**
3, DG2, SG2-A	3.12×10^{-4}	3.68×10^{-4}	2.11×10^{-3}	2.56×10^{-4}	1.04×10^{-2}	3.13×10^{-5}	**1.85×10^{-2}**
3, DG2, SG2-B, Base Case	1.62×10^{-3}	4.22×10^{-4}	1.10×10^{-2}	1.33×10^{-3}	1.05×10^{-2}	1.71×10^{-4}	**1.09×10^{-1}**
3, DG2, SG2-B, Option Case	1.41×10^{-2}	8.56×10^{-4}	9.54×10^{-2}	1.16×10^{-2}	3.20×10^{-2}	1.50×10^{-3}	**9.77×10^{-1}**
3, DG3, Base Case	1.51×10^{-3}	4.22×10^{-4}	1.02×10^{-2}	1.24×10^{-3}	1.05×10^{-2}	1.64×10^{-4}	**1.10×10^{-1}**
3, DG3, Option Case	1.53×10^{-2}	1.02×10^{-3}	1.04×10^{-1}	1.26×10^{-2}	3.21×10^{-2}	1.57×10^{-3}	**9.66×10^{-1}**

Note: The maximum Hazard Quotient under each alternative is indicated by **bold** text.
Key: COPC=constituent of potential concern; DG=Disposal Group; SG=Subgroup.

There would be no risk of long-term impacts on ecological resources of releases to groundwater under Waste Management Alternative 2, Disposal Group 1, Subgroups 1-A through 1-G. The largest risk index (a Hazard Quotient of 2.9) for groundwater releases under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C (see Table 5–173), is that calculated for aquatic biota, including salmonids, exposed to chromium in surface water at the Columbia River nearshore. This Hazard Quotient is three orders of magnitude greater than under Waste Management Alternative 1. No other risk indices exceed 1. This indicates no risk to ecological receptors from chromium or other chemical or radioactive COPCs released to groundwater at Hanford under Waste Management Alternative 2, Disposal Group 1.

5.3.3.2.2 Waste Management Alternative 2, Disposal Group 2

Predicted emissions of COPCs in air under Waste Management Alternative 2, Disposal Group 2, pose a greater probability of adverse impact on ecological receptors at the onsite maximum-exposure location than under Waste Management Alternative 2, Disposal Group 1 (see Table 5–172). The calculated Hazard Quotient for deer exposed to formaldehyde is 67 under Waste Management Alternative 2, Disposal Group 2, compared with 17 under Waste Management Alternative 2, Disposal Group 1. The chemical COPCs with the largest calculated Hazard Quotients for air releases are xylene (344) and formaldehyde (111) for the mouse at the onsite maximum-exposure location. Risk indices were not calculated separately for the air emissions under the different subgroups of Waste Management Alternative 2, Disposal Group 2 (i.e., Subgroups 2-A and 2-B).

There would be no risk of long-term impacts on ecological resources of releases to groundwater under Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A or 2-B (Base and Option Cases). The largest risk index (a Hazard Quotient of 0.97) for groundwater releases under Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case (see Table 5–173), is that calculated for aquatic biota, including salmonids, exposed to chromium in surface water at the Columbia River nearshore. This indicates no risk to ecological receptors from chemical or radioactive COPCs released to groundwater at Hanford under Waste Management Alternative 2, Disposal Group 2.

5.3.3.2.3 Waste Management Alternative 2, Disposal Group 3

Predicted emissions of COPCs in air under Waste Management Alternative 2, Disposal Group 3, pose a greater probability of adverse impact on ecological receptors at the onsite maximum-exposure location than under Waste Management Alternative 2, Disposal Group 2. The calculated Hazard Quotient for deer exposed to formaldehyde is 100 under Waste Management Alternative 2, Disposal Group 3 (see Table 5–172). The calculated formaldehyde Hazard Quotient under Waste Management Alternative 2, Disposal Group 3, is the maximum risk index for the mule deer under all alternatives (see Appendix P, Table P–5). The largest Hazard Quotients for the release of chemical COPCs to air were predicted for the mouse exposed to xylene (467) and formaldehyde (165) at the onsite maximum-exposure location.

There would be no risk of long-term impacts on ecological resources of releases to groundwater under Waste Management Alternative 2, Disposal Group 3 (Base and Option Cases). The largest risk index (a Hazard Quotient of 0.96) for groundwater releases under Waste Management Alternative 2, Disposal Group 3 (see Table 5–173), is that calculated for aquatic biota, including salmonids, exposed to chromium in surface water at the Columbia River nearshore. This indicates no risk to ecological receptors from chemical or radioactive COPCs released to groundwater at Hanford under Waste Management Alternative 2, Disposal Group 3.

5.3.3.3 Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas

Predicted emissions of COPCs in air under Waste Management Alternative 3 pose little risk to plants and a moderate risk to mammals at the onsite maximum-exposure location (see Table 5–172). These results are discussed below. There would be no risk to terrestrial, riparian, or aquatic ecological receptors from

releases to air under Waste Management Alternative 3 at the offsite maximum-exposure location (Columbia River nearshore).

Releases to air and resulting long-term impacts on ecological resources at the onsite maximum-exposure location would be similar under Waste Management Alternative 3, Disposal Groups 2 and 3. There would be a slight difference in peak air emissions between Disposal Groups 2 and 3 due to operation of an IDF and the RPPDF. An IDF and the RPPDF, while the same size, would operate for a longer period of time under Waste Management Alternative 3, Disposal Group 3. This would result in higher cumulative emissions of COPCs and slightly lower peak emissions of others (e.g., formaldehyde and ammonia under Disposal Group 3 compared with Disposal Group 2), with only minor differences in long-term impacts on ecological resources of air releases.

5.3.3.3.1 Waste Management Alternative 3, Disposal Group 1

Predicted emissions of COPCs in air under Waste Management Alternative 3, Disposal Group 1, pose a similar probability of adverse impact on ecological receptors at the onsite maximum-exposure location than under Waste Management Alternative 2, Disposal Group 1 (see Table 5–172). The calculated Hazard Quotient for deer exposed to formaldehyde is 16.5 under Waste Management Alternative 3, Disposal Group 1, compared with 17 under Waste Management Alternative 2, Disposal Group 1. The chemical COPCs with the largest calculated Hazard Quotients for air releases are xylene (84) and formaldehyde (27) for the mouse at the onsite maximum-exposure location. Risk indices were not calculated separately for the air emissions under the different subgroups of Waste Management Alternative 3, Disposal Group 1 (i.e., Subgroups 1-A through 1-G).

There would be no risk of long-term impacts on ecological resources of releases to groundwater under Waste Management Alternative 3, Disposal Group 1, Subgroups 1-A through 1-G. The largest risk index (a Hazard Quotient of 2.9) for groundwater releases under Waste Management Alternative 3, Disposal Group 1, Subgroup 1-C (see Table 5–173), is that calculated for aquatic biota, including salmonids, exposed to chromium in surface water at the Columbia River nearshore. This Hazard Quotient is three orders of magnitude greater than under Waste Management Alternative 1. No other risk indices exceed 1. This indicates no risk to ecological receptors from chemical or radioactive COPCs released to groundwater at Hanford under Waste Management Alternative 3, Disposal Group 1.

5.3.3.3.2 Waste Management Alternative 3, Disposal Group 2

Predicted emissions of COPCs in air under Waste Management Alternative 3, Disposal Group 2, pose a greater probability of adverse impact on ecological receptors at the onsite maximum-exposure location than under Waste Management Alternative 3, Disposal Group 1, and a similar probability of impact to that under Waste Management Alternative 2, Disposal Group 2 (see Table 5–172). The calculated Hazard Quotient for deer exposed to formaldehyde is 66 under Waste Management Alternative 3, Disposal Group 2, compared with 16 under Waste Management Alternative 3, Disposal Group 1, and 67 under Waste Management Alternative 2, Disposal Group 2. The chemical COPCs with the largest calculated Hazard Quotients for air releases are xylene (341) and formaldehyde (110) for the mouse at the onsite maximum-exposure location. Risk indices were not calculated separately for the air emissions under the different variants of Waste Management Alternative 3, Disposal Group 2 (i.e., Subgroups 2-A and 2-B).

There would be no risk of long-term impacts on ecological resources of releases to groundwater under Waste Management Alternative 3, Disposal Group 2, Subgroup 2-A or 2-B (Base and Option Cases). The largest risk index (a Hazard Quotient of 0.98) for groundwater releases under Waste Management Alternative 3, Disposal Group 2, Subgroup 2-B, Option Case (see Table 5–173), is that calculated for aquatic biota, including salmonids, exposed to chromium in surface water at the Columbia River nearshore. This indicates no risk to ecological receptors from chemical or radioactive COPCs released to groundwater at Hanford under Waste Management Alternative 3, Disposal Group 2.

5.3.3.3.3 Waste Management Alternative 3, Disposal Group 3

Predicted emissions of COPCs in air under Waste Management Alternative 3, Disposal Group 3, pose a greater probability of adverse impact on ecological receptors at the onsite maximum-exposure location than under Waste Management Alternative 3, Disposal Group 2. The calculated Hazard Quotient for deer exposed to formaldehyde is 98.7 under Waste Management Alternative 3, Disposal Group 3, compared with 66 under Waste Management Alternative 3, Disposal Group 2 (see Table 5–172). The chemical COPCs with the largest calculated Hazard Quotients for air release are xylene (463) and formaldehyde (163) for the mouse at the onsite maximum-exposure location.

There would be no risk of long-term impacts on ecological resources of releases to groundwater under Waste Management Alternative 3, Disposal Group 3 (Base and Option Cases). The largest risk index (a Hazard Quotient of 0.97) for groundwater releases under Waste Management Alternative 3, Disposal Group 3 (see Table 5–173), is that calculated for aquatic biota, including salmonids, exposed to chromium in surface water at the Columbia River nearshore. This indicates no risk to ecological receptors from chemical or radioactive COPCs released to groundwater at Hanford under Waste Management Alternative 3, Disposal Group 3.

5.3.4 Environmental Justice

Sections 5.3.1 and 5.3.2 evaluate groundwater impacts and associated potential long-term human health effects under the Waste Management alternatives. Receptors analyzed with a potential for environmental justice concerns include a resident farmer, an American Indian resident farmer, and an American Indian hunter-gatherer. The hypothetical resident farmer, which could represent a minority or low-income population, and American Indian resident farmer were both assumed to use only groundwater for drinking water ingestion and crop irrigation. While only a portion of the food consumed by the resident farmer was assumed to come from crops and animal products exposed to contaminated groundwater, all of the food consumed by the American Indian resident farmer was assumed to be exposed to contaminated groundwater. (See Appendix Q, Section Q.2.4.1, for assumed consumption levels for the different receptors.) The American Indian hunter-gatherer was assumed to have a subsistence consumption pattern that differs from the American Indian resident farmer. The American Indian hunter-gatherer would not cultivate crops, but rather would gather food from indigenous plants and harvest a larger amount of fish from the Columbia River, drink no milk, consume no eggs, and drink a larger amount of water (water that would be gathered from potentially contaminated surface-water sources); thus, this receptor is assumed to be exposed to a combination of surface water and groundwater. Given these assumptions, the two American Indian receptors would be most at risk from contaminated groundwater. These receptors were used to develop exposure scenarios at several on- and offsite locations identified in Appendix Q, Section Q.2.2.

Long-term human health impacts of waste management actions would be greatest under Waste Management Alternative 3, Disposal Group 1, Subgroup 1-C. Radionuclide releases under this alternative would result in doses at the IDF-West barrier that would exceed regulatory limits for the American Indian resident farmer. None of the hypothetical receptors at the IDF-East barrier, the Core Zone Boundary, the RPPDF barrier, the Columbia River nearshore, or the Columbia River surface-water location would be exposed to a dose in excess of regulatory limits, including the American Indian hunter-gather. Chemical releases under this alternative would result in exceedance of the Hazard Index for chromium at the IDF-East barrier for the resident farmer and the American Indian resident farmer and at the Core Zone Boundary for the American Indian resident farmer. Exceedances of the Hazard Index for nitrate would occur at the IDF-East barrier, the Core Zone Boundary, and Columbia River nearshore for the resident farmer and the American Indian resident farmer. None of the hypothetical receptors at the RPPDF barrier or the Columbia River surface-water location would be exposed to a Hazard Index in excess of regulatory limits.

The analysis determined that the greatest impact of any alternative on long-term human health could result in radiation doses in excess of regulatory limits and chemical exposures with a Hazard Index greater than 1 for receptors located on site at the IDF-East barrier, IDF-West barrier, Core Zone Boundary, or Columbia River nearshore. There are no such onsite receptors currently at Hanford. The onsite exposure scenarios do not currently exist and have never existed during Hanford operations. Therefore, the estimated high health risks for past years are hypothetical risks only; no persons were ever exposed at these levels. While it is possible for these receptor scenarios to develop in the future, none are expected for the foreseeable future because the Core Zone is designated for Industrial-Exclusive land use, the Columbia River nearshore is designated for Preservation (Hanford Reach National Monument), and the area between them is designated for Conservation (Mining) (DOE 1999). It is unlikely, therefore, that any of the Waste Management alternatives would pose a disproportionately high and adverse long-term human health risk to the offsite American Indian population. The greatest risk would be to the American Indian resident farmer at the IDF-West barrier. During the year of peak dose, this receptor would receive a radiation dose of 131 millirem. During the year of peak Hazard Index, this receptor would not be exposed to chemicals resulting in a Hazard Index greater than 1; however, the risk from the radiation dose at this location outweighs the nonradiological risk from chemical releases identified at the Core Zone Boundary and the Columbia River nearshore. The adverse impacts would also be applicable to non–American Indian receptors at the same locations, but to a lesser extent, because non–American Indian receptors are not expected to consume as much potentially contaminated food, e.g., fish, meat, milk.

5.4 COMBINATION OF ALTERNATIVES

The potential long-term environmental and human health impacts associated with implementation of alternatives and options for (1) Hanford SST system waste retrieval, treatment, and closure (i.e., tank closure), (2) decommissioning of FFTF and auxiliary facilities (i.e., FFTF decommissioning), and (3) management of waste resulting from other Hanford activities and limited volumes from other DOE sites (i.e., waste management) are presented separately in Sections 5.1, 5.2, and 5.3, respectively. The individual Tank Closure, FFTF Decommissioning, and Waste Management alternatives and options, as applicable, are described in detail in Chapter 2. This section presents the potential long-term, combined impacts on key air and groundwater resource indicators of implementing selected alternatives and options associated with the three sets of proposed actions.

To focus on those measures that provide the most meaningful and useful assessment of potential impacts, key resource indicators were selected from the total range of impact measures presented for each resource area or discipline (analyzed elsewhere in this chapter). As presented in this section, the combined-impact analyses provide a basis for determining the potential peak and/or total impact on an environmental resource area or human health indicator associated with implementation of the alternatives and options from each set of proposed actions analyzed in this EIS.

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 analysis purposes, the following 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:** all No Action Alternatives

- **Alternative Combination 2:** Tank Closure Alternative 2B (Expanded WTP Vitrification; Landfill Closure); FFTF Decommissioning Alternative 2 (Entombment) with the Idaho Option for disposition of RH-SCs and the Hanford Reuse Option for disposition of bulk sodium; and Waste Management Alternative 2 (Disposal in IDF, 200-East Area Only) with Disposal Group 1, Subgroup 1-A

- **Alternative Combination 3:** Tank Closure Alternative 6B (All Vitrification with Separations; Clean Closure), Base Case; FFTF Decommissioning Alternative 3 (Removal) with the Idaho Option for disposition of RH-SCs and the Hanford Reuse Option for disposition of bulk sodium; and Waste Management Alternative 2 (Disposal in IDF, 200-East Area Only) with Disposal Group 2, Subgroup 2-B

Alternative Combination 1 represents the potential short-term impacts of minimal DOE action and the greatest long-term impacts with respect to groundwater. Alternative Combination 2 is a midrange case representative of DOE's Preferred Alternative(s), as addressed in Chapter 2, Section 2.12. Alternative Combination 3 reflects the most conservative estimate of impacts for most resource areas in terms of the intensity of the potential impact and therefore represents, on the whole, a combination that would result in maximum potential short-term impacts, but would likely have the lowest long-term impacts on groundwater. For some resource areas, a combination that includes Tank Closure Alternative 6A, Option Case, would result in maximum impacts. Selection of these three alternative combinations for detailed analysis in this EIS is done only to establish overall impact-level reference cases for stakeholders and decisionmakers to consider and does not preclude the selection and implementation of different combinations of the various alternatives in support of final agency decisions.

5.4.1 Groundwater

5.4.1.1 Alternative Combination 1

This section describes the results of the long-term groundwater impacts analysis for Alternative Combination 1, which comprises Tank Closure Alternative 1, FFTF Decommissioning Alternative 1, and Waste Management Alternative 1. The focus is the combined long-term groundwater impacts of these alternatives. More detailed discussion of the individual impacts is provided in Sections 5.1.1, 5.2.1, and 5.3.1.

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

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

The COPC drivers were obtained from the combination of the COPC drivers for the three individual alternatives that compose the alternative combination. They fall into three categories. Iodine-129, technetium-99, chromium, and nitrate are all mobile (i.e., move with groundwater) and long-lived (relative to the 10,000-year period of analysis), or stable. They are essentially conservative tracers. Tritium is also mobile, but short-lived. The half-life of tritium is about 13 years, and tritium concentrations are strongly attenuated by radioactive decay during travel through the vadose zone and groundwater systems. Finally, uranium-238 and total uranium are long-lived, or stable, but are not as mobile as the other COPC drivers. These constituents move about seven times more slowly than groundwater. 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.

ANALYSIS OF RELEASE AND MASS BALANCE

This section presents the impacts of Alternative Combination 1 in terms of the total amount of COPCs released to the vadose zone, groundwater, and the Columbia River during the 10,000-year period of analysis. Releases of radionuclides are totaled in curies; chemicals, in kilograms.

Table 5–174 lists the release of the COPC drivers to the vadose zone. Under Alternative Combination 1, the release to the vadose zone is controlled by the inventory (i.e., 100 percent of the inventory is released

during the period of analysis). The release to the vadose zone under Alternative Combination 1 is dominated by sources associated with Tank Closure Alternative 1; releases from FFTF decommissioning and waste management sources account for less than 1 percent of the total for all of the COPCs except for tritium and total uranium. FFTF decommissioning accounts for about 6 percent of the total uranium released to the vadose zone, and Waste Management Alternative 1 sources account for about 7 percent of the tritium released to the vadose zone. This result suggests that the long-term impacts of Alternative Combination 1 would closely match the long-term impacts of Tank Closure Alternative 1.

Table 5–174. Alternative Combination 1 Releases of COPC Drivers to Vadose Zone

Alternative	Radioactive COPCs (curies)				Chemical COPCs (kilograms)		
	Hydrogen-3 (Tritium)	Iodine-129	Technetium-99	Uranium-238	Chromium	Nitrate	Total Uranium
Tank Closure Alternative 1	4.90×10^{4}	4.78×10^{1}	2.58×10^{4}	9.33×10^{2}	6.91×10^{5}	9.67×10^{7}	6.24×10^{5}
FFTF Decommissioning Alternative 1	3.72×10^{-1}	0.00	2.72×10^{1}	0.00	5.72×10^{-3}	0.00	3.77×10^{4}
Waste Management Alternative 1	3.50×10^{3}	1.31×10^{-3}	1.21	2.13×10^{-1}	1.79×10^{2}	2.98×10^{3}	2.74×10^{-1}
Total	$\mathbf{5.25\times10^{4}}$	$\mathbf{4.78\times10^{1}}$	$\mathbf{2.58\times10^{4}}$	$\mathbf{9.33\times10^{2}}$	$\mathbf{6.92\times10^{5}}$	$\mathbf{9.67\times10^{7}}$	$\mathbf{6.62\times10^{5}}$

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

Table 5–175 lists the release of the COPC drivers to groundwater. In addition to the inventory consideration discussed in the previous paragraph, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), the amount released to groundwater is essentially equal to the amount released to the vadose zone. For tritium, that amount is attenuated by radioactive decay during transit through the vadose zone. About 60 percent of the tritium released to the vadose zone reaches the unconfined aquifer. For uranium-238 and total uranium, the amount released to groundwater is lower than that released to the vadose zone because of retardation. Less than 4 percent of the uranium-238 and total uranium released to the vadose zone reaches the unconfined aquifer during the period of analysis.

Table 5–175. Alternative Combination 1 Releases of COPC Drivers to Groundwater

Alternative	Radioactive COPCs (curies)				Chemical COPCs (kilograms)		
	Hydrogen-3 (Tritium)	Iodine-129	Technetium-99	Uranium-238	Chromium	Nitrate	Total Uranium
Tank Closure Alternative 1	3.12×10^{4}	4.70×10^{1}	2.53×10^{4}	1.46×10^{1}	6.84×10^{5}	9.63×10^{7}	1.75×10^{4}
FFTF Decommissioning Alternative 1	5.79×10^{-7}	0.00	2.71×10^{1}	0.00	5.58×10^{-3}	0.00	4.24×10^{3}
Waste Management Alternative 1	3.80×10^{-7}	1.30×10^{-3}	1.19	3.95×10^{-6}	1.77×10^{2}	2.94×10^{3}	4.94×10^{-6}
Total	$\mathbf{3.12\times10^{4}}$	$\mathbf{4.70\times10^{1}}$	$\mathbf{2.53\times10^{4}}$	$\mathbf{1.46\times10^{1}}$	$\mathbf{6.85\times10^{5}}$	$\mathbf{9.63\times10^{7}}$	$\mathbf{2.16\times10^{4}}$

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

Table 5–176 lists the release of the COPC drivers to the Columbia River. Release to the Columbia River is controlled by the transport properties of the COPC drivers. For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), the amount released to the Columbia River is essentially equal to that released to groundwater. For tritium, the amount released to the Columbia River is attenuated by radioactive decay. Overall, only about 1 percent of the tritium released to groundwater reaches the Columbia River. For uranium-238 and total uranium, the amount released to the Columbia River is lower than that released to groundwater because of retardation in the aquifer. Overall, about 30 percent of the amount released to groundwater during the period of analysis reaches the Columbia River.

Table 5–176. Alternative Combination 1 Releases of COPC Drivers to the Columbia River

Alternative	Radioactive COPCs (curies)				Chemical COPCs (kilograms)		
	Hydrogen-3 (Tritium)	Iodine-129	Technetium-99	Uranium-238	Chromium	Nitrate	Total Uranium
Tank Closure Alternative 1	3.90×10^{2}	4.71×10^{1}	2.54×10^{4}	3.58	6.82×10^{5}	9.71×10^{7}	4.18×10^{3}
FFTF Decommissioning Alternative 1	2.50×10^{-8}	0.00	2.70×10^{1}	0.00	5.74×10^{-3}	0.00	2.68×10^{3}
Waste Management Alternative 1	0.00	1.31×10^{-3}	1.20	0.00	1.78×10^{2}	2.96×10^{3}	0.00
Total	**3.90×10^{2}**	**4.71×10^{1}**	**2.54×10^{4}**	**3.58**	**6.82×10^{5}**	**9.71×10^{7}**	**6.87×10^{3}**

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

ANALYSIS OF CONCENTRATION VERSUS TIME

This section describes the impacts of Alternative Combination 1 in terms of groundwater concentration versus time at the Core Zone Boundary and the Columbia River nearshore. Concentrations of radionuclides are in picocuries per liter; chemicals, in micrograms per liter. The benchmark concentration of each radionuclide and chemical is shown. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over 12 orders of magnitude. Table 5–177 lists the maximum concentrations of the COPCs in the peak year at the Core Zone Boundary and the Columbia River nearshore. The results indicate that technetium-99, iodine-129, nitrate, and chromium exceed their respective benchmark concentrations at both the Core Zone Boundary and the Columbia River nearshore. Tritium, uranium isotopes, and total uranium exceed their respective benchmark concentrations at the Core Zone Boundary only. The remaining COPCs in the table do not exceed the benchmark concentrations at either location during the period of analysis.

Table 5–177. Alternative Combination 1 Maximum COPC Concentrations in the Peak Year at the Core Zone Boundary and Columbia River Nearshore

Contaminant	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclide (picocuries per liter)			
Hydrogen-3 (tritium)	**660,000** (1956)	10,600 (1964)	20,000
Technetium-99	**35,000** (1956)	**1,700** (2999)	900
Iodine-129	**58.8** (3577)	**6.8** (4840)	1
Uranium isotopes (includes uranium-233, -234, -235, -238)	**32** (11,777)	1 (11,928)	15
Chemical (micrograms per liter)			
Chromium	**6,080** (1955)	**232** (2017)	100
Nitrate	**2,030,000** (1956)	**71,600** (1964)	45,000
Total uranium	**41** (11,778)	1 (11,788)	30

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

Key: COPC=constituent of potential concern.

Figure 5–1177 shows concentration versus time for tritium. Note that for visual clarity, the time period shown in this figure is from CY 1940 through CY 2440 (500 years), rather than the full 10,000-year period of analysis. Releases from cribs and trenches (ditches) cause Core Zone Boundary groundwater concentrations to exceed the benchmark concentration by about two orders of magnitude for a short period of time during the early part of the period of analysis. This time period is represented by the first series of sharp inflections in the curve for the Core Zone Boundary from about CY 1956 to CY 1980. During this time, groundwater concentrations at the Columbia River nearshore peak at less than an order of magnitude lower than the benchmark concentration. The later broad inflection occurring around CY 1990 represents the tritium contribution from past tank leaks. Because the half-life of tritium is less than 13 years, radioactive decay rapidly attenuates the groundwater concentration, and tritium is essentially not a factor at times later than CY 2100.

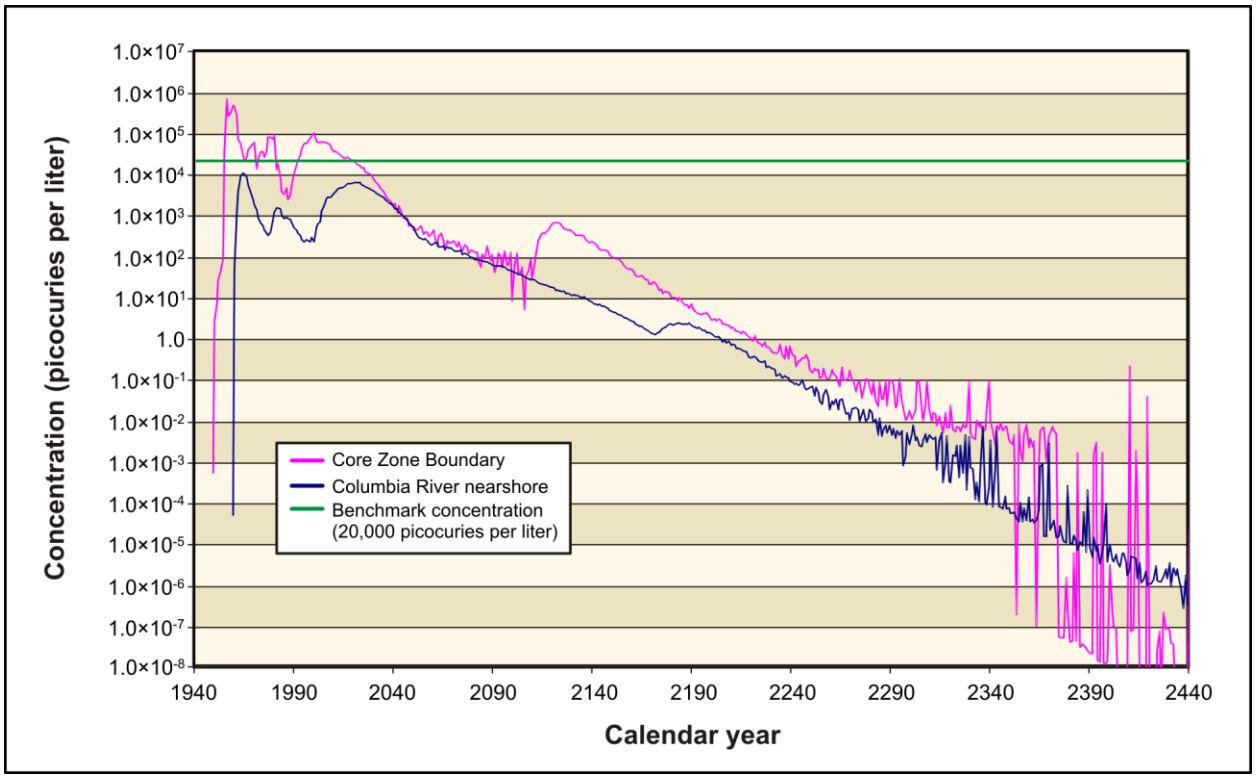


Figure 5–1177. Alternative Combination 1 Hydrogen-3 (Tritium) Concentration Versus Time

Figures 5–1178 through 5–1181 show concentration versus time for iodine-129, technetium-99, chromium, and nitrate (the conservative tracers). Iodine-129 concentrations in groundwater exceed benchmark concentrations by about one to two orders of magnitude during the first several thousand years of the analysis period. During this time, groundwater concentrations at the Columbia River nearshore exceed the benchmark concentration by less than an order of magnitude. Concentrations at the Core Zone Boundary start to decline around CY 4500 to levels below the benchmark concentration by around CY 8500. Concentrations at the Columbia River nearshore start to decline around CY 5300 to levels below the benchmark concentration by around CY 8000. Technetium-99, chromium, and nitrate concentrations show a similar curve, with chromium and nitrate concentrations at the Columbia River nearshore never exceeding benchmark concentrations.

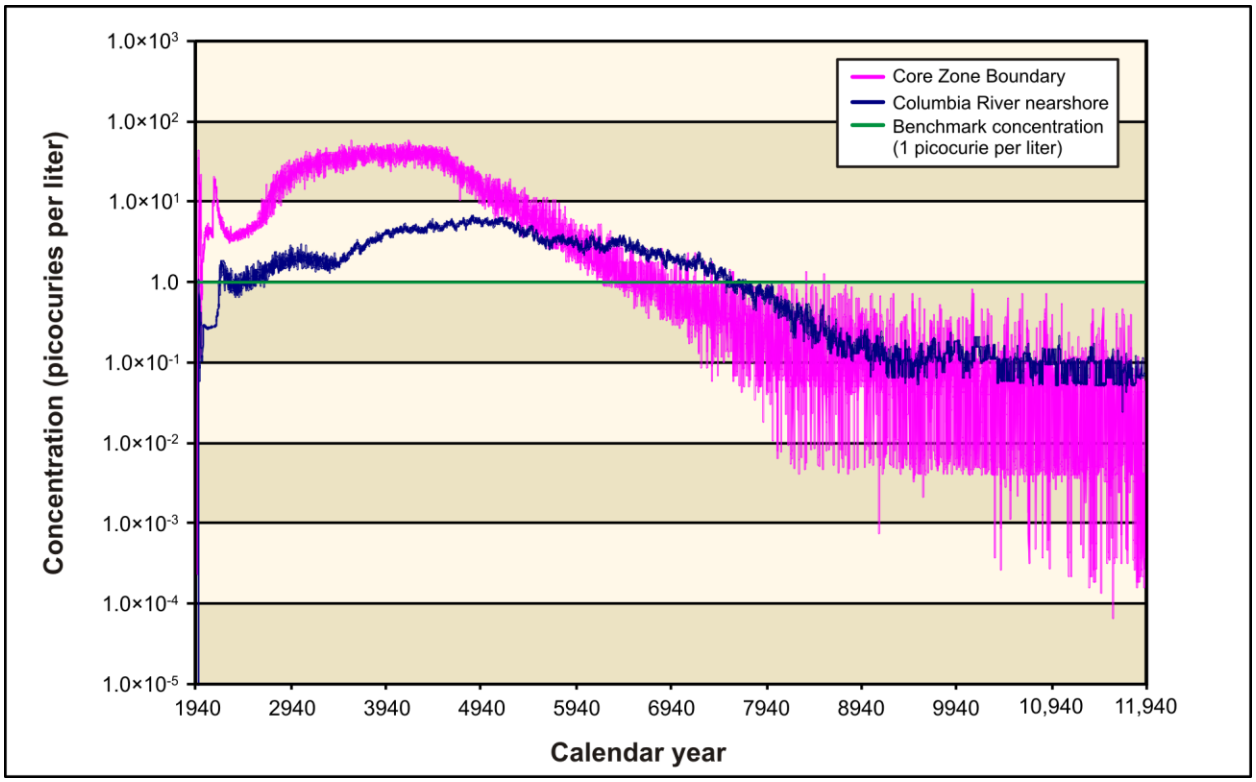


Figure 5–1178. Alternative Combination 1 Iodine-129 Concentration Versus Time

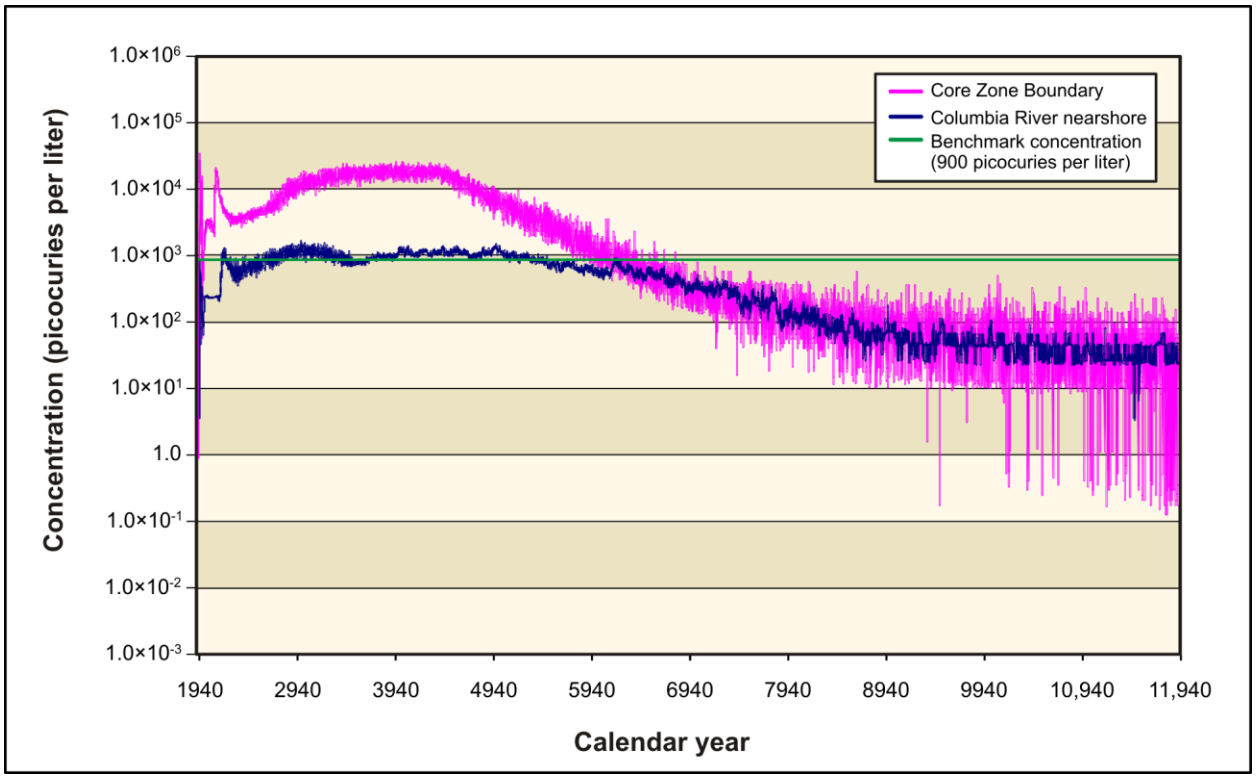


Figure 5–1179. Alternative Combination 1 Technetium-99 Concentration Versus Time

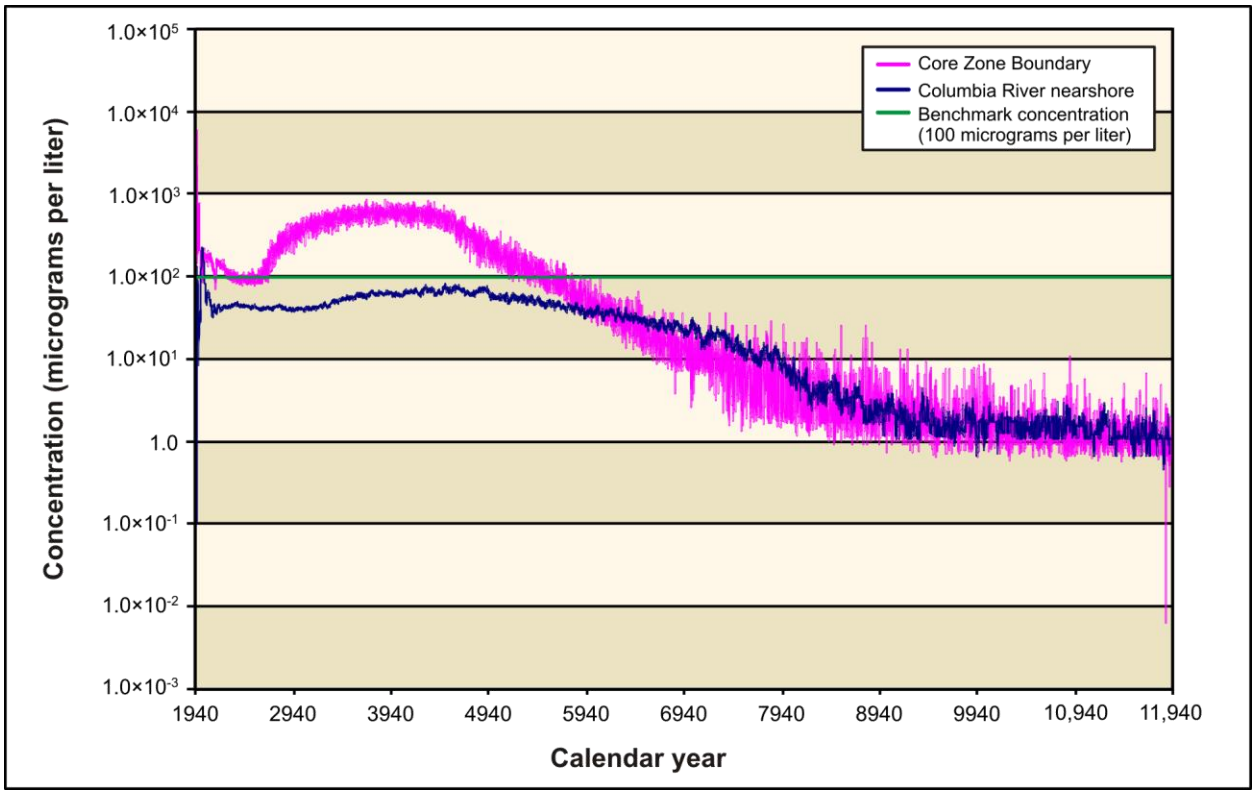


Figure 5–1180. Alternative Combination 1 Chromium Concentration Versus Time

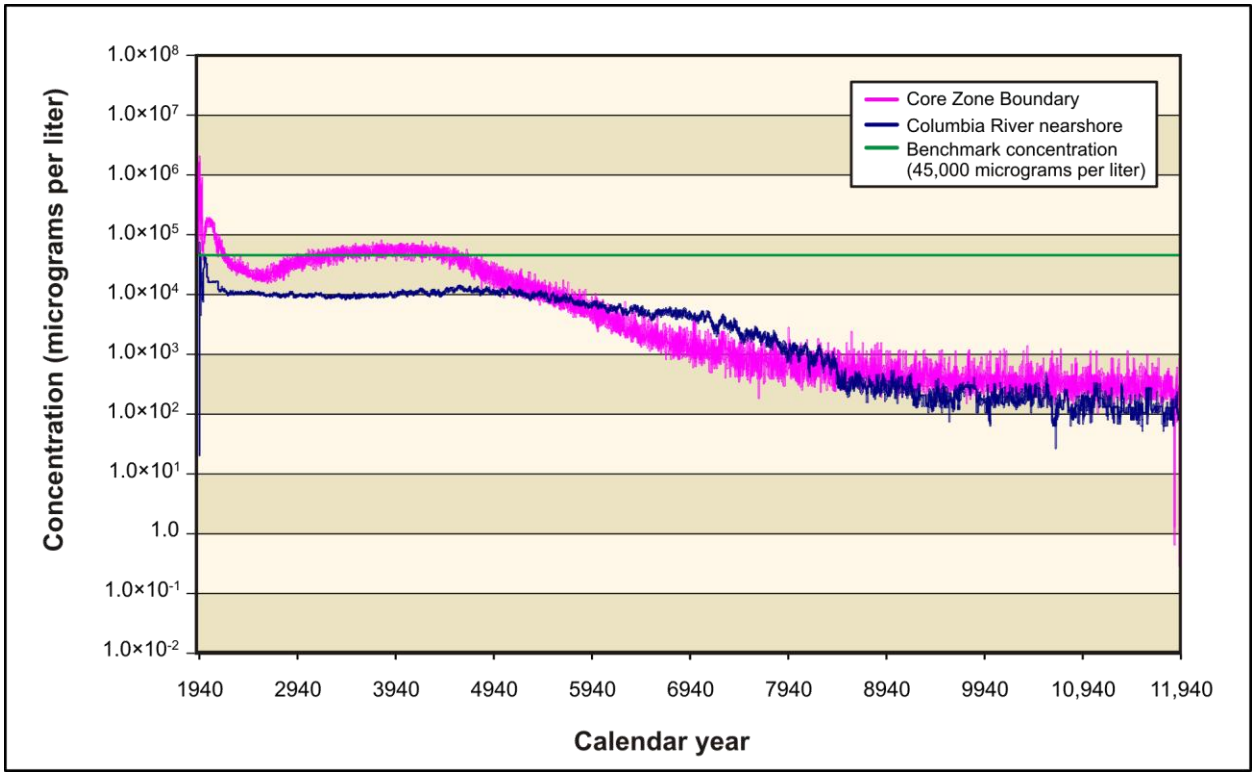


Figure 5–1181. Alternative Combination 1 Nitrate Concentration Versus Time

Figures 5–1182 and 5–1183 show concentration versus time for uranium-238 and total uranium. Concentrations of uranium-238 and total uranium rise throughout the period of analysis. The travel times of these COPCs from the source locations to the Core Zone Boundary and the Columbia River nearshore are retarded relative to the conservative tracers by about a factor of seven. Early releases from cribs and trenches (ditches) are represented by sharp inflections in the Core Zone Boundary curve around CY 1980 and CY 2250 that are approximately two to four orders of magnitude lower than benchmark concentrations. Releases from other tank farm sources cause uranium concentrations to rise, starting around CY 3700 at the Core Zone Boundary and CY 5600 at the Columbia River nearshore. Concentrations of both uranium-238 and total uranium approach and exceed the benchmark concentration, by less than an order of magnitude, at the Core Zone Boundary near the end of the period of analysis, around CY 11,000. Groundwater concentrations at the Columbia River nearshore rise throughout the period of analysis, but remain one to two orders of magnitude below the benchmark concentration by CY 11,940.

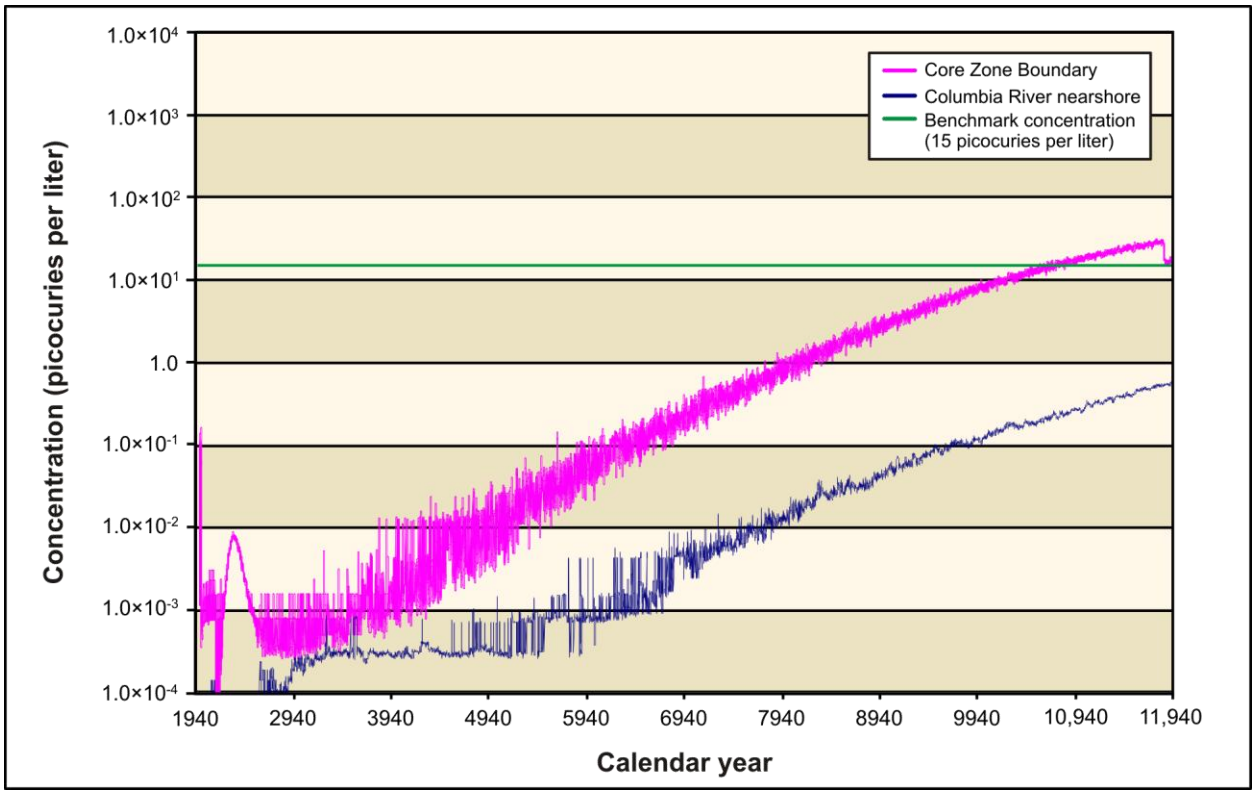


Figure 5–1182. Alternative Combination 1 Uranium-238 Concentration Versus Time

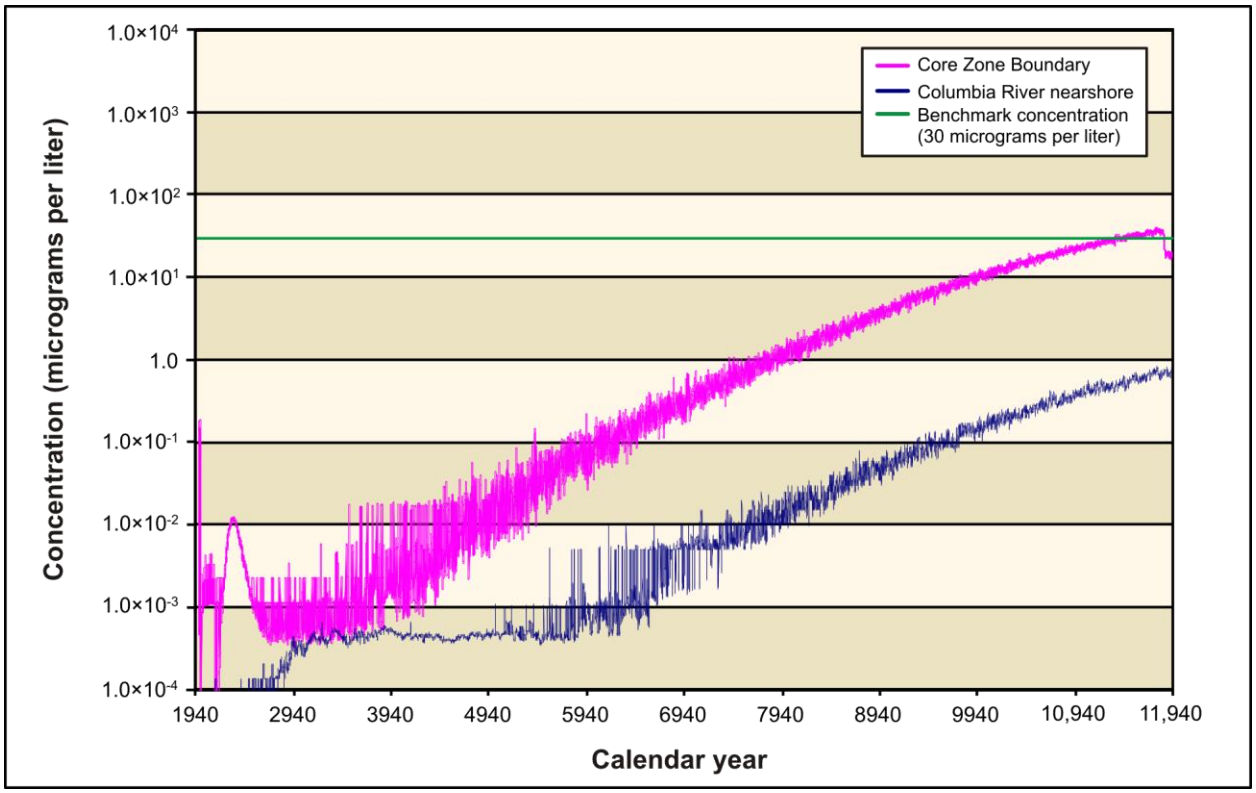
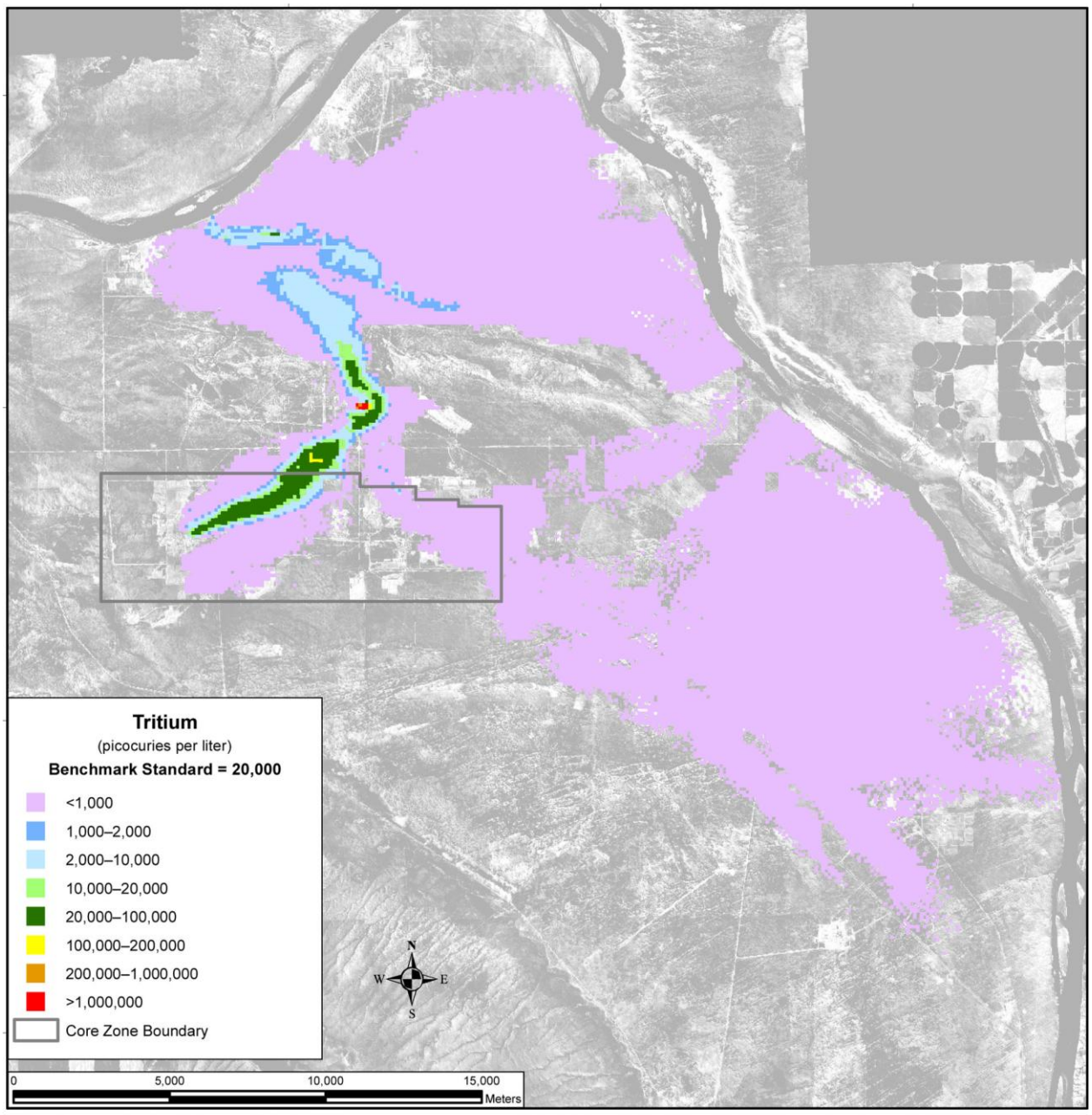


Figure 5–1183. Alternative Combination 1 Total Uranium Concentration Versus Time

ANALYSIS OF SPATIAL DISTRIBUTION OF CONCENTRATION

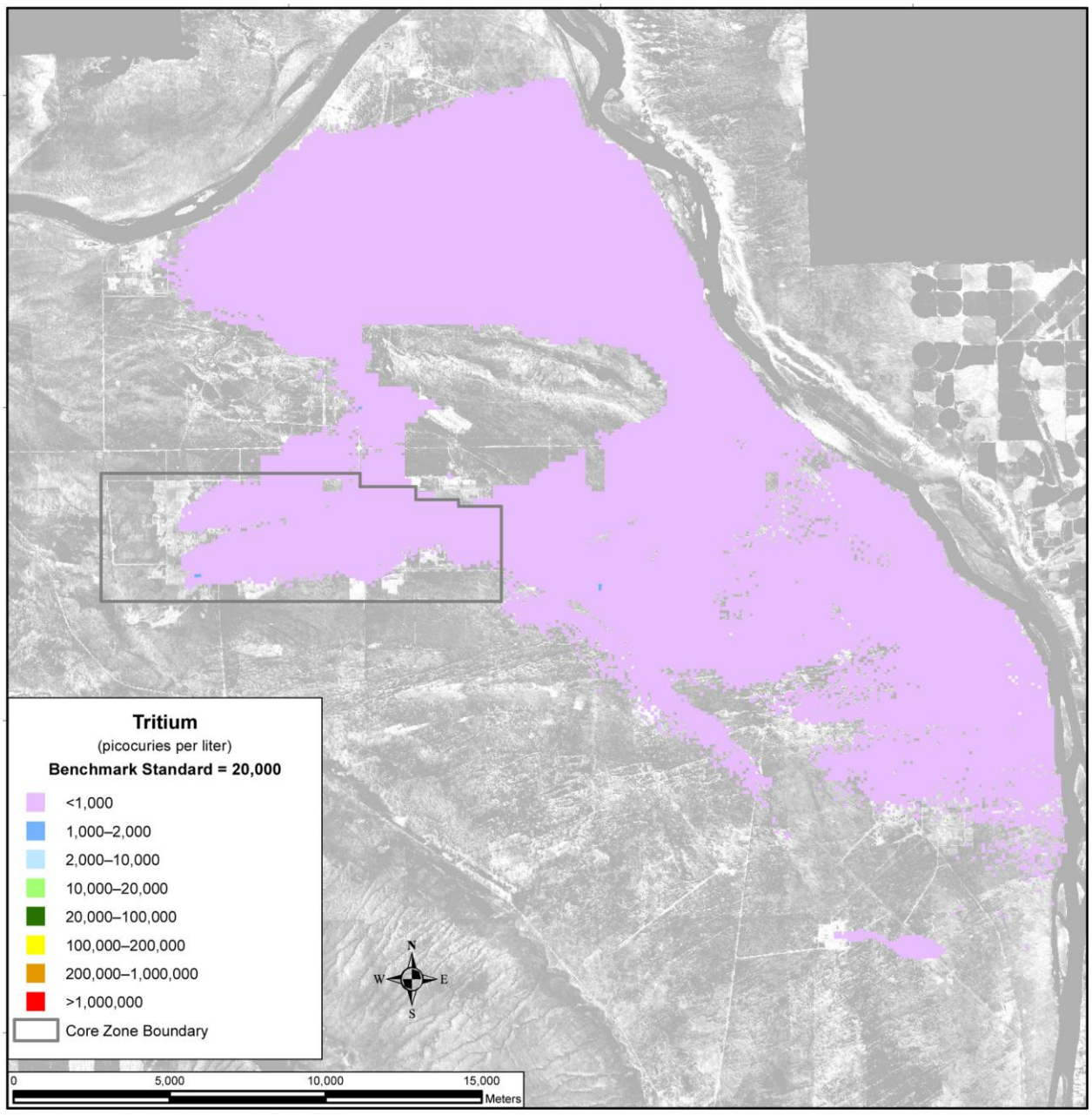
This section describes the impacts of Alternative Combination 1 in terms of the spatial distribution of COPC driver concentrations in groundwater at selected times. Concentrations of radionuclides are in picocuries per liter; chemicals, in micrograms per liter. Concentrations of each radionuclide and chemical are indicated by a color scale that is relative to the benchmark concentration. Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations less than the benchmark concentration are indicated by the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude.

Figure 5–1184 shows the spatial distribution of tritium concentrations in groundwater in CY 2010. Releases from cribs and trenches (ditches) and past leaks, associated primarily with the T, TX, and TY tank farms, result in a groundwater concentration plume (exceeding the benchmark concentration) that extends from the center part of the 200-West Area northeast, crossing the Core Zone Boundary and extending through Gable Gap. Peak concentrations in this plume are about 5 to 10 times greater than the benchmark concentration and are mostly contained within the Core Zone Boundary and south of Gable Gap. Tritium concentrations are attenuated by radioactive decay to levels less than one-twentieth of the benchmark concentration by CY 2135 (see Figure 5–1185).



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

Figure 5–1184. Alternative Combination 1 Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration, Calendar Year 2010

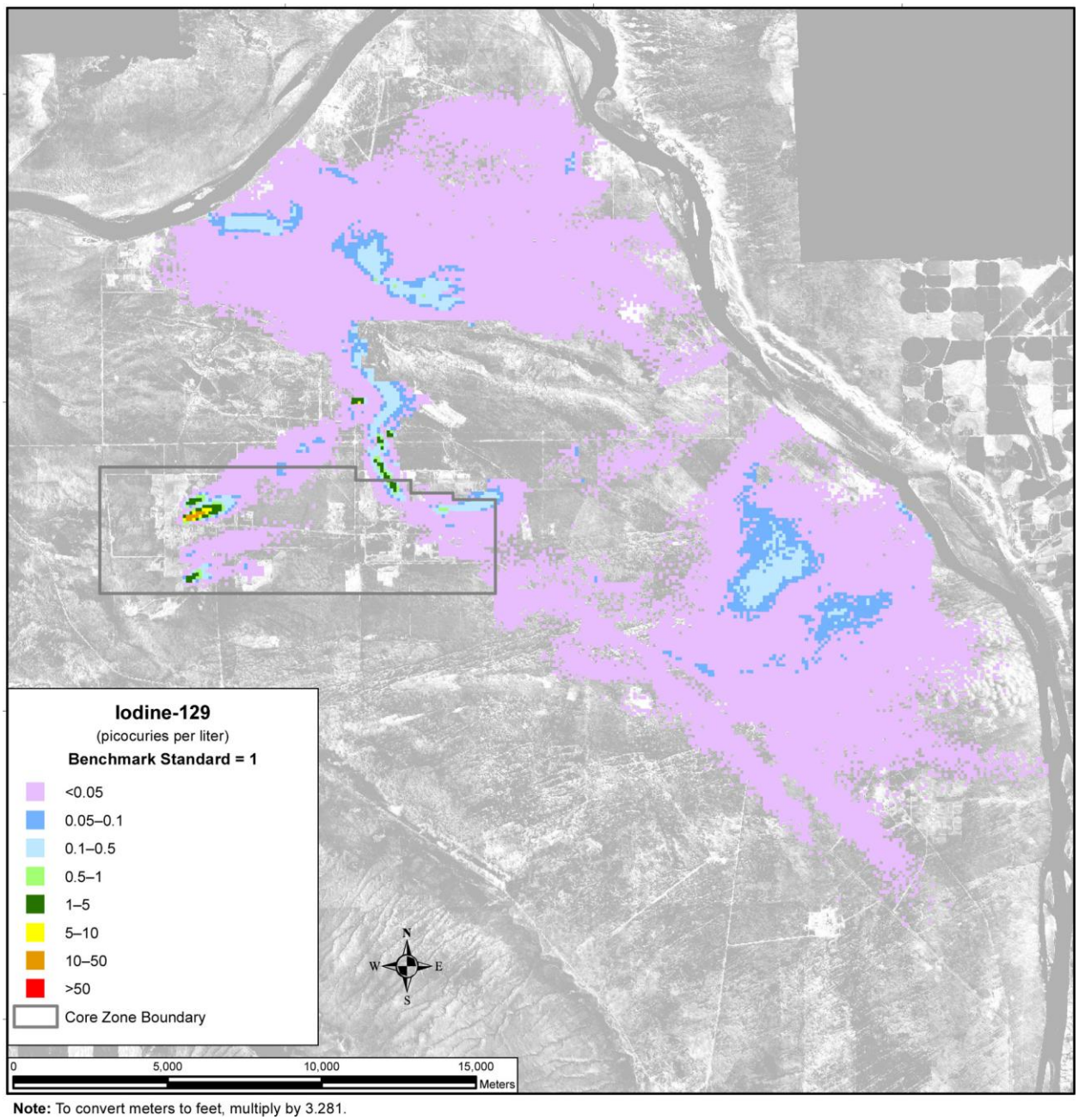


Note: To convert meters to feet, multiply by 3.281.

Figure 5–1185. Alternative Combination 1 Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration, Calendar Year 2135

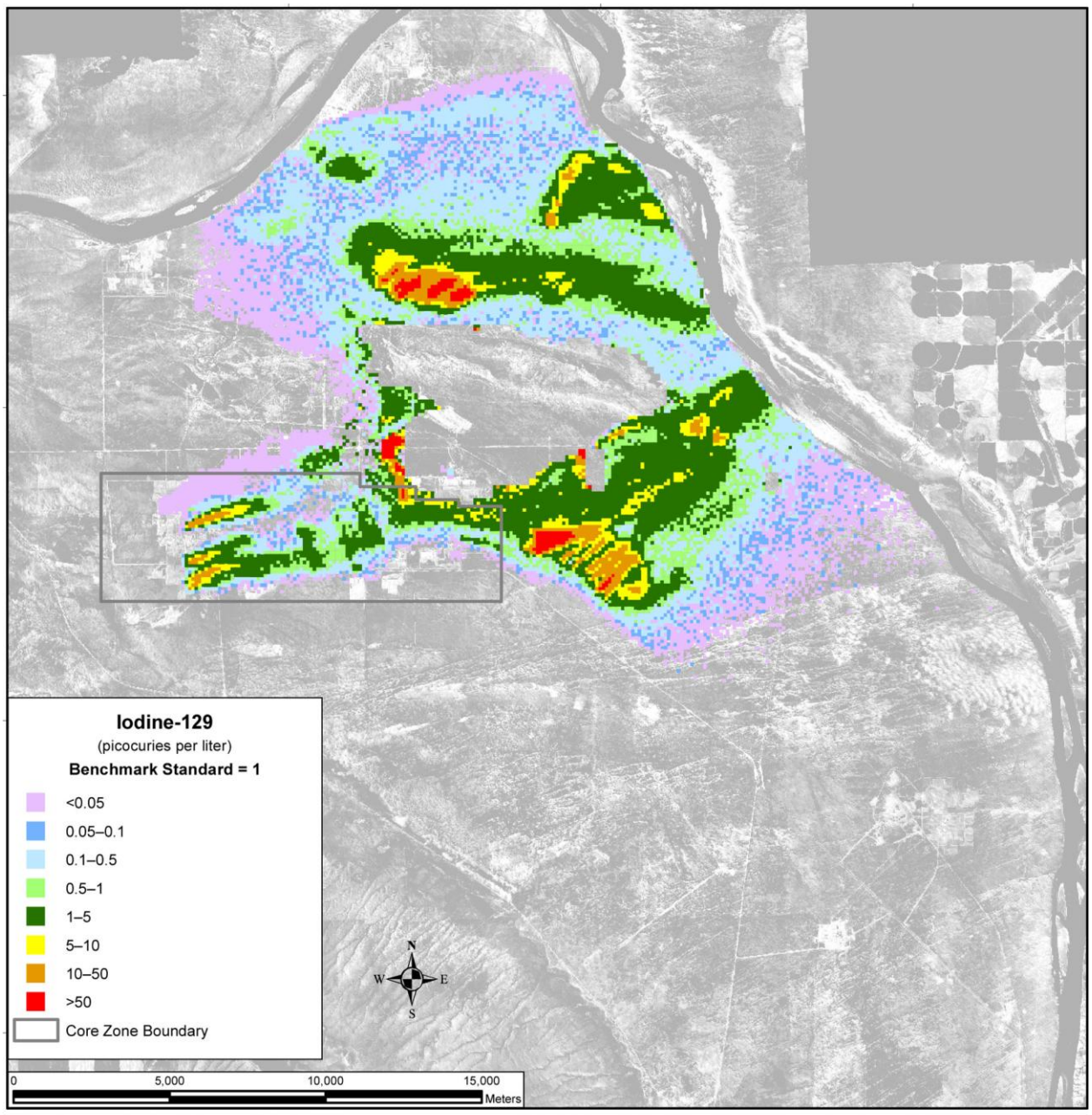
Figure 5–1186 shows the spatial distribution of iodine-129 concentrations in groundwater in CY 2010. Releases from cribs and trenches (ditches) and past leaks result in groundwater concentration plumes that exceed the benchmark concentration at the B, S, and T Barriers. Peak concentrations in these plumes are about 10 to 50 times greater than the benchmark and are mostly contained within the Core Zone Boundary. Around CY 3890, releases from other tank farm sources create a large plume with peak concentrations over 50 times greater than the benchmark concentration, extending from the A Barrier to the Columbia River nearshore (see Figure 5–1187). During this same time, the previously noted plumes originating from the B, S, and T Barriers and an additional plume extending from the U Barrier are evident and extend from the Core Zone Boundary north through Gable Gap. By CY 7140, most of the mass in these plumes reaches the Columbia River nearshore, with only isolated pockets of high-

concentration areas where the groundwater flow velocities are extremely small (see Figure 5–1188). Figure 5–1189 shows the total area for which iodine-129 concentrations in groundwater exceed the benchmark concentration as a function of time. The area of exceedance peaks between CY 3205 and CY 4605 as a result of releases from other tank farm sources. The other conservative tracers, technetium-99, chromium, and nitrate, show spatial distributions similar to iodine-129 at the selected times, CYs 2010, 3890, and 7140 (see Figures 5–1190 through 5–1192 and 5–1194 through 5–1199). Figure 5–1193 shows the total area for which technetium-99 concentrations in groundwater exceed the benchmark concentration as a function of time.



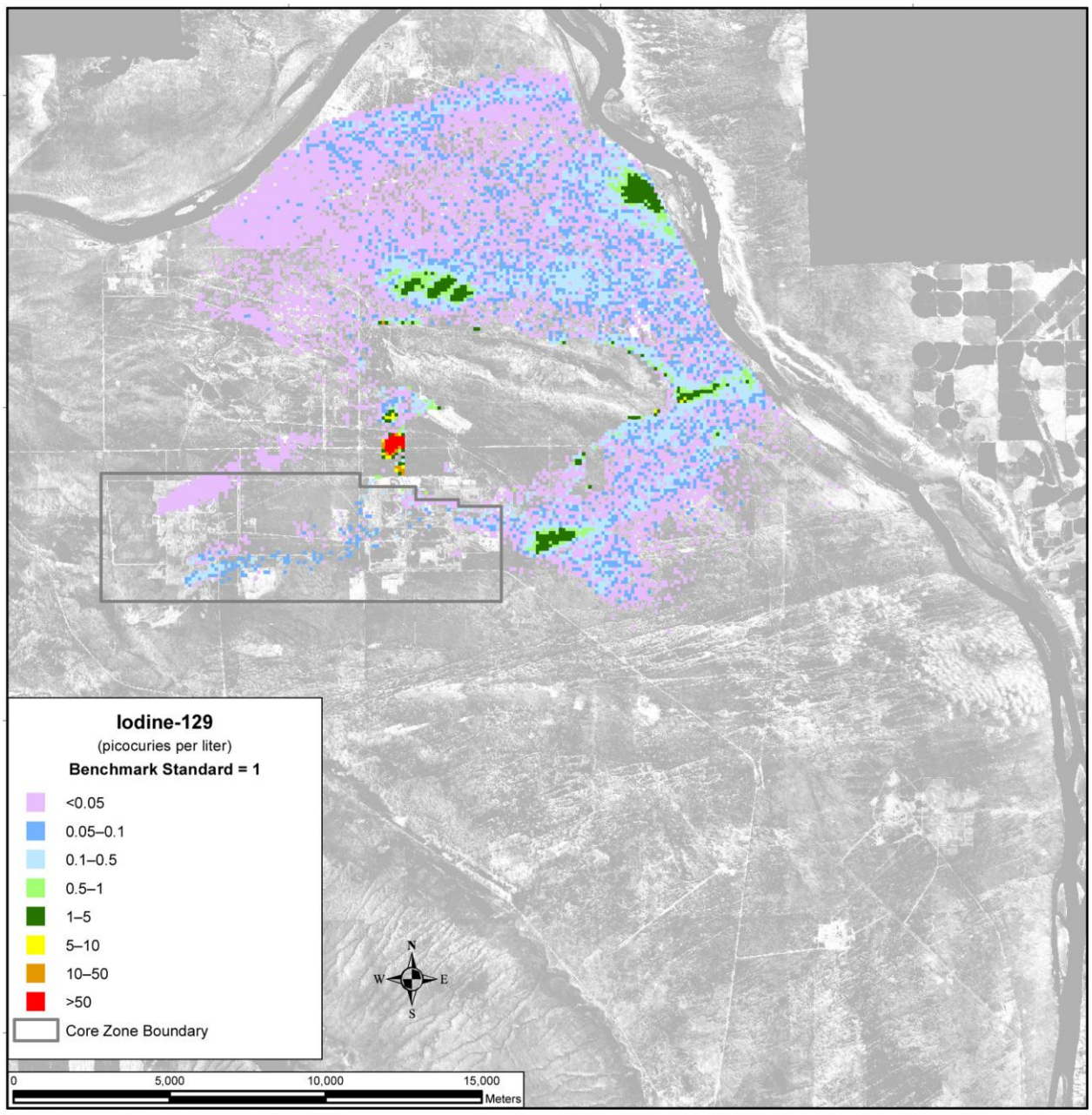
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1186. Alternative Combination 1 Spatial Distribution of Groundwater Iodine-129 Concentration, Calendar Year 2010



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

Figure 5–1187. Alternative Combination 1 Spatial Distribution of Groundwater Iodine-129 Concentration, Calendar Year 3890



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

Figure 5–1188. Alternative Combination 1 Spatial Distribution of Groundwater Iodine-129 Concentration, Calendar Year 7140

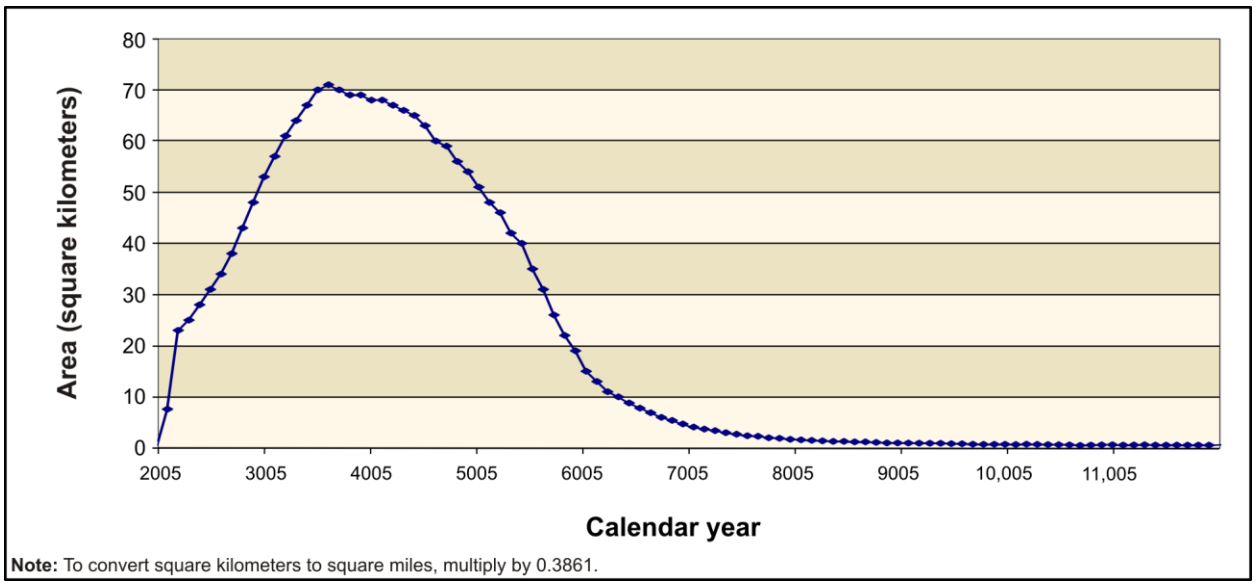
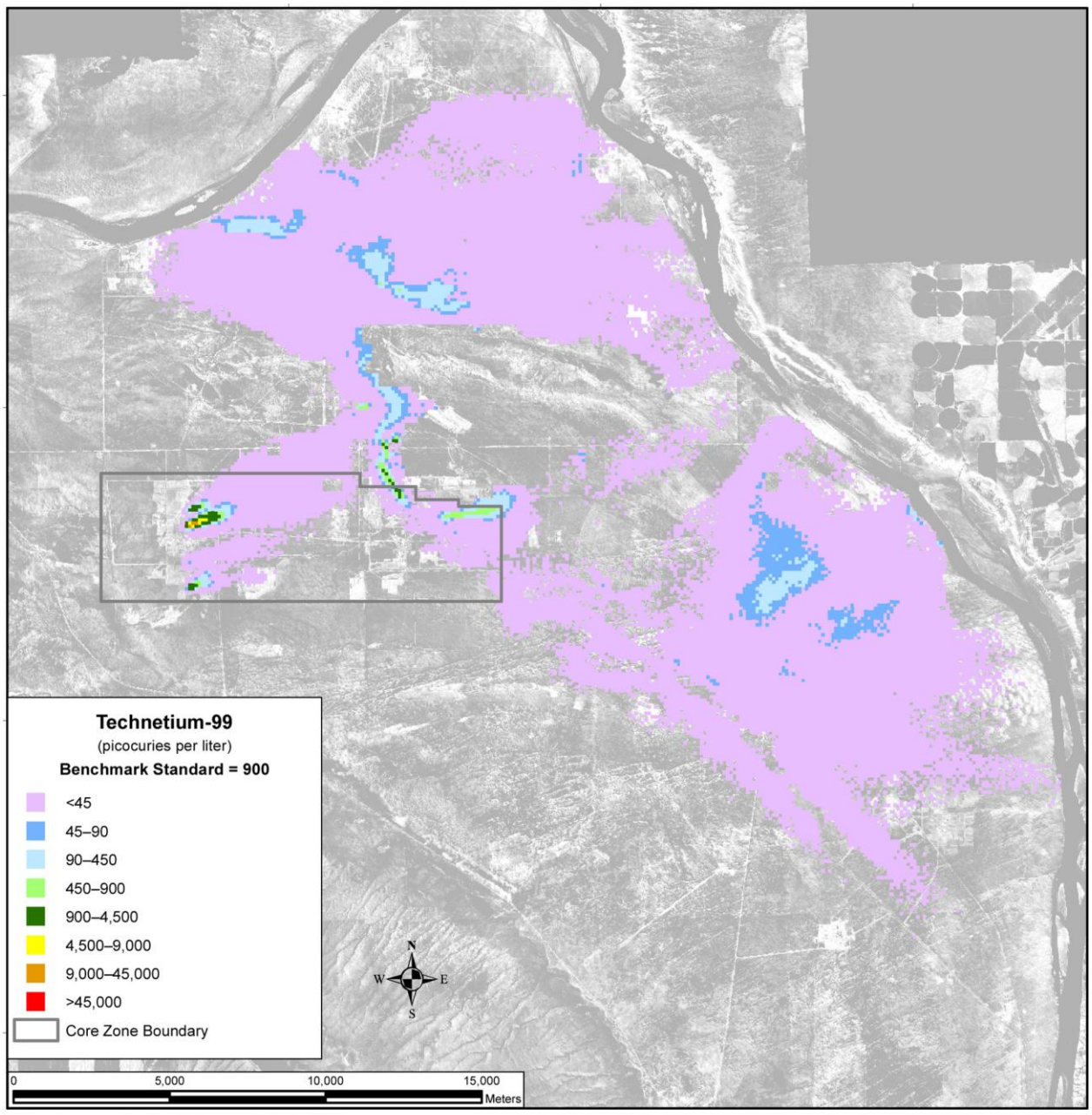
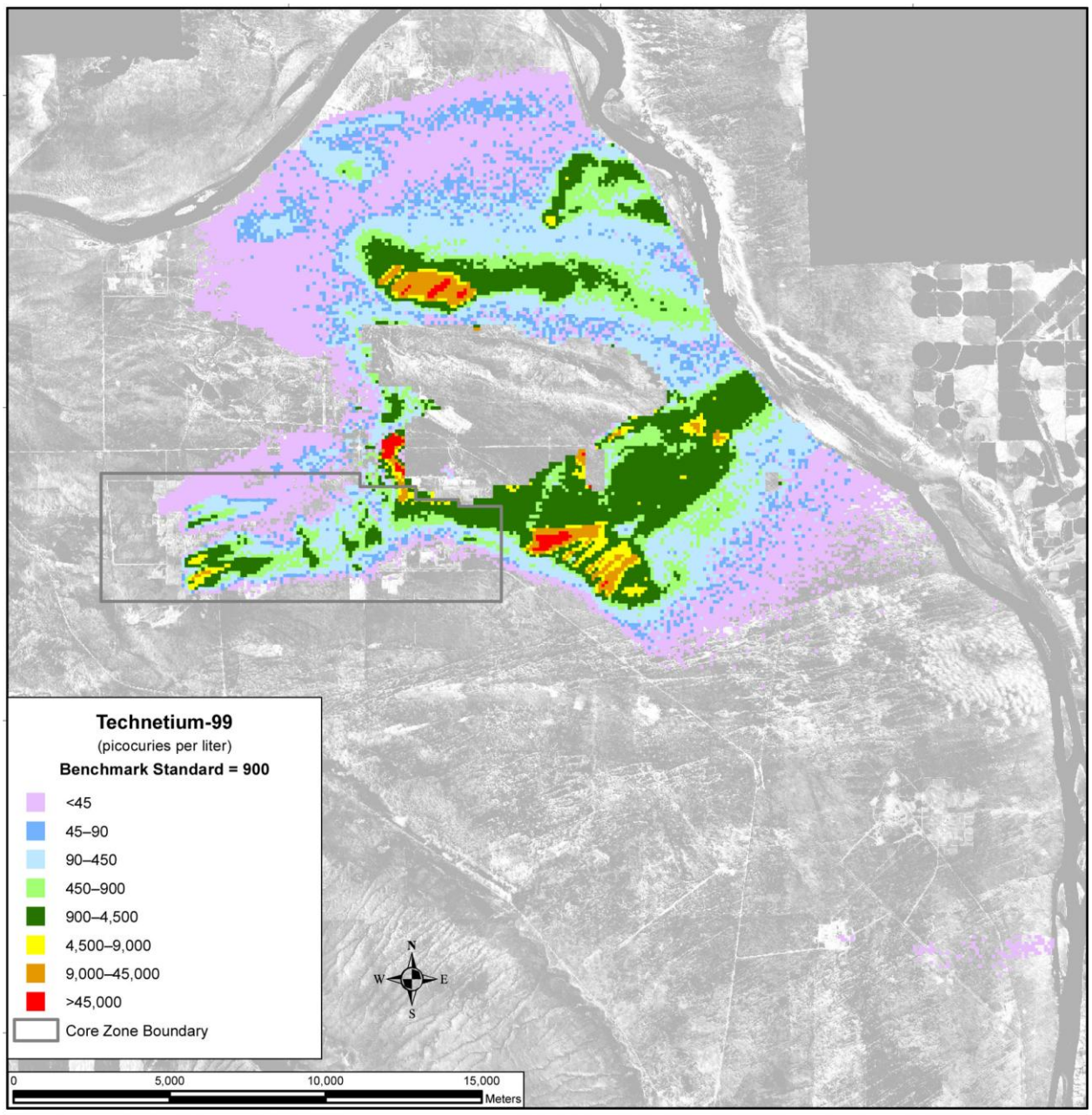


Figure 5–1189. Alternative Combination 1 Total Area of Groundwater Iodine-129 Concentration Exceeding the Benchmark Concentration as a Function of Time



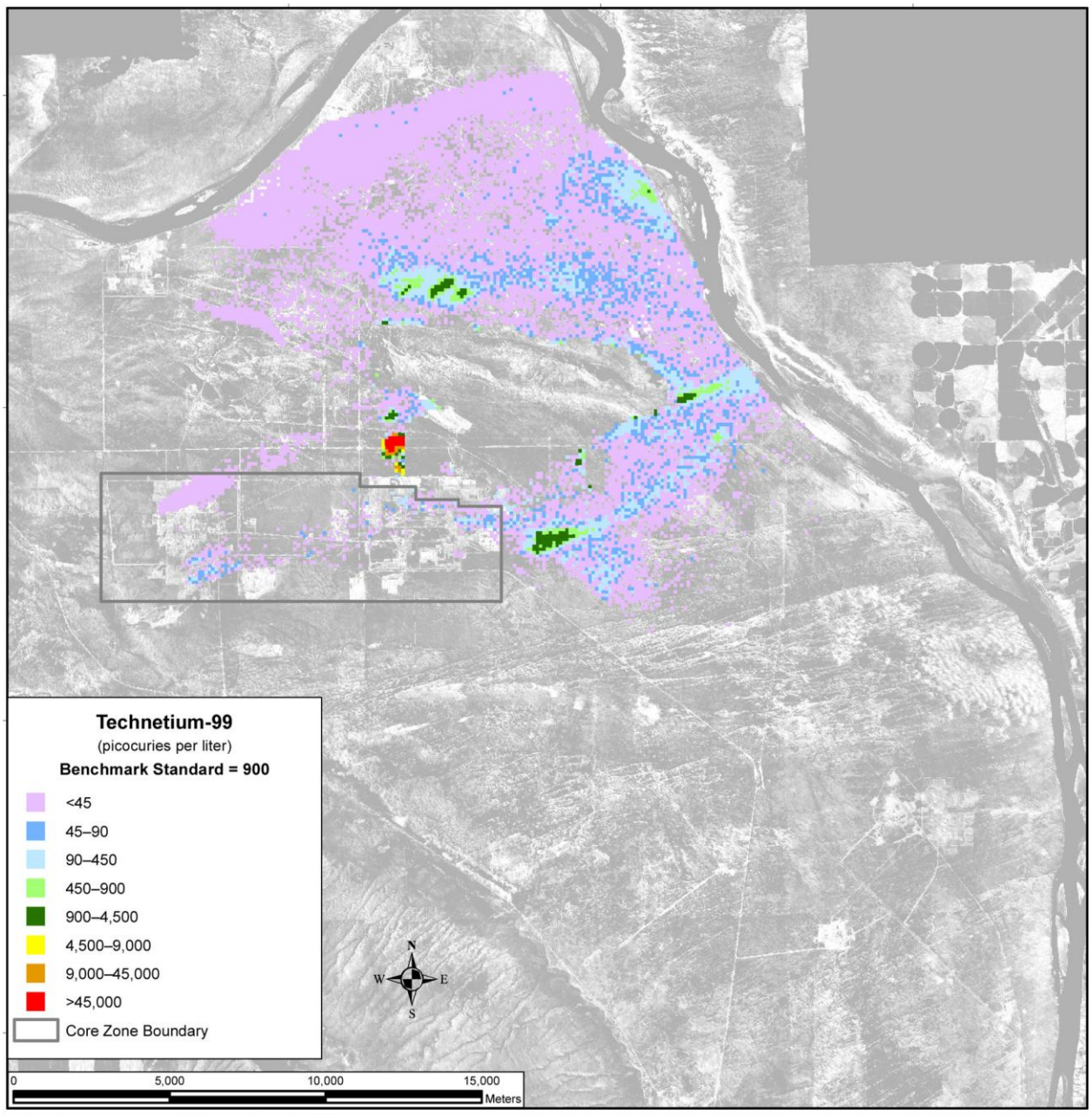
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1190. Alternative Combination 1 Spatial Distribution of Groundwater Technetium-99 Concentration, Calendar Year 2010



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

Figure 5–1191. Alternative Combination 1 Spatial Distribution of Groundwater Technetium-99 Concentration, Calendar Year 3890



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

Figure 5–1192. Alternative Combination 1 Spatial Distribution of Groundwater Technetium-99 Concentration, Calendar Year 7140

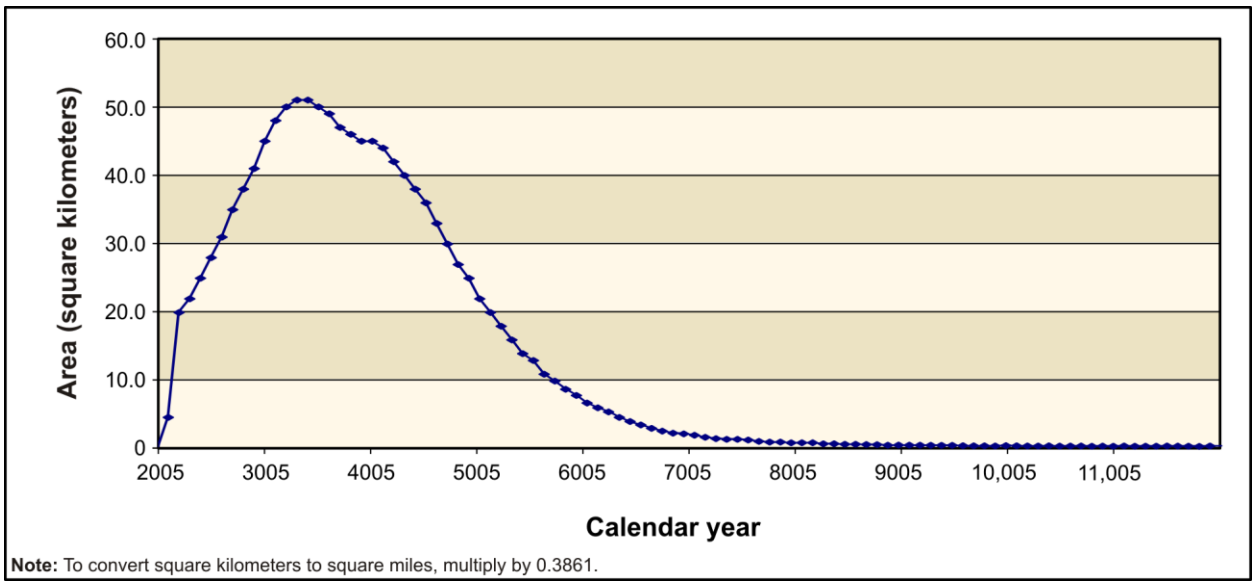
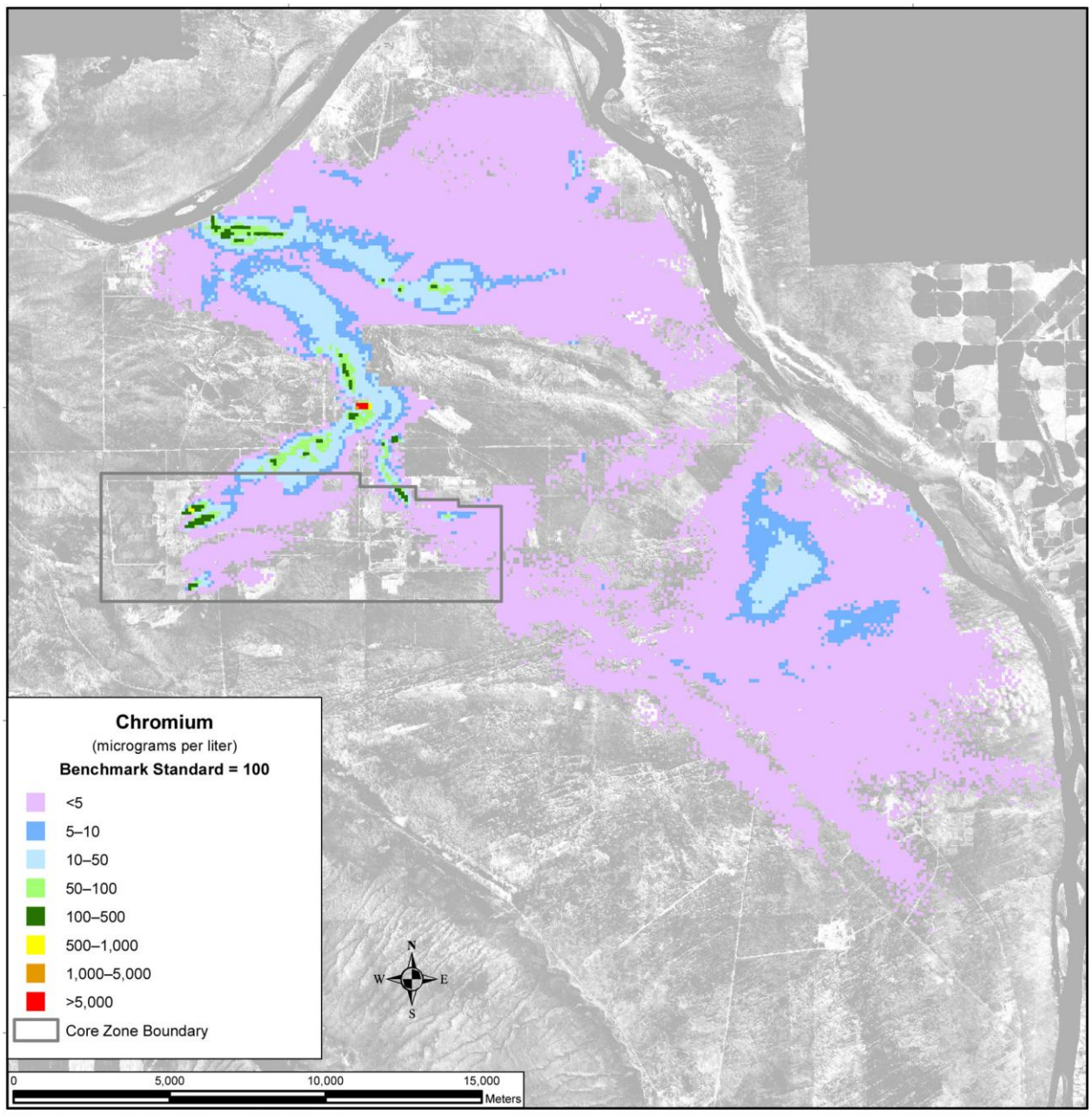
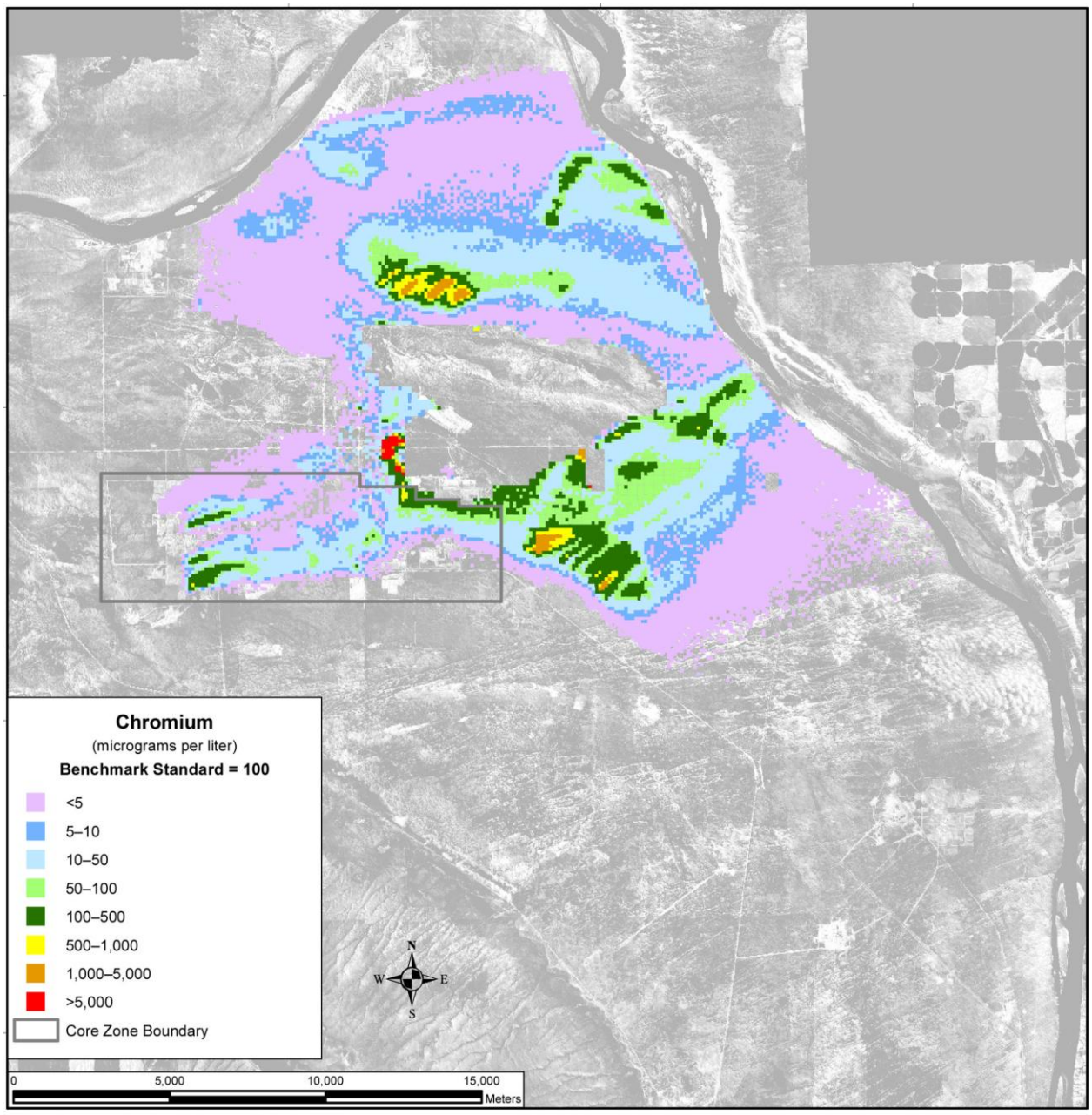


Figure 5–1193. Alternative Combination 1 Total Area of Groundwater Technetium-99 Concentration Exceeding the Benchmark Concentration as a Function of Time



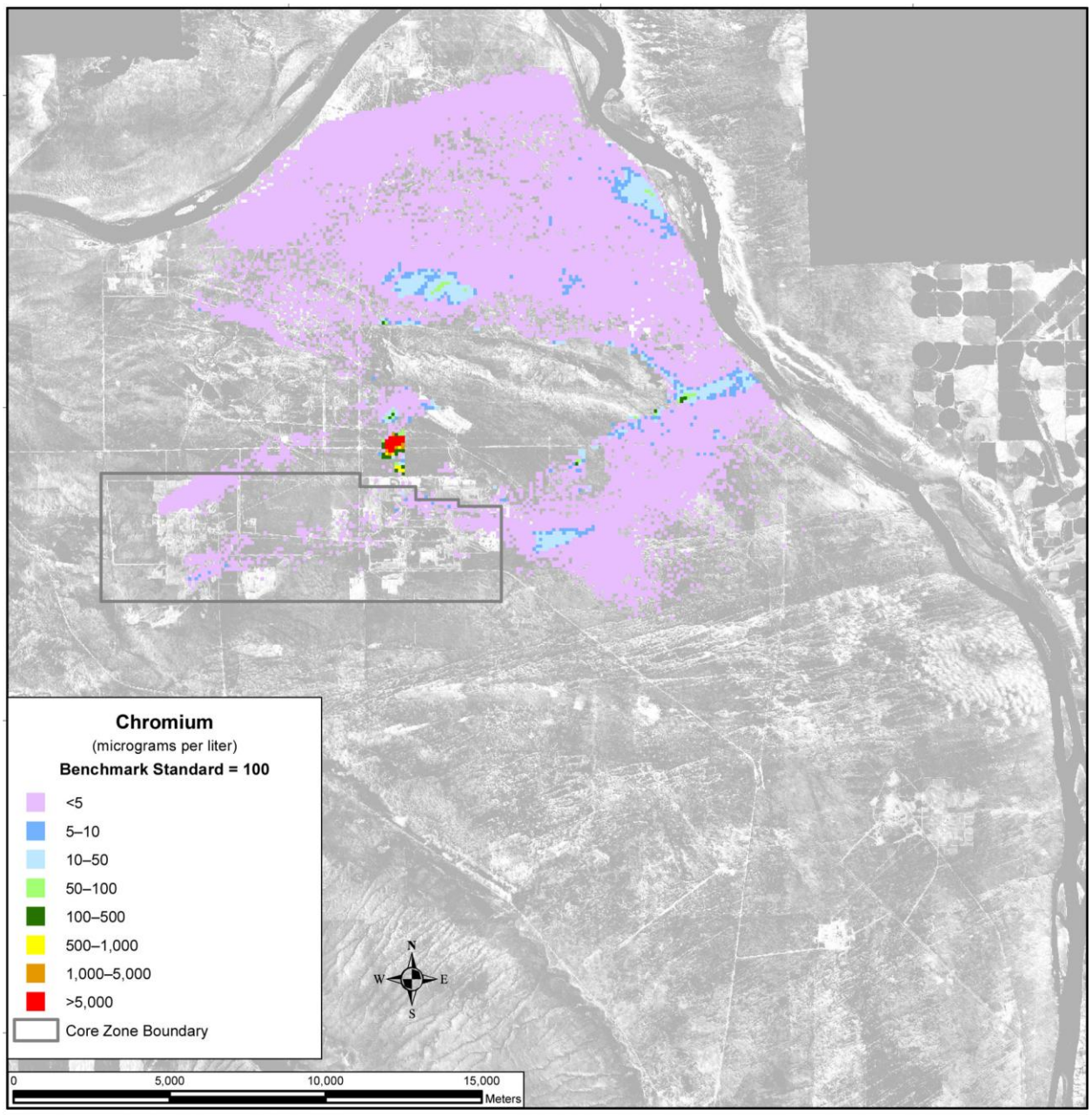
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1194. Alternative Combination 1 Spatial Distribution of Groundwater Chromium Concentration, Calendar Year 2010



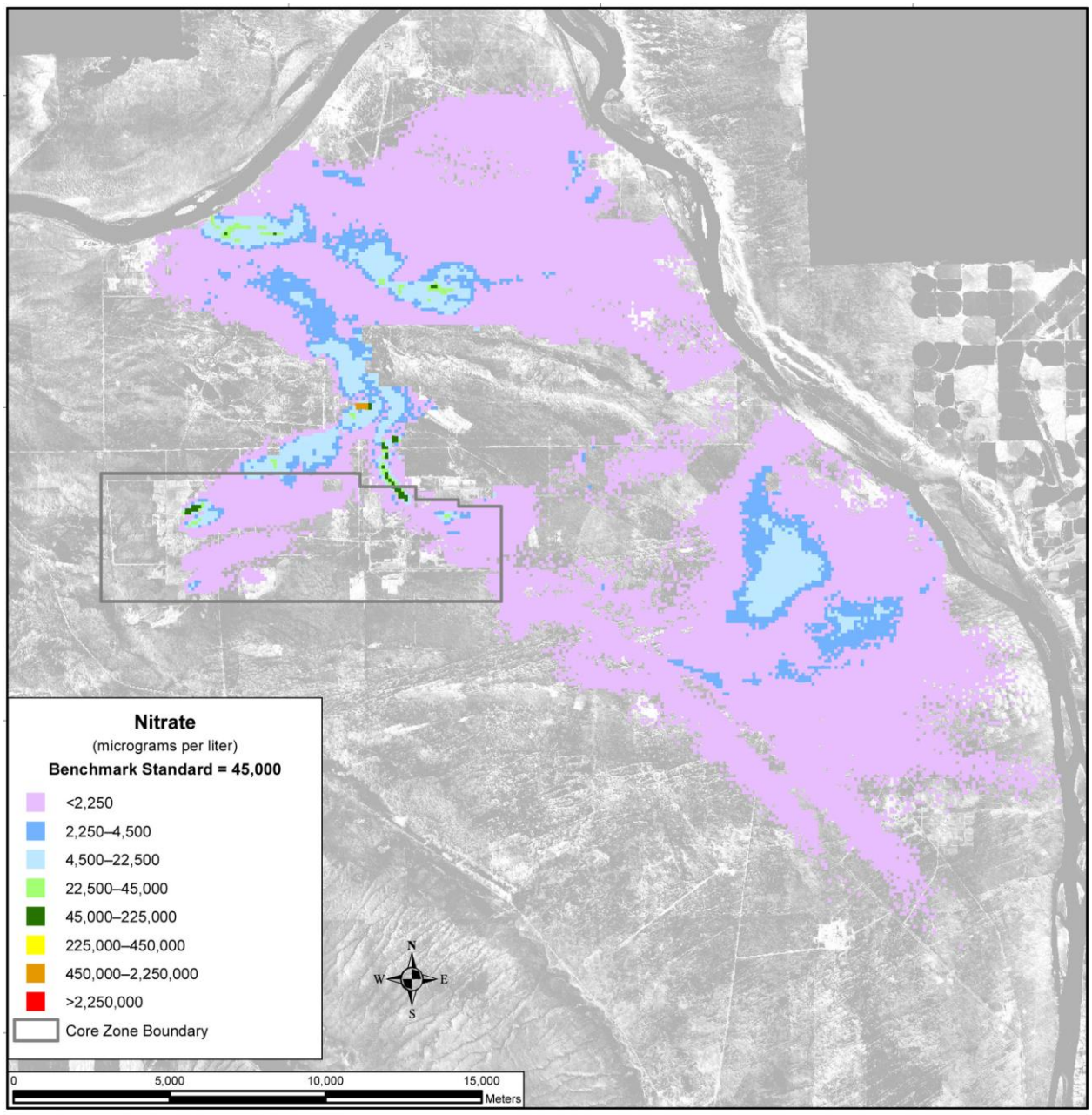
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1195. Alternative Combination 1 Spatial Distribution of Groundwater Chromium Concentration, Calendar Year 3890



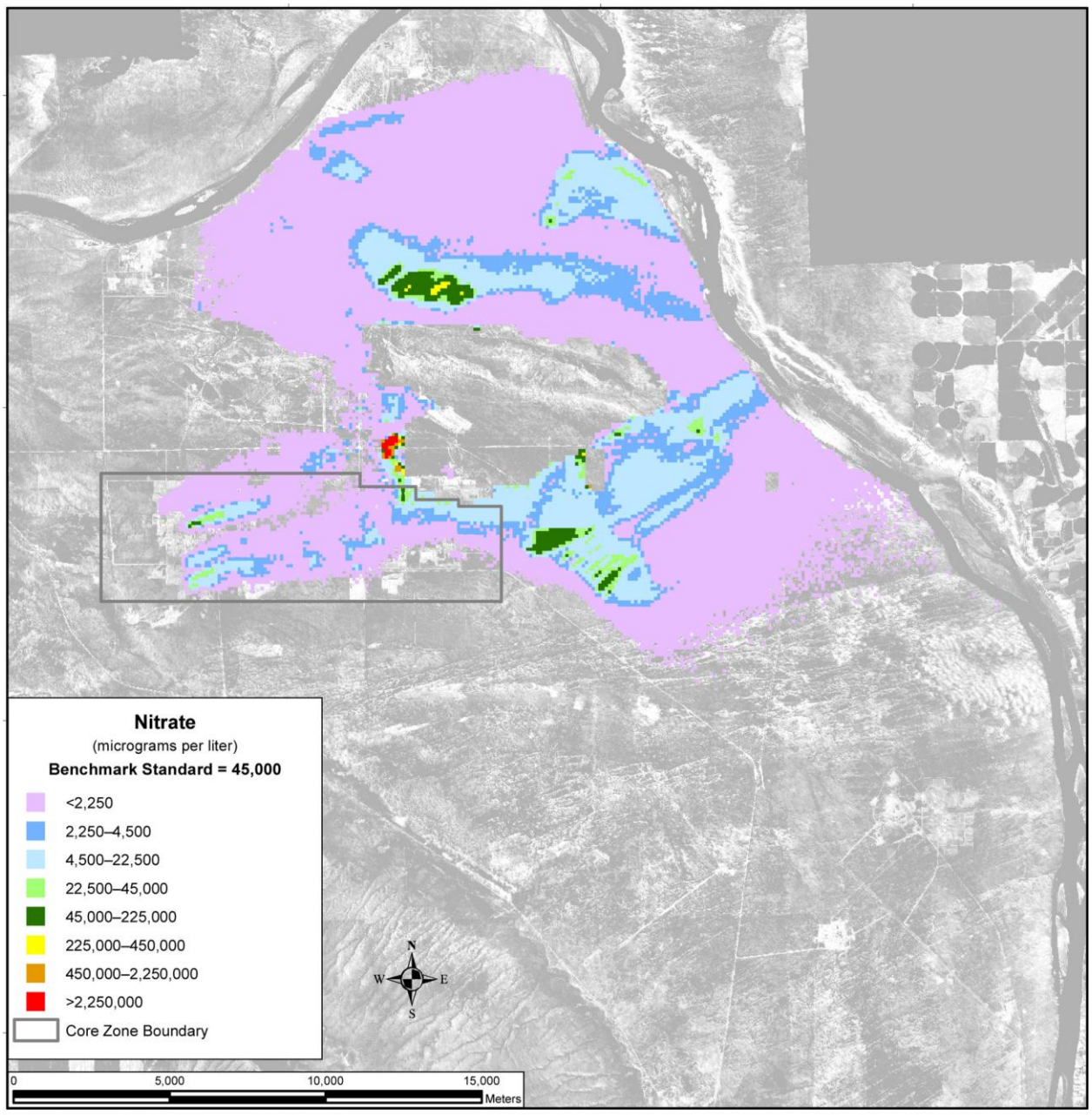
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1196. Alternative Combination 1 Spatial Distribution of Groundwater Chromium Concentration, Calendar Year 7140



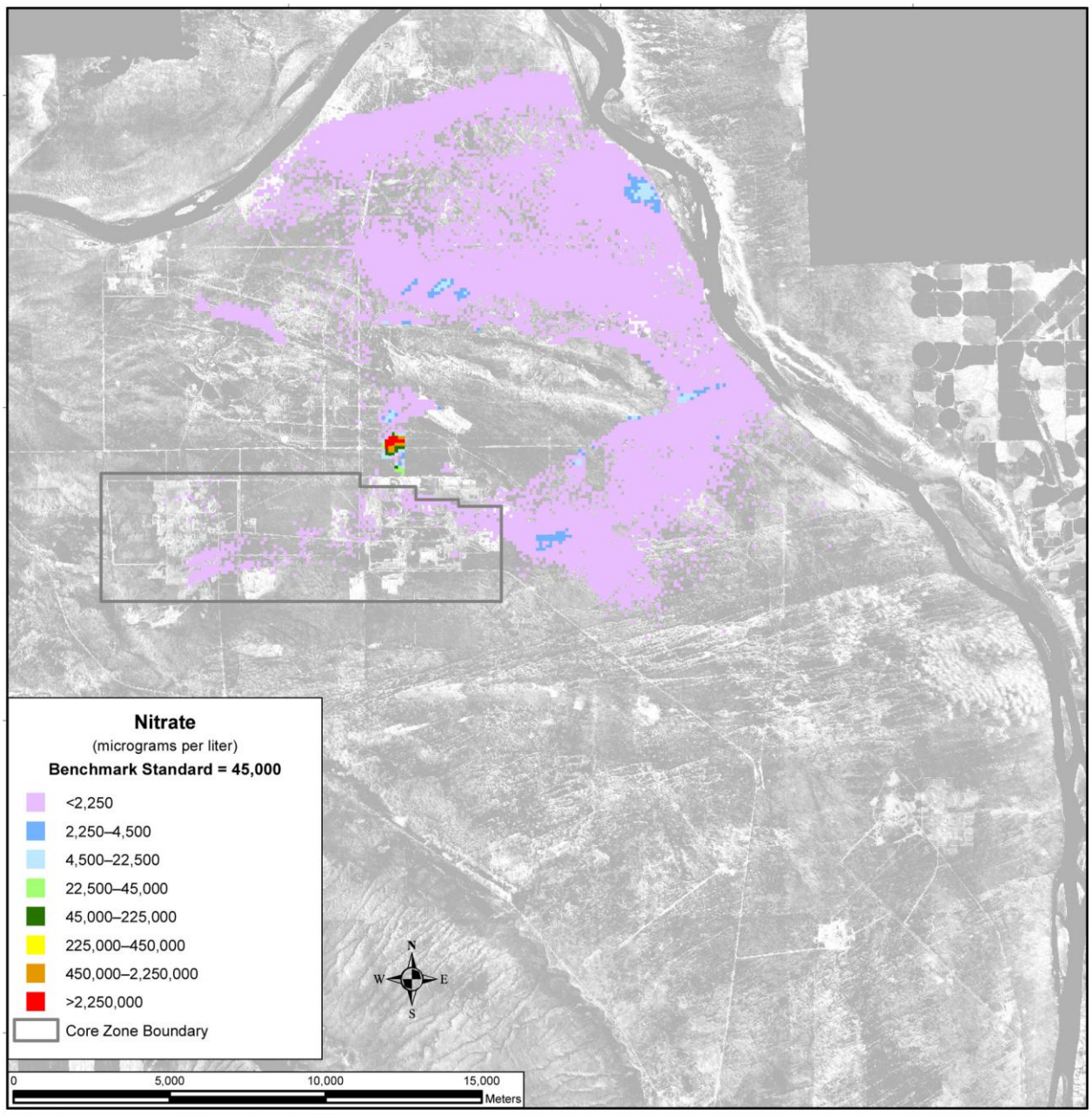
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1197. Alternative Combination 1 Spatial Distribution of Groundwater Nitrate Concentration, Calendar Year 2010



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

Figure 5–1198. Alternative Combination 1 Spatial Distribution of Groundwater Nitrate Concentration, Calendar Year 3890

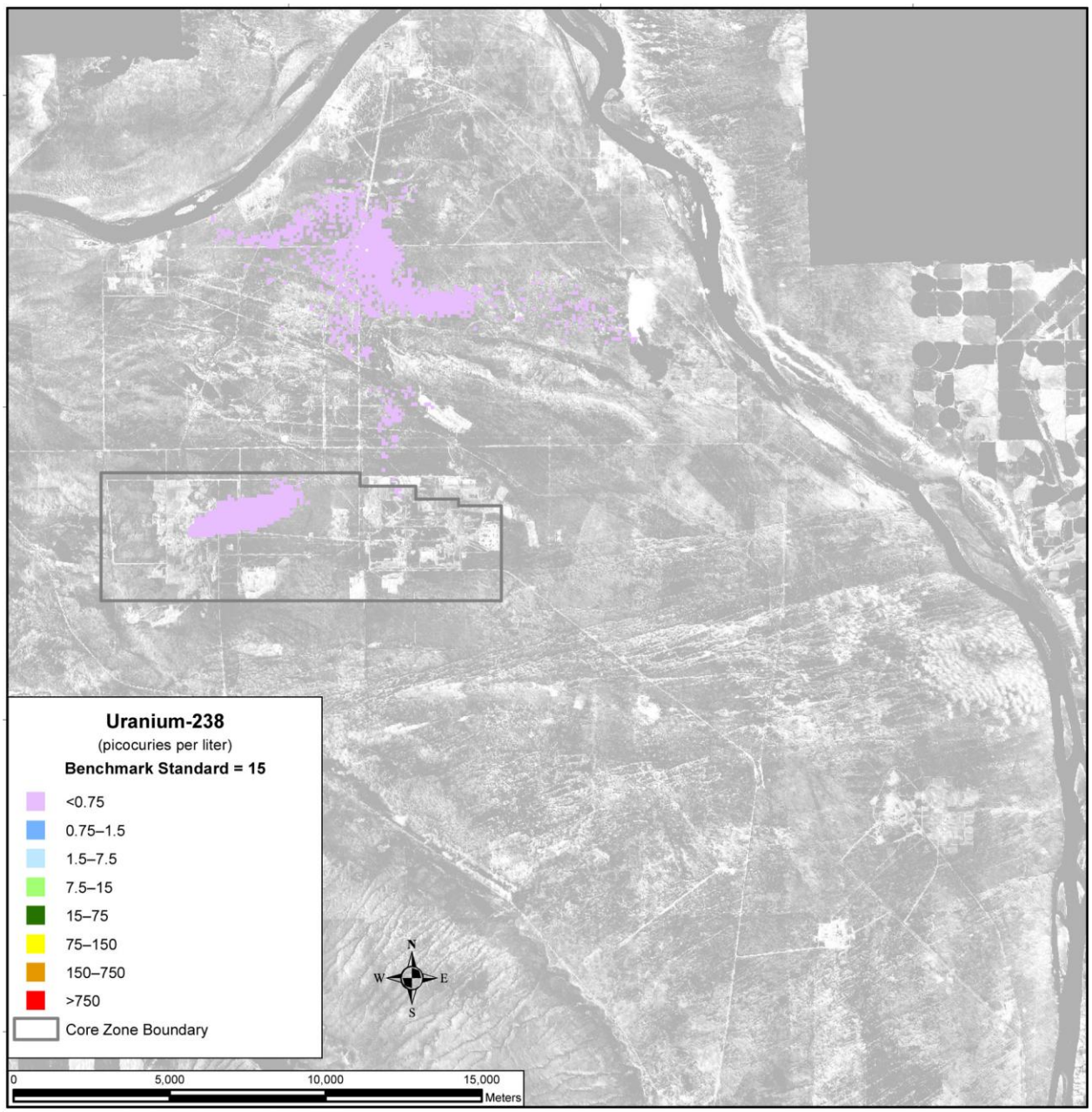


Note: To convert meters to feet, multiply by 3.281.

Figure 5–1199. Alternative Combination 1 Spatial Distribution of Groundwater Nitrate Concentration, Calendar Year 7140

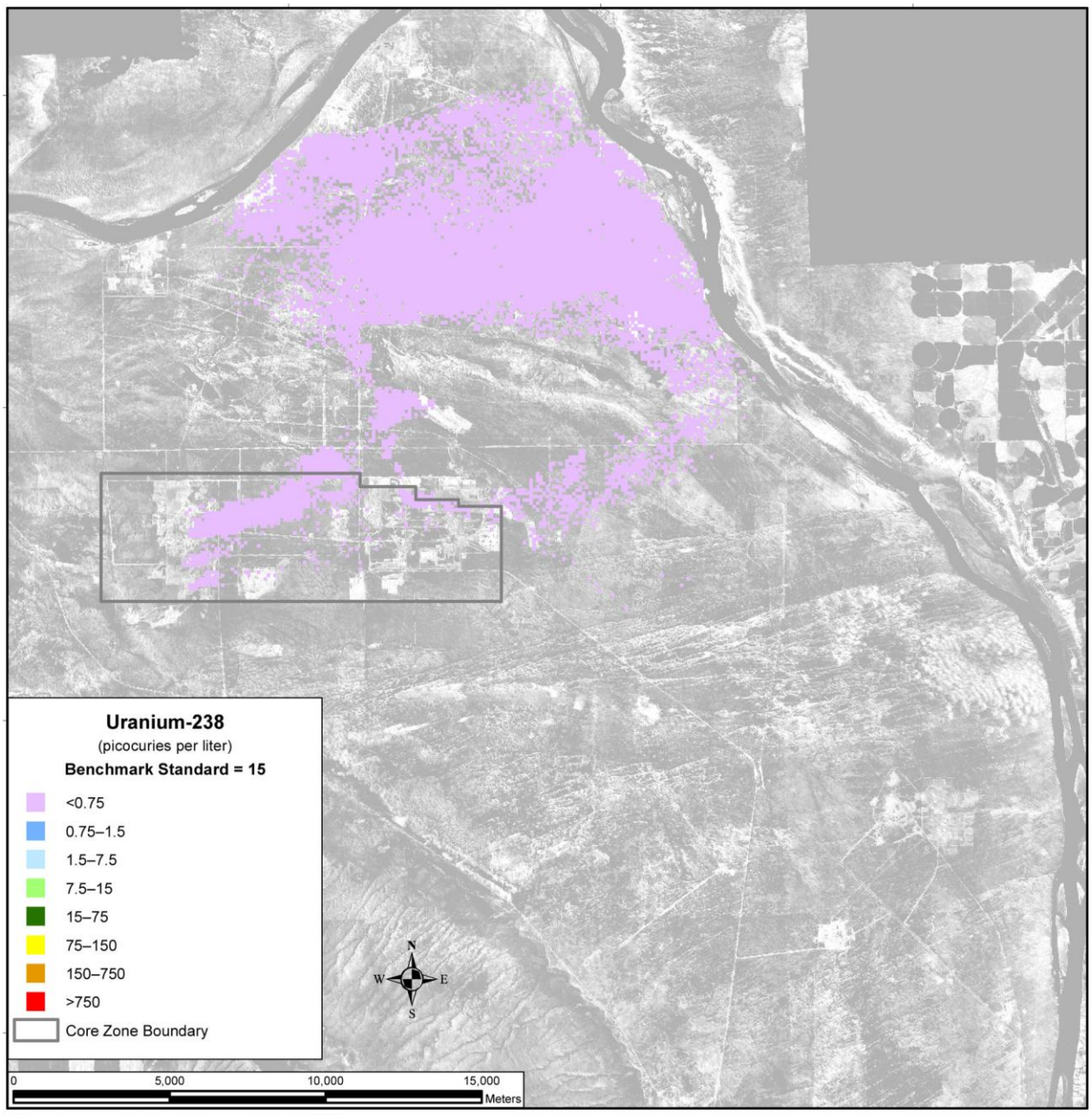
Uranium-238 and total uranium show a different spatial distribution in the analysis over time. These COPCs are not as mobile as those discussed above, moving about seven times more slowly than the pore-water velocity. As a result, travel times through the vadose zone are longer, release to the aquifer is delayed, and travel times through the aquifer to the Columbia River are longer. Figure 5–1200 shows the distribution of uranium-238 in CY 2135. There is a small plume associated with releases from cribs and trenches (ditches) and past leaks at the T Barrier that is less than one-twentieth of the benchmark concentration; this plume originates at the Core Zone Boundary and extends to the north side of Gable Mountain. By CY 3890 (see Figure 5–1201), the area of the plume has grown, but there are no significant increases in peak concentration. In CY 11,885 (see Figure 5–1202), the greatest development of the plume during the analysis period is seen, resulting primarily from releases of other tank farm sources at

the A and B Barriers. Figure 5–1203 shows the total area for which uranium-238 concentrations in groundwater exceed the benchmark concentration as a function of time. The area of exceedance is largest near the end of the period of analysis. Figures 5–1204 through 5–1206 show the corresponding spatial distribution for total uranium.



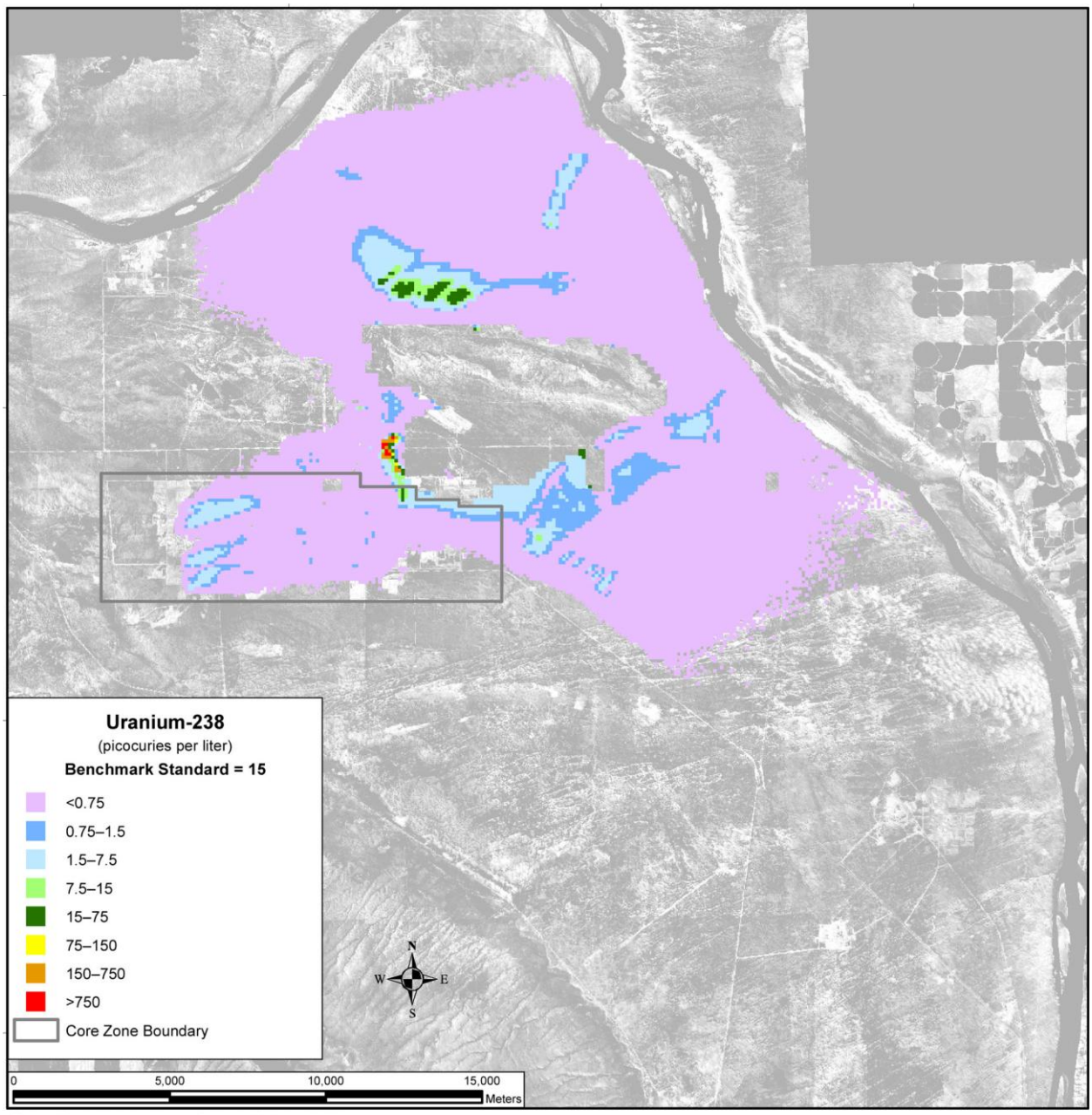
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1200. Alternative Combination 1 Spatial Distribution of Groundwater Uranium-238 Concentration, Calendar Year 2135



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

Figure 5–1201. Alternative Combination 1 Spatial Distribution of Groundwater Uranium-238 Concentration, Calendar Year 3890



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

Figure 5–1202. Alternative Combination 1 Spatial Distribution of Groundwater Uranium-238 Concentration, Calendar Year 11,885

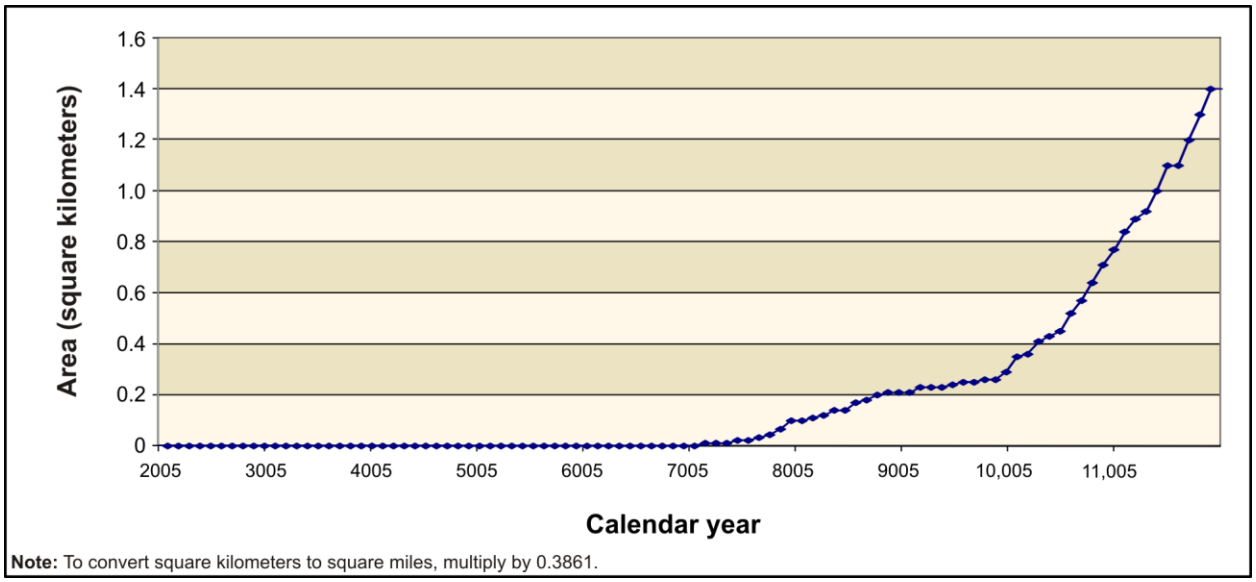
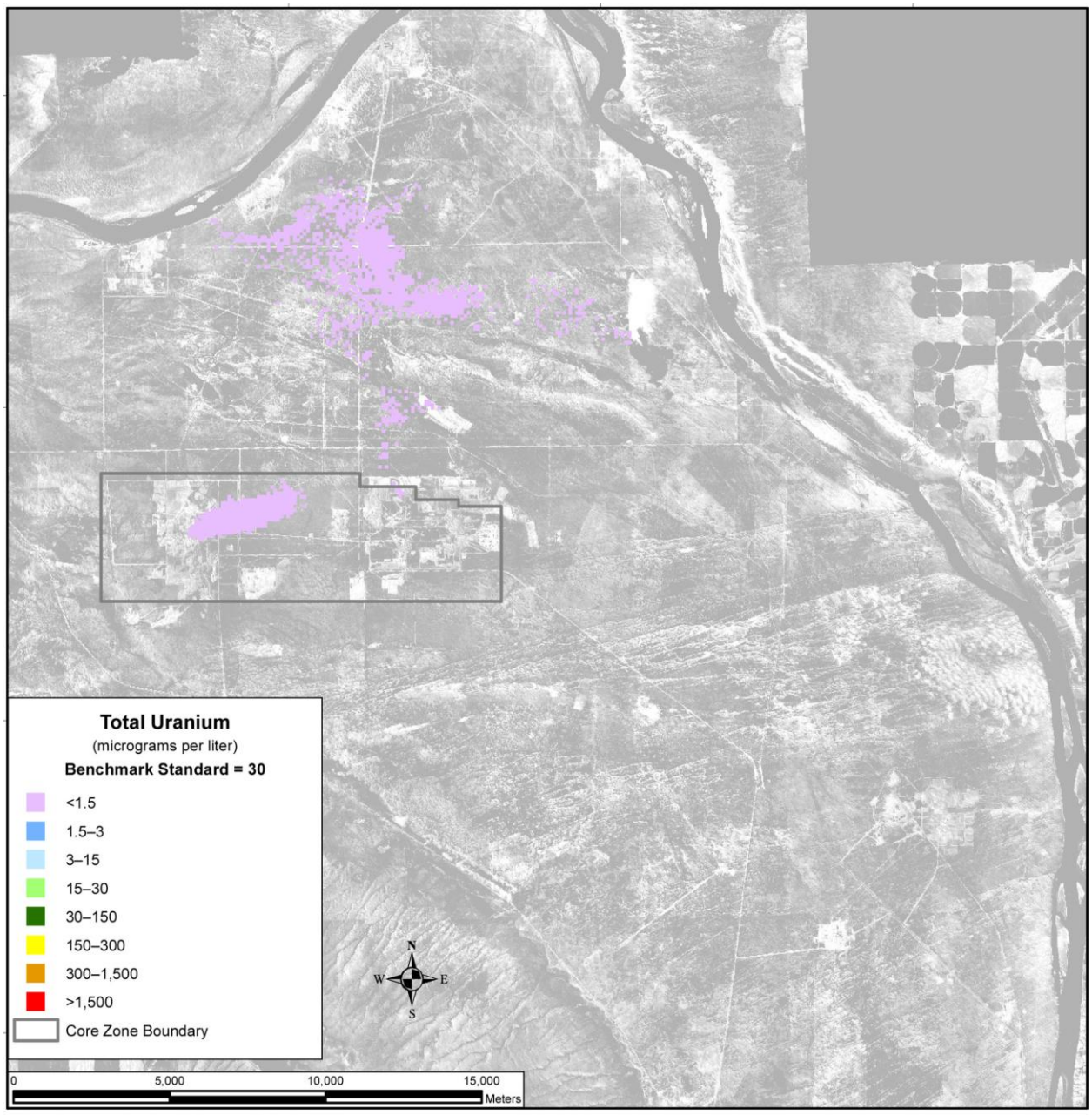
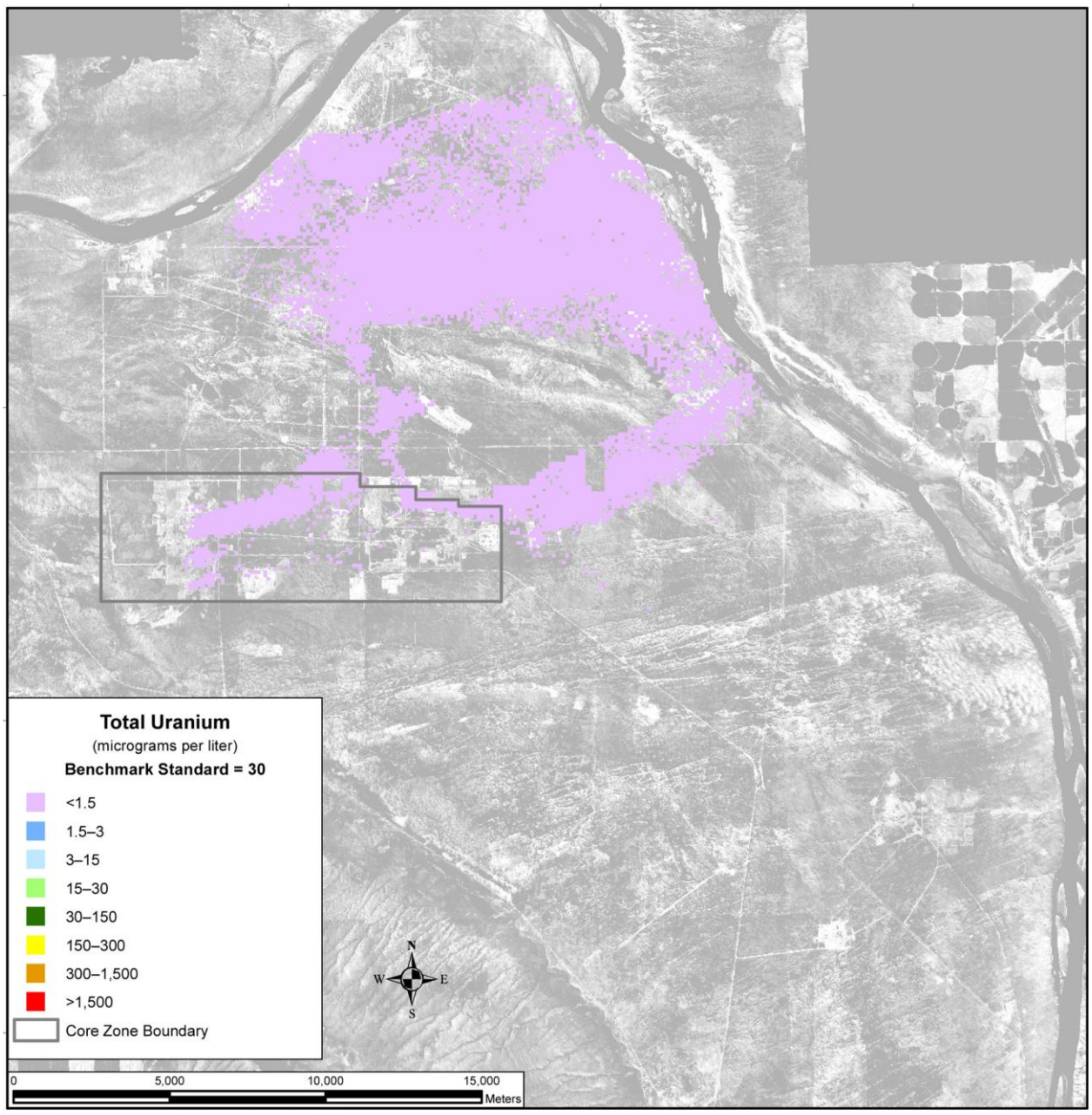


Figure 5–1203. Alternative Combination 1 Total Area of Groundwater Uranium-238 Concentration Exceeding the Benchmark Concentration as a Function of Time



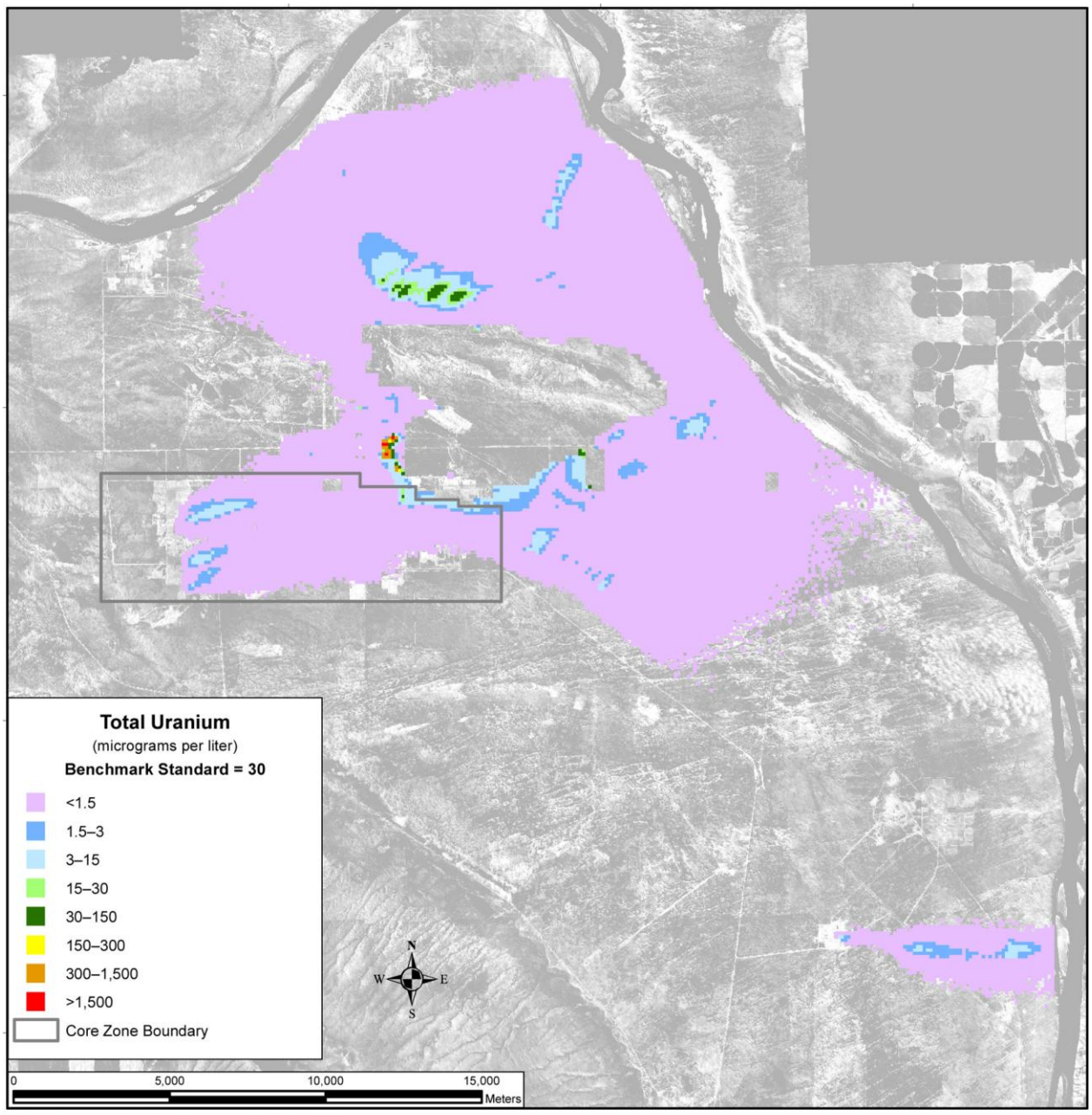
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1204. Alternative Combination 1 Spatial Distribution of Groundwater Total Uranium Concentration, Calendar Year 2135



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

Figure 5–1205. Alternative Combination 1 Spatial Distribution of Groundwater Total Uranium Concentration, Calendar Year 3890



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

Figure 5–1206. Alternative Combination 1 Spatial Distribution of Groundwater Total Uranium Concentration, Calendar Year 11,885

SUMMARY OF IMPACTS

The long-term impacts of Alternative Combination 1 are dominated by sources under Tank Closure Alternative 1. In general, the inventory remaining in the tank farms that becomes available for release to the environment at the beginning of the post–administrative control period is the predominant contributor. Discharges to cribs and trenches (ditches) and leaks during the past-practice period are secondary contributors. Contributions from Waste Management Alternative 1 and FFTF Decommissioning Alternative 1 sources account for well below 1 percent of the total amount released to the environment.

Concentrations of the conservative tracers at the Core Zone Boundary exceed benchmark concentrations by one to two orders of magnitude during most of the period of analysis. Concentrations at the Columbia

River nearshore are about two orders of magnitude lower, but for technetium-99, iodine-129, chromium, and nitrate, exceed the benchmark concentrations. The intensities and areas of these groundwater plumes peak between CY 3200 and CY 4000.

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

For uranium-238 and total uranium, limited mobility is an important factor governing the timeframe and scale of groundwater impacts. The concentrations of these retarded species exceed the benchmark concentration at the Core Zone Boundary after CY 11,000 and rise to within one to two orders of magnitude of the benchmark concentration at the Columbia River nearshore by the end of the period of analysis (CY 11,940). The intensity is highest and the area of the contamination plume largest near the end of the period of analysis.

5.4.1.2 Alternative Combination 2

This section describes the results of the long-term groundwater impacts analysis for Alternative Combination 2, which comprises Tank Closure Alternative 2B, FFTF Decommissioning Alternative 2, and Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A. The focus is the combined long-term groundwater impacts of these alternatives. More detailed discussion of the individual impacts is provided in Sections 5.1.1, 5.2.1, and 5.3.1.

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

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

The COPC drivers were obtained from the combination of the COPC drivers for the three individual alternatives that compose the alternative combination. They fall into three categories. Iodine-129, technetium-99, chromium, and nitrate are all mobile (i.e., move with groundwater) and long-lived (relative to the 10,000-year period of analysis), or stable. They are essentially conservative tracers. Tritium is also mobile, but short-lived. The half-life of tritium is 13 years, and tritium concentrations are strongly attenuated by radioactive decay during travel through the vadose zone and groundwater systems. Finally, uranium-238 and total uranium are long-lived, or stable, but are not as mobile as the other COPC drivers. These constituents move about seven times more slowly than groundwater. The other COPCs that were analyzed do not significantly contribute to risk or hazard during the period of analysis because of limited inventory, limited rates of release (i.e., retention in waste form), high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of these factors.

ANALYSIS OF RELEASE AND MASS BALANCE

This section presents the impacts of Alternative Combination 2 in terms of the total amount of COPCs released to the vadose zone, groundwater, and the Columbia River during the 10,000-year period of analysis. Releases of radionuclides are totaled in curies; chemicals, in kilograms.

Table 5–178 lists the release of the COPC drivers to the vadose zone. Under Alternative Combination 2, the release to the vadose zone is controlled by a combination of inventory and waste form. For tank closure and FFTF decommissioning sources, the entire inventory is released to the vadose zone during the period of analysis. For some waste management sources (e.g., ILAW glass), some of the inventory is not

released to the vadose zone during the 10,000-year period of analysis because of retention in the waste form. The release to the vadose zone under Alternative Combination 2 is dominated by sources associated with Tank Closure Alternative 2B for chromium, nitrate, and total uranium. For these COPC drivers, releases from FFTF decommissioning and waste management sources account for 0 percent of the total. For tritium, both tank closure sources and waste management sources contribute significantly to release to the vadose zone. For iodine-129, technetium-99, and uranium-238, releases to the vadose zone are dominated by waste management sources. Refer to Appendix M, "Release to Vadose Zone," for detailed information regarding the specific sources and corresponding mass released.

Table 5–178. Alternative Combination 2 Releases of COPC Drivers to Vadose Zone

Alternative	Radioactive COPCs (curies)				Chemical COPCs (kilograms)		
	Hydrogen-3 (Tritium)	Iodine-129	Technetium-99	Uranium-238	Chromium	Nitrate	Total Uranium
Tank Closure Alternative 2B, Case 1	4.58×10^{4}	1.42	8.19×10^{2}	4.05×10^{1}	9.98×10^{4}	2.70×10^{7}	3.39×10^{4}
FFTF Decommissioning Alternative 2	4.66×10^{-7}	0	2.72×10^{1}	0	0	0	0
Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A	5.94×10^{4}	4.92	2.08×10^{3}	3.49×10^{2}	2.96×10^{3}	9.05×10^{6}	2.94×10^{3}
Total	**1.05×10^{5}**	**6.34**	**2.92×10^{3}**	**3.89×10^{2}**	**1.03×10^{5}**	**3.61×10^{7}**	**3.69×10^{4}**

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

Table 5–179 lists the release of the COPC drivers to groundwater. In addition to the inventory and waste form considerations discussed in the previous paragraph and Appendix M, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. Note that delayed release to the vadose zone (i.e., retention in the waste form) can enhance retention in the vadose zone because contaminant mass released into the vadose zone near the end of the 10,000-year period of analysis may not reach the water table. For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), the amount released to groundwater ranges from 75 to 100 percent of 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 30 percent of the tritium released to the vadose zone reaches the unconfined aquifer. For uranium-238 and total uranium, the amount released to groundwater is lower than that released to the vadose zone because of retardation. Less than 4 percent of the uranium-238 and 1 percent of the total uranium released to the vadose zone reaches the unconfined aquifer during the period of analysis.

Table 5–179. Alternative Combination 2 Releases of COPC Drivers to Groundwater

Alternative	Radioactive COPCs (curies)				Chemical COPCs (kilograms)		
	Hydrogen-3 (Tritium)	Iodine-129	Technetium-99	Uranium-238	Chromium	Nitrate	Total Uranium
Tank Closure Alternative 2B, Case 1	3.12×10^{4}	1.42	8.20×10^{2}	1.66	1.03×10^{5}	2.78×10^{7}	1.46×10^{3}
FFTF Decommissioning Alternative 2	0	0	2.71×10^{1}	0	0	0	0
Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A	0	3.41	1.80×10^{3}	1.51×10^{-8}	2.87×10^{3}	9.02×10^{6}	1.38×10^{-4}
Total	**3.12×10^{4}**	**4.84**	**2.65×10^{3}**	**1.66**	**1.06×10^{5}**	**3.68×10^{7}**	**1.46×10^{3}**

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

Table 5–180 lists the release of the COPC drivers to the Columbia River. Release to the Columbia River is controlled by the transport properties of the COPC drivers. For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), the amount released to the Columbia River is essentially equal to the amount released to groundwater. For tritium, the amount released to the Columbia River is attenuated by radioactive decay. Overall, less than 1 percent of the tritium released to groundwater reaches the Columbia River. For uranium-238 and total uranium, the amount released to the Columbia River is less than that released to groundwater because of retardation in the aquifer. Overall, about 30 percent of the amount released to groundwater during the period of analysis reaches the Columbia River.

Table 5–180. Alternative Combination 2 Releases of COPC Drivers to the Columbia River

Alternative	Radioactive COPCs (curies)				Chemical COPCs (kilograms)		
	Hydrogen-3 (Tritium)	**Iodine-129**	**Technetium-99**	**Uranium-238**	**Chromium**	**Nitrate**	**Total Uranium**
Tank Closure Alternative 2B, Case 1	3.90×10^{2}	1.41	8.16×10^{2}	4.94×10^{-1}	1.06×10^{5}	2.86×10^{7}	3.82×10^{2}
FFTF Decommissioning Alternative 2	0	0	2.70×10^{1}	0	0	0	0
Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A	0	3.37	1.78×10^{3}	0	2.86×10^{3}	9.02×10^{6}	6.01×10^{-6}
Total	**3.90×10^{2}**	**4.78**	**2.63×10^{3}**	**4.94×10^{-1}**	**1.09×10^{5}**	**3.76×10^{7}**	**3.82×10^{2}**

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

ANALYSIS OF CONCENTRATION VERSUS TIME

This section presents the impacts of Alternative Combination 2 in terms of groundwater concentration versus time at the Core Zone Boundary and the Columbia River nearshore. Concentrations of radionuclides are in picocuries per liter; chemicals, in micrograms per liter (see Figures 5–1207 through 5–1213). The benchmark concentration of each radionuclide and chemical is also shown. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over five orders of magnitude. Table 5–181 lists the maximum concentrations of the COPCs in the peak year at the Core Zone Boundary and the Columbia River nearshore. The results indicate that iodine-129, chromium, and nitrate exceed their respective benchmark concentrations at both the Core Zone Boundary and the Columbia River nearshore. Tritium and technetium-99 exceed their respective benchmark concentrations at the Core Zone Boundary. The remaining COPCs in the table do not exceed the benchmark concentrations at either boundary during the period of analysis.

Table 5–181. Alternative Combination 2 Maximum COPC Concentrations in the Peak Year at the Core Zone Boundary and Columbia River Nearshore

Contaminant	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclide (picocuries per liter)			
Hydrogen-3 (tritium)	**672,000** (1956)	10,700 (1964)	20,000
Technetium-99	**33,700** (1956)	844 (1965)	900
Iodine-129	**42.3** (1956)	**1.1** (1964)	1
Uranium isotopes (includes uranium-233, -234, -235, -238)	3 (11,913)	0 (11,937)	15

Table 5–181. Alternative Combination 2 Maximum COPC Concentrations in the Peak Year at the Core Zone Boundary and Columbia River Nearshore *(continued)*

Contaminant	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Chemical (micrograms per liter)			
Chromium	**6,150** (1955)	**228** (2019)	100
Nitrate	**2,120,000** (1956)	**72,300** (1964)	45,000
Total uranium	4 (11,827)	0 (11,937)	30

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

Figure 5–1207 shows concentration versus time for tritium. Note that for visual clarity, the time period shown in this figure is from CY 1940 through CY 2440 rather than the full 10,000-year period of analysis. 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, the result of past releases from cribs and trenches (ditches). From about CY 1956 to CY 1980, groundwater concentrations at the Columbia River nearshore peak at less than an order of magnitude lower than the benchmark concentration. The later broad inflection occurring around CY 1990 represents tritium from past tank leaks. Because the half-life of tritium is less than 13 years, radioactive decay rapidly attenuates groundwater concentration, and tritium is essentially not a factor at times later than CY 2100. In addition, the retrieval of waste from the SSTs has significantly reduced the tritium concentrations associated with the tank residuals.

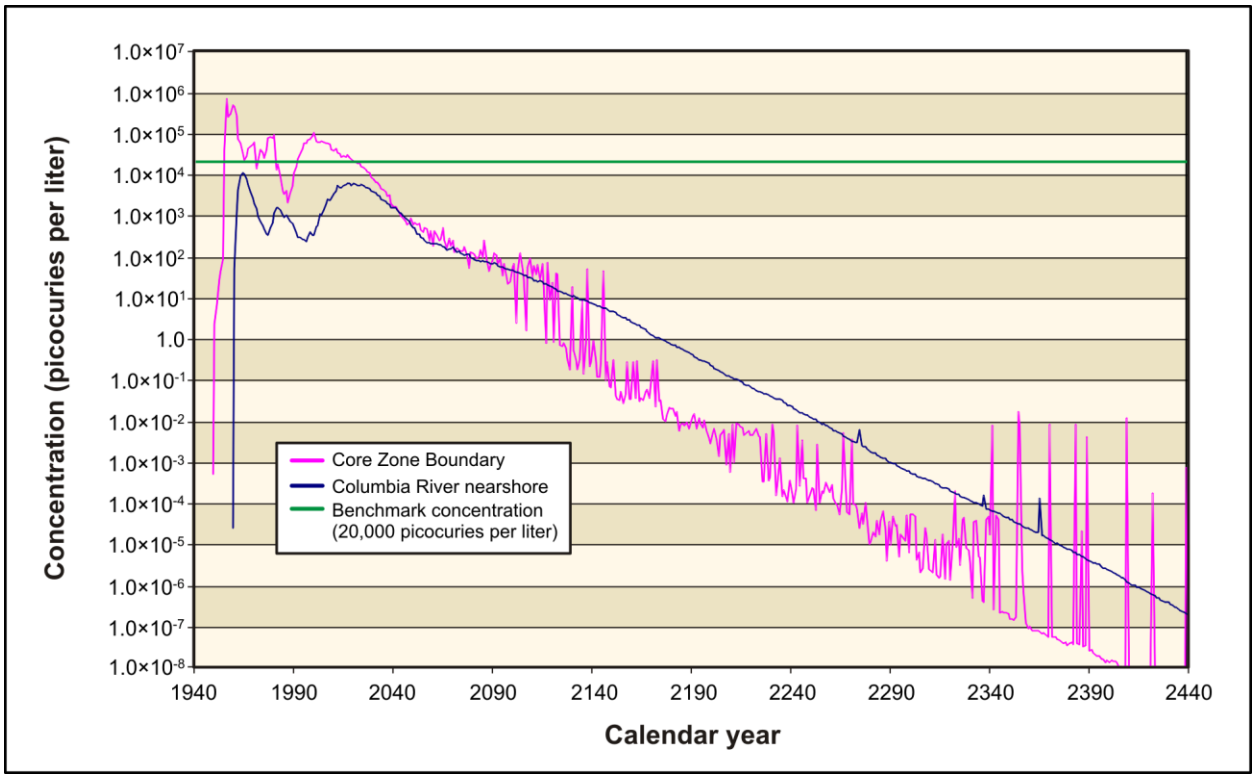


Figure 5–1207. Alternative Combination 2 Hydrogen-3 (Tritium) Concentration Versus Time

Figures 5–1208 and 5–1209 show concentration versus time for chromium and nitrate, the conservative tracers that are not affected by retention in the waste forms. Chromium and nitrate concentrations in groundwater peak in the beginning of the analysis period, around CY 1956, because of the releases from cribs and trenches (ditches), and exceed benchmark concentrations at the Core Zone Boundary by about two orders of magnitude. Concentrations at the Core Zone Boundary remain above the benchmark concentration during the first few hundred years of the analysis, until around CY 2300, at which time they decline to below the benchmark concentration and remain so throughout the remainder of the period of analysis. The broad characteristic part of the curve above the benchmark concentration representative of release from tank residuals under Alternative Combination 1 has been partially attenuated and shifted to later times under Alternative Combination 2 because of the actions implicit in Waste Management Alternative 2. Groundwater concentrations at the Columbia River nearshore present a similar pattern but with lower concentration levels. Both chromium and nitrate exceed the benchmark concentration at the Columbia River nearshore by less than an order of magnitude in the beginning of the analysis period. During later times in the analysis, the concentrations at the Core Zone Boundary and Columbia River nearshore are below the benchmark by about one and two orders of magnitude, respectively.

For iodine-129 and technetium-99, the behavior during the first 4,000 years is similar to that of chromium and nitrate (see Figures 5–1210 and 5–1211). After CY 6000, the effects of delayed release from waste management sources are seen, causing concentrations to rise at both the Core Zone Boundary and the Columbia River nearshore. The post-CY 6000 concentrations of both iodine-129 and technetium-99 rise to within less than an order of magnitude of, but never exceed, the benchmark concentrations at the Core Zone Boundary and Columbia River nearshore.

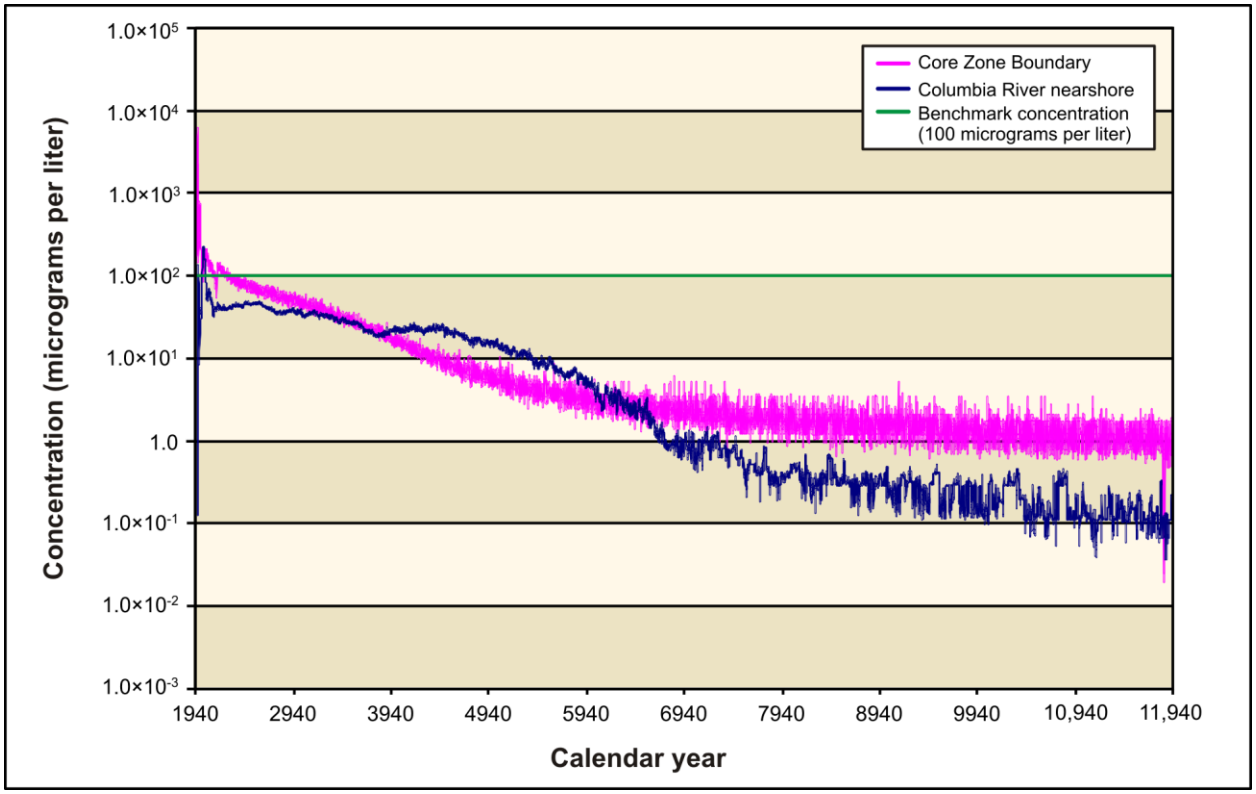


Figure 5–1208. Alternative Combination 2 Chromium Concentration Versus Time

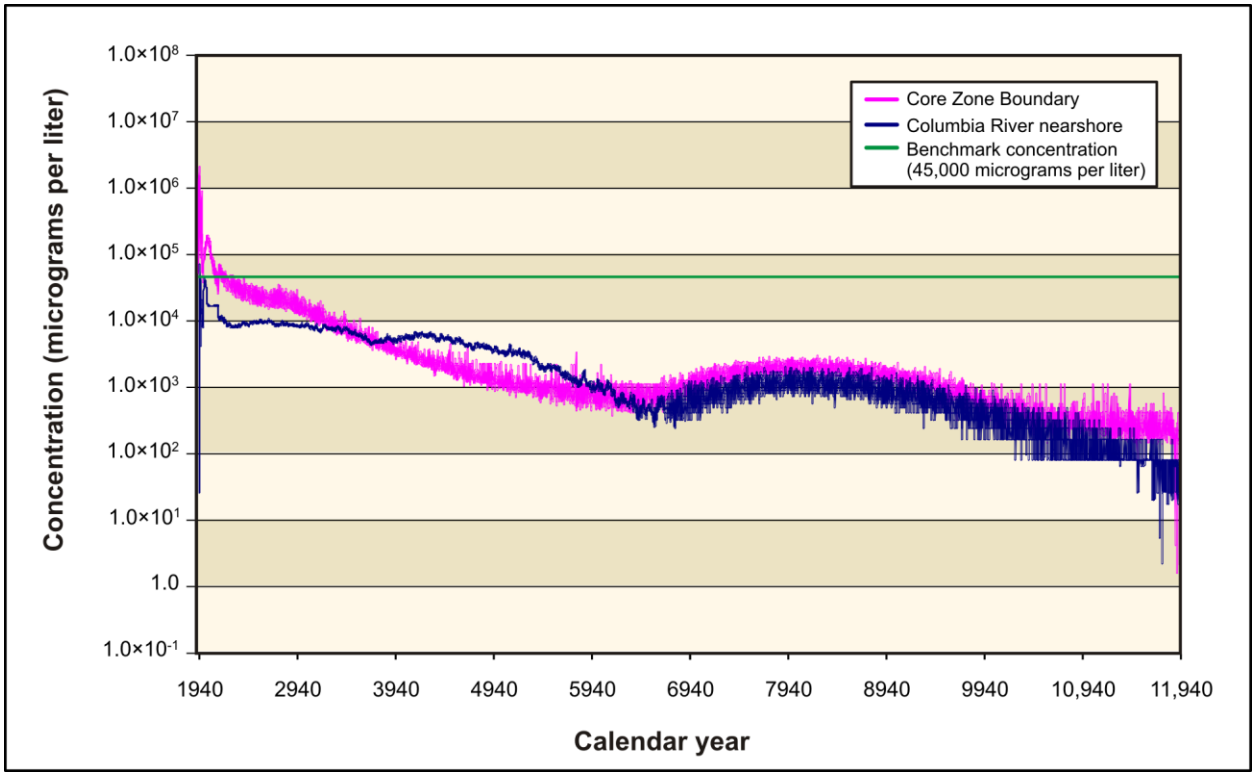


Figure 5–1209. Alternative Combination 2 Nitrate Concentration Versus Time

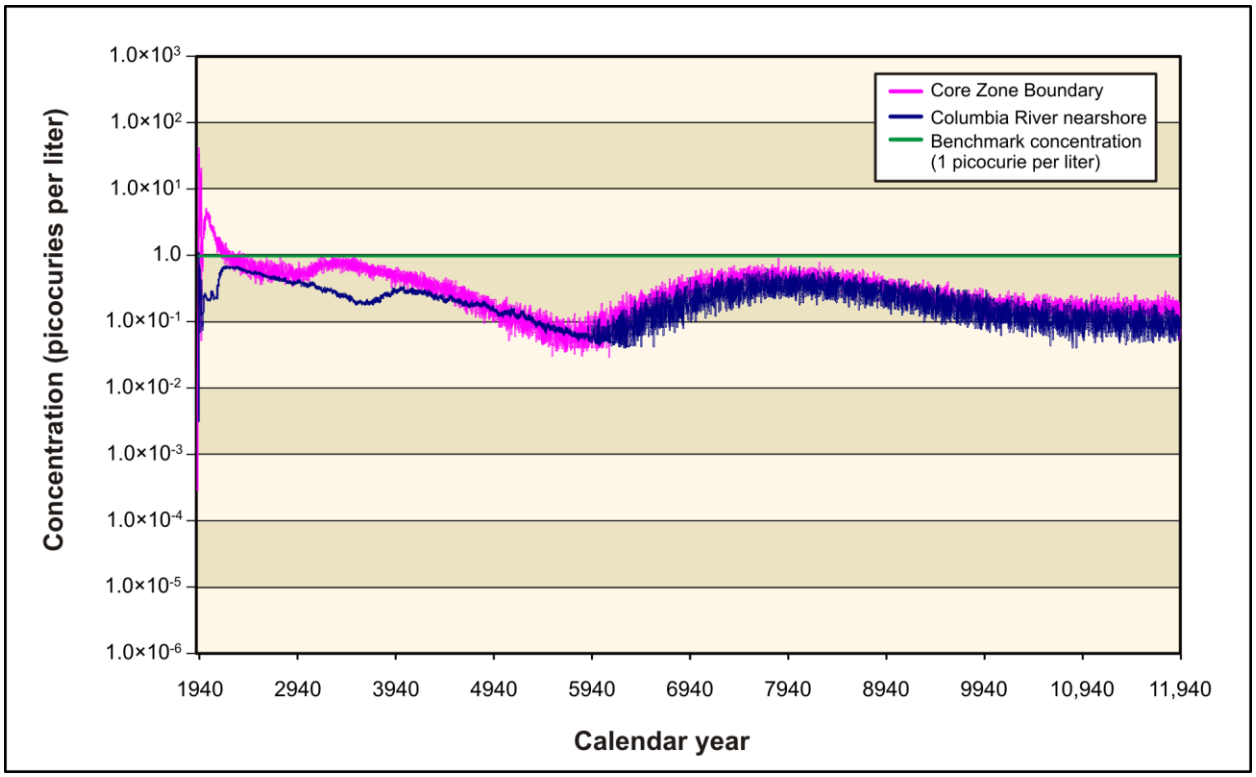


Figure 5–1210. Alternative Combination 2 Iodine-129 Concentration Versus Time

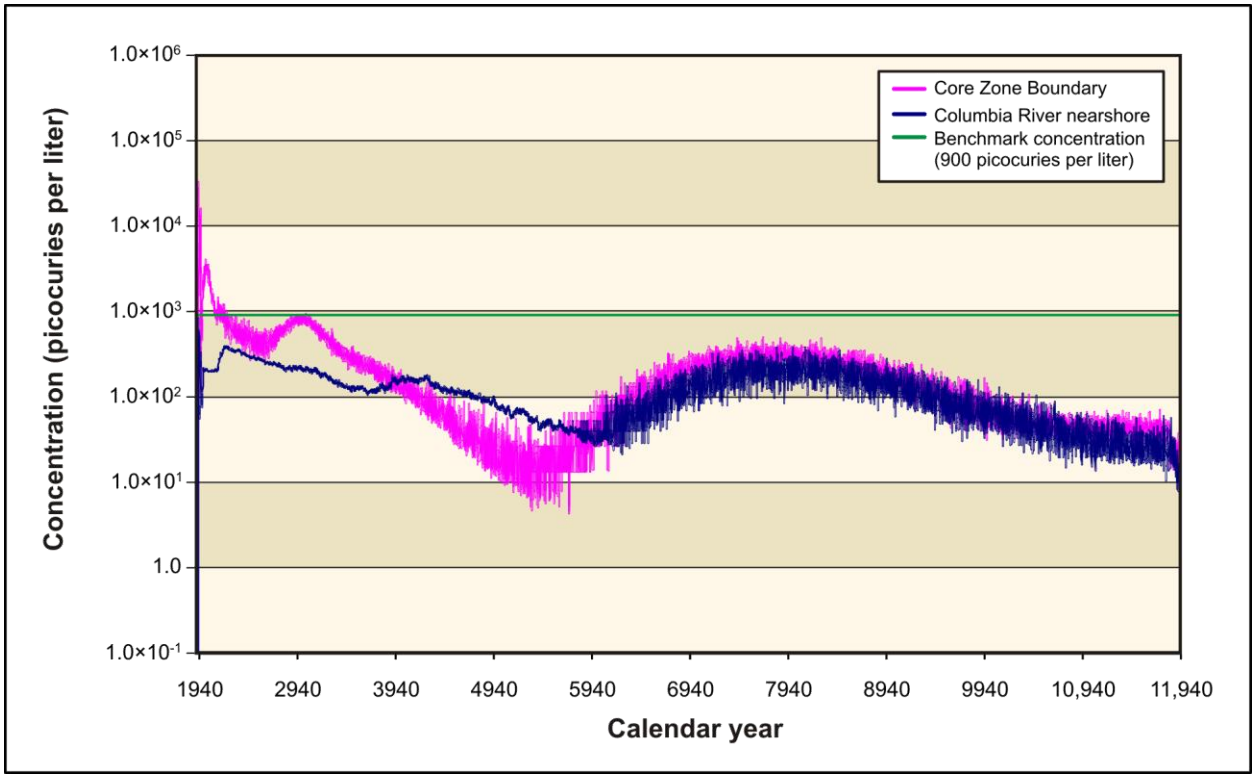


Figure 5–1211. Alternative Combination 2 Technetium-99 Concentration Versus Time

Figures 5–1212 and 5–1213 show concentration versus time for uranium-238 and total uranium. Early releases from cribs and trenches (ditches) and past tank leaks result in groundwater concentrations that are about two to three orders of magnitude lower than the benchmark concentrations at the Core Zone Boundary. After these initial peaks, concentrations at the Core Zone Boundary and Columbia River nearshore remain at four to five orders of magnitude below the benchmark concentrations for several thousand years. Around CY 4000, the concentrations begin to increase, steadily rising throughout the remainder of the analysis period. The travel times of these COPCs from the source locations to the Core Zone Boundary and the Columbia River nearshore are retarded relative to the conservative tracers by a factor of about seven. At the end of the analysis period, concentrations of both uranium-238 and total uranium are within about one order of magnitude of the benchmark concentrations at the Core Zone Boundary but never exceed the benchmark concentrations during the period of analysis. Groundwater concentrations at the Columbia River nearshore also rise throughout the period of analysis, but remain more than two orders of magnitude below the benchmark concentrations by CY 11,940. The attenuated behavior of uranium-238 and total uranium under Alternative Combination 2 can be contrasted with the behavior under Alternative Combination 1, where both uranium-238 and total uranium exceed the benchmark concentrations at the Core Zone Boundary late in the analysis period.

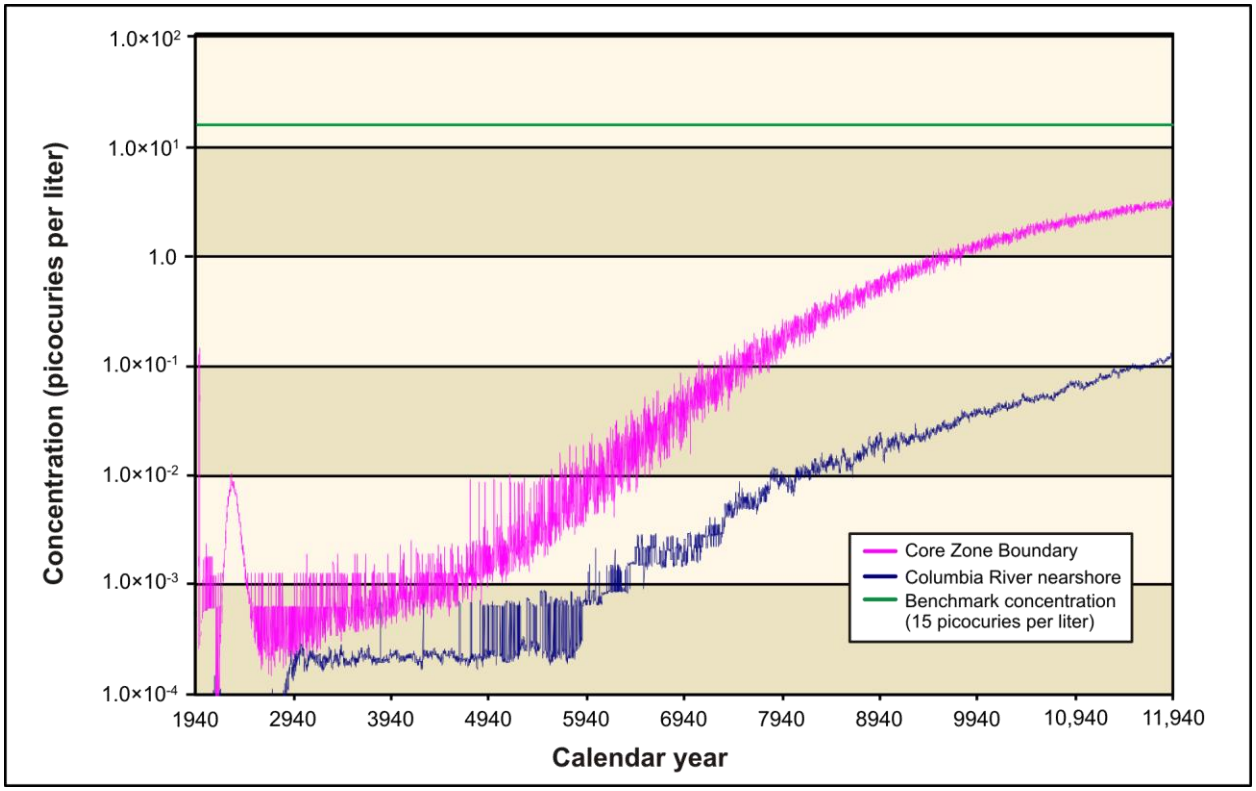


Figure 5–1212. Alternative Combination 2 Uranium-238 Concentration Versus Time

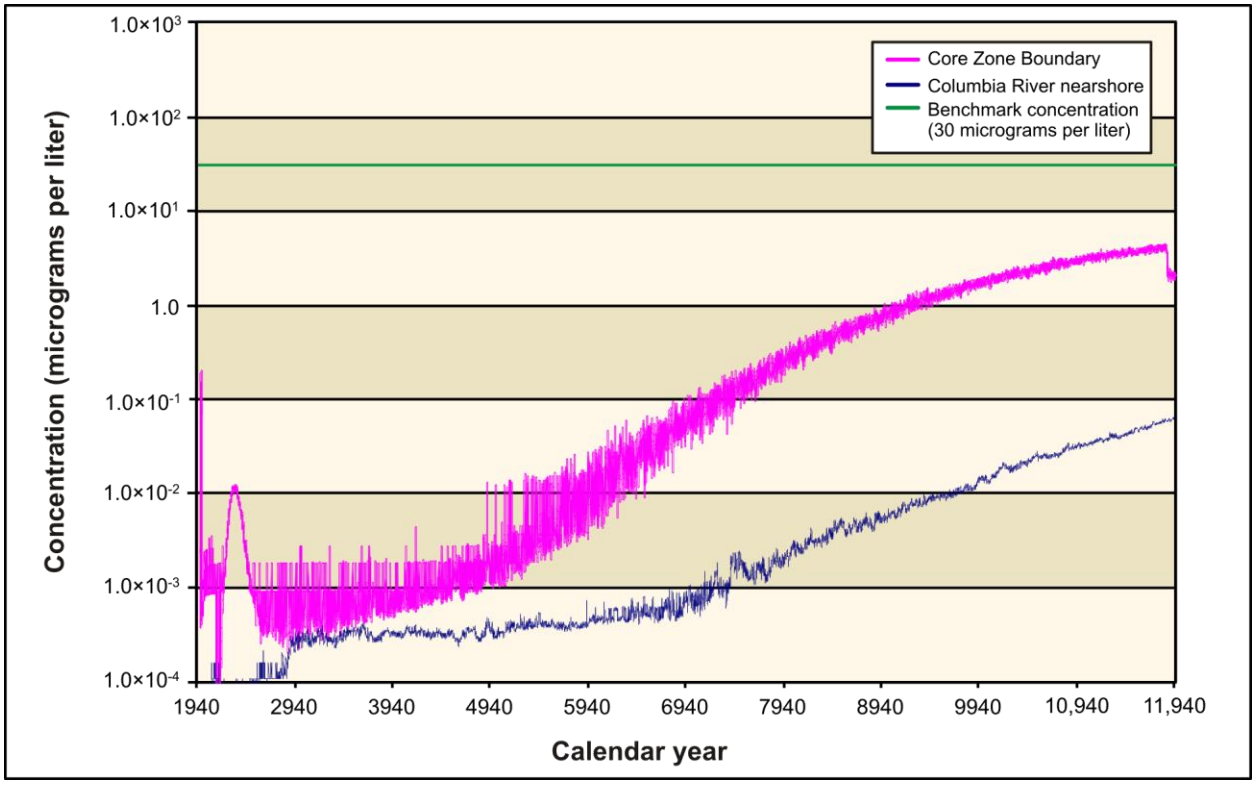
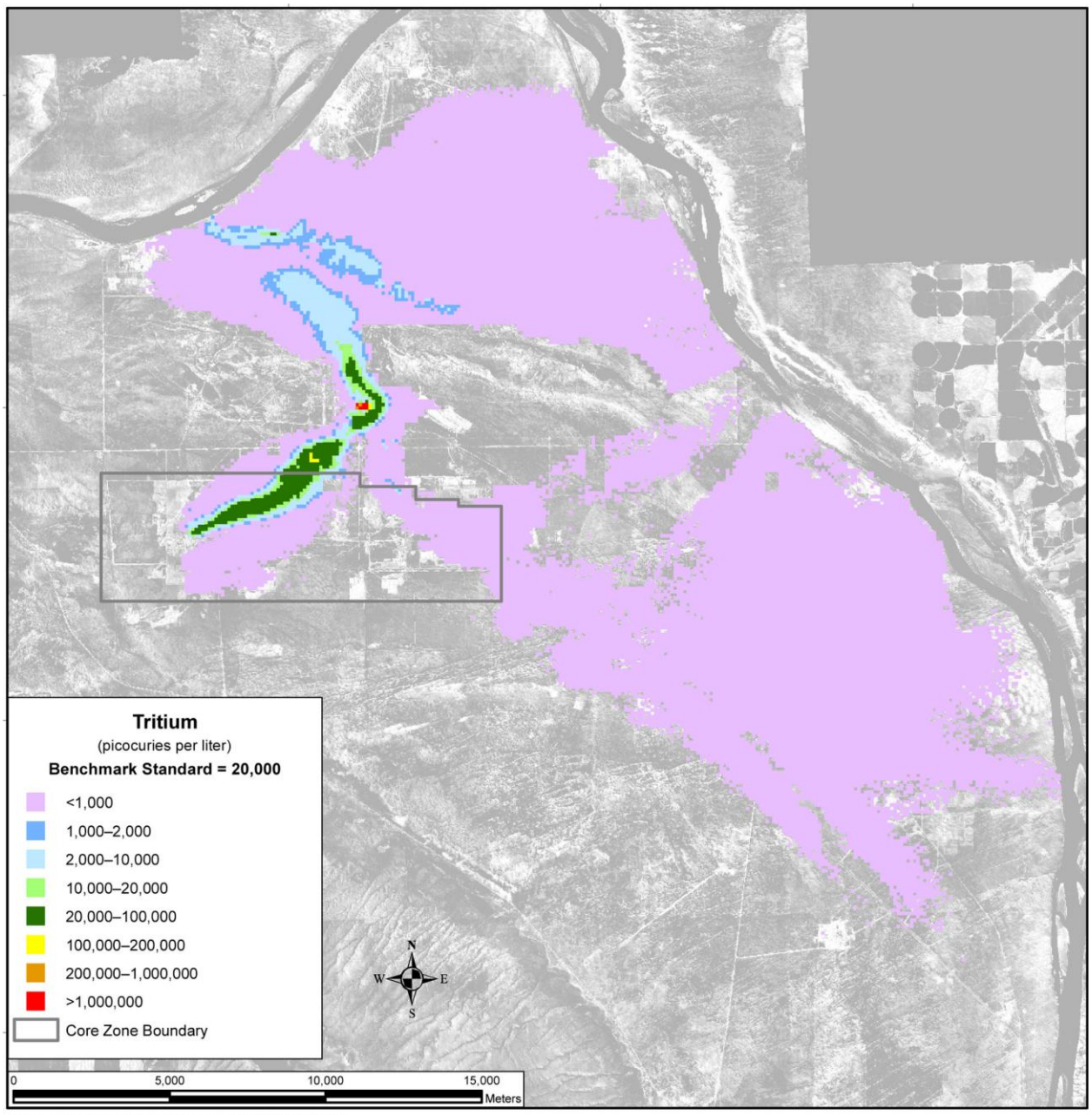


Figure 5–1213. Alternative Combination 2 Total Uranium Concentration Versus Time

ANALYSIS OF SPATIAL DISTRIBUTION OF CONCENTRATION

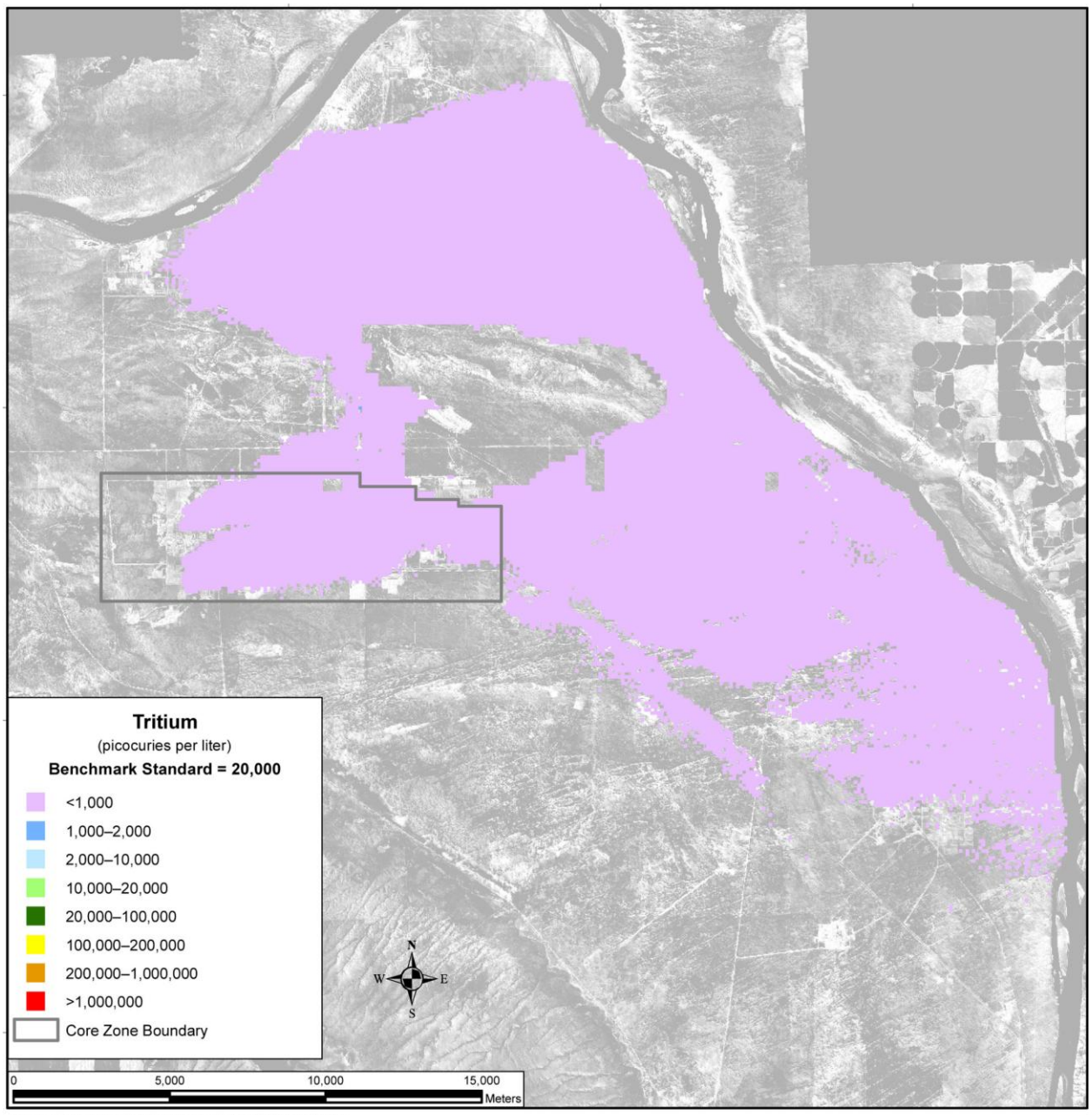
This section presents the impacts of Alternative Combination 2 in terms of the spatial distribution of COPC driver concentrations in groundwater at selected times. Concentrations of radionuclides are in picocuries per liter; chemicals, in micrograms per liter. Concentrations of each radionuclide and chemical are indicated by a color scale that is relative to the benchmark concentration. Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations less than the benchmark concentration are indicated by the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude.

Figure 5–1214 shows the spatial distribution of tritium concentrations in groundwater in CY 2010. Releases from cribs and trenches (ditches) and past leaks, associated primarily with the T, TX, and TY tank farms, result in a groundwater concentration plume (exceeding the benchmark concentration) that extends from the center part of the 200-West Area to the northeast, crosses the Core Zone Boundary, and continues toward Gable Gap. Peak concentrations in this plume are about 5 to 10 times greater than the benchmark. By CY 2135, the tritium plume has diminished to levels less than one-twentieth of the benchmark concentration (see Figure 5–1215).



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

Figure 5–1214. Alternative Combination 2 Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration, Calendar Year 2010

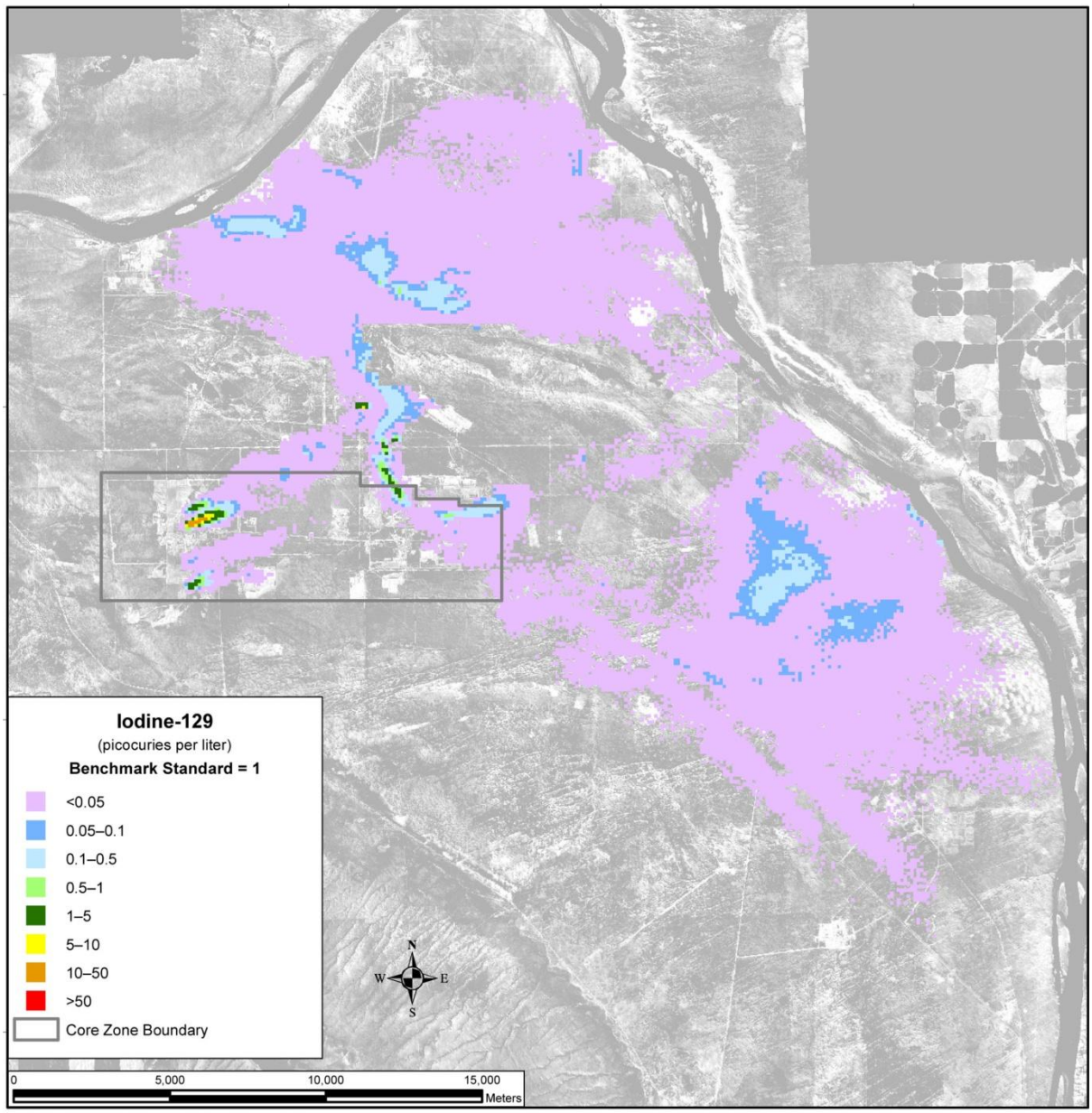


Note: To convert meters to feet, multiply by 3.281.

Figure 5–1215. Alternative Combination 2 Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration, Calendar Year 2135

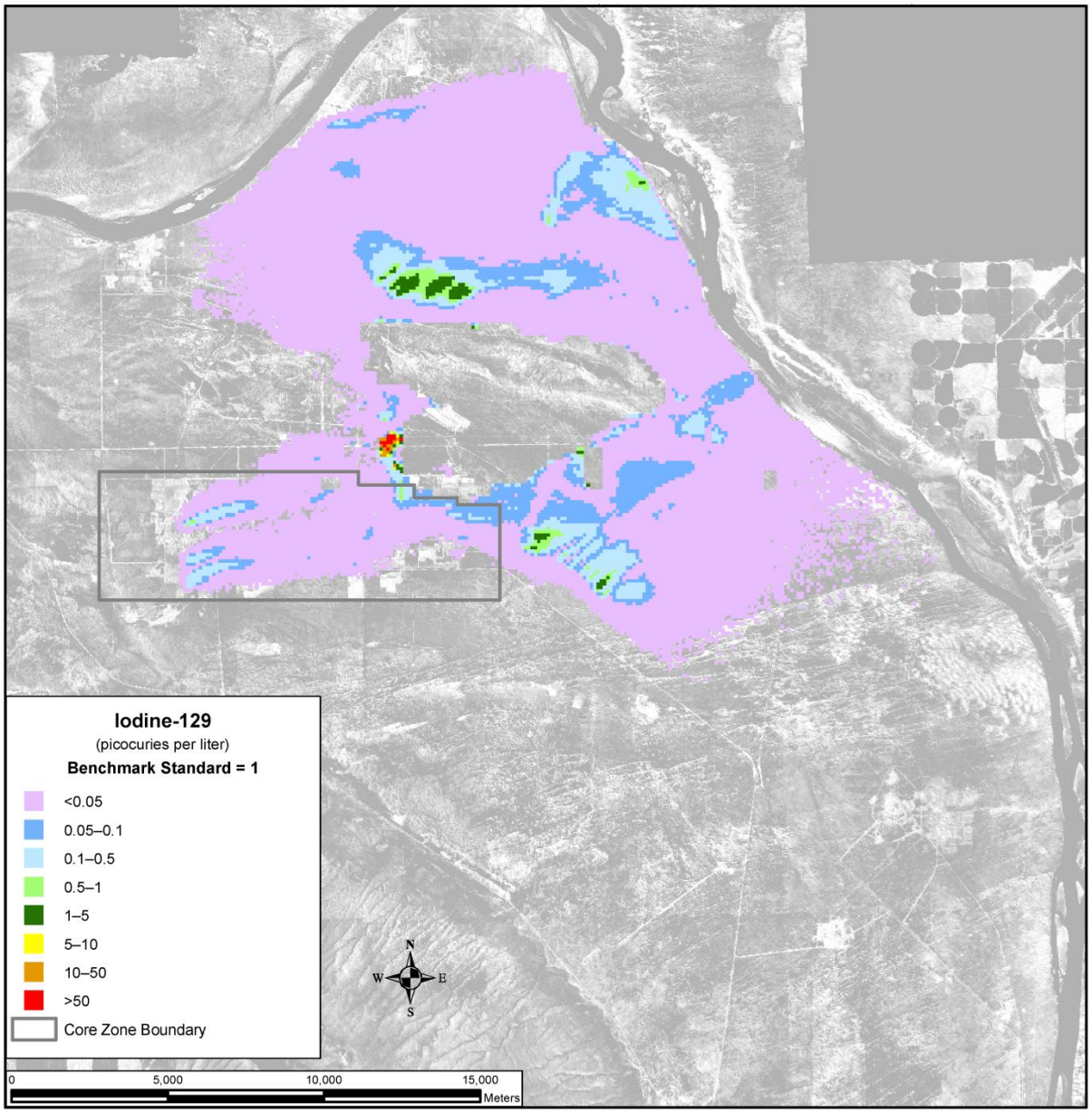
Figure 5–1216 shows the spatial distribution of iodine-129 concentrations in groundwater in CY 2010. Releases from cribs and trenches (ditches) and past leaks result in groundwater concentration plumes that exceed the benchmark concentration associated with the B, S, and T Barriers. Peak concentrations in these plumes range from about 10 to 50 times greater than the benchmark concentration and are mostly contained within the Core Zone Boundary. In CY 3890, releases from other tank farm sources have created a more widespread plume north of Gable Mountain with peak concentrations 10 to 50 times greater than the benchmark concentration. Another less intense plume that exceeds, but is within an order of magnitude of, the benchmark concentration extends east from the A Barrier toward the Columbia River (see Figure 5–1217). A comparison of this result against the corresponding distribution for Alternative Combination 1 (see Figure 5–1187) illustrates the reduction in impacts resulting from the retrieval of

other tank farm sources and, secondarily, from landfill closure. By CY 7140, the groundwater concentration distribution is driven primarily by waste management sources at IDF-East (see Figure 5–1218). The impact is characterized by a plume east of the Core Zone Boundary that exceeds the benchmark concentration by less than an order of magnitude. Because of retention in the waste forms, this impact lasts until the end of the 10,000-year period of analysis (see Figure 5–1219). Figure 5–1220 shows the total area for which iodine-129 concentrations in groundwater exceed the benchmark concentration as a function of time. Again, a comparison of this result with the corresponding distribution for Alternative Combination 1 (see Figure 5–1189) illustrates the reduction of impacts resulting from retrieval of other tank farm sources (around CY 4000), but also the increase in impacts associated with waste management sources, primarily offsite waste (around CY 9000). The other conservative tracers, technetium-99, chromium, and nitrate, show similar spatial distributions (see Figures 5–1221 through 5–1224 and 5–1226 through 5–1233). Figure 5–1225 shows the total area for which technetium-99 concentrations in groundwater exceed the benchmark concentration as a function of time.



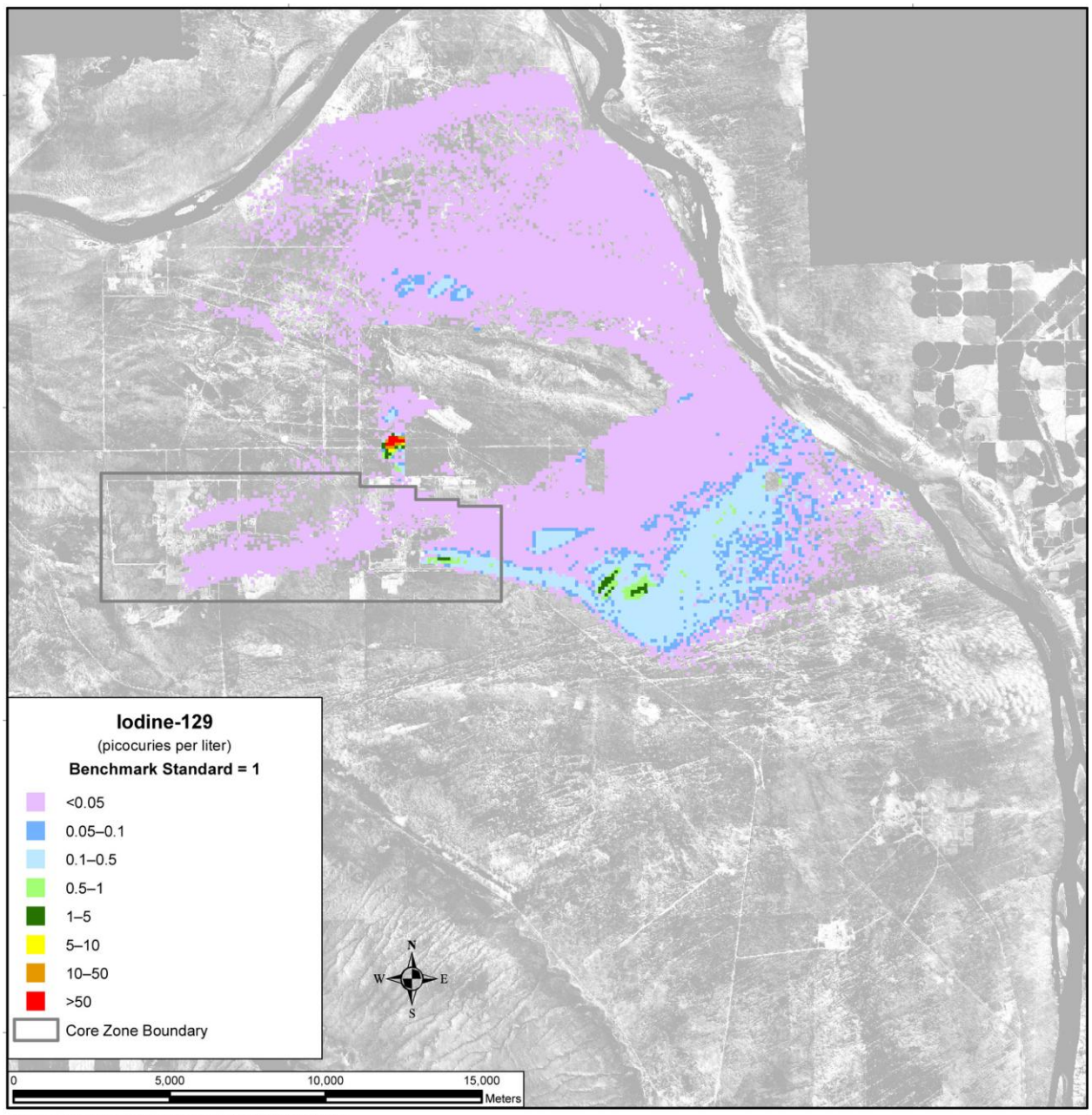
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1216. Alternative Combination 2 Spatial Distribution of Groundwater Iodine-129 Concentration, Calendar Year 2010



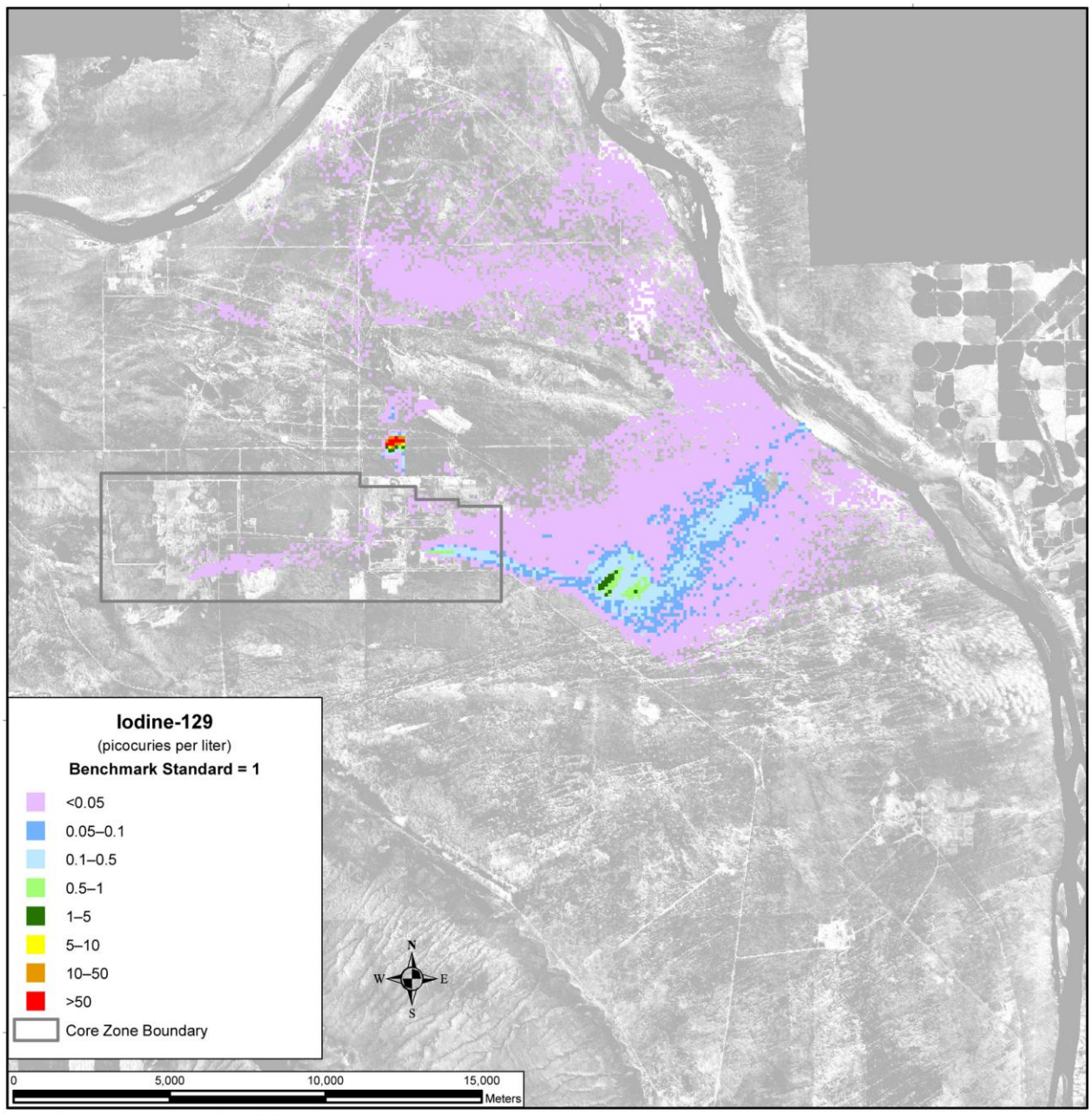
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1217. Alternative Combination 2 Spatial Distribution of Groundwater Iodine-129 Concentration, Calendar Year 3890



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

Figure 5–1218. Alternative Combination 2 Spatial Distribution of Groundwater Iodine-129 Concentration, Calendar Year 7140



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

Figure 5–1219. Alternative Combination 2 Spatial Distribution of Groundwater Iodine-129 Concentration, Calendar Year 11,885

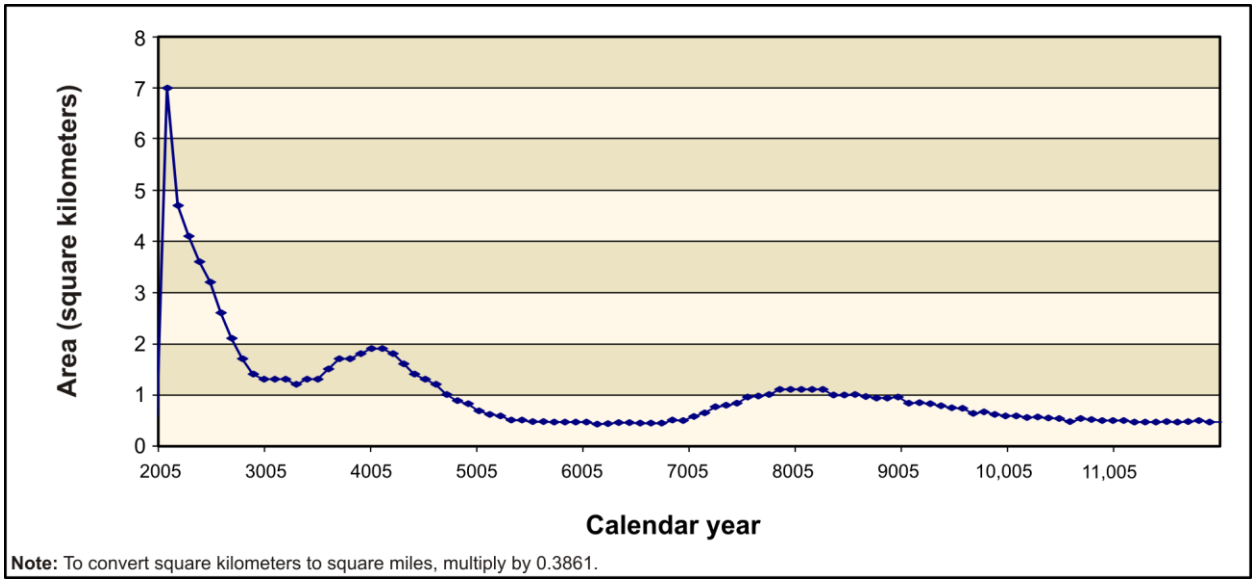
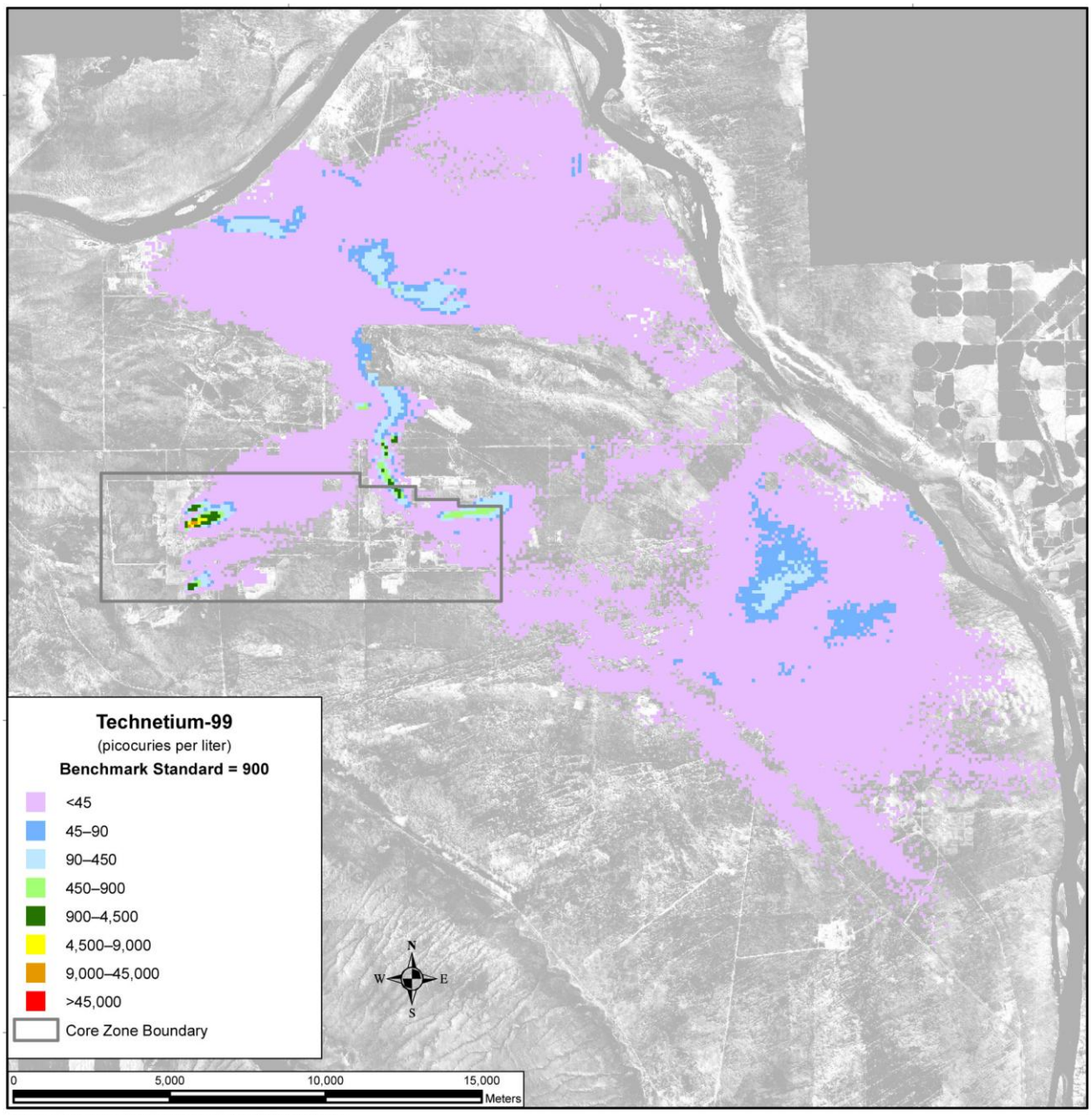
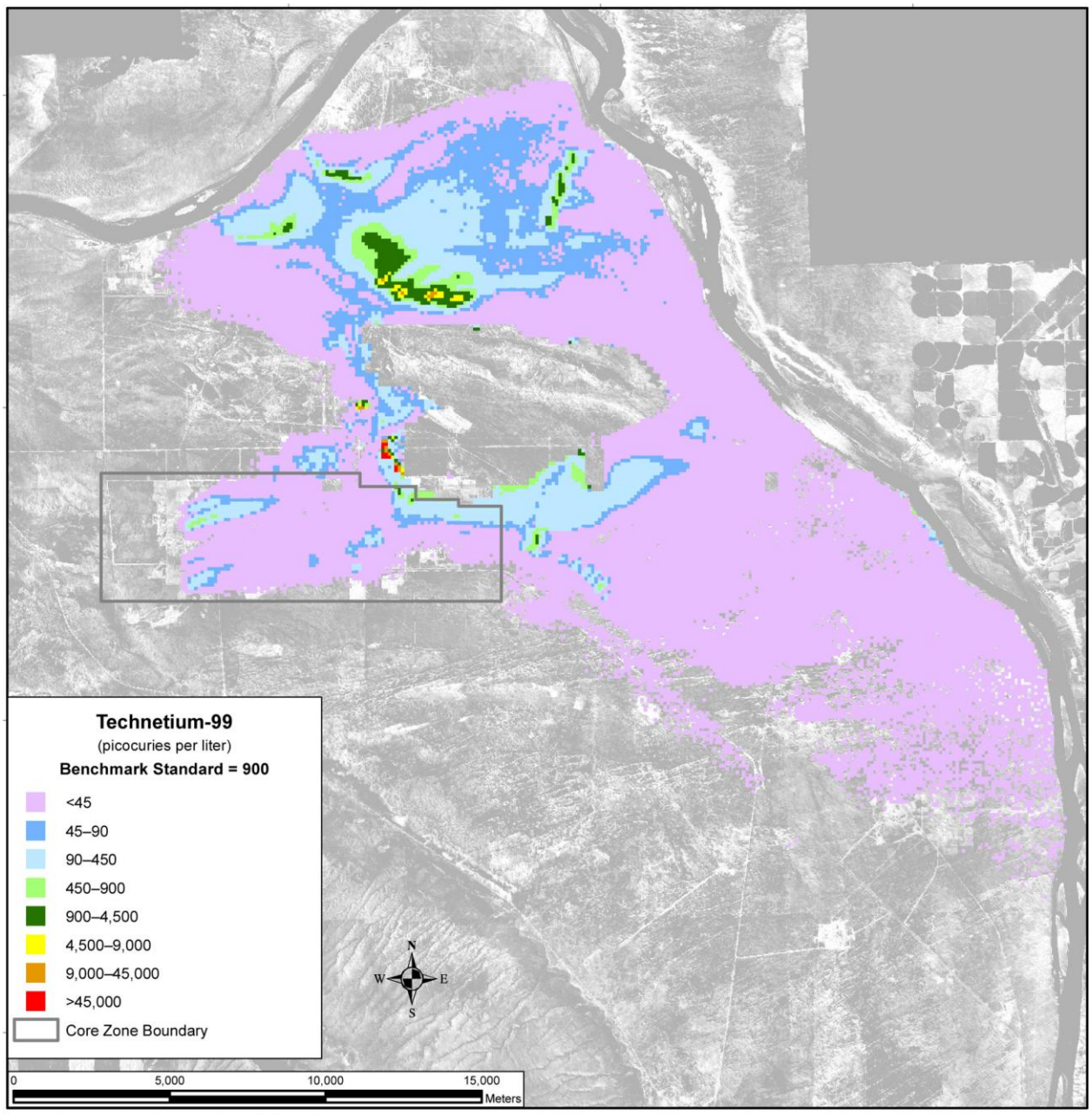


Figure 5–1220. Alternative Combination 2 Total Area of Groundwater Iodine-129 Concentration Exceeding the Benchmark Concentration as a Function of Time



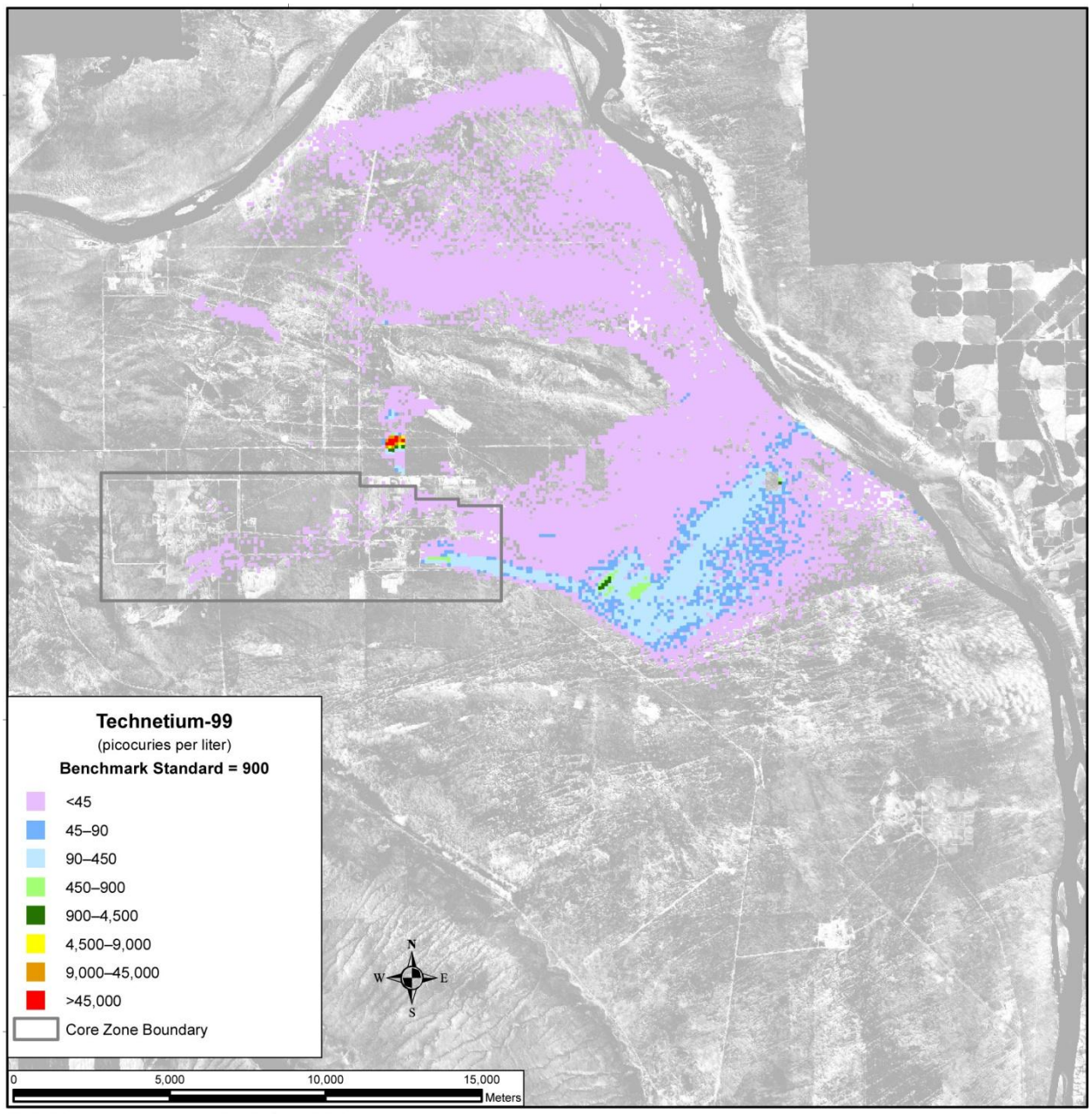
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1221. Alternative Combination 2 Spatial Distribution of Groundwater Technetium-99 Concentration, Calendar Year 2010



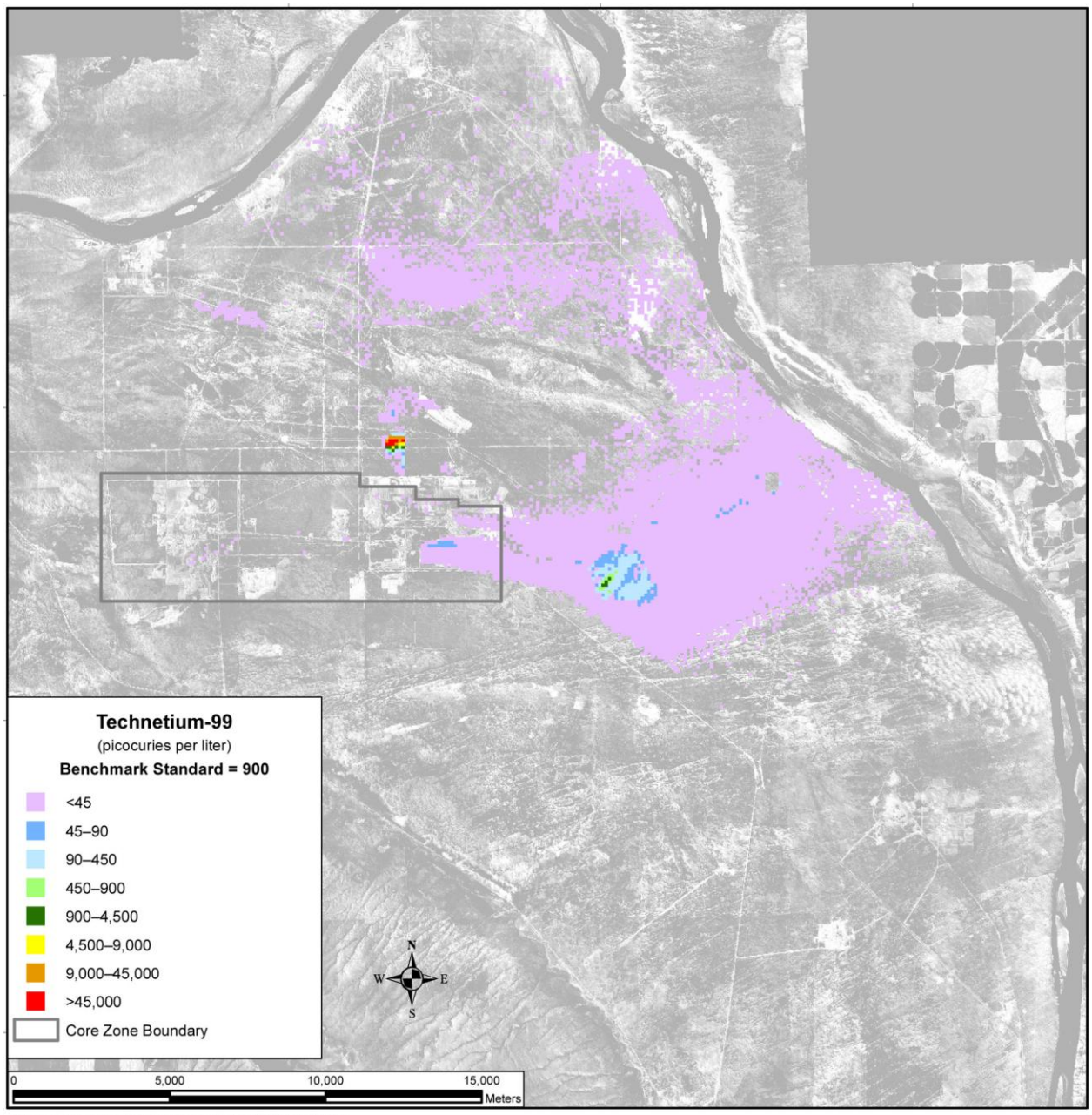
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1222. Alternative Combination 2 Spatial Distribution of Groundwater Technetium-99 Concentration, Calendar Year 2135



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

Figure 5–1223. Alternative Combination 2 Spatial Distribution of Groundwater Technetium-99 Concentration, Calendar Year 7140



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

Figure 5–1224. Alternative Combination 2 Spatial Distribution of Groundwater Technetium-99 Concentration, Calendar Year 11,885

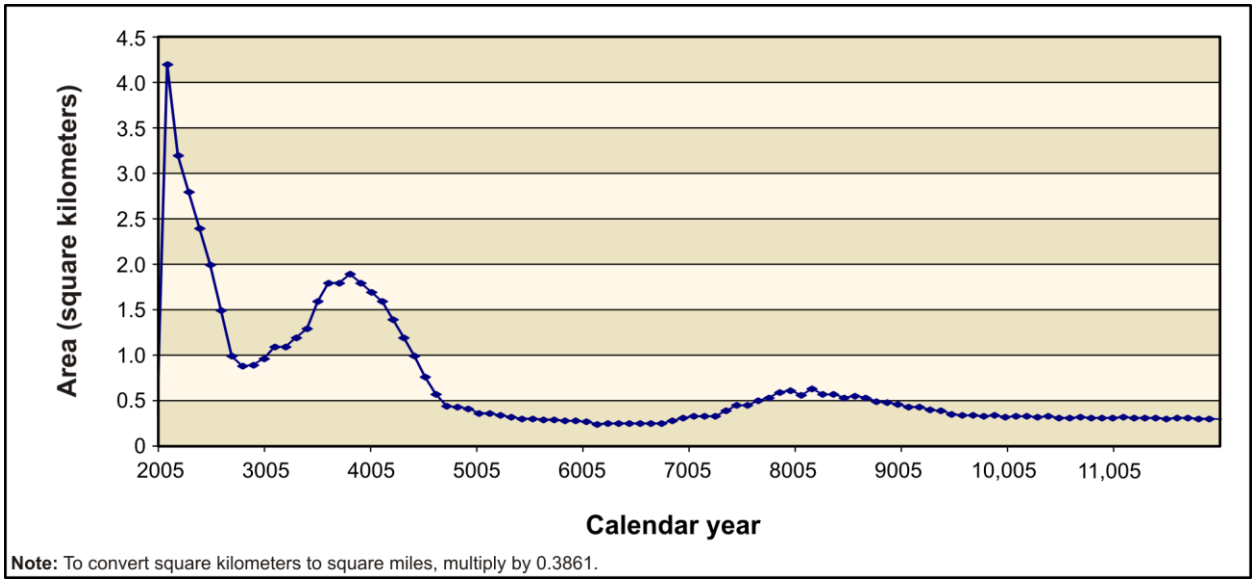
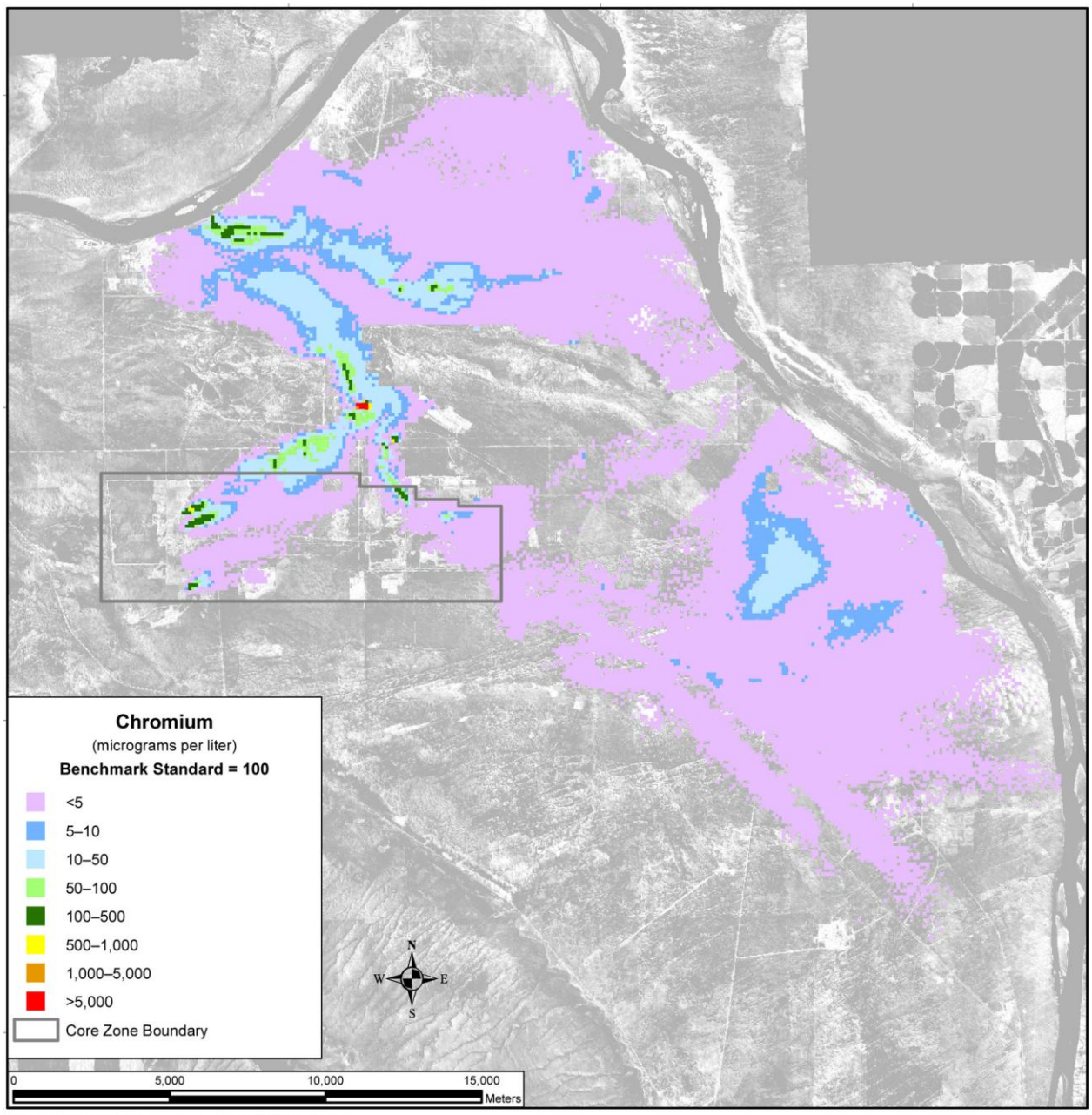
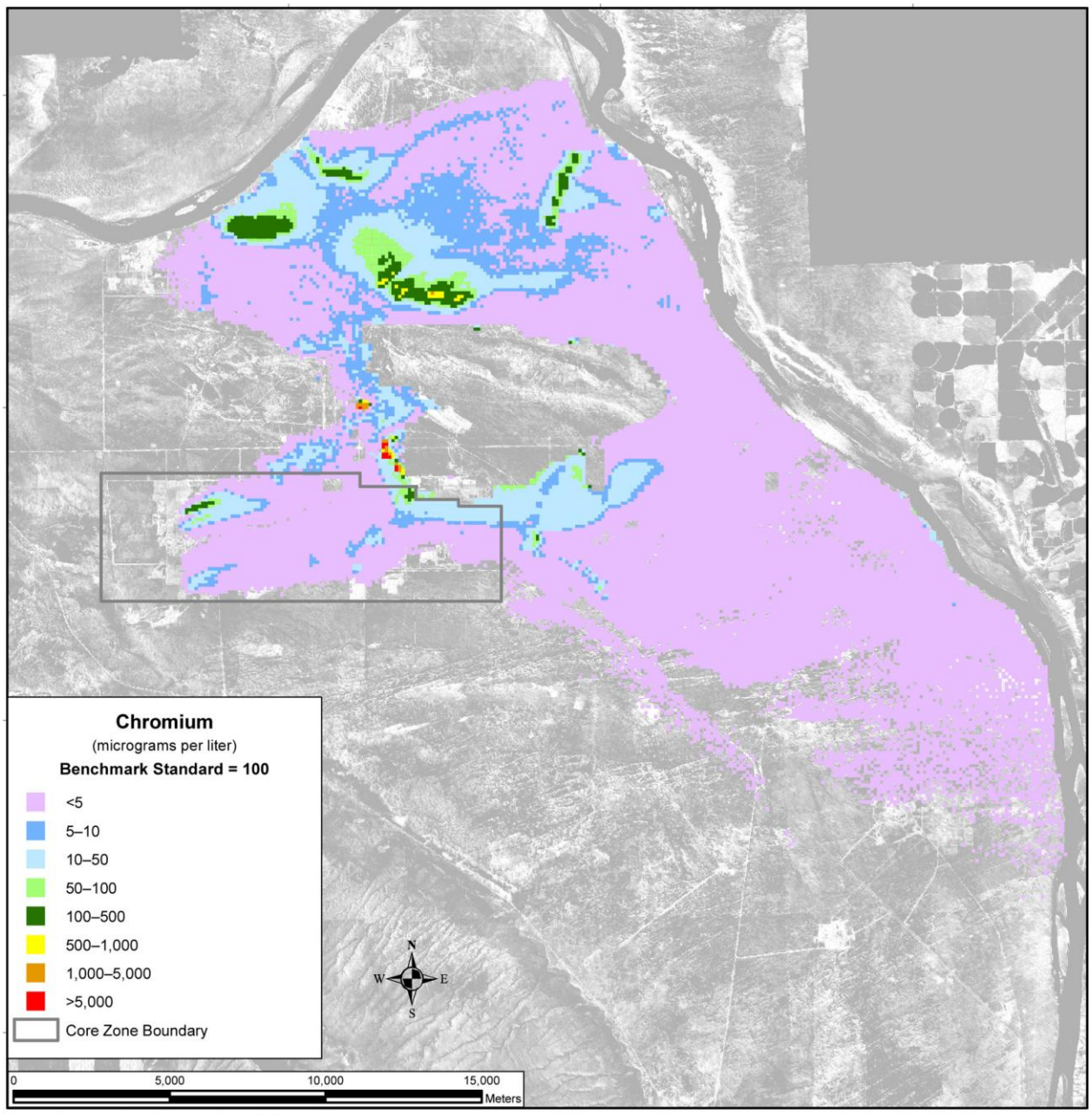


Figure 5–1225. Alternative Combination 2 Total Area of Groundwater Technetium-99 Concentration Exceeding the Benchmark Concentration as a Function of Time



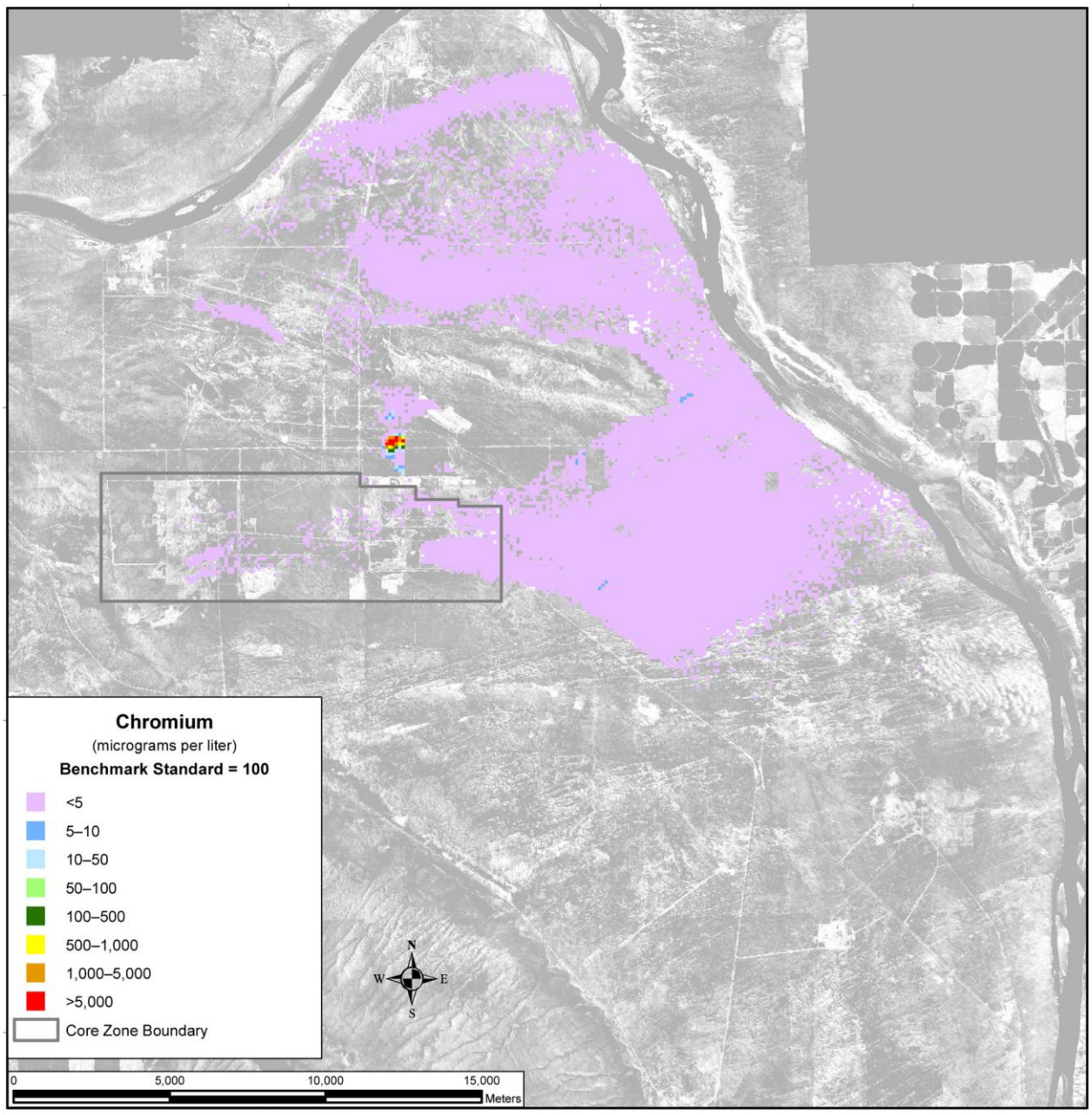
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1226. Alternative Combination 2 Spatial Distribution of Groundwater Chromium Concentration, Calendar Year 2010



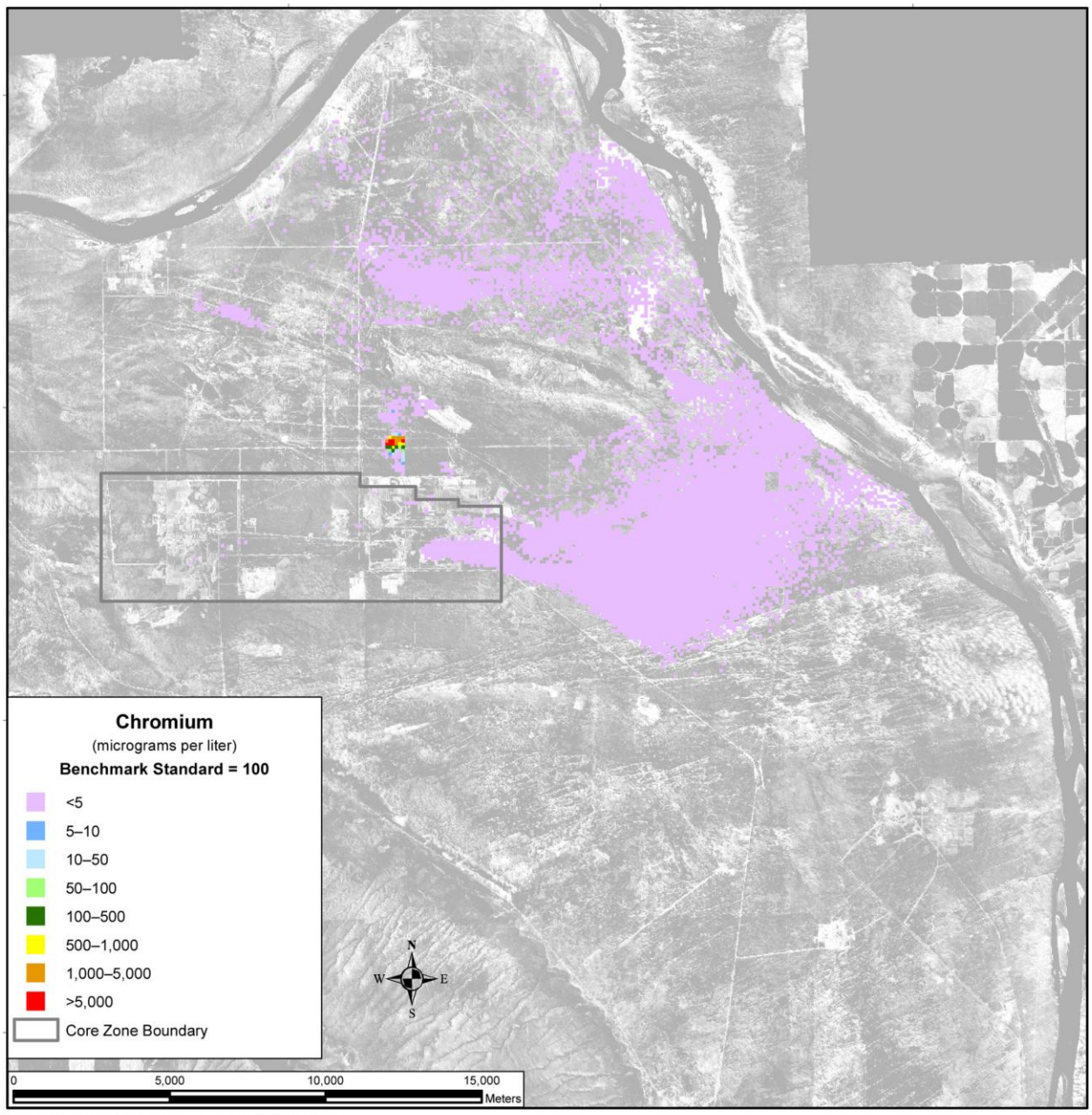
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1227. Alternative Combination 2 Spatial Distribution of Groundwater Chromium Concentration, Calendar Year 2135



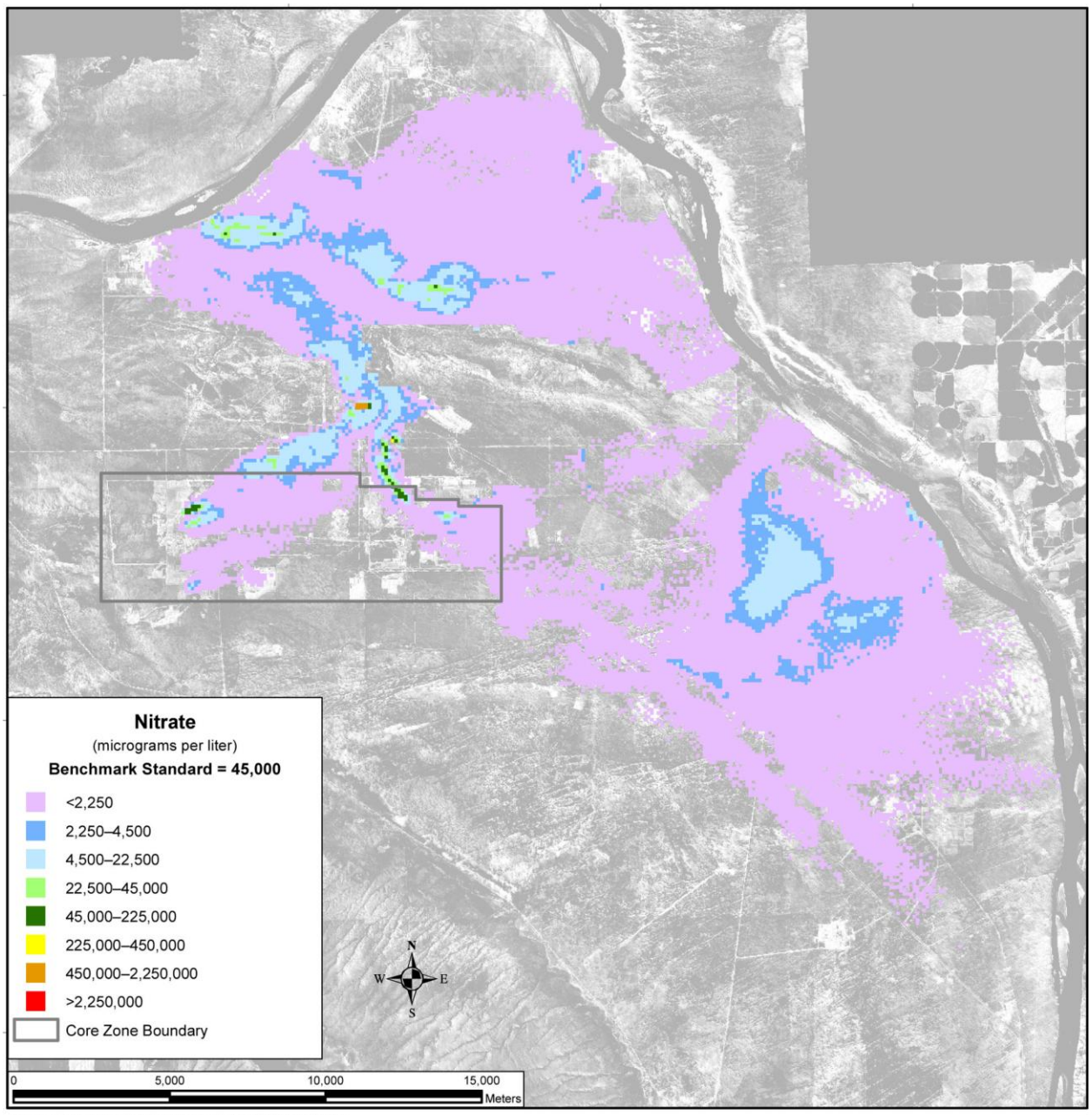
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1228. Alternative Combination 2 Spatial Distribution of Groundwater Chromium Concentration, Calendar Year 7140



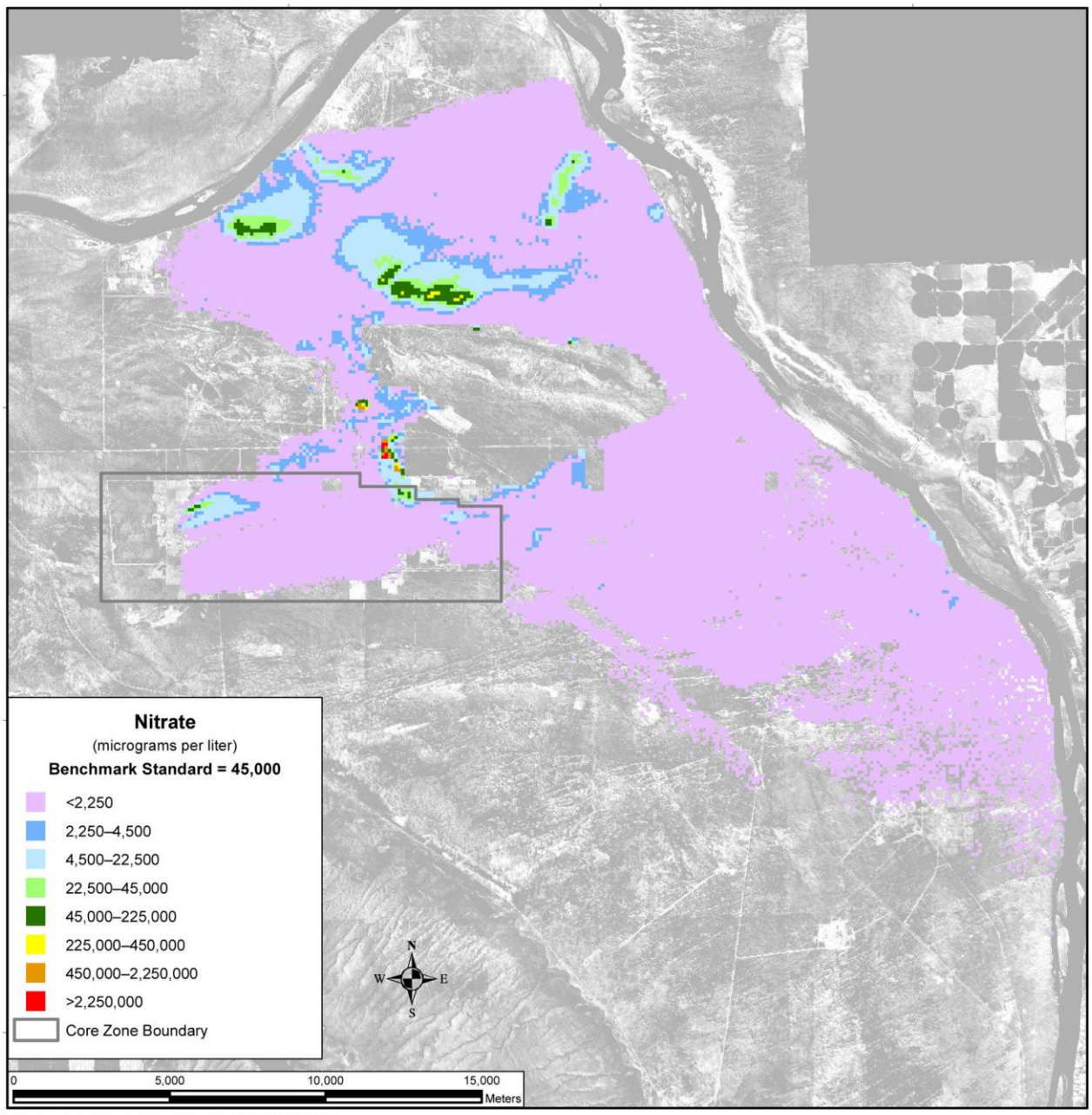
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1229. Alternative Combination 2 Spatial Distribution of Groundwater Chromium Concentration, Calendar Year 11,885



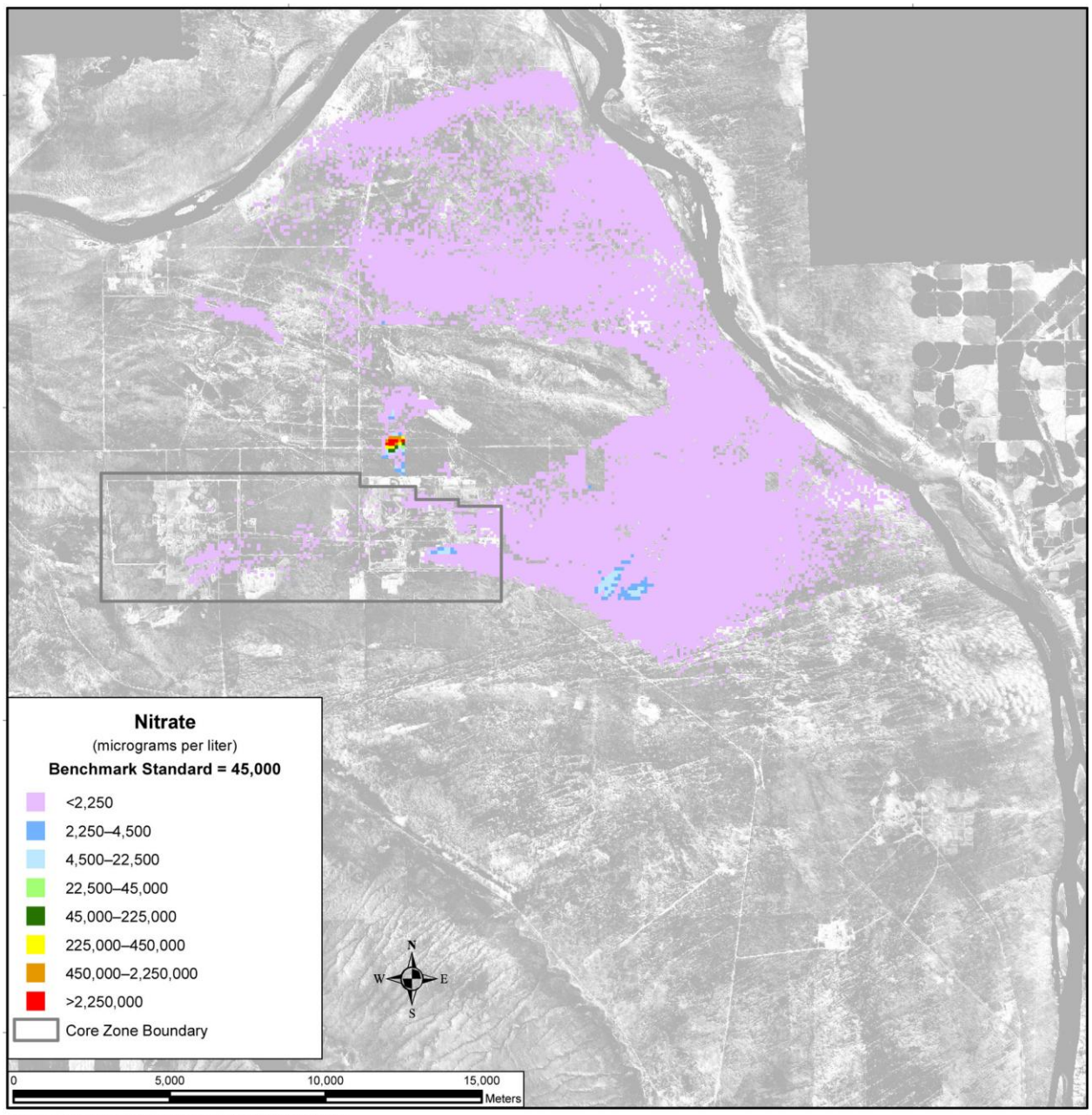
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1230. Alternative Combination 2 Spatial Distribution of Groundwater Nitrate Concentration, Calendar Year 2010



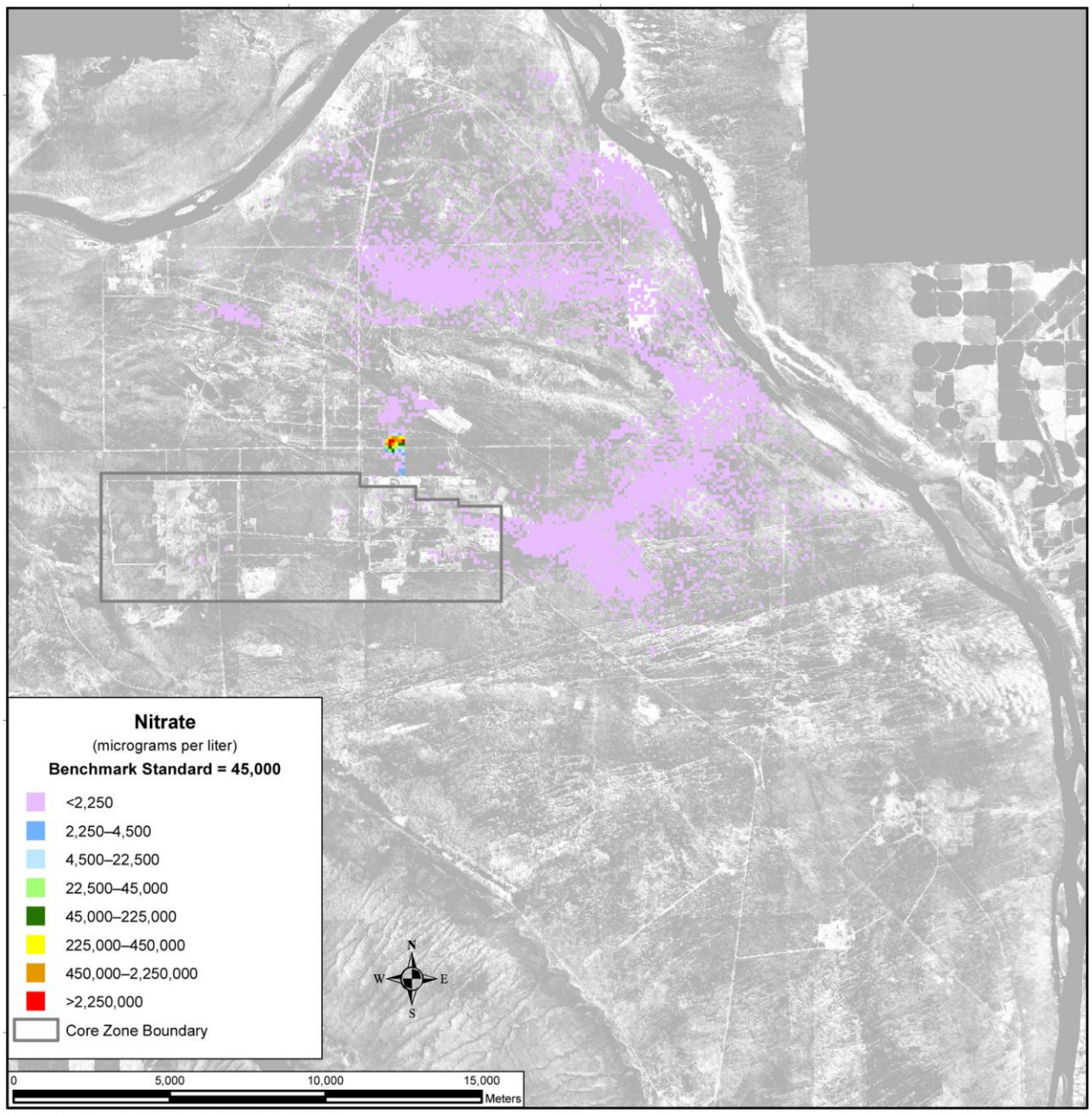
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1231. Alternative Combination 2 Spatial Distribution of Groundwater Nitrate Concentration, Calendar Year 2135



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

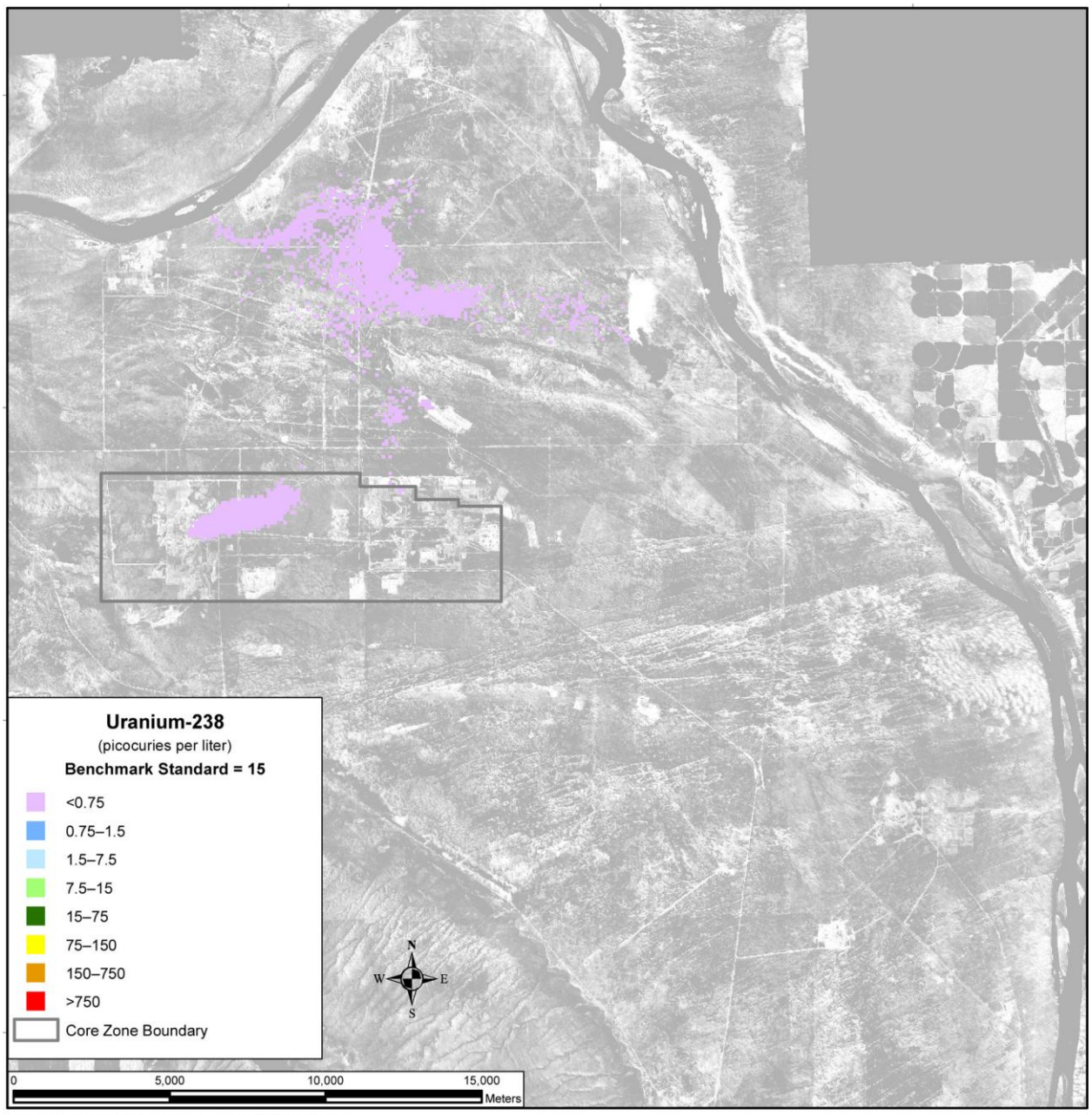
Figure 5–1232. Alternative Combination 2 Spatial Distribution of Groundwater Nitrate Concentration, Calendar Year 7140



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

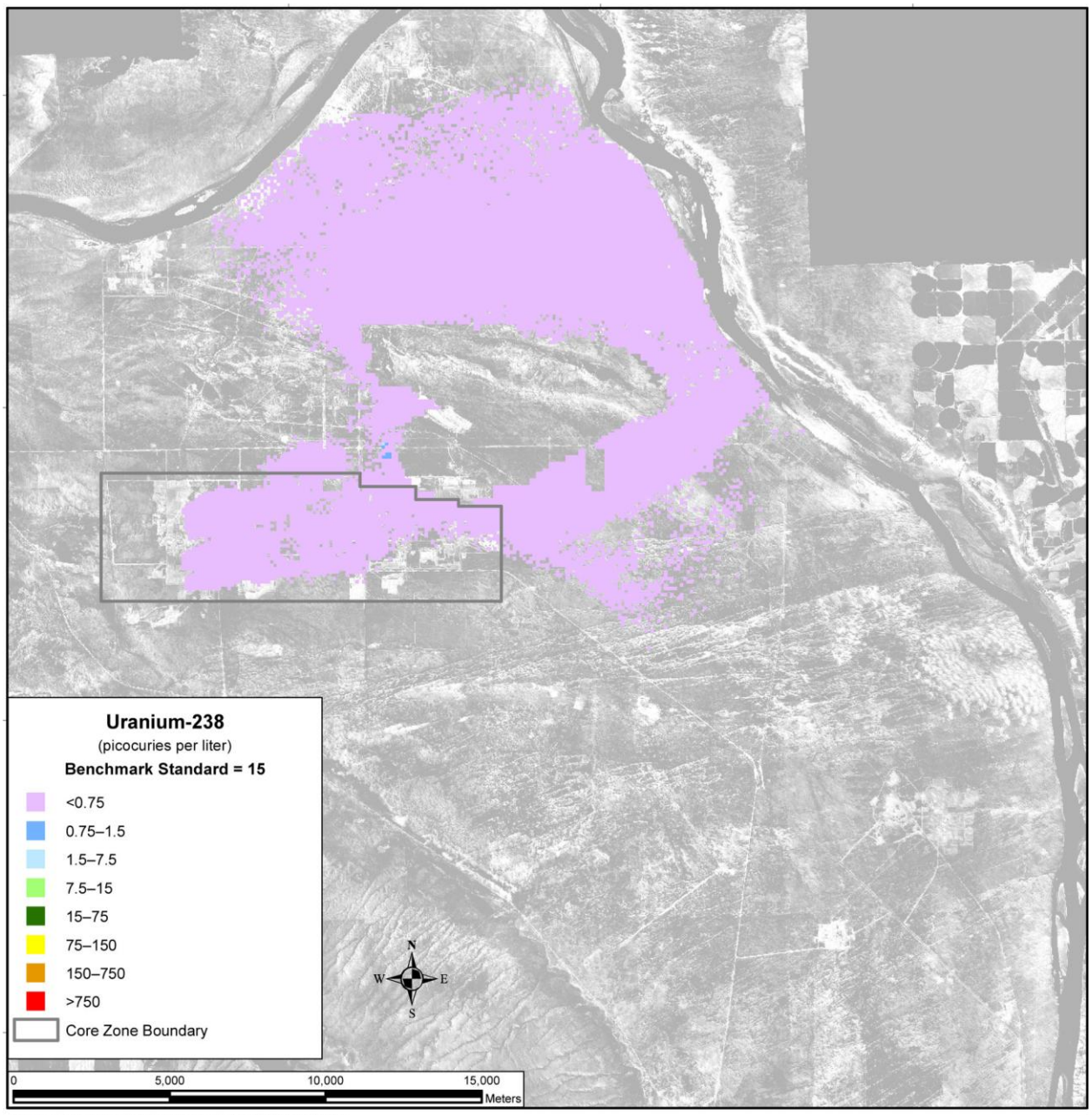
Figure 5–1233. Alternative Combination 2 Spatial Distribution of Groundwater Nitrate Concentration, Calendar Year 11,885

Uranium-238 and total uranium show different spatial distributions in the analysis over time. These COPCs are not as mobile as those discussed above, moving about seven times more slowly than the pore-water velocity. As a result, travel times through the vadose zone are longer, release to the aquifer is delayed, and travel times through the aquifer to the Columbia River are longer. Figure 5–1234 shows the distribution of uranium-238 in CY 2135. There is a small plume associated with cribs and trenches (ditches) and past leaks at the T Barrier that is less than one-twentieth of the benchmark concentration. The plume extends northeast through Gable Gap. By CY 7140 (see Figure 5–1235), the area of the plume has grown and extends to the Columbia River nearshore, but no significant increases in peak concentration are evident. In CY 11,885 (see Figure 5–1236), the greatest development of the plume during the analysis period is seen. Figure 5–1237 shows the total area for which uranium-238 concentrations in groundwater exceed the benchmark concentration as a function of time. The area of exceedance is largest near the end of the period of analysis. Figures 5–1238 through 5–1240 show the corresponding spatial distribution for total uranium.



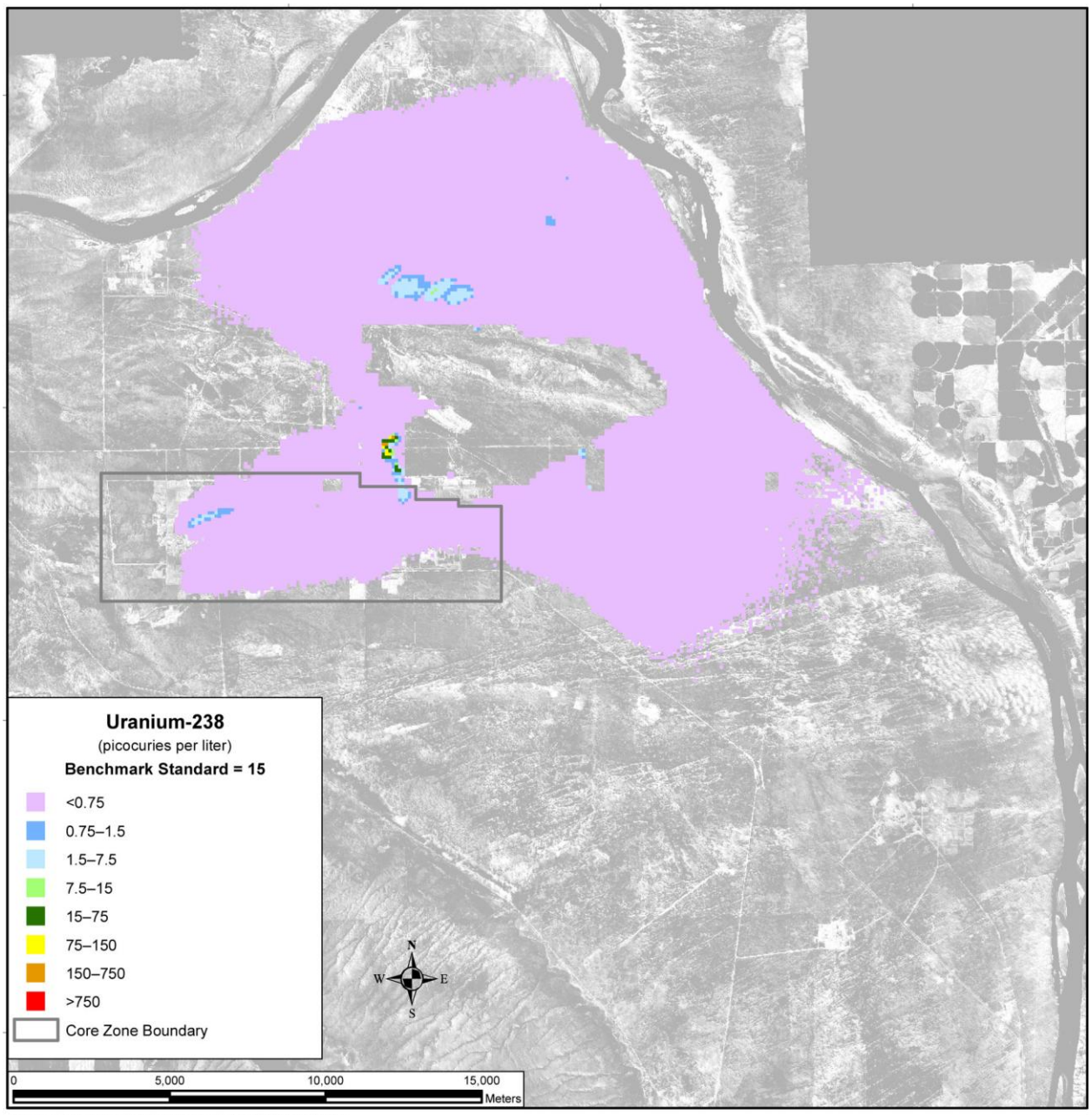
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1234. Alternative Combination 2 Spatial Distribution of Groundwater Uranium-238 Concentration, Calendar Year 2135



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

Figure 5–1235. Alternative Combination 2 Spatial Distribution of Groundwater Uranium-238 Concentration, Calendar Year 7140



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

Figure 5–1236. Alternative Combination 2 Spatial Distribution of Groundwater Uranium-238 Concentration, Calendar Year 11,885

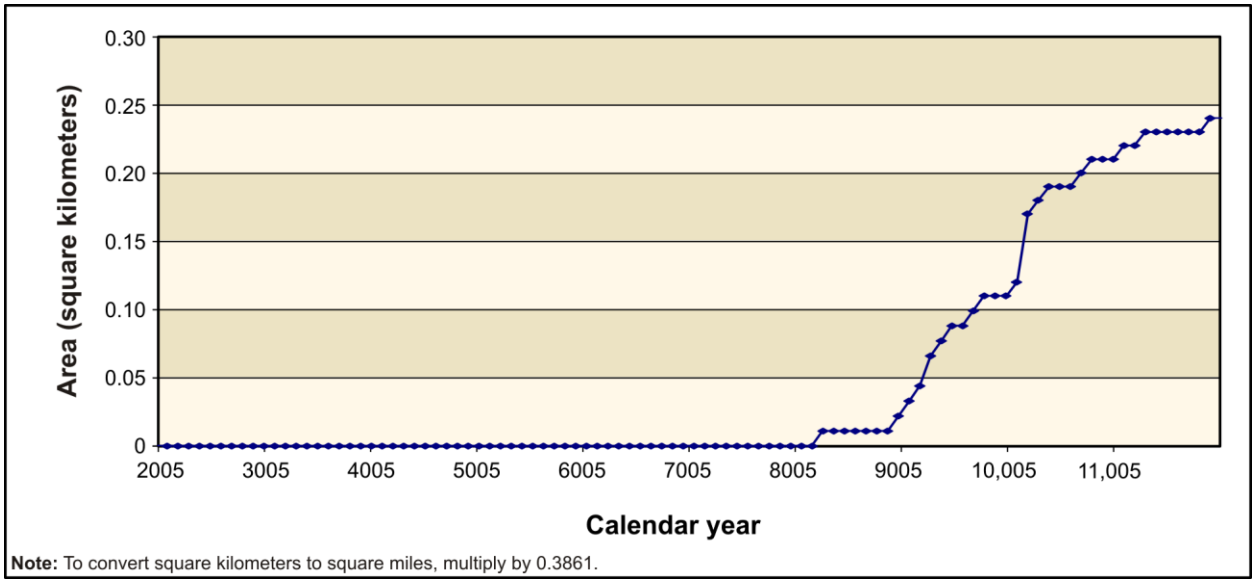
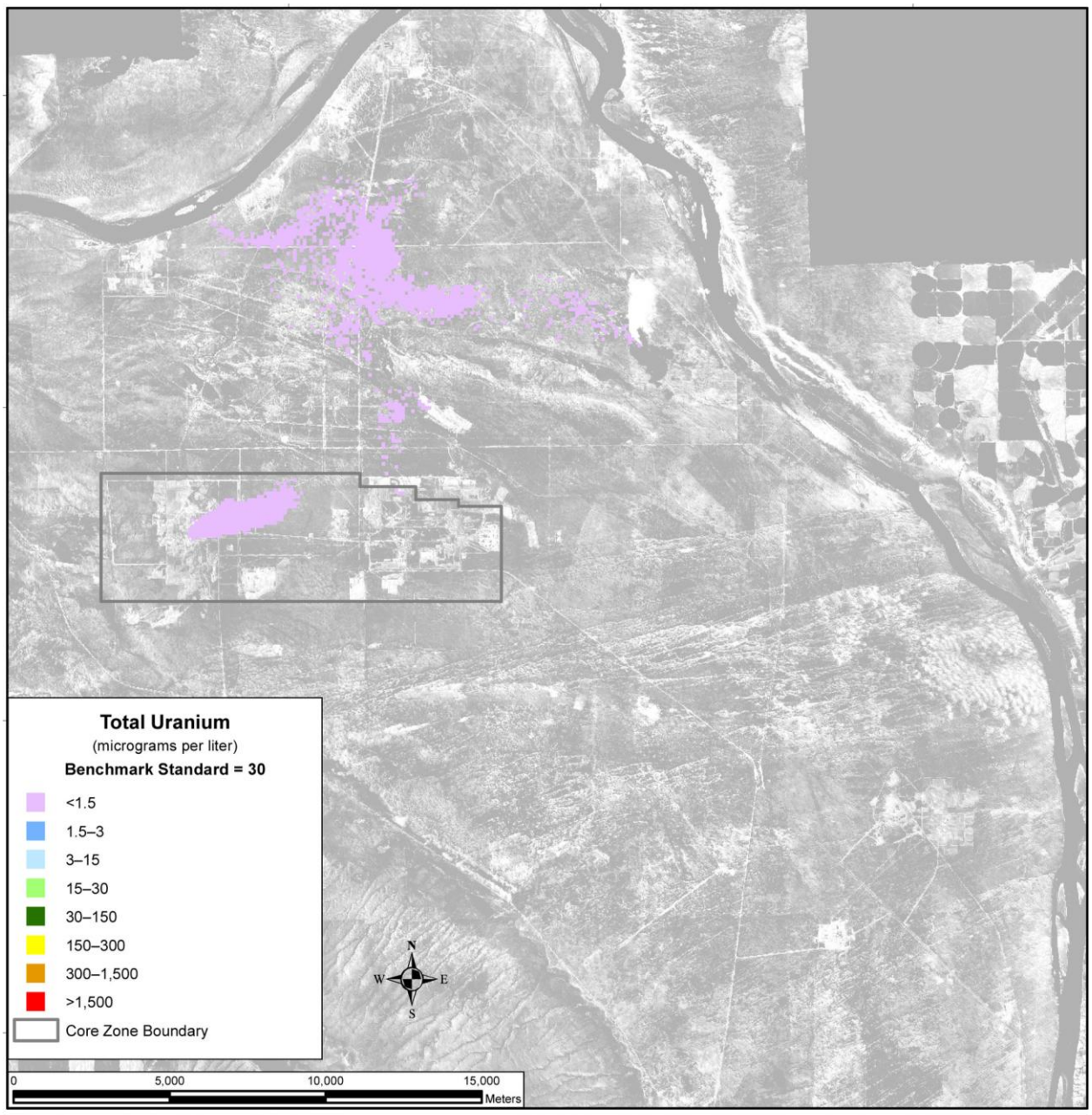
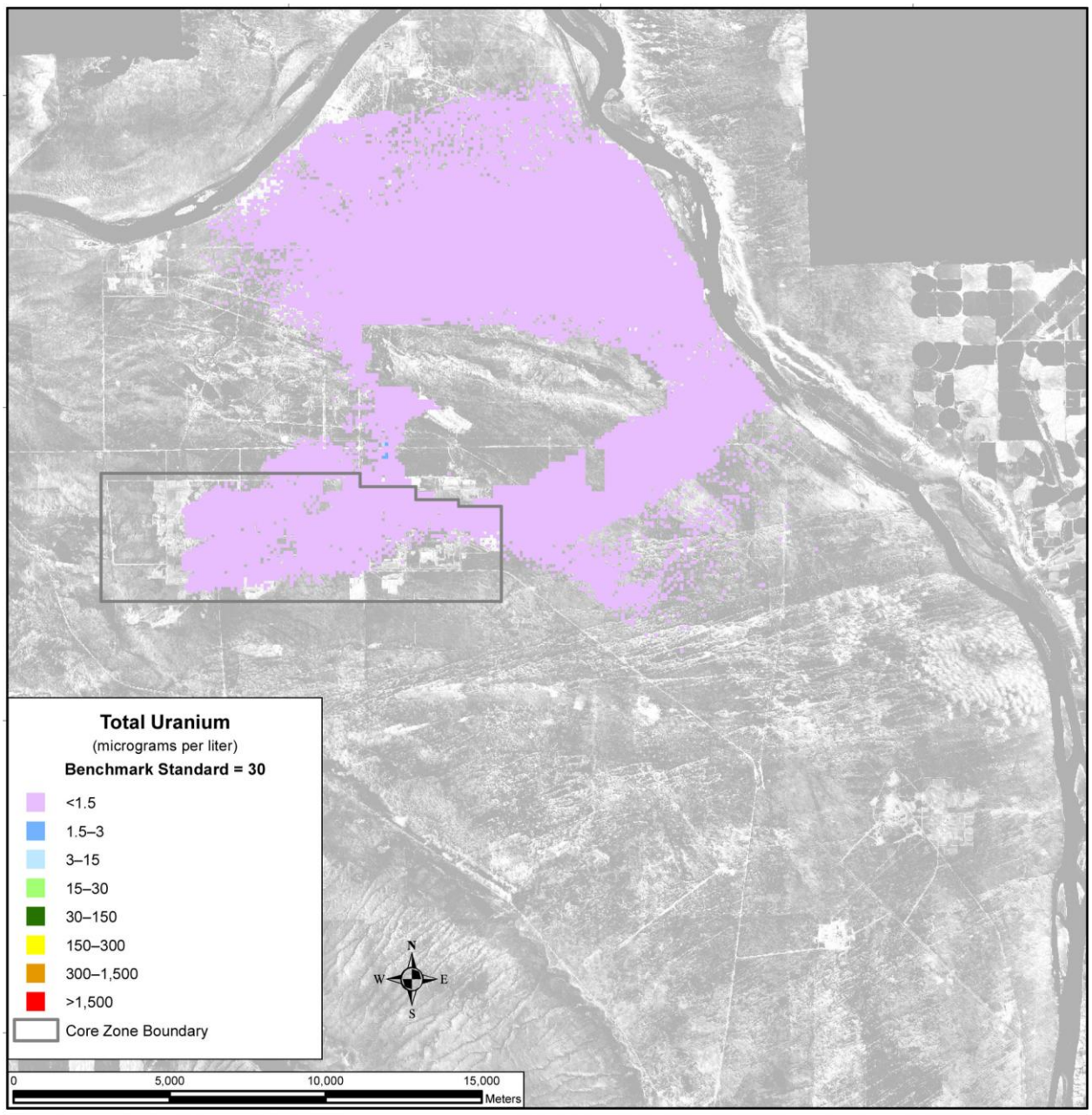


Figure 5–1237. Alternative Combination 2 Total Area of Groundwater Uranium-238 Concentration Exceeding the Benchmark Concentration as a Function of Time



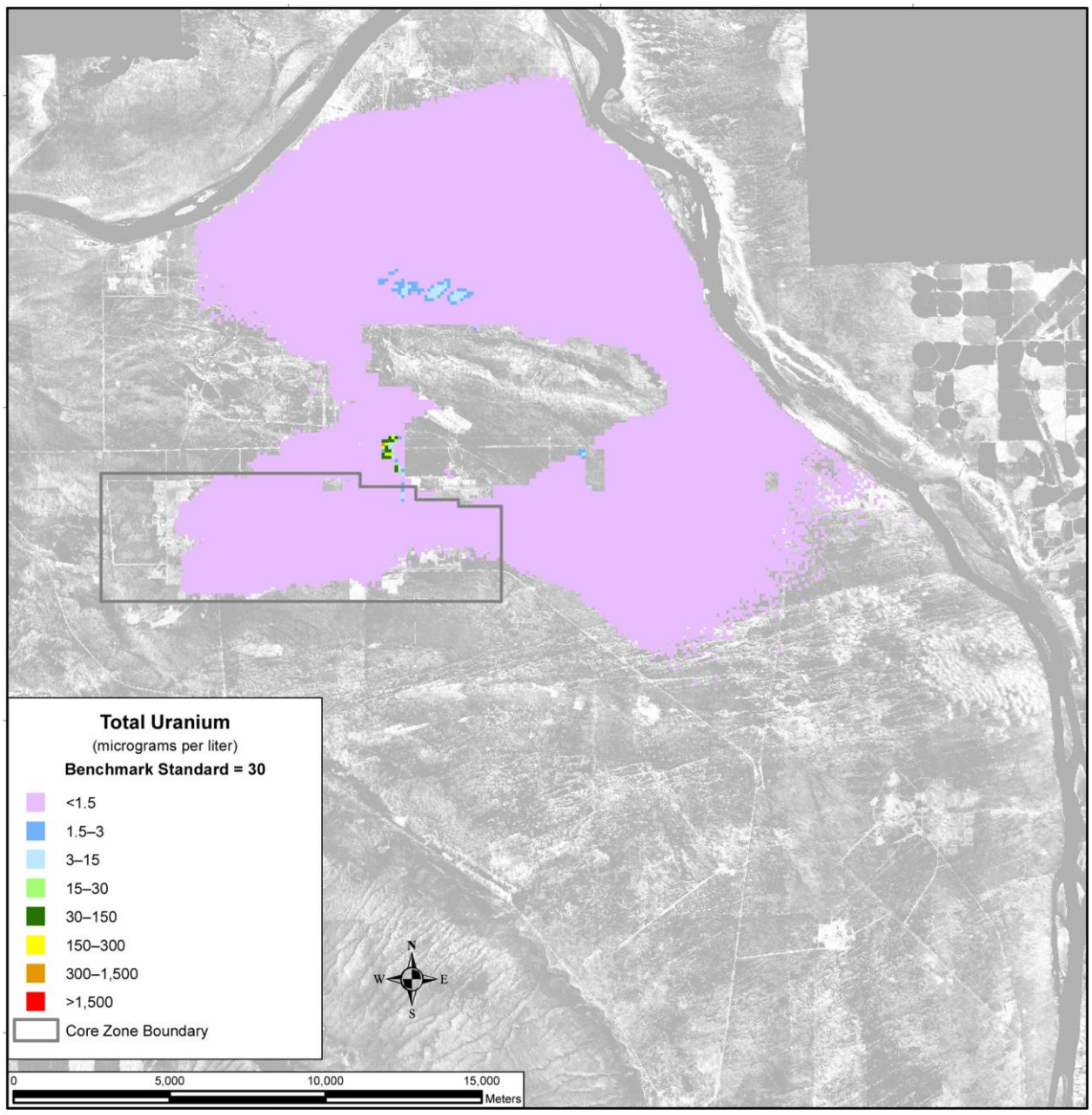
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1238. Alternative Combination 2 Spatial Distribution of Groundwater Total Uranium Concentration, Calendar Year 2135



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

Figure 5–1239. Alternative Combination 2 Spatial Distribution of Groundwater Total Uranium Concentration, Calendar Year 7140



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

Figure 5–1240. Alternative Combination 2 Spatial Distribution of Groundwater Total Uranium Concentration, Calendar Year 11,885

SUMMARY OF IMPACTS

The long-term impacts of Alternative Combination 2 are dominated by tank farm sources for tritium, uranium-238, chromium, nitrate, and total uranium. Initially, the dominant contributors of iodine-129 and technetium-99 are tank farm sources; then, from around CY 6000 throughout the remainder of the analysis period, waste management sources, particularly offsite waste disposed of in IDF-East, become the dominant contributors. Contributions from FFTF Decommissioning Alternative 2 sources account for well below 1 percent of the total amount released to the environment.

For tritium, concentrations at the Core Zone Boundary exceed the benchmark by one to two orders of magnitude during the first 100 years of the period of analysis. Concentrations at the Columbia River

nearshore approach but do not exceed the benchmark concentration during this time. Attenuation by radioactive decay is the predominant mechanism that limits the intensity and duration of groundwater impacts of tritium. After CY 2100, tritium impacts are essentially negligible.

For the conservative tracers, concentrations at the Core Zone Boundary exceed benchmark standards by one to two orders of magnitude during the early part of the period of analysis and then gradually decline and remain below the benchmark standards throughout the remainder of the period of analysis. Concentrations at the Columbia River nearshore are significantly lower. For chromium and nitrate, the concentration trend decreases with time past CY 6000. For iodine-129 and technetium-99, the concentration trend is relatively level with respect to time, and concentrations are within an order of magnitude of the benchmark concentration at both the Core Zone Boundary and the Columbia River nearshore from around CY 6000 to CY 9000. The intensities are highest and the areas of these groundwater plumes largest during the early and later parts of the period of analysis.

For uranium-238 and total uranium, limited mobility is an important factor governing the timeframe and scale of groundwater impacts. The concentrations of uranium-238 and total uranium rise to two to three orders of magnitude below the benchmark concentration at the Core Zone Boundary during the early part of the period of analysis and then gradually rise to within less than an order of magnitude below the benchmark concentration by the end of the period of analysis. Concentrations at the Columbia River nearshore gradually rise, peaking at two to three orders of magnitude below the benchmark concentration at the end of the period of analysis. The intensity is highest and the area of the contamination plume largest near the end of the period of analysis.

5.4.1.3 Alternative Combination 3

This section describes the results of the long-term groundwater impacts analysis for Alternative Combination 3, which comprises Tank Closure Alternative 6B, Base Case; FFTF Decommissioning Alternative 2; and Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case. The focus is the combined long-term groundwater impacts of these alternatives. More-detailed discussion of the individual impacts is provided in Sections 5.1.1, 5.2.1, and 5.3.1.

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

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

The COPC drivers were obtained from the combination of the COPC drivers for the three individual alternatives that compose the alternative combination. They fall into three categories. Iodine-129, technetium-99, chromium, and nitrate are all mobile (i.e., move with groundwater) and long-lived (relative to the 10,000-year period of analysis), or stable. They are essentially conservative tracers. Tritium is also mobile, but short-lived. The half-life of tritium is 13 years, and tritium concentrations are strongly attenuated by radioactive decay during travel through the vadose zone and groundwater systems. Finally, uranium-238 and total uranium are long-lived, or stable, but are not as mobile as the other COPC drivers. These constituents move about seven times more slowly than groundwater. The other COPCs that were analyzed do not significantly contribute to risk or hazard during the period of analysis because of limited inventory, limited rates of release (i.e., retention in waste form), high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of these factors.

ANALYSIS OF RELEASE AND MASS BALANCE

This section presents the impacts of Alternative Combination 3 in terms of the total amount of COPCs released to the vadose zone, groundwater, and the Columbia River during the 10,000-year period of analysis. Releases of radionuclides are totaled in curies; chemicals, in kilograms.

Table 5–182 lists the release of the COPC drivers to the vadose zone. Under Alternative Combination 3, the release to the vadose zone is controlled by a combination of inventory and waste form. For tank closure and FFTF decommissioning sources, the entire inventory is released to the vadose zone during the period of analysis. For some waste management sources (e.g., PPF glass), some of the inventory is not released to the vadose zone during the 10,000-year period of analysis because of retention in the waste form. The release to the vadose zone under Alternative Combination 3 is dominated by sources associated with Tank Closure Alternative 6B, Base Case, for chromium, nitrate, and total uranium. For these COPC drivers, releases from FFTF decommissioning and waste management sources account for less than 30 percent of the total. For tritium, both tank closure sources and waste management sources contribute significantly to release to the vadose zone. For iodine-129, technetium-99, and uranium-238, releases to the vadose zone are dominated by waste management sources. Refer to Appendix M, "Release to Vadose Zone," for detailed information regarding the specific sources and corresponding mass released.

Table 5–182. Alternative Combination 3 Releases of COPC Drivers to Vadose Zone

Alternative	Radioactive COPCs (curies)				Chemical COPCs (kilograms)		
	Hydrogen-3 (Tritium)	Iodine-129	Technetium-99	Uranium-238	Chromium	Nitrate	Total Uranium
Tank Closure Alternative 6B, Base Case	4.57×10^{4}	7.46×10^{-1}	4.05×10^{2}	2.10×10^{1}	9.04×10^{4}	2.55×10^{7}	2.19×10^{4}
FFTF Decommissioning Alternative 3	2.96×10^{-6}	0	4.52×10^{-6}	0	0	0	0
Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case	5.94×10^{4}	5.25	2.19×10^{3}	3.58×10^{2}	6.39×10^{3}	9.45×10^{6}	9.92×10^{3}
Total	$\mathbf{1.05\times10^{5}}$	**6.00**	$\mathbf{2.60\times10^{3}}$	$\mathbf{3.79\times10^{2}}$	$\mathbf{9.68\times10^{4}}$	$\mathbf{3.50\times10^{7}}$	$\mathbf{3.19\times10^{4}}$

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

Table 5–183 lists the release of the COPC drivers to groundwater. In addition to the inventory and waste form considerations discussed in the previous paragraph and Appendix M, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. Note that delayed release to the vadose zone (i.e., retention in the waste form) can enhance retention in the vadose zone because contaminant mass released into the vadose zone near the end of the 10,000-year period of analysis may not reach the water table. For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), the amount released to groundwater ranges from 75 to 100 percent of 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 30 percent of the tritium released to the vadose zone reaches the unconfined aquifer. For uranium-238 and total uranium, the amount released to groundwater is lower than that released to the vadose zone because of retardation. Less than 1 percent of the uranium-238 and total uranium released to the vadose zone reaches the unconfined aquifer during the period of analysis.

Table 5–183. Alternative Combination 3 Releases of COPC Drivers to Groundwater

Alternative	Radioactive COPCs (curies)				Chemical COPCs (kilograms)		
	Hydrogen-3 (Tritium)	Iodine-129	Technetium-99	Uranium-238	Chromium	Nitrate	Total Uranium
Tank Closure Alternative 6B, Base Case	3.12×10^{4}	6.56×10^{-1}	3.66×10^{2}	5.83×10^{-1}	9.21×10^{4}	2.62×10^{7}	2.02×10^{2}
FFTF Decommissioning Alternative 3	1.91×10^{-7}	0	4.54×10^{-6}	0	0	0	0
Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case	0	3.72	1.93×10^{3}	4.83×10^{-6}	6.37×10^{3}	9.39×10^{6}	1.36×10^{-2}
Total	**3.12×10^{4}**	**4.37**	**2.29×10^{3}**	**5.83×10^{-1}**	**9.84×10^{4}**	**3.56×10^{7}**	**2.02×10^{2}**

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

Table 5–184 lists the release of the COPC drivers to the Columbia River. Release to the Columbia River is controlled by the transport properties of the COPC drivers. For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), the amount released to the Columbia River is essentially equal to the amount released to groundwater. For tritium, the amount released to the Columbia River is attenuated by radioactive decay. Overall, only about 1 percent of the tritium released to groundwater reaches the Columbia River. For uranium-238 and total uranium, the amount released to the Columbia River is lower than that released to groundwater because of retardation in the aquifer. Overall, about 40 percent of the amount released to groundwater during the period of analysis reaches the Columbia River.

Table 5–184. Alternative Combination 3 Releases of COPC Drivers to Columbia River

Alternative	Radioactive COPCs (curies)				Chemical COPCs (kilograms)		
	Hydrogen-3 (Tritium)	Iodine-129	Technetium-99	Uranium-238	Chromium	Nitrate	Total Uranium
Tank Closure Alternative 6B, Base Case	3.90×10^{2}	6.51×10^{-1}	3.63×10^{2}	2.26×10^{-1}	9.45×10^{4}	2.70×10^{7}	7.26×10^{1}
FFTF Decommissioning Alternative 3	0	0	4.55×10^{-6}	0	0	0	0
Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case	0	3.66	1.91×10^{3}	0	6.35×10^{3}	9.37×10^{6}	5.70×10^{-4}
Total	**3.90×10^{2}**	**4.31**	**2.28×10^{3}**	**2.26×10^{-1}**	**1.01×10^{5}**	**3.64×10^{7}**	**7.26×10^{1}**

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

ANALYSIS OF CONCENTRATION VERSUS TIME

This section presents the impacts of Alternative Combination 3 in terms of groundwater concentration versus time at the Core Zone Boundary and the Columbia River nearshore. Concentrations of radionuclides are in picocuries per liter; chemicals, in micrograms per liter (see Figures 5–1241 through 5–1247). The benchmark concentration of each radionuclide and chemical is also shown. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over five orders of magnitude. Table 5–185 lists the maximum concentrations of the COPCs in the peak year at the Core Zone Boundary and the Columbia River nearshore. The results indicate that iodine-129, nitrate, and chromium exceed their respective benchmark concentrations at both the Core Zone Boundary and Columbia River nearshore. Tritium and technetium-99 only exceed their respective benchmark concentrations at the Core Zone Boundary. The remaining COPCs do not exceed the benchmark concentrations at either boundary during the period of analysis.

Table 5–185. Alternative Combination 3 Maximum COPC Concentrations in the Peak Year at the Core Zone Boundary and Columbia River Nearshore

Contaminant	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclide (picocuries per liter)			
Hydrogen-3 (tritium)	**672,000** (1956)	10,700 (1964)	20,000
Technetium-99	**33,700** (1956)	844 (1965)	900
Iodine-129	**42.3** (1956)	**1.1** (1964)	1
Uranium-238	0.2 (11,835)	0.1 (11,935)	15
Chemical (micrograms per liter)			
Chromium	**6,150** (1955)	**228** (2019)	100
Nitrate	**2,120,000** (1956)	**72,300** (1964)	45,000
Total uranium	0.2 (11,754)	0.02 (11,852)	30

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

Figure 5–1241 shows concentration versus time for tritium. Note that for visual clarity, the time period shown in this figure is from CY 1940 through CY 2440 rather than the full 10,000-year period of analysis. 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, the result of the past releases from cribs and trenches (ditches). From about CY 1956 to CY 1980, groundwater concentrations at the Columbia River nearshore peak at less than an order of magnitude lower than the benchmark concentration. The later broad inflection occurring around CY 1990 represents tritium from past tank leaks. Because the half-life of tritium is less than 13 years, radioactive decay rapidly attenuates groundwater concentration, and tritium is essentially not a factor at times later than CY 2100. In addition, the retrieval of waste from the SSTs and removal of contaminated soil during clean closure has significantly reduced the tritium concentrations associated with releases from the tank residuals relative to Alternative Combinations 1 and 2.

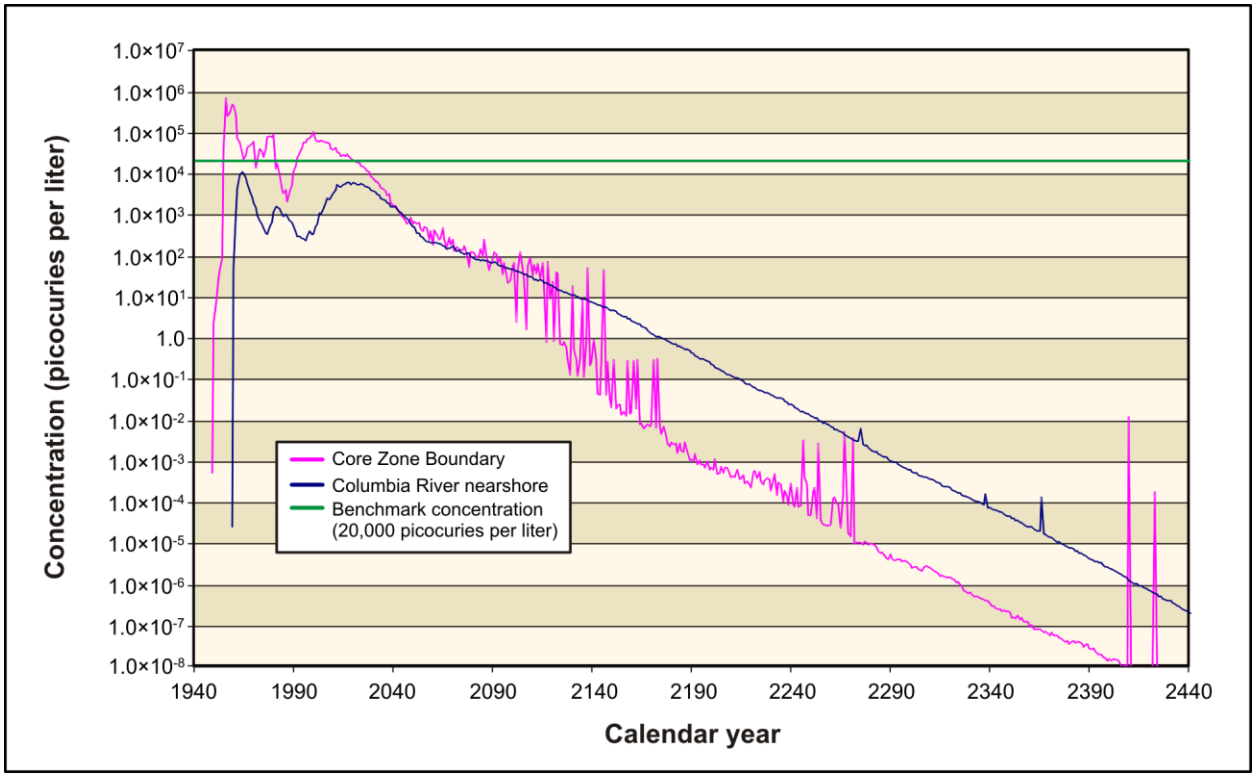


Figure 5–1241. Alternative Combination 3 Hydrogen-3 (Tritium) Concentration Versus Time

Figures 5–1242 and 5–1243 show concentration versus time for chromium and nitrate, the conservative tracers that are not affected by retention in the waste forms. Chromium and nitrate concentrations in groundwater peak in the beginning of the analysis period, around CY 1956, because of the releases from cribs and trenches (ditches), and exceed benchmark concentrations at the Core Zone Boundary by about two orders of magnitude. Concentrations at the Core Zone Boundary remain above the benchmark concentration during the first few hundred years of the analysis, until around CY 2300, at which time they decline to below the benchmark concentration and remain so throughout the remainder of the period of analysis. The broad characteristic part of the curve above the benchmark concentration representative of release from tank residuals under Alternative Combination 1 has been partially attenuated and shifted to later times under Alternative Combination 3 because of the actions implicit in Waste Management Alternative 2. Groundwater concentrations at the Columbia River nearshore present a similar pattern but with lower concentration levels. Both chromium and nitrate exceed the benchmark concentration at the Columbia River nearshore by less than an order of magnitude in the beginning of the analysis period. During later times in the analysis, the concentrations at the Core Zone Boundary and Columbia River nearshore are below the benchmark by about one and two orders of magnitude, respectively.

For iodine-129 and technetium-99, the behavior during the first 4,000 years is similar to that of chromium and nitrate (see Figures 5–1244 and 5–1245). After CY 6000, the effects of delayed release from waste management sources are seen, causing concentrations to rise at both the Core Zone Boundary and the Columbia River nearshore. The post-CY 6000 concentrations of both iodine-129 and technetium-99 rise to within less than an order of magnitude of, but never exceed, the benchmark concentrations at the Core Zone Boundary and Columbia River nearshore.

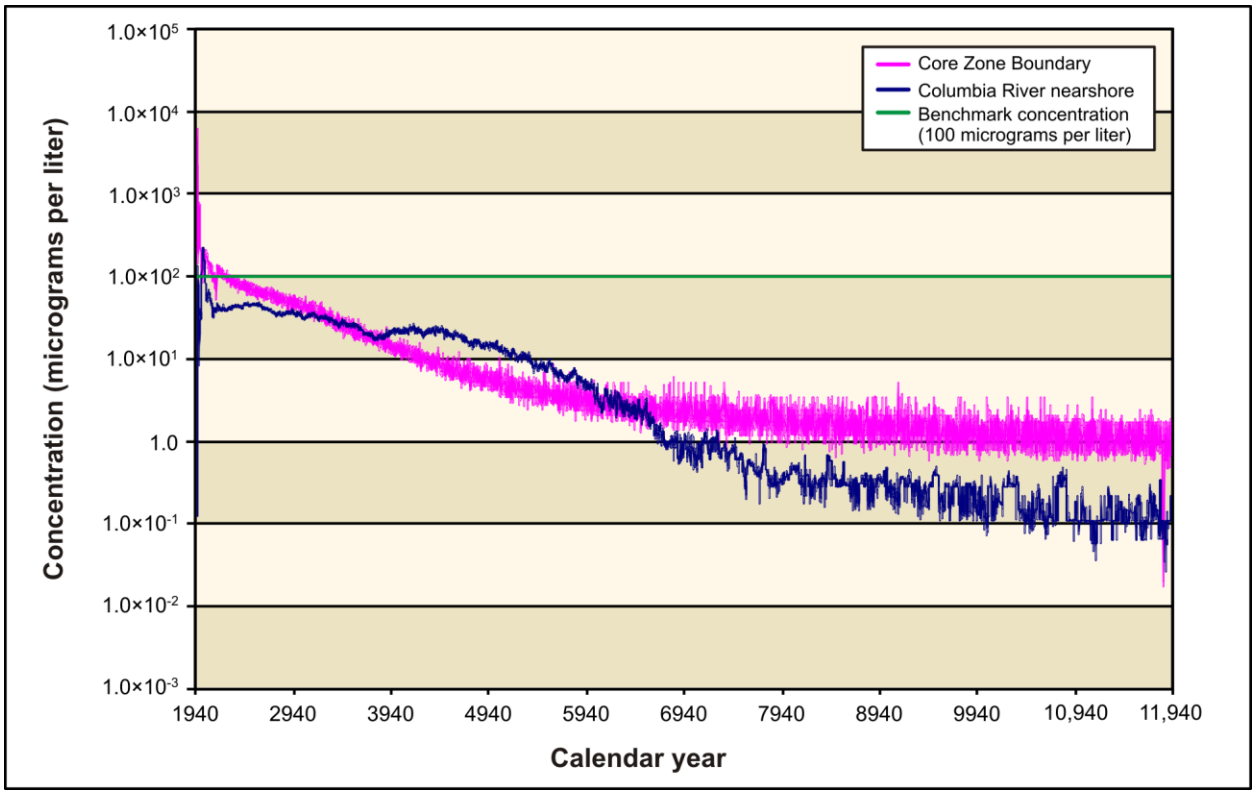


Figure 5–1242. Alternative Combination 3 Chromium Concentration Versus Time

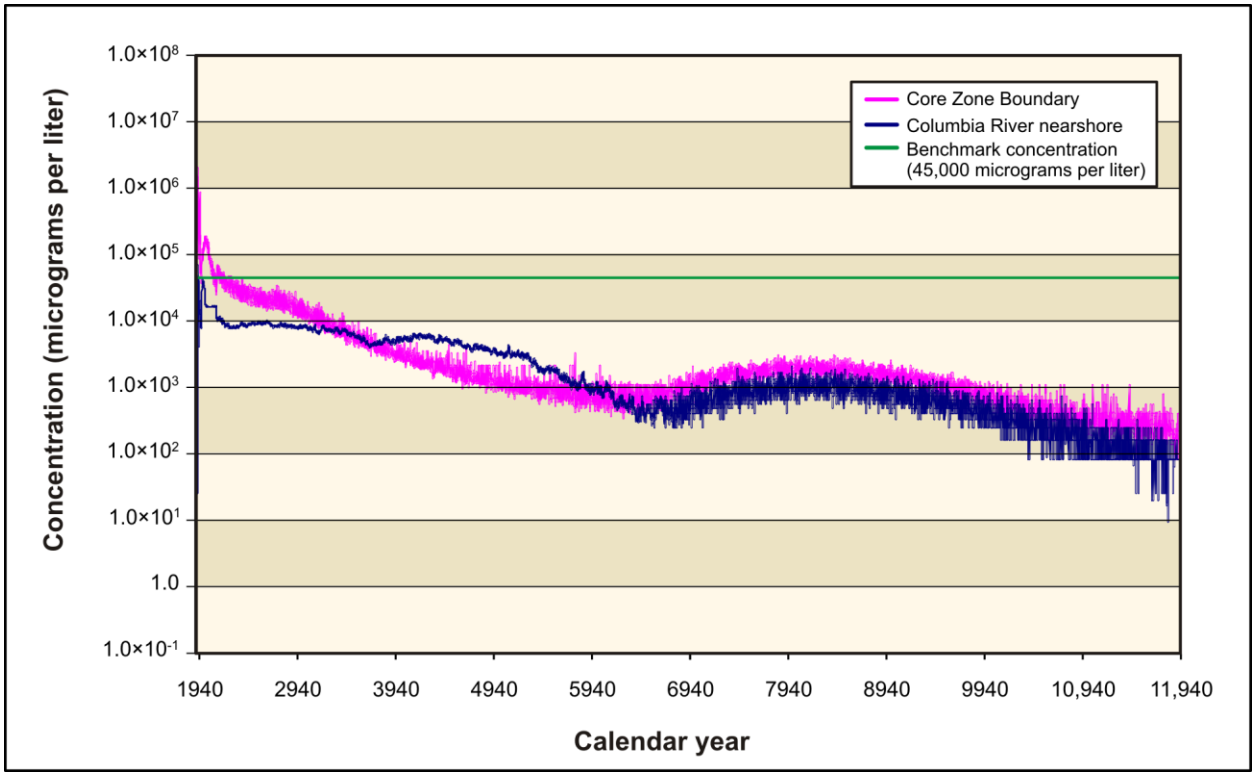


Figure 5–1243. Alternative Combination 3 Nitrate Concentration Versus Time

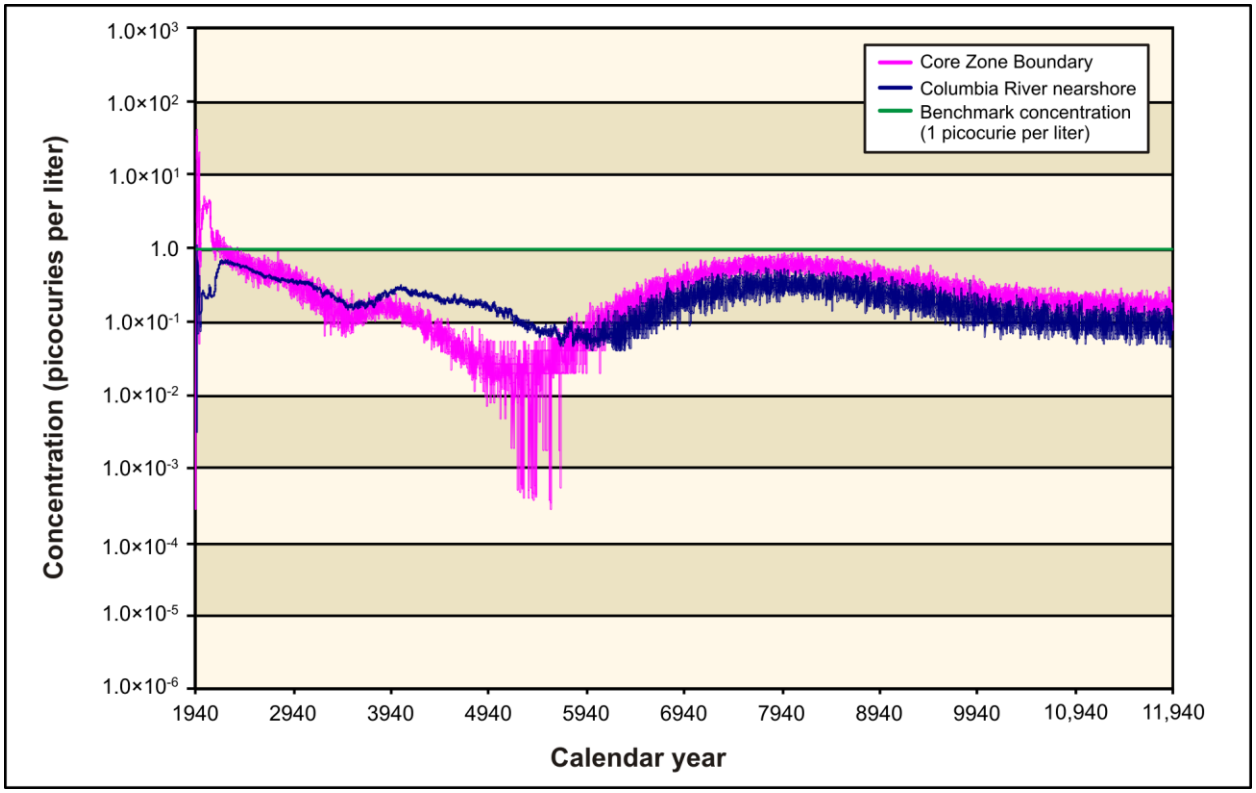


Figure 5–1244. Alternative Combination 3 Iodine-129 Concentration Versus Time

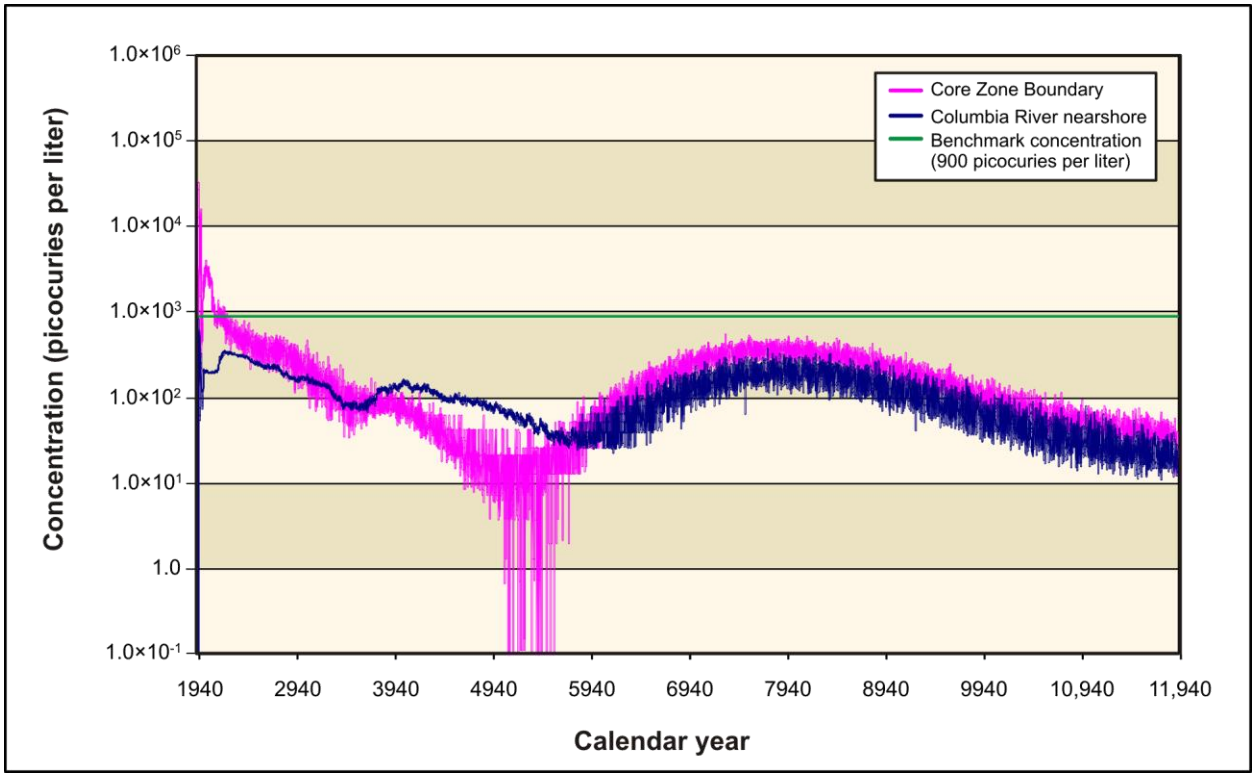


Figure 5–1245. Alternative Combination 3 Technetium-99 Concentration Versus Time

Figures 5–1246 and 5–1247 show concentration versus time for uranium-238 and total uranium. Early releases from cribs and trenches (ditches) and past tank leaks result in groundwater concentrations that are about two orders of magnitude lower than the benchmark concentrations at the Core Zone Boundary. After these initial peaks, concentrations at the Core Zone Boundary and Columbia River nearshore remain at four to five orders of magnitude below the benchmark concentrations for several thousand years. Around CY 4000, the concentrations begin to increase, steadily rising throughout the remainder of the analysis period. The travel times of these COPCs from the source locations to the Core Zone Boundary and Columbia River nearshore are retarded relative to the conservative tracers by a factor of about seven. At the end of the analysis period, concentrations of both uranium-238 and total uranium are within about two orders of magnitude of the benchmark concentrations at the Core Zone Boundary but never exceed the benchmark concentrations during the period of analysis. Groundwater concentrations at the Columbia River nearshore also rise throughout the period of analysis, but remain more than two orders of magnitude below the benchmark concentration by CY 11,940. The attenuated behavior of uranium-238 and total uranium under Alternative Combination 3 can be contrasted with the behavior under Alternative Combination 1, where both uranium-238 and total uranium exceed the benchmark concentrations at the Core Zone Boundary late in the analysis period.

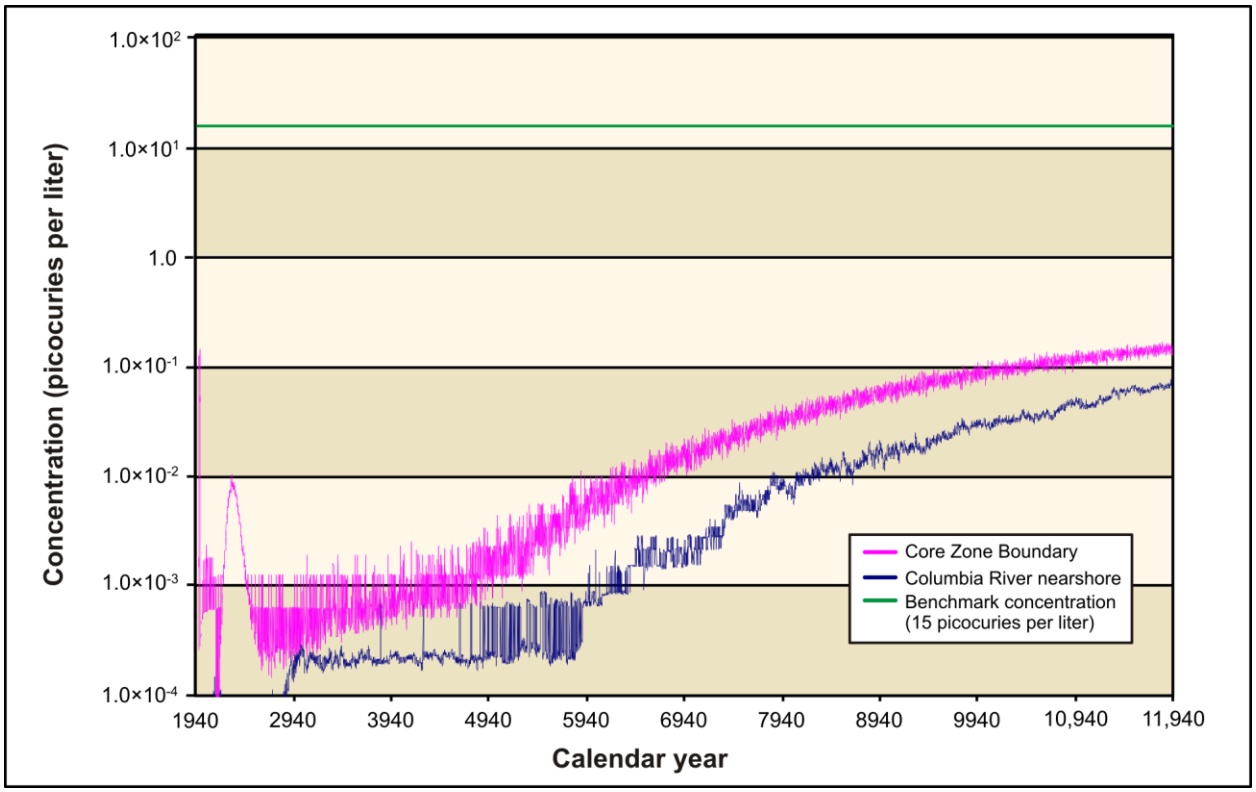


Figure 5–1246. Alternative Combination 3 Uranium-238 Concentration Versus Time

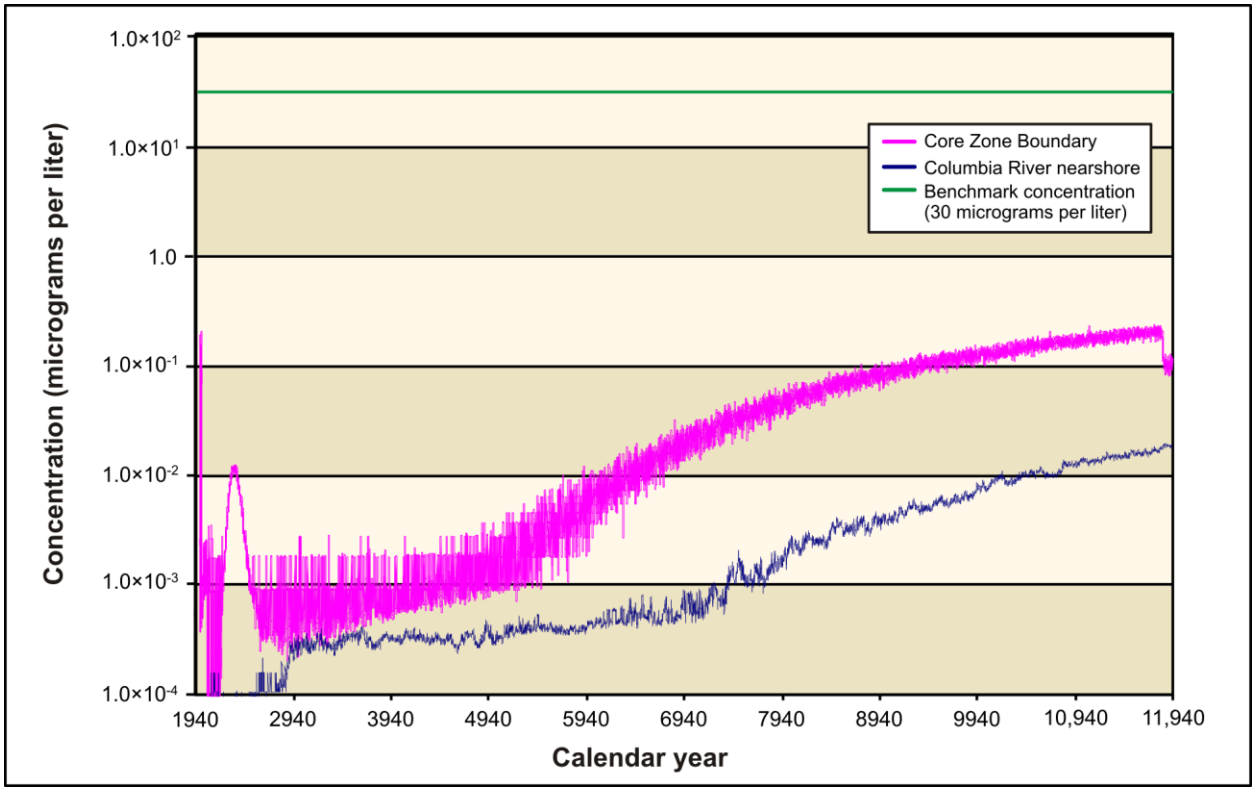
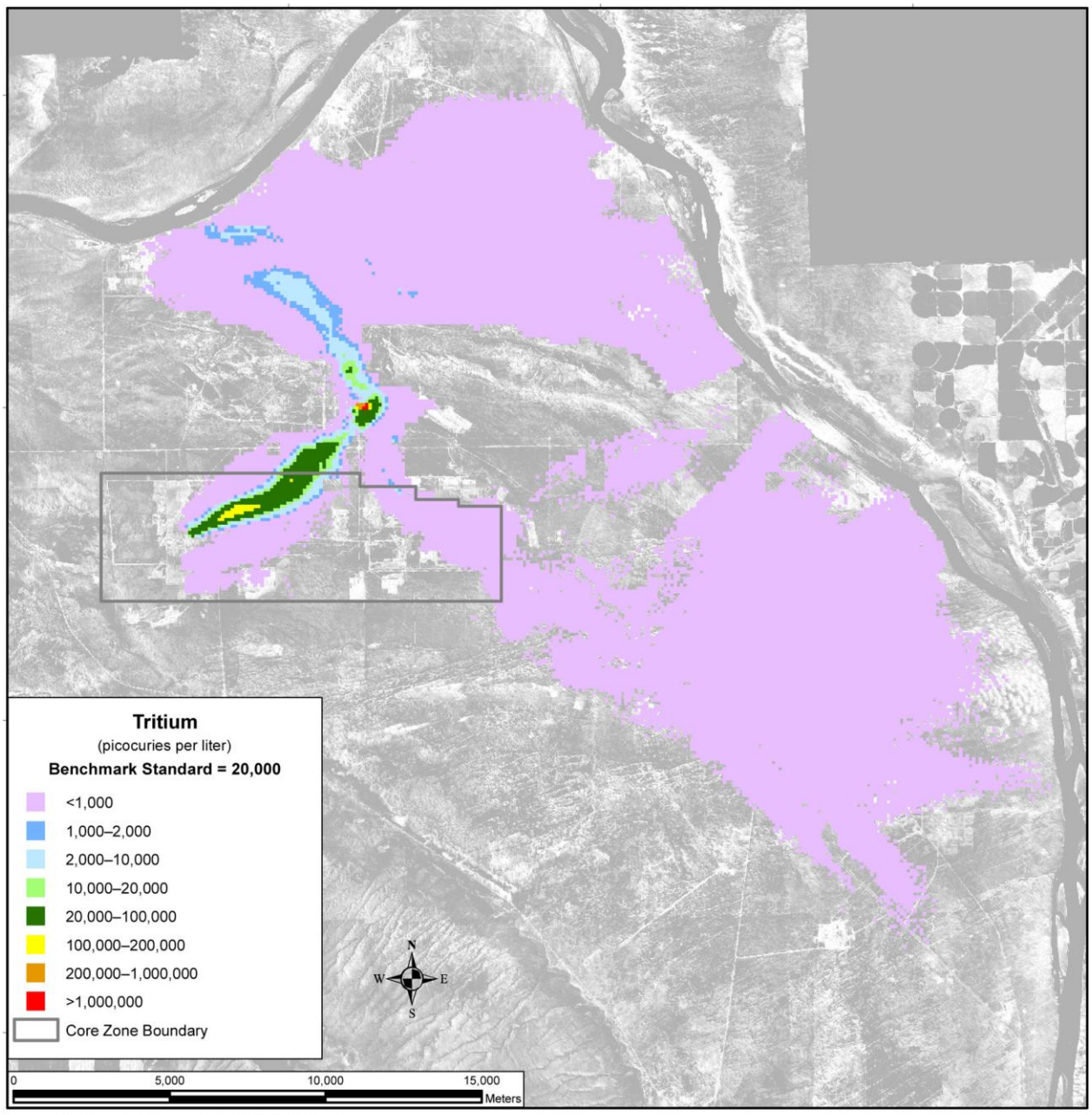


Figure 5–1247. Alternative Combination 3 Total Uranium Concentration Versus Time

ANALYSIS OF SPATIAL DISTRIBUTION OF CONCENTRATION

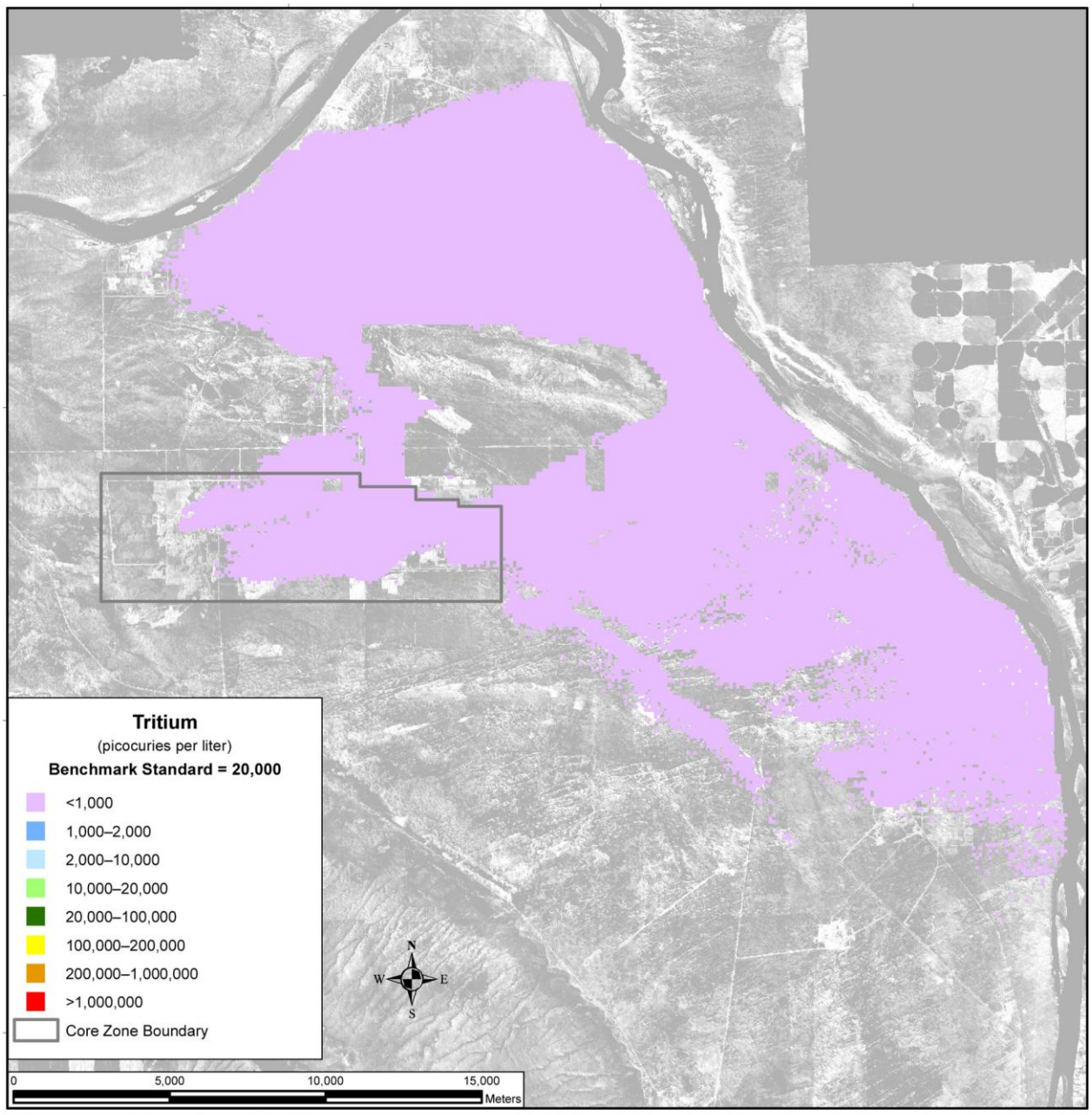
This section presents the impacts of Alternative Combination 3 in terms of the spatial distribution of COPC driver concentrations in groundwater at selected times. Concentrations of radionuclides are in picocuries per liter; chemicals, in micrograms per liter. Concentrations of each radionuclide and chemical are indicated by a color scale that is relative to the benchmark concentration. Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations less than the benchmark concentration are indicated by the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude.

Figure 5–1248 shows the spatial distribution of tritium concentrations in groundwater in CY 2010. Releases from cribs and trenches (ditches) and past leaks, associated primarily with the T, TX, and TY tank farms, result in a groundwater concentration plume (exceeding the benchmark concentration) that extends from the center part of the 200-West Area northeast, crosses the Core Zone Boundary, and continues toward Gable Gap. Peak concentrations in this plume are about 5 to 10 times greater than the benchmark. By CY 2135, the tritium plume has diminished to levels less than one-twentieth of the benchmark concentration (see Figure 5–1249).



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

Figure 5–1248. Alternative Combination 3 Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration, Calendar Year 2010

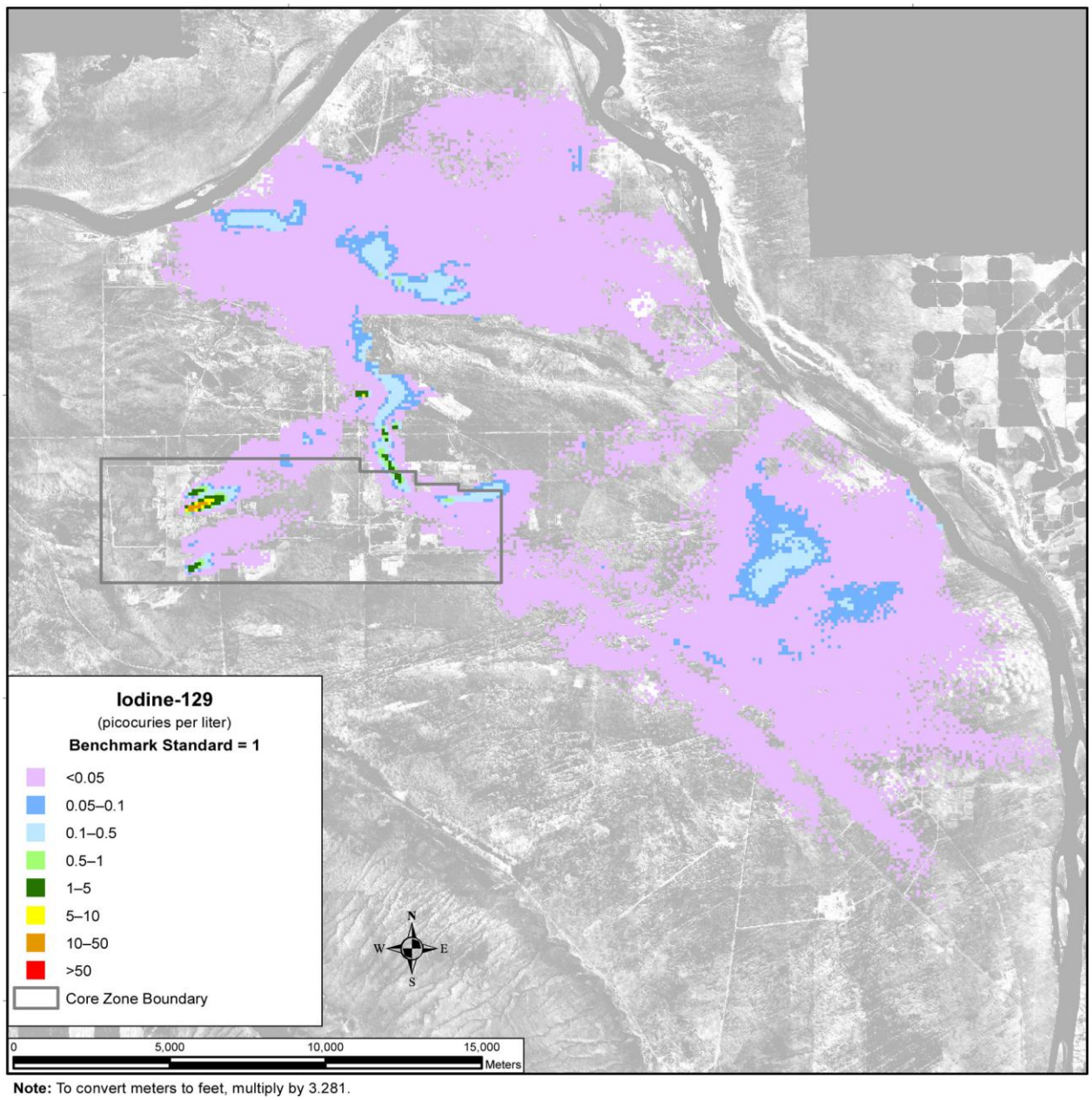


Note: To convert meters to feet, multiply by 3.281.

Figure 5–1249. Alternative Combination 3 Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration, Calendar Year 2135

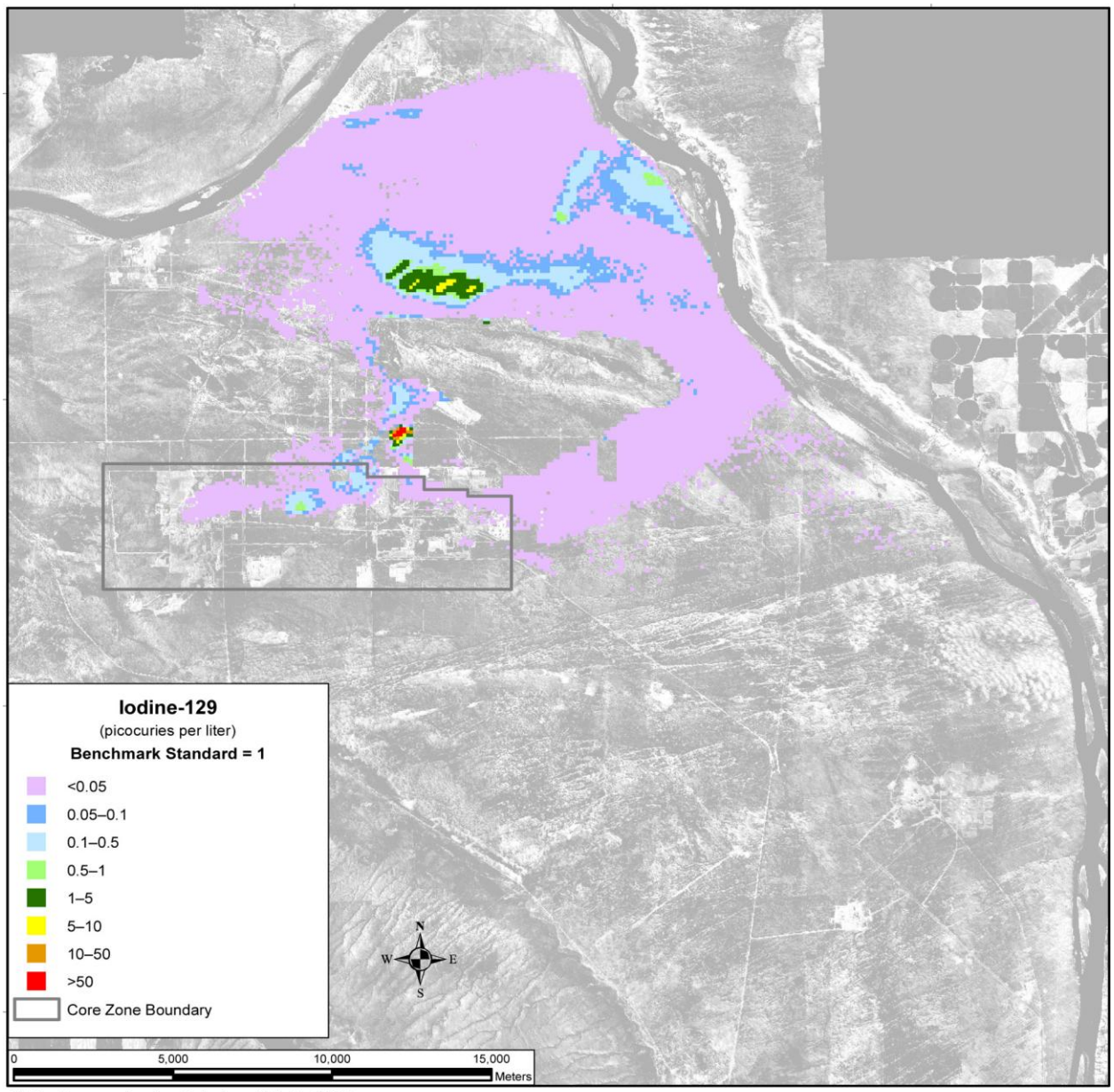
Figure 5–1250 shows the spatial distribution of iodine-129 concentrations in groundwater in CY 2010. Releases from cribs and trenches (ditches) and past leaks result in groundwater concentration plumes that exceed the benchmark concentration associated with the B, S, and T Barriers. Peak concentrations in these plumes range from about 10 to 50 times greater than the benchmark concentration and are mostly contained within the Core Zone Boundary. Around CY 3890, releases from the RPPDF create a rather small plume near the center of the Core Zone, with concentrations around the benchmark concentration (see Figure 5–1251). A comparison of this result against the corresponding distribution for Alternative Combination 1 (see Figure 5–1187) illustrates the reduction in impacts resulting from retrieval of other tank farm sources and from clean closure. By CY 7140, the groundwater concentration distribution is driven primarily by waste management sources at IDF-East (see Figure 5–1252). The impact is

characterized by a plume east of the Core Zone Boundary that exceeds the benchmark concentration by more than an order of magnitude. Because of retention in the waste forms, this impact lasts until the end of the 10,000-year period of analysis (see Figure 5–1253). Figure 5–1254 shows the total area for which iodine-129 concentrations in groundwater exceed the benchmark concentration as a function of time. Again, a comparison of this result with the corresponding distribution for Alternative Combination 1 (see Figure 5–1189) illustrates the reduction of impacts resulting from retrieval of other tank farm sources (around CY 4000), but also the increase in impacts associated with waste management sources, primarily offsite waste (around CY 9000). The other conservative tracers, technetium-99, chromium, and nitrate, show similar spatial distributions (see Figures 5–1255 through 5–1259 and 5–1261 through 5–1270). Figure 5–1260 shows the total area for which technetium-99 concentrations in groundwater exceed the benchmark concentration as a function of time.



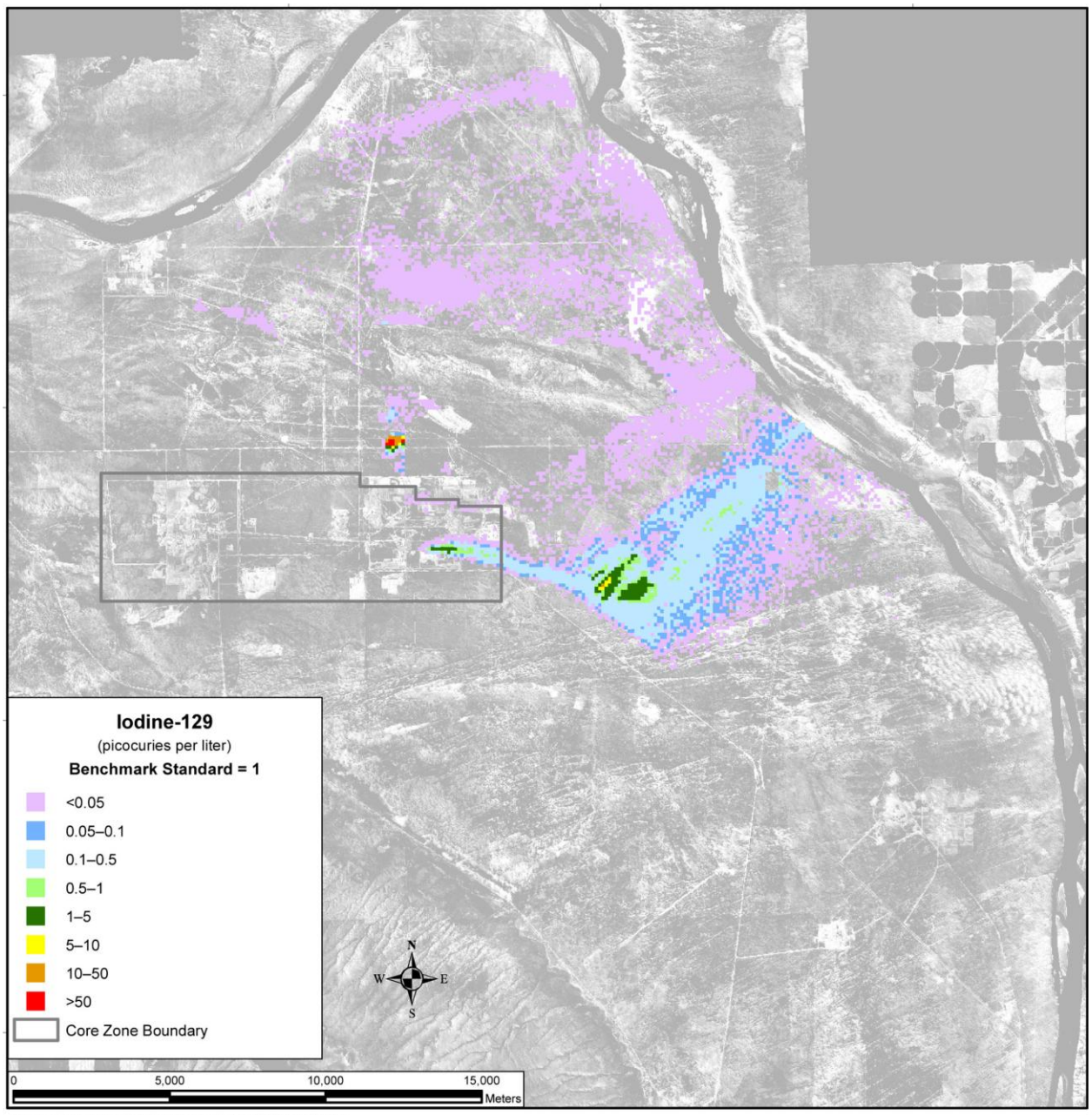
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1250. Alternative Combination 3 Spatial Distribution of Groundwater Iodine-129 Concentration, Calendar Year 2010



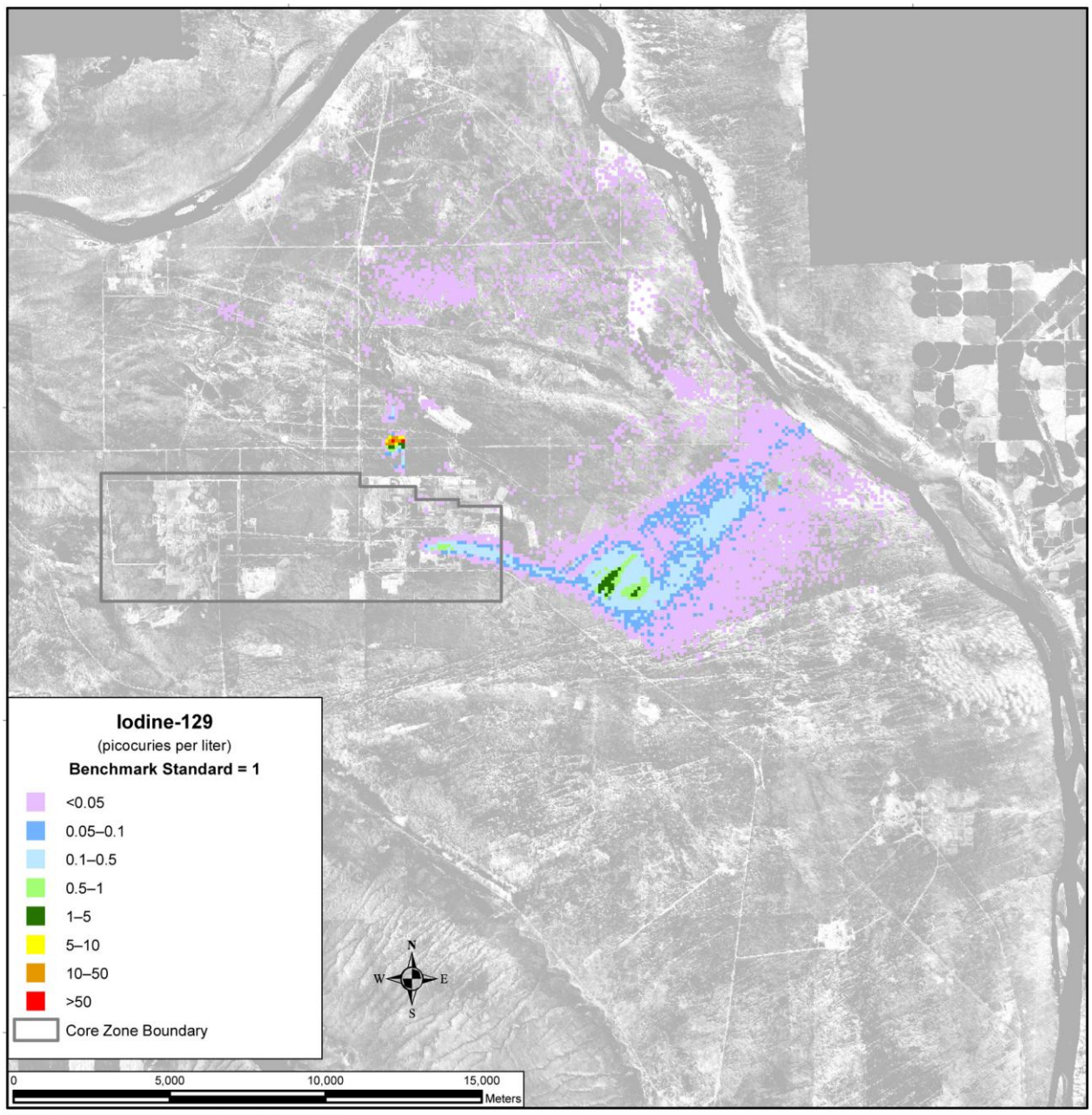
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1251. Alternative Combination 3 Spatial Distribution of Groundwater Iodine-129 Concentration, Calendar Year 3890



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

Figure 5–1252. Alternative Combination 3 Spatial Distribution of Groundwater Iodine-129 Concentration, Calendar Year 7140



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

Figure 5–1253. Alternative Combination 3 Spatial Distribution of Groundwater Iodine-129 Concentration, Calendar Year 11,885

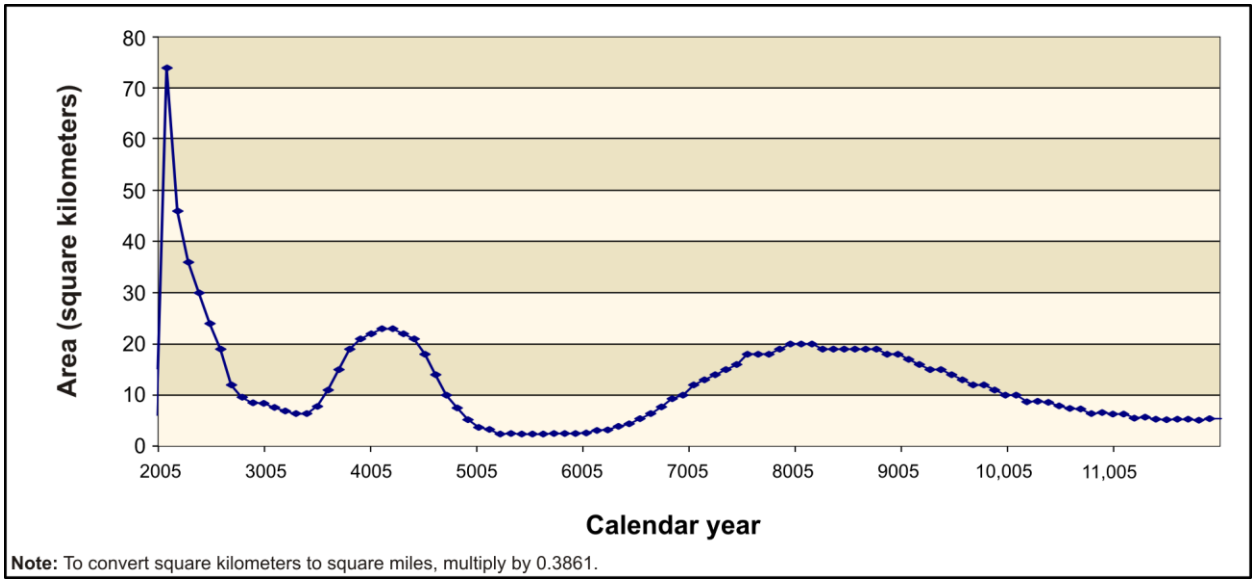
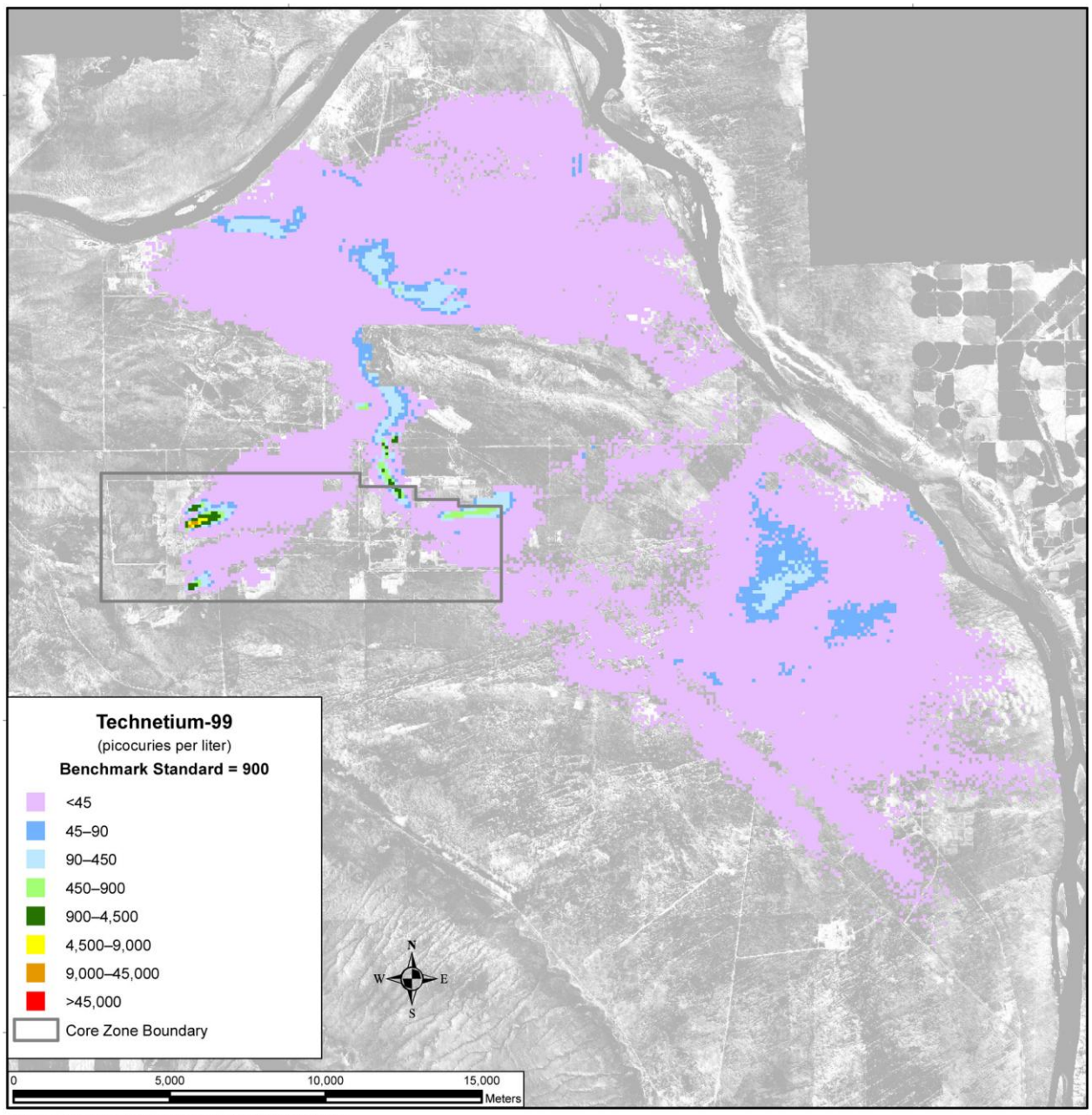
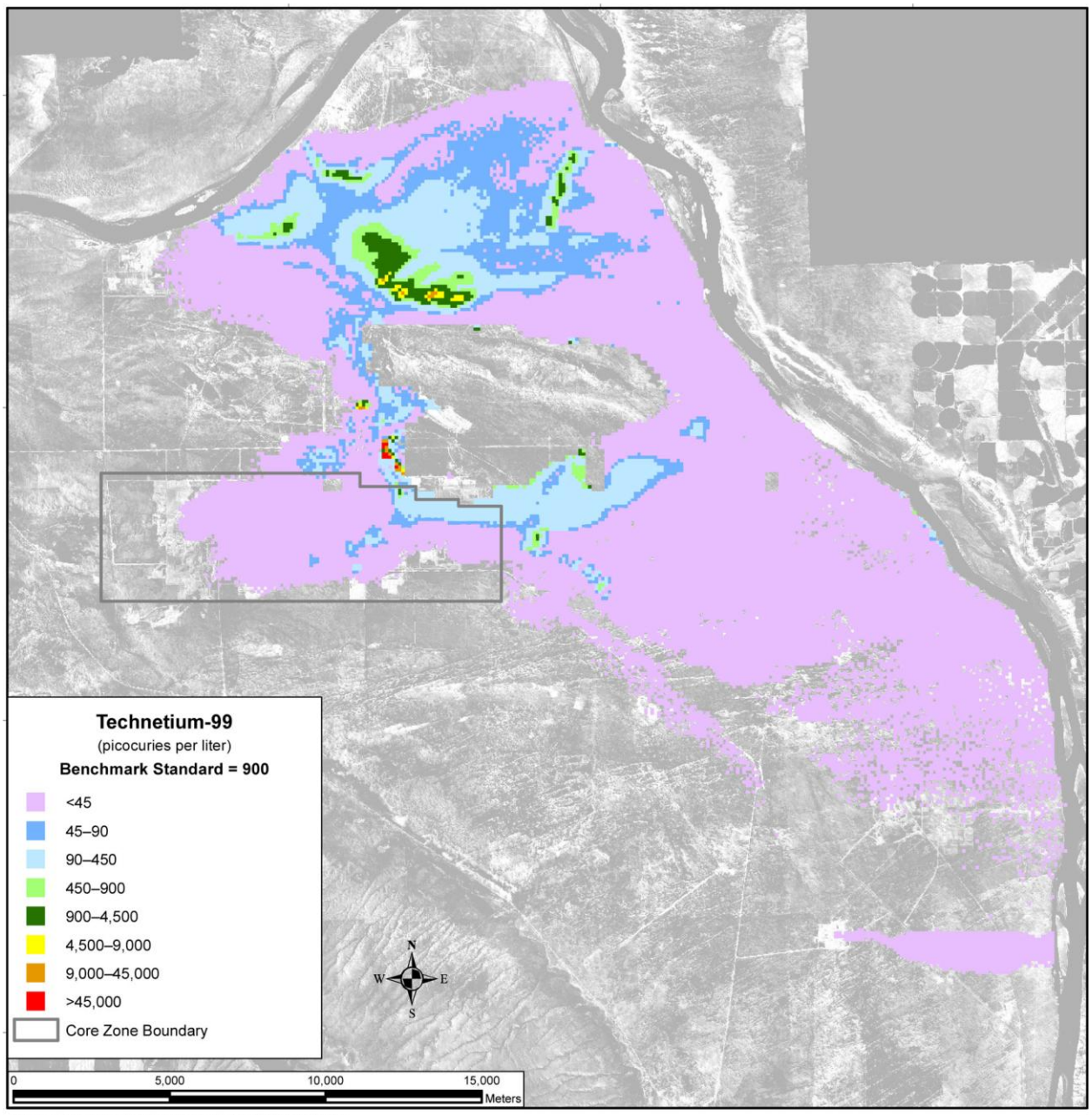


Figure 5–1254. Alternative Combination 3 Total Area of Groundwater Iodine-129 Concentration Exceeding the Benchmark Concentration as a Function of Time



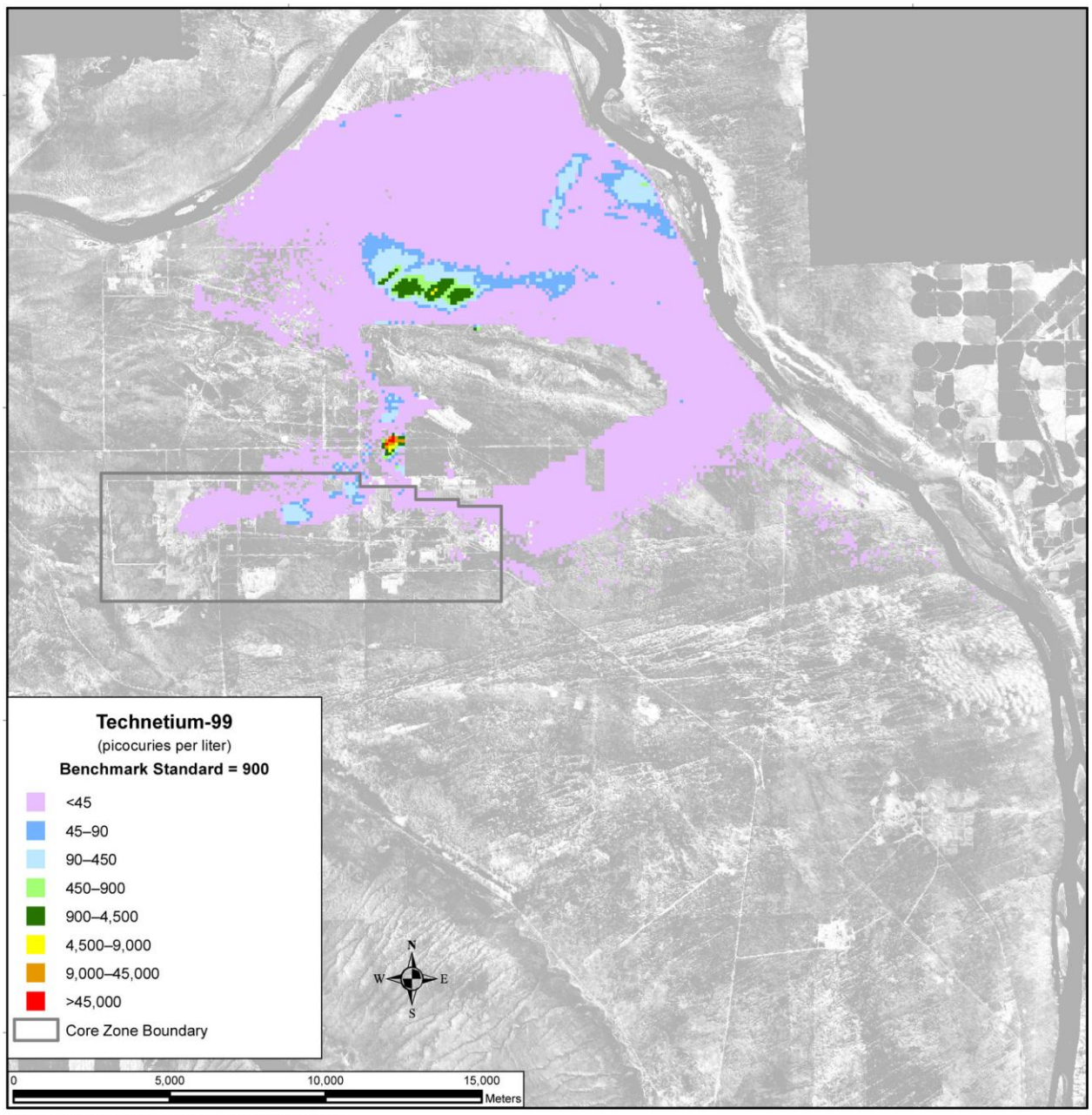
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1255. Alternative Combination 3 Spatial Distribution of Groundwater Technetium-99 Concentration, Calendar Year 2010



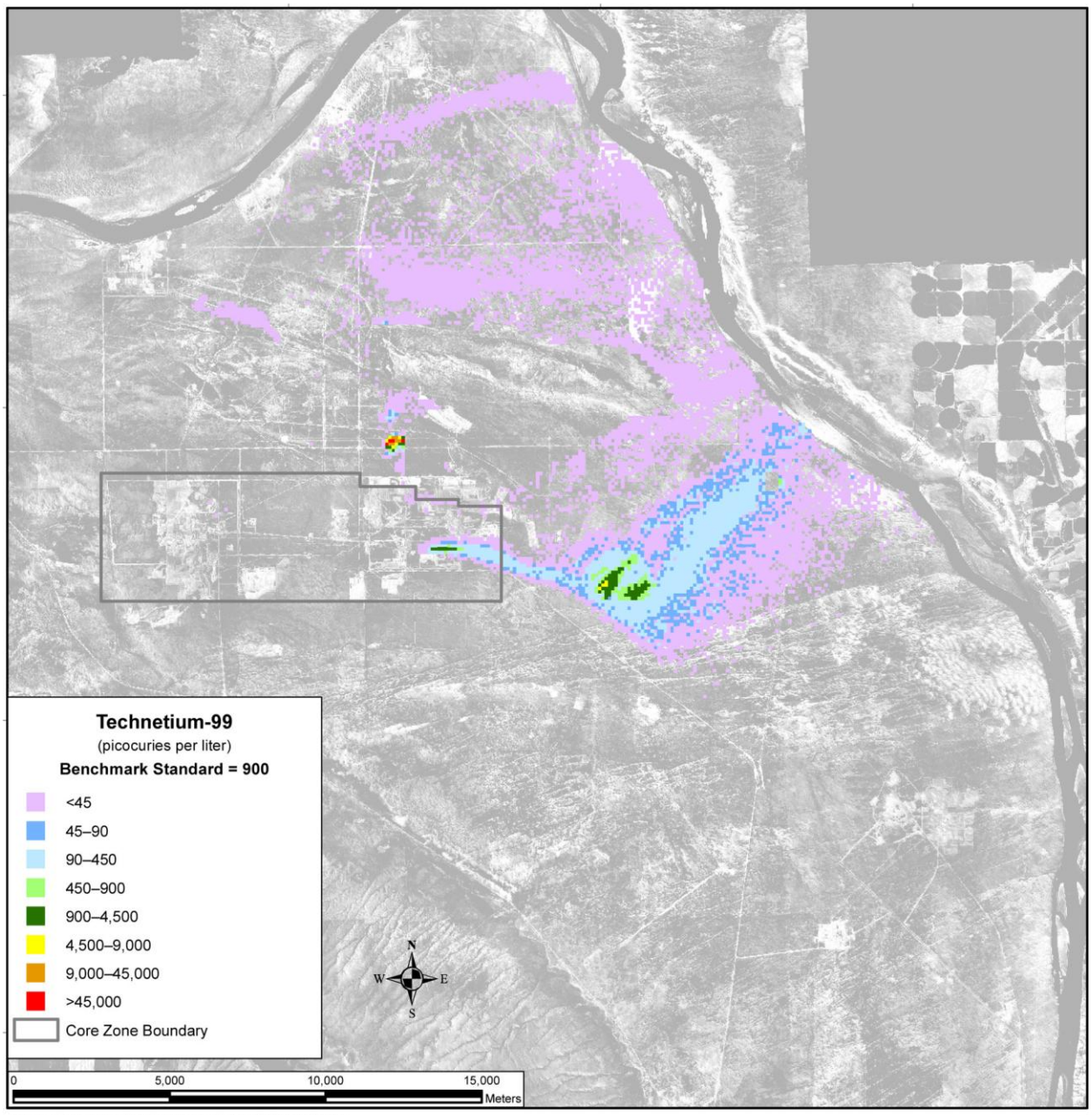
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1256. Alternative Combination 3 Spatial Distribution of Groundwater Technetium-99 Concentration, Calendar Year 2135



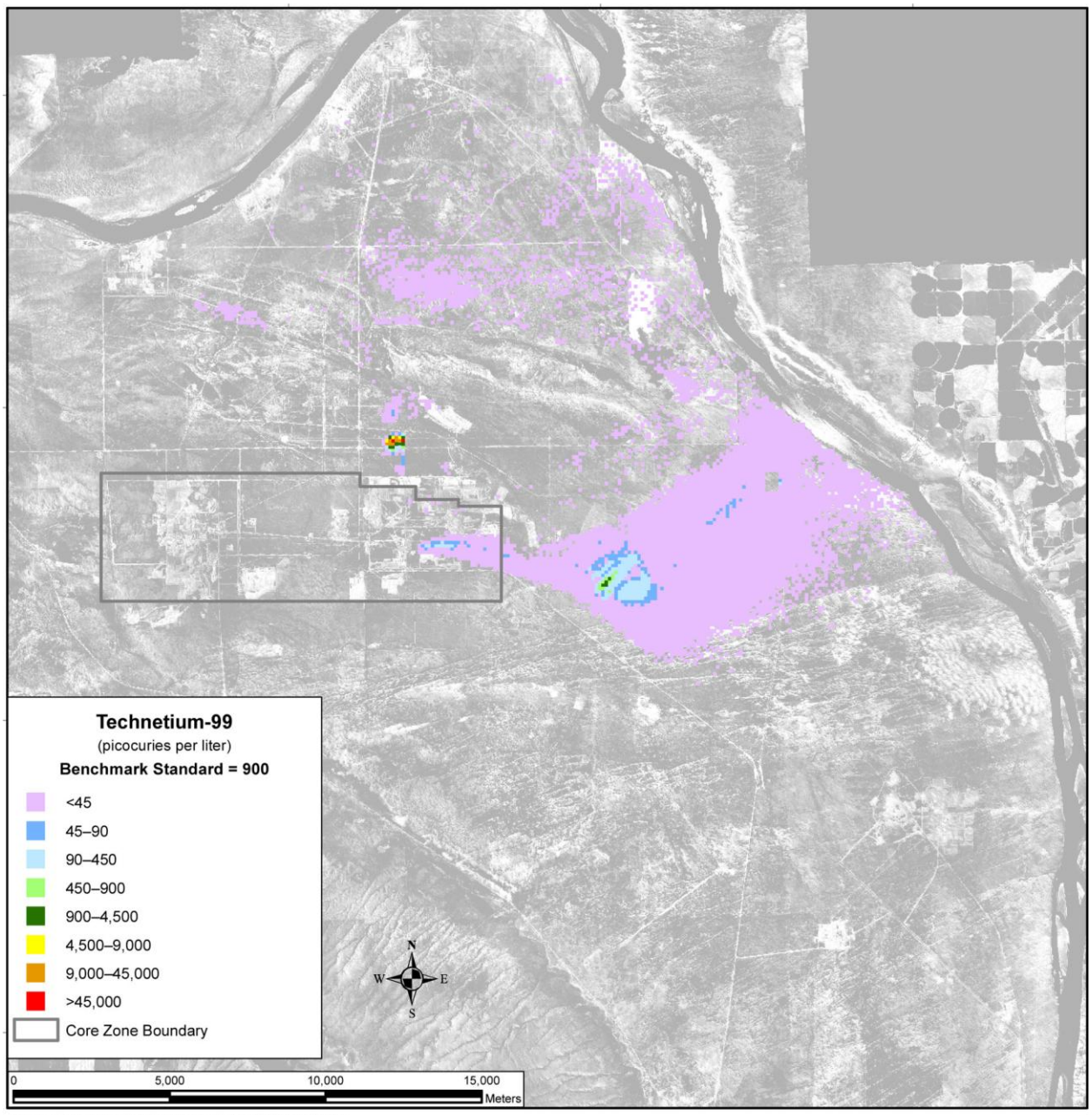
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1257. Alternative Combination 3 Spatial Distribution of Groundwater Technetium-99 Concentration, Calendar Year 3890



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

Figure 5–1258. Alternative Combination 3 Spatial Distribution of Groundwater Technetium-99 Concentration, Calendar Year 7140



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

Figure 5–1259. Alternative Combination 3 Spatial Distribution of Groundwater Technetium-99 Concentration, Calendar Year 11,885

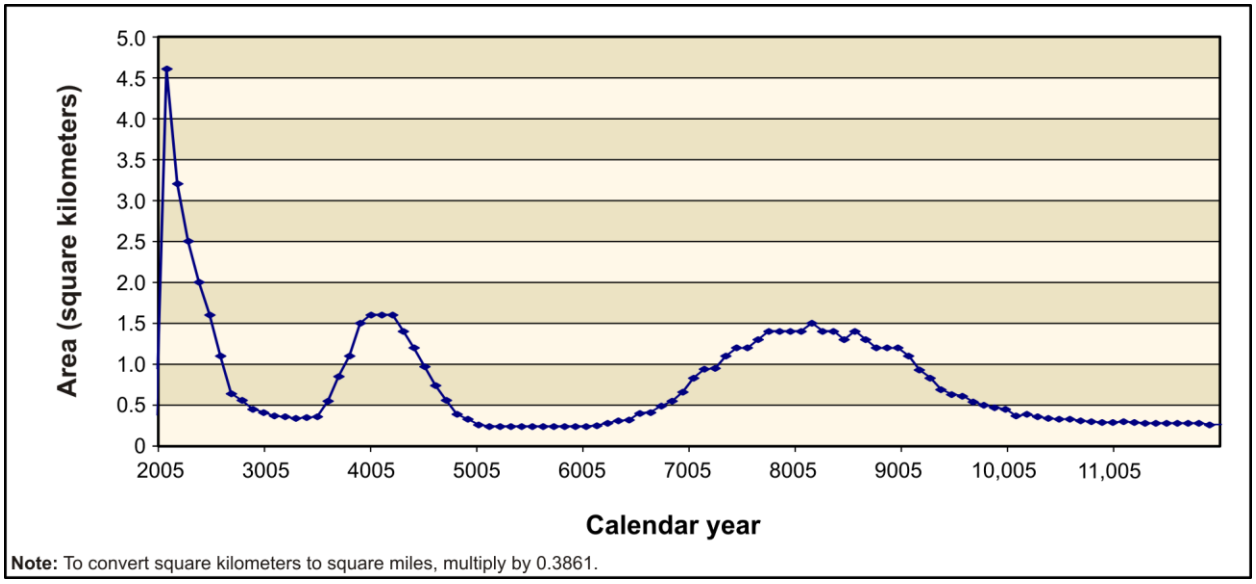
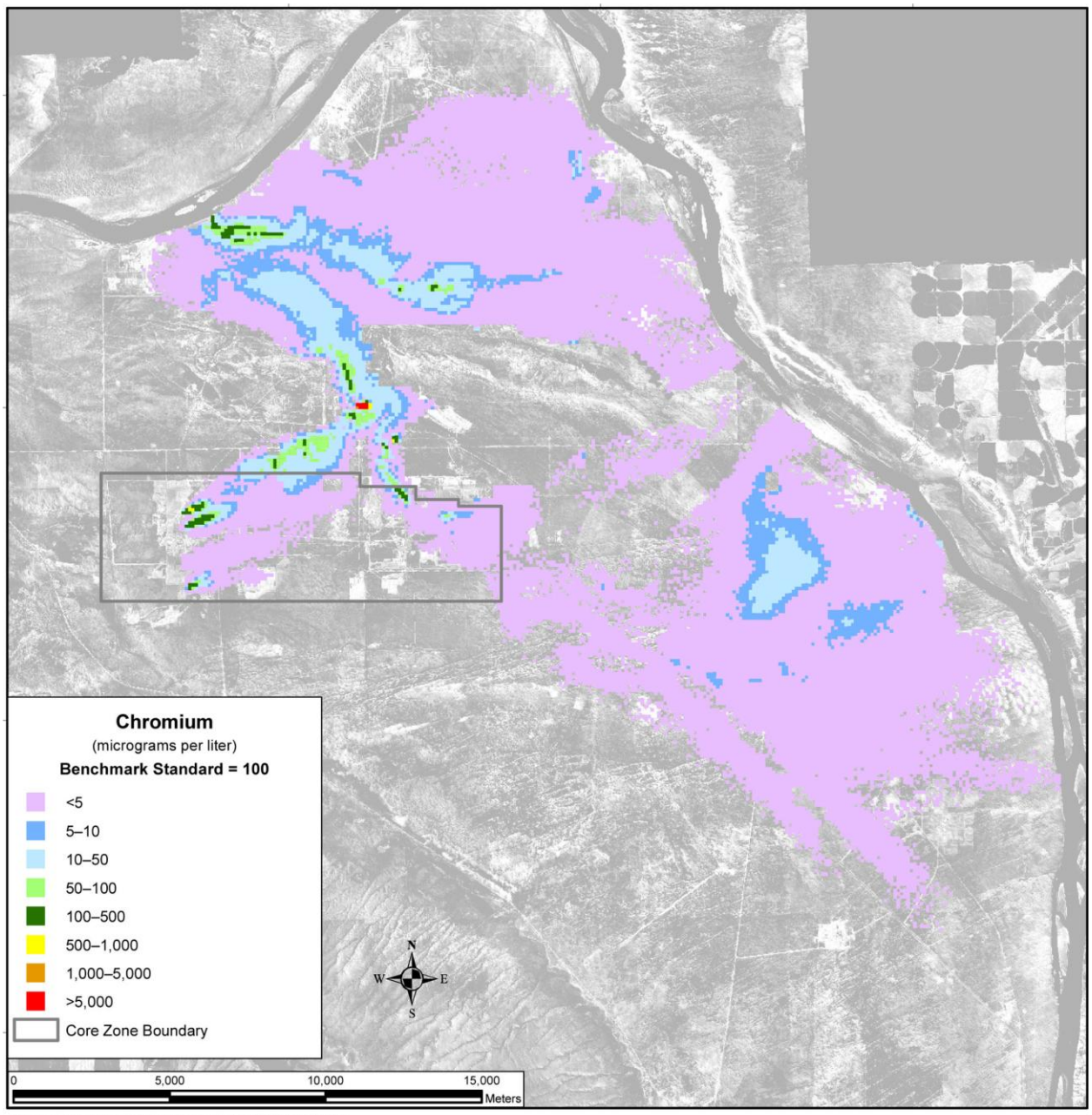
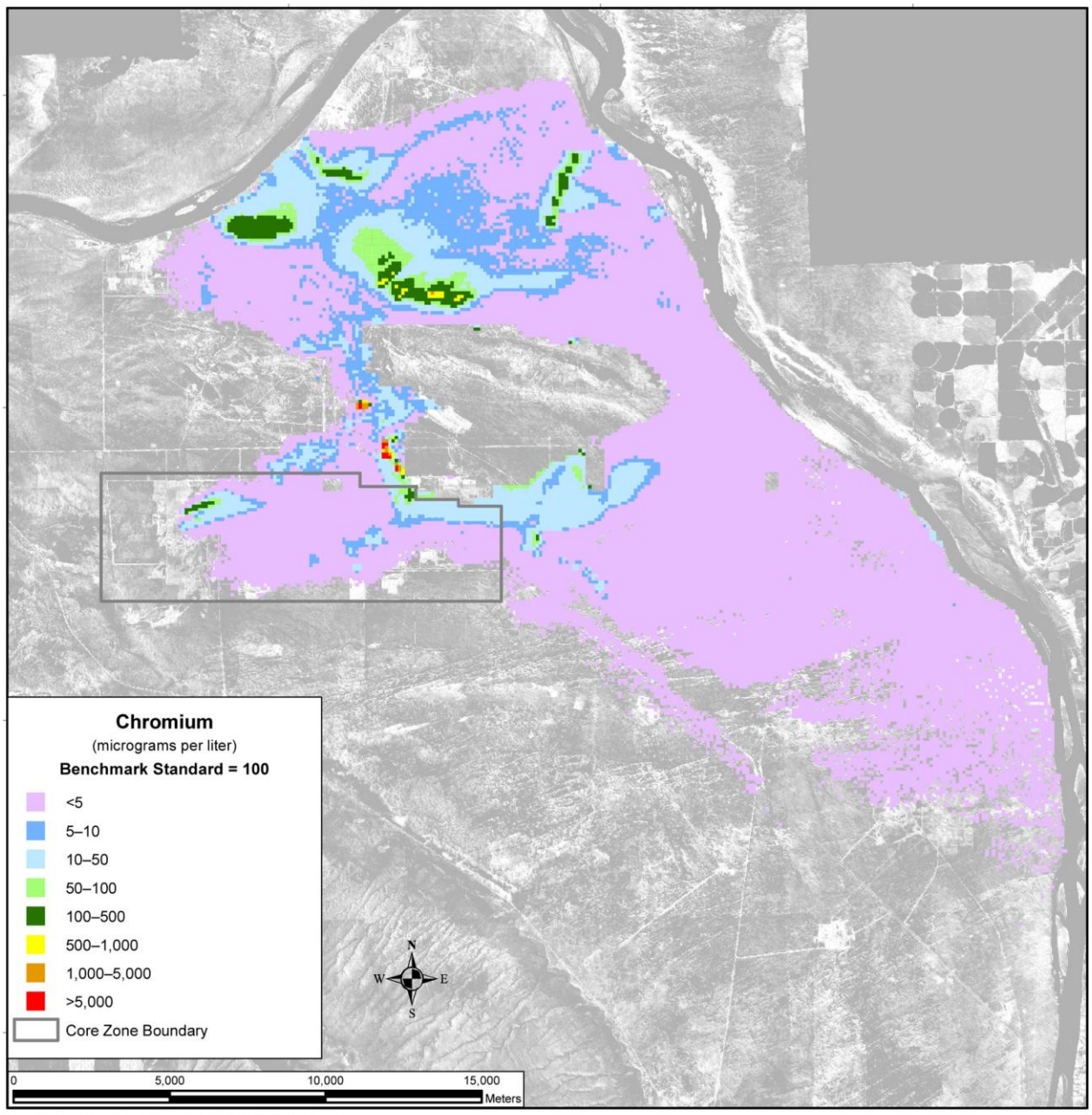


Figure 5–1260. Alternative Combination 3 Total Area of Groundwater Technetium-99 Concentration Exceeding the Benchmark Concentration as a Function of Time



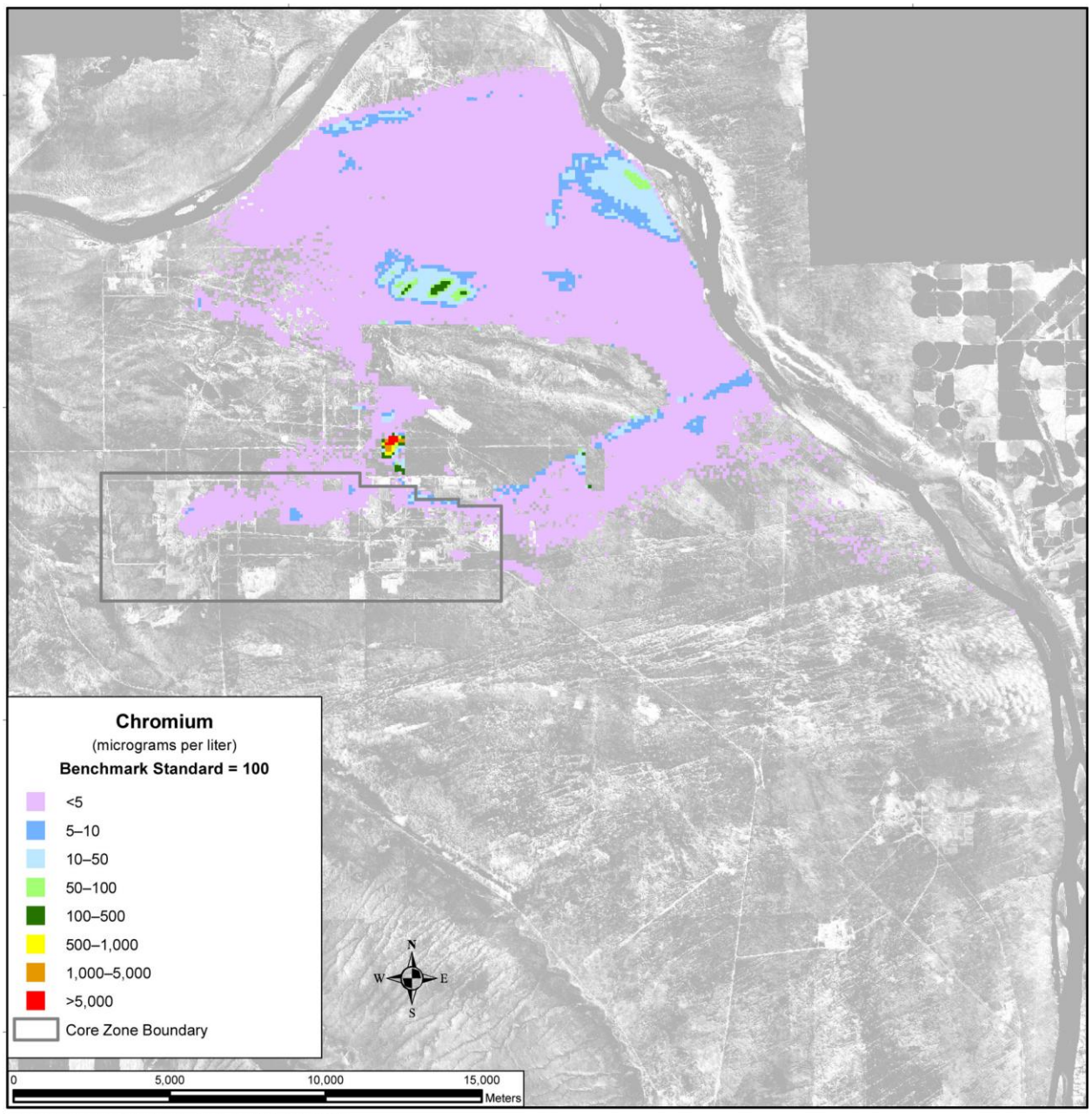
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1261. Alternative Combination 3 Spatial Distribution of Groundwater Chromium Concentration, Calendar Year 2010



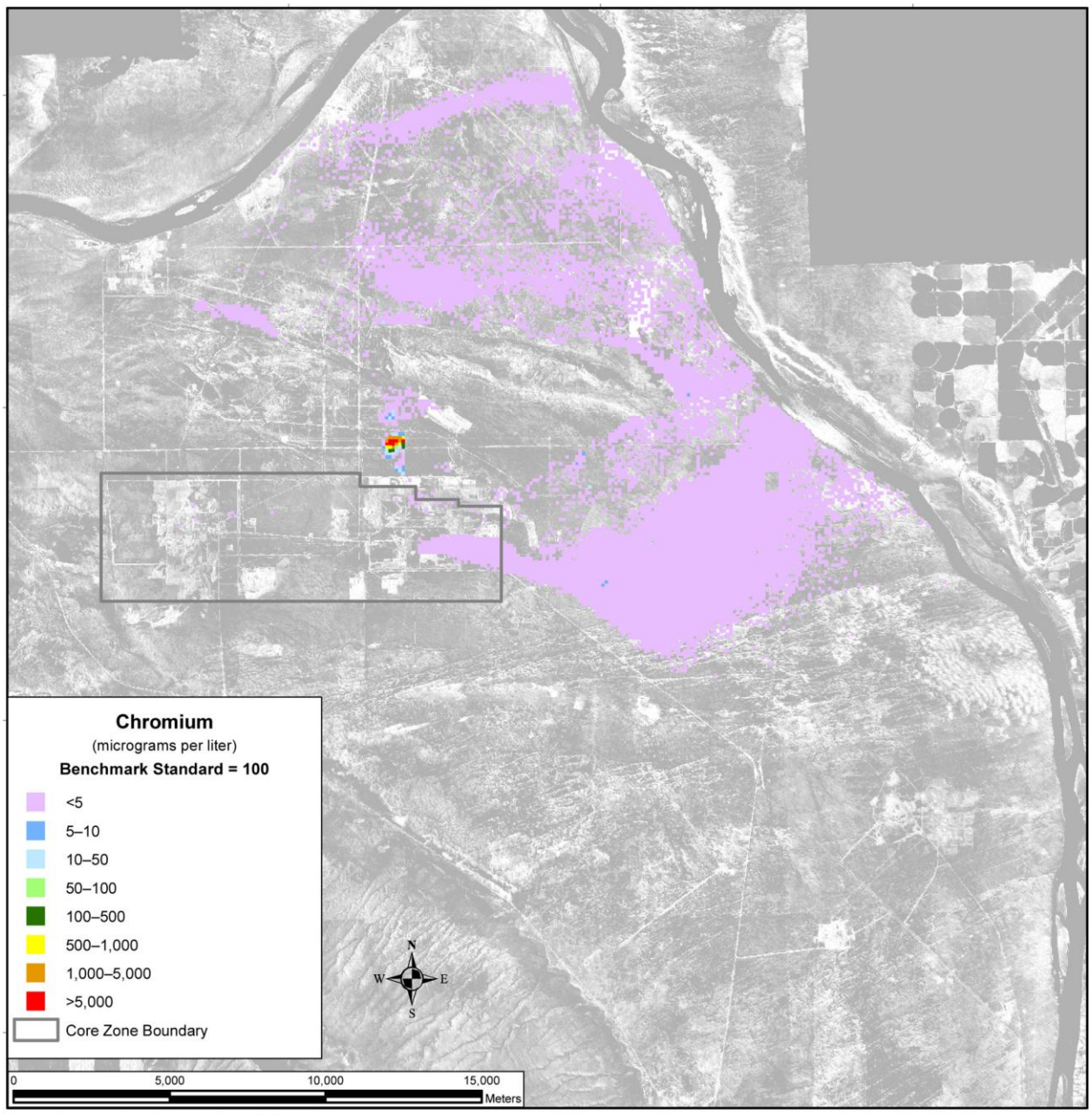
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1262. Alternative Combination 3 Spatial Distribution of Groundwater Chromium Concentration, Calendar Year 2135



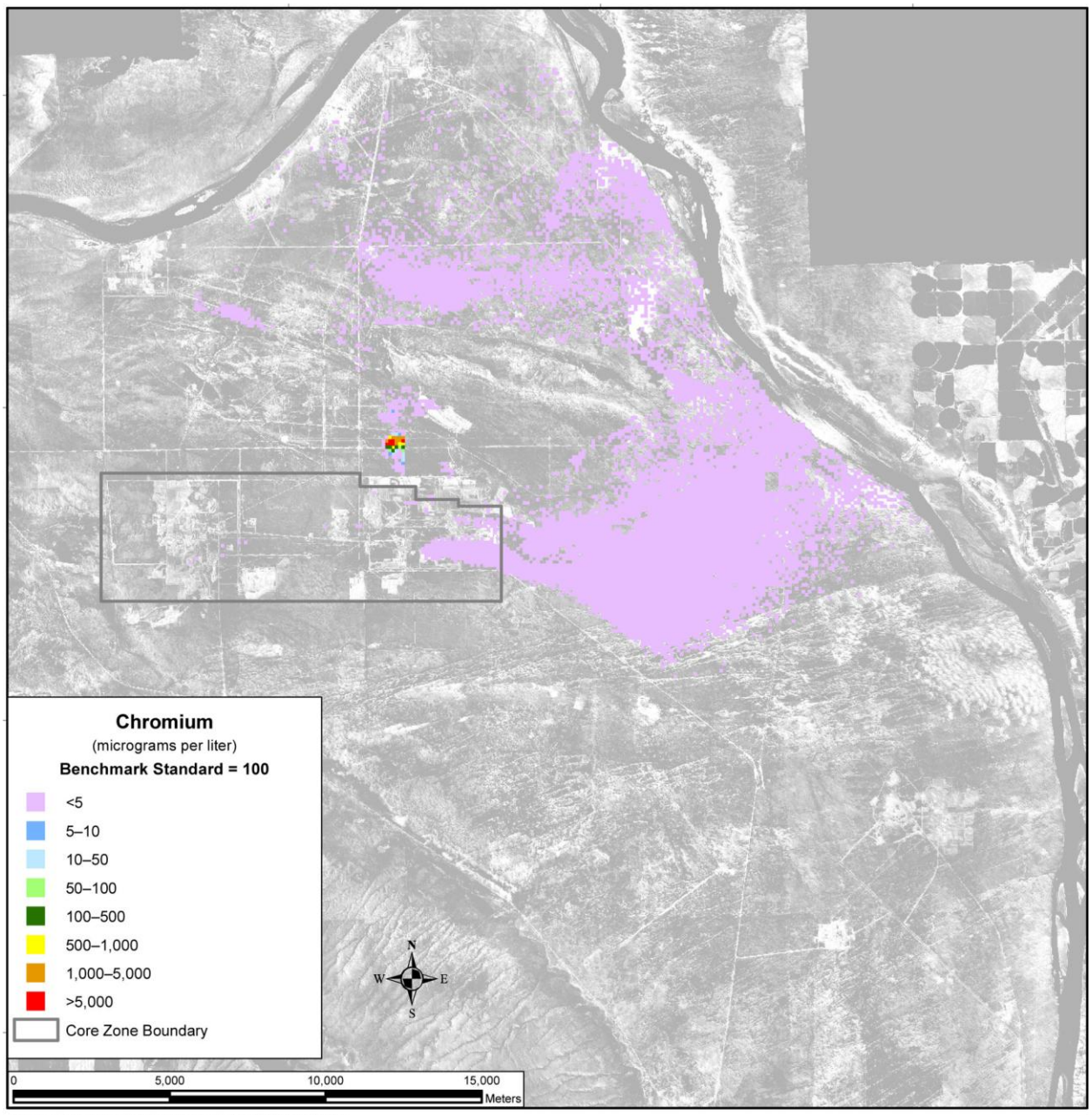
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1263. Alternative Combination 3 Spatial Distribution of Groundwater Chromium Concentration, Calendar Year 3890



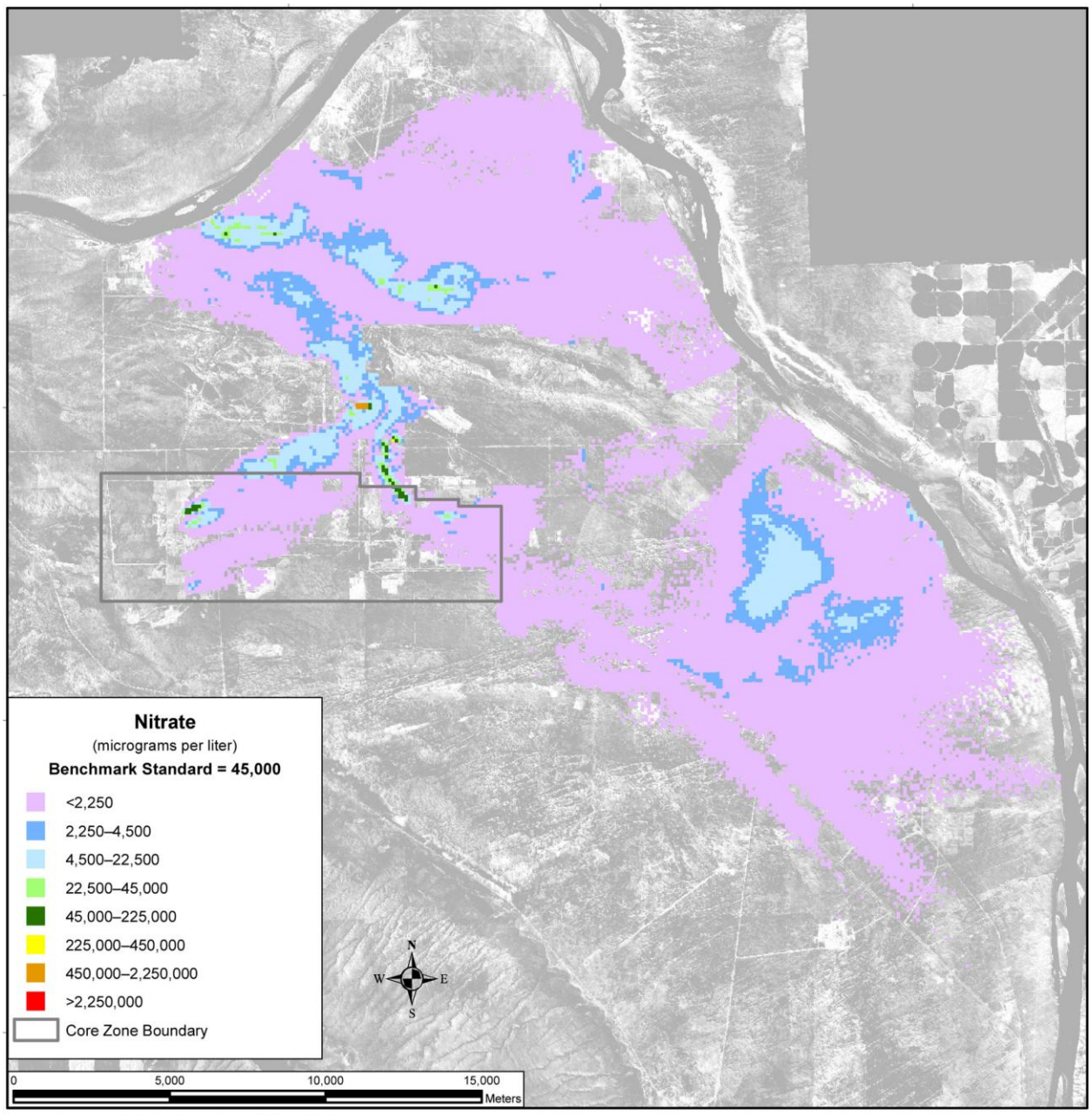
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1264. Alternative Combination 3 Spatial Distribution of Groundwater Chromium Concentration, Calendar Year 7140



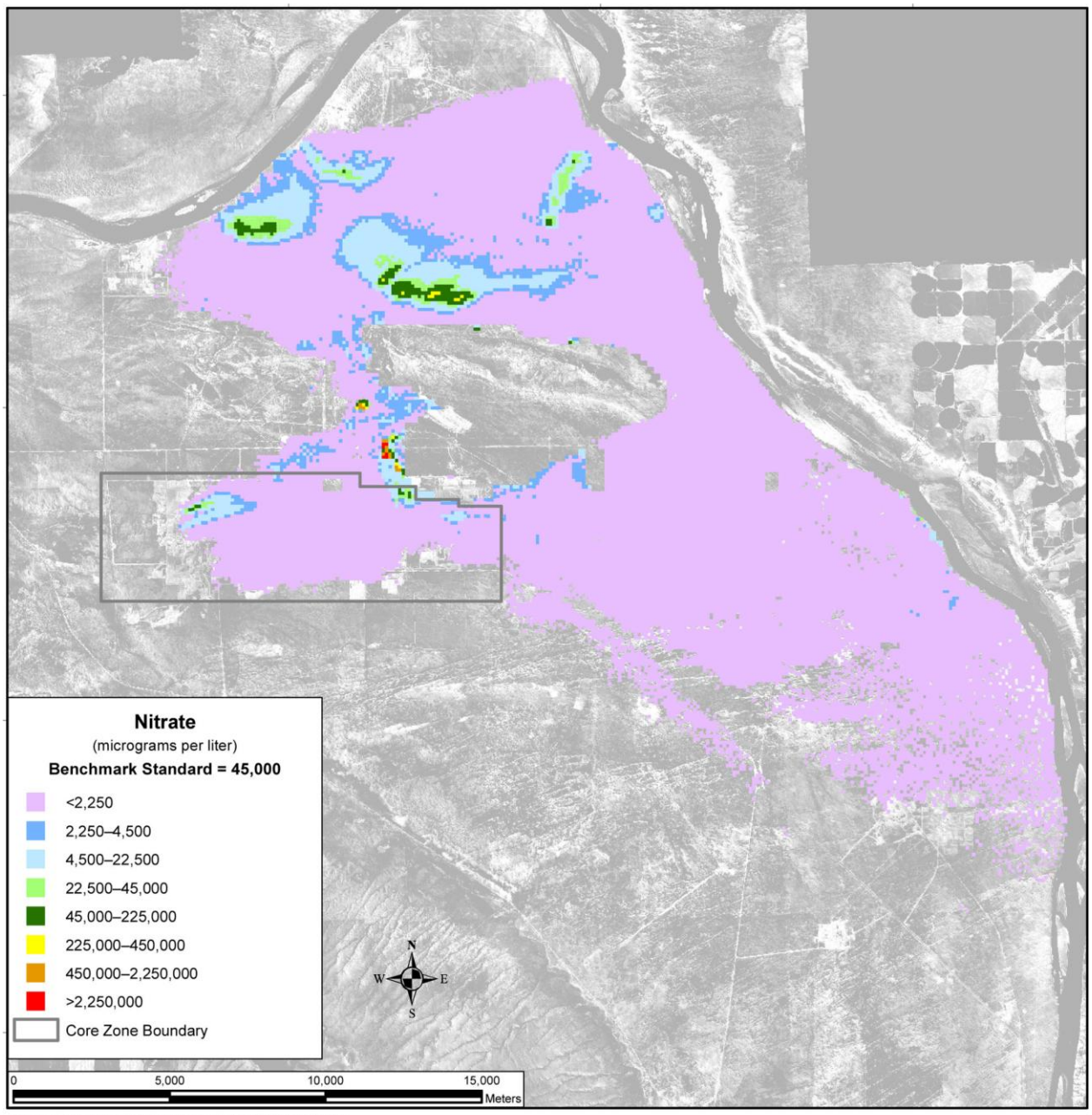
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1265. Alternative Combination 3 Spatial Distribution of Groundwater Chromium Concentration, Calendar Year 11,885



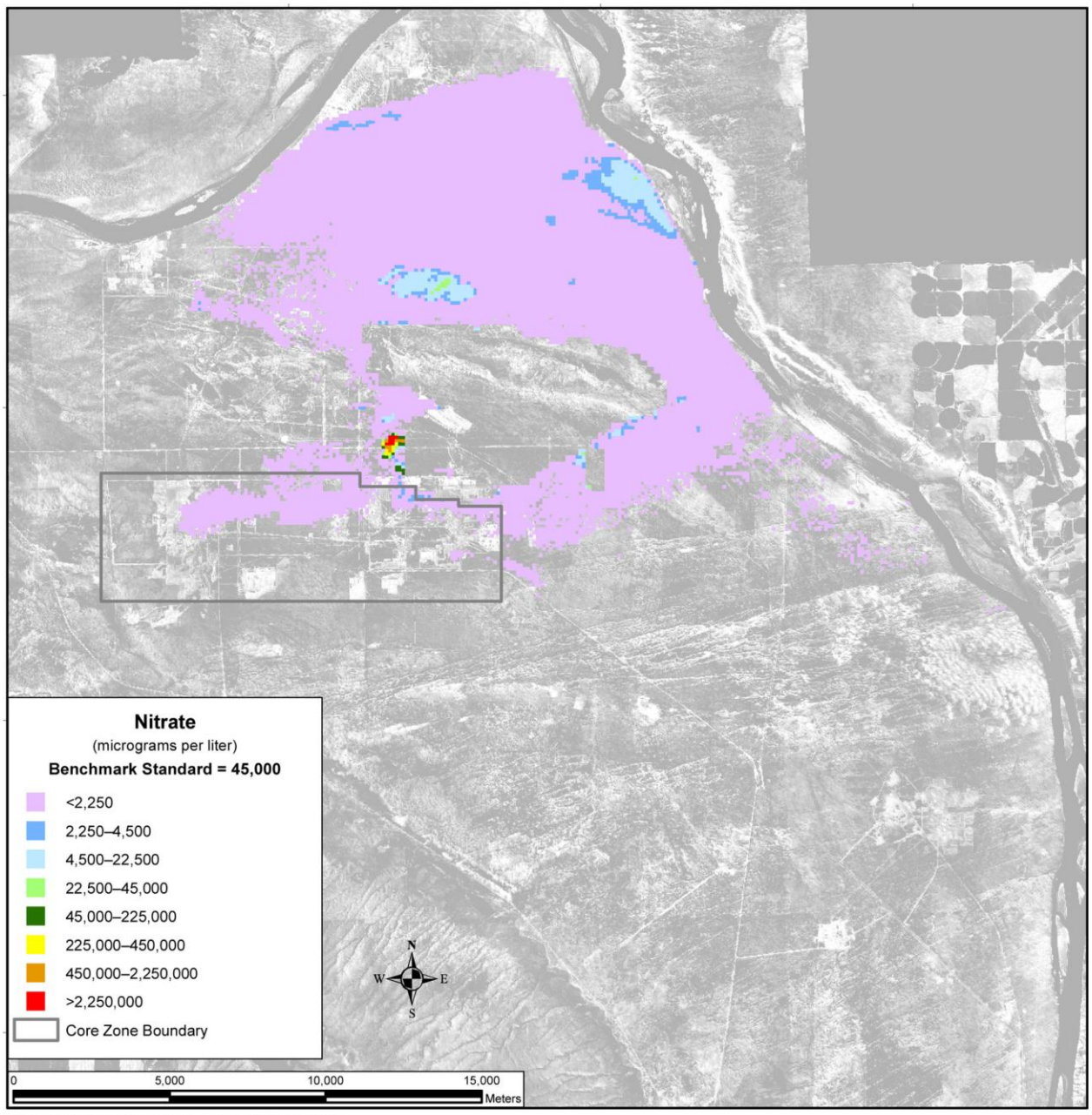
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1266. Alternative Combination 3 Spatial Distribution of Groundwater Nitrate Concentration, Calendar Year 2010



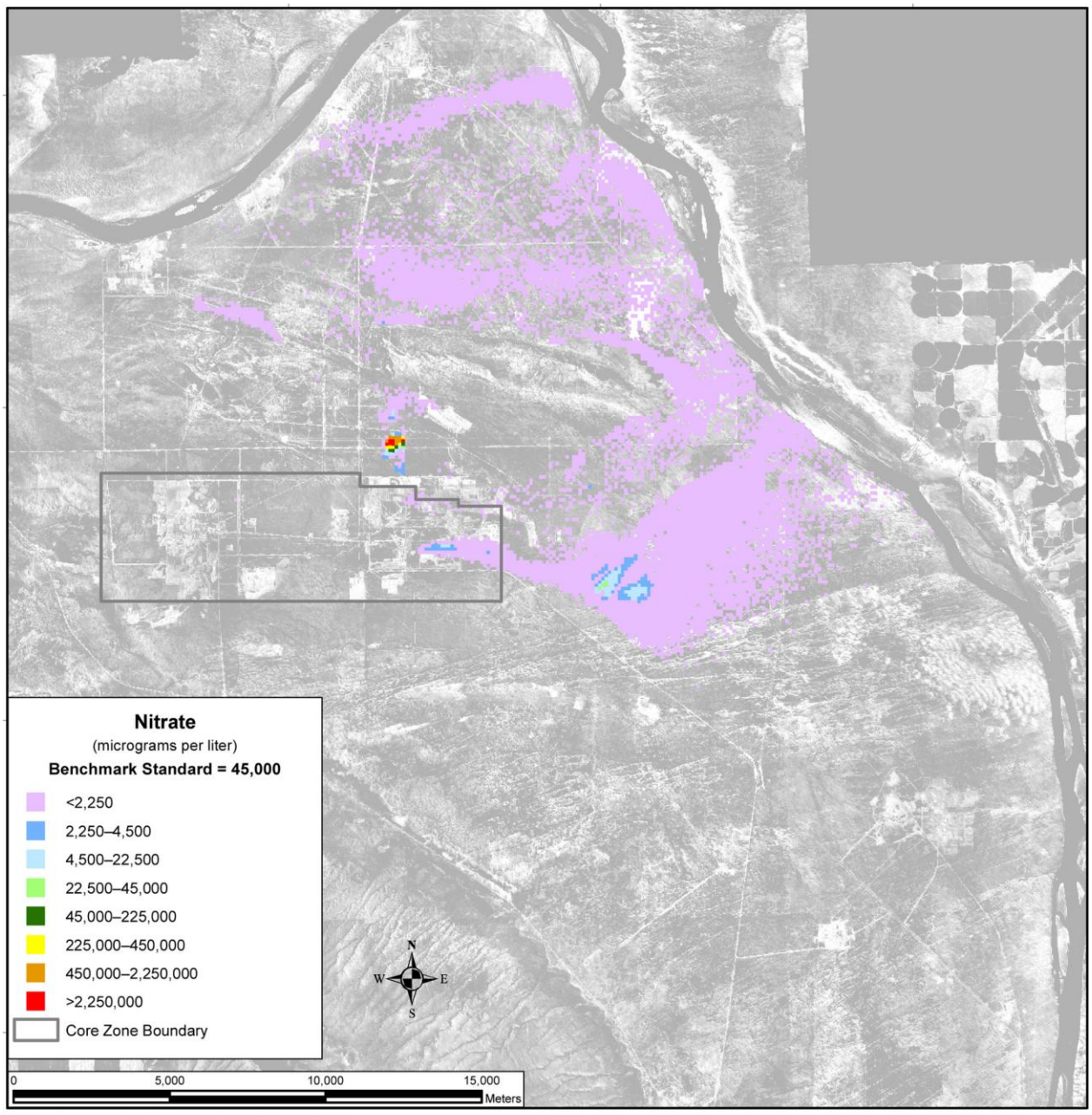
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1267. Alternative Combination 3 Spatial Distribution of Groundwater Nitrate Concentration, Calendar Year 2135



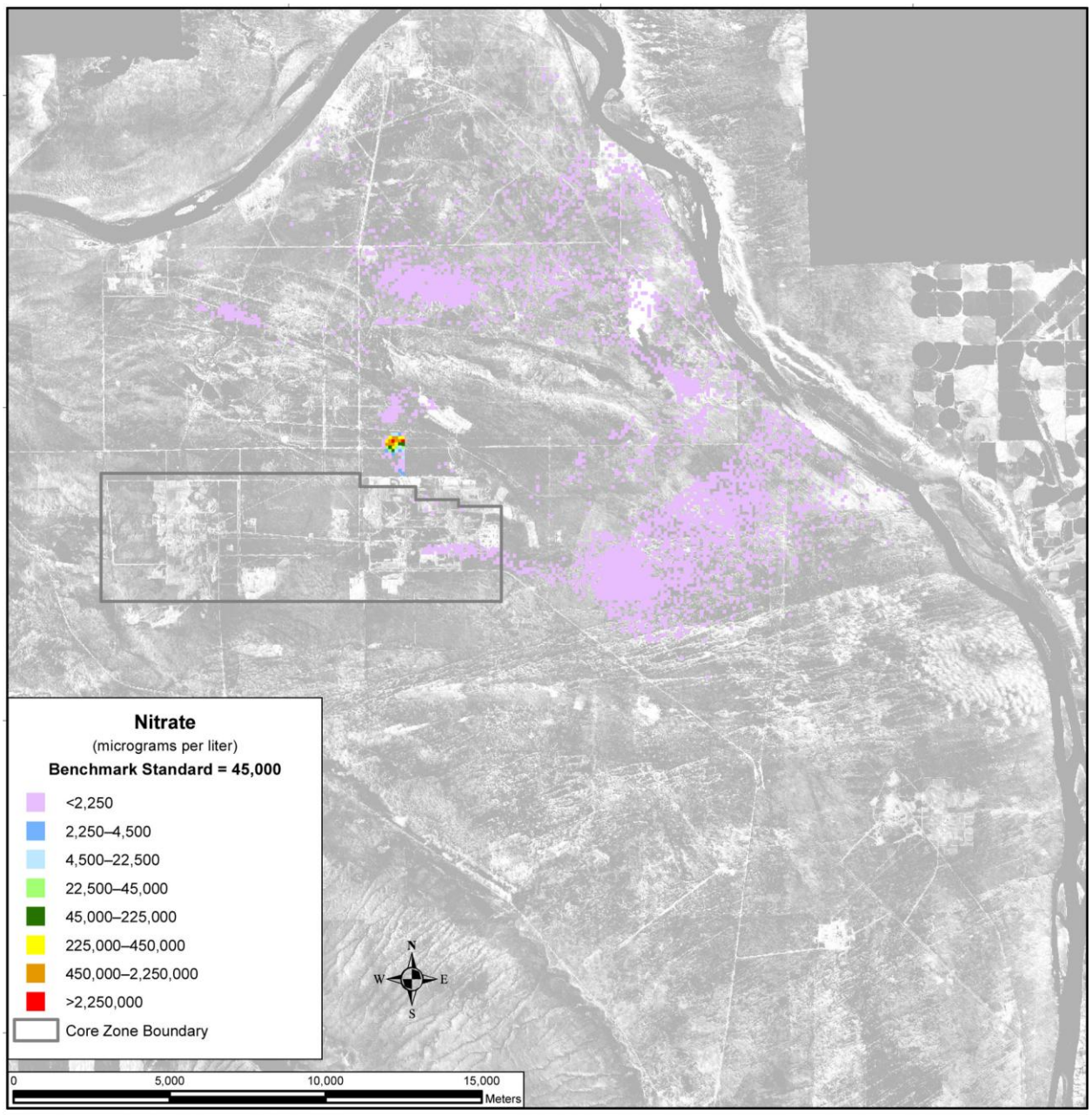
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1268. Alternative Combination 3 Spatial Distribution of Groundwater Nitrate Concentration, Calendar Year 3890



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

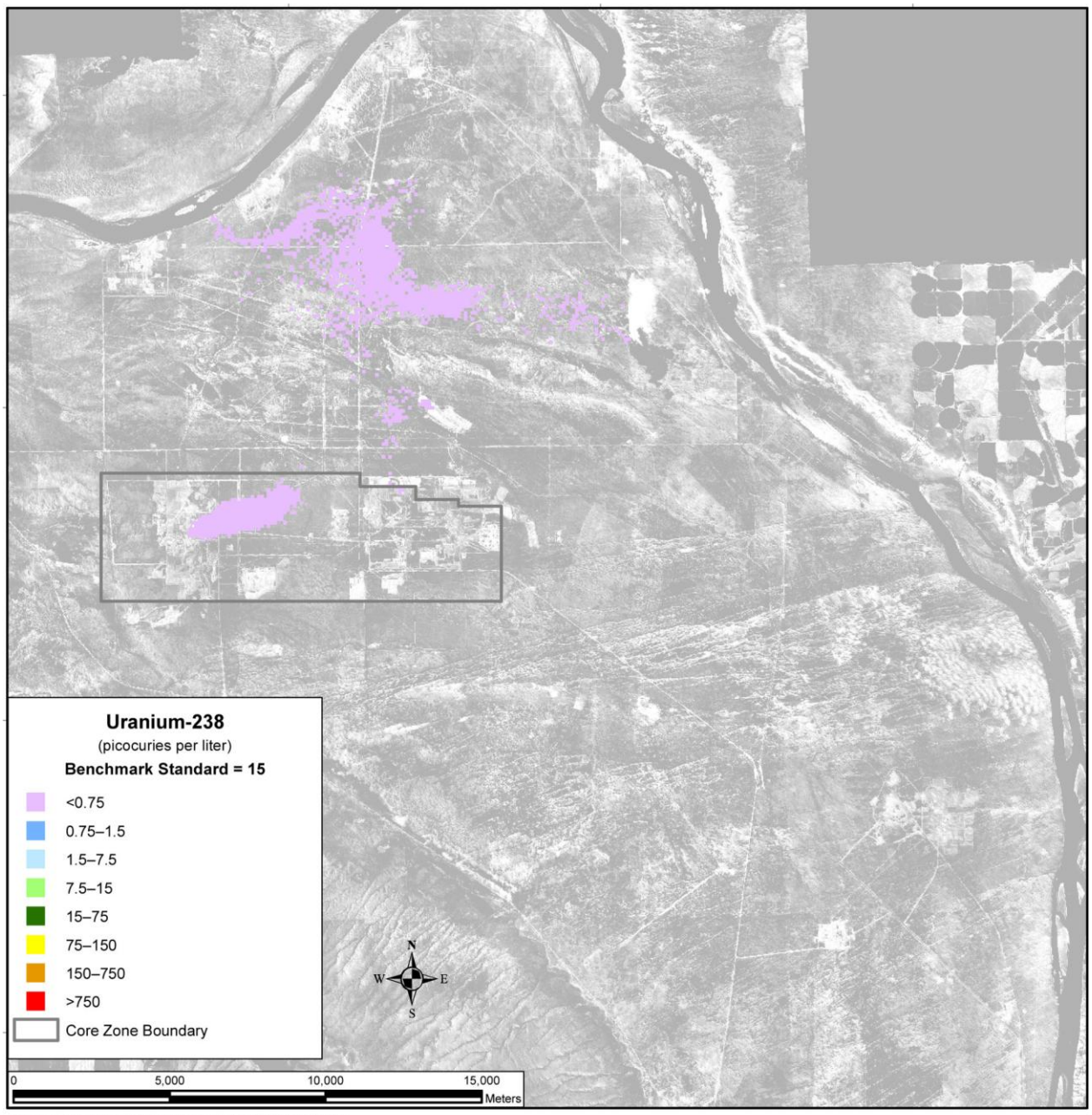
Figure 5–1269. Alternative Combination 3 Spatial Distribution of Groundwater Nitrate Concentration, Calendar Year 7140



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

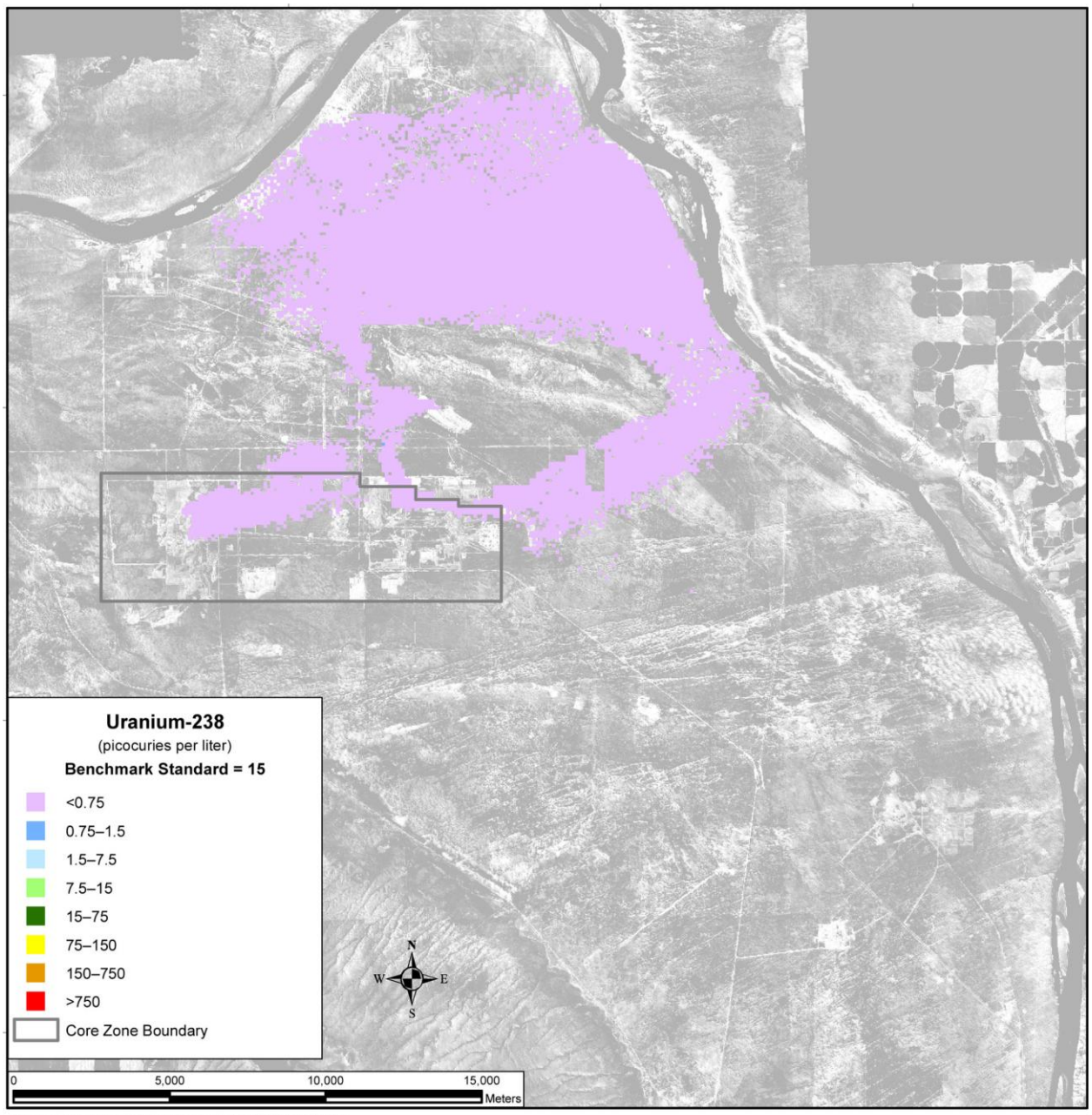
Figure 5–1270. Alternative Combination 3 Spatial Distribution of Groundwater Nitrate Concentration, Calendar Year 11,885

Uranium-238 and total uranium show different spatial distributions in the analysis over time. These COPCs are not as mobile as those discussed above, moving about seven times more slowly than the pore-water velocity. As a result, travel times through the vadose zone are longer, release to the aquifer is delayed, and travel times through the aquifer to the Columbia River nearshore are longer. Figure 5–1271 shows the distribution of uranium-238 in CY 2135. There is a small plume associated with cribs and trenches (ditches) and past leaks at the T Barrier that is less than one-twentieth of the benchmark concentration. The plume extends northeast through Gable Gap. By CY 7140 (see Figure 5–1272), the area of the plume has grown and extends to the Columbia River nearshore, but no significant increases in peak concentration are evident. In CY 11,885 (see Figure 5–1273), the greatest development of the plume during the analysis period is seen. Figure 5–1274 shows the total area for which uranium-238 concentrations in groundwater exceed the benchmark concentration as a function of time. The area of exceedance is seen only at the very end of the period of analysis and then in only a relatively small area, between 0.010 and 0.012 square kilometers (0.0039 and 0.0046 square miles). Figures 5–1275 through 5–1277 show the corresponding spatial distribution for total uranium.



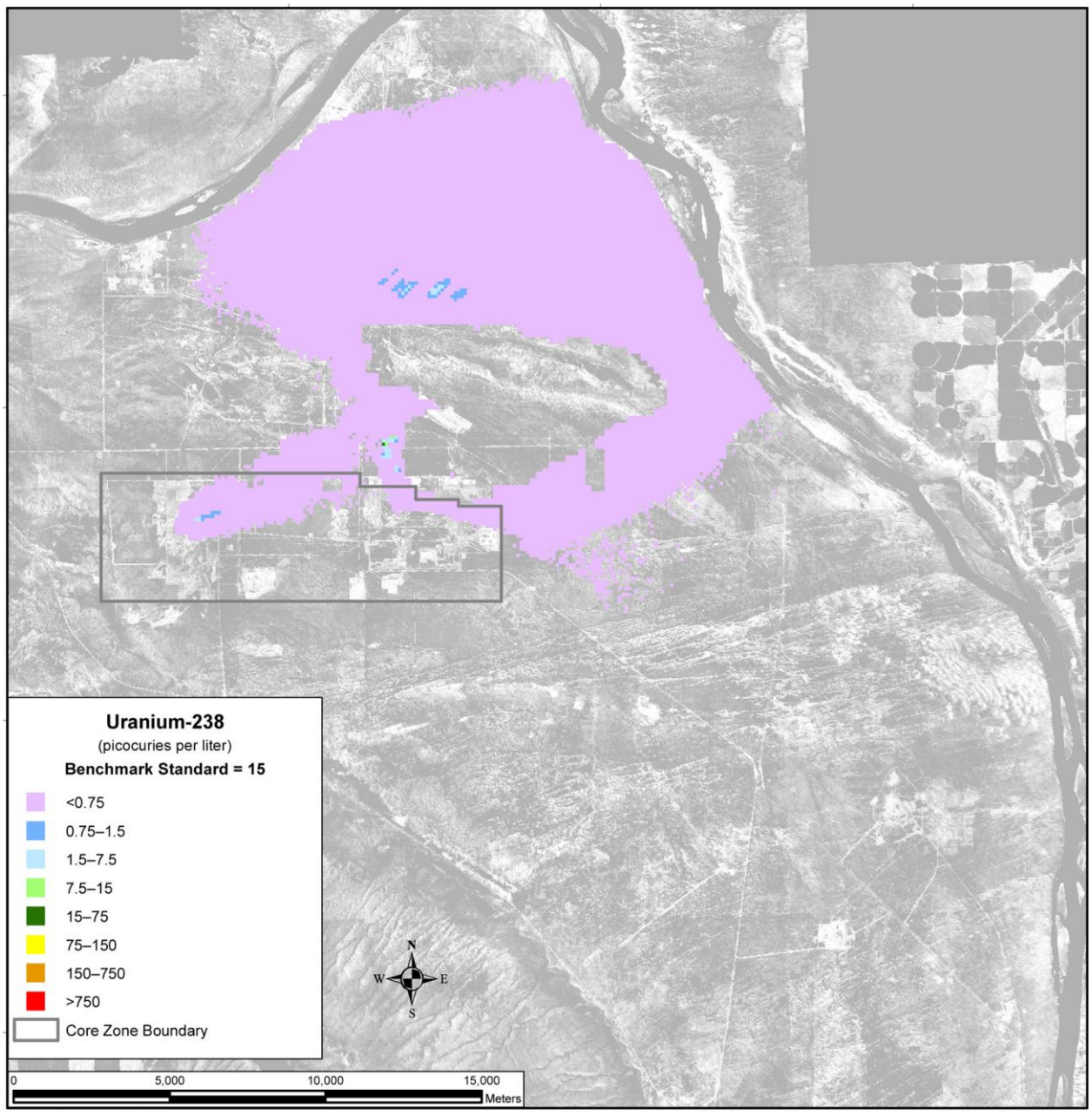
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1271. Alternative Combination 3 Spatial Distribution of Groundwater Uranium-238 Concentration, Calendar Year 2135



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

Figure 5–1272. Alternative Combination 3 Spatial Distribution of Groundwater Uranium-238 Concentration, Calendar Year 7140



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

Figure 5–1273. Alternative Combination 3 Spatial Distribution of Groundwater Uranium-238 Concentration, Calendar Year 11,885

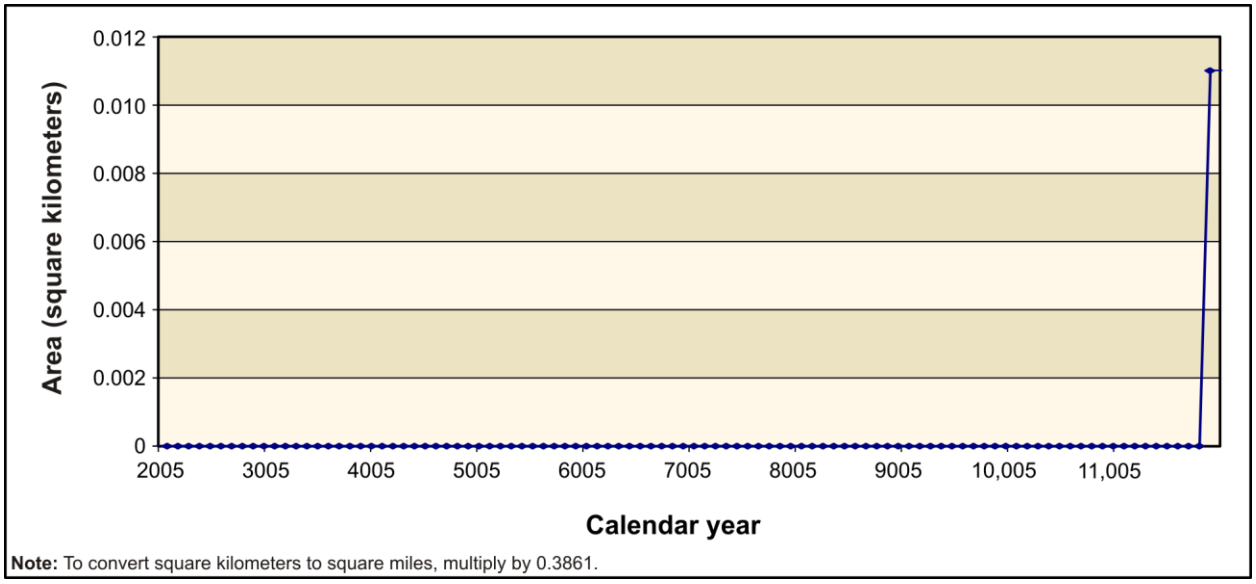
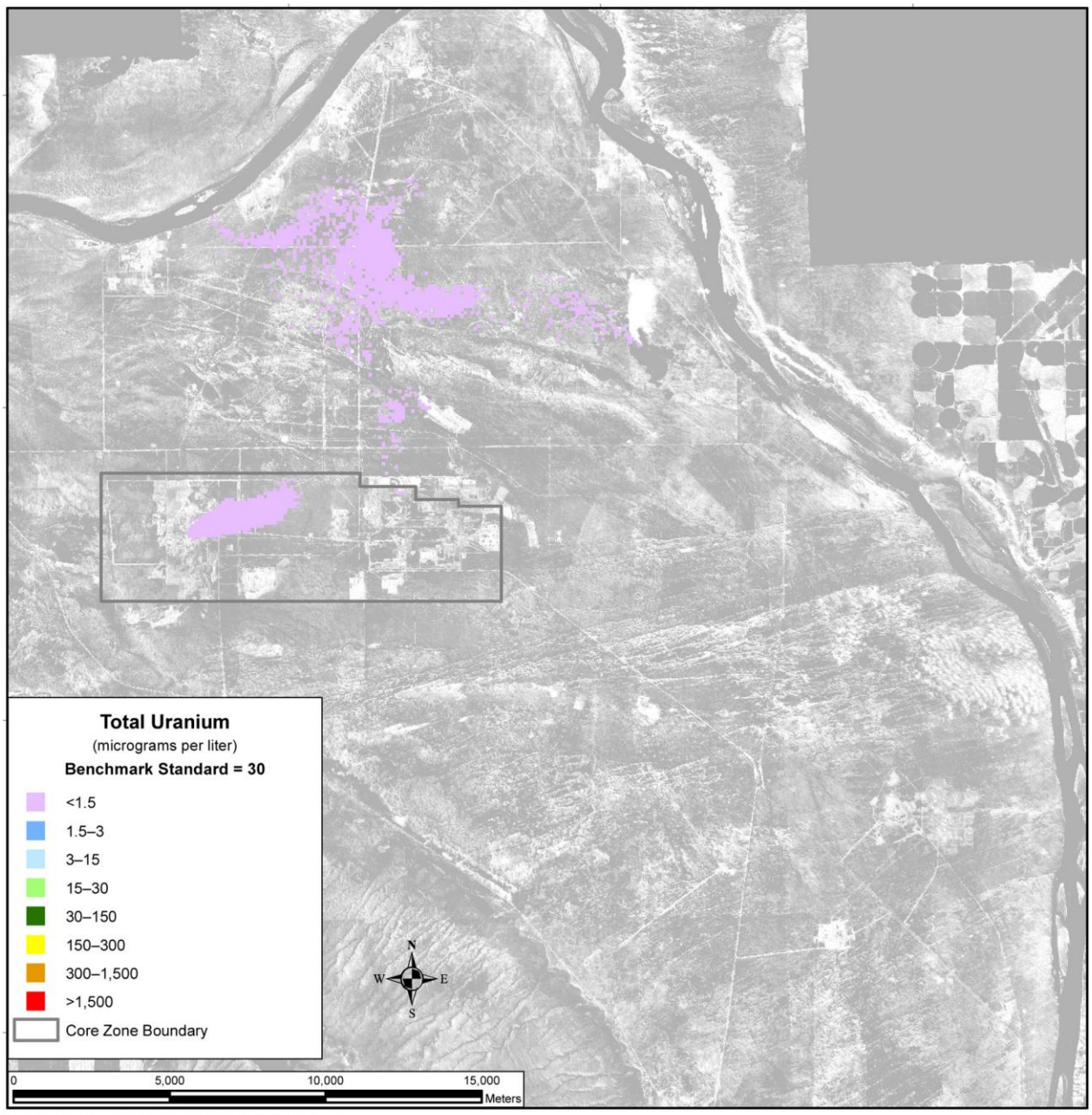
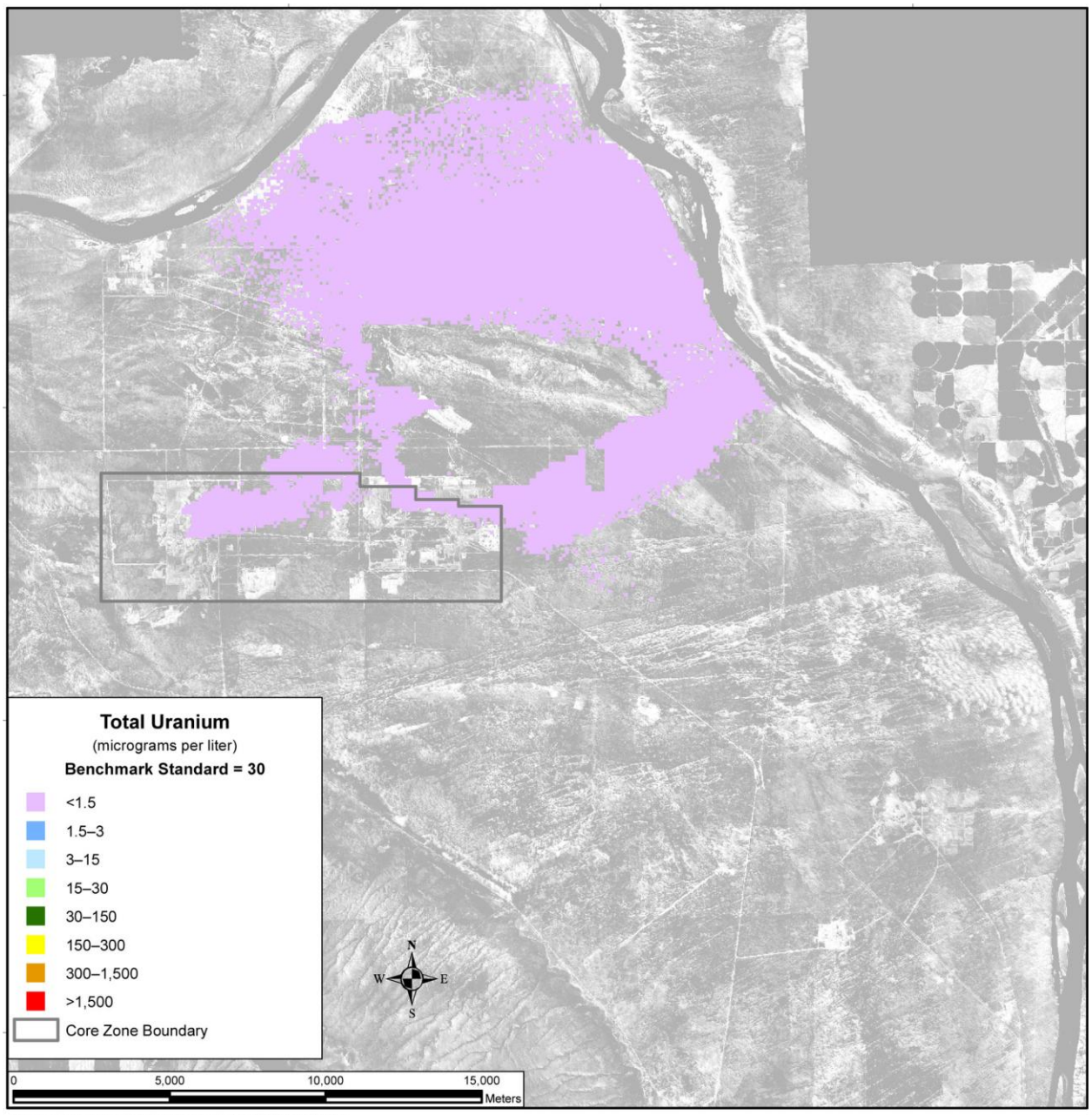


Figure 5–1274. Alternative Combination 3 Total Area of Groundwater Uranium-238 Concentration Exceeding the Benchmark Concentration as a Function of Time



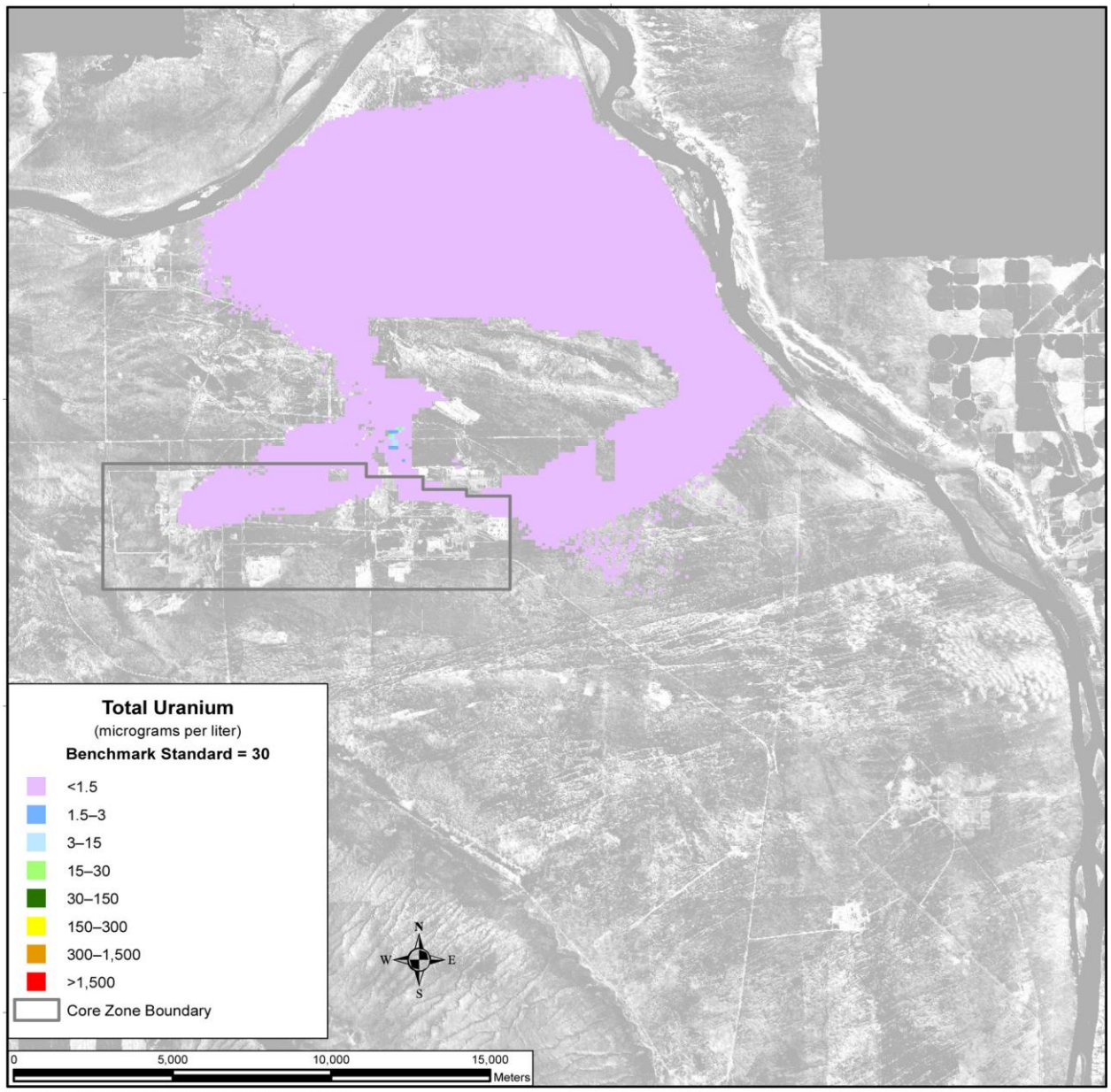
Note: To convert meters to feet, multiply by 3.281.

Figure 5–1275. Alternative Combination 3 Spatial Distribution of Groundwater Total Uranium Concentration, Calendar Year 2135



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

Figure 5–1276. Alternative Combination 3 Spatial Distribution of Groundwater Total Uranium Concentration, Calendar Year 7140



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

Figure 5–1277. Alternative Combination 3 Spatial Distribution of Groundwater Total Uranium Concentration, Calendar Year 11,885

SUMMARY OF IMPACTS

The long-term impacts of Alternative Combination 3 are dominated by tank farm sources (cribs and trenches [ditches] and past leaks) for tritium, uranium-238, chromium, nitrate, and total uranium. The dominant contributors of iodine-129 and technetium-99 are waste management sources, particularly offsite waste disposed of in IDF-East. Contributions from FFTF Decommissioning Alternative 3 sources are essentially negligible.

For the conservative tracers, concentrations at the Core Zone Boundary exceed benchmark standards by an order of magnitude during the first several thousand years of the period of analysis, and concentrations at the Columbia River nearshore are about an order of magnitude or more lower. For chromium and nitrate, the concentration trend decreases with time past CY 6000. For iodine-129 and technetium-99, the

concentration trend is level with respect to time, and concentrations are within an order of magnitude of the benchmark concentration at both the Core Zone Boundary and the Columbia River nearshore. The intensities are highest and the areas of these groundwater plumes largest during the early and later parts of the period of analysis.

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

For uranium-238 and total uranium, limited mobility is an important factor governing the timeframe and scale of groundwater impacts. The concentrations of these retarded species approach, but do not exceed, the benchmark at the Core Zone Boundary beyond CY 9000, and remain at least an order of magnitude lower than the benchmark at the Columbia River nearshore after CY 10,000. The intensity is highest and the area of the contamination plume largest near the end of the period of analysis.

5.4.2 Human Health Impacts

This section evaluates long-term impacts on human health as a result of the three combinations of Tank Closure, FFTF Decommissioning, and Waste Management alternatives. Alternative Combination 1 comprises the No Action Alternatives for tank closure (Tank Closure Alternative 1), FFTF decommissioning (FFTF Decommissioning Alternative 1), and waste management (Waste Management Alternative 1). Alternative Combination 2 comprises Tank Closure Alternative 2B; FFTF Decommissioning Alternative 2 (Entombment); and Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A. Alternative Combination 3 comprises Tank Closure Alternative 6B, Base Case; FFTF Decommissioning Alternative 3 (Removal); and Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case.

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

The four measures of human health impact considered in this analysis were calculated for each year for 10,000 years for each receptor at four locations (i.e., facility barriers, Core Zone Boundary, Columbia River nearshore, and Columbia River surface water). This is a large amount of information that must be summarized to allow interpretation of results. The method chosen is to present dose for the year of maximum dose, risk for the year of maximum risk, and Hazard Index for the year of maximum Hazard Index. This choice is based on regulation of radiological impacts expressed as dose and the observation that peak risk and peak noncarcinogenic impacts expressed as Hazard Index may occur at times other than that of peak dose. Also, to summarize time dependence of impacts, time series of lifetime risk are presented only for locations of likely maximum impact, that is, nearfield barriers and the Core Zone Boundary.

Onsite locations comprise the facility barriers, Core Zone Boundary, and Columbia River nearshore. Offsite locations comprise access points to Columbia River surface water near the site and at population centers downstream of the site. Estimates of concentrations of constituents in the Columbia River surface water are used to calculate impacts for both offsite location points of analysis. The total population of downstream water users was assumed to be 5 million people for the entire 10,000-year period of analysis

(DOE 1987). Four types of receptors are considered. The first type, a drinking-water well user, uses groundwater as a source of drinking water. The second type, a resident farmer, uses either groundwater or surface water for drinking water consumption and irrigation of crops. Garden size and crop yield are adequate to produce approximately 25 percent of average requirements of crops and animal products. The third type, an American Indian resident farmer, also uses either groundwater or surface water for drinking water consumption and irrigation of crops. Garden size and crop yield are adequate to produce the entirety of the receptor's average requirements for crops and animal products. The fourth type, an American Indian hunter-gatherer, is impacted by both groundwater and surface water because he uses surface water for drinking water consumption and consumes both wild plant materials, which use groundwater, and game, which use 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 dose impacts is evaluated by comparison with the 100-millirem-per-year all-exposure-modes standard specified for protection of the public and the environment in DOE Order 458.1, *Radiation Protection of the Public and the Environment*. The level of protection provided for the drinking water pathway is evaluated by comparison with applicable drinking water standards presented in Section 5.1.1. Population doses are compared against a total effective dose equivalent from natural background sources of 311 millirem per year for a member of the population of the United States (NCRP 2009). The significance of noncarcinogenic chemical impacts is evaluated by comparison against a guideline value of unity (1) for Hazard Index. Estimation of Hazard Index less than unity indicates that observable effects would not occur.

5.4.2.1 Alternative Combination 1

Potential human health impacts of Alternative Combination 1 for the years of peak impact for the time period beginning in CY 1940 are summarized in Tables 5–186 and 5–187. The key radioactive constituent contributors to human health risk are tritium, technetium-99, iodine-129, and uranium isotopes, and the key chemical constituent contributors are chromium and nitrate. For radionuclides, the dose standard would be exceeded at the Core Zone Boundary for the drinking-water well user, resident farmer, and American Indian resident farmer. The Hazard Index guideline would be exceeded due primarily to chromium and nitrate at the Core Zone Boundary and the Columbia River nearshore location for the drinking-water well user, resident farmer, and American Indian resident farmer. The Hazard Index guideline would also be exceeded for the American Indian hunter-gatherer at the Columbia River nearshore. Population dose is estimated as 3.12 person-rem per year for the year of maximum impact.

The time series of lifetime radiological risk for the drinking-water well user at the Core Zone Boundary are presented in Figures 5–1278 and 5–1279 for Tank Closure Alternative 1 and Waste Management Alternative 1, respectively. The time series of lifetime radiological risk for the drinking-water well user at the FFTF barrier is presented in Figure 5–1280 for FFTF Decommissioning Alternative 1. Impacts estimated for FFTF Decommissioning Alternative 1 and Waste Management Alternative 1 are lower than those estimated for Tank Closure Alternative 1 because FFTF has a lower inventory of radioactive constituents and Waste Management Alternative 1 considers disposal only of onsite LLW that is not related to tank closure activities. Tank Closure Alternative 1 assumes catastrophic failure of HLW tanks after loss of institutional control, leading to lifetime risk for the drinking-water well user at the Core Zone Boundary on the order of 0.003 in CY 1960 due to releases from cribs and trenches (ditches), on the order of 0.002 in CY 3960 due to failure of the HLW tanks, and on the order of 5×10^{-5} over the long term. Planned discharges to cribs and trenches (ditches) and past leaks from tanks produce estimates of a high level of risk for the near-term period and elevated risk extending through the entire long-term period.

Table 5–186. Alternative Combination 1 Drinking-Water Well User and Resident Farmer Long-Term Human Health Impact Summary

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index	Rad. Risk at Year of Peak Rad. Risk	Nonrad. Risk at Year of Peak Nonrad. Risk	Total Risk at Year of Peak Total Risk	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index	Rad. Risk at Year of Peak Rad. Risk	Nonrad. Risk at Year of Peak Nonrad. Risk	Total Risk at Year of Peak Total Risk
On Site										
Core Zone Boundary	1.51×10^{2}	8.84×10^{1}	2.98×10^{-3}	1.13×10^{-12}	2.98×10^{-3}	2.63×10^{2}	3.13×10^{2}	8.04×10^{-3}	2.39×10^{-8}	8.04×10^{-3}
Columbia River nearshore	4.37	2.97	1.11×10^{-4}	2.41×10^{-13}	1.11×10^{-4}	9.02	1.14×10^{1}	3.45×10^{-4}	9.09×10^{-10}	3.45×10^{-4}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	6.24×10^{-4}	8.90×10^{-4}	2.54×10^{-8}	6.85×10^{-14}	2.54×10^{-8}

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

Table 5–187. Alternative Combination 1 American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impact Summary

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index	Rad. Risk at Year of Peak Rad. Risk	Nonrad. Risk at Year of Peak Nonrad. Risk	Total Risk at Year of Peak Total Risk	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index	Rad. Risk at Year of Peak Rad. Risk	Nonrad. Risk at Year of Peak Nonrad. Risk	Total Risk at Year of Peak Total Risk
On Site										
Core Zone Boundary	4.50×10^{2}	6.77×10^{2}	1.66×10^{-2}	1.09×10^{-3}	1.71×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.68×10^{1}	2.44×10^{1}	7.49×10^{-4}	4.17×10^{-5}	7.57×10^{-4}	9.75×10^{-2}	4.58	3.08×10^{-6}	4.17×10^{-5}	4.28×10^{-5}
Off Site										
Columbia River	2.32×10^{-3}	4.51×10^{-1}	8.59×10^{-8}	3.14×10^{-9}	8.63×10^{-8}	N/A	N/A	N/A	N/A	N/A

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

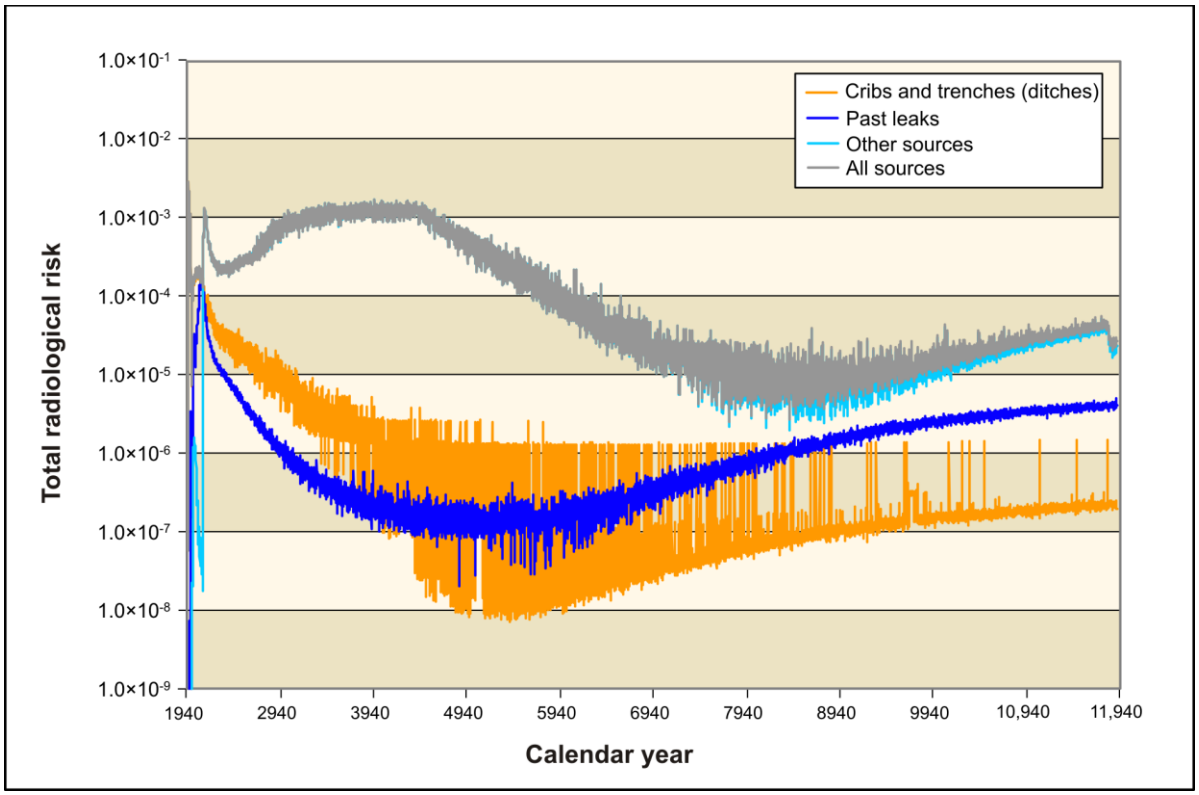


Figure 5–1278. Tank Closure Alternative 1 Time Series of Lifetime Radiological Risk for the Drinking-Water Well User at the Core Zone Boundary

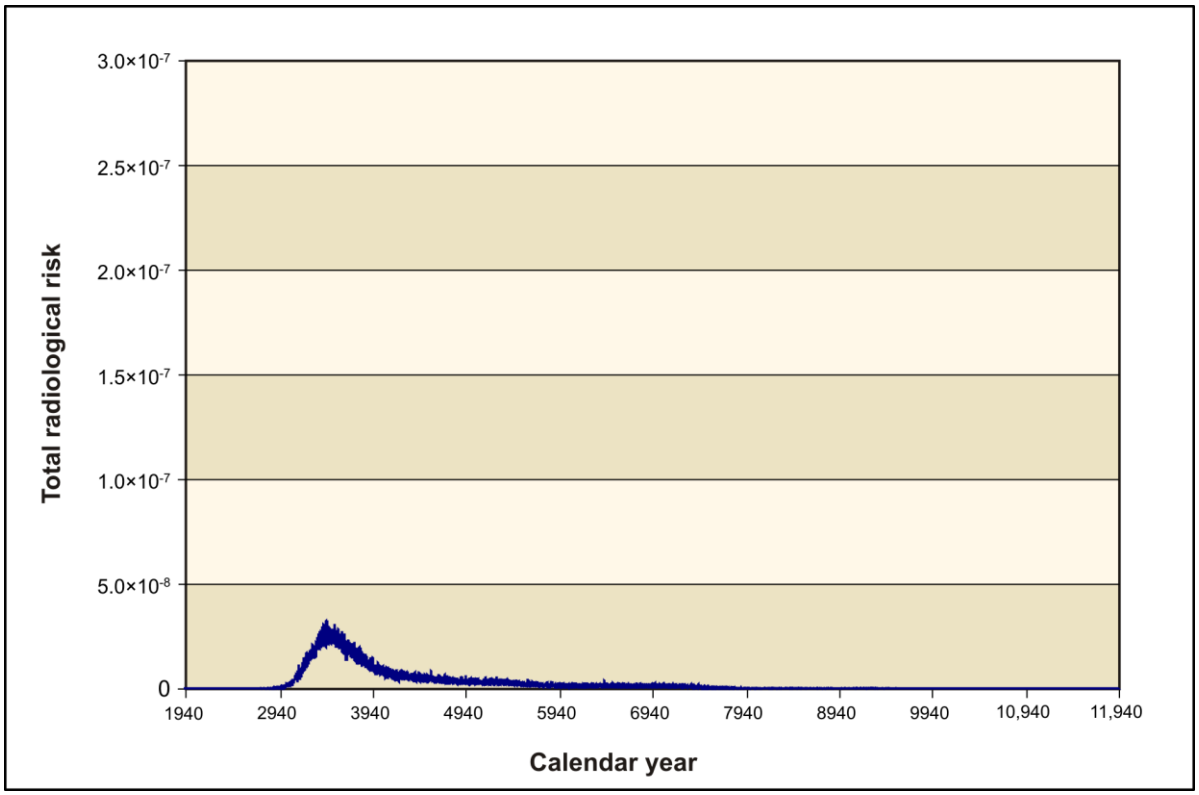


Figure 5–1279. Waste Management Alternative 1 Time Series of Lifetime Radiological Risk for the Drinking-Water Well User at the Core Zone Boundary

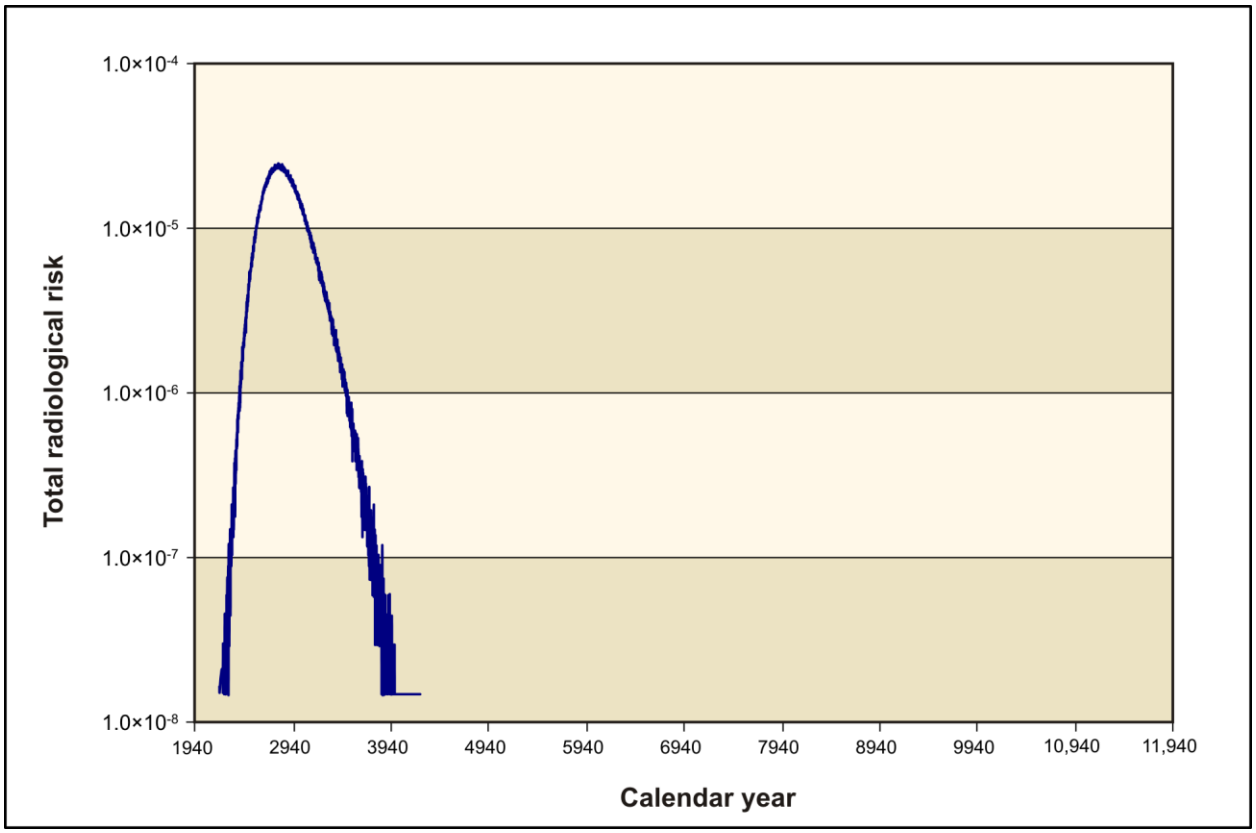


Figure 5–1280. FFTF Decommissioning Alternative 1 Time Series of Lifetime Radiological Risk for the Drinking-Water Well User at the FFTF Barrier

5.4.2.2 Alternative Combination 2

Potential human health impacts of Alternative Combination 2 for the year of peak impact for the time period beginning in CY 1940 are summarized in Tables 5–188 and 5–189. The key radioactive constituent contributors to human health risk are tritium, technetium-99, and iodine-129, and the key chemical constituent contributors are chromium, nitrate, and total uranium. For radionuclides, the dose standard would be exceeded at the Core Zone Boundary and Columbia River nearshore for the drinking-water well user, resident farmer, and American Indian resident farmer. The Hazard Index guideline would also be exceeded at the Columbia River nearshore for the American Indian hunter-gatherer. Population dose is estimated as 1.72 person-rem per year for the year of maximum impact.

The time series of lifetime radiological risk for the drinking-water well user at the Core Zone Boundary are presented in Figures 5–1281 and 5–1282 for Tank Closure Alternative 2B and Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, respectively. The time series of lifetime radiological risk for the drinking-water well user at the FFTF barrier is presented in Figure 5–1283 for FFTF Decommissioning Alternative 2. Tank Closure Alternative 2B assumes retrieval of 99 percent of tank waste, producing a significant reduction in impacts relative to Tank Closure Alternative 1. Peak lifetime risk at the Core Zone Boundary for the drinking-water well user due to future releases from the tank farms is reduced by a factor of approximately 50 to 6×10^{-5}. Estimates of impacts for planned discharges to cribs and trenches (ditches) and past leaks from tanks are similar to those for Tank Closure Alternative 1, with estimates of a high level of risk, approximately 0.003, for the near-term period and elevated risk extending through the entire long-term period. The estimate of peak lifetime risk at the Core Zone Boundary under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, is approximately 2×10^{-5}. Disposal of offsite waste in IDF-East is the major contributor to this risk, while disposal of ETF-generated and tank closure secondary waste accounts for the remainder of the total risk. The estimate of peak lifetime risk for release from the entombed FFTF is approximately 2×10^{-5}.

Table 5–188. Alternative Combination 2 Drinking-Water Well User and Resident Farmer Long-Term Human Health Impact Summary

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index	Rad. Risk at Year of Peak Rad. Risk	Nonrad. Risk at Year of Peak Nonrad. Risk	Total Risk at Year of Peak Total Risk	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index	Rad. Risk at Year of Peak Rad. Risk	Nonrad. Risk at Year of Peak Nonrad. Risk	Total Risk at Year of Peak Total Risk
On Site										
Core Zone Boundary	1.50×10^{2}	8.96×10^{1}	2.91×10^{-3}	0.00	2.91×10^{-3}	2.58×10^{2}	3.25×10^{2}	7.78×10^{-3}	2.41×10^{-8}	7.78×10^{-3}
Columbia River nearshore	3.00	2.88	6.49×10^{-5}	0.00	6.49×10^{-5}	5.51	1.15×10^{1}	1.85×10^{-4}	8.95×10^{-10}	1.85×10^{-4}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	3.44×10^{-4}	8.95×10^{-4}	1.11×10^{-8}	6.82×10^{-14}	1.11×10^{-8}

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

Table 5–189. Alternative Combination 2 American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impact Summary

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index	Rad. Risk at Year of Peak Rad. Risk	Nonrad. Risk at Year of Peak Nonrad. Risk	Total Risk at Year of Peak Total Risk	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index	Rad. Risk at Year of Peak Rad. Risk	Nonrad. Risk at Year of Peak Nonrad. Risk	Total Risk at Year of Peak Total Risk
On Site										
Core Zone Boundary	4.39×10^{2}	7.04×10^{2}	1.60×10^{-2}	1.11×10^{-3}	1.66×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	9.82	2.47×10^{1}	3.90×10^{-4}	4.10×10^{-5}	4.12×10^{-4}	9.67×10^{-2}	4.61	2.66×10^{-6}	4.10×10^{-5}	4.20×10^{-5}
Off Site										
Columbia River	9.82×10^{-4}	4.55×10^{-1}	3.41×10^{-8}	3.13×10^{-9}	3.53×10^{-8}	N/A	N/A	N/A	N/A	N/A

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

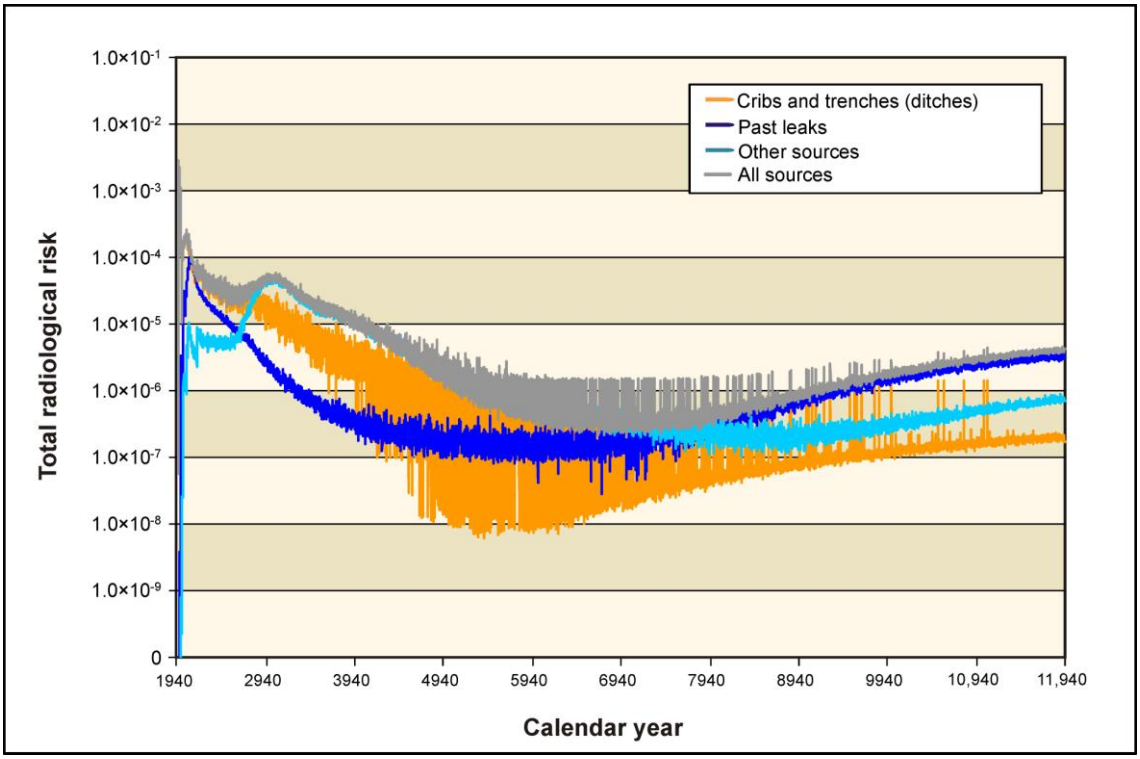


Figure 5–1281. Tank Closure Alternative 2B Time Series of Lifetime Radiological Risk for the Drinking-Water Well User at the Core Zone Boundary

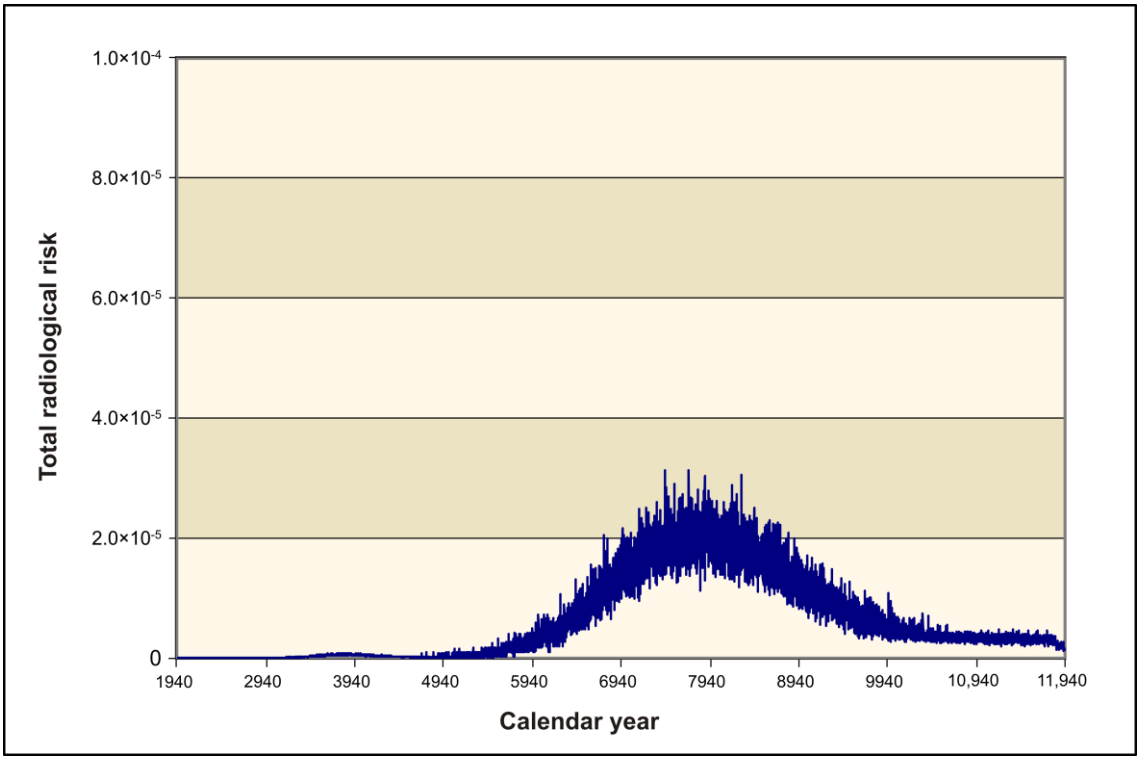


Figure 5–1282. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Time Series of Lifetime Radiological Risk for the Drinking-Water Well User at the Core Zone Boundary

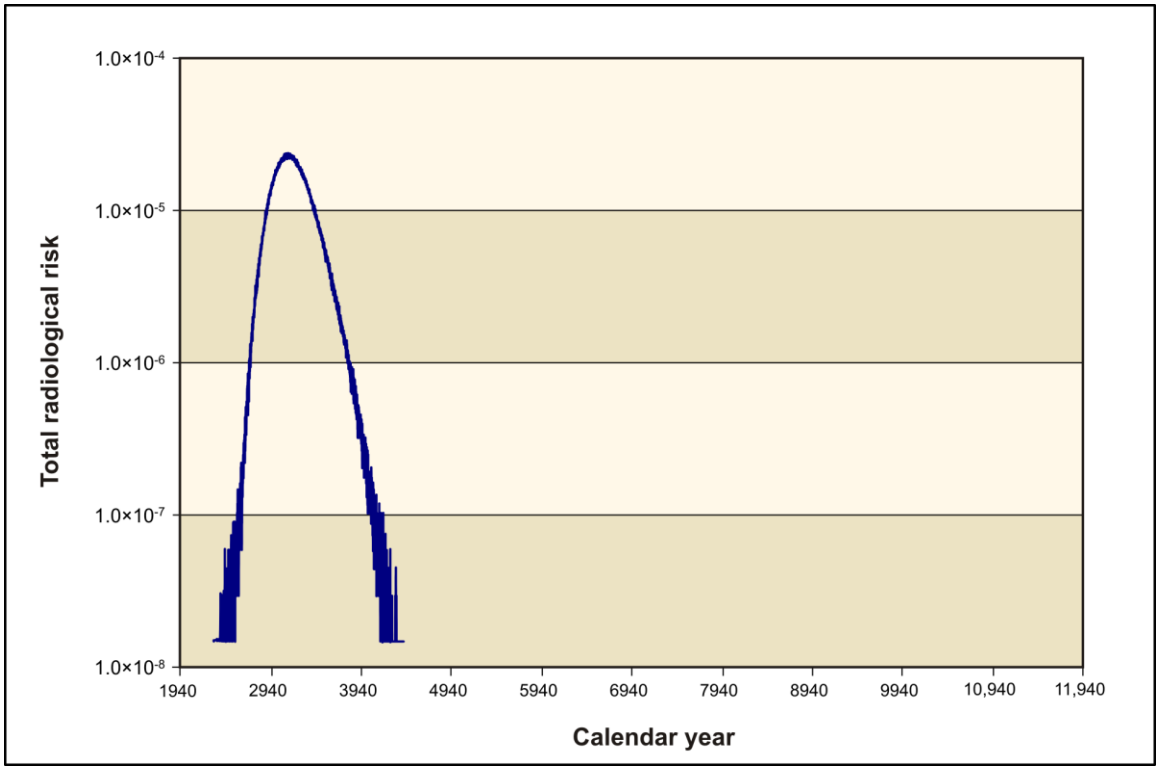


Figure 5–1283. FFTF Decommissioning Alternative 2 Time Series of Lifetime Radiological Risk for the Drinking-Water Well User at the FFTF Barrier

5.4.2.3 Alternative Combination 3

Potential human health impacts of Alternative Combination 3 are summarized in Tables 5–190 and 5–191. The key radioactive constituent contributors to human health risk are tritium, technetium-99, and iodine-129, and the key chemical constituent contributors are chromium, nitrate, and total uranium. For radionuclides, the dose standard would be exceeded at the Core Zone Boundary for the drinking-water well user, resident farmer, and American Indian resident farmer. The Hazard Index guideline would be exceeded due primarily to chromium and nitrate at the Core Zone Boundary and Columbia River nearshore for the drinking-water well user, resident farmer, and American Indian resident farmer. The Hazard Index guideline would also be exceeded at the Columbia River nearshore for the American Indian hunter-gatherer. Population dose is estimated as 1.72 person-rem per year for the year of maximum impact.

The time series of lifetime radiological risk for the drinking-water well user at the Core Zone Boundary are presented in Figures 5–1284 and 5–1285 for Tank Closure Alternative 6B, Base Case, and Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, respectively. Tank Closure Alternative 6B, Base Case, assumes removal of the HLW tanks and recovery of tank farm contaminated soil, producing a significant reduction in impacts relative to both Tank Closure Alternatives 1 and 2B. Risk due to future releases from the tank farms is eliminated. Estimates of impacts for planned discharges to cribs and trenches (ditches) are similar to those for Tank Closure Alternatives 1 and 2B, but long-term risk from past tank leaks is reduced by a factor of approximately 200 to approximately 2×10^{-7}. The estimate of peak lifetime risk at the Core Zone Boundary for Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, approximately 3×10^{-5}, is slightly higher than that for Alternative 2, Disposal Group 1, Subgroup 1-A, reflecting disposal of greater quantities of waste. Disposal of offsite waste in IDF-East is the major contributor to the peak lifetime risk, while disposal of ETF-generated and tank closure secondary waste is a secondary contributor. Increase of the disposal inventory for the RPPDF accentuates the pulse in the risk curve (see Figure 5–1285) centered at CY 4000. Risk due to releases from FFTF is decreased by removal under FFTF Decommissioning Alternative 3.

Table 5–190. Alternative Combination 3 Drinking-Water Well User and Resident Farmer Long-Term Human Health Impact Summary

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index	Rad. Risk at Year of Peak Rad. Risk	Nonrad. Risk at Year of Peak Nonrad. Risk	Total Risk at Year of Peak Total Risk	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index	Rad. Risk at Year of Peak Rad. Risk	Nonrad. Risk at Year of Peak Nonrad. Risk	Total Risk at Year of Peak Total Risk
On Site										
Core Zone Boundary	1.50×10^{2}	8.96×10^{1}	2.91×10^{-3}	0.00	2.91×10^{-3}	2.58×10^{2}	3.25×10^{2}	7.78×10^{-3}	2.41×10^{-8}	7.78×10^{-3}
Columbia River nearshore	3.00	2.88	6.49×10^{-5}	0.00	6.49×10^{-5}	5.51	1.15×10^{1}	1.85×10^{-4}	8.95×10^{-10}	1.85×10^{-4}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	3.44×10^{-4}	8.95×10^{-4}	1.11×10^{-8}	6.82×10^{-14}	1.11×10^{-8}

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

Table 5–191. Alternative Combination 3 American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impact Summary

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index	Rad. Risk at Year of Peak Rad. Risk	Nonrad. Risk at Year of Peak Nonrad. Risk	Total Risk at Year of Peak Total Risk	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index	Rad. Risk at Year of Peak Rad. Risk	Nonrad. Risk at Year of Peak Nonrad. Risk	Total Risk at Year of Peak Total Risk
On Site										
Core Zone Boundary	4.39×10^{2}	7.04×10^{2}	1.60×10^{-2}	1.11×10^{-3}	1.66×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	9.82	2.47×10^{1}	3.90×10^{-4}	4.10×10^{-5}	4.12×10^{-4}	9.67×10^{-2}	4.61	2.66×10^{-6}	4.10×10^{-5}	4.20×10^{-5}
Off Site										
Columbia River	9.82×10^{-4}	4.55×10^{-1}	3.41×10^{-8}	3.13×10^{-9}	3.53×10^{-8}	N/A	N/A	N/A	N/A	N/A

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

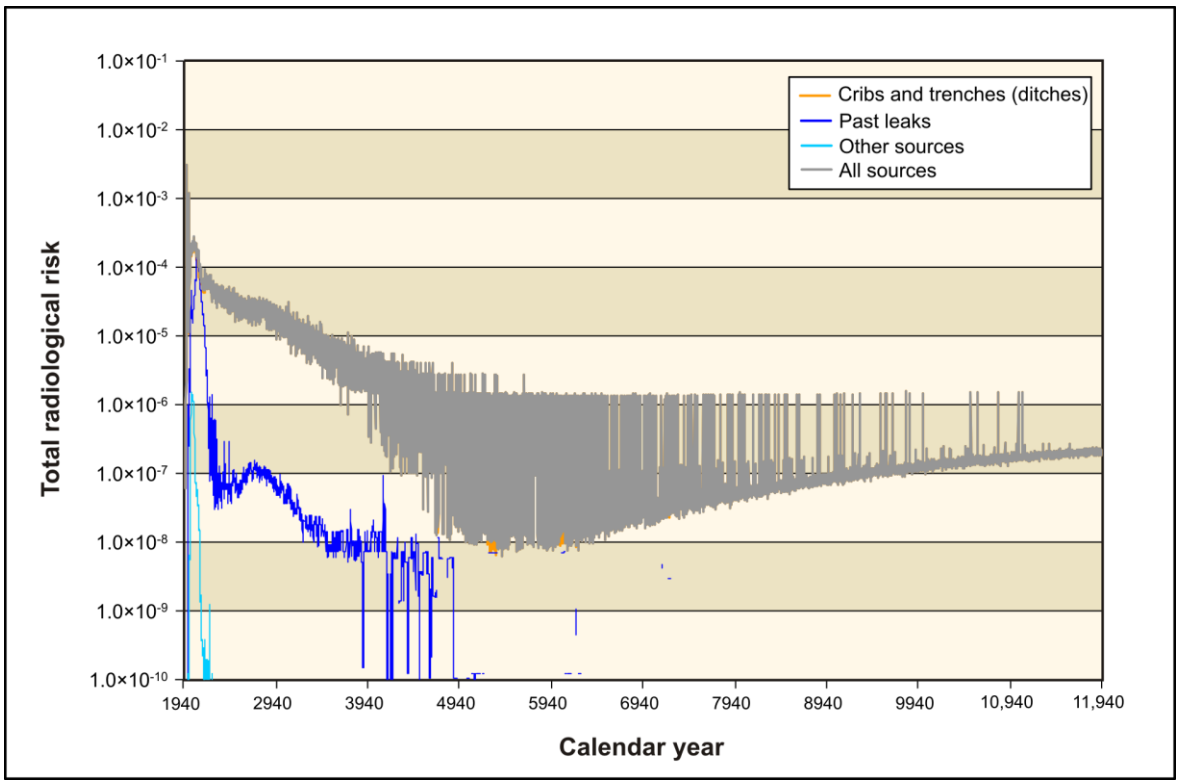


Figure 5–1284. Tank Closure Alternative 6B, Base Case, Time Series of Lifetime Radiological Risk for the Drinking-Water Well User at the Core Zone Boundary

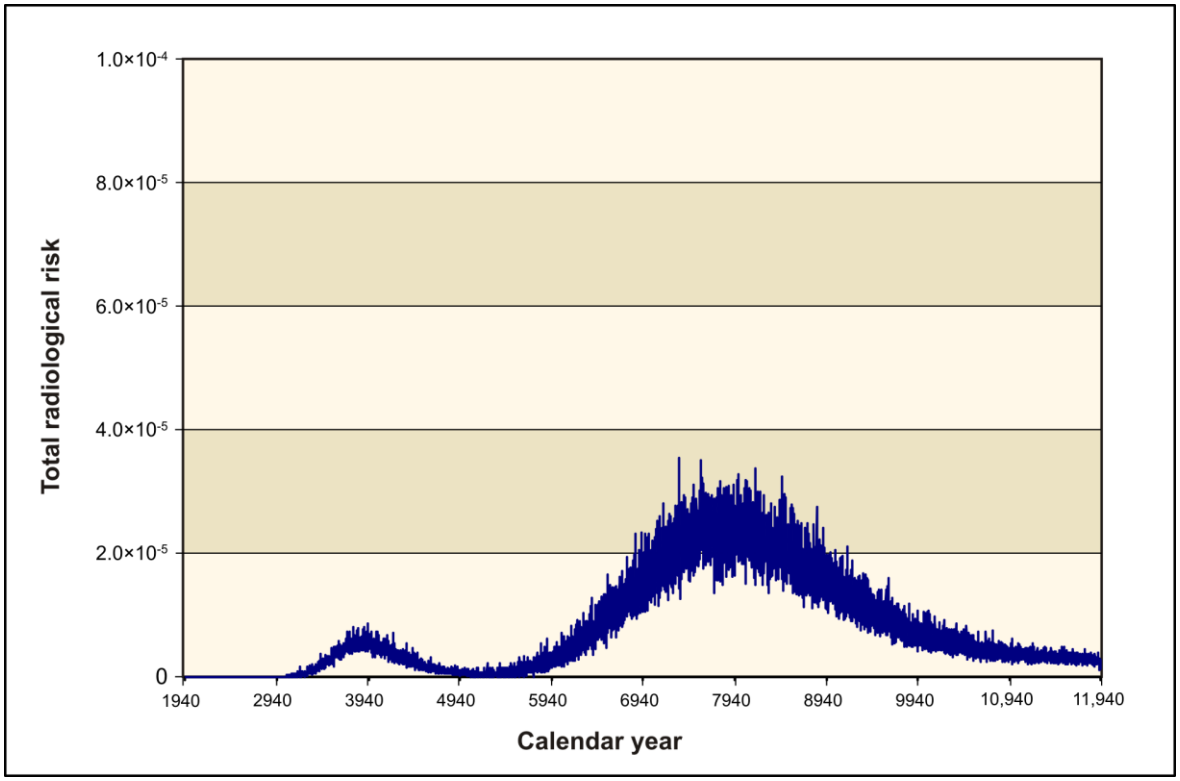


Figure 5–1285. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Time Series of Lifetime Radiological Risk for the Drinking-Water Well User at the Core Zone Boundary

5.4.3 Ecological Risk

This section presents the results of the evaluation of long-term impacts on ecological resources of releases to air and groundwater under three combinations of Tank Closure, FFTF Decommissioning, and Waste Management alternatives.

The long-term impacts on terrestrial ecological resources of releases to air at Hanford were evaluated at the onsite maximum-exposure location (Core Zone Boundary) and on terrestrial, riparian, and aquatic resources, at the offsite maximum-exposure location (Columbia River). Impacts on ecological resources of releases to groundwater were evaluated at the Columbia River. Risk indices could not be calculated for soil-dwelling invertebrates, lizards, toads, or birds exposed to organic compound COPCs because this *TC & WM EIS* does not include toxicity reference values for these receptors for these COPCs. The uncertainty about the risk to ecological resources from releases to air and groundwater under the *TC & WM EIS* alternatives is discussed in Appendix P (see Sections P.2.2 and P.3.2). Calculated risk indices are presented below for the COPCs with the highest Hazard Quotients or Hazard Indices for each receptor.

The highest risk indices for ecological receptors were calculated for Alternative Combinations 1 and 3. The risk indices calculated for plants, omnivorous mammals (Great Basin pocket mouse), and mammalian top carnivores (coyote) from air releases are highest under Alternative Combination 1. Among the combinations of alternatives, risk indices calculated for soil-dwelling invertebrates, side-blotched lizard, herbivorous mammals (mule deer), herbivorous birds (mourning dove), omnivorous birds (western meadowlark), and avian top carnivores (burrowing owl) are highest under Alternative Combination 3 (see Table 5–192). Predicted emissions of chemical COPCs in air under Alternative Combination 1 pose a small risk to plants (toluene Hazard Quotient is 47) and a moderate risk to mice and coyotes at the onsite maximum-exposure location. The largest calculated Hazard Quotients are those for the mouse at the onsite maximum-exposure location: xylene (2,119), as shown in Table 5–192; toluene (339); formaldehyde (80); and benzene (17) (SAIC 2011a). Predicted emissions of chemical COPCs in air under Alternative Combination 3 pose a small probability of adverse impacts on the mourning dove and burrowing owl (mercury Hazard Quotients less than 10) and a moderate probability for the side-blotched lizard (mercury Hazard Quotient is 172.6), meadowlark (mercury Hazard Quotient is 104), and mule deer (formaldehyde Hazard Quotient is 91) at the onsite maximum-exposure location. There would be minimal to no risk to soil-dwelling invertebrates at the onsite maximum-exposure location (calculated mercury Hazard Quotient is 1.03).

There would be minimal to no risk to terrestrial, riparian, or aquatic ecological receptors from releases to air under any of the alternative combinations at the offsite maximum-exposure location (Columbia River). The calculated Hazard Quotient is 2.4 for the mouse exposed to xylene at the Columbia River under Alternative Combination 1.

The risk indices for each of the alternative combinations is the sum of the risk indices for the individual Tank Closure, FFTF Decommissioning, and Waste Management alternatives included in the combination. Alternative Combination 3 has the highest calculated risk indices for the side-blotched lizard, mule deer, mourning dove, western meadowlark, and burrowing owl (see Table 5–192). Alternative Combination 3 includes Tank Closure Alternative 6B, and the calculated indices for Tank Closure Alternative 6B are larger than the indices for Tank Closure Alternatives 1 and 2B, which are included, respectively, in Alternative Combinations 1 and 2. The calculated risk indices for these receptors under Tank Closure Alternative 6B are not the largest for such receptors—the largest are those under Tank Closure Alternatives 3A and 3C (see Table 5–80). Alternative Combination 1 has the highest calculated risk indices for plants, the Great Basin pocket mouse, and the coyote (see Table 5–192). Alternative Combination 1 includes FFTF Decommissioning Alternative 1, and the calculated indices for FFTF Decommissioning Alternative 1 are much larger than the indices for FFTF Decommissioning

Alternatives 2 and 3, which are included, respectively, in Alternative Combinations 2 and 3 (SAIC 2011a).

For groundwater releases, risk indices exceed 1 for aquatic biota, including salmonids, exposed to chromium under all alternative combinations, corresponding to the Hazard Quotients exceeding 1 under the Tank Closure alternatives included in those alternative combinations (see Table 5–193). Waste Management Alternatives 2 and 3 (Disposal Group 1, Subgroups 1-C, 1-E, and 1-F), which have Hazard Quotients that exceed 1 for aquatic biota, do not contribute to the risk indices for alternative combinations (SAIC 2011b). The spotted sandpiper and least weasel have Hazard Quotients for chromium and nitrate, respectively, between 1 and 2 for Alternative Combinations 2 and 3, because these combinations include Tank Closure Alternatives 2B and 6B, respectively. There are no other receptors with risk indices exceeding 1 under the alternative combinations, including for all radioactive COPCs (see Appendix P, Table P–12).

Table 5–192. Alternative Combinations – Long-Term Impacts of Chemical COPC Releases to Air on Terrestrial Resources at the Onsite Maximum-Exposure Location

Alternative Combination	Maximum Hazard Quotient of Chemical COPC by Receptor								
	Plants	Soil-Dwelling Invertebrate	Side-Blotched Lizard	Great Basin Pocket Mouse	Coyote	Mule Deer	Meadow-lark	Mourning Dove	Burrowing Owl
	Toluene	Mercury	Mercury	Xylene	Xylene	Formaldehyde	Mercury	Mercury	Mercury
1	4.69×10^{1}	0.00	0.00	**2.12×10^{3}**	2.69×10^{2}	4.84×10^{1}	0.00	0.00	0.00
2	3.99	9.85×10^{-1}	**1.66×10^{2}**	1.92×10^{2}	2.44×10^{1}	3.00×10^{1}	9.95×10^{1}	8.22	6.92
3	1.03×10^{1}	1.03	1.73×10^{2}	**5.03×10^{2}**	6.39×10^{1}	9.08×10^{1}	1.04×10^{2}	8.56	7.21

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

Table 5–193. Alternative Combinations – Long-Term Impacts of Contaminant Releases to Groundwater on Aquatic and Riparian Receptors at the Columbia River

Alternative Combination	Maximum Hazard Quotient or Hazard Index of Chemical or Radioactive COPC by Receptor						
	Benthic Invertebrate	Muskrat	Spotted Sandpiper	Raccoon	Least Weasel	Bald Eagle	Aquatic Biota/Salmonids
	Chromium	Nitrate	Chromium	Chromium	Nitrate	Chromium	Chromium
1	1.69×10^{-1}	1.41×10^{-2}	1.15	1.39×10^{-1}	1.36	3.71×10^{-2}	**4.32×10^{1}**
2	1.67×10^{-1}	1.43×10^{-2}	1.13	1.37×10^{-1}	1.37	3.69×10^{-2}	**4.31×10^{1}**
3	1.67×10^{-1}	1.43×10^{-2}	1.13	1.37×10^{-1}	1.37	3.69×10^{-2}	**4.31×10^{1}**

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

5.4.4 Environmental Justice

Sections 5.4.1 and 5.4.2 evaluate groundwater impacts and associated potential long-term human health effects under the combinations of alternatives. Receptors analyzed with a potential for environmental justice concerns include a resident farmer, an American Indian resident farmer, and an American Indian hunter-gatherer. The hypothetical resident farmer, which could represent a minority or low-income population, and American Indian resident farmer were both assumed to use only groundwater for drinking water ingestion and crop irrigation. While only a portion of the food consumed by the resident farmer was assumed to come from crops and animal products exposed to contaminated groundwater, all of the food consumed by the American Indian resident farmer was assumed to be exposed to contaminated groundwater. (See Appendix Q, Section Q.2.4.1, for assumed consumption levels for the different receptors.) The American Indian hunter-gatherer was assumed to have a subsistence consumption pattern that differs from the American Indian resident farmer. The American Indian hunter-gatherer would not cultivate crops, but rather would gather food from indigenous plants and harvest a larger amount of fish from the Columbia River, drink no milk, consume no eggs, and drink a larger amount of water (water that would be gathered from potentially contaminated surface-water sources); thus, this receptor is assumed to be exposed to a combination of surface water and groundwater. Given these assumptions, the two American Indian receptors would be most at risk from contaminated groundwater. These receptors were used to develop exposure scenarios at several on- and offsite locations identified in Section Q.2.2.

Long-term human health impacts of actions associated with the combinations of alternatives analyzed would be greatest under Alternative Combination 1. Under this combination of alternatives, radionuclide releases would result in the dose at the Core Zone Boundary exceeding regulatory limits for the resident farmer and the American Indian resident farmer. None of the hypothetical receptors at the Columbia River nearshore or the Columbia River surface-water location would be exposed to a dose in excess of regulatory limits, including the American Indian hunter gatherer. Chemical releases under Alternative Combination 1 would result in exceedance of the Hazard Index guidelines for chromium and nitrate at the Core Zone Boundary and the Columbia River nearshore for the resident farmer and American Indian resident farmer and an exceedance of the Hazard Index guideline for nitrate at the Columbia River nearshore for the American Indian hunter-gatherer. None of the hypothetical receptors at the Columbia River surface water location would experience a Hazard Index in excess of Federal regulations.

The analysis determined that the greatest impact of any alternative combination on long-term human health could result in radiation doses in excess of regulatory limits and chemical exposures with a Hazard Index greater than 1 for receptors located on site at the Core Zone Boundary and the Columbia River nearshore. There are no such onsite receptors currently at Hanford. The onsite exposure scenarios do not currently exist and have never existed during Hanford operations. Therefore, the estimated high health risks for past years are hypothetical risks only; no persons were ever exposed at these levels. While it is possible for these receptor scenarios to develop in the future, none are expected for the foreseeable future because the Core Zone is designated for Industrial-Exclusive land use, the Columbia River nearshore is designated for Preservation (Hanford Reach National Monument), and the area between them is designated for Conservation (Mining) (DOE 1999). It is unlikely, therefore, that any of the combinations of alternatives would pose a disproportionately high and adverse long-term human health risk to American Indian populations at offsite locations. The greatest risk would be to the American Indian resident farmer at the Core Zone Boundary. During the year of peak dose, this receptor would receive a radiation dose of 450 millirem. During the year of peak Hazard Index, this receptor would be exposed to chemicals resulting in a Hazard Index greater than 1. The adverse impacts would also be applicable to non–American Indian receptors at the same locations, but to a lesser extent, because non–American Indian receptors are not expected to consume as much potentially contaminated food, e.g., fish, meat, milk.

5.5 REFERENCES

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