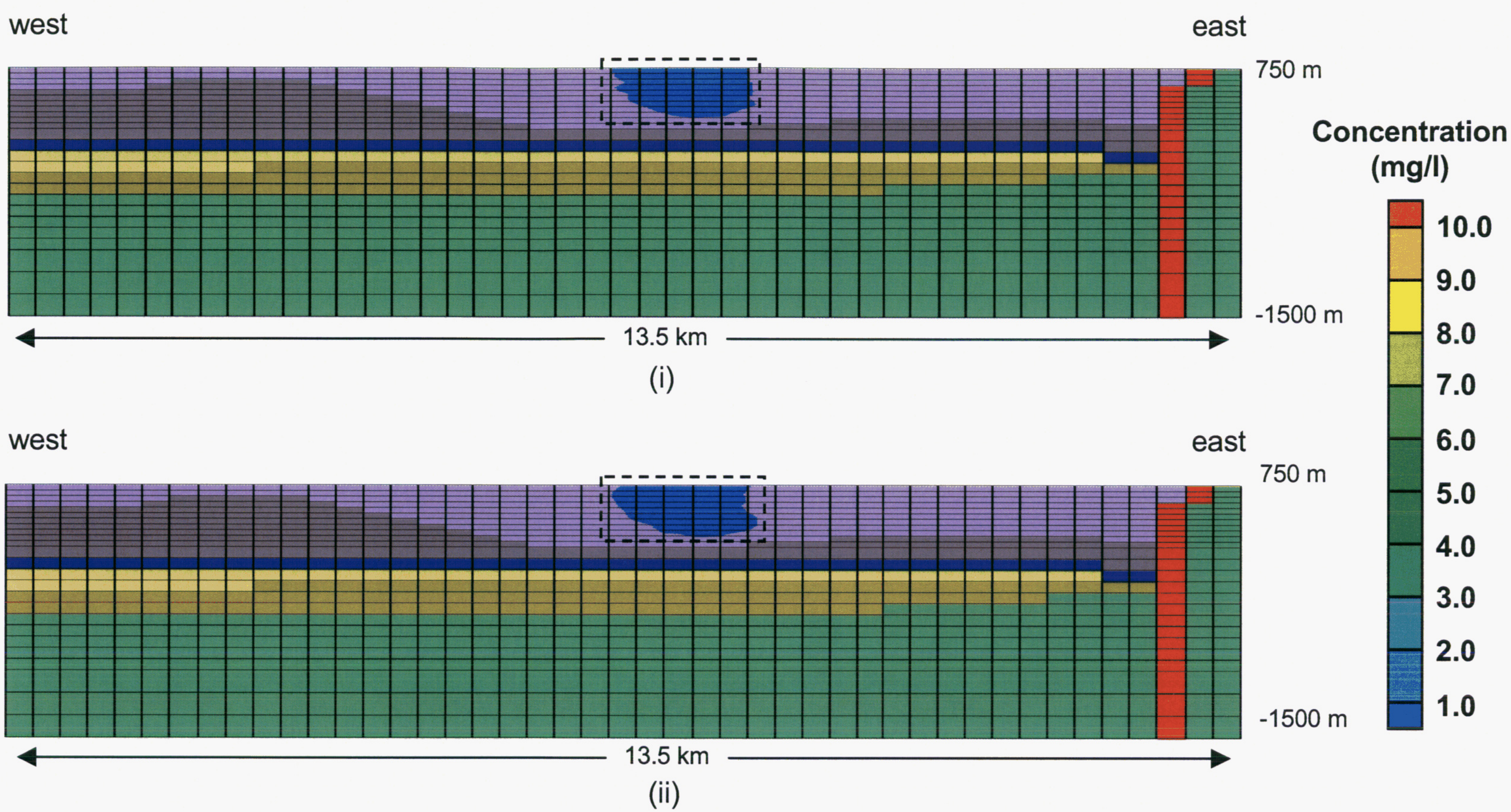


Figure 3-6 a. Vertical Cross Sections Along the Regulatory Compliance Boundary Showing the Cross-Sectional Dimensions of the Plumes Computed Using a Longitudinal Dispersivity of 1 m (Northern and Southern Sources) and (i) Commonly Used Dispersivity Ratios [(α_L/α_{TH}) = 10 and (α_L/α_{TV}) = 100] and (ii) DOE Dispersivity Ratios [(α_L/α_{TH}) = 200 and (α_L/α_{TV}) = 20,000). The Dash Outline Encloses the Region Occupied by the Plume. [1 m = 3.28 ft; 1 km = 0.62 mi]

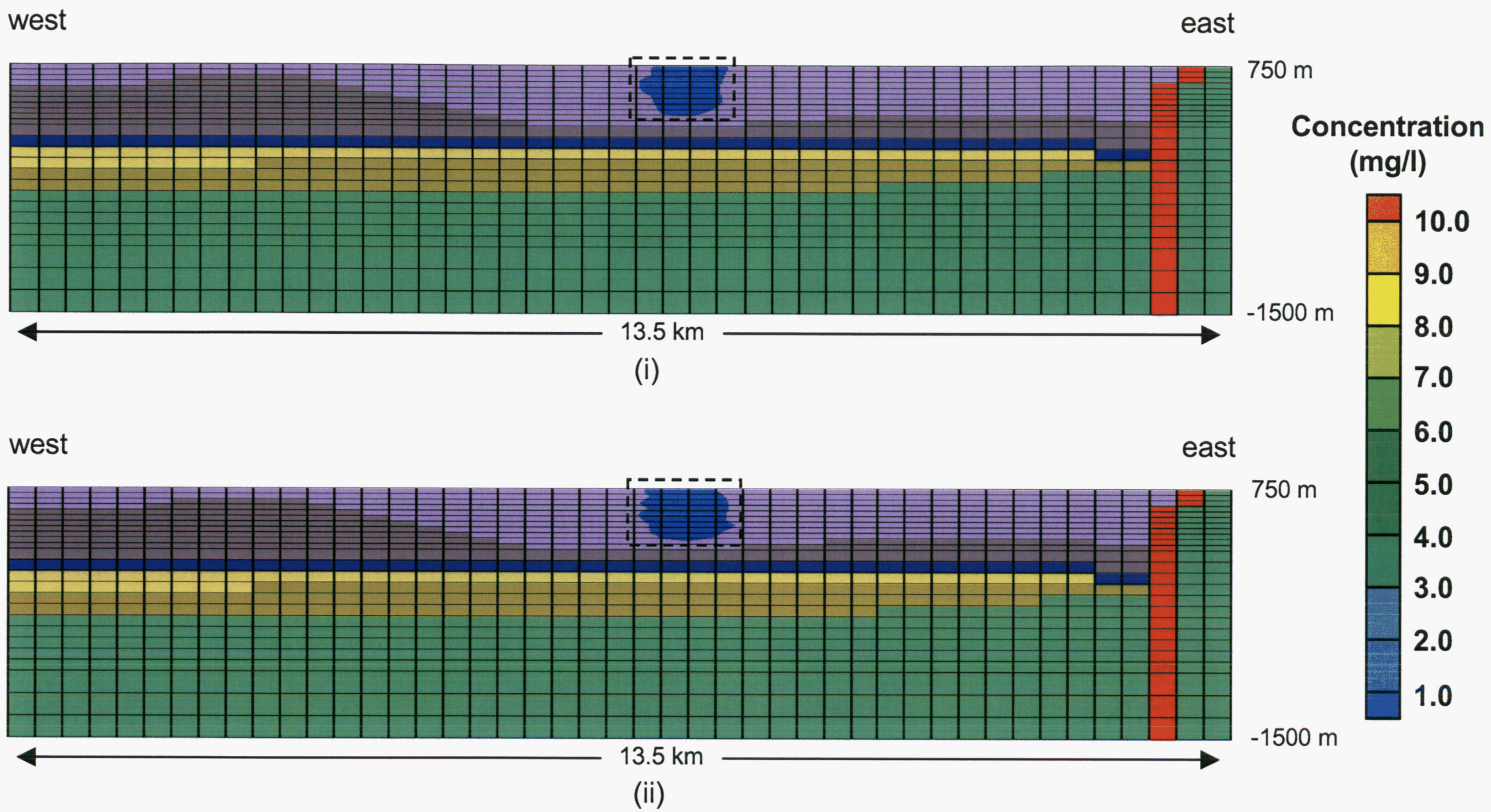
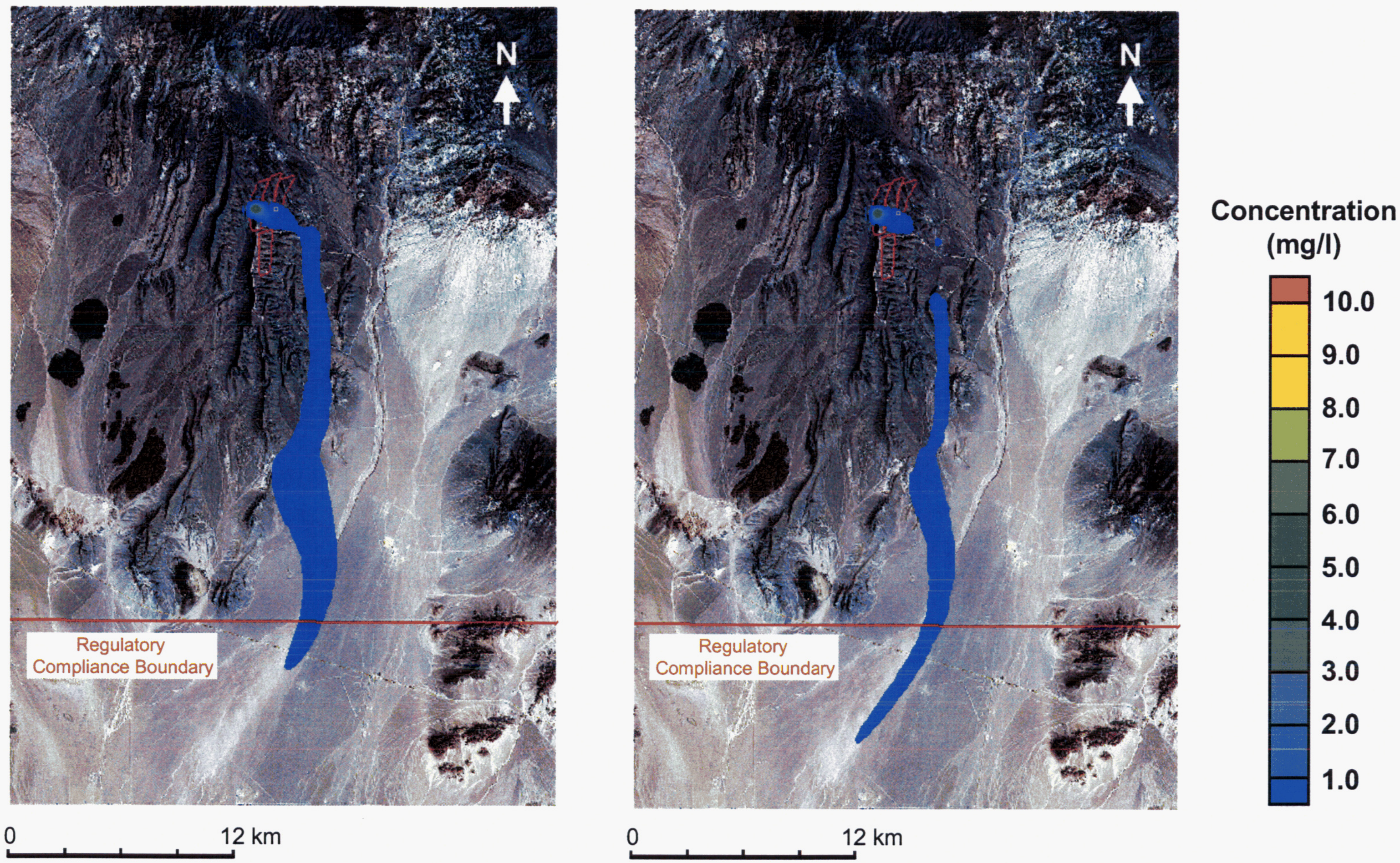


Figure 3-6 b. Vertical Cross Sections Along the Regulatory Compliance Boundary Showing the Cross-Sectional Dimensions of the Plumes Computed Using a Longitudinal Dispersivity of 1 m (Eastern and Western Sources) and (i) Commonly Used Dispersivity Ratios [(α_L/α_{TH}) = 10 and (α_L/α_{TV}) = 100] and (ii) DOE Dispersivity Ratios [(α_L/α_{TH}) = 200 and (α_L/α_{TV}) = 20,000]. The Dash Outline Encloses the Region Occupied by the Plume. [1 m = 3.28 ft; 1 km = 0.62 mi]



(i) (ii)

Figure 3-7 a. Plan View of Plumes From a Single Western Source Computed Using a Longitudinal Dispersivity of 100 m and (i) Commonly Used Dispersivity Ratios [(α_L/α_{TH}) = 10 and (α_L/α_{TV}) = 100] and (ii) DOE Dispersivity Ratios [(α_L/α_{TH}) = 200 and (α_L/α_{TV}) = 20,000]. The Elevation of the Horizontal Slice Through the Aquifer Is 725 m. [1 m = 3.28 ft; 1 km = 0.62 mi]

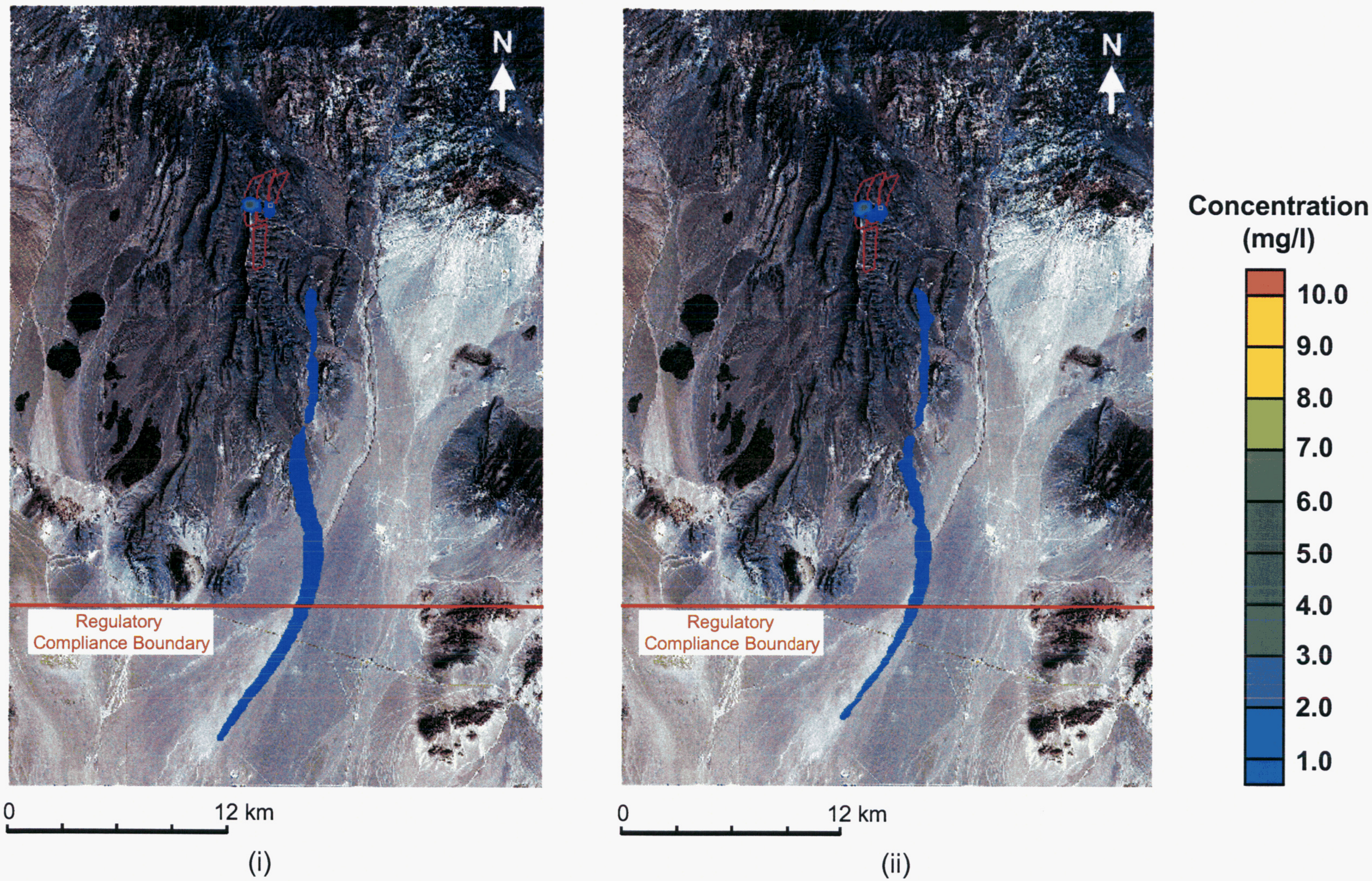


Figure 3-7 b. Plan View of Plumes From a Single Western Source Computed Using a Longitudinal Dispersivity of 10 m and (i) Commonly Used Dispersivity Ratios [(α_L/α_{TH}) = 10 and (α_L/α_{TV}) = 100] and (ii) DOE Dispersivity Ratios [(α_L/α_{TH}) = 200 and (α_L/α_{TV}) = 20,000]. The Elevation of the Horizontal Slice Through the Aquifer Is 725 m. [1 m = 3.28 ft; 1 km = 0.62 mi]

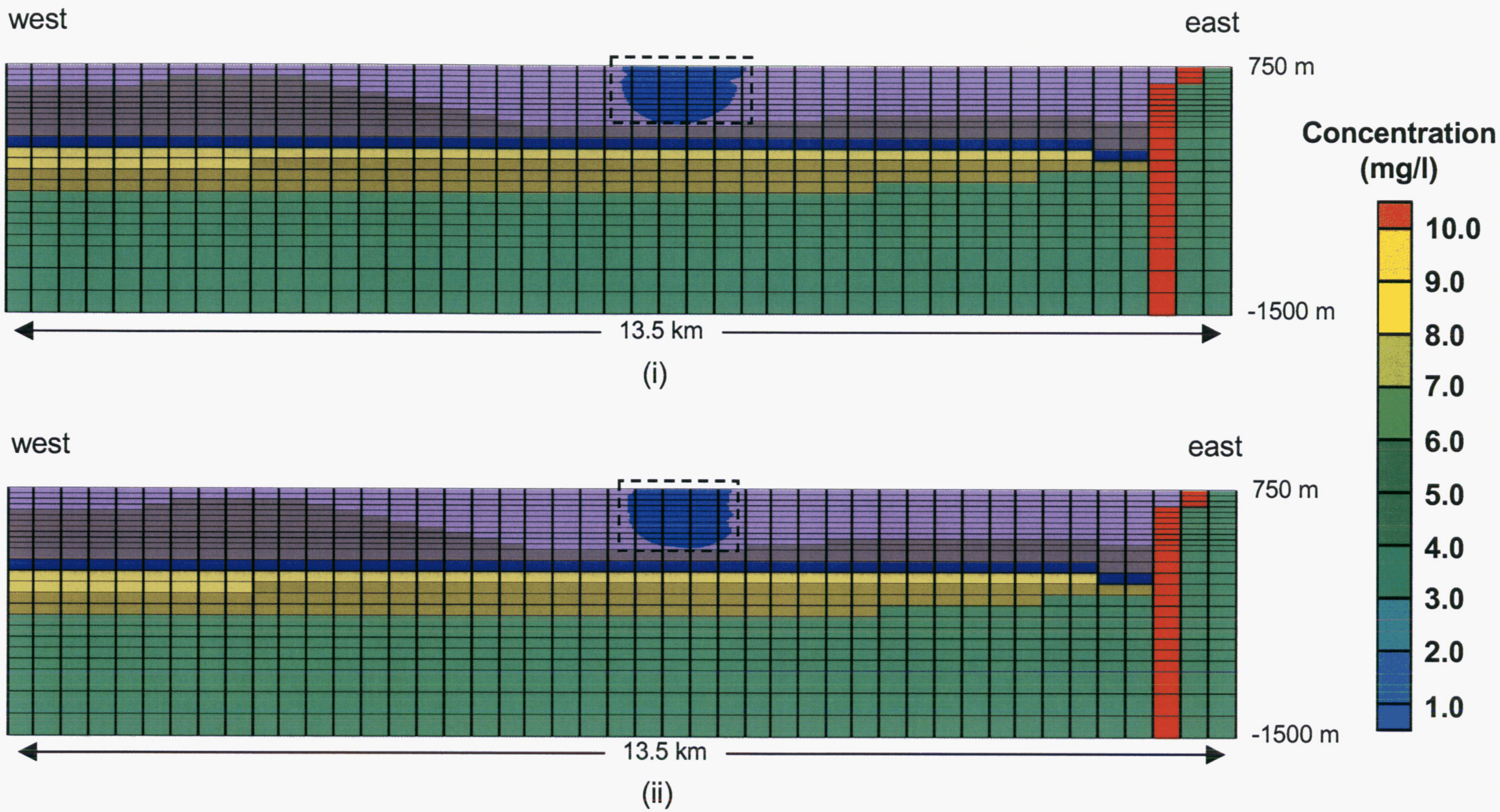


Figure 3-8 a. Vertical Cross Sections Along the Regulatory Compliance Boundary Showing the Cross-Sectional Dimensions of the Plumes Computed Using a Longitudinal Dispersivity of 100 m and (i) Commonly Used Dispersivity Ratios [(α_L/α_{TH}) = 10 and (α_L/α_{TV}) = 100] and (ii) DOE Dispersivity Ratios [(α_L/α_{TH}) = 200 and (α_L/α_{TV}) = 20,000]. The Dash Outline Encloses the Region Occupied by the Plume. [1 m = 3.28 ft; 1 km = 0.62 mi]

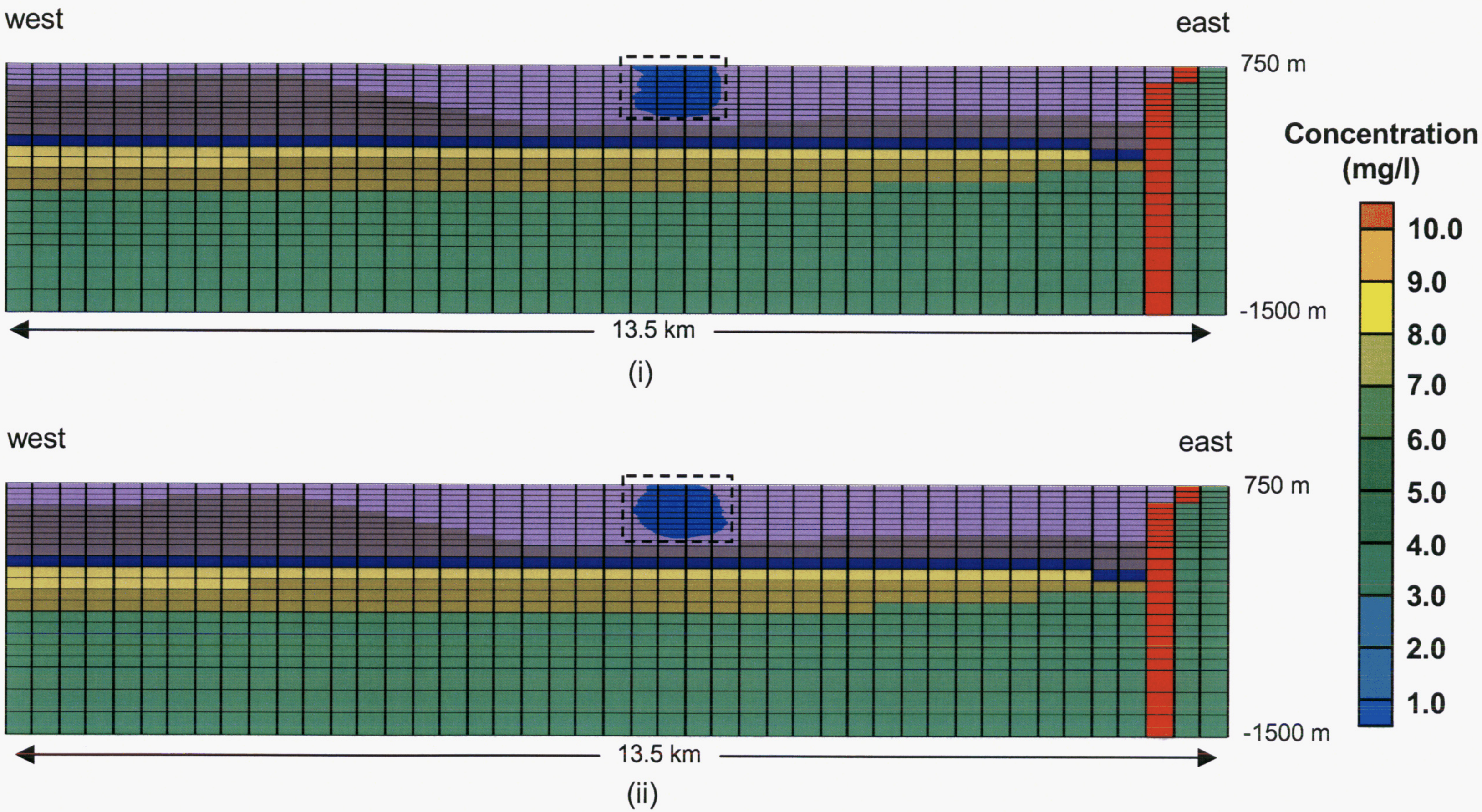


Figure 3-8 b. Vertical Cross Section Along the Regulatory Compliance Boundary Showing the Cross-Sectional Dimensions of the Plumes Computed Using a Longitudinal Dispersivity of 10 m and (i) Commonly Used Dispersivity Ratios [(α_L/α_{TH}) = 10 and (α_L/α_{TV}) = 100] and (ii) DOE Dispersivity Ratios [(α_L/α_{TH}) = 200 and (α_L/α_{TV}) = 20,000]. The Dash Outline Encloses the Region Occupied by the Plume. [1 m = 3.28 ft; 1 km = 0.62 mi]

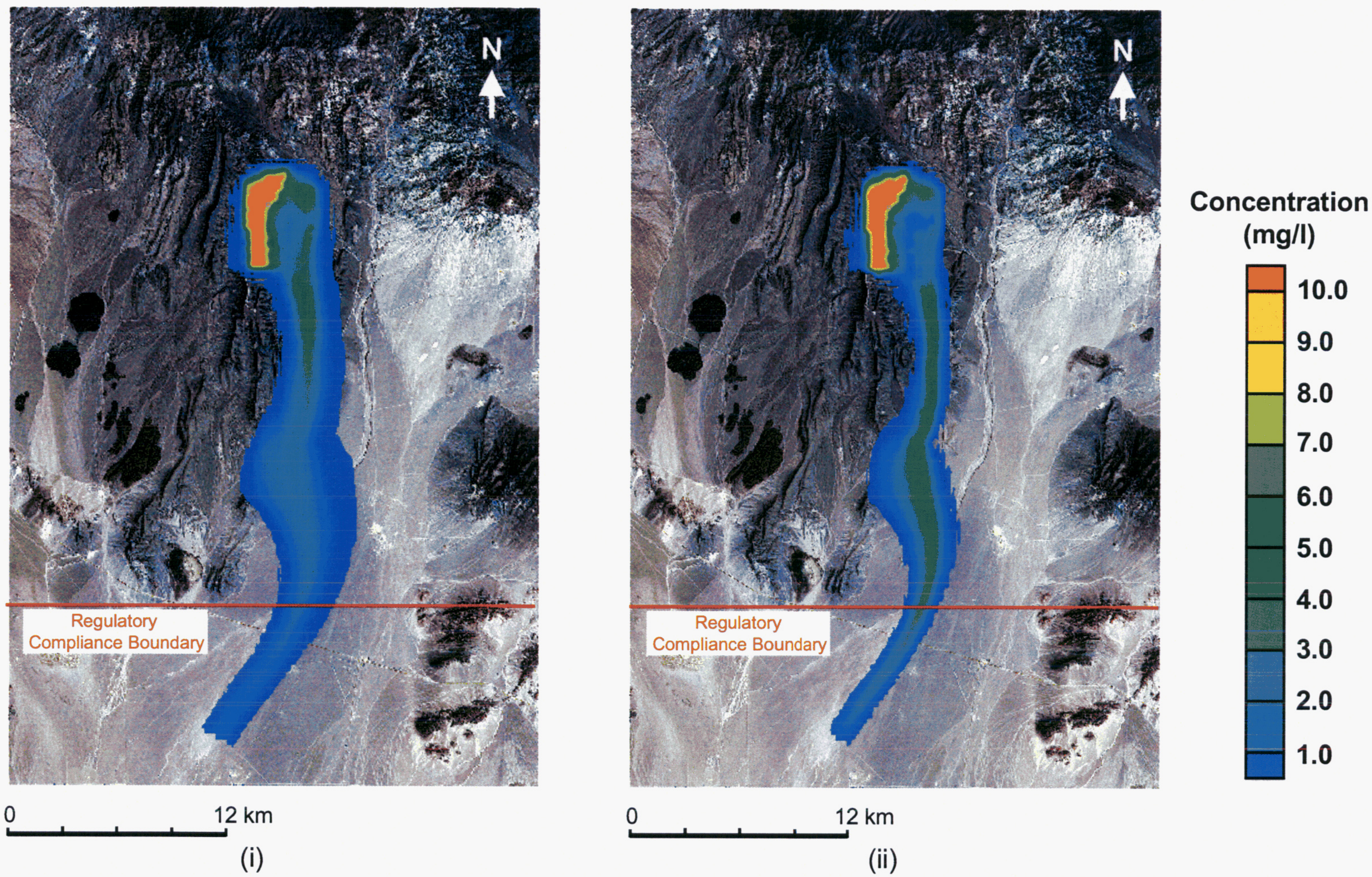


Figure 3-9 a. Plan View of the Plumes Computed Assuming All Sources Within the Repository Footprint Are Active, a Longitudinal Dispersivity of 170 m for the Tuff Hydrostratigraphy and a Longitudinal Dispersivity of 100 m for the Alluvium Hydrostratigraphy, and (i) Commonly Used Dispersivity Ratios [(α_L/α_{TH}) = 10 and (α_L/α_{TV}) = 100] and (ii) DOE dispersivity ratios [(α_L/α_{TH}) = 200 and (α_L/α_{TV}) = 20,000]. The Elevation of the Horizontal Slice Through the Aquifer Is 725 m. [1 m = 3.28 ft; 1 km = 0.62 mi]

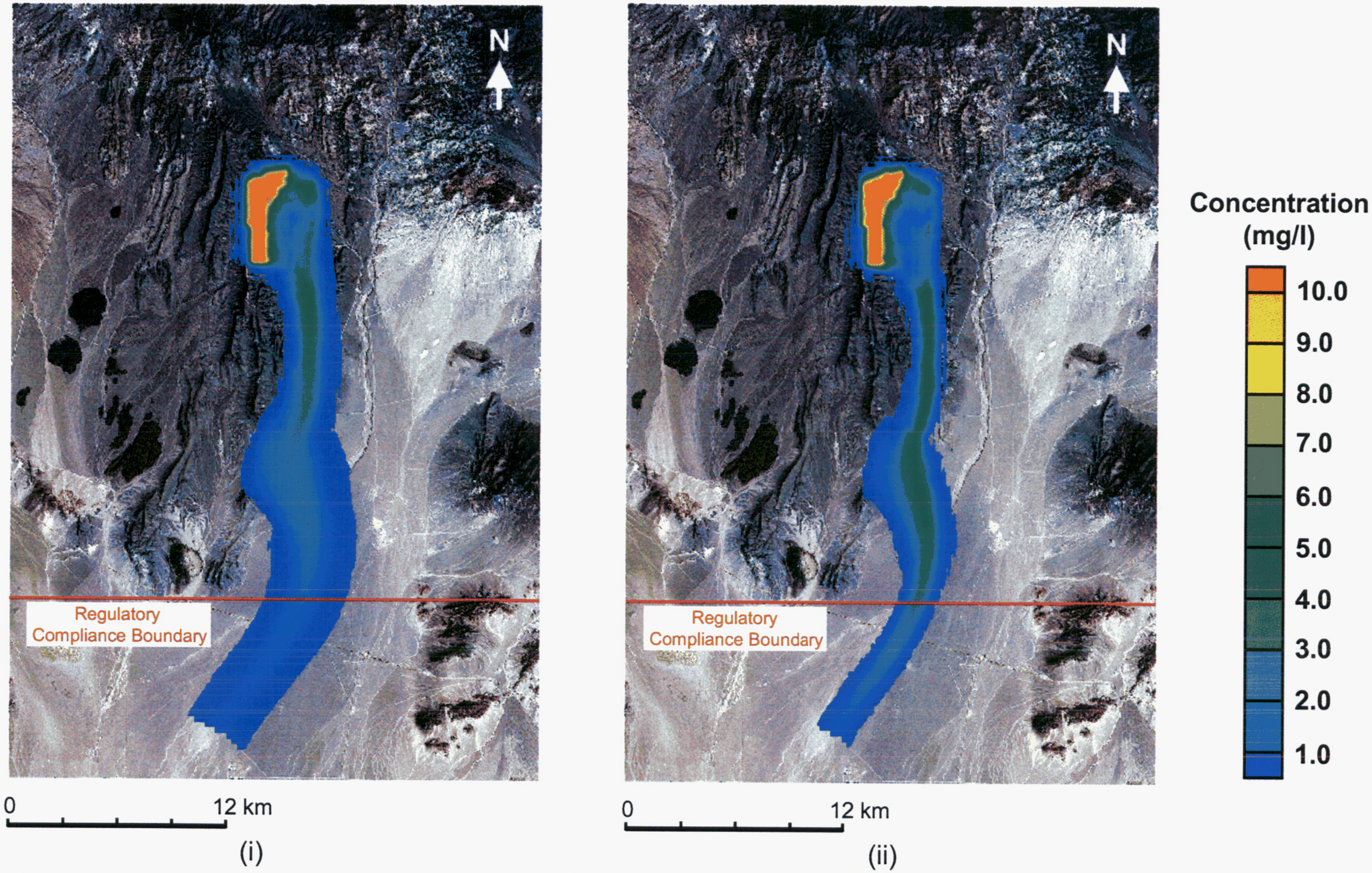


Figure 3-9 b. Plan View of the Plumes Computed Assuming All Sources Within the Repository Footprint Are Active, a Longitudinal Dispersivity of 135 m for the Tuff Hydrostratigraphy and a Longitudinal Dispersivity of 450 m for the Alluvium Hydrostratigraphy, and (i) Commonly Used Dispersivity Ratios [(α_L/α_{TH}) = 10 and (α_L/α_{TV}) = 100] and (ii) DOE Dispersivity Ratios [(α_L/α_{TH}) = 200 and (α_L/α_{TV}) = 20,000]. The Elevation of the Horizontal Slice Through the Aquifer Is 725 m. [1 m = 3.28 ft; 1 km = 0.62 mi]

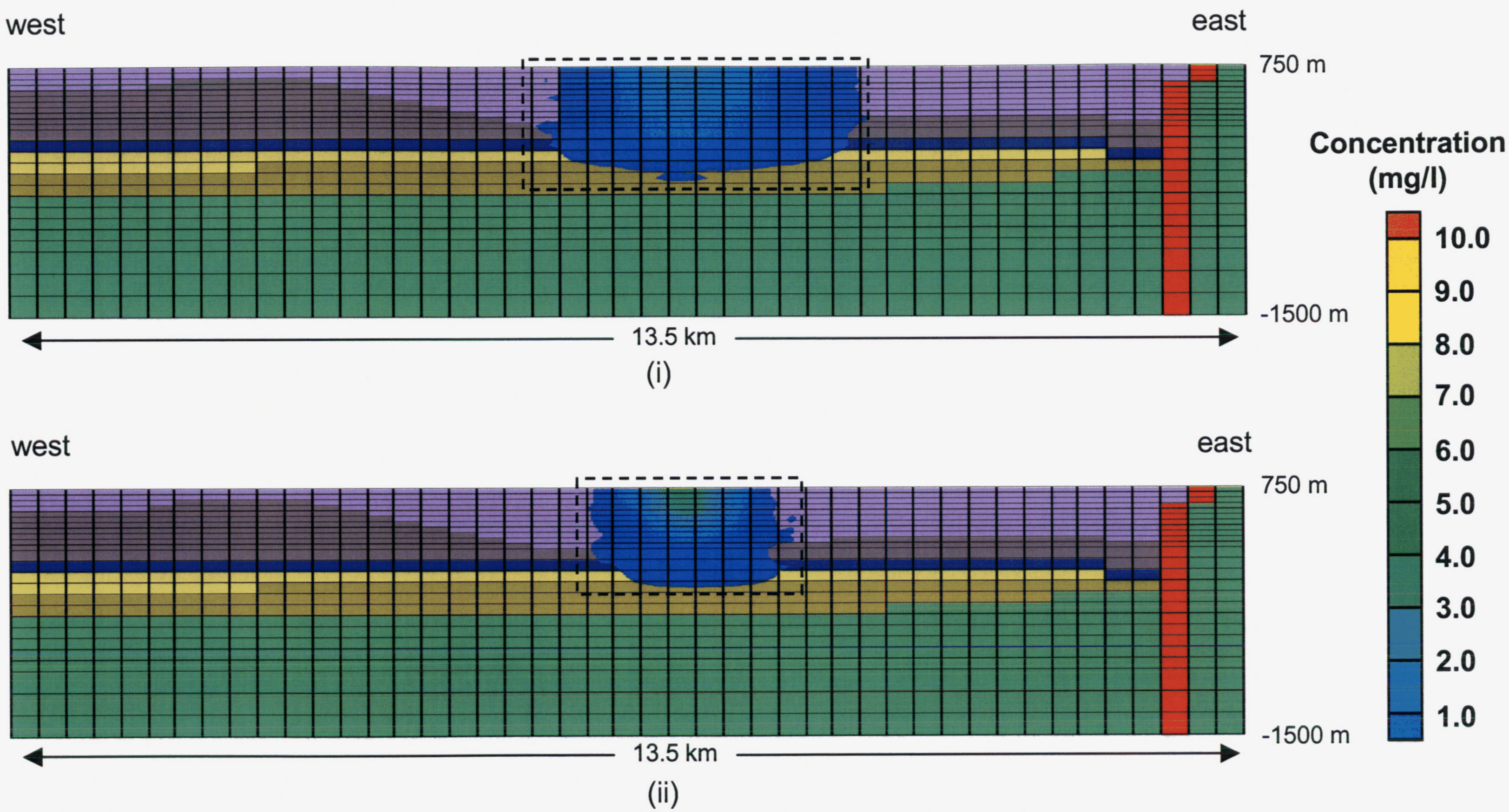


Figure 3-10 a. Vertical Cross Sections Along the Regulatory Compliance Boundary Showing the Cross-Sectional Dimensions of the Plume Computed Assuming All Sources Within the Repository Footprint Are Active, a Longitudinal Dispersivity of 170 m for the Tuff Hydrostratigraphy, a Longitudinal Dispersivity of 100 m for the Alluvium Hydrostratigraphy, and (i) commonly used dispersivity ratios [(α_L/α_{TH}) = 10 and (α_L/α_{TV}) = 100)] and (ii) DOE Dispersivity Ratios [(α_L/α_{TH}) = 200 and (α_L/α_{TV}) = 20,000)]. The Dash Outline Encloses the Region Occupied by the Plume. [1 m = 3.28 ft; 1 km = 0.62 mi]

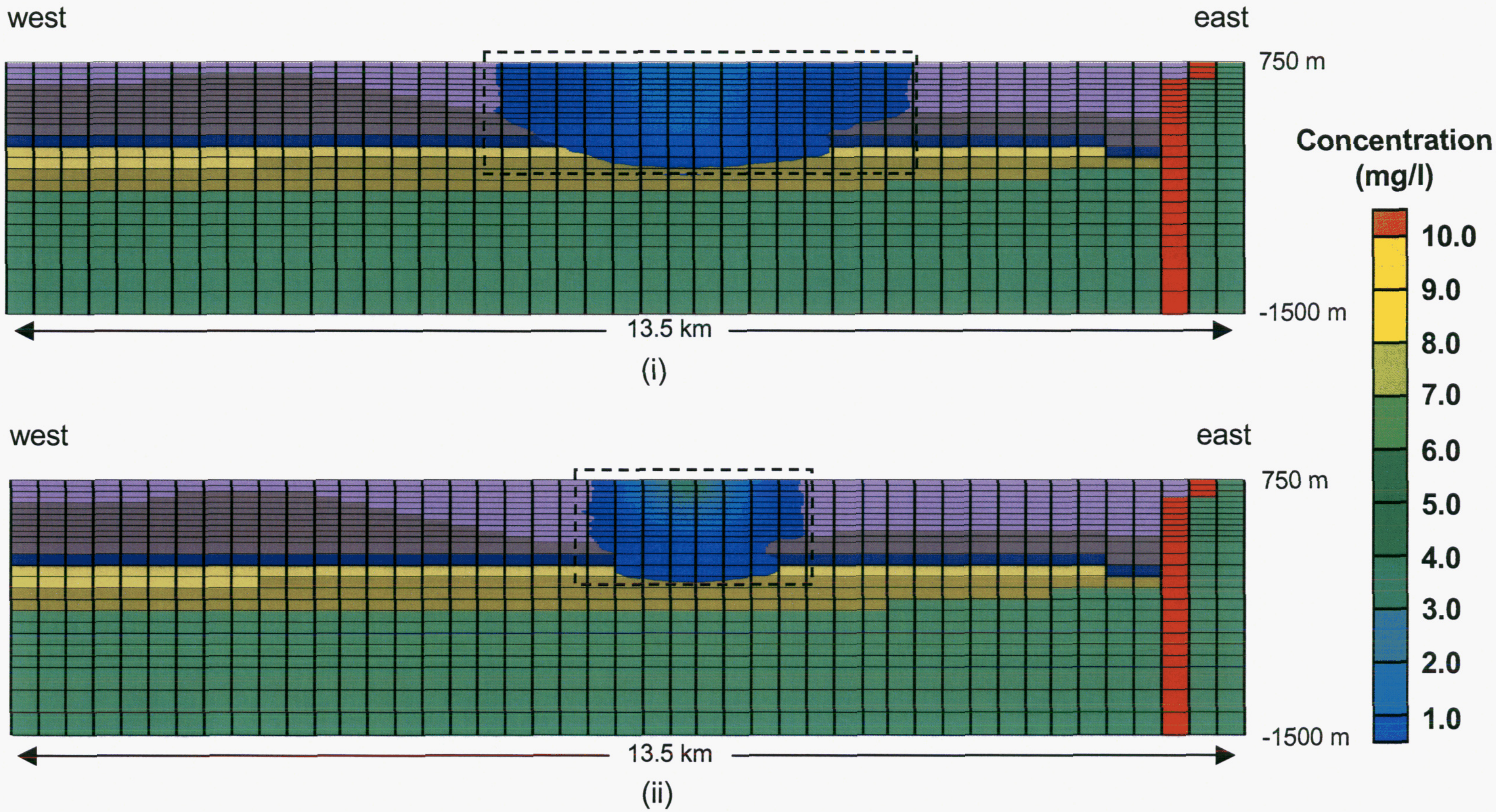


Figure 3-10 b. Vertical Cross Sections along the Regulatory Compliance Boundary Showing the Cross-Sectional Dimensions of the Plume Computed Assuming All Sources Within the Repository Footprint Are Active, a Longitudinal Dispersivity of 135 m for the Tuff Hydrostratigraphy, a Longitudinal Dispersivity of 450 m for the Alluvium Hydrostratigraphy, and (i) Commonly Used Dispersivity Ratios [(α_L/α_{TH}) = 10 and (α_L/α_{TV}) = 100] and (ii) DOE Dispersivity Ratios [(α_L/α_{TH}) = 200 and (α_L/α_{TV}) = 20,000]. The Dash Outline Encloses the Region Occupied by the Plume. [1 m = 3.28 ft; 1 km = 0.62 mi]

4 SUMMARY AND CONCLUSIONS

The analysis performed in this work considered a range of plumes sizes that may evolve from the potential repository. These were generated by modifying the (i) plume source size, (ii) source location, and (iii) dispersivity values used in the simulations. Large plumes were generated by combining large source sizes with large dispersivity values, and small plumes were generated by combining small source sizes with small dispersivity values. To support the analyses, longitudinal dispersivity values drawn from the distributions in the TPA Version 5.0.1 code and Bechtel SAIC Company, LLC (2004) were used. In addition, horizontal and vertical dispersivity values used in the analyses were based on ratios of longitudinal dispersivity to horizontal and vertical dispersivity that are either (i) contained in the Bechtel SAIC Company, LLC (2004) or (ii) commonly used in industry.

The simulations showed that for conservative solutes, relatively large groundwater plumes may evolve at the location of the regulatory compliance boundary. Conditions favorable for the development of relatively large solute plumes at the site were found to include (i) large source sizes and (ii) large dispersivity values sampled from the NRC and DOE distributions. The analyses showed that for a given source size and longitudinal dispersivity, plumes based on the DOE ratios relating longitudinal dispersivity to horizontal and transverse dispersivity resulted in narrower plumes than those based on more commonly used ratios in industry. Based on the simulations performed as part of this work, it can be concluded that the sizes of plumes crossing the regulatory compliance boundary could range from several hundred meters in width to greater than 4 km [2.5 mi] in width. In addition, plumes could extend to depths greater than 600 m [1,968 ft] with the lower volcanic confining unit significantly attenuating the vertical spreading of the plume.

The analyses also looked at the annual groundwater flow through the plumes at the location of the regulatory compliance boundary. For the analyses, the plume boundary was defined as the point at which the normalized concentration was 10^{-3}. The results of the analyses indicate that for small plumes the annual groundwater flow through the plumes can be less than 0.25×10^6 m^3/yr [200 acre-ft/yr]. For the large plumes considered, the annual groundwater flow through the plumes at the regulatory compliance boundary can exceed 1.23×10^6 m^3/yr [1,000 acre-ft/yr]. Wider plumes than those simulated are possible at the site if the DOE probability density function used to define the longitudinal dispersivity in the DOE total system performance assessment model is sampled at the upper 99-percent confidence interval. At that level, the longitudinal dispersivity used in the transport abstraction model would be approximately 1.8 km [1.1 mi], which is significantly larger than values currently used in this analysis.

The simulations involving both large and small plumes showed the location where the plumes transition from the tuff hydrostratigraphy to the alluvium hydrostigraphy. The simulation results showed that at the water table, the travel distance in the alluvium is between 3.3 and 5.1 km [2.1 and 3.2 mi]. This distance is consistent with the 1- to 6-km [0.6- to 3.7-mi] travel distance used by the NRC TPA Version 5.0.1. code

4.1 Future Work

The solute transport model discussed in this report currently simulates the transport of a conservative solute. The use of a conservative solute to simulate transport processes from the repository footprint may provide (i) a reasonable range for the arrival time of solutes at the regulatory compliance boundary, (ii) a reasonable range for the plume dimensions and annual flow through plumes at the regulatory compliance boundary, and (iii) a reasonable range for peak solute concentrations at the regulatory compliance boundary. Future work that could improve the current solute transport model and add more realism to the model might include

(i) The inclusion of radionuclide species that are the focus of regulatory concern. This update to the model could include support for (a) radionuclide decay and in-growth and (b) chemical reactions, including sorption. This could support investigations of processes and assumptions currently implemented in the TPA Version 5.0.1 code.

(ii) Investigation of the importance of dual porosity models for the tuff and alluvium to aspects of the transport process that are important to regulatory performance.

(iii) Refinement of the model grid to capture smaller scale geologic structures that may influence the transport of small plumes at the site. This investigation will further assess whether it is possible for widely spaced, small, isolated plumes to cross the regulatory compliance boundary and whether the presence of such features can alter the transport pathway.

5 REFERENCES

Bechtel SAIC Company, LLC. "Saturated Zone Flow and Transport Model Abstraction." Las Vegas, Nevada: Bechtel SAIC Company, LLC. 2004.

Environmental Modeling Research Laboratory. "GMS Version 5.1." Salt Lake City, Utah: Brigham Young University, Environmental Modeling Research Laboratory. 2005.

———. "GMS Version 3.0 Reference Manual." Salt Lake City, Utah: Brigham Young University, Environmental Modeling Research Laboratory. 1999.

Freyberg, D.L. "A Natural Gradient Experiment on Solute Transport in a Sand Aquifer: 2. Spatial Moments and the Advection and Dispersion of Non-Reactive Tracers." *Water Resources Research*. Vol. 22, No. 13. pp. 2,031–2,046. 1986.

Harbaugh, A.W. and M.G. McDonald. "User's Documentation for MODFLOW-96, An Update to the U.S. Geological Survey Modular Finite-Difference Groundwater Flow Model." U.S. Geological Survey Open File Report 96-485. 1996.

Harbaugh, A.W., E.R. Banta, M.C. Hill, and M.G. McDonald. "MODFLOW-2000, The U.S. Geological Survey Modular Ground-Water Model—User Guide to Modularization Concepts and the Ground-Water Flow Process." U.S. Geological Survey Open File Report 00-92. 2000.

Lawrence Berkeley National Laboratory. "Software Finite Element Heat and Mass Transfer (FEHM) Version 2.0 SUN, P.C." 10086-2.20-00. Berkeley, California: Lawrence Berkeley National Laboratory. 2003.

Mohanty, S., R. Codell, J.M. Menchaca, R. Janetzke, M. Smith, P. LaPlante, M. Rahimi, and A. Lozano. "System-Level Performance Assessment of the Proposed Repository at Yucca Mountain Using the TPA Version 4.1 Code." CNWRA 2002-05. Rev. 1. San Antonio, Texas: CNWRA. 2002.

NRC. NUREG–1804, "Yucca Mountain Review Plan—Final Report." Rev. 2. Washington, DC: NRC. July 2003.

Rehfeldt, K.R. and L.W. Gelhar. "Stochastic Analysis of Dispersion in Unsteady Flow in Heterogeneous Aquifers." *Water Resources Research*. Vol. 28, No. 8. pp. 2,085–2,099. 1992.

Sims, D.W., J.A. Stamatakos, D.A. Ferrill, H.L. McKague, D.A. Farrell, and A. Armstrong. "Three-Dimensional Structural Model of the Amargosa Desert, Version 1.0: Report to Accompany Model Transfer to the Nuclear Regulatory Commission." San Antonio, Texas: CNWRA. 1999.

Winterle, J. "Simulation of Spring Flows South of Yucca Mountain, Nevada, Following a Potential Future Water Table Rise." San Antonio, Texas: CNWRA. 2005.

———. "Evaluation of Alternative Concepts for Saturated Zone Flow: Effects of Recharge and Water Table Rise on Flow Paths and Travel Times at Yucca Mountain." San Antonio, Texas: CNWRA. 2003.

Winterle, J., M. Hill, and C. Manepally. "Concepts of Saturated Zone Modeling for Development of a Site-Scale Groundwater Flow Model for Yucca Mountain." San Antonio, Texas: CNWRA. 2002.

Zheng, C.M. and P.P. Wang. "MT3DMS: A Modular Three-Dimensional Multispecies Transport Model for Simulation of Advection, Dispersion, and Chemical Reactions of Contaminants in Groundwater Systems; Documentation and User's Guide." Contract Report SERDP–99–1. Vicksburg, Mississippi: U.S. Army Engineer Research and Development Center. 1999.