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NUREG-2184

Supplement to the U.S. Department of Energy's Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada

Final Report

Office of Nuclear Material Safety and Safeguards

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Final Report

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ABSTRACT

This "Supplement to the Department of Energy's Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada" (supplement) evaluates the potential environmental impacts on groundwater and impacts associated with the discharge of any contaminated groundwater to the ground surface due to potential releases from a geologic repository for spent nuclear fuel and high-level radioactive waste at Yucca Mountain, Nye County, Nevada. This supplements the U.S. Department of Energy's (DOE's) 2002 "Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada" and 2008 "Final Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada," in accordance with the findings and scope outlined in the U.S. Nuclear Regulatory Commission (NRC) staff's 2008 "Adoption Determination Report for the U.S. Department of Energy's Environmental Impact Statements for the Proposed Geologic Repository at Yucca Mountain."

This supplement describes the affected environment and assesses the potential environmental impacts with respect to potential contaminant releases from the repository that could be transported through the volcanic-alluvial aquifer in Fortymile Wash and the Amargosa Desert, and to the Furnace Creek/Middle Basin area of Death Valley. This supplement evaluates the potential radiological and nonradiological impacts—over a one million year period—on the aquifer environment, soils, ecology, and public health, as well as the potential for disproportionate impacts on minority or low-income populations. In addition, this supplement assesses the potential for cumulative impacts associated with other past, present, or reasonably foreseeable future actions. The NRC staff finds that each of the potential direct, indirect, and cumulative impacts on the resources evaluated in this supplement would be SMALL.

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EXECUTIVE SUMMARY

This supplement evaluates the potential environmental impacts on groundwater and impacts associated with the discharge of any contaminated groundwater to the ground surface due to potential releases from a geologic repository for spent nuclear fuel and high-level radioactive waste at Yucca Mountain, Nye County, Nevada. This supplements the U.S. Department of Energy's (DOE's) 2002 "Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada" and 2008 "Final Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada," in accordance with the findings and scope outlined in the U.S. Nuclear Regulatory Commission (NRC) staff's 2008 "Adoption Determination Report for the U.S. Department of Energy's Environmental Impact Statements for the Proposed Geologic Repository at Yucca Mountain."

In Section 3.2.1.4.2 of the Adoption Determination Report (ADR), the NRC staff found that DOE's environmental impact statements (EISs) did not adequately characterize impacts from potential contaminant releases to groundwater and from surface discharges of groundwater. Specifically, DOE's analysis does not provide adequate discussion of the cumulative amounts of radiological and nonradiological contaminants that may enter the groundwater over time and how these contaminants would behave in the aquifer and surrounding environments. This supplement provides the information the NRC staff identified as necessary in its ADR. Two distinct but related aspects of potential impacts on the groundwater system are addressed in this supplement. These are (i) the nature and extent of the repository's impacts on groundwater in the aquifer (beyond the postclosure compliance location) and (ii) the potential impacts of the discharge of potentially contaminated groundwater to the ground surface.

This supplement describes the affected environment with respect to the groundwater flow path for potential contaminant releases from the repository that could be transported beyond the postclosure compliance location through the volcanic-alluvial aquifer in Fortymile Wash and the Amargosa Desert, and to the Furnace Creek/Middle Basin area of Death Valley. The analysis in this supplement considers both radiological and nonradiological contaminants. Using groundwater modeling, the NRC staff finds that contaminants from the repository would be captured by groundwater withdrawal along the flow path, such as the current pumping in the Amargosa Farms area, or would continue to Death Valley in the absence of such pumping. Thus, this supplement provides a description of the flow path from the postclosure compliance location to Death Valley, the locations of current groundwater withdrawal, and locations of potential natural discharge along the groundwater flow path. The supplement evaluates the potential groundwater-related environmental impacts at these locations over a one-million year period following repository closure.

To evaluate the environmental impacts, this supplement assumes the repository and performance characteristics in the DOE license application, as evaluated in the NRC staff's Safety Evaluation Report. This supplement describes the potential impacts that could occur under different climate conditions and under different assumptions for groundwater withdrawal. The analysis in this supplement encompasses the range of credible future climates and human activities affecting groundwater in the Yucca Mountain region, and includes conservative assumptions for future conditions and processes. Future climates are projected to include periods that are relatively hot and dry (similar to present-day conditions) and periods that are relatively cooler and wetter over the one-million-year time period. These climate states are based on geologic evidence of past climate change cycles in the region. They are also

consistent with DOE's model of repository performance, in that they capture the rates of contaminant release and transport through the groundwater system. Projected human-induced climate change (a future climate that is warmer and drier than present, or the longer persistence of the present-day climate conditions) is represented within the range of potential climate conditions, repository performance, and water use considered in this supplement.

This supplement evaluates the potential impacts on the aquifer environment, soils, ecology, and public health, as well as the potential for disproportionate impacts on minority or low-income populations. In addition, this supplement assesses the potential for cumulative impacts that may be associated with other past, present, or reasonably foreseeable future actions. Cumulative impacts on groundwater and from surface discharges of groundwater are the potential impacts of the proposed repository when added to the aggregate effects of other past, present, and reasonably foreseeable future actions.

During the 91-day public comment period on the draft supplement, the NRC staff conducted five public meetings. The first public meeting, in Rockville, Maryland, featured a live webcast and moderated teleconference line to accommodate remote participants. Public meetings were also held in Las Vegas, Nevada, and Amargosa Valley, Nevada. The final two meetings were teleconference-only to ensure that stakeholders unable to participate in the previous public meetings were afforded another opportunity to present oral comments. Including comment letters and oral comments, the NRC received over 1,200 comments on the draft supplement. The NRC staff's responses to these comments are in Appendix B of the supplement. Several changes were made to the final supplement in response to comments received on the draft supplement, as discussed in detail in the comment responses in Appendix B.

The NRC staff finds that all of the impacts on the resources evaluated in this supplement would be SMALL. The NRC staff's analysis includes the impact of potential radiological and nonradiological releases from the repository on the aquifer environment and at surface discharge locations of groundwater beyond the postclosure compliance location. The peak estimated annual individual radiological dose over the one-million-year period at any of the evaluated locations is 1.3 mrem [0.013 mSv]. This maximum dose is associated with pumping and irrigation at the Amargosa Farms area, and the estimated radiological dose at other potential surface discharge locations is lower. The NRC staff concludes that the estimated radiological doses are SMALL because they are a small fraction of the background radiation dose of 300 mrem/yr [3.0 mSv/yr] (including radon), and much less than the NRC annual dose standards for a Yucca Mountain repository in 10 CFR Part 63 {15 mrem [0.15 mSv] for the first 10,000 years, and 100 mrem [1 mSv] for one million years, after permanent closure}. Based on conservative assumptions about the potential for health effects from exposure to low doses of radiation, the NRC staff expects that the estimated radiation dose would contribute only a negligible increase in the risk of cancer or severe hereditary effects in the potentially exposed population. Impacts to other resources at all of the affected environments beyond the postclosure compliance location from radiological and nonradiological material from the repository would also be SMALL. The cumulative impact analysis concludes that, when considered in addition to the incremental impacts of the proposed action, the potential impacts of other past, present, or reasonably foreseeable future actions would also be SMALL.

ACRONYMS AND ABBREVIATIONS

ACHP	Advisory Council on Historic Preservation
ADR	Adoption Determination Report
BLM	Bureau of Land Management
CCD	Census County Division
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
DOE	U.S. Department of Energy
DOI	U.S. Department of the Interior
DVRFS	Death Valley Regional Flow System
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
FEPs	features, events, and processes
FR	*Federal Register*
HLW	high-level radioactive waste
IAEA	International Atomic Energy Agency
I	iodine
ICRP	International Commission on Radiological Protection
LLRW	low-level radioactive waste
MCL	mean concentration limit
Mo	molybdenum
mrem	millirem
mSv	milliSievert
NDWR	Nevada Division of Water Resources
NEDP	National External Diploma Program
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
Ni	nickel
NNSA	National Nuclear Security Administration
NNSS	Nevada National Security Site
Np	neptunium
NRC	U.S. Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act
NWRPO	Nuclear Waste Repository Project Office
Pu	plutonium
RFFAs	reasonably foreseeable future actions
RMEI	reasonably maximally exposed individual

ROD	record of decision
SAR	Safety Analysis Report
Se	selenium
SEIS	supplemental environmental impact statement
SER	Safety Evaluation Report
SEZ	solar energy zone
SHPO	State Historic Preservation Office
SNF	spent nuclear fuel
SNWA	Southern Nevada Water Authority
SNDWR	State of Nevada Division of Water Resources
SWEIS	Site-Wide Environmental Impact Statement
Tc	technetium
TDS	total dissolved solids
Th	thorium
TSPA	Total System Performance Assessment
U	uranium
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
V	vanadium

1 INTRODUCTION

This "Supplement to the Department of Energy's Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada" (supplement) evaluates the potential environmental impacts on groundwater and impacts associated with the discharge of any contaminated groundwater to the surface due to potential releases from a geologic repository for spent nuclear fuel (SNF) and high-level radioactive waste (HLW) at Yucca Mountain, Nye County, Nevada. This supplements the U.S. Department of Energy's (DOE's) 2002 "Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada" (DOE, 2002) and 2008 "Final Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada" (DOE, 2008a), in accordance with the findings and scope outlined in the U.S. Nuclear Regulatory Commission (NRC) staff's 2008 "Adoption Determination Report for the U.S. Department of Energy's Environmental Impact Statements for the Proposed Geologic Repository at Yucca Mountain" (NRC, 2008a).

The NRC staff has prepared this supplement pursuant to the National Environmental Policy Act of 1969, as amended (NEPA) and the Nuclear Waste Policy Act of 1982, as amended (NWPA), as implemented in NRC's regulations in Title 10 of the *Code of Federal Regulations* (CFR) Part 51.

1.1 Background—License Application and EIS Adoption Review Process

The NWPA specifies that in the United States, SNF and HLW will be disposed of in a deep geologic repository. Amendments to the NWPA in 1987 identified Yucca Mountain, Nevada, as the single candidate site for characterization as a potential geologic repository. DOE prepared a final environmental impact statement (EIS) related to the construction, operation, and closure of a potential geologic repository for HLW at Yucca Mountain, Nevada, in February 2002. The EIS accompanied the Secretary of Energy's site recommendation to the President on February 14, 2002, pursuant to NWPA Section 114(f). In July 2002, Congress passed and the President signed a joint resolution designating Yucca Mountain as the site for development of a geologic repository. In October 2006, DOE announced its intent to prepare a supplemental EIS to update the 2002 EIS (71 FR 60490).

DOE published a final supplemental EIS (SEIS) in June 2008. Also that June, DOE submitted its license application (DOE, 2008b), including the 2002 EIS and 2008 SEIS to NRC seeking authorization to construct a geologic repository at Yucca Mountain. In accordance with NWPA Section 114(f)(5) and NRC's regulations in 10 CFR 51.109, NRC is to adopt DOE's EIS to "the extent practicable." The NRC staff reviewed DOE's EISs and found, as stated in its Adoption Determination Report (ADR), that it is practicable for NRC to adopt the EISs, with further supplementation (NRC, 2008a). Specifically, the NRC staff determined that a supplement was needed because the NRC staff concluded that DOE's EISs did not adequately address potential repository-related impacts on groundwater and from surface discharges of groundwater.

After docketing the DOE license application and issuing the ADR in September 2008, the NRC staff began its licensing review and development of its Safety Evaluation Report (SER). In October 2008, the Commission issued a Notice of Hearing and Opportunity to Petition to Intervene, which began the adjudicatory process (NRC, 2008b).

In February 2010, the Secretary of Energy stated that the "Administration has determined that developing a repository at Yucca Mountain, Nevada is not a workable option." (DOE, 2010) DOE filed a motion with the Atomic Safety and Licensing Board presiding over the adjudication seeking permission to withdraw its license application. The Board denied that request in June 2010, and the Commission did not overturn the Board's decision. After Congress reduced funding for the NRC's review of the license application, NRC began an orderly closure of its Yucca Mountain activities. On September 30, 2011, the Board suspended the adjudicatory proceeding, and the NRC staff's Yucca Mountain license application review activities ceased.

In August 2013, the U.S. Court of Appeals for the District of Columbia Circuit issued a decision directing the NRC to resume the licensing process for DOE's license application. In November 2013, the Commission directed the NRC staff to complete the SER and requested that DOE prepare the EIS supplement that the NRC staff had determined to be necessary in the ADR. DOE informed the NRC that it would update a 2009 technical analysis it provided to NRC (DOE, 2014a; 2009a), but that it would not prepare a supplement to its EISs (DOE, 2014b).

In January 2015, the NRC staff completed the five-volume SER (NRC, 2015a,b; 2014b; 2010a). In February 2015, the Commission directed the NRC staff to prepare the EIS supplement. The adjudicatory proceeding remains suspended.

1.2 Scope and Assumptions

The NRC staff's general approach in this supplement for evaluating the potential impacts to groundwater and from the surface discharge of groundwater is identified in the NRC staff's 2008 ADR and follows the guidance in NUREG–1748, "Environmental Review Guidance for Licensing Actions Associated with the Office of Nuclear Material Safety and Safeguards Programs: Final Report" (NRC, 2003).

1.2.1 Need for Supplementation and Scope of the Analysis

Section 3.2.1.4 of the ADR describes the NRC staff's evaluation of the adequacy of the analyses in DOE's 2002 and 2008 EISs. Since the ADR was prepared (in 2008), the NRC staff has not identified new information that would change the NRC staff's position regarding the scope of this supplement, which is described in detail in the ADR. However, information may be identified that requires further supplementation of DOE's 2002 and 2008 EISs in the future.

Section 3.2.1.4.2 of the ADR, "Impacts on Groundwater and from Surface Discharge of Groundwater," provides the NRC's staff's assessment of the groundwater and surface discharge impact analyses in DOE's EISs. As described in the ADR, the NRC staff finds that the EISs did not adequately characterize potential contaminant release to groundwater and from surface discharges of groundwater. While DOE's analysis of the postclosure behavior of the repository recognizes that the release of contaminants to groundwater can be expected over the long term, the analysis does not provide adequate discussion of the cumulative amounts of radiological and nonradiological contaminants that may enter the groundwater over time, and how these contaminants would behave in the aquifer and surrounding environments.

This supplement provides the information the NRC staff identified as necessary in its ADR. Two distinct but related aspects of potential impacts on the groundwater system are addressed in this supplement. These are (i) the nature and extent of the repository's impacts on groundwater in the aquifer and (ii) the potential impacts of the discharge of potentially contaminated groundwater to the ground surface. These two aspects are described further below:

Impacts on Groundwater

- A description of the full extent of the volcanic-alluvial aquifer, particularly those parts that could become contaminated, and how water (and potential contaminants) can leave the flow system.

- An analysis of the cumulative amount of radiological and nonradiological contaminants that can be reasonably expected to enter the aquifer from the repository, and the amount that could reasonably remain over time.

- Estimates of contamination in the groundwater, given potential accumulation of radiological and nonradiological contaminants.

Impacts from Surface Discharges of Groundwater

- A description of the locations of potential natural discharge of contaminated groundwater for present and expected future wetter periods.

- A description of the physical processes at potential surface discharge locations that could affect accumulation, concentration, and potential remobilization of contaminants carried by groundwater.

- Estimates of the amount of contaminants that could be deposited at or near the surface, including estimates of the amount of discharged groundwater and near-surface evaporation; the amounts of radiological and nonradiological contaminants in that groundwater; contaminant concentrations in resulting deposits; and potential environmental impacts.

This supplement assesses the potential groundwater and surface discharge impacts over a period of approximately one million years after repository closure.

1.2.2 Analysis Assumptions

The analyses in this supplement make the following assumptions:

- Repository characteristics and performance are consistent with the information DOE provided in its license application, as well as the conclusions in the NRC staff's SER. The NRC staff found (i) the analytic models in DOE's performance assessment for the repository to be technically sound and to provide an acceptable representation of repository performance, including the representation of unlikely features, events, and processes (FEPs); and (ii) DOE's technical basis for excluding certain FEPs from the performance assessment was acceptable (NRC, 2014a; Section 2.2.1.4.1). Information from DOE's application, supporting documents, and the NRC staff's SER, is referenced in this supplement where appropriate.

- The current population in the area near Yucca Mountain and its distribution (as discussed in NRC, 2015a; Section 2.1.1.1.3.2, Regional Demography) will continue for the period analyzed in the supplement (approximately one million years). The supplement assumes the current range of human activities will also continue for this period. This is consistent with 10 CFR Part 63, Subpart L.

- With the exception of assumptions concerning groundwater pumping (described below), the NRC staff did not speculate about the types of future human activities that could occur far in the future. Unsupportable assumptions about human activities far in the future would result in correspondingly unsupportable conclusions about the potential impacts. This is consistent with NRC regulations in 10 CFR 63.305(b) and the U.S. Environmental Protection Agency regulations in 40 CFR 197.15, which direct the DOE not to project changes in society, the biosphere (other than climate), human biology, or increases or decreases of human knowledge or technology.

This supplement describes the potential impacts that could occur under different climate conditions and different groundwater-use rates. These conditions are described as analysis cases that provide a representative range of credible future climates and human activities affecting groundwater in the Yucca Mountain area. These cases are discussed in more detail in Section 2.3. Based on data from past climates in the Yucca Mountain region, future climates are projected to include interglacial periods that are relatively hot and dry (similar to present conditions) and periods that are relatively cooler and wetter. The present-day climate is an interglacial period. The analysis in this supplement makes no assumptions about the timing of these potential future climate states, only that such conditions can be expected to occur sometime during the approximately one-million-year period evaluated in this supplement.

In addition, the supplement considers two scenarios concerning potential groundwater withdrawal to encompass uncertainty in predicting future human activity that may affect the groundwater. These scenarios, considered in the analysis cases in Chapter 2 of this document, include the scenario where significant pumping for irrigation purposes (i.e., substantial removal of groundwater) will occur, as well as the scenario where limited or no pumping (i.e., no substantial removal of groundwater) will occur. Both of these pumping scenarios are considered for both the dry and wet climate states described above to create the analysis cases evaluated in this supplement. The NRC staff is addressing different pumping cases and different climate states because the amount of groundwater pumping affects where groundwater ultimately reaches the surface, while a wetter climate affects the amount of groundwater flow, and thus the concentrations of contaminants in the groundwater. As discussed in Chapter 2 of this document, changes in climate are not expected to significantly affect the groundwater flow paths in the area.

Presently available information about human-induced climate change from the release of greenhouse gases indicates that for this region, the most potentially significant long-term effect is that the present-day interglacial climate (hot and dry) would persist longer than it would in the absence of human-induced change (NRC, 2014a; Section 2.2.1.3.5). Projected human-induced climate change is represented within the range of potential climate conditions (i.e., both dry and wet climate states) and water use (i.e., both substantial and no substantial removal of groundwater from the system) considered in this supplement.

1.2.3 Significance of Environmental Impacts

The NRC has established standards of significance for assessing environmental impacts. In NRC environmental reviews, significance indicates the importance of potential environmental impacts and is determined by considering two variables: (i) context and (ii) intensity. Context is the geographic, biophysical, and social setting in which effects are expected to occur. Intensity refers to the severity of the impact. The NRC uses a three-level standard of significance based upon the President's Council on Environmental Quality guidelines in 40 CFR 1508.27 and as provided in the NRC's environmental review guidance in NUREG–1748 (NRC, 2003):

SMALL: The environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource.

MODERATE: The environmental effects are sufficient to alter noticeably, but not to destabilize, important attributes of the resource.

LARGE: The environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource.

1.3 Public and Agency Involvement

The NRC staff announced its intent to develop this supplement in the *Federal Register* (FR) on March 12, 2015 (80 FR 13029). The NRC staff also issued a press release, and notified the hearing participants and other stakeholders.

Pursuant to 10 CFR 51.26(d), the NRC staff did not conduct scoping for this supplement, the scope of which was established by the ADR. The NRC staff did not identify any cooperating agencies for this supplement, nor did the NRC staff receive any formal requests for cooperating agency status.

The NRC staff provided a 60-day public comment period for this draft supplement that was later extended to 91 days. The comment period began on August 21, 2015 (80 FR 50875) and closed on November 20, 2015 (80 FR 56501). During the comment period, the NRC staff conducted five public meetings. The first public meeting, in Rockville, Maryland, featured a live webcast and moderated teleconference line to accommodate remote participants. Public meetings were also held in Las Vegas, Nevada, and Amargosa Valley, Nevada. The final two meetings were teleconference-only to ensure that stakeholders unable to participate in the previous public meetings were afforded another opportunity to present comments. The NRC received over 1,200 oral and written comments on the draft supplement. The NRC staff's responses to these comments are in Appendix B.

1.4 Document Purpose and Structure

This supplement does not reflect a change to DOE's proposed action or to DOE's purpose and need for the proposed action. DOE's purpose and need for the proposed action, as described in Chapter 1 of DOE's 2002 EIS and 2008 SEIS, is that for many years civilian and defense-related activities have produced SNF and HLW, and these materials have accumulated—and continue to accumulate—at commercial and DOE sites across the United States. In passing the NWPA in 1982, Congress affirmed that the Federal Government is responsible for the permanent disposal of SNF and HLW. As discussed in Section 1.1, in the 1987 amendments to the Act, the Yucca Mountain site was designated for further consideration as a repository for the permanent disposal of these materials. (DOE, 2002)

DOE's proposed action, as described in Chapter 2 of the 2002 EIS and 2008 SEIS, is the construction, operation, monitoring, and closure of a repository for the disposal of SNF and HLW at Yucca Mountain, Nevada. The NRC's proposed action would be the issuance of an authorization to DOE for the construction of a repository at Yucca Mountain, as described in DOE's license application. This supplement also does not reflect a change in the alternatives DOE presented in Chapter 2 of its EISs, which are the proposed action and the no action alternative of not constructing a repository. As discussed in the ADR, these aspects of DOE's NEPA analysis are not affected by this supplement, and they are not addressed further.

This supplement presents additional information about the impacts of potential repository contamination of groundwater, as well as the potential impacts associated with the discharge of contaminated groundwater to the surface. As such, the supplement affects the information presented in DOE's analyses of affected environment, impacts after repository closure, and cumulative impacts in its EISs.

Chapter 2 of this supplement describes the potentially affected groundwater and surface environments and the potentially affected resource areas for each environment. Chapter 3 describes the potential impacts of repository contamination of groundwater and from the surface discharge of groundwater. Chapter 4 describes cumulative impacts associated with potential repository contamination of groundwater and the surface discharge of that groundwater. Chapter 5 provides a summary of the NRC staff's impact findings.

2 AFFECTED ENVIRONMENT

2.1 Introduction

The U.S. Department of Energy's (DOE's) Environmental Impact Statement (EIS) (DOE, 2002, Chapter 5) and Supplemental Environmental Impact Statement (SEIS) (DOE, 2008a, Chapter 5) described the affected environment from the Yucca Mountain repository site to the location of the reasonably maximally exposed individual (RMEI), or postclosure compliance location,[1] in the Amargosa Desert using information from a model that DOE developed for its license application (DOE, 2008b). The RMEI location is characterized using features of present-day conditions and activities at Amargosa Farms (the south-central portion of Amargosa Desert, as shown in Figure 2-1). Amargosa Farms is the primary area of population and groundwater pumping in the town of Amargosa Valley. Using these conditions, the location of the RMEI is approximately 18 km [11 mi] from Yucca Mountain, along the flow path of the predominant groundwater flow, and approximately at the southern boundary of the Nevada National Security Site (NNSS) (NRC, 2014a). For locations beyond the postclosure compliance location, the analysis in DOE's 2002 EIS and 2008 SEIS scaled the results calculated for the postclosure compliance location to generic locations at 30 km [19 mi] and 60 km [37 mi] from the repository in the predominant direction of groundwater flow.

The U.S. Nuclear Regulatory Commission (NRC) staff's review of DOE's EISs found that it was practicable for the NRC to adopt the 2002 EIS and 2008 SEIS, but with further supplementation (NRC, 2008a). The NRC staff concluded that a supplement was needed to describe the full spatial extent of the volcanic-alluvial aquifer beyond the postclosure compliance location, particularly those parts that could become contaminated by potential releases from the repository, and how water (and potential contaminants) could leave the flow system. Specifically, the NRC staff's review of the EISs concluded that the affected groundwater environments, and any impacts, were not adequately identified and described by DOE's analyses for areas beyond the postclosure compliance location.

This chapter provides a description of the affected environment with respect to the groundwater flow path for potential releases from the repository that could be transported beyond the postclosure compliance location through the volcanic-alluvial aquifer in Fortymile Wash and Amargosa Desert. Groundwater flow and potential releases traveling beyond the postclosure compliance location, if uninterrupted, would discharge in Death Valley. Death Valley is the ultimate discharge area for groundwater flow in the Death Valley Regional Groundwater Flow System (DVRFS) (Figure 2-1). Importantly, discharge to the surface (e.g., springs) and the pumping of groundwater along the flow path towards Death Valley reduces the amounts of groundwater (and therefore, the amount of any contaminants) that discharge in Death Valley. This chapter provides a description of the flow path towards Death Valley, and the locations of potential natural discharge along the groundwater flow path for present and expected future cooler and wetter periods. It also evaluates current and potential future water use that might affect the groundwater flow paths and natural discharge for present and future wetter periods.

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[1]The term "postclosure compliance location" is used throughout the supplement for the postclosure regulatory compliance location. This point is defined and specified at 10 CFR 63.312(a) as the point of compliance for calculating dose with respect to postclosure individual protection, human intrusion, and groundwater protection standards. This location is based on the definition of the controlled area in 10 CFR 63.302. The model DOE used to support its license application calculates radiological dose to a reasonably maximally exposed individual located at a point on the NNSS boundary that is approximately 18 km [11 mi] south of the analyzed repository footprint in the predominant direction of groundwater flow.

Figure 2-1. Location of Selected Geographical Features Within the Death Valley Regional Groundwater Flow System. NNSS Is the Nevada National Security Site (Previously Called the Nevada Test Site). Modified From Belcher and Sweetkind (2010).

The affected environment for contaminants released from the repository, therefore, includes the aquifer itself as well as the sites where groundwater could discharge to the surface, either through pumping or natural processes.

In particular, this chapter describes:

(i) Groundwater Environment (Section 2.2)

- Aquifers in the region potentially affected by releases from Yucca Mountain, including aquifers along the flow path from Yucca Mountain to Death Valley
- Effects of groundwater pumping on groundwater flow
- Effects of the present and possible future climates on groundwater flow

(ii) Surface Discharge Environment (Section 2.3)

- Present-day discharge sites for releases from Yucca Mountain along potential flow paths beyond the postclosure compliance location
- Paleodischarge sites (areas of prehistorical, but not current surface discharge) during wetter and cooler climates as indicators of potential future discharge

(iii) Groundwater Modeling (Section 2.4)

- Effects of pumping on groundwater conditions
- Effects of climate on future flow paths

(iv) Water Use and Quality (Section 2.5)

- Water use along potential flow paths
- Groundwater quality in the Yucca Mountain region

(v) Analysis Cases for Assessing Impacts (Section 2.6)

- Present-day pumping levels (all potential contaminant releases are assumed to be captured by pumping wells at the postclosure compliance location)
- No future pumping (surface discharges downstream of the postclosure compliance location under present and possible future climates)

The descriptions of groundwater flow and surface discharges in this chapter are drawn from sources including the U.S. Geological Survey (USGS) (e.g., Belcher and Sweetkind, 2010), Nye County (Nye County NWRPO, 2009), and Inyo County (e.g., Bredehoeft and King, 2010; Bredehoeft et al., 2008; Inyo County, 2007), as well as independent NRC staff analyses (e.g., NRC, 2014a). The descriptions in this chapter also incorporate further work by DOE on the flow system beyond the postclosure compliance location (DOE, 2014a; 2009a).

2.1.1 Regional Demography

As discussed in Chapter 1, the NRC staff assumes the current population and its distribution, as well as the current range of human activities, will continue for the entire period analyzed in the supplement. This is consistent with NRC regulations in title 10 of the *Code of Federal Regulations* (CFR) 63.305(b) and U.S. Environmental Protection Agency (EPA) regulations in 40 CFR 197.15, which direct DOE not to project changes in society, the biosphere (other than climate), human biology, or increases or decreases in human knowledge or technology.

Using data from the 2010 U.S. census, the NRC staff found in its Safety Evaluation Report (SER) (NRC, 2015a; Section 2.1.1.1.3.2) that DOE's assessment of the demographic characteristics of the area surrounding Yucca Mountain was accurate. In its license application, DOE described population locations, regional population centers, and provided population projections for a 50-year period (2017-2067) (DOE, 2008b; Section 1.1.2). DOE's assessment encompassed an 84-km [52-mi] radial area, centered on the repository site. The area comprises parts of Clark, Esmeralda, Lincoln, and Nye Counties in Nevada, and Inyo County in California. DOE provided a baseline population distribution within the 84-km [52-mi] radius for the 50-year period. DOE did not identify any permanent residents closer than about 22 km [13.7 mi] to the repository site. The nearest resident population was located in the town of Amargosa Valley, Nevada.

Town of Amargosa Valley

The unincorporated town of Amargosa Valley, previously called Lathrop Wells, contains an informally defined area called Amargosa Farms that is the primary populated and farming area of the town. The town borders the southwest corner of the Nevada National Security Site and the postclosure compliance location, and extends south and southwestward covering an area of 505 mi^2 [1,308 km^2], as shown in the Amargosa Valley Area Plan (2009). Much of the town of Amargosa Valley is not in the groundwater pathway from Yucca Mountain; however, the Amargosa Farms area is within the range of uncertainty for the pathway of groundwater from Yucca Mountain.

For its SER, the NRC staff performed independent confirmatory calculations for DOE's baseline 2003 population distribution within 84 km [52 mi] of the repository. The NRC staff's results are consistent with DOE's information. The NRC staff also compared the U.S. Census Bureau data for the 2010 population distribution within 84 km [52 mi] of the repository location with that of DOE's projected population distribution data and found that DOE's estimate is generally higher, and therefore conservative in terms of potential impacts. The NRC staff further found in the SER that DOE identified all significant population centers within an appropriate demographic study area {within 84 km [52 mi]} and used population data consistent with other acceptable evaluations of demography and population centers in the repository area (NRC, 2015a).

The NRC staff incorporates by reference its SER assessment (NRC, 2015a; Section 2.1.1.1.3.2) and DOE's license application description of regional demography (DOE, 2008b; Section 1.1.2) because the NRC staff has determined that groundwater could discharge to the surface in or near population centers. These population centers are the town of Amargosa Valley and Death Valley National Park (NRC, 2015a; Section 2.1.1.1.3.2., Population Centers). The population in Death Valley includes the Timbisha Shoshone Tribe community located on a 314-acre [1.27-km^2] parcel of land in the Furnace Creek area. The Tribe has federally appropriated rights to 92 acre-feet per year [0.113 million m^3/yr] of surface and groundwater to support this community (DOE, 2014a; 16 U.S.C. 410aaa).

2.2 Groundwater Environment

2.2.1 Aquifers in the Death Valley Region

The DVRFS lies within the southern portion of the arid, internally drained region known as the Great Basin. The principal groundwater-bearing units in the DVRFS can be classified as volcanic, alluvial, or carbonate aquifers (DOE, 2014a; 2008a), depending on the types of rock or sediment through which the groundwater flows. The mountainous areas in the north-central portion of the DVRFS are mostly of volcanic origin and contain associated volcanic aquifers (i.e., aquifers composed principally of fractured tuff and other volcanic rocks). In the lower elevations and in portions of the southern area, the volcanic aquifer in some areas connects with relatively young permeable basin fill sediments (mostly deposited by streams, also called alluvium or alluvial deposits) in valleys across the DVRFS. These sediments comprise the affected alluvial aquifer. The lowermost aquifer is a deep regional groundwater system formed of thick sequences of older, highly permeable carbonate rocks that foster interbasinal groundwater flow between basins that are topographically closed (Belcher and Sweetkind, 2010), as illustrated schematically in Figure 2-2. Regional groundwater flow in the DVRFS through the carbonate rock sequence is affected by complex geologic structures caused by regional faulting and fracturing. These geological structures can enhance or impede flow (DOE, 2008b, Section 2.3.9). Although the carbonate aquifer is generally regionally connected and fast flowing (Sweetkind et al., 2010; Winograd and Thordarson, 1975), there is also some evidence from geochemical and temperature data that it may be locally compartmentalized (e.g., Bushman et al., 2010; Nye County NWRPO, 2009). The compartmentalized areas are a possible consequence of a complex geological structure in the DVRFS, where local faulting may intersperse less-permeable units.

The basin fill sediments and fractured volcanic rocks form local aquifers, and in some areas they are well connected such that groundwater can flow easily from volcanic to alluvial sections. The volcanic and alluvial aquifers interact with the regional carbonate aquifer either through (i) vertical flow if the carbonate aquifer underlies the volcanic-alluvial aquifer, or (ii) lateral flow, where the carbonate aquifer, due to faulting, juxtaposes alluvial-volcanic aquifers (Belcher and Sweetkind, 2010). At any one location, confining layers between the aquifers at different depths allow varying degrees of water exchange between aquifers.

The NRC staff's description of the entire regional flow system derives from the integration of geologic data (rock units and structures), hydrologic data (potentiometric and hydrologic properties of the rock), water chemistry data, and temperature data for each aquifer in the flow system (e.g., Belcher and Sweetkind, 2010; DOE, 2014a). For example, water levels in wells across the DVRFS provide data regarding the hydraulic gradient, and thus, the potential directions of water flow. These include indications of the potential for vertical flow between aquifers and differing horizontal flow directions of shallow and deep aquifers. Also, water temperature can provide indications of deeper groundwater interacting with shallower aquifers, or of deeper water discharging to the ground surface.

Groundwater chemical compositions are used to understand groundwater flow paths and identify areas in which groundwater mixing occurs. Groundwater chemistry is influenced by interactions with the rock through which it flows. Interactions may include dissolution of minerals, ion-exchange between the water and minerals, chemical alteration of mineral phases, and precipitation of new mineral phases. Through these interactions, the groundwater develops a chemical composition that is characteristic of a particular aquifer system. For example, groundwater in the volcanic tuff aquifer system typically has relatively low ionic strength and has

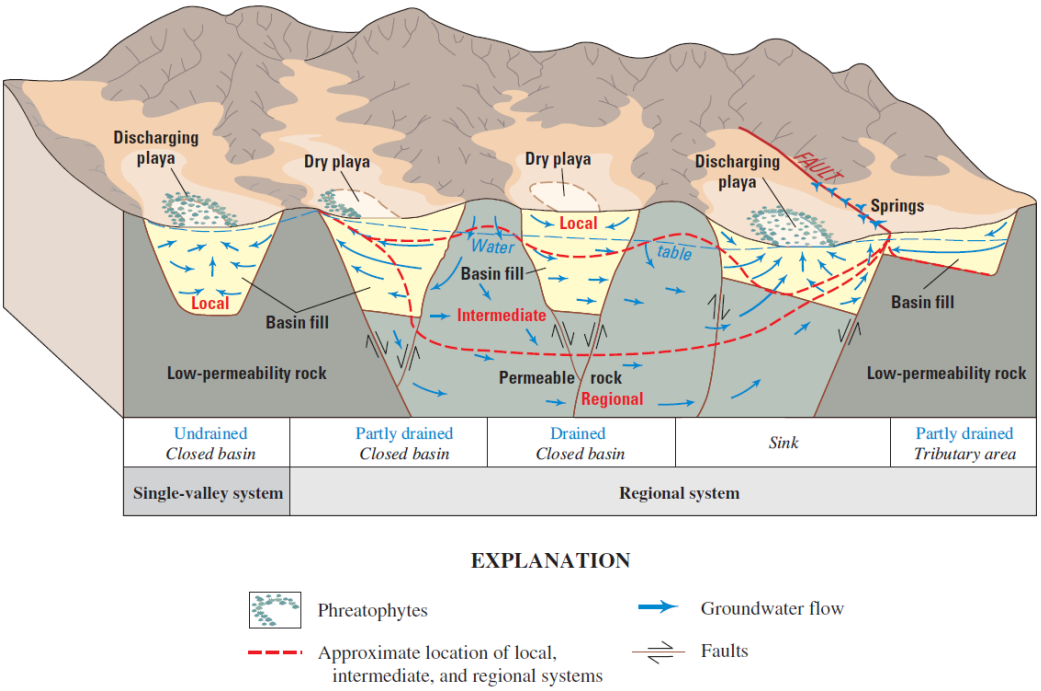

Figure 2-2. Schematic Block Diagram Illustrating the Structural Relations Among Mountain Blocks, Valleys, and Groundwater Flow in the Region (Modified From Eakin et al., 1976). Taken From Belcher and Sweetkind (2010; Figure D-1).

higher concentrations of sodium, potassium, and silica derived from the volcanic source rocks. In contrast, groundwater in the carbonate aquifer is dominated by dissolved calcium, magnesium, and bicarbonate.

Groundwater Subregions, Basins, and Sections

To simplify modeling of the entire DVRFS and support modeling at different scales, the USGS created a hierarchy of subregions, basins, and sections, from largest to smallest, respectively (most recently described in Belcher and Sweetkind, 2010). DOE used earlier versions of the USGS delineation of these groundwater flow areas (e.g., Belcher, 2004; Belcher et al., 2002) at different scales in its EIS (DOE, 2002) and SEIS (DOE, 2008a). This delineation is a reasonable method for conceptualizing the DVRFS, and this supplement utilizes the same terminology. The delineation is reasonable because it is based on (i) an understanding of the geology, including the rock units and structures that may influence groundwater flow; (ii) observations or estimates of hydrologic information, including potentiometric surface (for unconfined aquifers, the water table elevation is the potentiometric surface) and hydrological properties of hydrogeological units; (iii) hydrogeochemical and thermal information; and (iv) groundwater modeling that integrates all the hydrogeological information together. Modeling the groundwater system involves characterizing the inflows and outflows for each section, basin, and subregion. The inflows and outflows include recharge, lateral inflow and outflow between areas, pumping, discharge related to springs, and evapotranspiration (movement of water directly to air from ground surface and from plants).

Following the hierarchical delineation by the USGS, the DVRFS is divided at the largest scale level into three subregions (Belcher and Sweetkind, 2010). The proposed repository site at Yucca Mountain is in volcanic tuff and lies above part of the large volcanic aquifer in the Central Death Valley Subregion (Figures 2-1 and 2-3). As discussed in the subsequent sections, this Subregion contains the aquifers likely to be affected by contaminants released from the repository. Some small portion of groundwater flow from beneath Yucca Mountain may enter the Southern Death Valley Subregion to the south and east. The third subregion, to the west and north of the Central Death Valley Subregion, is the Northern Death Valley Subregion, and is not affected by flow from beneath Yucca Mountain. The subregions are further subdivided into basins, which themselves are subdivided into sections. Yucca Mountain falls in the Fortymile Canyon Section, which is part of the Alkali Flat-Furnace Creek Basin, which is part of the Central Death Valley Subregion, as shown in Figure 2-3.

The other two basins delineated in the Central Death Valley Subregion (Pahute Mesa-Oasis Valley and Ash Meadows Basins) contribute lateral water flow into the Alkali Flat-Furnace Creek Basin at its northern, eastern, and western boundaries.

The NRC staff next evaluates the principal groundwater flow path between Yucca Mountain and Death Valley, within the Alkali Flat-Furnace Creek Basin, and the potential minor flow into the Southern Death Valley Subregion.

2.2.2 Aquifers Along the Flow Path From Yucca Mountain

This section describes the expected flow path for groundwater from below the proposed repository. In the 2002 EIS and 2008 SEIS, DOE described the flow path from the repository to the area of pumping at the postclosure compliance location in the Amargosa Desert. DOE described the flow of water in the unsaturated zone through the repository and vertically downward to the underlying saturated volcanic rocks. This flow path is the same as that described in DOE's Safety Analysis Report (SAR) for performance of the repository (DOE, 2008b, Section 2.3.9). DOE found that such water flow is the principal means of release of contaminants from repository once the engineered barriers cease to contain the waste (DOE, 2008a,b). The NRC staff found the description of this flow path to the postclosure compliance location to be acceptable in its Adoption Determination Report (ADR) (NRC, 2008a); the NRC staff's review of repository performance is given in its SER (NRC, 2014a; Section 2.2.1.3.8).

Amargosa River

The Amargosa River is an intermittent waterway, 298 km [185 mi] long, in southern Nevada and eastern California. It drains the Amargosa Valley in the Amargosa Desert and other smaller valleys on its way to Death Valley. Except for a small portion of its route near Beatty, Nevada, and a portion in the Amargosa Canyon (near the towns of Shoshone and Tecopa) in California, the river flows above ground only after rare major rainstorm events in the region (see also Menges, 2008).

The flow system that passes below Yucca Mountain trends southward along Fortymile Wash in the Fortymile Canyon Section (Figure 2-3). Beyond the postclosure compliance location, it merges with east-southeast flow in the Amargosa Desert and continues south towards Amargosa Farms. The next sections of this chapter provide descriptions of the groundwater flow path in the Amargosa Farms area of the southcentral portion of the Amargosa River Section, and between the Amargosa Farms area and Death Valley, predominantly westward through the carbonate aquifer at the eastern Funeral Mountains (the Funeral Mountain Section of the flow path). In addition, the potential, minor flow from Amargosa Farms to Alkali Flat is also

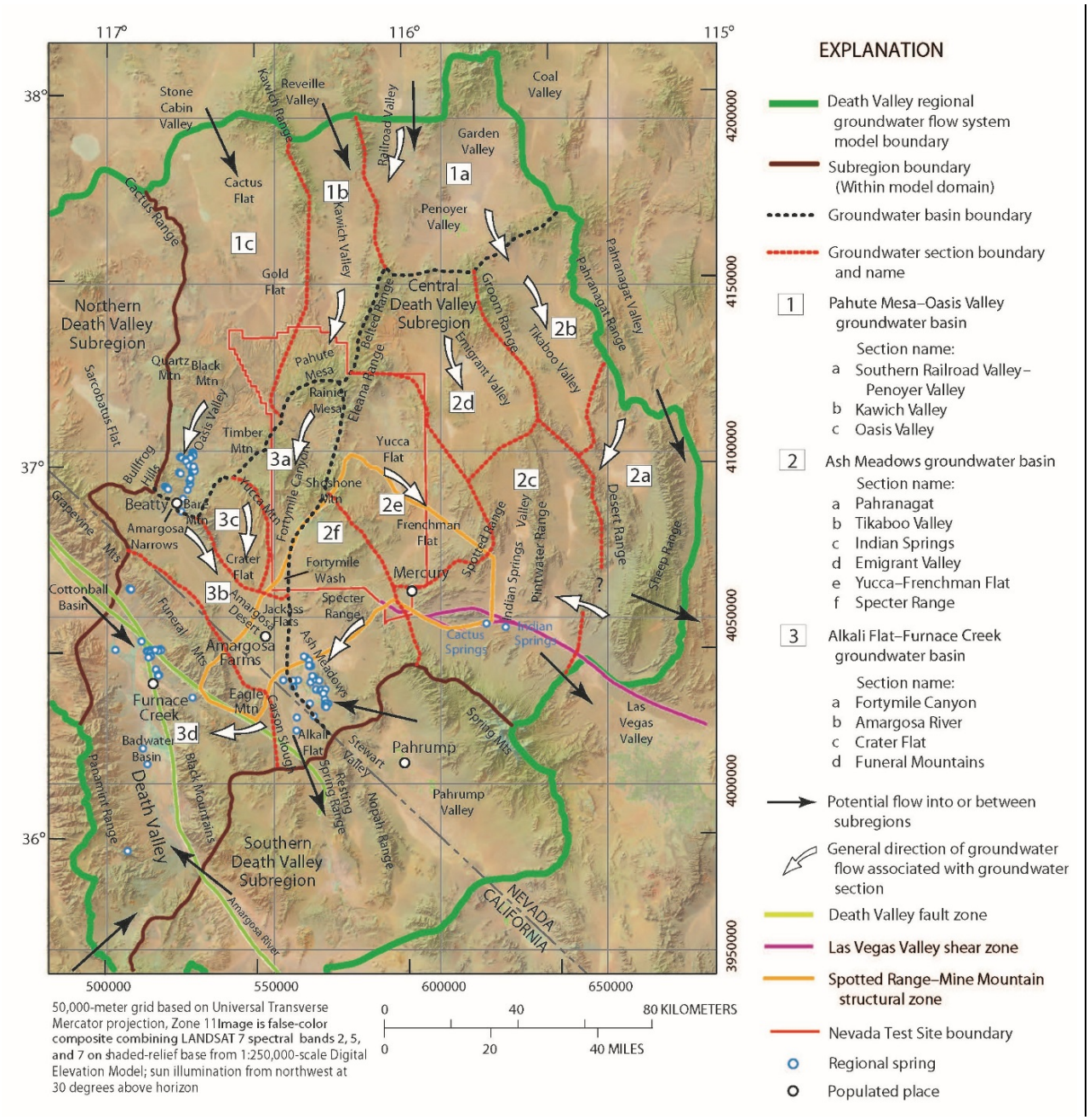

Figure 2-3. Death Valley Regional Groundwater Flow System (Outline in Green) With Further Delineations of Central Death Valley Subregion (Brown Line) Showing Basins (Black Dotted Lines), Numbered Sections (Numbered and Red Lines), and Flow Directions. Taken From Belcher and Sweetkind (2010; Figure D–7).

described. As discussed in the sections below, particle tracking analysis using the DVRFS model indicates the possible pathways for contaminants from a repository at Yucca Mountain past the Amargosa Farms area are westward through the Funeral Mountains to Death Valley, or along the Amargosa River course to discharge at Alkali Flat.

Fortymile Canyon Section

The first portion of the flow path is in the Fortymile Canyon Section (Figure 2-3; labeled 3a). As described in the 2008 SEIS, infiltrating water at Yucca Mountain passes through the unsaturated zone, reaches the uppermost volcanic aquifer, and then flows east to southeast to join the larger volume of groundwater flowing southward along Fortymile Wash towards Amargosa Desert. The first part of this flow path is within the volcanic aquifer. Flow in these volcanic rocks occurs predominantly in networks of fracture and fault zones. Along Fortymile Wash, the strata (layers) of the volcanic aquifer thin and transition into the sediments of the alluvial aquifer. The groundwater then exits the fractured volcanic tuffs and enters the relatively unconsolidated granular porous media of the alluvial aquifer. This transition occurs in the vicinity of the Highway 95 fault (a poorly-expressed west-northwest striking high-angle fault zone that occurs just south of the southern boundary of NNSS, as shown in Figures 2-1 and 2-3, near the label "Jackass Flats"). The Highway 95 fault appears to be the southern boundary of the volcanic aquifers, based on a fault zone geometry inferred from borehole and geophysical data (DOE, 2008a; Nye County NWRPO, 2009). The fault juxtaposes fractured volcanic rocks on the north side with less permeable alluvial sediments on the south side. Nye County investigators proposed that contact with the less permeable alluvial sediments causes the southward groundwater to flow up into an overlying alluvial aquifer system, which continues to the Amargosa Desert (Nye County NWRPO, 2009). Hydraulic measurements conducted by DOE and Nye County support a slight upward gradient in the alluvial aquifer (DOE, 2008a; p. 3–33), which, when combined with the stratified alluvial sediments, indicates that a groundwater plume emanating from Yucca Mountain would remain in the upper portion of the uppermost alluvial aquifer in the Amargosa Desert. The transition from the Fortymile Canyon Section to the Amargosa River Section coincides approximately with the postclosure compliance location {approximately 18 km [11 mi]} along the flow path from the proposed repository site. In this area, distributed recharge occurs in mountainous areas and focused recharge from intermittent streamflow occurs in smaller washes. Losses from the aquifer are predominantly by evapotranspiration.

Amargosa River Section

The next portion of the flow path is in the Amargosa River Section (Figure 2-3; labeled 3b). The groundwater flow path from Yucca Mountain goes southward from Fortymile Wash into the Amargosa Desert. Groundwater geochemical data indicate that the flow paths within the alluvial aquifer of Fortymile Wash are readily identifiable along the length of Fortymile Wash and southward across the Amargosa Desert (Figure 2-4) (Kilroy, 1991; SNL, 2007a). Amargosa Farms is a small farming community which occupies the area where the alluvial fan (a fan- or cone-shaped deposit of sediment built up by streams) from Fortymile Wash meets the broad, dry Amargosa River bed in the Amargosa Desert, south of the postclosure compliance location along the Yucca Mountain flow path (Figure 2-1). The Amargosa Farms area is not a hydrographic area defined on Figure 2-3; it lies within the southcentral portion of the Amargosa River Section. At present, extensive groundwater pumping for irrigation and drinking water occurs in Amargosa Farms. Groundwater withdrawal contributes more to losses within the Amargosa River Section than evapotranspiration. Groundwater pumping, mostly in the Amargosa Farms area, has been on the order of 17,600 acre-ft/yr [21.7 million m^3/yr] for the past several decades (DOE, 2014a, Table 2-1; NDWR, 2015). By comparison, evapotranspiration losses from the Amargosa River Section were estimated to be 1,350 acre-ft/yr [1.67 million m^3/yr] (DOE, 2014a, Table 2-1). Due to groundwater pumping from 1952 to 1987, the maximum drawdown of the water table was more than 9 m [30 ft] over a region more than 10 km [6 mi] across, east to west, centered on the irrigation wells distributed

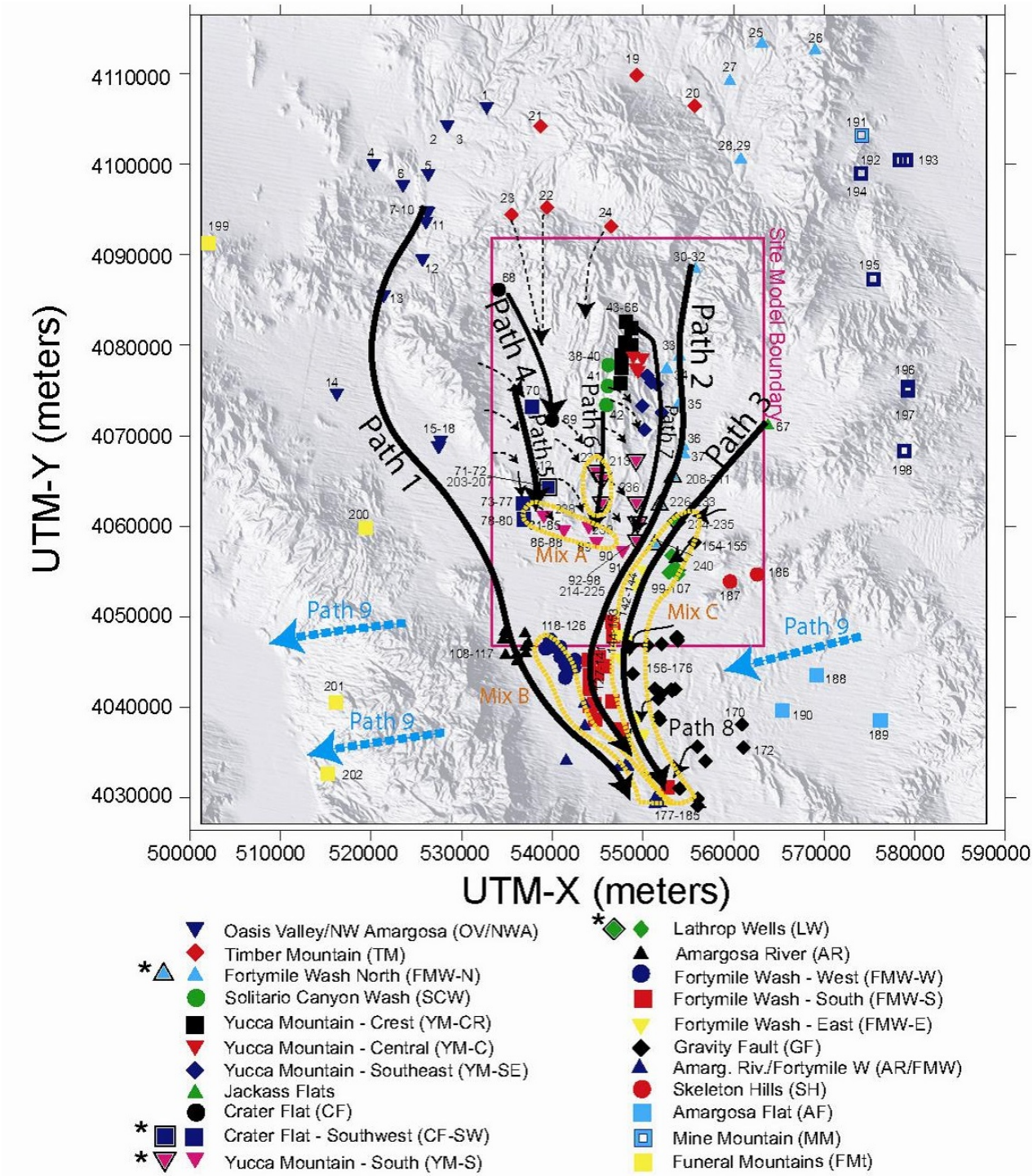

Figure 2-4. Groundwater Flow Paths Inferred From Groundwater Geochemical Analyses (From SNL, 2007a, Figure B6-15). Flow Path 2, Which Merges With Flow Path 7, Represents the Direction of Flow From Yucca Mountain. Flow Path 2 and Flow Path 1 (Amargosa River) Converge Near the Location of the State Line Deposits.

around the Amargosa Farms area (Kilroy, 1991). Studies by the Bureau of Land Management (BLM) (BLM, 2010) reported the maximum drawdown of the water table as being more than 90 ft [27 m] in 2003. At the southern end of the Amargosa Farms area, near the lower margin of the Fortymile Wash alluvial fan, are the State Line Deposits (also referred to as the Stateline deposits), fossil spring deposits that occur over an area 10–15 km [6–9 mi] long and approximately 5-km [3-mi] wide (Paces and Whelan, 2012). These deposits formed during past wetter climates; the youngest units date from more than 30,000 years ago. There are presently no springs near the State Line Deposits, although dense vegetation at nearby Franklin Well indicates a relatively shallow water table. The fossil deposits have a variety of complex geochemical compositions that represent the likely mixing of the Amargosa River and Fortymile Wash groundwater, with some inflow from the carbonate aquifer (Paces and Whelan, 2012). Within the State Line Deposits area, groundwater flow gradients in the vicinity of freshwater limestone deposits and bedrock structures indicate upward flow from the carbonate aquifer below the alluvial sediments of Amargosa Valley (Kilroy, 1991; Paces and Whelan, 2012). The groundwater flow direction in the regional carbonate aquifer in this area is west to southwest, in comparison to the southward flowing groundwater in the alluvial sediments of the Amargosa Farms area (Belcher and Sweetkind, 2010; DOE, 2014a).

Ash Meadows and Devils Hole

Ash Meadows is a National Wildlife Refuge, a 40-acre detached unit of Death Valley National Park. It contains more than 30 seeps and springs, including Devils Hole, fed by water from the carbonate aquifer. The caves at Devils Hole provide habitat for the only naturally occurring population of the endangered Devils Hole Pupfish (Cyprinodon diabolis).

East of the Amargosa Farms area are Ash Meadows and Devils Hole, which are part of the Ash Meadows Basin hydrographic area (Figure 2-3). Ash Meadows Basin is the largest in the Central Death Valley Subregion. Flow in the carbonate aquifer is southwesterly to westerly in the Ash Meadows Basin, approaching the north-south and northwest trending high-angle faults in the Ash Meadows area. The faults cause much of the carbonate groundwater to be discharged in Ash Meadows as spring flows and through evapotranspiration (Winograd and Thordarson, 1975). Groundwater that is not discharged in Ash Meadows mixes to the south with flow from the volcanic and alluvial aquifers of the Alkali Flat-Furnace Creek Basin (Levich et al., 2000), as described below.

West of Ash Meadows, there is a steep hydraulic gradient coincident with the north-south trending high-angle fault between the alluvial sediments of Amargosa Farms and the carbonate rock exposed at the ground surface in Ash Meadows (Belcher and Sweetkind, 2010). All of the present-day springs in Ash Meadows are in the area of the carbonate rocks. The surface exposure of carbonate rocks in Ash Meadows is in sharp contrast to the hydrologic conditions in the central portion of Amargosa Desert, where the carbonates are present far below the thick sequence of alluvial sediments. The steep hydraulic gradient across the north-south trending fault indicates little mixing of alluvial aquifer waters to the west with carbonate waters to the east in the present-day climate. Given the direction of the hydraulic gradient, any connection between the uppermost and underlying aquifers in this area is likely to be flow from the carbonate aquifer of Ash Meadows to the alluvial aquifer in the Amargosa Farms area. Further south, the waters of the two aquifers likely mix in the area between the Nevada-California state line and Alkali Flat (Figure 2-3). This is because the north-south trending high-angle fault appears to end further south near the Nevada-California state line (Belcher and Sweetkind, 2010; Figure B-26).

South of Amargosa Farms, the groundwater from the alluvial aquifer under Amargosa Farms can flow either southwestward or southward. Flow to the southwest is through the fractured

carbonate rock at the southeastern end of the Funeral Mountains to eventual discharge at Furnace Creek springs or evaporation in the Middle Basin of Death Valley (Figure 2-3). A possible alternative flow path southward from Amargosa Farms follows the dry bed of the Amargosa River. For this flow path, water moves in the thinning alluvial sediments along the Amargosa River towards Alkali Flat (also known as Franklin Lake Playa), where the groundwater intermittently discharges to the surface, or continues along the Amargosa River into the Shoshone-Tecopa Section of the Southern Death Valley Subregion. There is uncertainty in how the westward flowing carbonate aquifer interacts with the southward flowing alluvial aquifer of the Amargosa River Section, but geochemical data indicate that mixing occurs in the general area between the Nevada-California state line and Alkali Flat (Faunt et al., 2010a).

Analysis of potential flow beyond Amargosa Farms, using a modification of the DVRFS model, indicates that in the absence of pumping in Amargosa Farms over the last century, the flow path would dominantly trend to the southwest under the eastern end of the Funeral Mountains (DOE, 2014a). The model used was based on Belcher and Sweetkind (2010), modified to include pumping data from 1913 to 2003 (SNL, 2014). Flow pathways can be identified in the model by releasing nominal "particles" at the postclosure compliance location and tracking their movement within the DVRFS. Adsorption, colloidal filtering, decay, or other mechanisms that would preclude the particles from moving with the water are not included in this analysis, so the particle tracking represents unrestrained movement of water-borne contaminants. In the model runs, 8,024 particles were released and tracked from the postclosure compliance location. The 8,024 particles were derived from the release of 10,000 particles at repository locations in the Yucca Mountain Site-Scale Flow Model (SNL, 2009). The NRC staff has found DOE's model for saturated zone flow in the vicinity of the repository and its integration of the multiple models to be acceptable as part of its safety evaluation (NRC, 2014a; Section 2.2.1.3.8).

When historic data for pumping are considered in the DVRFS model, all particles are captured by the wells in Amargosa Farms (Figure 2-5, Pumping). When no pumping is included (the prepumping model, representing groundwater conditions prior to 1913), two pathways were identified (DOE, 2014a). The predominant path identified was approximately southward through Amargosa Farms and turning southwestward to westward beneath the Funeral Mountains to the springs at Furnace Creek and on to Middle Basin in Death Valley (Figure 2-5, No Pumping). A potential alternative, but less likely, path was identified by 2 particles (out of the 8,024) that traveled southward to and discharged at Alkali Flat. The flow path of the few particles tracked to Alkali Flat arises from the uncertainties in the model parameters, and may represent the possibility that a limited amount of water diverts from the predominant pathway. The particle tracking approach is a recognized method for understanding contaminant transport in hydrologic models (e.g., Faunt et al., 2010b). The NRC staff concludes that the use of particle tracking in the DVRFS model is a reasonable means of defining the potential paths that contaminants may follow, consistent with the flow fields of the DVRFS. Further information on the particle tracking model is given in Appendix A to this supplement.

The groundwater flow path from Amargosa Farms southwest through the Funeral Mountains continues towards the springs near Furnace Creek and to Middle Basin in Death Valley. The likelihood of flow through the carbonate blocks at the southeastern end of the Funeral Mountains was identified through research conducted by the USGS (Belcher and Sweetkind, 2010) and Inyo County (2007); (Bredehoeft et al., 2008), which defined the relatively permeable carbonate units within the Funeral Mountains.

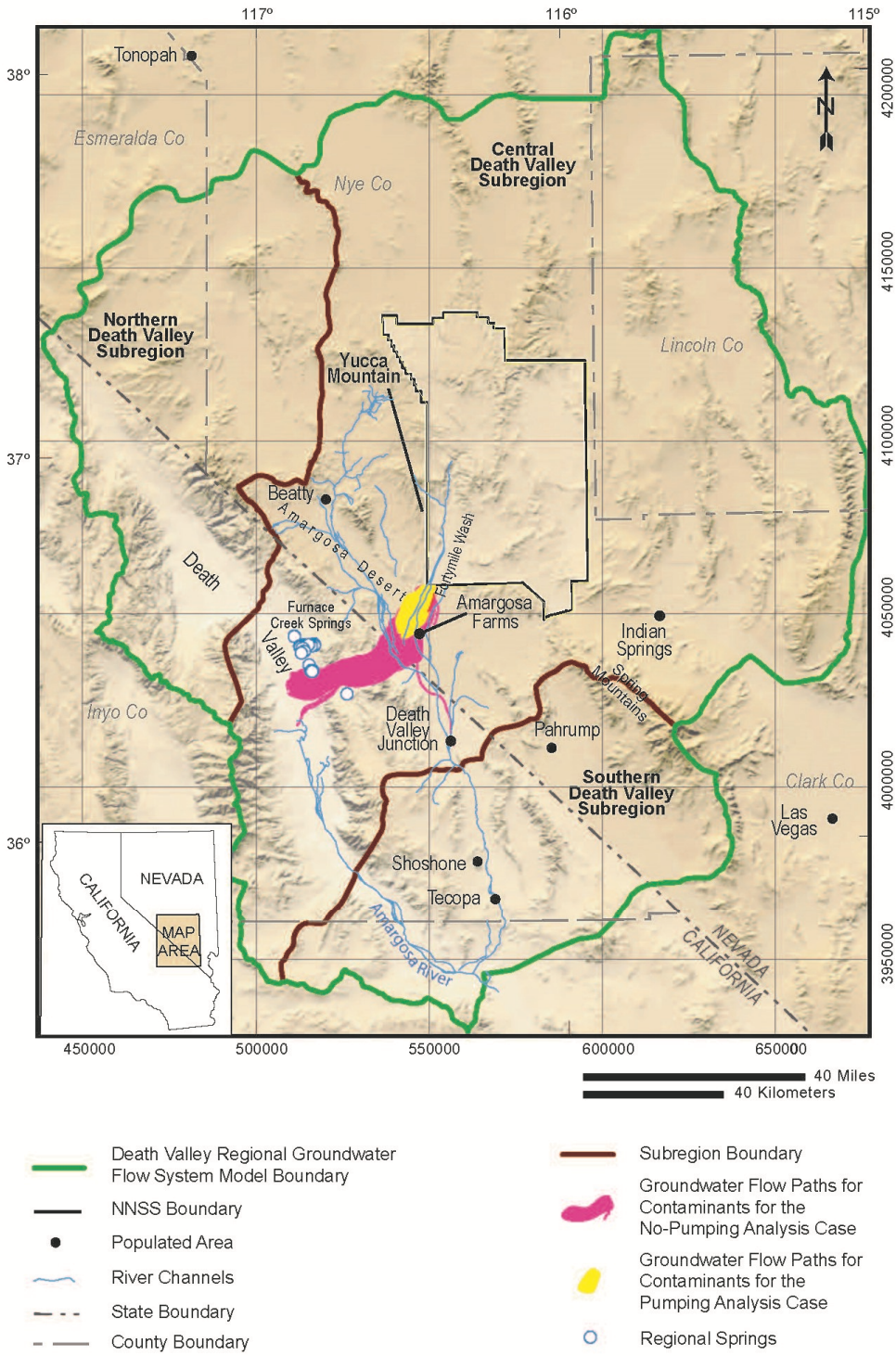

Figure 2-5. Groundwater Flow Paths for Contaminants for the Pumping (Yellow) and the No Pumping (Fuchsia) Analysis Cases. The Flow Paths Are Delineated Using Particle Tracks and the Death Valley Regional Groundwater Flow System. Springs in the Region of Furnace Creek Are Shown as Open Circles. Modified From Belcher and Sweetkind (2010) and SNL (2009).

The likelihood of this southwesterly flow path differs from that identified in earlier DOE analysis (2008 SEIS; p.3-31), which indicated that the majority of the water moved instead to the south from the Amargosa Farms area, generally following the trace of the Amargosa River and discharging at Alkali Flat, but did not include the presence of highly transmissive carbonate units beneath the Funeral Mountains. Flow conditions in the absence of pumping in Amargosa Farms are not well characterized, so some possible flow towards Alkali Flat cannot be excluded.

This alternate flow path is described further in the subsection on Alkali Flat and the Southern Death Valley Subregion.

Funeral Mountain Section

As previously noted, in the absence of pumping in Amargosa Farms, the more likely path for groundwater originating from Yucca Mountain is predominantly to the Funeral Mountain Section (Figure 2-3; labeled 3d) through the fractured carbonate rock of the southeastern part of the Funeral Mountains (the main flow path shown in Figure 3-1 of DOE, 2014a). Flow southwestward beneath the Funeral Mountains is likely in the fast-flowing fractured carbonate aquifer (Bredehoeft and King, 2010). This groundwater would then feed the springs of the Furnace Creek area of Death Valley. Water from these springs is currently used to support activities in the Furnace Creek area of Death Valley National Park. In the absence of human activity, discharges at these springs could reinfiltrate into the Death Valley alluvial fans and evaporate or transpire further downstream in the fans, or evaporate from the Middle Basin playa at the floor of Death Valley (Belcher and Sweetkind, 2010).

The geochemistry of water at the Furnace Creek springs is similar to that at the springs of Ash Meadows, and to that of the regional carbonate aquifer generally (DOE, 2014a; 2008a). The chemistry of the water at the springs appears to have equilibrated (i.e., reflects the mineral content of) with the surrounding carbonate rock as indicated by the calcium, magnesium, and bicarbonate composition in the water. Further similarity of water discharging from the Furnace Creek springs to water discharging at Ash Meadows is shown in their content of rare earth elements (Johannesson et al., 1997). In addition, strontium isotope measurements also indicate that the groundwater interacted with older metamorphic or igneous rocks (Levich et al., 2000) in the central part of the Funeral Mountains. Furthermore, information from potentiometric and structural geology maps and water temperature measurements also support groundwater in the eastern regional carbonate aquifer flowing westward through Ash Meadows, under the southern part of the Amargosa Desert and the eastern end of the Funeral Mountains, to the springs at Furnace Creek. Geochemical and other data are consistent with the interpretation that under present pumping conditions at Amargosa Farms, the Furnace Creek springs do not include a significant component of water from the alluvial aquifer in that area. The data from the Furnace Creek springs are also consistent with water from the alluvial aquifer mixing with a larger volume of water flowing in the carbonate aquifer, or water that has equilibrated with the carbonate rocks of the Funeral Mountains.

Evapotranspiration causes a much larger amount of groundwater loss than spring discharge in the Funeral Mountain Section. Three large springs (Texas, Travertine, and Nevares) at Furnace Creek together have a discharge of 2,300 acre-ft/yr [2.8 million m^3/yr] (DOE, 2014a; Table 2-1). The annual estimate of evapotranspiration for the Funeral Mountain Section is approximately 10 times larger than this spring discharge (DOE, 2014a; Table 2-1). There is also a small amount of groundwater pumping in the Funeral Mountain Section, but this pumping does not occur near the groundwater flow path from Yucca Mountain, and thus does not impact the path for potential contaminants.

Alkali Flat and Southern Death Valley Subregion

An alternative flow path for groundwater from Yucca Mountain is along the trace of the Amargosa River to Alkali Flat (DOE, 2014a). As previously noted, flow to Alkali Flat was considered more likely prior to updated information on aquifer units in the Funeral Mountains. This path is now seen as much less likely, but some flow in this direction cannot be ruled out, and discharge in Alkali Flat is considered as a potentially affected environment in this supplement.

Based on the modeling results (DOE, 2014a), contaminant transport along the flow path beyond Alkali Flat is unlikely. Past Alkali Flat, the groundwater flow path follows the trace of the Amargosa River southward through the Shoshone-Tecopa Section and California Valley Section of the Southern Death Valley Subregion, and then continues along the Amargosa River as it turns westward through the Ibex Hills Section. Springs occur at several locations in the Shoshone-Tecopa and California Sections, leading to perennial flow in stretches of the river channel. Groundwater not lost to evapotranspiration, the springs along the river, or pumping from two wells near the town of Tecopa, continues to the flow path's endpoint at Badwater Basin, the lowest-elevation playa and salt pan in Death Valley.

The aquifer in Pahrump Valley, in the northeastern portion of the Southern Death Valley Subregion, does not directly interact with the alluvial-volcanic aquifer in the Amargosa River Section, but likely contributes groundwater flow to the lower (southern) part of the Amargosa River near Death Valley (Belcher and Sweetkind, 2010; Chapters C and D). The Pahrump Valley Section has extensive recharge in the surrounding mountainous areas as well as extensive pumping for agriculture in the Pahrump Valley. Under present and expected future wetter conditions, no contaminants from the repository would reach the aquifer in Pahrump Valley, based on the regional flow gradients (Belcher and Sweetkind, 2010).

In the Shoshone-Tecopa, California Valley, and Ibex Hills Sections, more groundwater is lost through evapotranspiration {12,350 acre-ft/yr [15.2 million m^3/yr]} than through pumping (DOE, 2014a; Table 2-1). Wells in these areas extract only on the order of 27 acre-ft/yr [0.033 million m^3/yr] of groundwater (DOE, 2014a; Table 2-1).

2.2.3 Effects of Groundwater Pumping on Flow

In the 2002 EIS and 2008 SEIS, DOE provided a discussion of pumping in the DVRFS with additional detail for the Amargosa Desert. In the 2008 SEIS, DOE reported pumping rates based on irrigation estimates generated by the Nevada Division of Water Resources [(NDWR), see LaCamera et al., 2005]. Analyses in this supplement use pumping rates from DOE (2014a), which were generated by the USGS using a different approach for estimating irrigation (Moreo and Justet, 2008) that led to somewhat higher estimates of pumping

rates. For example, for the period from 1994 to 2003, the pumping rates in the Amargosa Desert estimated by the NDWR are 72 to 84 percent of those estimated by the USGS. The different methods are described further in Section 2.4 (Groundwater Modeling). This section of the supplement provides a brief description of pumping rates for all water uses in the DVRFS, including the updated rates provided in DOE (2014a).

Groundwater Pumping in DVRFS

Significant pumping in the region started in 1913 and increased from the 1940s to 1960s. The pumping rates varied at approximately the same levels from the 1970s to the present-day for the DVRFS (Moreo and Justet, 2008; Figure 2). There are three major groundwater pumping areas within the DVRFS: Amargosa Valley, Pahrump Valley, and Penoyer Valley. In Amargosa Valley, an average of 16,800 acre/ft [20.7 million m^3] of groundwater was withdrawn annually from 1994 to 2003, of which 85 percent was used for irrigation and 13 percent was used for mining, domestic, and commercial purposes. Annual pumping variations are generally a result of crop and irrigation cycles. In Pahrump Valley, the largest groundwater withdrawal area in the DVRFS, annual pumping estimates ranged from approximately 20,000 to 33,000 acre-ft [25 to 41 million m^3] from 1994 to 2003. Compared to Amargosa Valley, a larger fraction of the pumped water in Pahrump Valley was used for domestic purposes and the public water supply, rather than agriculture. Water used for irrigation ranged from approximately 50 percent to 75 percent during the period 1993 to 2003, and this fraction decreased over time. Groundwater withdrawal in the Penoyer Valley (northeastern portion of DVRFS, outside of the area that influences groundwater flow from beneath Yucca Mountain) was about 12,600 acre-ft/yr [15.5 million m^3/yr] and was used primarily for irrigation with the pumping rate holding relatively steady from 1994 through 2003. Over the entire DVRFS for 2003, about 55,700 acre-ft [68.7 million m^3] of groundwater was pumped, of which 69 percent was used for irrigation; 13 percent for domestic; and 18 percent for public supply, commercial, and mining activities (Moreo and Justet, 2008). Comparable data for the entire DVRFS for more recent years are not readily available, but the available records for the area from the State of Nevada Division of Water Resources suggest that these volumes and fractions have not changed significantly (NDWR, 2015).

Groundwater Pumping in Amargosa Valley

Historically, agricultural irrigation used 80 percent of annual groundwater withdrawal in Nye County, Nevada, which includes both Pahrump and Amargosa Valleys. Domestic and mining water supplies used the majority of the remaining 20 percent (DOE, 2014a). Outside of Pahrump Valley, the primary irrigation area is Amargosa Farms, in the south-central portion of Amargosa Valley. In the Amargosa Valley, total annual groundwater withdrawals averaged 16,800 acre-feet [20.7 million m^3] from 1994 through 2003, with a minimum and maximum of 14,100 and 21,100 acre-ft [17.4 and 26 million m^3] (Moreo and Justet, 2008). Estimates of pumping rates since 2003 are available from the State of Nevada's Division of Water Resources (NDWR, 2015). For Amargosa Valley[2], the State of Nevada estimates of groundwater withdrawal rates from 2006 to 2012 range from 15,400 to 18,000 acre-ft/yr [19 million to 22.2 million m^3/yr] with an average of 16,700 acre-ft/yr [20.6 million m^3/yr].

In its 2008 SEIS and in DOE (2014a), DOE suggested that present-day pumping rates for the Amargosa Farms areas may not be sustainable due to proximity to Devils Hole and the potential impact of pumping on water levels there. As DOE described in its 2002 EIS and 2008 SEIS, strict limits on groundwater withdrawal in the Ash Meadows area have been instituted to protect the water level in Devils Hole and the endangered Devils Hole pupfish. Withdrawals from within Ash Meadows are a very small portion (less than 1 percent) of the total withdrawals from the

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[2]Amargosa Valley is referred to as the Amargosa Desert Hydrographic Basin (#230) in the State of Nevada Division of Water Resources designation system (NDWR, 2015). The DVRFS includes multiple hydrographic basins in the State of Nevada classification system, as well as groundwater basins in California.

Amargosa Desert Hydrographic Basin (DOE, 2008a). Information provided at a State of Nevada administrative hearing in 2007 (Taylor, 2008) showed that the water level in Devils Hole was within 0.7 ft [0.2 m] of the minimum threshold. Accordingly, the Nevada State Engineer issued an order (Taylor, 2008) that would deny any water rights applications within 25 mi [40 km] of Devils Hole, and any change applications that place the point of diversion to within 25 mi [40 km] of Devils Hole (with some exceptions). This 25-mi [40 km] radius encompasses the Amargosa Farms area. The State Engineer's order essentially limits future pumping rates in areas beyond Ash Meadows that may impact Devils Hole. These restrictions may also render the present-day pumping rates at the Amargosa Farms area unsustainable, as further analysis (SNL, 2009) indicates that the protected water level at Devils Hole could be reached by 2016, assuming only the continuation of current groundwater pumping.

2.2.4 Past and Future Climates

Understanding of possible future climates is important for the affected environment, as a climate that is cooler and/or wetter than the present-day climate can affect several aspects of groundwater flow, particularly groundwater levels, flow rates, and potential surface discharges. Recharge of the aquifers in the DVRFS by infiltrating water occurs predominantly at higher elevations on mountains and ridges where soils are thin, and along washes and riverbeds when water is flowing (DOE, 2008b, Section 2.3.1). Recharge is not evenly distributed over the DVRFS, and would change in a wetter climate. An increase in recharge (from increased precipitation and increased infiltration) would raise water levels in aquifers, which can cause surface discharge where the water table reaches the ground surface.

In the southern Great Basin, precipitation and temperature are the two most important climate variables affecting groundwater conditions (e.g., Garfin et al., 2014). DOE developed projections that consider potential cooler/wetter future climates as part of its assessment of repository performance (DOE, 2008b). The climate projection developed by DOE for the Yucca Mountain site can be appropriately applied to the entire DVRFS because it is based on regional information on past climates and a general understanding of how similar conditions can be expected to occur in the future.

Reconstructions of regional past climates in the southern Great Basin, including the Yucca Mountain region, show patterns of periods that are relatively hot and dry (similar to present conditions) and periods that are relatively cooler and wetter (e.g., Reheis et al., 2008). Wetter phases in the region, represented by high stands of paleolakes, do not necessarily correspond to the full glacial conditions known from global reconstructions, but have occurred during glacial transition periods (e.g., Smith and Street-Perrott, 1983).

These reconstructions of past climate states are the best indicators of expected future climates. Using paleoclimate reconstructions as a basis, DOE has defined three climate states in addition to the present-day interglacial climate that are expected to occur over the next million years (DOE, 2008b, Section 2.3.1). These are (i) a monsoonal climate that is warm and wetter compared to the present-day interglacial climate, with a shift in the seasonality of precipitation; (ii) a glacial-transition climate with cooler and wetter conditions compared to the present-day climate; and (iii) a full-glacial climate, which represents the maximum extent of cool conditions recorded in paleorecords. DOE included the interglacial, monsoonal, and glacial-transition climate states in its performance assessment for the repository over the first 10,000 years following permanent closure, and used a prescribed deep percolation rate (the amount of water reaching the repository) for the remainder of the one million year period, as provided in

10 CFR 63.342 (DOE, 2008b, Section 2.3.1.2). The NRC staff found DOE's model for future climate states to be acceptable as part of its safety evaluation (NRC, 2014a; Section 2.2.1.3.5).

For this supplement, the most significant considerations for groundwater are the overall flow paths and flow rates, and potential changes in the water table that could affect locations of surface discharge, as these can affect contaminants from the repository in the aquifer and at surface discharge locations. For these effects, the present day interglacial (hot and dry) and glacial or glacial-transition (cooler and wetter) climates represent the range of potential climate effects on groundwater in the DVRFS. A monsoonal climate is not considered further in this supplement because the effects on groundwater of that climate state fall between those of the present-day and cooler/wetter climate states (i.e., a warm, wet climate would have less impact on groundwater than a cooler/wetter climate). The effects of the cooler/wetter climate on the impacts addressed in this supplement are included in several aspects of the NRC staff's analysis. The potential climate impacts on repository releases are captured through the use of the DOE performance assessment outputs for contaminants reaching the postclosure compliance location (which includes the effects of increased water flow reaching the repository). Adjustments to groundwater velocity are used to incorporate the higher groundwater flow rates expected in a cooler/wetter climate. Potential changes in surface discharge locations are included by considering the fossil deposits that formed during past cooler and wetter periods. Appendix A provides details on the methods used to evaluate the effects of different climate states.

The analysis in this supplement makes no assumptions about the timing of the potential future climate states, only that such conditions can be expected to occur during the one-million-year period considered in this supplement. Notably, key indicators of past wetter climates, such as deposits from former high lake levels and past surface discharges of groundwater (paleodischarge sites), provide useful insight into changes in groundwater conditions regardless of when they occurred. The analysis in this supplement assumes that potential releases of contaminants from the repository can occur independently of the climate state, so the timing of changes in climate has no effect on the impact analysis.

The principal changes to groundwater in the Yucca Mountain region from cooler and wetter climates in the future are potentiometric surfaces (water table in the unconfined, upper aquifer) that are higher than present day conditions, changes in the flow paths, and changes to flow rates. One consequence of a shift to a cooler/wetter climate is that elevated water tables could lead to discharge at new locations. Present-day types of natural discharge are described in Section 2.3, including potential locations of discharge under a cooler/wetter climate state (Section 2.3.4). A second consequence is the possible alteration of pumping rates and irrigation strategies; in a cooler/wetter climate, less irrigation water would be needed to maintain the same set of crops. A third consequence is that the local or regional groundwater quantity, flow rates, and flow distributions may change due to changes in hydraulic gradients and the water table position. The consequences of this uncertainty in pumping rates is considered in Section 2.5 and in Chapter 3. Potential changes to groundwater flow in future climates are also discussed in Section 2.4.

Presently available information about human-induced climate change from the release of greenhouse gases indicates that, for this region, the most notable effects on groundwater would be increased heat and aridity in the near term, and over longer term, potentially extending the duration of the present-day interglacial climate (hot and dry) for longer than it would persist in the absence of human-induced change (e.g., Garfin et al., 2014). The principal effects of a climate that is warmer and drier than the present-day climate is to delay the release and

transport of contaminants from a repository. This is because releases depend on water entering the repository by infiltration and percolation, and transport depends on the amount and rate of water flow through the unsaturated and saturated zones (DOE, 2008b, Enclosure 8; NRC, 2014a, Section 2.2.1.3.5). Therefore, the impacts from potential human-induced climate change are captured within the range of conditions for climate and water use considered in this supplement.

2.3 Surface Discharge Environments

Present-day natural surface discharge sites from the groundwater system in the desert of the southern Great Basin cover a spectrum of types, from seeps onto the ground surface (springs) to wet or dry playas. Groundwater discharges as springs where the water table reaches the ground surface. Wet playas occur in low areas where the water table is below the ground surface to depths of less than 5 m [16 ft] (Reynolds et al., 2007). Dry playas occur where the water table is at greater depths {greater than 5 m [16 ft]}; though at much greater depths, and depending on the soil type, evaporation becomes minimal. Springs discharging to the ground surface may reinfiltrate downstream. Surface discharges in desert environments can vary seasonally and year to year, depending on precipitation and other factors. Springs or streams in desert environments where water is always flowing are referred to as perennial. Those that vary between wet and dry periods are referred to as ephemeral.

In a wet playa, capillary action (water moving through pores in the soil, or wicking) brings water to the surface or near-surface, where evaporation causes dissolved material in the water to precipitate as mineral deposits within or on existing sediments. Texturally, soils found at wet playas differ from those at dry playas (Reynolds et al., 2007). Mineral deposits near the surface in wet playas are described as fluffy, puffy, and soft. Wind erosion can redistribute the finer-grained minerals. Soils at dry playas, however, are described as generally compact and hard. The potential for wind erosion, and thus wind redistribution of deposited minerals, is relatively low at dry playas (Reynolds et al., 2007). Spatial and temporal variations add complexity to classifying discharge locations. For example, low-lying areas may have springs and a complex distribution of wet and dry playas. Seasonally or from year to year, features at a discharge location may change between dry or wet playas, or to springs or standing water. The distinction between wet and dry playas is important for the analysis of impacts in Chapter 3 of this supplement because the wind-driven redistribution of surface material that could contain contaminants deposited from groundwater depends on the nature of the deposits. As noted above, redistribution of precipitated material by wind is more likely from wet playas than from dry playas.

Geographically, locations of natural discharge sites fall into two categories. The first type is seeps (springs) and focused evapotranspiration along alluvial fans or faults. The second type occurs where there is a confluence of the water table with low-lying areas, such as the bottom of a valley. At the first type, water may either evapotranspirate or flow downslope and infiltrate back into the ground. At the second type, water evaporates, or transpires if plants are present.

As previously noted, the chemistry of spring water reflects the rock through which the water has flowed. Water equilibrated with carbonate rock is of a calcium-magnesium-bicarbonate composition and generally contains more dissolved chemicals than water equilibrated with volcanic rock or volcanic-derived sediments, which has higher concentrations of sodium, potassium, and silica. This water chemistry plays a role in what minerals precipitate as the groundwater evaporates at a discharge site, which in turn can affect what contaminants could be present in surface deposits.

2.3.1 Ecology at Surface Discharge Sites

The region south of Yucca Mountain, where the surface water discharge locations discussed in this supplement are located, is within the Mojave Basin and Range ecoregion (Bryce et al., 2003; Griffith et al., 2011). The Mojave Basin and Range ecoregion is composed of broad basins and scattered mountains that are generally lower, warmer, and drier than those of the Central Basin and Range located north of the Mojave Basin and Range ecoregion (north of Beatty, Nevada). The broader Mojave Basin and Range ecoregion is further subdivided into smaller ecoregions: State Line/Franklin Well, Ash Meadows, and Alkali Flat, which are located within the Amargosa Desert ecoregion, and Furnace Creek springs and Middle Basin, which are located within the Death Valley/Mojave Central Trough ecoregion (Bryce et al., 2003; Griffith et al., 2011).

The landscape in this region consists of north-south trending mountains separated by valleys. The creosote bush (Larrea tridentata)—white bursage (Ambrosia dumosa) association covers approximately 70 percent of the Mojave Desert, especially on lower valley floors (MacMahon, 2000; p. 292). These two desert scrub plants dominate much of the lower slopes and alluvial fans at the base of the mountain ranges and extend down into many of the inter-mountain basins. Plant species typically found with creosote bush—white bursage association in the Mojave Desert include Shockley's goldenhead (Acamptopappus shockleyi), Anderson's wolfberry (Lycium andersonii), range ratany (Krameria parvifolia), Mojave yucca (Yucca schidigera), California jointfir (Ephedra funerea), spiny hopsage (Grayia spinosa), and winterfat (Krascheninnikovia lanata). Blackbrush (Coleogyne ramosissima) and Joshua tree (Yucca brevifolia)–dominated vegetation series are present on mid-elevation mountains and hillsides. On alkaline flats, vegetation transitions to species dominated by saltbush (Atriplex ssp.), saltgrass (Distichlis stricta), alkali sacaton grass (Sporobolus airoides), and iodine bush (Allenrolfea occidentalis) or pickleweed (Salicornia spp.) (Bryce et al., 2003). The mixed saltbush-greasewood (Sarcobatus vermiculatus)-dominated vegetation series is common on the basin floor in Death Valley (MacMahon, 2000; p. 267). Iodine bush and pickleweed-dominated vegetation series and saltgrass-dominated vegetation series are present on wet basin-fill and lacustrine deposits.

Wildlife species often use multiple habitat types throughout their life cycle and move within corridors or between patches that contain acceptable habitat. As an example, riparian areas and wetlands are key features for a large number of wildlife species throughout the Mojave Basin and Range ecoregion. Some animals, endemic species, survive only in a particular area such as within the subdivided Amargosa Desert ecoregion. Other animals live throughout the region, while others pass through the region during migration. Common terrestrial wildlife found in the Amargosa Desert and Death Valley/Mojave Central Trough ecoregions include mammals such as the desert bighorn sheep (Ovis canadensis), desert kit fox (Vulpes macrotis), coyote (Canis latrans), ground squirrels [e.g., white-tailed antelope squirrel (Ammospermophilus leucurus), bats (e.g., California myotis (Myotis californicus) and the western pipistrelle (Parastrellus Hesperus)], desert cottontails (Sylvilagus audobonii), black-tailed jackrabbit (Lepus californicus), and rodents (e.g., kangaroo rat (Dipodmys spp.) (Digital Desert, 2015). Birds found in these areas include a number of species of eagles, hawks, owls, quail, roadrunners, finches, warblers and orioles. Reptiles include the desert tortoise (Gopherus agassizii) and several species of rattlesnake and lizard. Insects (e.g., butterflies and moths, tarantula hawk wasps, beetles, ants, grasshoppers), and arachnids (e.g., scorpions, tarantulas, wolf spiders, crab spiders) are also an important part of the desert ecosystem.

Significant landscape changes may occur within the Mojave Basin and Range ecoregion in the short term and long term in response to climate change. Modeling the next five decades suggests that in response to possible near-term climate change, the lowest-elevation basins throughout the ecoregion, where surface water discharge locations are currently or are expected to occur, could transition from warm desert scrub into relatively barren areas, the expansion of some desert playas, and the slow expansion/transformation of the mixed salt-desert scrub vegetation type (Comer et al., 2013). Areas currently dominated by Joshua tree and blackbrush-scrub type vegetation could transition to a creosote bush-dominated scrub vegetation type. In a similar manner, a future cooler/wetter climate will lead to changes in the type and abundance of vegetation. Changes in species composition, community types, and distribution ranges can be expected, with pinyon-juniper woodlands and other less-arid Great Basin species likely to become more prevalent in the region during this climate state (DOE, 2008b, Section 2.3.1.3.2.1.5; NRC, 2014a, Section 2.2.1.3.5). The exact mechanisms for these transformative vegetation changes will likely vary by type and location with varying speed and intensity.

The linkages between key climate variables and ecosystem dynamics across the Mojave Basin and Range are not well understood. While the long-term climate-related trends are highly unpredictable, and the resulting ecosystem dynamics are speculative (Comer et al., 2013), the details of particular ecological changes are not necessary for assessing the impacts considered in this supplement. As discussed in Chapter 3, the impacts at the discharge locations are not dependent on the specific nature of the vegetation that is present, but are instead driven by the amount of surface discharge, the concentration of potential contaminants, and the type of discharge environment (e.g., springs, playa, or salt pan).

Ecological characteristics of specific sites are discussed in the subsequent sections.

2.3.2 Cultural Resources at Surface Discharge Sites

The NRC staff has determined that historic and cultural resources may be located in or around current surface discharge areas, described in Section 2.3.3, or in paleodischarge areas (which are also potential future discharge locations), described in Section 2.3.4. Previous analysis of cultural resources by DOE in its EISs for the repository at Yucca Mountain focused on the repository site and the surrounding controlled area. In its 2002 EIS, DOE identified as its region of influence for cultural resources “the land areas that would be disturbed by the proposed repository activities (as described in Chapter 2) and areas in the analyzed land withdrawal area where impacts could occur” (DOE, 2002; Section 3.1.6). DOE updated this information in Section 3.1.6 of the 2008 SEIS, which states that DOE widened the region of influence to include land that DOE had proposed for an access road from U.S. Highway 95, and land where DOE would construct offsite facilities. Section 3.1.6 of the 2008 SEIS also notes that DOE had developed a draft programmatic agreement among DOE, the Advisory Council on Historic Preservation, and the Nevada State Historic Preservation Office for cultural resources management related to activities that would be associated with development of the proposed repository (DOE, 2008a). In February 2009, DOE finalized its programmatic agreement (DOE, 2009b). The area covered by the agreement “includes all site activities conducted by [DOE] and its contractors for the licensing and development of Yucca Mountain as a repository for disposal of spent nuclear fuel and high-level radioactive waste that have the potential to affect historic properties, and that are located within the boundaries of the Yucca Mountain Project Operator-Controlled Area.”

The affected environments considered in this supplement are outside of the nominally controlled area considered by DOE in its previous assessments, and could include historic and cultural resources. For example, members of the Timbisha Shoshone Tribe reside on a 314-acre [1.27-km^2] parcel of trust land located in the Furnace Creek area of Death Valley, near Furnace Creek springs. As previously noted, the tribe has federally appropriated rights to 92 acre-feet per year [0.113 million m^3/yr] of surface and groundwater in the area (DOE, 2014a; 16 U.S.C. 410aaa). Section 3.3 is the NRC staff's consideration of impacts on cultural resources.

2.3.3 Present-Day Discharge Sites

This section describes present-day sites of natural surface discharge near or along the flow path from Yucca Mountain to Death Valley in terms of the groundwater flow pathways discussed in Section 2.2. Table 2-1 provides annual estimates of surface discharge for six different areas discussed in the text. Evapotranspiration and spring discharge in arid environments can be difficult to measure or estimate and, thus, leads to some uncertainty. For example, a spring discharge rate of 5 cubic feet per second (cfs) [4.4×10^6 m^3 annually] is estimated by Jensen et al. (2004), whereas a rate of 3.2 cfs [2.83×10^6 m^3 annually] is estimated by Belcher and Sweetkind (2010). For consistency, all estimates of discharge in Table 2-1 are taken from Belcher and Sweetkind (2010). This approach is conservative, because using the lower rate of discharge results in a higher potential contaminant concentration for the same amount of contaminants in the smaller water volume. Figure 2-6 shows the discharge locations discussed in the following sections.

As described in Section 2.2.2, the predominant flow path is southwestward from Amargosa Farms, beneath the eastern end of the Funeral Mountains. Another path is southward from Amargosa Farms towards Alkali Flat. In addition to these, other sites of minor discharge in the Amargosa Farms area and areas immediately south are discussed in this section.

Discharge Locations along the Flow Path Southwest from Amargosa Farms

The springs at Furnace Creek in Death Valley (Figure 2-6) discharge groundwater that has flowed under the Funeral Mountains. The springs in the Furnace Creek area appear to be controlled by major structural features (Fridrich et al., 2012). The Texas, Travertine, and Nevares Springs at Furnace Creek are surrounded by shrubs and grasses. The discharge is predominantly a calcium-magnesium-bicarbonate water reflective of the regional carbonate aquifer. Engineered structures have been built at several of the Furnace Creek springs to manage the water for use in Death Valley. Section 2.5.1 provides more information on water use.

Middle Basin (Figure 2-6) is a local low point in Death Valley that is down gradient from Furnace Creek. Groundwater that does not discharge at the three Furnace Creek springs, or that re-infiltrates after discharging from the springs, flows down an alluvial fan to the salt pan at Middle Basin. Along the alluvial fan, there are numerous small springs surrounded by a variety of desert shrubs, trees, and grasses. Direct evaporation occurs in the salt pan at the bottom of the alluvial fan. As a salt pan, Middle Basin is a low point or depression in the ground in which saline water has evaporated, leaving salt deposits.

Table 2-1. Annual Discharge Estimates for Natural Discharge Locations. In Most of the Areas, Estimates of Discharge Rates Could Not Readily Separate Contributions From Evapotranspiration and Spring Flow. Ash Meadows Data Is Provided for Comparison. [Data From Belcher and Sweetkind (2010), Tables C–1 and C–2.]			
Discharge Area	**Prominent Springs Present?**	**Evapotranspiration plus Spring Flow (millions of m^3)**	**Spring Flow (millions of m^3)**
Alkali Flat-Franklin Lake	—	1.23	—
Shoshone-Tecopa	Yes	10.5	
Furnace Creek	Yes	—	2.83
Middle Basin of Death Valley	—	2.42	—
Franklin Well	—	0.43	—
Ash Meadows	Yes	22.2	—

Discharge Locations along the Flow Path South from Amargosa Farms

Alkali Flat, also known as the Franklin Lake Playa, is a broad area south of Amargosa Farms along the dry bed of the Amargosa River (Figure 2-6). Deposits at the site reflect intermittent spring discharge and wet and dry playas (Reynolds et al., 2007). Salt pan, soft and fluffy wet playa deposits, and hard and compacted dry playa deposits are distributed near or intermixed with channel deposits at the confluence of Carson Slough (an ephemeral stream that intermittently flows south from Ash Meadows) and the Amargosa River. The present-day water table at Alkali Flat varies from 0 to 4 m [0 to 13 ft] below the ground surface. Water is supplied to the flat from Ash Meadows along Carson Slough and from the Amargosa River. Surface discharge is dominated by loss to evaporation and, to some extent, transpiration by scattered low scrub vegetation, although intermittent surface flow can occur during brief wetter periods such as major rainfall events (e.g., Beck and Glancy,1995; Tanko and Glancy, 2001). Surface water in the wet playa portion primarily flows off the playa and continues along the Amargosa River bed (Reynolds et al., 2007); little standing water has been observed in this area. Chemistry of the water varies widely, from dilute to highly saline. Water in the thin alluvial sediments is confined to those sediments. Two springs in the northern part of the flat have relatively dilute water; water emanating from a well and from a spring have 1,000 mg/l [ppm] and <5,000 mg/l [ppm], respectively, of total dissolved solids. By contrast, total dissolved solids reaches 80,000 mg/l [ppm] in water from the wet playa portions of the flat. The water at Alkali Flat is of insufficient quantity and too saline to be of beneficial human use (Czarnecki and Stannard, 1997).

Most of the surface of Alkali Flat is not vegetated (Czarnecki and Stannard, 1997). Vegetated areas are limited mainly to along the braided river channel with relatively lower salt content. About 1 to 5 percent of the total surface area of the playa {total area roughly 16 km^2 [6 mi^2]} consists of sparsely distributed mounds primarily covered with greasewood, seepweed (Suaeda fruticosa), and saltbush. Small quantities of saltgrass are concentrated near the few springs and seeps at the northern and eastern playa margins.

The Shoshone and Tecopa portions of the Amargosa River, south of Alkali Flat, are perennial under the present-day climate (Menges, 2008). Water that does not discharge at Alkali Flat flows in the alluvial sediments of the Amargosa River valley. The quantity of groundwater discharge is sufficient to maintain a flowing river year-round for a short stretch near Shoshone

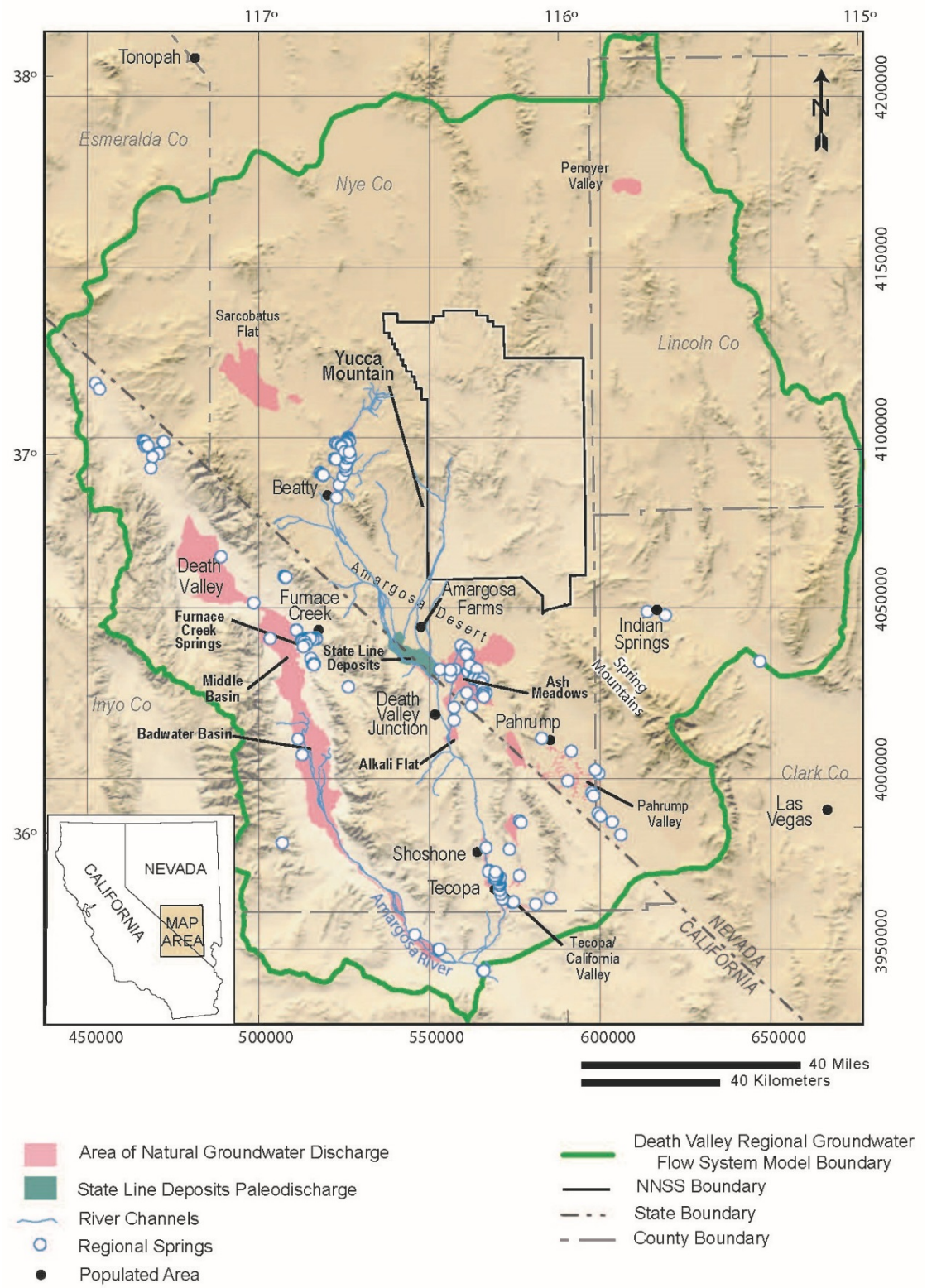


Figure 2-6. Location of Natural Groundwater Discharge Areas, Including Springs and Playas, in the Death Valley Regional Groundwater Flow System. Modified From Belcher and Sweetkind (2010).

and a longer stretch {about 8 km [5 mi]} south of Tecopa, although Zdon and Associates (2014) report surface flow in the channel for a 40-km [25-mi] stretch of the Amargosa River. The source water for the springs in this section is primarily the regional carbonate aquifer system but may include a small component that flows along the relatively shallow alluvial system beneath the river channel from Alkali Flat to Shoshone (Zdon et al., 2015; Zdon and Associates, 2014, 2015; Davisson and Associates, 2014). Based on geochemical analyses of water from the springs (Zdon et al., 2015; Zdon and Associates, 2014; Larsen et al., 2001), the source of the groundwater for the springs is the Spring Mountains and the Kingston Range, and from the carbonate aquifer that also supplies water to Ash Meadows.

Other Discharge Locations in the Amargosa Farms Area

Evidence of paleosprings in the Amargosa Farms area is found in the State Line Deposits, which extend southward from the Amargosa Farms area and span a section of the dry Amargosa River bed. The surface exposures of these deposits consist of a complex distribution of Holocene playa sediments and older freshwater limestone rocks interspersed with channel and alluvial fan deposits (Kilroy, 1991). At present, this area is not likely to have significant water loss by evapotranspiration, as described in Belcher and Sweetkind (2010, Chapter C), except for the limited Franklin Well area, as discussed below. The water table in the State Line Deposits area varies from 1.8 to 10 m [6 to 33 ft] below the surface, based on well measurements from the 1980s (Kilroy, 1991; Paces and Whelan, 2012). The water table is closest to the ground surface immediately to the southwest of the deposits, in the vegetated Franklin Well area. In the area of the State Line Deposits, the water table depth is within the range of a potential wet playa environment. Groundwater drawdown from pumping in the Amargosa Farms area over the last century may have extended to parts of the State Line Deposits area, and thus, in the absence of pumping at Amargosa Farms, evaporation may occur over a larger area in the State Line Deposits wherever the water table is within 5 m [16 ft] of the ground surface (following the delineation by Reynolds et al., 2007). The State Line Deposits area could be a potential minor discharge location for water flowing from Yucca Mountain under the present-day climate (or in a future cooler/wetter climate), but only if pumping in the Amargosa Farms area is significantly reduced. However, there is no evidence of recent springs in the State Line area, and the youngest dated State Line spring deposits formed approximately 30,000 years ago (Paces and Whelan, 2012).

The Franklin Well area is a small linear band along the base of the alluvial fan from the southern end of Funeral Mountains and the Amargosa River bed. Adjacent to the State Line Deposits, the Franklin Well area includes an approximately 8 km [5 mi] section with locally dense vegetation and associated evapotranspiration. Belcher and Sweetkind (2010) estimated a small amount of evapotranspiration discharge for this area (Table 2-1), but gave no further description. The specific source of the water in this narrow zone is not well defined. Possible sources include northward flowing groundwater in the alluvial fan bordering the Funeral Mountains, eastward flowing groundwater along the Amargosa River channel, and southward flowing groundwater in the alluvial aquifer under the Amargosa Farms area (Belcher and Sweetkind, 2010; Figure C–2). The southward flowing groundwater in the alluvial aquifer under Amargosa Farms includes groundwater from beneath Yucca Mountain.

The woodland vegetation of the Franklin Well area is comprised mostly of mesquite (Prosopis spp.), saltcedar (Tamarix spp.), and desert willow trees (Chilopsis linearis), with some meadow grasses and shrubs. The dense to moderately dense grassland vegetation in the area is primarily saltgrass and/or short rushes with an occasional tree or shrub (Laczniak et al., 2001).

Ash Meadows

Ash Meadows is in the neighboring basin to the east of Amargosa Farms and, as such, is not a discharge location for groundwater flowing from Yucca Mountain. Ash Meadows is a large area of wetlands and pools fed by springs. The springs are surrounded by a broad area of grass meadows interspersed with moderately dense to sparse stands of trees and shrubs. The source of water to the springs is the regional carbonate aquifer, which is fed by recharge from the Spring Mountains, which flows from the east and northeast towards Ash Meadows (Belcher et al., 2012). The groundwater flowing from the Ash Meadows area mixes with the Amargosa River flow path, well south of Yucca Mountain, along Carson Slough and Alkali Flat, as described above.

Ash Meadows is a well-studied desert wetland ecosystem encompassing over 23,000 acres [93 km^2] of spring-fed wetlands surrounded by sparse, relatively dry grassland interspersed with sparse to moderately dense stands of trees and shrubs (Belcher et al., 2012). According to Laczniak et al. (1999, pp. 7–8):

> Areas influenced by local springflow include groves of ash (Fraxinus velutina var. coriacea), cottonwood (Populus fremontii), willow (Salix exigua), and mesquite (Prosopis glandulosa torreyana and P. pubescens); thick stands of saltcedar (Tamarix aphylla, T. parviflora, and T. ramosissima); expansive meadows of saltgrass, wire-grass (Juncus balticus, J. cooperi, and J. nodosus), and bunch grass (Sporobolus airoides); and open marshland of cattails (Typha domingensis), reeds (Phragmites australis), and bulrush (Scirpus robustus). More typical Mojave Desert flora, primarily sparse covers of healthy creosote bush (Larrea tridentata), saltbush and desert holly (Atriplex hymemelytra), dominate upland areas not influenced by local spring discharge.

In summary, the principal natural discharge site under present conditions for groundwater potentially contaminated by releases from a repository at Yucca Mountain is in the Furnace Creek/Middle Basin of Death Valley. Minor discharge sites for contaminants include Alkali Flat and the area of the State Line Deposits. The present-day extensive surface discharge in nearby Ash Meadows is fed from a separate basin in the DVRFS, and is not a discharge location for potential repository contaminant releases.

2.3.4 Paleodischarge Sites

During cooler/wetter climates, groundwater would continue to discharge at the present-day sites, and potentially, at additional sites in Amargosa Valley and along the flow path from Yucca Mountain to Death Valley. The volume of future groundwater discharges at present-day sites would likely increase, as would the area of wet playas. Evaporation may decrease due to cooler temperatures. New discharge sites would likely form as the water table rises.

Evidence of paleodischarge sites found in Amargosa Desert and across the DVRFS serve both to identify possible future discharge locations and to constrain the potential increases in the elevation of the water table. These sites provide calibration targets[3] for groundwater flow

[3]Calibration targets are known information used to constrain other less well-known inputs in a groundwater model

models and are useful in identifying or precluding other potential discharge sites. Notably, results of numerical groundwater modeling, as discussed in Section 2.4, suggest that even though flow rates and discharge locations may vary, the flow path does not significantly change between drier and wetter periods.

Amargosa Desert Sites

Data derived from fossils, rock types, mineralogy, and chemistry at discharge sites across the Amargosa Desert provide consistent indicators of the timing, flow history, and characteristics of these discharge sites (Paces and Whelan, 2012; Paces et al., 1997). The State Line Deposits and several Crater Flat area deposits were discharge sites under past cooler/wetter climates. These are representative of potential discharge sites along the present-day and potential future groundwater path from Yucca Mountain under a cooler/wetter future climate.

As described in Section 2.2.2, the State Line Deposits area (Figure 2-6) falls directly along the path of groundwater flowing from Yucca Mountain (DOE, 2014a). Observations from the discharge deposits show a complex interplay of surface flow and spring discharge in the southern part of the Amargosa Desert (Belcher and Sweetkind, 2010). The discharge deposits indicate that the groundwater generally reflects the mineral content of the volcanic-derived alluvial sediments of Amargosa Valley. The deposits also indicate contributions from (i) the lower carbonate aquifer, as indicated by the freshwater limestone deposits and (ii) older metamorphic rocks to the south in the Funeral Mountains, as indicated by the strontium isotopic composition (Paces and Whelan, 2012; Paces et al., 1997). Based on the areal distribution of discharge deposits at the ground surface and at depth, and the present-day topography, the water table rise in a cooler/wetter climate would likely be no more than 30 m [98 ft] in this part of the southern Amargosa Desert (Paces and Whelan, 2012). Information from the fossils, mineralogy, and stratigraphy (relative relations of the rock layers) indicates that these ancient discharge sites existed in a diverse wetland environment fed by springs and perennial or seasonal flow along the Amargosa River (Paces and Whelan, 2012). This wetland environment included wet ground, seeps, marshes, flowing channels, and open pools. Surrounding areas supported phreatophyte (deep-rooted) vegetation with associated discharge by evapotranspiration. Isotopic dating of the deposits indicates that the springs were active at several times during the transition into the last glacial maximum, with measured ages of roughly 100,000 and 40,000 years before present.

Several small areas of paleodischarge deposits, marked in Figure 2-6, occur northeast of the State Line Deposits, but west of Ash Meadows. These are much more limited in extent and have not been studied in as much detail as the State Line Deposits. Given their locations, these deposits are more likely related to groundwater from Ash Meadows during past wetter climates, rather than the southward flowing volcanic-alluvial aquifer system in Fortymile Wash. The present depth-to-water table at this location is greater than the possible water table rise in the alluvial aquifer during wetter climate conditions (Paces and Whelan, 2012). For these reasons, these locations are not likely to represent potential future discharge sites for groundwater from the Yucca Mountain flow system.

Three paleodischarge deposits are present at the southern end of Crater Flat (Figure 2-6), on a smaller scale and with much less carbonate deposition compared to the State Line Deposits (Paces and Whelan, 2012). All three deposits have geochemical signatures of water equilibrated with alluvial sediments derived from tuff (volcanic rock) and a lesser amount of carbonate rock (Paces et al., 1997). Differences in the stratigraphy at the three sites, together with those in the State Line Deposits area, suggest that these deposits formed in local ponds

and marshes, rather than in a large lake across the Amargosa Desert (Paces et al., 1997). Diatomites (deposits composed of fossil diatoms, microscopic organisms with a silica shell) are present at all the Amargosa discharge sites, though only the Lathrop Wells site has a thick sequence. The presence of diatomites, along with other fossils (shells of ostracodes and mollusks) indicate a paleoenvironment of open water such as flowing springs, pools, and wetlands (Paces and Whelan, 2012). The three Crater Flat deposits occur at elevations of 790 to 835 m [2,591 to 2,739 ft] (Paces and Whelan, 2012). These elevations indicate the water table elevation exiting Crater Flat during the wetter periods. Nye County research wells indicate that the present-day depth to the water table ranges from 8 to 31 m [2.4 to 9.5 ft] at the three paleodischarge sites (Paces and Whelan, 2012). Importantly, geochemical data and age determinations indicate flow at the Crater Flat paleodischarge locations was active during roughly the same time periods as at the State Line location (Paces and Whelan, 2012; Paces et al., 1997), indicating that the discharge was likely related to regional climate effects. However, none of the three Crater Flat sites is located along a present or past flow path from Yucca Mountain, based on an analysis of the elevations and potential extent of water table rise at Yucca Mountain (Paces et al., 1997; SNL, 2007a). Instead, particle tracking model results for future wetter climates indicate that flow from the northwest below Crater Flat was the likely source for the Crater Flat discharge deposits (Winterle, 2005).

Alkali Flat to Death Valley

The Carson Slough and Amargosa River flow systems (groundwater and surface water) feed Alkali Flat (Franklin Lake Playa). Evidence from Devils Hole shows that the water table fluctuated between 5 and 9 m [16 and 30 ft] higher at Ash Meadows during the glacial periods of the last 116,000 years (DOE, 2014a). This rise, along with possible perennial flow in the Amargosa River, suggests that in future wetter climates, a larger amount of groundwater and surface flow would reach Alkali Flat than under the present-day climate. Today, Alkali Flat is mostly a flow-through system (Reynolds et al., 2007). The very low topographic gradient suggests that greater flow will not lead to extensive standing water, and that the area would remain an assemblage of variable extents of wet and dry playas in future climates. Additional flow in the river bed continues down to Death Valley, where potentially standing water (and during some periods, an extensive lake) remained year-around during wetter climates, based on paleorecords (e.g., paleo-Lake Manly; Paces and Whelan, 2012; Smith and Street-Perrott, 1983).

2.3.5 Summary of Surface Discharge Environments

Surface discharge environments along the Yucca Mountain flow path fall into three generic types: (i) pumping for irrigation and other uses, as at Amargosa Farms; (ii) discharge at springs, such as at Furnace Creek or the paleo-State Line Deposits; and (iii) discharge at wet and dry playas and salt pans, such as at Alkali Flat or Middle Basin. These types encompass the range of discharge environments expected under current and future climate conditions.

2.4 Groundwater Modeling

In the 2008 SEIS, DOE provided a description of the two groundwater flow models of different scales that were used to quantify flow in and around the DVRFS. The small-scale model covers Yucca Mountain and southward to Amargosa Desert (the Yucca Mountain Site Scale model). This model remains unchanged since 2008 in DOE (2014a). The Yucca Mountain Site Scale model provides flow information for groundwater conditions near Yucca Mountain, which DOE used to support its evaluation of repository performance in its SAR (DOE, 2008b). The DVRFS

model is the larger scale model used by DOE in its SAR; it provides information about areas beyond those in the Yucca Mountain Site Scale model. As previously noted, the NRC staff has found DOE's integration of the multiple models for saturated zone flow to be acceptable as part of the NRC's safety evaluation (NRC, 2014a; Section 2.2.1.3.8). For its 2002 EIS and 2008 SEIS analysis, DOE used the DVRFS model and its representation of groundwater flow beyond the postclosure compliance location and along the flow path to Death Valley. The 2008 SEIS describes the DVRFS model, as documented by the USGS in Belcher (2004). The USGS has since updated the documentation of the DVRFS model (Belcher and Sweetkind, 2010), but the information about the model in the updated report is substantively unchanged (Belcher and Sweetkind, 2010).

DOE used a slight modification of the Belcher and Sweetkind (2010) model in its 2014 analyses (DOE, 2014a). DOE used the 2004 DVRFS model to calculate the groundwater conditions (e.g., water table position) present before extensive pumping in Amargosa Farms (nominally for conditions in 1913). The model input parameters were then adjusted to match the transient (changing) conditions that account for groundwater pumping from the period of 1913 to 1998 (Belcher and Sweetkind, 2010). DOE (2014a) incorporated an expanded pumping data set from Moreo and Justet (2008) that accounted for the period 1913 to 2003, to further update the DVRFS model. As previously noted in Section 2.2.3, pumping records since 2003 indicate little change in the past decade, so this update and analysis capture current pumping rates (NDWR, 2015). This update and DOE's observations from modeling several scenarios are described below, especially as they pertain to the affected environment beyond the postclosure compliance location.

Effects of Pumping on Groundwater Conditions

As described in Section 2.2.3 (Groundwater Pumping), substantial pumping in the area began in 1913 and has increased markedly in the past several decades. Evaluation of groundwater conditions without pumping is an important starting point for comparisons with paleorecords for calibrations to account for transient conditions caused by pumping, and for analyzing the groundwater impacts if no pumping were to occur in the future.

Estimates of pumping rates changed as the DVRFS model evolved from its early version (e.g., D'Agnese et al., 1999), to that used in the 2002 EIS, the 2008 SEIS, and in DOE (2014a). Pumping rates for irrigation, the primary use of groundwater in the Amargosa Farms area, are typically not directly measured. Model groundwater pumping, therefore, is from indirect estimates. Not only does irrigation usage vary from year to year, but techniques differ for estimating the pumping rates for irrigation (DOE, 2014a). The methods used by the USGS and the NDWR are both based on reliable data for the amount of land under irrigation, but use different water application rates (amount per acre) to generate estimates of pumping rates. Groundwater pumping estimates for the DVRFS in the 2002 EIS and the 2008 SEIS are different from those used by the USGS in developing its updated model (Belcher and Sweetkind, 2010). The 2002 EIS and 2008 SEIS used estimates from the State of Nevada, whereas Belcher and Sweetkind (2010) used estimates developed by the USGS that were slightly greater (by about 20–30 percent) than those of the State of Nevada. Use of greater pumping rates may lead to over-estimates of flow rates and potentiometric elevations (e.g., water table for unconfined aquifers) in the absence of pumping.

The Belcher (2004) model was first calibrated to account for steady-state groundwater levels prior to 1913, before significant pumping occurred in the area of the DVRFS. This no-pumping condition provides an estimate of the water table position and flow path directions in the

Amargosa Farms area without the water table decrease caused by pumping. The model was then calibrated for transient conditions using values for water level, spring flows, evapotranspiration, and pumping as they changed over time from 1913 to 1998 (DOE, 2014a). The results of these calibrations were compared with measured water table positions as they changed until 1998.

Uncertainties in future pumping rates were considered in DOE (2014a), especially concerning the effect on the water level in Devils Hole and on the positive vertical gradient from the regional carbonate aquifer to the overlying alluvial aquifer in the Amargosa Farms area. Using the USGS DVRFS model, DOE conducted simulations of long-term pumping, up to 500 years, at the 2003 groundwater pumping rates. These simulations were done both with and without an additional 10,600 acre-ft/yr [13.1 million m^3/yr] of withdrawal from the lower carbonate and alluvial aquifers in Tikapoo and Three Lakes Valleys, as proposed by the Southern Nevada Water Authority for additional supply wells east of the NNSS (SNL, 2009). The modeling results suggested that the upward hydraulic gradient in the lower carbonate aquifer would be maintained after 500 years of additional pumping and would be within 3 percent of that predicted for no-pumping steady-state conditions. Simulation results with the additional annual withdrawal quantity proposed by the SNWA indicated little additional impact on water levels beyond that calculated without the SNWA-proposed withdrawal (SNL, 2009). In any case, continued heavy pumping from the shallow alluvial aquifers would result in an increase in the upward vertical gradient of the lower carbonate aquifer in the Amargosa Desert (SNL, 2009), at least until the pumping rate triggered the restrictions discussed in Section 2.2.3 regarding impacts on the water levels at Devils Hole.

Potential impacts from other basin withdrawals in eastern Nevada proposed by the SNWA, besides those from the Tikapoo and Three Lakes Valleys, are not considered in this supplement. This is because permits have not been issued for such withdrawals, the groundwater withdrawal amounts are highly speculative, and, according to SNWA, such projects would only be pursued when needed to supply future demands (SNWA, 2015). The NRC staff did consider the proposed project that includes Delamar, Dry Lake, Cave, and Spring Valleys, for which an application for water rights has been submitted, but the permit is the subject of litigation (SNWA, 2015). A Bureau of Land Management (BLM) Final EIS has been completed for this project, which includes modeling results indicating no significant impact to groundwater conditions in Amargosa Farms or along the groundwater path to Death Valley (BLM, 2012c). The NRC staff has reviewed the BLM report, and agrees with its conclusion based upon the geologic separation of the hydrologic basins.

For the analyses of impacts in this supplement, the NRC staff used results based on the updated DVRFS model (Belcher and Sweetkind, 2010; DOE, 2014a), which included expanded pumping data for 1913 to 2003. Consistent with its previous evaluation of saturated zone flow in the area (NRC, 2014a, Section 2.2.1.3.8), the NRC staff has concluded that the updated DVRFS model is a reasonable representation of the regional groundwater system. Values of groundwater flow velocity derived from the updated DVRFS model were used as inputs to groundwater transport calculations (DOE, 2014a). The NRC staff used the result of these calculations to determine the potential impacts when groundwater pumping is assumed to occur (Section 3.3.1) and when no pumping is assumed to occur (Section 3.3.3).

Effects of Climate on Future Flow Paths

D'Agnese et al. (1999) simulated the future groundwater environment by using increased recharge to reflect expected future climate conditions and assessing the impact on groundwater

conditions. The different distribution and increased values of recharge were intended to reflect cooler and wetter conditions comparable to the glacial climate of 21,000 years ago. The model used by D'Agnese et al. (1999) was a predecessor to the current version of the DVRFS model (Belcher and Sweetkind, 2010), but the models are sufficiently alike to expect similar conclusions for the effect of climate change. D'Agnese et al. (1999) found that the elevated water table calculated for the cooler/wetter climate had generally the same shape as the present day water table. This means that the directions of flow along the path from Yucca Mountain would not likely differ between present-day conditions and a future cooler/wetter climate. This analysis also found that the extent of water table rise for this cooler/wetter climate was consistent with the observed locations of paleodischarge deposits. The D'Agnese et al. (1999) model predicted that the confluence of Fortymile Wash and the Amargosa River would be a discharge location under future wetter conditions, consistent with discharge at the State Line Deposits area. Furthermore, the model results suggested that long stretches of both channels would become perennial streams. D'Agnese et al. (1999) noted that flow in the rivers, along with the increased discharge of groundwater, in a cooler/wetter climate state would be sufficient to supply the water in paleo-Lake Manly in Death Valley.

2.5 Water Use and Quality

This section provides a brief description of water use and quality for areas south of Amargosa Farms, along the flow path to Death Valley.

In the 2002 EIS and 2008 SEIS, DOE provided a description of water use and the biosphere for the Yucca Mountain area and south to the postclosure compliance location, approximately 18 km [11 mi] along the flow path. Beyond the postclosure compliance location, water from wells or springs is used in Amargosa Farms, and Furnace Creek. Amargosa Farms and Furnace Creek are along the primary flow path for groundwater from Yucca Mountain. The 2002 EIS and 2008 SEIS list water uses in the Amargosa Valley as irrigation, mining (mostly in western Amargosa Valley), livestock, and for quasi-municipal, commercial, or domestic water supply. DOE (2014a) states that water from the Furnace Creek springs (Texas, Travertine, and Nevares) is used to support Death Valley National Park and the Timbisha Shoshone Tribe, which occupies several hundred acres within Death Valley National Park. The springs support the commercial and domestic water supplies, including a small commercial date farm.

The 2002 EIS and 2008 SEIS provide descriptions of regional groundwater quality, including for the area of pumping in Amargosa Farms. Generally, the quality of the groundwater in Amargosa Farms is good, and the tested groundwater sources met the EPA's primary drinking-water standards (DOE, 2014a; 2008a). Some groundwater samples from the Amargosa Farms area contained concentrations of naturally occurring arsenic above EPA primary drinking water standards; as noted in DOE (2014a), these samples were not collected from drinking water systems, so the EPA standards are not directly applicable. Water from Texas Spring at Furnace Creek (again, not collected from a drinking water system) had similar high arsenic levels, and also had naturally occurring lead and fluoride concentrations above drinking-water standards (DOE, 2014a). Concentrations of selected groundwater constituents are given in Table 2-2, for potential contaminants released from the proposed repository.

The quality of water discharged to playas, either as intermittent seeps, standing water, or runoff, is variable but is often highly saline. Because of the low amount of water, lack of reliability, and poor quality of this water, it is not of practical use by humans and has not been developed for use.

Table 2-2. Concentrations of Naturally-Occurring Constituents in Groundwater From Amargosa Farms and Furnace Creek Springs, for Potential Contaminants Contributing to Impacts Discussed in Chapter 3.			
Constituent	**Groundwater Amargosa Farms**	**Discharges from Furnace Creek Springs**	**Federal Drinking Water Standard (40 CFR 141)**
Total Uranium (µg/L)	2.55	5.1	30
Molybdenum (mg/L)	0.007	(0.03)	None
Vanadium (mg/L)	(0.01)	(0.01)	None
Nickel (mg/L)	—	—	None
Data from highest value given in DOE, 2008a, Table 3-19, or DOE, 2014a, Table 2-2. Parentheses indicate concentration below detection; value in parentheses is detection limit.			

2.6 Analysis Cases for Assessing Impacts

Any potential changes in the affected groundwater environment would be due to changes to the regional and local groundwater system that affect flow paths, amount of flow, or discharge locations. As discussed above, changes to the groundwater system over the one-million-year period depend primarily on two factors that will likely vary in the future: climate state (through changes in the amount of groundwater recharge and losses through evapotranspiration) and the amount of regional pumping (through the lowering of the water table and possible capture of contaminants). To address these two factors, two analysis cases are considered that provide a reasonable range of conditions to assess the affected environment and potential impacts.

- Analysis Case 1: Pumping in Amargosa Farms for current uses at current rates
- Analysis Case 2: Natural surface discharge at and downstream from Amargosa Farms with limited or no pumping in Amargosa Farms

The analysis cases address both pumping in the Amargosa Farms area (substantial removal of groundwater from the system) and no pumping, and thus account for uncertainty in future pumping levels. Analysis Case 1 considers present-day rates of pumping in Amargosa Farms. At present-day extraction rates, all the contaminant releases from a repository at Yucca Mountain are assumed to be captured by the pumping wells (see Figure 2-5), consistent with the analysis assumption for water extraction at the postclosure compliance location (DOE, 2008b; NRC, 2014a).

Analysis Case 2 accounts for surface discharges beyond the postclosure compliance location in the case of limited or no pumping in Amargosa Farms. In this case, contaminants could reach locations further along the flow path, as far as Death Valley. With little or no pumping in Amargosa Farms, contaminants from a repository could discharge to the surface at areas similar to the State Line Deposits or Alkali Flat, or to Furnace Creek springs and Middle Basin in Death Valley (see Figure 2-5).

As discussed in Section 2.3.2, paleodischarge sites from water flowing beneath Yucca Mountain have not been identified along the flow path upgradient from Amargosa Farms. Although the future flow path is subject to some uncertainty, analyses suggest that it would not change appreciably (Section 2.4). For this reason, natural discharge of contaminated water is not

expected between Yucca Mountain and Amargosa Farms, even under future cooler and wetter climates, thus possible impacts from natural discharge are not considered for that area.

Therefore, these analysis cases reasonably capture the credible range of future conditions, encompassing future climate change and potential changes in groundwater extraction in Amargosa Farms. Two important factors related to future pumping rates further support this conclusion. The first is the restriction on groundwater pumping due to basin withdrawal related to impacts on water levels at Devils Hole (Section 2.2.3). Because of this restriction, the pumping rate is not likely to be greater than that over the past several decades, and may be less in the future. The second factor is that in a future cooler/wetter climate, the demand for groundwater for irrigation could lessen and pumping could decrease. In such a climate of lower evaporation and increased precipitation, less irrigation would be required to support present-day farming. If pumping decreases substantially, groundwater withdrawal may not capture all of the contaminants from a repository. In this case, potential impacts could occur at downstream discharge locations. These are addressed in Analysis Case 2, which assumes most contaminants reach discharge locations downstream of Amargosa Farms.

Thus, potential impacts at Amargosa Farms under the present climate and pumping rates, or a cooler/wetter climate and somewhat reduced pumping rates, are addressed by Analysis Case 1 (which assumes all contaminants are captured at Amargosa Farms). Potential impacts downstream of Amargosa Farms under both climate states with limited or no pumping are addressed by Analysis Case 2. The impacts for these two analysis cases are discussed in Chapter 3.

3 ENVIRONMENTAL IMPACTS

The affected environment described in Chapter 2 includes the aquifer and the surface discharge sites beyond the postclosure compliance location at approximately 18 km [11 mi] along the groundwater flow path from Yucca Mountain. This chapter assesses the potential impacts for these environments from contaminants released from the proposed repository.

In Chapter 5 of its Final Environmental Impact Statement (EIS) (DOE, 2002), the U.S. Department of Energy (DOE) described its approach and analyses for estimating potential impacts on human health, other biological impacts, and environmental impacts from releases of radioactive and nonradioactive materials to the environment after closure of the proposed repository at Yucca Mountain. Using a similar approach and analysis for its 2008 Supplemental Environmental Impact Statement (SEIS) (DOE, 2008a), DOE summarized, incorporated by reference, and updated information presented in Chapter 5 of the 2002 EIS. In the 2002 EIS and 2008 SEIS, DOE described the affected environment and impacts up to the postclosure compliance location at approximately 18-km [11-mi] distance along the flow path from the repository. At the postclosure compliance location, the impacts were estimated for the reasonably maximally exposed individual (RMEI), consistent with the RMEI characteristics in 10 CFR Part 63. In its 2008 SEIS, DOE stated that the environmental impacts beyond the postclosure compliance location would be less than those at the postclosure compliance location. In its Adoption Determination Report (ADR) (NRC, 2008a), the NRC staff determined that it could adopt the general approach used by DOE in estimating releases from the repository and the impacts at the postclosure compliance location, but concluded that the affected environment and any impacts for areas *beyond* the postclosure compliance location were not adequately described in the 2002 EIS and 2008 SEIS for potential releases of radiological and nonradiological contaminants from the repository.

In this NRC staff-prepared supplement, impacts on water and soil, ecology, cultural resources, and environmental justice are provided for locations beyond the postclosure compliance location, drawing on the previous work by DOE and its subsequent analyses in DOE (2014a). The affected environment is described in Chapter 2, including potential locations for groundwater pumping and types of natural surface discharge in the Yucca Mountain groundwater flow path beyond the postclosure compliance location, downstream to Death Valley.

The description of water and soil impacts is in Section 3.1, ecological impacts in Section 3.2, cultural resources in Section 3.3, and environmental justice in Section 3.4. A summary of impacts is provided in Section 3.5.

3.1 Impacts on the Aquifer, Water and Soil

In the 2002 EIS and 2008 SEIS, DOE provided radiological impacts for the RMEI at the postclosure compliance location (also called the RMEI location) for the 10,000-year and one million-year periods following repository closure for a stylized scenario of groundwater pumping for irrigation of limited local food cultivation. The scenarios analyzed by DOE follow the characteristics of the RMEI in 10 CFR 63.312.

DOE's analysis of radiological impacts for the RMEI in its 2002 EIS and 2008 SEIS is based on results from its Total System Performance Assessment (TSPA) model for performance of the repository after permanent closure (DOE, 2008b, Chapter 2). The development of the model involved a systematic assessment of potential features, events, and processes that could affect

the release of radioactive material from the repository, transport of that material beyond the site boundary, and radiological exposure to the RMEI. The postclosure compliance location is defined in 10 CFR 63.312 as the point where the RMEI would receive the greatest dose. Doses beyond this location along the groundwater flow path are lower due to dispersion and sorption of contaminants in the aquifer, along with radioactive decay during longer transport times. The NRC staff found DOE's TSPA methodology to be acceptable as part of its safety evaluation (NRC, 2014a, Section 2.2.1.4.1).

In the 2002 EIS, but not in the 2008 SEIS, DOE scaled results from the postclosure compliance location to account for dispersion in the groundwater system to estimate impacts 30 and 60 km [19 and 37 mi] downstream from the repository. These distances from Yucca Mountain approximate the distances to Amargosa Farms and to Alkali Flat, respectively. In the 2002 EIS and 2008 SEIS, DOE provided chemical toxicity impacts in terms of a bounding analysis at the RMEI location only for the first 10,000 years after repository closure.

This supplement provides updated impact information for groundwater pumping in the Amargosa Farms area, and provides impacts at sites of natural surface discharge along the flow path between the postclosure compliance location and Death Valley along the Yucca Mountain groundwater flow path. The impacts include those from both radiological and nonradiological contaminants at pumping locations (Amargosa Farms) and at natural discharge locations for one million years; results at earlier times are also provided. Impacts from groundwater contamination prior to this timeframe are not expected, as described in the NRC's Safety Evaluation Report (SER) and in DOE's EISs (DOE, 2008a, 2002; NRC, 2014a).

As discussed in Chapter 2, impacts are analyzed accounting for uncertainty in both future pumping rates and climate using two analysis cases. Consideration of the type of discharge site (pumping from wells or natural surface discharge), uncertainties in future pumping rates in Amargosa Farms, and potential future climate states leads to delineation of two cases for the analysis of impacts. These cases encompass the reasonable range of future conditions and activities. These analysis cases are as follows:

Analysis Case 1: Pumping at Amargosa Farms

- Present-day and future cooler and wetter climate states

Analysis Case 2: Surface Discharge Downstream of Amargosa Farms

- Assumes limited or no pumping in Amargosa Farms
- Present-day and future cooler and wetter climate states

The first analysis case assumes that the pumping rate and well distribution in Amargosa Farms is comparable to the present-day and is sufficient to extract any contaminants released from the repository to the groundwater system. It also assumes that the present-day pumping rates will continue into the future. Both present-day climate and a future cooler/wetter climate are considered in the pumping scenario of Analysis Case 1 (Section 3.1.1). The second analysis case assumes that limited or no pumping occurs in Amargosa Farms and, thus, all contaminants would migrate to natural discharge locations along the path from Amargosa Desert to Death Valley (Section 3.1.2). Downstream natural surface discharge locations considered in Analysis Case 2 include natural spring discharges in the State Line Deposits/Franklin Well area, Furnace Creek, and the playa/salt pan of Middle Basin of

Death Valley. An additional potential flow path to surface discharge to a playa/salt pan environment at Alkali Flat is also considered (see Section 2.3.3). Analysis Case 2 also addresses both present-day and future cooler/wetter climates. The methods used in this analysis are summarized in the next section, and described in more detail in Appendix A.

Considering the uncertainty in future pumping projections, it is likely that future conditions would lie somewhere between the two analysis cases. Thus, these two analysis cases are not additive. They represent, instead, the endpoints of the spectrum of future scenarios addressing the uncertainty of pumping in Amargosa Farms. Possible future scenarios could fall at (in an extreme case) or between these endpoints. For example, some reduced amount of pumping in Amargosa Farms would extract some fraction of a contaminant plume, and the remainder would be transported down the flow path. In this case, the impacts at Amargosa Farms would be less than those described in Analysis Case 1, and the impacts downstream would be less than those described in Analysis Case 2. As discussed below, the magnitude of the environmental impacts in a given setting is generally proportional to the amount of contaminants present in that setting. Uncertainty in climate is addressed by determining the peak impact from either the present-day or a future cooler/wetter climate for each impacted environment.

The next three sections summarize the methods used in analyzing impacts, the mass balance approach for contaminants in the aquifer, and information on typical human radiation exposure from all sources, as well as applicable regulatory standards for radiation and other potential contaminants. The subsequent sections then describe the results for each of the two Analysis Cases.

Analysis Method

The impact analysis in this supplement builds off the DOE results for the postclosure compliance location (DOE, 2008a; 2002), which the NRC staff found acceptable in its ADR (NRC, 2008a), as well as DOE's assessment of overall repository performance (DOE, 2008b; NRC, 2014a). From this basis, an analytical solution is then used to calculate the transport of radiological and nonradiological material beyond the postclosure compliance location to affected environments along the groundwater flow path to Death Valley. This analytical solution is part of an analysis framework that includes source term development, transport, and impact calculations. This framework is described in detail in Appendix A, which includes descriptions of (i) source terms (i.e., calculated releases from the repository) for radiological and nonradiological contaminants, (ii) models of contaminant transport from the repository to the postclosure compliance location, (iii) models of contaminant transport beyond the postclosure compliance location along the flow path to discharge locations, and (iv) processes that may occur at discharge locations that may affect concentrations and exposures at different types of affected environments.

The results of these calculations and impacts at each location for the analysis cases are provided in tables and plots in the following sections for 10,000 and one million years following repository closure. In some cases, the greatest (peak) concentration values for contaminants at a given location do not occur exactly at the 10,000- or one-million-year times, due to the pattern of the releases from the repository over time and the effects of sorption during transport. This is particularly apparent for some of the nonradiological contaminants (e.g., nickel), where conservative assumptions in the model for release from the repository and significant sorption during transport strongly affect the peak values (see Figure A–1 and Appendix A for further details). Therefore, the "Peak Value" tables in this chapter give the highest calculated values for the initial 10,000-year period and the 10,000-to-one million-year period under the different

model conditions (in cases where the greatest value occurs after 10,000 years, the value at 10,000 years is given in the "10,000 years" column). In addition, specific times of peak contaminant concentrations at each location are discussed in the following sections. In all tables, very small values (less than 10^{-9}) have been rounded to zero.

Mass Balance Description

The NRC staff concluded in the ADR (NRC, 2008a) that a description was needed of the accumulated amounts of radiological and nonradiological contaminants from the repository that may enter the groundwater over time, as well as a description of where those contaminants would travel along the flow path.

Sections 3.1.1 and 3.1.2 of this chapter consider impacts to groundwater and surface discharge using mass flux (the amount of a contaminant moving through the system), accumulation, exposure pathways, and dose. As part of the impacts described in these sections, the amount of radiological and nonradiological material from the repository is estimated that will (i) discharge to the surface at specific locations and accumulate in soils and (ii) reside in the aquifer environment (dissolved in water and sorbed to rock) between those locations. In Sections 3.1.1 and 3.1.2, subsections for Aquifer Environment and Soils include descriptions of where contamination may occur along the path between the postclosure compliance location and Death Valley for present-day and wetter climates for two time frames: 10,000 and one million years.

Impacts of Calculated Contaminant Levels

This section provides context for the calculated radiological and nonradiological concentrations, radiological dose, and nonradiological body intake used to determine the level of impact from releases at Yucca Mountain to different areas of the affected environment.

Radiation Exposure and Cancer Risk

Public health data do not absolutely establish the occurrence of cancer following exposure to low doses and dose rates of radiation below about 10,000 mrem [100 mSv]. Studies of occupational workers who are chronically exposed to low levels of radiation above normal background have shown no adverse biological effects. Even so, the radiation protection community conservatively assumes that any amount of radiation may pose some risk for causing cancer and hereditary effect, and that the risk is higher for higher radiation exposures. The linear no-threshold (LNT) dose-response relationship is used to describe the relationship between radiation dose and the occurrence of cancer. This dose-response model suggests that any increase in dose, no matter how small, results in an incremental increase in risk. The NRC accepts the LNT hypothesis as a conservative model for estimating radiation risk.

On average, Americans receive a radiation dose of approximately 620 mrem/yr [6.2 mSv/yr] (NRC, 2015c). Half {310 mrem/yr [3.1 mSv/yr]} comes from man-made sources of radiation, including medical, commercial, and industrial sources. The other half of this dose comes from natural background radiation, which is predominantly due to exposure to radon in air.[1] In general, a yearly dose of 620 mrem [6.2 mSv] has not been shown to cause humans any harm (NRC, 2015c). The natural background radiation, excluding

[1]Radon exposure varies depending on several factors, including geographic location, housing type, ventilation, and local geology. On average in the U.S., radon exposure accounts for a dose of approximately 200 mrem/yr [2.0 mSv/yr] (NRC, 2015c).

radon, for a resident of Amargosa Valley is 96 mrem/yr [0.96 mSv/yr] (DOE 2002, Table 3-30). For this supplement, a total natural background radiation exposure at Amargosa Farms of approximately 300 mrem/yr [3.0 mSv/yr] (including radon) is used as a comparison to the estimated doses for populations at affected environments along the flow path from Amargosa Farms to Death Valley.

Further context for the dose values provided in this supplement is the average annual dose estimated for the postclosure compliance location from the 2008 SEIS. DOE calculated maximum average annual dose for the RMEI at the postclosure compliance location to be 0.24 mrem/yr [0.0024 mSv/yr] for the initial 10,000 years after repository closure, and the maximum average annual dose one million years after closure to be 2.0 mrem/yr [0.02 mSv/yr] (DOE, 2008a, Section 2.4.1). The NRC staff has found DOE's calculations to be acceptable as part of its safety evaluation (NRC, 2014a, Section 2.2.1.4.1). The regulatory safety standards in 40 CFR Part 197 and 10 CFR Part 63 for the RMEI are 15 and 100 mrem/yr [0.15 and 1.0 mSv/yr] for the 10,000 and one million year periods, respectively.

One way to understand the impact of radiological dose is in terms of a risk of causing cancer or a severe hereditary effect. This can be done through a conversion factor, which assumes a simple linear relationship between the dose and the risk of these health effects. Using the conversion factor for members of the public recommended by the International Committee on Radiological Protection (ICRP) (ICRP, 2007), the probability of a latent cancer fatality, nonfatal cancer, or severe hereditary effect from a 1.0 mrem/yr [0.01 mSv/yr] dose is 5.7×10^{-7}, or less than one in one million.

For nonradiological chemical contaminants, impacts to human health are compared to the U.S. Environmental Protection Agency (EPA) Oral Reference Dose (EPA, 1999a,b; 1997a,b; 1994), which is the chemical level below which no detectable human health effects would occur. In this supplement, uranium (U) is evaluated for both radiological and nonradiological contaminants, because in addition to being radioactive, it has a notable toxicity as a heavy metal. For nonradiological analysis, U concentrations are given as a sum of the U isotopes from the radionuclide calculations, since the chemical risk of U does not depend on the particular isotope.

EPA Oral Reference Dose

The Oral Reference Dose is an estimate of a daily oral exposure of a chemical to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. In the U.S., the EPA establishes the Oral Reference Dose after a thorough review of the health effects data for individual chemicals.

Additional comparisons provide context on the quantities and concentrations of potential repository contaminants that may be present in groundwater or discharge to the surface and accumulate in soil. Calculated concentrations of nonradiological materials in water and soils are compared to natural background levels from water and soil analyses, where available. Reference values for soil concentration impacts are the soil screening levels used in determining the need for further evaluation or remediation during cleanup of contaminated land. The EPA has established generic soil screening levels for many chemicals, including nickel (Ni), molybdenum (Mo), vanadium (V) and U (EPA, 2015). These screening levels are not cleanup standards, but are used a guidelines for determining the need for further action. The screening levels for specific contaminants are included in the subsequent sections, as appropriate.

3.1.1 Analysis Case 1: Pumping at Amargosa Farms

In the 2002 EIS and 2008 SEIS, DOE provided estimates of impacts for the RMEI at the postclosure compliance location. In its ADR, the NRC staff found this impact assessment for the RMEI location to be acceptable for adoption (NRC, 2008a). In this supplement, impacts are estimated at the nearest population center to the repository location, Amargosa Farms, which is approximately 17 km [11 mi] beyond the postclosure compliance location, or approximately 35 km [22 mi] along the flow path from Yucca Mountain. This distance is representative of the primary irrigation and farming areas in Amargosa Farms, which range from 14 to 20 km [9 to 12 mi] from the postclosure compliance location. There are residents and businesses between the primary farming areas and the postclosure compliance location. Most of the wells supplying water to residents and businesses are close to the farming area. There is an isolated set of several wells just south of the junction of Highways 95 and 373, which is consistent with the DOE determination that that there were no permanent residents closer than 22 km [13.7 mi], from the postclosure compliance location, as described in Section 2.1.1 of this supplement. In its evaluation of impacts on these residential and business wells, the NRC staff conservatively adopts the analysis in DOE (2008a) for the RMEI. This is because the same dose pathways used for the impacts at Amargosa Farms in this supplement are those identified by DOE in its EISs for the RMEI. These are appropriate because the dose pathways for the RMEI were based on activities and lifestyles of residents in Amargosa Farms. Amargosa Farms is a community that uses groundwater pumping for irrigation and for its commercial and domestic water supply. The dose pathways for a resident of Amargosa Farms are external (body) exposure, inhalation, and ingestion of crops, meat, and soil. Details of these pathways are described in Appendix A and in DOE (2014a, Table B-2).

Impacts in this section are described in terms of (i) the amount of contaminants from the repository in the groundwater system between the postclosure compliance location and Amargosa Farms, (ii) the concentration of contaminants in the groundwater at the Amargosa Farms area, (iii) the concentration of contaminants in soils at the Amargosa Farms area due to irrigation, and (iv) the radiological dose and body intake of contaminants for the identified exposure pathways. Together, these items provide a description of the distribution of contaminants present in the aquifer and the impact of radiological and nonradiological contaminants on the affected environment. This section addresses the impacts under both the present day and the cooler/wetter climate states.

The transport model uses a path length of 17 km [11 mi; the distance from the RMEI location to Amargosa Farms] and transport properties that are distance-weighted from each segment of the pathway (see Appendix A, Section A.1.2). Transport segments are the different hydrogeological model units in the Death Valley Regional Flow System (DVRFS) model that predict the groundwater flow from Yucca Mountain along the path from the postclosure compliance location to (in this case) Amargosa Farms. For items (ii) to (iv) in the previous paragraph, several other parameter values are required:

- The mass flux of radiological and nonradiological material from the repository reaching wells at Amargosa Farms is calculated using the 2003 pumping rate of 16,828 acre-feet/year [20.7 million m^3/year] taken from Moreo and Justet (2008). This pumping rate is more than five times larger than the value used in the 2008 SEIS for the RMEI, which calculated contaminant concentrations based on a withdrawal rate of 3,000 acre-feet/year [3.7 million m^3/year].

- Transport in the aquifer to Amargosa Farms is calculated using a value of 0.00613 m/day [0.020 ft/day] for the specific discharge (flow rate) along the 17 km [11 mi] path in the present-day climate (see Appendix A, Section A.1.2). For the wetter climate, the specific discharge is multiplied by a factor of 3.9 (DOE, 2014a; 2008b, Section 2.3.9). An average porosity in the aquifer of 0.16 is used for both climate states.

- Contaminated water extracted by pumping can be recycled into the aquifer through irrigation and other uses, as water pumped to the surface can infiltrate, reach the water table, and be pumped again (see Appendix A, Section A.2.1 for details of the irrigation recycling model). The analysis in this supplement uses a value of 86 percent for the recycling fraction (the amount of water pumped to the surface that reaches the water table), and a value of 100 percent for the recapture fraction (the fraction of that water which is then captured by pumping and returned to the surface). These values are conservative in that they assume that contaminants are brought to the affected environment with high efficiency. These values result in an overall factor of 0.86 for contaminant recycling through well pumping for Amargosa Farms, compared to the value of 0.11 for the RMEI at the compliance location in previous recycling analyses (DOE, 2014a; Kalinina and Arnold, 2013; SNL, 2007b). A larger value for this factor leads to greater calculated contaminant concentrations in the exposure pathways, greater estimates of dose and body intake, and greater calculated values of contaminants accumulating in soils.

- Dose conversion factors used in this analysis are derived from DOE (2008b, Table 2.3.10-12) with adjustments for potential secular disequilibrium of decay chain radionuclides (see Appendix A, Section A.1.2). The NRC staff has found these dose conversion factors to be acceptable as part of its safety evaluation (NRC, 2014a, Section 2.2.1.3.14)

All radiological and nonradiological contaminants in the releases from the repository (which becomes the source term for this evaluation) are analyzed in the transport and accumulation models. Only those radionuclides that (i) reach the affected environment, beyond the postclosure compliance location and to the Amargosa Farms area, and (ii) are major contributors to the calculated dose, are described in the sections that follow. Calculated concentrations of other radionuclides are extremely low and do not contribute to estimates of dose or other environmental impacts. For Analysis Case 1 (Pumping in Amargosa Farms), the radionuclides that are significant contributors to dose at Amargosa Farms area are technetium (Tc)-99, iodine (I)-129, selenium (Se)-79, uranium (U)-233, thorium (Th)-230, neptunium (Np)-237, and uranium (U)-234 for both the present-day and wetter climates, in their approximate order of significance. The relative significance of radionuclides varies with time due to the timing of release from the repository and due to sorption, decay, and radionuclide ingrowth during transport. Nonsorbing species (e.g., Tc and I) are not delayed during transport and reach the affected environment faster than sorbing species (such as U or Th). All four of the nonradiological chemical species in the source term from the repository (Mo, Ni, V, and U) reach the Amargosa Farms area.

Aquifer Environment

This section describes the total amount of contaminants from the repository in the aquifer environment between the postclosure compliance location and the Amargosa Farms area. This amount changes over time, as contaminants are released from the repository and are transported by water to the aquifer and then downstream along the flow path. The

concentration of these contaminants in the groundwater at Amargosa Farms is then calculated from the amount of contaminants present in the groundwater, and the volume of water affected by the pumping. The amount of contaminants in the aquifer, and the contaminant concentration in the groundwater, represent the impacts on the aquifer.

The term "aquifer environment" includes both the subsurface rock (porous media, predominantly alluvial sediments) and water within the pores of the rock, and is used here to include the contaminants both dissolved in the water and sorbed onto the rock. The amount of the contaminants in the aquifer environment between the postclosure compliance location and the Amargosa Farms area, based on mass balance calculations, is provided in Table 3-1a. The values in Table 3-1a result from calculating the difference between the mass of the contaminants that reach the postclosure compliance location and the contaminants that accumulate in the Amargosa Farms area. These values were calculated from the releases from the repository over time, the amounts transported downstream, and the amounts retained within the aquifer by sorption on rock surfaces. The mass flux released from the repository that reaches the postclosure compliance location was obtained from the DOE's TSPA results (DOE, 2014a), The NRC staff has found DOE's TSPA methodology to be acceptable as part of its safety evaluation (NRC, 2014a, Section 2.2.1.4.1). For U and Th, a combined value is reported that includes all the identified isotopes in the source term and daughter products. The mass of contaminants includes the effects of radioactive decay over time.

These results show how different contaminants behave in the aquifer environment. At a given time, the nonsorbing species Tc-99, I-129, and Mo show much greater accumulation at Amargosa Farms (Table 3-1b) than in the aquifer environment between the postclosure compliance location and Amargosa Farms (Table 3-1a). This is because these species migrate more readily than sorbing species, and are not retained in the aquifer (except as dissolved in the groundwater). In contrast, sorbing species such as U, Th, Np, Ni, and V are present in the aquifer both sorbed onto the rock surfaces and dissolved in the groundwater.

They therefore accumulate in the aquifer environment between the postclosure compliance location and Amargosa Farms. At 10,000 years after permanent closure, these sorbing species are present in the aquifer upstream from Amargosa Farms, but have a very small (or no) presence at Amargosa Farms (Table 3-1b), as they are held back on the rock surfaces within the aquifer. Over the one million year period, these species reach Amargosa Farms in greater abundance, but still show appreciable accumulation within the aquifer.

The amounts of the six predominant radionuclides listed in Table 3-1a (by activity, in Curies) and nonradiological material (by mass, in grams) are used to calculate the average concentration of each contaminant in the aquifer environment between the postclosure compliance location and Amargosa Farms. This calculation requires an estimate of the volume occupied by the contaminant plume. These geometric assumptions give an affected aquifer volume of 5.1 km^3 [1.2 mi^3]. For an average porosity of 0.16 (DOE, 2014a), this volume contains 0.82 km^3 [0.2 mi^3] of water. Appendix A provides more detail on this calculation and its inputs.

As noted above, the average concentration of a contaminant in the aquifer includes both the contaminants in the groundwater and those sorbed onto the rock surface. For a sorbing species, only some fraction of the contaminant will be dissolved in the groundwater. The groundwater concentrations are calculated using the amounts in the groundwater (not sorbed to the rock), and the appropriate volume of water (see Appendix A, Section A.2.1).

Table 3-1a. Amount of Selected Radiological and Nonradiological Material From the Repository in the Aquifer Environment Between the Postclosure Compliance Location and Amargosa Farms. [1 kg = 2.2 lbs]				
	Present-Day Climate		**Cooler/Wetter Climate**	
	10,000 years	**1 million years**	**10,000 years**	**1 million years**
U isotopes (Ci)	1.5	290	1.5	81
Th isotopes (Ci)	0.18	160	0.18	46
Np-237 (Ci)	1.4	140	1.4	38
I-129 (Ci)	3.2×10^{-4}	0.18	3.4×10^{-5}	0.018
Tc-99 (Ci)	5.1	95	1.3	23
Se-79 (Ci)	5.8	75	5.8	20
Mo (kg)	1.3×10^{5}	8.9×10^{4}	1.1×10^{5}	9.5×10^{4}
Ni (kg)	4.2×10^{6}	7.3×10^{6}	1.7×10^{7}	3.3×10^{6}
V (kg)	2.2×10^{3}	2.6×10^{3}	2.2×10^{3}	1.3×10^{3}

U = uranium, Th = thorium, Np = neptunium, I = iodine, Tc = technetium, Se = selenium, Mo = molybdenum, Ni = nickel, V = vanadium
See Appendix A, Section A.2, for the methods of calculation.

Table 3-1b. Amount of Selected Radiological and Nonradiological Material From the Repository Accumulated at the Amargosa Farms Area. [1 kg = 2.2 lbs]				
	Present-Day Climate		**Cooler/Wetter Climate**	
	10,000 years	**1 million years**	**10,000 years**	**1 million years**
U isotopes (Ci)	0	1,030	4.0×10^{-8}	1,240
Th isotopes (Ci)	0	630	3.2×10^{-9}	740
Np-237 (Ci)	0	450	0	540
I-129 (Ci)	2.4	1,340	2.4	1,340
Tc-99 (Ci)	5	1,250	1,260	22,800
Se-79 (Ci)	0	130	0	180
Mo (kg)	1.3×10^{6}	2.1×10^{7}	1.3×10^{6}	2.1×10^{7}
Ni (kg)	0	7.3×10^{7}	0	7.7×10^{7}
V (kg)	0	4.0×10^{5}	0	4.0×10^{5}

U = uranium, Th = thorium, Np = neptunium, I = iodine, Tc = technetium, Se = selenium, Mo = molybdenum, Ni = nickel, V = vanadium
See Appendix A, Section A.2, for the methods of calculation.

Table 3-2 provides concentrations of radiological and nonradiological material calculated for the groundwater in the vicinity of Amargosa Farms. The concentrations are calculated by dividing the mass flux to the Amargosa Farms area by the pumping rate from all wells in the area. Consistent with their behavior in the overall repository performance assessment, Tc-99 and I-129 are present in relatively higher quantities than other radiological contaminants because of their transport characteristics (i.e., they do not sorb). The amount of U reflects its high abundance in the repository waste inventory. As shown in Table 3-2, a cooler/wetter climate has variable effects on the calculated groundwater concentrations at Amargosa Valley. For

Table 3-2. Peak Groundwater Concentrations of Radiological and Nonradiological Material From the Repository in the Aquifer at Amargosa Farms				
	Present-Day Climate		**Cooler/Wetter Climate**	
	10,000 years	**1 million years**	**10,000 years**	**1 million years**
U isotopes (pCi/L)	0	0.064	7.1×10^{-12}	0.073
Th isotopes (pCi/L)	0	0.005	4.2×10^{-13}	0.002
Np-237 (pCi/L)	0	0.053	0	0.069
I-129 (pCi/L)*	0.007	0.13	0.013	0.13
Tc-99 (pCi/L)*	4.3	8.8	5.3	8.8
Se-79 (pCi/L)*	0	0.03	0.009	0.05
Mo (mg/L)†	7.3×10^{-3}	1.9×10^{-4}	7.1×10^{-3}	1.9×10^{-4}
Ni (mg/L)	0	5.6×10^{-3}*	0	0.011‡
V (mg/L)*	0	3.2×10^{-5}	0	3.2×10^{-5}

*Peak value occurs after 100,000 years, but before 1 million years
†Peak value occurs at 10,000 years after closure
‡Peak value occurs after 10,000 years, but before 100,000 years
U = uranium, Th = thorium, Np = neptunium, I = iodine, Tc = technetium, Se = selenium, Mo = molybdenum, Ni = nickel, V = vanadium

some contaminants, a wetter climate leads to slightly higher concentrations compared to the drier climate (e.g., I-129 and Tc-99 at 10,000 years), as these nonsorbing contaminants move more rapidly along the flow path. In others, the calculated concentrations show little or no difference (e.g., Mo, V, and Ni), as the amount of contaminant moving through the system

(the mass flux) is not strongly affected by the groundwater flow rates.
Overall, the concentrations of radionuclides and other contaminants from the repository for groundwater at Amargosa Farms are uniformly very low. For example, the EPA Maximum Contaminant Level (MCL)[2] for alpha-particle emitting radionuclides in drinking water is 15 pCi/L, compared to the calculated total for all alpha-emitting radionuclides in Table 3-2 of less than 0.1 pCi/L.

The highest calculated total uranium concentration of 0.073 pCi/L (Table 3-2) in the groundwater at Amargosa Farms corresponds to less than 0.02 µg/L; for comparison, the EPA MCL for U in drinking water is 30 µg/L. While no MCLs have been established for the metals Mo and V, the calculated groundwater concentrations for these potential contaminants are all much lower than one part per million, which is comparable to the levels occurring naturally at present (Table 2-2). The calculated peak concentration of Ni in groundwater at Amargosa Farms, for each climate state, does not occur at 10,000 years or one million years after repository closure. The peak concentration for Ni in groundwater at this location is 0.011 mg/L,

[2]MCLs are EPA standards for drinking water quality that are established under the Safe Drinking Water Act. An MCL is the highest level of a contaminant that is allowed in public drinking water systems.

and is estimated to occur at 70,000 years for the cooler/wetter climate. This concentration is much lower than the EPA National Recommended Water Quality Criteria level for Ni of 0.61 mg/L (EPA, 2014).

Based on the analysis described above, the NRC staff concludes that the accumulation of radiological and nonradiological material released from the repository to the aquifer environment between the postclosure compliance location and Amargosa Farms would be minimal and not noticeably affect the quality of the aquifer environment. Thus, the NRC staff concludes that the impact on the aquifer environment beyond the postclosure compliance location would be SMALL.

Soil

This section describes the accumulation of contaminants in soils at Amargosa Farms. As described in Chapter 2, pumping is the dominant means of groundwater discharge to the surface at Amargosa Farms (the only other discharge is by very limited evapotranspiration along the Amargosa River Section of the flow system; Section 2.2.2). Thus, any potential accumulation of contaminants in soils in this area would be from irrigation. The NRC staff calculated soil contaminant concentrations using the irrigation recycling model described in Appendix A, Section A.2.1. The model accounts for accumulation in soil of both radiological and nonradiological contaminants. Calculated values of contaminants from the repository in the soils at Amargosa Farms are given in Table 3-3.

For both the present-day and potential future cooler/wetter climate, the primary radionuclides that would accumulate in the soil are U-238, U-235, Np-237, Pu-242, U-233, and Th-230 (Table 3–3). Note that the nonsorbing radionuclides (I-129 and Tc-99) do not accumulate in soil as they remain dissolved in groundwater. The calculated soil concentrations for all of these radionuclides are very low for both climate states. The calculated soil concentration for the radionuclides in Table 3-3 correspond to a total activity of less than 1 pCi/g, and would not appreciably contribute to dose or other environmental impacts.

Nonradiological contaminants show the greatest calculated concentrations at one million years (Table 3-3). For comparison, also shown in Table 3-3 are concentrations of some elements measured in sediment samples in well cuttings from Fortymile Wash, just north of the Amargosa Farms area (Bertetti and Prikryl, 2003). The cuttings are samples of alluvial sediments that are geochemically and mineralogically similar to those found in the upper part of the sediment column at the Amargosa Farms area. Also included in Table 3-3 are the generic soil screening levels for residential soil for the nonradiological contaminants (EPA, 2015).

None of the nonradiological contaminants show any appreciable accumulation in the soil at Amargosa Farms, and all are well below soil screening levels or the natural abundance in local sediments. The estimated highest concentration of Ni in the soil at Amargosa Farms for the present-day climate and cooler/wetter states occurs approximately 260,000 and 70,000 years, respectively, after repository closure. The calculated peak soil concentration at those times is 14 ppm. After those times for each climate state, the levels of Ni from the repository in the groundwater decrease, and Ni is leached from the soil by continued irrigation, leading to a lower concentration at one million years.

Based on the analysis described previously, the NRC staff concludes that the accumulation in soils at Amargosa Farms of radiological and nonradiological material released from the

Table 3-3. Peak Concentrations of Radionuclides and Chemical Materials in Soils at Amargosa Farms Area for Analysis Case 1 (Pumping)						
Peak Soil Concentration (ppm)	Present-Day Climate		Cooler/Wetter Climate		Local Natural Sediments*	Soil Screening Level†
	10,000 years	1 million years	10,000 years	1 million years		
Np-237	0	8.0×10^{-5}	0	1.0×10^{-4}	—	—
Pu-242	0	0	0	3.1×10^{-5}	—	—
U-235	0	5.2×10^{-4}	0	5.8×10^{-4}	—	—
Th-230	0	3.6×10^{-6}	0	1.2×10^{-6}	—	—
U-238	0	0.02	0	0.025	—	—
U-233	0	5.7×10^{-6}	0	6.5×10^{-6}	—	—
Mo‡	0.08	0.002	0.04	0.001	—	390
Ni	0	14§	0	14‖	17.8	1,500
V§	0	0.022	0	0.012	22.4	390
U (all isotopes)	0	0.023	0	0.026	3.9	230

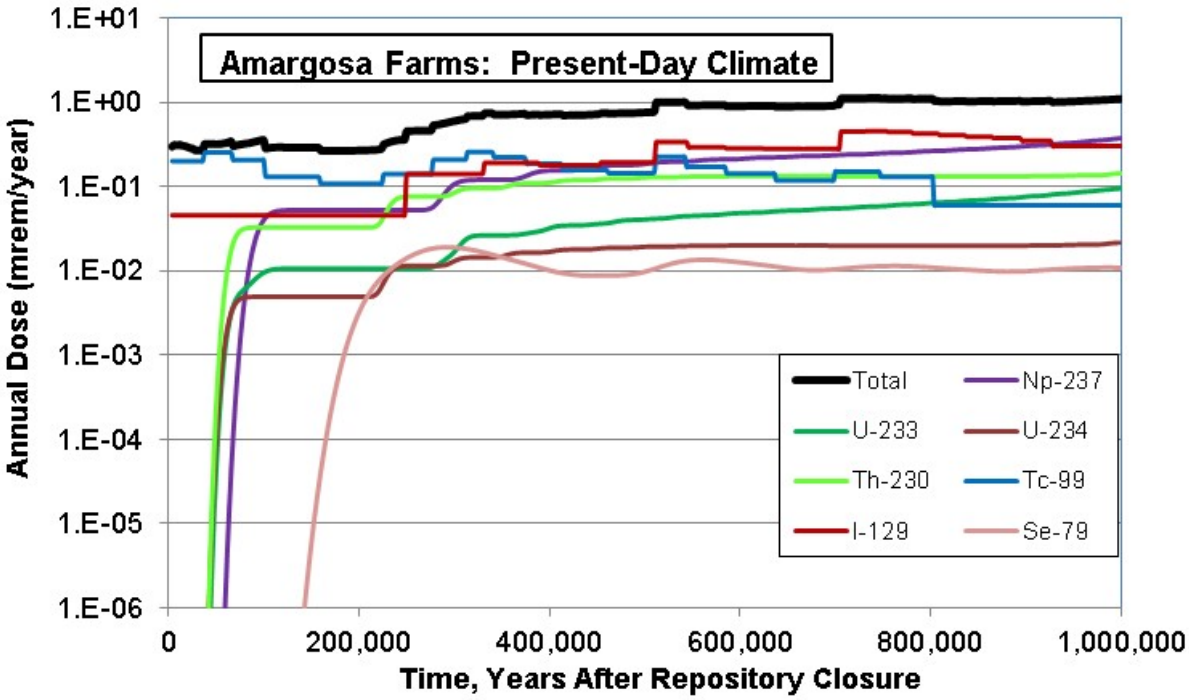
*ppm, from Bertetti and Prikryl (2003)
†ppm, values shown are for total Mo and V, and for soluble salts of Ni and U in residential soil (EPA, 2015)
‡ Peak value occurs at 10,000 years after closure
§ Peak value occurs after 100,000 years, but before 1 million years
‖ Peak value occurs after 10,000 years, but before 100,000 years
Np = neptunium, Pu = plutonium, U = uranium, Th = thorium, Mo = molybdenum, Ni = nickel, V = vanadium
Soil radionuclide concentrations assume the contamination is in the top 0.25 m [0.82 ft] of soil and the soil bulk density is 1,500 kg/m^3 [94 lb/ft^3]

otherwise not noticeably affect soil concentrations. Thus, the NRC staff finds that the impact on soils at Amargosa Farms would be SMALL.

Public Health

The biosphere dose pathways used for this supplement for Amargosa Farms are the same as those identified in DOE's 2008 EIS and for the RMEI in DOE's Safety Analysis Report: (i) external exposure; (ii) inhalation of soil particles and from use of evaporative coolers; and (iii) ingestion from water, crops, animal products, fish, and soil. The NRC staff has found these exposure pathways for the RMEI to be acceptable as part of its safety evaluation (NRC, 2014a, Section 2.2.1.3.14). As further discussed in Sections A.1.3 and A.2.2 of Appendix A, the values for the dose conversion factors have not changed from those in the 2008 SEIS, except for adjustments for secular disequilibrium. Dose conversion factors for the present-day climate were used for both the present-day and future cooler/wetter climate. This approach is conservative because dose conversion factors for cooler and wetter climates would be expected to be lower than those for the present-day climate (Appendix A, Section A.2.3).

The largest contributors to dose for both the present-day and wetter climate at Amargosa Farms are I-129, Tc-99, Np-237, and Th-230 (Figure 3-1). At 10,000 years, I-129 and Tc-99 are the primary contributors to dose. They do not sorb onto rock grains, but rather remain dissolved in water. The other radionuclides shown in Figure 3-1 sorb to various degrees, and thus arrive at Amargosa Farms later. The dose curves in Figure 3-1 also illustrate the effect of a wetter climate on transport and, consequently, dose. The higher specific discharge rate for the wetter climate leads to the more rapid transport of several radionuclides, and thus relatively earlier steady-state contributions to dose (expressed in Figure 3-1 as a shift of the dose curves to the



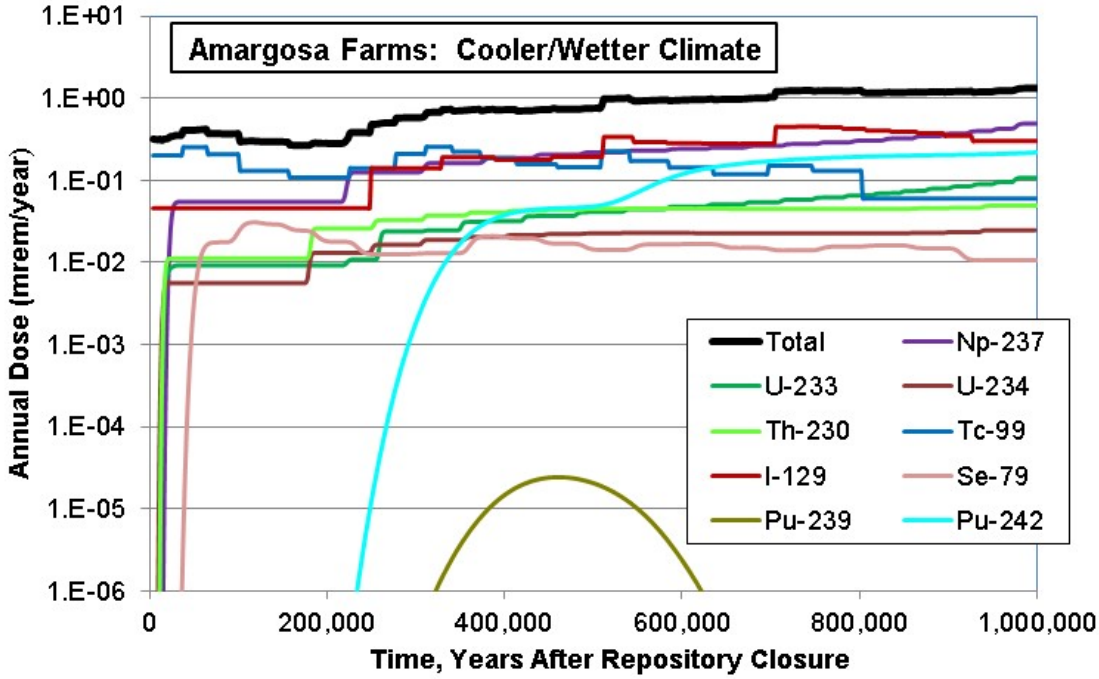


Figure 3-1. Dose History of Selected Radionuclides at Amargosa Farms for the Present-Day (Top) and Cooler/Wetter (Bottom) Climates

left for the wetter climate, as compared to the curves for the present-day climate). Peak doses, considering all radionuclides, are shown in Table 3-4 for 10,000 and one million years for both

climate states. The peak dose of 1.3 mrem/yr [0.013 mSv/yr] in Table 3-4 is lower than the dose from natural background levels of approximately 300 mrem/yr [3.0 mSv/yr] (including radon) for Amargosa Valley, and lower than that calculated for the RMEI at the postclosure compliance location closer to the repository (DOE, 2008b). Furthermore, the peak values estimated for 10,000 and one million years for the present-day and cooler/wetter climate are much lower than the NRC annual dose standards for a Yucca Mountain repository in 10 CFR Part 63 {15 mrem [0.15 mSv] for the first 10,000 years, and 100 mrem [1 mSv] for one million years, after permanent closure}.

Potential health effects from the nonradiological contaminants are considered for a nominal body intake from ingestion of contaminated water, assuming daily intake for a 70-kilogram person drinking 2 liters of water daily. Human health impacts of the nonradiological contaminants are assessed by comparing daily intakes with EPA's Oral Reference Dose standard (EPA, 1999a,b; 1997a,b; 1994). Estimated values of peak daily intakes for each of the nonradiological contaminants are summarized in Table 3-5 for the one-million-year period. In accord with the calculations for the aquifer environment between the postclosure compliance location and Amargosa Farms, the peak daily intake for Ni is estimated to occur at 260,000 years. The peak value of 0.0023 mg/kg [3.7×10^{-8} oz/lb] body weight/day corresponds to the peak values in groundwater Ni concentration for the cooler/wetter climate. The calculated peak daily intake for Ni for the present-day climate is lower than that estimated for the cooler/wetter climate. The estimated values of daily intake are all much lower than the EPA Oral Reference Doses.

Based on the above analyses of radiological and nonradiological material released from the repository to the Amargosa Farms area, the NRC staff finds that the impact to public health beyond the postclosure compliance location would be SMALL, as the contribution from both radiological and nonradiological contaminants is generally nominal, and in all cases below applicable impact and reference standards and limits.

3.1.2 Analysis Case 2: Surface Discharge Downstream of Amargosa Farms

This section addresses impacts from surface discharge at downstream locations in the case of limited or no pumping at Amargosa Farms. For this case, contaminants from the repository would travel past the Amargosa Farms area and could reach the surface environment at the downstream locations discussed in Section 2.3. This Analysis Case considers both the present day and cooler/wetter climate states.

In the 2002 EIS, DOE scaled results from the RMEI location to account for groundwater dispersion to estimate impacts at 30 and 60 km [19 and 37 mi] from the repository, which are approximately the distances from the repository to Amargosa Farms and Alkali Flat, respectively. In the 2002 EIS and 2008 SEIS, DOE stated that the contaminants would discharge to the surface at Alkali Flat, but the DOE discussion of these impacts is limited to a statement that no detrimental radiological impacts on plants and animals are expected.

In this supplement, impacts at natural discharge sites along the groundwater pathway beyond the postclosure compliance location are analyzed. This Analysis Case addresses discharge of contaminants by springs or playas at the State Line Deposits/Franklin Well area (which would occur under a cooler/wetter climate only), the springs at Furnace Creek, and the playa/salt pan at Middle Basin of Death Valley. Results from the DVRFS groundwater model indicate that in the absence of pumping of the aquifer at Amargosa Farms, the predominant discharge site of

Table 3-4. Peak Annual Dose Estimates for the Amargosa Farms Area		
	Peak Annual Dose (mrem/yr)*	
	10,000 years	1 million years
Present-day Climate	0.22	1.1
Cooler/Wetter Climate	0.25	1.3
*1.0 mrem/yr = 0.01 mSv/yr		

Table 3-5. Impact of Nonradiological Contaminants at Amargosa Farms Using Estimates of Body Intake					
Peak Daily Intakes (mg/kg body-weight/day)	Present-Day Climate		Cooler/Wetter Climate		EPA Oral Reference Dose
	10,000 years	1 million years	10,000 years	1 million years	
Mo*	1.5×10^{-3}	4.1×10^{-5}	1.5×10^{-3}	4.1×10^{-5}	5.0×10^{-3}
Ni	0	1.2×10^{-3} †	0	2.3×10^{-3} ‡	2.0×10^{-2}
V‡	0	6.7×10^{-6}	0	6.7×10^{-6}	9.0×10^{-3}
U (all isotopes)	0	3.5×10^{-6}	0	3.8×10^{-6}	3.0×10^{-3}
*Peak value occurs at 10,000 years after closure †Peak value occurs after 100,000 years, but before 1 million years ‡Peak value occurs after 10,000 years, but before 100,000 years Mo = molybdenum, Ni = nickel, V = vanadium, U = uranium					

contaminants transported from Yucca Mountain for the present-day climate would be Middle Basin in Death Valley (Chapter 2; see also Belcher and Sweetkind, 2010).

Along the way to Middle Basin, some amount of groundwater contaminants may be discharged at the springs in the Furnace Creek area. In a future wetter climate, another potential location for natural discharge is springs in the State Line Deposits/Franklin Well area. In addition, groundwater modeling indicates that beyond the State Line area, a very small fraction (2 out of 8,024 modeled particles, or 0.03 percent) of contaminants may move southward toward Alkali Flat, rather than Middle Basin (Chapter 2). This discharge location is considered as an alternative pathway to the expected pathway (State Line–Furnace Creek–Middle Basin).

Descriptions of potential impacts are provided for natural discharge at the State Line Deposits/Franklin Well area (Section 3.1.2.1), Furnace Creek and Middle Basin of Death Valley (Section 3.1.2.2), and Alkali Flat (Section 3.1.2.3). For each of the locations, the peak impact is estimated by conservatively assuming that the entire plume of potential contaminants discharges at that single location. This is conservative because it is likely that radiological and nonradiological contaminants in the plume would discharge at multiple surface locations that may be active at the same time.

3.1.2.1 State Line Deposits/Franklin Well Area

As discussed in Chapter 2, the State Line Deposits area is located approximately 21 km [13 mi] beyond the postclosure compliance location, or 39 km [24 mi] from the repository along the

Yucca Mountain flow path. These paleospring deposits occur where the Amargosa River and Fortymile Wash join. The water table approaches the ground surface in the present-day climate, and reached the ground surface during past wetter climates to produce deposits that formed in playas, springs, marshes, and ponds (Section 2.3.4). The Franklin Well area refers to the narrow band of dense vegetation along the Amargosa River channel at the southern extent of the State Line Deposits area. In the present-day climate, the Amargosa River only flows after significant precipitation events in most of Amargosa Desert, including in the Franklin Well area. For the present-day climate, a small amount of natural discharge occurs at the Franklin Well area as evapotranspiration from a dominantly mesquite thicket along the river channel.

To estimate impacts in the State Line/Franklin Well area, the transport and biosphere model inputs and assumptions are derived from the present hydrologic characteristics and environmental inferences from the paleospring deposits observed in the region. In the present-day climate, discharge occurs at the Franklin Well area only as evapotranspiration in the Amargosa River channel. For a cooler/wetter climate, discharge is projected to occur in the entire State Line Deposits/Franklin Well area in a combination of springs, pools, marshes, and wet and dry playas. The discharge rate during a future cooler/wetter climate can be estimated based on the extent of the deposits and similar modern springs in the region. One modern analog, albeit on a larger scale, may be Ash Meadows. The present-day Ash Meadows area of springs, marshes, pools and playas is approximately twice the area of the State Line deposits, and has similar types of discharge to that indicated for the State Line Deposits area. Present day discharge at Ash Meadows is estimated to be 60,372 m^3/day [17,865 acre-ft/yr] (Belcher and Sweetkind, 2010, Table F-4). Prior to water use restrictions related to Devils Hole, water was diverted from pools and ponds, and was pumped from the ground for agriculture in Ash Meadows. Whereas limited water diversion for agriculture at a future, wetter State Line Deposits area is possible, extensive agriculture in the area of the State Line Deposits is unlikely due to the high concentrations of salts in the soils. Therefore, biosphere and dose pathway modeling for a cooler/wetter climate at the State Line Deposits/Franklin Well area includes (i) inhalation of resuspended dust from wet and dry playas, (ii) ingestion of water and soil, and (iii) subsistence farming using water diverted from less saline pools and springs. Recycling and recapture of irrigated water are not applicable for water diverted from pools and springs for agriculture because unlike the case of well-pumping irrigation, any irrigation water diverted from springs or pools is typically used downstream from its source, and thus the contaminants pass only once through the local soil. Transport properties for the State Line Deposits/Franklin Well area, except for the distance, are the same as used for the calculations for Amargosa Farms, as the characteristics of the aquifer are the same. For the estimated impacts at the State Line area, the NRC staff conservatively assumes that the entire plume discharges to that location.

Aquifer Environment

Several features of the aquifer environment at the State Line Deposits/Franklin Well area indicate that groundwater concentrations and accumulations of sorbed material onto sediments would be lower than in the aquifer environment at Amargosa Farms:

- The area is a short distance further downstream from the Amargosa Farms area. The amount of radiological and nonradiological material expected in the aquifer environment, both sorbed to alluvial sediment grains and dissolved in the groundwater would therefore be slightly less than at Amargosa Farms due to additional dispersion and decay. Except for the additional distance, the transport processes to Amargosa Farms and to the State Line Deposits/Franklin Well area are similar.

- No additional concentrating mechanisms occur in State Line Deposits/Franklin Well area, such as the recycling/infiltration of water used for agriculture, compared to those at the aquifer environment at Amargosa Farms.

- Whereas there are indications that water from the carbonate aquifer contributed to the paleospring deposits at the State Line Deposits/Franklin Well area (discussed in Section 2.3.4), the groundwater is still dominantly derived from an alluvial/volcanic aquifer, based on its chemical characteristics. Any amount of water from the underlying uncontaminated carbonate aquifer would dilute the contaminants in the groundwater at this location, and lower their concentrations in the aquifer.

- Groundwater from the northwest (Amargosa Desert) and south (Funeral Mountain alluvial fan) contribute to the groundwater flow in the area. These uncontaminated sources would similarly reduce aquifer contaminant concentrations.

As noted above, the NRC staff found the impacts to the aquifer environment in the Amargosa Farms area to be SMALL. As the impacts at the State Line Deposits/Franklin Well area would be less than those at Amargosa Farms, the NRC staff finds that the impacts on the aquifer environment at the State Line Deposits/Franklin Well area would be SMALL.

Soil

This section describes the accumulation of repository materials in soils at the State Line Deposits/Franklin Well area for the wetter climate. Because of the very limited area where the water table is potentially close enough to the ground surface for contaminants to enter the soil in present-day climate conditions, an insignificant amount of precipitation of radiological and nonradiological contamination from the repository is expected to occur. However, in a cooler/wetter climate state where the water table could rise approximately 20 to 30 m [66 to 98 ft] (Section 2.3.4), a larger area would be affected and soil concentrations of contaminants could be greater.

The NRC staff uses two approaches to estimate the soil concentration of contaminants for the cooler/wetter climate to account for the range of processes that occur in this type of environment. These approaches are for contaminants in evaporite minerals at a wet playa-type discharge setting, and for contaminants in sediments collecting in a salt marsh-type discharge setting. These are the environments inferred from the paleospring deposits in this location (Section 2.3.4). In the first approach, evaporation from a wet playa-type of discharge site is conservatively assumed for the entire State Line Deposits/Franklin Well area. This approach leads to the greatest calculated contaminant concentration in soils at the State Line Deposits/Franklin Well area, as it assumes extensive formation of evaporite minerals in playa-type areas, which strongly concentrates contaminants from groundwater. The concentrations of contaminants in soil and evaporite deposits within the wet playa are calculated using the estimated concentrations of the contaminant and total dissolved solids (TDS) content of the groundwater. This model for soil concentration assumes that as water is lost by evaporation, contaminants in groundwater are incorporated into newly formed evaporite minerals. The contaminant concentration is higher in evaporites formed from relatively dilute water (low TDS) than from water with the same concentration of contaminants but a greater initial content of (noncontaminant) dissolved material, as a greater amount of evaporation is needed to form evaporites from water with a low amount of TDS. These calculations conservatively use water with a relatively low TDS [257 ppm, as measured in groundwater from well J-13 in Fortymile Wash (DOE, 2014a)]. An additional conservatism is that the model

assumes that the “soil” is composed entirely of minerals formed by evaporation of the groundwater. While this can be observed in some local areas of extreme aridity (for example, in salt pans in Death Valley), wet and dry playas typically contain significant amounts of nonevaporite material, with mineral grains transported to the playa by wind or running water (like the playa environments indicated by the paleospring deposits in the State Line area; Section 2.3.4). This assumption thus represents a conservative means of estimating contaminant concentrations in the soil.

The second approach assumes accumulation of contaminants in soils formed from sediments in spring-fed marshes and pools. Unlike the first approach, this method does not assume complete evaporation of the groundwater. Instead, this approach assumes that contaminants accumulate on sediment that forms soils in a marsh/pool environment like that seen in nearby wet areas, such as Ash Meadows. The calculation of soil contaminant concentration used in this approach is similar to that described for the Amargosa Farms area (Section 3.1.1), except that no recapture and recycling is included. Table 3-6 provides the estimated radiological and nonradiological contaminant soil concentrations for both approaches.

The calculated soil concentrations in Table 3-6 show similar patterns to Amargosa Farms for sorbing and nonsorbing radionuclides and metals. Estimates of sorbing radionuclide (Np-227 and U isotopes) and metal (Ni and V) contaminants are zero at the State Line Deposits/Franklin Well area at 10,000 years, for both calculation models. The nonsorbing contaminants (I-129, Tc-99, and Mo) are estimated to be present in low concentrations at 10,000 years. As expected, the calculated concentrations are significantly greater for the more-conservative evaporite model, particularly for the nonsorbing contaminants, but are still very low.

At one million years, the calculations show all of the contaminants from the repository present in the soils at the State Line Deposits/Franklin Well area, with most concentrations still very low. As expected, the more conservative evaporite model gives a greater calculated concentration than the salt marsh model for those contaminants estimated to occur in the soil. Even using the evaporite model, the values calculated for all contaminants are all very low for both time periods. As was the case for Amargosa Farms, the estimated peak soil concentration for Ni at this location occurs between 10,000 and one million years after repository closure, at approximately 84,000 years, and reaches a maximum of 3.4 ppm using the Salt Marsh Model for a short period of time before decreasing. The estimated concentrations for all of the nonradiological contaminants are lower than the EPA generic soil screening levels (Table 3-3).

Based on the analysis above for the accumulation in soils of radiological and nonradiological contaminants from the repository and the associated conservative assumptions used in the analysis, the NRC staff finds that the impact on soils at State Line Deposits/Franklin Well area would be SMALL.

Public Health

Combined radionuclide peak dose (considering all radionuclides) and body intake for nonradiological contaminants are given in Table 3-7 for 10,000 and one million years for the cooler/wetter climate, and the contributors to radiological dose are shown in Figure 3-2. The largest contributors to radiological dose for both the present-day and the wetter climate at the State Line Deposits area are I-129, Tc-99, Np-237, and Pu-242 (Figure 3-2). At 10,000 years, I-129 and Tc-99 are the primary contributors to dose. They do not sorb onto rock grains, but rather remain dissolved in water. The other radionuclides in Figure 3-2 sorb to various degrees, and thus arrive later.

Table 3-6. Peak Soil Concentrations of Radiological and Nonradiological Contaminants at the State Line Deposits/Franklin Well Area in a Cooler/Wetter Climate State, Calculated Using the Evaporite and Salt Marsh Soil Models

Concentration (ppm)	Evaporite Soil Model (Playa)		Salt Marsh Soil Model	
	10,000 years	1 million years	10,000 years	1 million years
Np-237	0	7.1×10^{-4}	0	2.7×10^{-5}
U-235	0	3.1×10^{-3}	0	1.5×10^{-4}
U-238	0	0.13	0	6.6×10^{-3}
U-233	0	3.4×10^{-5}	0	1.7×10^{-6}
Tc-99*	3.0×10^{-3}	3.8×10^{-3}	2.5×10^{-6}	1.7×10^{-6}
I-129*	5.5×10^{-4}	5.5×10^{-3}	7.8×10^{-6}	5.1×10^{-5}
Mo†	52	1.4	0.011	3.1×10^{-4}
Ni‡	0	75	0	3.4
V*	0	0.23	0	0.003
U (all isotopes)	0	0.14	0	0.007

*Peak value occurs after 100,000 years, but before 1 million years
†Peak value occurs at 10,000 years after closure
‡Peak value occurs after 10,000 years, but before 100,000 years
U = uranium, Th = thorium, Np = neptunium, I = iodine, Tc = technetium, Se = selenium, Mo = molybdenum, Ni = nickel, V = vanadium

Table 3-7. Peak Annual Dose and Body Intake Estimates for the Cooler/Wetter Climate at the State Line Deposits/Franklin Well Area

	10,000 years	1 million years	
Peak Dose (mrem/yr)*	0.034	0.28	
	Body Intake Estimates		Oral Reference Dose
	10,000 years	1 million years	
Mo (mg/kg body-weight/day)*	3.8×10^{-4}	1.0×10^{-5}	5.0×10^{-3}
Ni (mg/kg body-weight/day)†	0	5.5×10^{-4}	2.0×10^{-2}
V (mg/kg body-weight/day)‡	0	1.7×10^{-6}	9.0×10^{-3}
U (mg/kg body-weight/day)	0	1.0×10^{-6}	3.0×10^{-3}

*Peak value occurs at 10,000 years after closure
†Peak value occurs after 10,000 years, but before 100,000 years
‡Peak value occurs after 100,000 years, but before 1 million years
Note: 1.0 mrem/yr = 0.01 mSv/yr
Mo = molybdenum, Ni = nickel, V vanadium, U = uranium

Estimates of dose and body intake for the present-day climate are extremely small because of the small area affected (Franklin Well area) and limited amount of evapotranspiration. For the cooler/wetter climate, the peak dose of 0.28 mrem/yr [0.0028 mSv/yr] is substantially lower than the dose from natural background levels {approximately 300 mrem/yr [3.0 mSv/yr], including radon} for the Amargosa Farms area. Peak values estimated for 10,000 and one million years for the cooler/wetter climate are much lower than the NRC annual dose standards for a Yucca Mountain repository in 10 CFR Part 63 {15 mrem [0.15 mSv] for the first 10,000 years, and 100 mrem [1 mSv] for one million years, after permanent closure}.

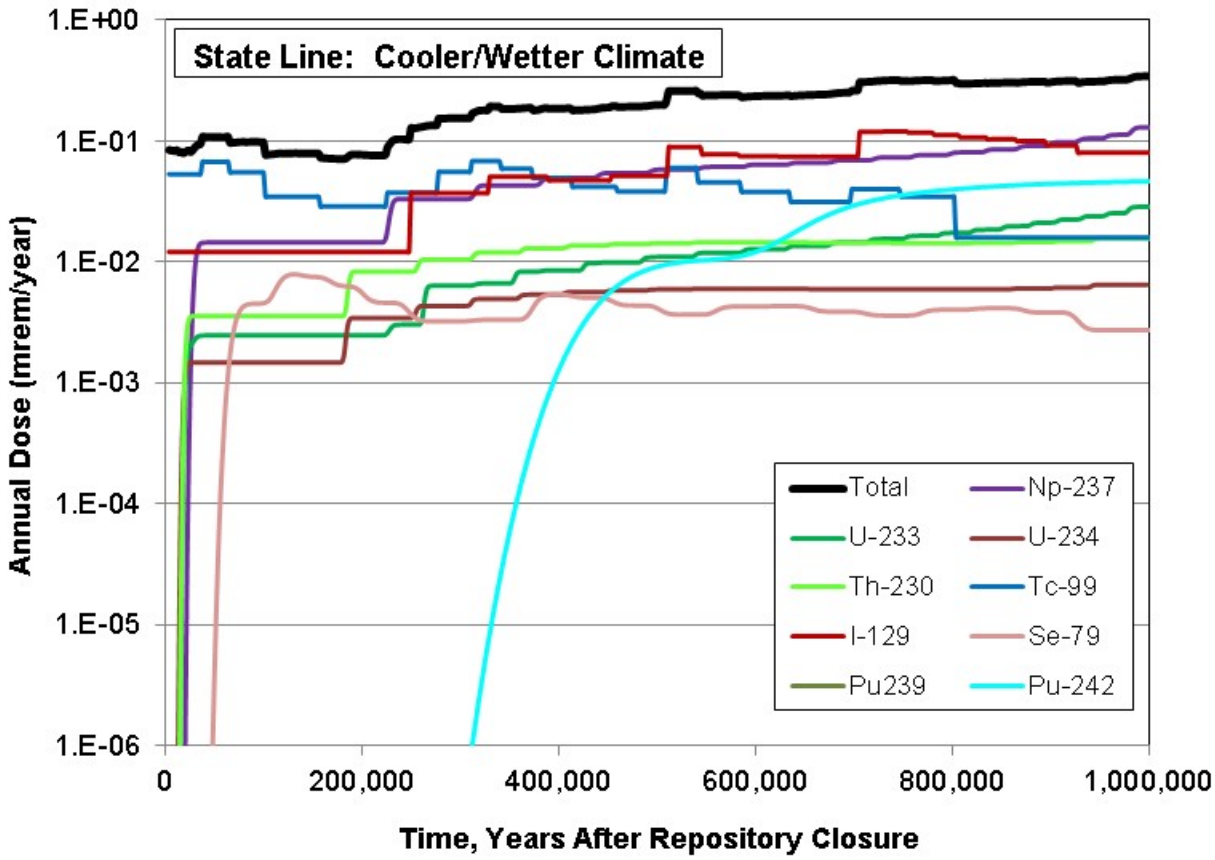


Figure 3-2. Dose History of Selected Radionuclides at State Line Deposits/Franklin Well Area for the Cooler/Wetter Climate

The peak daily intake value for Ni at the State Line Deposits/Franklin Well area corresponds to its maximum groundwater and soil concentration at this location. The maximum of 0.001 mg/kg body weight/day occurs at approximately 88,000 years after repository closure. For all of the nonradiological contaminants at this location, the estimates of body intake are significantly lower than the EPA Oral Reference Dose. Based on the analyses above of radiological and nonradiological material potentially released from the repository to the State Line Deposits/Franklin Well area, the NRC staff finds that the impact to public health would be SMALL.

3.1.2.2 Furnace Creek and Middle Basin

The Furnace Creek area and Middle Basin of Death Valley are located approximately 56 km [35 mi] beyond the postclosure compliance location. As discussed in Section 2.2.2, under scenarios in which there is no pumping at the Amargosa Farms area, groundwater modeling indicates that the majority of contaminants transported from Yucca Mountain would be discharged in Middle Basin of Death Valley (Belcher and Sweetkind, 2010). Contaminated groundwater could also discharge at the springs in the Furnace Creek area, a short distance upgradient from Middle Basin (Belcher and Sweetkind, 2010; DOE, 2014a). For the estimated

impacts at Furnace Creek or Middle Basin, the NRC staff conservatively assumes that the entire plume discharges at that location. For these locations, the impact types are the same as for Amargosa Farms (Section 3.1.1): (i) the amount of contaminants from the repository in the groundwater system, (ii) the concentration of contaminants in the groundwater, (ii) the concentration of contaminants in soils, and (iv) the radiological dose and body intake of contaminants for the relevant exposure pathways. Biosphere dose conversion factors for the Furnace Creek and Middle Basin areas are based on exposures to full-time residents in the local environments (see Appendix A, Section A.2.2).

The transport model uses a path length of 56 km [35 mi] and transport properties that are distance-weighted for each segment of the pathway (see Appendix A, Section A.1.2). The specific inputs and assumptions used to determine the impacts are:

- The mass flux of radiological and nonradiological material reaching the potential discharge locations at Furnace Creek or Middle Basin is calculated using observations of spring discharge and evaporation losses. Total discharge from the springs at Furnace Creek is 2,294 acre-ft/yr [2.83 million m^3/yr]. Discharge in the playa environment at Middle Basin occurs through evaporation, and observed evaporation losses were 1,962 acre-ft/yr [2.4 million m^3/yr] at that location (Belcher and Sweetkind, 2010; Table F-4).

- Transport in the aquifer to Furnace Creek is calculated using a value of 0.00046 m/day [0.0015 ft/day] for the specific discharge (flow rate) along the 56 km [35 mi] path in the present-day climate (see Appendix A, Section A.1.2). For the wetter climate, the specific discharge is multiplied by a factor of 3.9 (DOE, 2014a; 2008b, Section 2.3.9). An average porosity in the aquifer of 0.11 is used for both climate states.

- A value of 257 ppm is used for the groundwater TDS content. This is the same conservative value used in the State Line Deposits area analysis, and lower than values typically observed at discharges from springs at Furnace Creek. As discussed in Section 3.1.2.1, using a lower TDS value is conservative. The TDS value is used to determine the total mass of evaporite deposits that could form. This affects the calculated concentration of contaminants in evaporite deposits.

- Dose conversion factors used in the analyses are derived from DOE (2008b, Table 2.3.10-12) with adjustments for secular disequilibrium (see Appendix A, Section A.1.2).

All radiological and nonradiological contaminants in the source term are analyzed in the transport models, but only the predominant elements reaching the affected environment of Furnace Creek or Middle Basin are described in detail below. Estimates for other contaminants produce extremely low concentration values, and they do not contribute to estimates of dose or toxic exposure. For this Analysis Case 2 (Discharge at Furnace Creek or Middle Basin), the radionuclides that are significant contributors to dose are Tc-99 and I-129 for both the present day and wetter climates. Because of sorption (and to a lesser degree, radioactive decay) along the long transport path, none of the other analyzed radionuclides reach the Death Valley locations and contribute to dose within the one-million-year analysis period for either climate scenario. Similar to the radionuclides, only the nonsorbing nonradiological contaminant, Mo, reaches the discharge locations in Death Valley over the one-million-year analysis period.

Aquifer Environment

This section describes (i) the amount of material from the repository that could be deposited in the aquifer environment between the postclosure compliance location at 18 km [11 mi] and the Death Valley discharge locations 56 km [35 mi] down the flow path, and (ii) the concentration of contaminants in the groundwater at the Death Valley discharge locations.

The amount of radiological and nonradiological contaminants in the aquifer environment between the postclosure compliance location and the potential Death Valley discharge locations, based on mass balance calculations, is provided in Table 3-8. The term "aquifer environment" includes both the rock and water along the groundwater flow path from Yucca Mountain. Thus, the contaminants are both dissolved in the water and sorbed onto the porous media of the aquifer matrix, which includes the alluvial fill of the Amargosa Desert and the carbonate rocks underlying the Funeral Mountains. The values in Table 3-8 are calculated by subtracting the mass of material accumulated at the discharge locations from the cumulative mass released to the postclosure compliance location.

Many of the contaminants shown in Table 3-8 (U, Th, Np, Se, Ni, and V; all but Tc-99, I-129, and Mo) do not discharge to the surface in Death Valley within one million years due to the decay of radionuclides and sorption effects. For these contaminants, all of the material that is released beyond the postclosure compliance location (which would have been discharged at Amargosa Farms at the present pumping rates for Analysis Case 1) is retained within the aquifer system and does not discharge to the surface.

Table 3-9 presents the estimated average concentrations of the radiological and nonradiological contaminants in groundwater discharging to the surface at the Furnace Creek area for this Analysis Case (limited or no pumping at Amargosa Farms). The concentrations are calculated by dividing the mass flux to Death Valley by the discharge rate at Furnace Creek. Under the lower flow volumes associated with the present-day climate, no contaminants reach the Furnace Creek area before 10,000 years after repository closure. Estimated contaminant concentrations at one million years are greater for the present-day climate state because there is less dilution of the contaminants in the groundwater. Although the contaminants arrive at Furnace Creek earlier in the cooler/wetter climate state, the contaminant concentration is lower.

Groundwater at Middle Basin would have similar concentrations, but as described in Section 2.3.3, there is presently no spring discharge at Middle Basin, and it is unlikely that free-flowing water would appear in that wet playa environment (see discussion in Appendix A, Section A.2.2). Because sorption and decay processes significantly impact transport over the long transport pathway to Death Valley, only nonsorbing contaminants (I-129, Tc-99, and Mo) are found in groundwater discharging to the surface in Death Valley.

At Furnace Creek, the maximum concentration of Mo in the groundwater occurs approximately 58,000 years after repository closure for the present-day climate (under the cooler/wetter climate, the peak arrives at 20,000 years after closure, at a lower concentration). The major release of this contaminant from the repository occurs fairly early after repository closure (see Appendix A), and as a nonsorbing element, transport of Mo is not significantly delayed in the aquifer. The estimate of the maximum Mo concentration in the groundwater is 0.05 mg/L and declines after this time. As noted previously, EPA has not set an MCL or National Recommended Water Quality Criteria level for Mo, but the peak concentration is much lower than 1 ppm and near the detection limit for Mo for the levels given in Table 2-1.

Table 3-8. Amount of Radiological and Nonradiological Material (From the Repository) in the Aquifer Environment Between the Postclosure Compliance Location and Death Valley				
	Present-Day Climate		**Cooler/Wetter Climate**	
	10,000 years	**1 million years**	**10,000 years**	**1 million years**
U isotopes (Ci)	1.5	1,320	1.5	1,320
Th isotopes (Ci)	0.18	790	0.18	790
Np-237 (Ci)	1.4	580	1.4	580
I-129 (Ci)	2.5	65	2.2	15
Tc-99 (Ci)	1,260	1,520	1,160	435
Se-79 (Ci)	5.8	200	5.8	200
Mo (kg)	1.4×10^6	2.9×10^5	1.4×10^6	1.3×10^5
V (kg)	2.2×10^3	4.0×10^5	2.2×10^3	4.0×10^5
Ni (kg)	1.2×10^6	8.0×10^7	1.2×10^6	8.0×10^7
U = uranium, Th = thorium, Np = neptunium, I = iodine, Tc = technetium, Se = selenium, Mo = molybdenum, Ni = nickel,				

Table 3-9. Peak Concentrations of Radiological and Nonradiological Material From the Repository Discharging in Groundwater at Furnace Creek, Death Valley				
	Present-Day Climate		**Cooler/Wetter Climate**	
	10,000 years	**1 million years**	**10,000 years**	**1 million years**
U isotopes (pCi/L)	0	0	0	0
Th isotopes (pCi/L)	0	0	0	0
Np-237 (pCi/L)	0	0	0	0
I-129 (pCi/L)*	0	0.97	0.02	0.24
Tc-99 (pCi/L)*	0	58	9.3	16
Se-79 (pCi/L)	0	0	0	0
Mo (mg/L)†	0	0.05	0	0.013
V (mg/L)	0	0	0	0
Ni (mg/L)	0	0	0	0
*Peak value occurs after 100,000 years, but before 1 million years †Peak value occurs after 10,000 years, but before 100,000 years U = uranium, Th = thorium, Np = neptunium, I = iodine, Tc = technetium, Se = selenium, Mo = molybdenum, V = vanadium, Ni = nickel				

Because the only radiological and nonradiological material reaching Furnace Creek and Middle Basin are small amounts of Tc-99, I-129, and Mo, the NRC staff finds that the impact on the aquifer environment at Furnace Creek and Middle Basin would be SMALL.

Soil

This section describes the accumulation of potential contaminants from the repository in soils at Middle Basin or Furnace Creek. The concentrations of contaminants in soil and evaporite

deposits within the wet playa are calculated using the estimated concentrations of the contaminant and TDS content of the groundwater, as in the evaporite model calculation for the State Line Deposits area (Section 3.1.2.1). Essentially, as water is lost due to evaporation, forming evaporites and other minerals, the contaminants in groundwater are incorporated into the newly formed solids. The concentration of the contaminant in the resulting solid is calculated by dividing the contaminant concentration in the groundwater by the TDS of the groundwater. The same conservative low value of TDS (257 ppm) is used here as in the previous evaporite model calculations (Section 3.1.2.1). The measured values of spring discharge waters at Furnace Creek are approximately 600 ppm TDS (Steinkampf and Werrell, 1998). Using this value for TDS in the evaporite model would decrease the calculated concentration in the soil to less than half that of the present estimate. Table 3-10 provides the calculated concentrations of radiological and nonradiological contaminants in soil and evaporite at Middle Basin. These values are derived from estimates in DOE (2014a, Table B-15) and the observed evaporation-driven discharge rates at Middle Basin (Belcher and Sweetkind, 2010). The values calculated for Middle Basin are limiting for possible soil accumulations at Furnace Creek. This is because any potential soil contamination from natural spring discharge at Furnace Creek would likely occur in a marsh/pool environment, rather than the wet playa environment in the topographic low at Middle Basin. As discussed in Section 3.1.2.1, modeling contaminant accumulation as a process that forms evaporites is very conservative, and results in greater concentrations than would form in an environment with less extreme evaporation. Potential accumulations of contaminants in soil at Furnace Creek are therefore expected to be less than those shown in Table 3-10 for the Middle Basin playa.

No radionuclide contaminants reach Middle Basin within 10,000 years in the present-day climate state, even with no pumping in Amargosa Farms. In the cooler/wetter climate state, I-129 and Tc-99 are present in Death Valley groundwater at 10,000 years, and therefore would be found in Middle Basin soils, although at very low levels. Due to radioactive decay, maximum Tc-99 soil/evaporite concentration is reached at about 358,000 years for the present-day climate and at about 328,000 years in the cooler/wetter climate; both climates have slightly smaller Tc-99 peaks at approximately 50,000 and 550,000 years. The I-129 concentration continues to increase slowly over the one-million-year period in both climate states.

For nonradiological contaminants, only the nonsorbing element Mo reaches Middle Basin. Under the present-day climate scenario, Mo reaches a maximum soil/evaporite concentration at about 58,000 years. The estimated maximum value is 208 ppm under the present-day climate state. The maximum value occurs slightly earlier for the cooler/wetter climate, but is lower. The maximum value decreases in the soil as the groundwater concentration decreases over time. This maximum is lower than the EPA soil screening level of 390 ppm for Mo in residential soils (Table 3-3). Studies of evaporation pits collecting irrigation water in the San Joaquin Valley have measured similar amounts of natural Mo concentrations (up to 94 ppm in soil/evaporite) as observed in the wetter climate scenario (Tanji et al., 1992). As discussed for the evaporite model results at the State Line Deposits area (Section 3.1.2.1), the environments where evaporites form are generally inhospitable due to the high salt concentrations and lack of potable water.

Because there is very little accumulation of radiological contaminants (only Tc-99 and I-129, and at very low levels) in soils at Middle Basin or Furnace Creek, and because accumulations of the one nonradiological contaminant present (Mo) is likely to be elevated only in barren and uninhabitable portions of these areas, the NRC staff finds that soil impacts from radiological and nonradiological contaminants associated with natural groundwater discharges at Middle Basin and Furnace Creek would be SMALL.

Table 3-10. Peak Soil/Evaporite Contaminant Concentrations for Middle Basin, Death Valley				
	Present-Day Climate		**Cooler/Wetter Climate**	
	10,000 years	**1 million years**	**10,000 years**	**1 million years**
I-129 (ppm)*	0	0.025	0.0005	0.006
Tc-99 (ppm)*	0	0.015	0.002	0.004
Mo (ppm)†	0	208	2.1×10^{-6}	61

*Peak value occurs after 100,000 years, but before 1 million years
†Peak value occurs after 10,000 years, but before 100,000 years
I = Iodine, Tc = technetium, Mo = molybdenum

Public Health

Biosphere dose pathways used in DOE's 2008 SEIS are very similar to those used for the postclosure compliance location, as the latter are based on the diet and living style of the people who now reside in the Town of Amargosa Valley, Nevada (as prescribed in 10 CFR 63.312). However, there are some significant modifications necessary for the application of these pathways to residents in areas of natural surface discharge, like Death Valley, as compared to the groundwater pumping areas of Amargosa Farms. These include, in the absence of extensive agriculture, the lack of significant irrigation and groundwater recycling. In Death Valley, most discharge is by evapotranspiration (DOE, 2014a). In the Furnace Creek area, much of the natural spring discharge is captured in engineered structures for use in local facilities (tourist lodgings and housing for National Park service personnel). And as previously noted (Section 2.1.1), the Timbisha Shoshone tribal community near Furnace Creek has federally appropriated rights to 92 acre-feet per year [0.113 million m3/yr] of surface and groundwater.

The biosphere dose pathways used in this supplement for the Death Valley locations include (i) external exposure, (ii) inhalation of soil/evaporite particulates and water vapor from evaporative coolers, and (iii) ingestion of water and soil/evaporite particulates. Ingestion of locally-grown crops, animal products, and fish was not included as a pathway for the natural discharge areas of Death Valley because there is very little current agricultural production in the Furnace Creek area (only a small commercial date farm) and wet playas such as Middle Basin are not suited for future agricultural production due to the salt content of the soil and water. Likewise, for wet playa-type discharges (such as Middle Basin), ingestion of water and exposure from evaporative coolers were also excluded as pathways because the saline water in the wet playa is not potable. Even in a cooler/wetter climate, the wet playa water would be unsuitable for use as drinking water or for use in agriculture.

For assessing impacts at the natural discharge locations in Death Valley, this supplement uses biosphere dose conversion factors similar to those developed based on exposure rates for full-time residents of the Amargosa Farms area and used in the 2008 SEIS. The factors are modified for the different exposure pathways in Death Valley compared to Amargosa Farms, and they include corrections to account for secular disequilibrium. Dose conversion factors for the present-day climate are used for both present-day and future wetter climate scenarios because the dose conversion factors for cooler and wetter climates would be lower than those used for the present-day climate. Appendix A, Section A.2.3 provides more information on the biosphere dose pathways and dose conversion factors used in this supplement.

Furnace Creek Radiological Contaminants

Peak annual dose estimates for Furnace Creek are given in Table 3-11 for both climate states. As discussed in the previous sections on impacts on the aquifer and soil, only a limited amount of radionuclides reach the natural discharge locations in Death Valley. The principal radionuclides that contribute to dose at Furnace Creek are Tc-99 and I-129 (Figure 3-3). The contribution from Tc-99 begins to decrease at about 364,000 years after repository closure due to its shorter half-life than I-129 (~200,000 years compared to 15.7 million years). Under the lower flow rates associated with the present-day climate, no radiological contaminants reach the Furnace Creek area before 10,000 years after repository closure. Estimated peak annual doses for the one million-year period are slightly greater for the present-day climate state because there is less dilution of the contaminants in the groundwater. Although the contaminants arrive at Furnace Creek earlier in the cooler/wetter climate state, the peak dose is lower due to the lower groundwater contaminant concentrations. The estimated peak annual doses are much lower than the NRC annual dose standards for a Yucca Mountain repository in 10 CFR Part 63 {15 mrem [0.15 mSv] for the first 10,000 years, and 100 mrem [1 mSv] for one million years, after permanent closure}.

Furnace Creek Nonradiological Contaminants

Peak daily intakes of the nonradiological contaminant Mo at Furnace Creek are given in Table 3-12 for both climate states. As discussed in the previous sections on impacts on the aquifer and soil, Mo is the only nonradiological contaminant present in groundwater discharging from springs at Furnace Creek, and only at the one million year period. The calculated peak daily intake at Furnace Creek correlates with the maximum peak concentration in groundwater and soil approximately 58,000 years after repository closure for the present-day climate state and is 1.3×10^{-3} mg/kg body-weight/day (as with the groundwater, the maximum for the cooler/wetter climate occurs slightly earlier and is a lower value). Human health impacts of the nonradiological contaminants are assessed by comparing daily intakes with EPA's Oral Reference Dose standard (EPA, 1999a,b; 1997a,b; 1994). For ingestion of potentially contaminated water, daily intake is estimated for a 70-kg person drinking 2 L [0.53 gal] of water daily. The estimated maximum value of daily intake is lower than the EPA Oral Reference Dose.

Middle Basin Radiological Contaminants

Peak annual dose estimates for Middle Basin are given in Table 3-13 for both climate states. As at the Furnace Creek area, the radiological contaminants that contribute to estimated dose in Middle Basin of Death Valley are limited to those elements whose transport in groundwater is not delayed due to sorption processes. As groundwater flows to Middle Basin and evaporates, these elements are incorporated into the resulting evaporite mineral deposits. Again, Tc-99 and I-129 are the primary contributors to dose (Figure 3-4). As at the Furnace Creek area (Figure 3-3), the contribution from Tc-99 decreases beginning at about 364,000 years after repository closure due to its shorter half-life than that of I-129. Similar to the results at the Furnace Creek area, dose estimates are greatest at one million years under the present-day climate scenario because of the dilution of the radiological contaminants in the larger groundwater flow volume under the cooler/wetter climate state, although the contaminants arrive sooner under the cooler/wetter conditions.

Table 3-11. Peak Annual Dose Estimates for the Furnace Creek Area		
	Peak Annual Dose (mrem/yr)*	
	10,000 years	1 million years
Present-day Climate	0.0	0.16
Cooler/Wetter Climate	0.015	0.042
*1.0 mrem/yr = 0.01 mSv/yr		

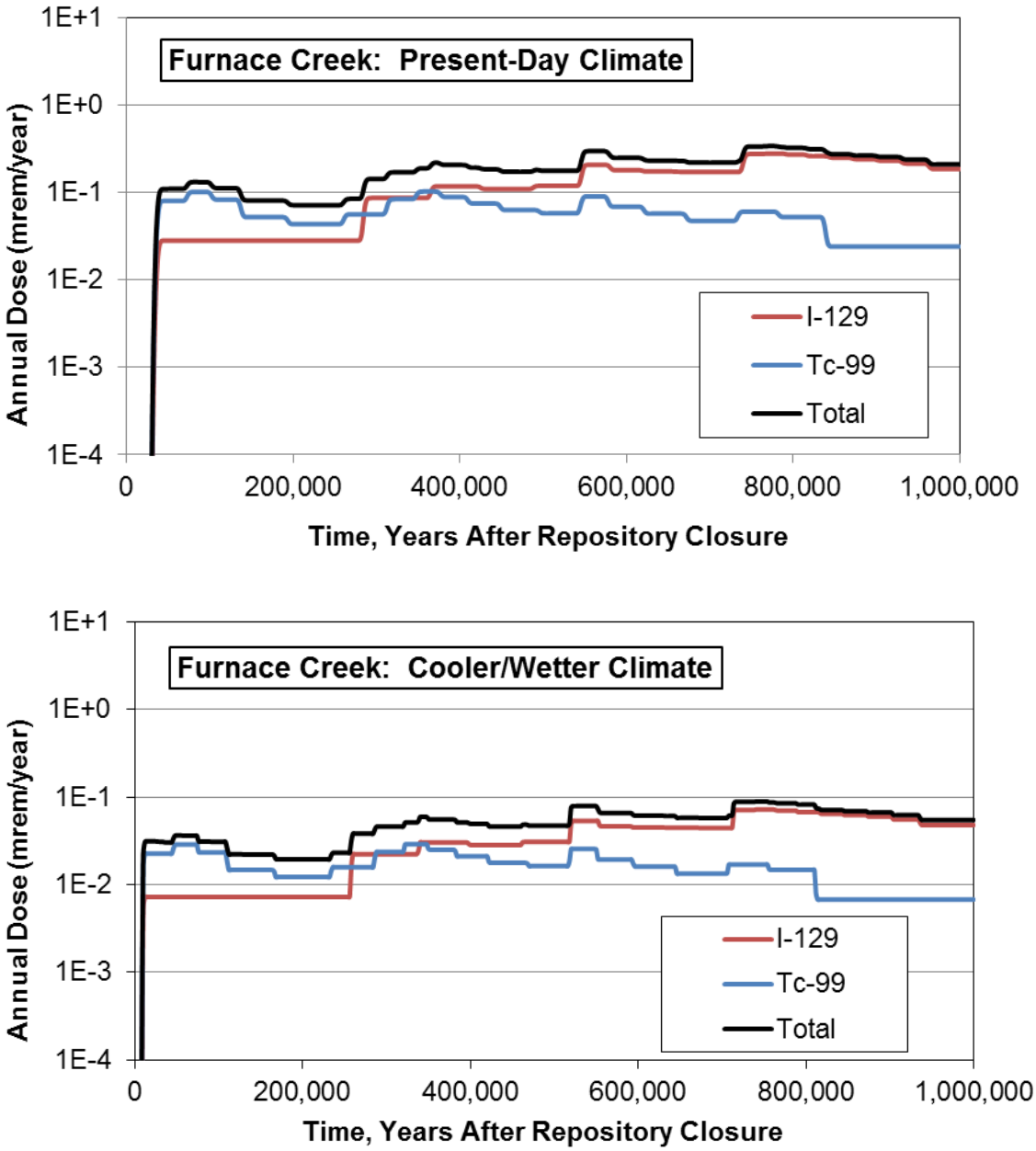


Figure 3-3. Dose History for Selected Radionuclides and Total Dose at the Furnace Creek Area for the Present-Day (Top) and the Cooler/Wetter (Bottom) Climate States.

Table 3-12. Peak Daily Intake for Mo at Furnace Creek			
Peak Daily Intake* (mg/kg body-weight/day)	**Present-Day Climate**	**Cooler/Wetter Climate**	**Oral Reference Dose**
Mo	1.3×10^{-3}	3.8×10^{-4}	5.0×10^{-3}
*Calculated peak daily intake for Mo occurs at 58,000 years after repository closure for the present-day climate, and at 20,000 years for the cooler/wetter climate. Mo = molybdenum			

Table 3-13. Peak Annual Dose Estimates for Middle Basin		
	Peak Annual Dose (mrem/yr)*	
	10,000 years	**1 million years**
Present-day Climate	0.0	0.16
Cooler/Wetter Climate	0.015	0.042
*1.0 mrem/yr = 0.01 mSv/yr		

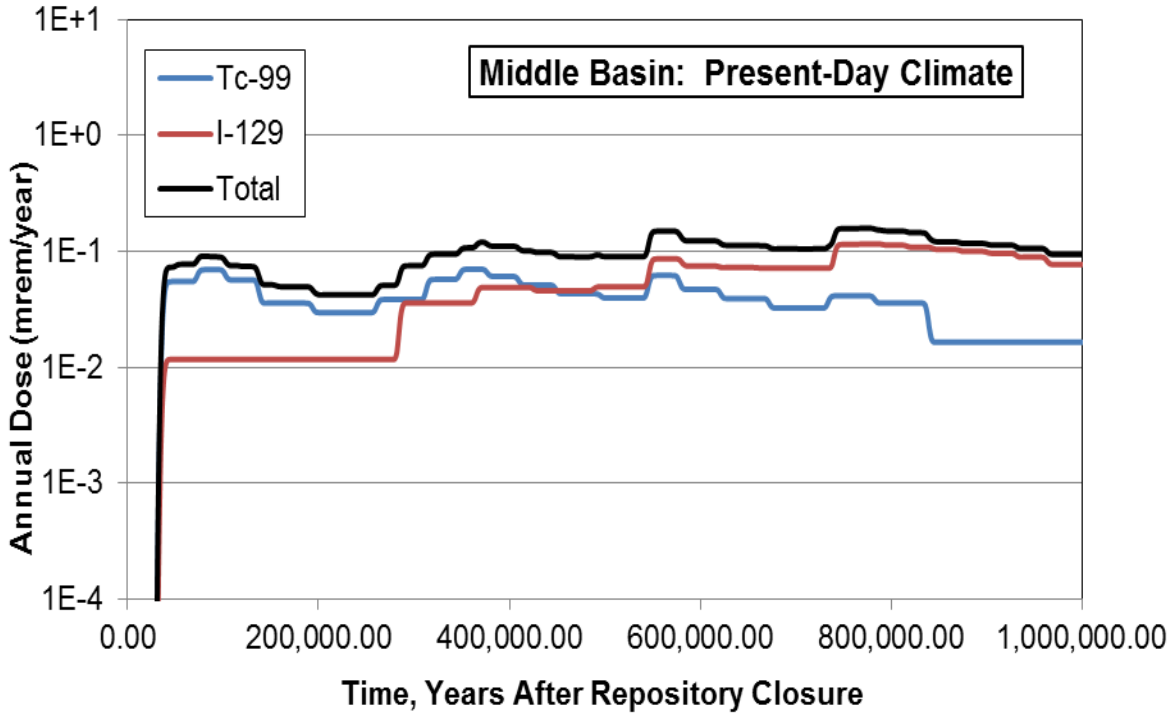
The peak annual dose estimates for Middle Basin are lower for both climate states than those for the Furnace Creek area. The low dose estimates are primarily due to the absence of a drinking water pathway at Middle Basin, given the high salinity of any standing water on the wet playa. As with the Furnace Creek results, estimated peak annual doses are much lower than the NRC dose standards for a Yucca Mountain repository in 10 CFR Part 63 {15 mrem [0.15 mSv] for the first 10,000 years, and 100 mrem [1 mSv] for one million years, after permanent closure}.

Middle Basin Nonradiological Contaminants

Peak daily intakes of nonradiological contaminants at Middle Basin are given in Table 3-14 for both climate states. As at Furnace Creek, Mo is the only nonradiological contaminant present in groundwater discharging at Middle Basin. At this location, Mo is present only at one million years under the present-day climate state, but is present both at 10,000 and one million years under the cooler/wetter climate state.

Human health impacts of nonradiological contaminants are assessed by comparing daily intakes with EPA's Oral Reference Dose standard (EPA, 1999a,b; 1997a,b; 1994). At this location, the principal pathway is ingestion and inhalation of contaminated soil, as the water at this location is not potable. As previously noted, the peak concentration for molybdenum occurs approximately 58,000 years after repository closure for the present-day climate (the peak is lower for the cooler/wetter climate, but occurs earlier). The peak Mo daily intake at Middle Basin is estimated to be 3×10^{-4} mg/kg body weight/day. The estimated values of daily intake in Table 3-14 and the peak value are both lower than the EPA Oral Reference Dose.

Based on the above, estimated doses from radiological contaminants at Furnace Creek and Middle Basin would be very low for both climate states {less than 1 mrem/year [0.01 mSv/yr]}, and the peak daily intakes of nonradiological contaminants would also be very low (below the EPA Oral Reference Dose). Therefore, the NRC staff finds that impacts to public health from radiological and nonradiological contaminants associated with natural groundwater discharges at Furnace Creek and Middle Basin of Death Valley would be SMALL.



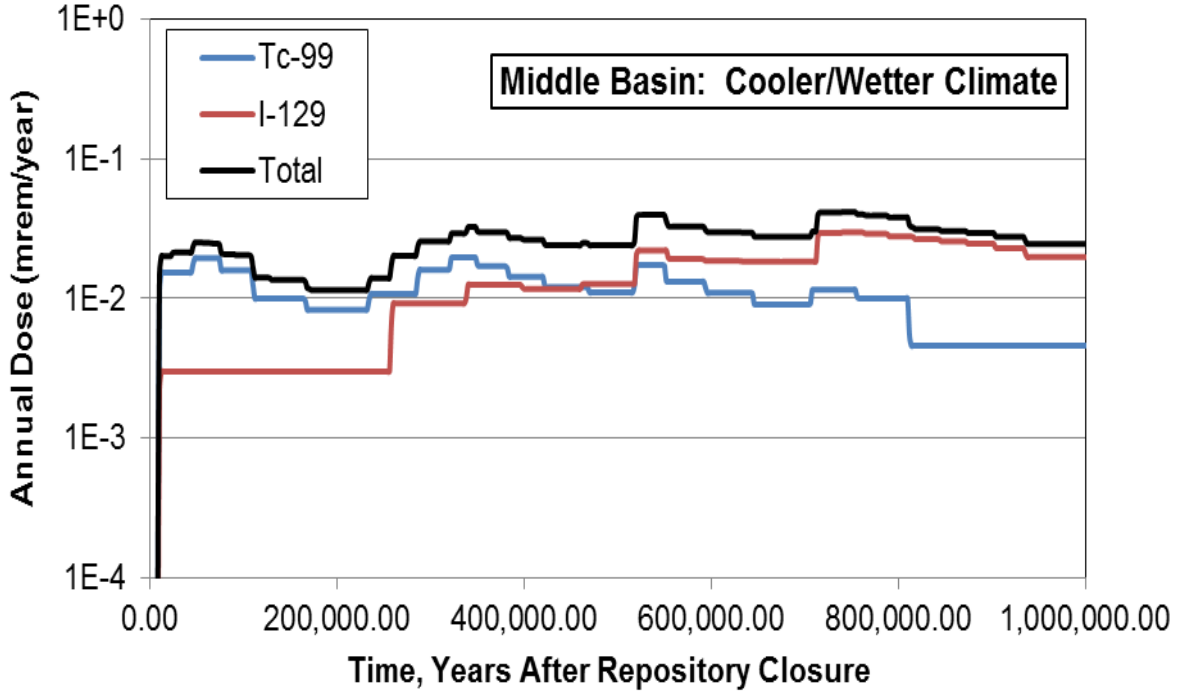


Figure 3-4. Dose History for Selected Radionuclides and Total Dose at Middle Basin for the Present-Day (Top) and Cooler/Wetter (Bottom) Climate States

Table 3-14. Peak Daily Intake for Mo at Middle Basin			
Peak Daily Intake* (mg/kg body-weight/day)	**Present-Day Climate**	**Cooler/Wetter Climate**	**Oral Reference Dose**
Mo	3.0×10^{-4}	1.8×10^{-5}	5.0×10^{-3}

*Calculated peak daily intake for Mo occurs at 58,000 years after repository closure for the present-day climate, and at 20,000 years for the cooler/wetter climate.
Mo = molybdenum

3.1.2.3 Alkali Flat

Alkali Flat is located approximately 45 km [28 mi] from the postclosure compliance location, or 63 km [39 mi] from the proposed repository. The groundwater at Alkali Flat is a combination of groundwater flowing from Ash Meadows and groundwater from western Amargosa Desert and Fortymile Wash. As discussed in Section 2.2.2, under scenarios in which there is no pumping in the Amargosa Farms area, groundwater modeling indicates that the majority of contaminants transported from Yucca Mountain will be discharged in Middle Basin, and to a lesser extent, at Furnace Creek (or the State Line Deposits area in a wetter climate) prior to reaching Middle Basin (Belcher and Sweetkind, 2010; DOE, 2014a). DVRFS modeling indicated that only a small fraction of contaminants could be directed southward toward the Alkali Flat area (Belcher and Sweetkind, 2010; DOE, 2014a).

There are no people living at Alkali Flat. The water composition is highly variable, from saline to relatively dilute (low TDS), with the more-dilute water found in the small springs on the upstream side of the playa. Due to the lack of residents and the very limited amount of potable water at the site, potential exposure pathways are limited to inhalation and exposure to resuspended dust from evaporites in which radiological and nonradiological contaminants may have precipitated from evaporation of groundwater discharge.

Estimates of groundwater, soil, and surface discharge mass and concentration at Alkali Flat were not explicitly calculated for this supplement, as the impacts can be estimated from the estimates for the other, more-likely discharge areas. Alkali Flat is similar to Middle Basin in its dominantly playa environment, and in its inhospitable conditions and lack of habitation. But Alkali Flat is more distant from present population centers, and is less likely to have visitors or temporary occupants. The exposure pathways and biological dose conversion factors used for a playa at Middle Basin are therefore applicable (and conservative) for Alkali Flat. The fraction of the contaminant plume reaching Alkali Flat is expected to be very small (less than one percent of the potential release reaching the postclosure compliance location, based on DVRFS modeling). Thus, the results in Section 3.1.2.2 for release of the entire plume at Middle Basin are likely to overestimate the contaminants in the groundwater or accumulated in soil at Alkali Flat (even though the transport path is marginally shorter from the repository to Alkali Flat). For these reasons, the NRC staff finds that the impacts at Alkali Flat would be a small fraction of those calculated for Middle Basin under both climate states, which were found to be SMALL, above. Therefore, the aquifer environment, soil, and public health (radiation dose and body intake of chemicals) impacts for Alkali Flat would be SMALL.

3.2 Ecological Impacts

The NRC staff evaluated the potential for ecological impacts from radionuclides and chemical constituents at the potential locations for surface discharges of groundwater to the environment

by considering the estimated radiation doses to humans (as a general indicator of the magnitude of radiological exposure), the concentrations of chemical constituents in various environmental media, and available information about how nonhuman biota could be impacted by radiological and chemical exposures. Relatively few studies have established impact levels for nonhuman biota exposed to radionuclides. Data on the impacts of nonradiological contaminants are more abundant but still limited (Hinck et al., 2010; Poston et al., 2011; Sample et al., 1996). Most available data on both radiological and nonradiological contaminants are from laboratory animal toxicity studies that do not address chronic exposure or ecosystem-level impacts. Nonhuman biota exhibit varying levels of sensitivity to radiation and chemical exposures (Poston et al., 2011; Sample et al., 1996), although some biological receptors are potentially more or less susceptible than others. For example, the more highly developed phylogenetic classes of organisms (plants and animals) tend to be more susceptible to radiation effects than less developed ones (Poston et al., 2011).

Given the very low doses estimated for Amargosa Farms, the State Line Deposits/Franklin Well area, and for Furnace Creek/Middle Basin in the previous sections, the NRC did not specifically calculate doses to nonhuman biota from radiological contaminants at these locations. The NRC staff considers it unlikely that nonhuman biota would receive doses significantly greater than the human dose estimates when the latter are a small fraction of the background exposure level. Based on this analysis, the NRC staff concludes that the potential for ecological impacts from radiological contaminants at these locations would be SMALL.

The NRC staff evaluated the potential for nonhuman biota to be exposed to potentially harmful levels of chemical constituents at Amargosa Farms, State Line Deposits/Franklin Well area, and Furnace Creek/Middle Basin based on the aquifer and soil concentrations in Sections 3.1.1 and 3.1.2 for present-day and cooler/wetter climates and for both the 10,000 year and one-million-year time-frames. Comparisons of the estimated groundwater and soil concentrations for the nonradiological contaminants to ecological impact concentrations are given for the three areas in Tables 3-15, 3-16, and 3-17. The water and soil concentrations shown in these tables are for the climate state showing the greatest concentration over the one million year time period for each area. Two approaches are used in Section 3.1.2.1 to estimate contaminant concentrations in surficial material: the evaporite model for playas and the salt marsh model for areas near and downstream from springs and pools. The values in Table 3-16 are derived from the salt marsh model because biota would dominantly be associated with springs and pools; and would be sparse on the saline playas.

The ecological impact values shown in Tables 3-15, 3-16, and 3-17 are derived from various data, depending on the applicability and availability of information and considering the wildlife that are representative of the region. Water concentration values are based on EPA aquatic life criteria (EPA, 2014) (available only for Ni) or the reported ranges of adverse ecological effect concentrations in scientific literature compilations. The threshold range for U in water is the range of reported guideline values in Hinck et al. (2010). The ranges for Mo and V in water are from Sample et al. (1996). The ecological impact values for soil concentrations of Ni and V are the EPA ecological soil screening levels (EPA, 2007; 2005).

These EPA levels were developed to support screening analyses to identify potential ecological concerns at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites that may need further, more detailed, evaluation (e.g., ecological risk assessment). EPA stated that it expected that any federal, state, tribal or private environmental assessment could use the values to screen soil contaminants (EPA, 2003). The soil range for Mo is based on dietary concentrations where adverse effects have been observed in the most

Table 3-15. Comparison of Estimated Groundwater and Soil Concentrations* of Contaminants at Amargosa Farms With Ecological Impact Concentrations (ppm)

Constituent	Estimated Water Concentration	Ecological Impact Concentration†	Estimated Soil Concentration	Ecological Impact Concentration†
Mo	7.3×10^{-3}	0.6–107	0.08	100–500
Ni	0.02	0.052	14.0	38–280
V	6.4×10^{-9}	0.835–200	4.5×10^{-4}	7.8–280
U (all isotopes)	1.9×10^{-4}‡	0.0026–69	0.026	5–200

*Concentrations in ppm (mg/L or mg/kg) are peak values that consider both the present-day and cooler/wetter climates.
†The ecological impact values are from various sources, based on applicability and availability of information including EPA (2014; 2007; 2005), Hinck et al. (2010), and Eisler (1989), as described in Section 3.2.
‡Concentration in ppm (mg/L) calculated from total uranium activity per liter from Table 3-2.
Mo = molybdenum, Ni = nickel, V = vanadium, U = uranium

Table 3-16. Comparison of Estimated Groundwater and Soil Concentrations* of Contaminants at State Line/Franklin Well With Ecological Impact Concentrations (ppm)

Constituent	Estimated Water Concentration†	Ecological Impact Concentration‡	Estimated Soil Concentration§	Ecological Impact Concentration‡
Mo	$<7.3 \times 10^{-3}$	0.6–107	0.011	100–500
Ni	<0.02	0.052	3.4	38–280
V	$<6.4 \times 10^{-9}$	0.835–200	3.0×10^{-3}	7.8–280
U (all isotopes)	$<1.9 \times 10^{-4}$‖	0.0026–69	0.007	5–200

*Concentrations in ppm (mg/L or mg/kg) are peak values that consider both the present-day and cooler/wetter climates.
†Estimated aquifer concentration at State Line/Franklin Well is down gradient from Amargosa Farms and would, therefore, be less than the Amargosa Farms estimate.
‡Sources as in Table 3-15.
§Soil concentrations are based on values from the irrigation recycling model approach, Section 3.1.2.1
‖Concentration of U in water calculated from total uranium activity per liter from Table 3-2.
Mo = molybdenum, Ni = nickel, V = vanadium, U = uranium

Table 3-17. Comparison of Estimated Groundwater and Soil Concentrations* of Contaminants at Death Valley Middle Basin† With Ecological Impact Concentrations (ppm)

Constituent	Estimated Water Concentration	Ecological Impact Concentration‡	Estimated Soil Concentration	Ecological Impact Concentration‡
Mo	0.05	0.6–107	208	100–500
Ni	0.0	0.052	0.0	38–280
V	0.0	0.835–200	0.0	7.8–280
U (all isotopes)	0.0	0.0026–69	0.0	5–200

*Concentrations in ppm (mg/L or mg/kg) are peak values that consider both the present-day and cooler/wetter climates
†Furnace Creek groundwater concentrations would be similar, but there would be no accumulation of constituents in soil, as described in Section 3.1.2.1.
‡Sources as in Table 3-15.
Mo = molybdenum, Ni = nickel, V = vanadium, U = uranium

sensitive applicable organisms (rabbits and birds) (Eisler, 1989). This dietary concentration is compared with the estimated soil concentration, based on the assumption that the plants consumed by the organisms would be in equilibrium with the estimated soil concentration. The U range is the soil concentration-based guidance levels reported by Hinck et al., 2010).

The results of the NRC staff's comparison of the estimated aquifer and soil concentrations with the ecological impact concentrations are provided in Tables 3-15 through 3-17. The estimated water and soil concentrations of Mo, Ni, V, and U at Amargosa Farms, the State Line Deposits/Franklin Well area, and at Furnace Creek/Middle Basin are generally below the ecological impact concentrations. The only exception is for Mo in the evaporite soil at Middle Basin. As previously discussed, this conservative value is for a highly saline soil which can support only sparse, if any, vegetation, and thus could not be the principal support for nonhuman biota. Therefore, the NRC staff concludes that environmental impacts to nonhuman biota from these chemical constituents would be SMALL.

Because the NRC staff finds that only a very small fraction of the contaminants are expected to reach Alkali Flat (Section 3.1.2.3), impacts to nonhuman biota at Alkali Flat would be much less than at the areas evaluated above. In addition, Alkali Flat is expected to remain dominantly a playa environment with sparse amounts of salt-tolerant vegetation growing in highly saline surficial material. Based on this analysis, the NRC staff concludes that the potential for ecological impacts from radiological and nonradiological contaminants at Alkali Flat would be SMALL.

In summary, based on the analyses in this section, the NRC staff concludes that the potential for ecological impacts from radiological and nonradiological contaminants at all of the surface discharge locations would be SMALL.

3.3 Historic and Cultural Resources

As stated in Section 2.3.2, historic and cultural resources may be located in or around current surface discharge areas, described in Section 2.3.3, or in paleospring discharge areas (and potential future discharge locations), described in Section 2.3.4. This section briefly describes DOE's analysis of impacts on cultural resources in its EISs, summarizes the NRC staff conclusions in its 2008 ADR, describes the scope of DOE's programmatic agreement with the Nevada State Historic Preservation Office (SHPO) and the Advisory Council on Historic Preservation (ACHP) under the National Historic Preservation Act (NHPA) (see Section 3.3.3), describes more recent work by DOE to evaluate impacts on historic and cultural resources, and provides the NRC staff's conclusions regarding impacts to historic and cultural resources at surface discharge locations.

3.3.1 Assessments in the DOE Environmental Impact Statements

DOE's historic and cultural resource analyses in its EISs for the proposed repository at Yucca Mountain focused on the repository site and the surrounding controlled area. Section 4.1.5 of the 2002 EIS contains DOE's evaluation of the potential environmental impacts of the proposed repository on historic and cultural resources. DOE updated its historic and cultural resources impact assessment in Sections 4.1.5 and 4.3.2.5 of the 2008 SEIS. Section 4.1.5 of the 2008 SEIS provides an update to the expected historic and cultural resources impacts, accounting for new information and an expanded region of influence, including land that DOE had proposed for an access road from U.S. Highway 95 and land where DOE would construct offsite facilities. Section 4.3.2.5 of the 2008 SEIS assesses the potential

historic and cultural resource impacts of proposed infrastructure improvements, such as the construction or replacement of roads, the installation of transmission lines, and various on-site improvements.

In its 2002 EIS, DOE also noted that the "Native American view of resource management and preservation is holistic in its definition of 'cultural resource,' incorporating all elements of the natural and physical environment in an interrelated context. Moreover, this view includes little or no differentiation between types of impacts (direct versus indirect), but considers all impacts to be adverse and immune to mitigation." DOE also summarized the results of studies that delineated several Native American sites, areas, and resources in DOE's region of influence for cultural resources. DOE further stated that it would continue its Native American Interaction Program throughout the construction, operation, closure, and monitoring of the repository (DOE, 2002; Section 4.1.5.2).

3.3.2 Assessment in the NRC Staff's Adoption Determination Report (2008)

Section 3.2.1.4.1 of the ADR notes that DOE identified and described in its EISs the status of its NHPA consultation processes. The ADR states that some of the bases for EIS impact analyses and proposed mitigation measures include the anticipated results of these processes or other investigations that were ongoing, and that DOE committed in various sections of its EISs to resolving these ongoing activities. The ADR highlights two activities relevant to historic and cultural resources:

- DOE had been consulting with the Nevada SHPO and the ACHP to develop a programmatic agreement for the proposed repository.
- DOE indicated its intent to have continuing discussions with Native American tribes through its Native American Interaction Program and proposed establishing a "mitigation advisory board" to explore ways to address concerns about adverse impacts.

The ADR notes that, as indicated in NUREG–1748 (NRC, 2003; Section 5.1.4), an EIS should describe the current status of the required permit applications and consultations, but it is not necessary that all permitting and consultation activities be completed before publication of the final EIS. Additionally, the ADR notes that the Council on Environmental Quality (CEQ) regulations at 40 CFR 1502.22 state that an EIS may document incomplete or unavailable information provided the EIS clearly indicates such information is lacking. The NRC staff concluded in the ADR that the discussions of these ongoing activities in the DOE EISs meet NRC regulations and are consistent with NRC guidance.

The ADR also addresses how DOE assessed the impacts of the proposed repository on historic and cultural resources. As discussed further in the ADR, the two main components of DOE's analysis were (i) a description of DOE's efforts to assess effects on specific historic and cultural resources and (ii) a discussion of Native American viewpoints, which DOE characterizes as an opposing viewpoint. The ADR also notes that in its EISs, DOE further indicates its intent to continue its Native American Interaction Program to comply with the various laws that may affect Native American cultural practices, and to establish one or more mitigation advisory boards to address concerns about adverse impacts. The NRC staff concluded in the ADR that the consideration of Native American concerns and the impacts assessed on historic and cultural resources in the DOE EISs is adequate under the National Environmental Policy Act (NEPA).

3.3.3 DOE's Programmatic Agreement (2009)

As discussed in Section 2.3.2, in 2009 DOE finalized a programmatic agreement with the ACHP and the Nevada SHPO concerning the development of a repository at Yucca Mountain (DOE, 2009b). The area covered by the agreement "includes all site activities conducted by [DOE] and its contractors for the licensing and development of Yucca Mountain as a repository for disposal of spent nuclear fuel and high-level radioactive waste that have the potential to affect historic properties, and that are located within the boundaries of the Yucca Mountain Project Operator-Controlled Area… In the event the DOE is granted the proposed land withdrawal area depicted in Figure 1, this Agreement will be amended to expand the [Yucca Mountain Project Operator-Controlled Area]" to include the land withdrawal area (DOE, 2009a; Section A.1). The programmatic agreement further states that impacts from activities that support the repository, but which occur outside of the Operator-Controlled Area, are outside the scope of the agreement and would need to be considered separately. The agreement states that DOE would consult with the SHPO and appropriate State agencies, as necessary, regarding compliance with any applicable State and Federal laws or regulations (DOE, 2009a; Section A.1 and A.2). The agreement also states that should the NRC grant a construction authorization for the proposed repository, the NRC may use the agreement to fulfill its obligations under Section 106 of the NHPA.

3.3.4 Additional DOE Analysis (2014)

DOE's 2014 analysis of the potential impacts of the repository on groundwater and on surface discharges of groundwater (DOE, 2014a) includes a discussion of Native American concerns and provides an assessment of the potential impacts on Furnace Creek area residents of using and consuming groundwater that could contain contaminants from the repository. This assessment does not provide an accounting of any historic and cultural resources that may be present at or near surface discharge locations.

3.3.5 NRC Staff Evaluation

The NRC staff concluded in its ADR that DOE adequately addressed the potential impacts on historic and cultural resources in its EISs, given DOE's defined region of influence and given that some consultation processes were still ongoing at the time the final 2008 SEIS was published. Based on the region of influence DOE described in its EISs (DOE, 2008a; 2002), the NRC staff concludes that the affected environments considered in this supplement are outside the region DOE evaluated in its EISs' assessments of these impacts, and that the NRC staff found acceptable in its ADR. The NRC staff acknowledges that DOE has developed a programmatic agreement to specifically address impacts on historic properties under the NHPA. However, the NRC staff notes that the agreement scope does not include areas outside the Operator-Controlled Area and that the agreement states that any impacts outside this area would need to be addressed separately. In addition, the DOE programmatic agreement focuses on proposed activities within the state of Nevada, and some of the affected areas identified in this supplement (and in DOE, 2014a) are in California. Thus, the NRC staff concludes that DOE would need to assess whether further consultation and investigation are necessary to account for potential impacts on cultural resources that may be located in areas where groundwater discharges to the surface.

3.4 Environmental Justice

Environmental justice refers to a Federal policy implemented to ensure that minority, low-income, and tribal communities historically excluded from environmental decision-making are given equal opportunities to participate in decision-making processes. This section discusses potential environmental justice issues related to the evaluations in this supplement for impacts on groundwater and the surface discharge of groundwater. Specifically, this section summarizes the environmental justice analysis in DOE's EISs, describes more recent work by DOE to evaluate environmental justice impacts, and provides the NRC staff's analysis and conclusions regarding environmental justice impacts from groundwater or surface discharges of groundwater.

Under Executive Order 12898 (59 FR 7629), Federal agencies are responsible for identifying and addressing potentially disproportionately high and adverse human health and environmental impacts on minority and low-income populations. In 2004, the NRC issued a Policy Statement on the Treatment of Environmental Justice Matters in NRC Regulatory and Licensing Actions (69 FR 52040), which states that "The Commission is committed to the general goals set forth in Executive Order 12898, and strives to meet those goals as part of its National Environmental Policy Act (NEPA) review process."

Disproportionately high and adverse human health effects occur when the risk or rate of exposure to an environmental hazard for a minority or low-income population is significant and exceeds the risk or exposure rate for the general population or for another appropriate comparison group. Disproportionately high environmental effects refer to impacts or risks of impacts on the natural or physical environment in a minority or low-income community that are significant and appreciably exceed the environmental impact on the larger community.

3.4.1 Assessments in DOE's Environmental Impact Statements

In its EISs, DOE provided an analysis of environmental justice impacts but did not identify groundwater as a resource area for which potential environmental justice impacts could occur. Because DOE did not provide an environmental justice analysis for impacts from groundwater or from surface discharges of groundwater, the NRC staff concludes that, consistent with the finding in the ADR with regard to the need for further supplementation, this discussion in the EISs is incomplete. The NRC staff's assessment is provided in the next section.

3.4.2 NRC Staff Assessment

This section assesses the potential for disproportionately high and adverse human health or environmental effects on minority and low-income populations that could result from groundwater containing contaminants from the repository. As stated in Section 2.1.1, the NRC staff incorporates by reference its SER assessment and DOE's license application description of regional demography. For this analysis, the affected area consists of population centers located along the groundwater flow path from Yucca Mountain. Section 2.1.1 describes population centers within an 84-km [52-mi] radius of Yucca Mountain, comprising parts of Clark, Esmeralda, Lincoln, and Nye Counties in Nevada, and Inyo County in California. Within that radius, there are two population centers that the NRC staff has determined are located along the groundwater flow path from Yucca Mountain. The potentially-affected population centers are the town of Amargosa Valley in Nye County, Nevada, and Death Valley National Park in

Inyo County, California (NRC, 2015a; Section 2.1.1.1.3.2., Population Centers). The NRC staff's analysis of potential environmental justice impacts at these two locations is provided below.

Impacts on Minority and Low-Income Populations in the Amargosa Valley Area

The Amargosa Valley Census County Division (CCD) is a census area of Nye County, Nevada, located along the groundwater flow path from Yucca Mountain. Table 3-18 provides a summary of minority and low-income populations for this group.

NRC guidance states that minority and low-income populations with differences greater than 20 percentage points higher than the state or county percentages, or that exceed 50 percent of the census (typically at the block level) group, may be considered to be significant (NRC, 2003). Following this guidance, the NRC staff considers the minority population in the Amargosa Valley CCD to be a significant environmental justice population (NRC, 2003). The NRC staff, therefore, evaluated whether the minority and low-income populations could experience disproportionately high and adverse human health and environmental effects from groundwater impacts. The groundwater impacts in the town of Amargosa Valley (which includes the Amargosa Farms area) would be from pumping potentially contaminated groundwater used primarily for irrigation (Section 2.3). Section 3.1.1 describes the potential groundwater impacts in Amargosa Farms. Amargosa Farms pumps groundwater for irrigation and for its commercial and domestic water supply. The dose pathways for a resident of Amargosa Farms are external (body) exposure, inhalation, and ingestion of water, crops, animal products, fish, and soil. Section 3.1.1 describes the concentration of contaminants in the groundwater at the Amargosa Farms area (see Table 3-2), the concentration of contaminants in soils in the Amargosa Farms area due to irrigation (see Table 3-3), and the dose and body intake values for radiological contaminants (see Table 3-4) and nonradiological contaminants (see Table 3-5).

In Section 3.1.1, the NRC staff finds that both for the present-day and wetter climates: (i) the impacts at Amargosa Farms from radiological and nonradiological contaminants to the aquifer environment would be SMALL; (ii) the impacts on soils at Amargosa Farms would be SMALL; and (iii) the impacts on public health at Amargosa Farms would be SMALL. Further, the peak dose of 1.3 mrem/yr [0.013 mSv/yr] in Table 3-4 is substantially smaller that the dose from natural background levels of approximately 300 mrem/yr [3.0 mSv/yr] (including radon) for Amargosa Valley.

Based on its conclusions in Section 3.1.1 concerning impacts on groundwater, soils, and public health, the NRC staff finds no environmental pathway that would affect minority or low-income populations differently from other segments of the general population. Therefore, the NRC staff concludes that no disproportionately high and adverse health or environmental impacts would occur to minority or low-income segments of the population in the Amargosa Valley area.

Impacts on Minority and Low-Income Populations at Death Valley National Park

The Death Valley CCD, located in Inyo County, California, is a census population located along the groundwater flow path from Yucca Mountain, and includes the Furnace Creek springs area in Death Valley National Park. Table 3-19 provides a summary of minority and low-income populations for this group.

Based upon census data, the NRC staff does not consider the Death Valley CCD to be a significant environmental justice community (NRC, 2003). However, as noted in Chapter 2, the

Table 3-18. 2010 Minority Populations and 2010-2014 5-Year Poverty Estimates for the Amargosa Valley Area			
	Amargosa Valley Census County Division	**Nye County**	**Nevada**
Percent Minority (Including Hispanic and Latino Ethnicity)*	50	21	46
Percent of Persons Below the Poverty Level†	31	19	16

*Minority population based on 2010 U.S. Census. Minority population includes persons of Hispanic, Latino, or Spanish origin who are considered an ethnic minority and may be of any race (USCB, 2010).
†Population below poverty level based on 2010-2014 American Community Survey 5-year estimates.
Source: U.S. Census Bureau American Fact Finder <http://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml> (accessed April 19, 2016)
Percentages are rounded to the nearest whole number.

Table 3-19. 2010 Minority Populations and 2010-2014 5-Year Poverty Estimates for the Death Valley Area			
	Death Valley Census County Division	**Inyo County**	**California**
Percent Minority (Including Hispanic and Latino Ethnicity)*	19	34	60
Percent of Persons Below the Poverty Level†	23	14	16

*Minority population based on 2010 U.S. Census. Minority population includes persons of Hispanic, Latino, or Spanish origin who are considered an ethnic minority and may be of any race (USCB, 2010).
†Population below poverty level based on 2010-2014 American Community Survey 5-year estimates.
Source: U.S. Census Bureau American Fact Finder http://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml (accessed April 19, 2016)
Percentages are rounded to the nearest whole number

population in the Death Valley CCD includes the Timbisha Shoshone Tribe community located on a 314-acre [1.27-km^2] parcel of land in the Furnace Creek area. The Tribe has federally appropriated rights to 92 acre-ft/year [0.113 million m^3/yr] of surface and groundwater. The springs in the Furnace Creek area, including the Furnace Creek, Texas, Travertine, and Salt Springs, are of traditional and cultural importance to the Tribe (DOE, 2014a). Because of the unique characteristics of the Timbisha Shoshone Tribe community within the Death Valley CCD, the NRC staff evaluated whether disproportionately high and adverse human health and environmental effects from groundwater impacts would affect the community. As discussed below, the NRC staff finds that the Timbisha Shoshone Tribe would not experience disproportionately high and adverse human health or environmental effects from the proposed repository.

Section 3.1.2 describes the impacts of surface discharges, assuming no pumping at Amargosa Farms, for both the present-day and cooler/wetter climate states. The assumption of no pumping at Amargosa Farms models the maximum quantity of groundwater, and potential contaminants, to discharge at surface locations in Death Valley (as discussed in Chapter 2; with present pumping rates at Amargosa farms, no contaminants from the repository would reach Death Valley). The sites where discharges of radiological and nonradiological contaminants

could occur are springs at the State Line Deposits/Franklin Well area (under a wetter climate only), springs at Furnace Creek, and the playa/salt pan at Middle Basin of Death Valley. The NRC staff estimated the peak impact at these two areas by conservatively assuming that the entire contaminant plume would discharge at each location. Biosphere dose conversion factors for these areas are based on exposures to full-time residents. As stated in Section 3.1.2.2, the dose pathways for a resident in these areas include external exposure, inhalation of soil/evaporite particulates and water vapor from evaporative coolers, and ingestion of water and soil/evaporite particulates. The NRC staff did not evaluate the ingestion of crops, animal products, and fish as pathways because there is little current agricultural production near the Furnace Creek area, and the NRC staff does not expect that wet playas would be used for agriculture. Likewise, for the Middle Basin wet playa, the NRC staff did not include the ingestion of water and exposure from evaporative coolers as pathways because the saline content of the water is unsuitable for such uses. Even in wetter climates, the wet playa water would be unsuitable for use as drinking water or in agriculture.

In Section 3.1.2.2, the NRC staff concludes that for the Furnace Creek area and for Middle Basin for the present-day and wetter climates: (i) the impact to the accessible environment for those locations would be SMALL; (ii) the soil impacts associated with groundwater discharges at Furnace Creek and Middle Basin would be SMALL; and (iii) the potential public health impacts from radiological and nonradiological contaminants associated with natural groundwater discharges at Furnace Creek and Middle Basin would be SMALL.

In Section 3.5 of its analysis of groundwater impacts (DOE, 2014a), DOE provided a discussion of potential impacts on members of the Timbisha Shoshone Tribe. This analysis is consistent with the NRC staff's conclusion. Based on its analysis, DOE states (DOE, 2014a; p.3-28):

> DOE has identified no high and adverse potential impacts to members of the general public associated with exposure to contaminants that may occur in groundwater following closure of a repository at Yucca Mountain. Further, DOE has not identified subsections of the population, including minority or low-income populations that would receive disproportionate impacts. Likewise, DOE has identified no unique exposure pathways that would expose minority or low-income populations to disproportionately high and adverse impacts. The Department acknowledges the sensitivities and cultural practices of the Timbisha Shoshone Tribe concerning the use and purity of springs in the [Furnace] Creek area; however, the information included in this Analysis of Postclosure Groundwater Impacts demonstrates that the potential concentrations of contaminants in those springs would be so low that there would be virtually no potential health effects associated with the use of those springs. Thus, this document supports the Department's previous conclusion that no disproportionately high and adverse impacts would result from a repository.

Based on its conclusions in Section 3.1.2 concerning impacts on groundwater, soils, and public health, the NRC staff finds no environmental pathway that would physiologically affect minority or low-income populations differently from other segments of the general population; therefore, the NRC staff concludes that no disproportionately high and adverse health or environmental impacts would occur to minority or low-income segments of the population in the Death Valley area.

3.4.3 NRC Staff Conclusion

The NRC staff acknowledges the sensitivities and cultural practices of the Timbisha Shoshone Tribe concerning the use and purity of springs in the Furnace Creek area. Based on the analysis above, the NRC staff determines that there would be no disproportionately high and adverse human health or environmental effects from uses or discharges of groundwater flowing from the repository on minority or low-income segments of the populations in the Amargosa Valley area and in Death Valley National Park.

3.5 Summary

In its 2008 SEIS, DOE determined that the waterborne pathway (groundwater flow to discharge locations downstream) would dominate potential postclosure impacts of a repository at Yucca Mountain. DOE found that its estimated mean annual individual dose at the postclosure compliance location was a small fraction of the 15 mrem/yr [0.15 mSv/yr] standard in 40 CFR Part 197 (for the first 10,000 years after closure). Similarly, DOE found that the estimated annual dose for the one–million-year period was a small fraction of the annual limit. DOE also found that significant human impacts from chemicals and anticipated adverse impacts to biological resources would be unlikely.

In this supplement, the NRC staff finds that the impacts to groundwater and from surface discharges of groundwater beyond the postclosure compliance location are SMALL.

The peak radiological dose from estimates for all locations evaluated in this supplement is 1.3 mrem/yr [0.013 mSv/yr], which occurs in the Amargosa Farms area for Analysis Case 1 (pumping). The NRC staff finds that the calculated radiological doses are SMALL because they are much lower than the NRC annual dose standards for a Yucca Mountain repository in 10 CFR Part 63 {15 mrem [0.15 mSv] for the first 10,000 years, and 100 mrem [1 mSv] for one million years, after permanent closure}. The peak dose estimates considered uncertainty in climate and pumping rates. Based on conservative assumptions about the potential for health effects from exposure to low doses of radiation, the estimated radiation dose is expected to contribute a negligible increase in the risk of cancer or severe hereditary effects in the potentially exposed population.

Impacts to all of the affected environments beyond the postclosure compliance location from nonradiological (chemicals) material from the repository were also found to be SMALL, as were radiological and nonradiological ecological impacts (Section 3.2).

4 CUMULATIVE IMPACTS

Chapter 3 of this supplement contains the U.S. Nuclear Regulatory Commission (NRC) staff's assessment of impacts on groundwater and on surface discharges of groundwater. In this chapter, the NRC staff evaluates the cumulative impacts of the direct and indirect impacts described in Chapter 3 when aggregated with the impacts of other actions that could affect the same resources. The NRC staff also evaluates how its findings in Chapter 3 and cumulative impact findings in this chapter affect the conclusions provided by U.S. Department of Energy (DOE) in its assessment of cumulative impacts on groundwater in Chapter 8 of its environmental impact statement (EIS) (DOE, 2002) and Chapter 8 of its supplemental EIS (SEIS) (DOE, 2008a).

A cumulative impact is "the impact on the environment that results from the incremental impact of [an] action when added to other past, present, and reasonably foreseeable future actions, regardless of what agency (Federal or non-Federal) or person undertakes such other actions" (NRC, 2003). Cumulative impacts can result from actions that are individually minor, but collectively significant, taking place over a period of time. A proposed project could contribute to cumulative impacts when its environmental impacts overlap with those of other past, present, or reasonably foreseeable future actions (RFFAs) in a given area. It is possible that a small impact from a proposed action could result in a larger cumulative impact when considered in combination with the impacts of other actions. The term "reasonably foreseeable" refers to future actions for which there is a reasonable expectation that the action could occur, such as a proposed action under analysis or a project that has already started.

This chapter is organized as follows: Section 4.1 describes the NRC staff's methodology in evaluating cumulative impacts; Section 4.2 describes the spatial and temporal boundaries for this cumulative impacts assessment; Section 4.3 describes the affected resource areas, consistent with the NRC staff's evaluation of impacts in Chapter 3; Section 4.4 identifies other related past, present, and reasonably foreseeable future actions that could contribute to cumulative impacts; and Section 4.5 presents the NRC staff's cumulative impacts analysis for the resource areas identified in Section 4.3 and Chapter 3. Sections 4.4 and 4.5 are each divided into two sections: the first section presents the information DOE provided in its 2002 and 2008 EISs; the second section presents the NRC staff's supplement to the 2002 and 2008 EISs, based upon the impacts evaluated in Chapter 3.

Because DOE's 2008 SEIS summarizes, incorporates by reference, and updates the information in the 2002 EIS, this chapter primarily refers to the 2008 SEIS. In addition, the NRC staff accepts the information in the 2002 EIS and the 2008 SEIS, unless otherwise noted in this chapter. As stated in the Adoption Determination Report (ADR), "[t]he NRC staff concludes that the 2002 EIS, the Repository Supplemental EIS, and the Rail Corridor SEIS meet NRC completeness and adequacy requirements in title10 of the *Code of Federal Regulations* (CFR) 51.91 and in 10 CFR Part 51, Subpart A, Appendix A, and that the EISs are generally consistent with NRC's National Environmental Policy Act (NEPA) guidance in NUREG–1748."

4.1 Methodology for Supplementing DOE's Cumulative Groundwater Impacts Analysis

This cumulative impacts assessment examines the incremental groundwater impacts of the repository, as evaluated in this supplement, in combination with other past, present, and RFFAs. The general approach for assessing cumulative groundwater impacts is based on the principles and guidance described in NRC environmental review guidance (NRC, 2003), which

incorporates by reference CEQ's *Considering Cumulative Effects under the National Environmental Policy Act* (CEQ, 1997) and EPA's *Consideration of Cumulative Impacts in EPA Review of NEPA Documents* (EPA, 1999c). Based on the review of applicable portions of these documents and the NRC's regulations for implementing NEPA in 10 CFR Part 51, the NRC staff used the following methodology for assessing cumulative impacts in this supplement:

1. The NRC staff reviewed the cumulative impacts analyses in DOE's EISs to determine how these analyses should be supplemented in light of the NRC staff's findings in Chapter 3 of this supplement. As noted in Chapter 1, the NRC staff did not conduct a scoping process for this supplement because the scope is already defined in the NRC staff's ADR.

2. The NRC staff identified several additional RFFAs that were not previously identified in DOE's EISs, but which could impact the relevant resource areas. The NRC staff evaluated these actions, along with the actions previously identified by DOE, in the cumulative impacts assessment in this supplement.

3. The affected environment for the cumulative impact analysis is described in Chapter 2. The direct and indirect impacts on particular resources, as described in Chapter 3, form the basis for the analysis in this chapter.

4.2 Spatial and Temporal Boundaries for Cumulative Groundwater Impacts

The spatial boundary for cumulative groundwater impacts consists of the area of the aquifer beneath Yucca Mountain and along the aquifer's flow path that could be affected by contaminant releases from the proposed repository (as described in detail in Section 2.2) or by other activities having the potential to affect groundwater. The spatial boundary also includes the types of areas aboveground where the groundwater from the Yucca Mountain flow path could naturally discharge to the surface (described in Section 2.3) or where groundwater is pumped, such as at Amargosa Farms (described in Section 2.2.2 and 2.2.3).

The temporal boundaries for cumulative impacts include impacts from past actions and extend to one million years after repository closure. The descriptions of the affected environment provided by DOE (2014a; 2008a; 2002), as supplemented by the NRC staff (Chapter 2), already encompasses the impacts of past human actions that may have previously affected groundwater. The affected area includes vast and remote areas of limited human activity in a predominantly naturally occurring state. Thus, the NRC staff concludes that the description of the affected environment in Chapter 2 provides a reasonable baseline for the assessment of cumulative groundwater impacts. The long duration of the temporal boundary is necessary because, as described in Section 3.1.2, DOE and the NRC staff's analyses indicate that contaminants released gradually from the repository would travel through the aquifer and potentially reach ground surface locations over a very long timeframe after repository closure. The analyses cover a period of one million years following repository closure, the nominal "period of geologic stability" used as a basis for defining the postclosure compliance period (70 FR 53,313). The NRC staff conducted a review to identify any near-term activities that could contribute to long-term cumulative groundwater impacts. However, the NRC staff concludes that using unsupportable assumptions about human activities occurring over the next

one million years would result in correspondingly unsupportable conclusions about the potential impacts.[1]

4.3 Potentially Affected Resources

Chapter 2 provides descriptions of the resource areas that could be affected by potential groundwater contamination from the repository and surface discharges of contaminated groundwater. These areas and their location in Chapter 2 are listed as follows.

- Groundwater in the volcanic-alluvial aquifer, described in Section 2.2.
- Resources associated with pumping and irrigation at Amargosa Farms, described in Sections 2.2 and 2.3. The resources potentially affected at groundwater pumping locations include groundwater, soils, ecological resources, and public health (including environmental justice concerns).
- Resources at current natural surface discharge locations (springs and playas) and potential future sites of natural surface discharge under a reasonably foreseeable wetter climate state, described in Section 2.3. The resources potentially affected at surface discharge locations include groundwater, soils, ecological resources, public health (including environmental justice concerns), and cultural resources.

Other past, present, or reasonably foreseeable future actions could contribute to potential cumulative impacts on these resources, in addition to the impacts from the proposed repository. These other actions are discussed in Section 4.4, and their potential impacts, along with impacts from the proposed repository, on these resource areas are discussed in Section 4.5.

4.4 Other Past, Present, and Reasonably Foreseeable Future Actions

This section summarizes the other past, present, and future actions identified by DOE in the 2002 and 2008 EISs (Section 4.4.1) and by the NRC staff for this supplement (Section 4.4.2). As described by the CEQ, identifying RFFAs is a critical component of a cumulative impacts analysis (CEQ, 1997). However, CEQ also recognizes that agencies should not engage in speculation in an effort to identify all actions that could contribute to overall potential cumulative effects. Given the long timeframes considered in this supplement, as described in Chapter 2, it is not possible to identify or reasonable to speculate about all potential public and private projects that could contribute to cumulative groundwater impacts over the course of the next one million years. Therefore, the NRC staff reviewed available information for the spatial boundary, including information in NEPA analyses and resource management plans, which together provide a reasonable picture of potential present or foreseeable future actions.

4.4.1 Actions Identified in DOE's EISs

Section 8.1 of the 2008 SEIS incorporates by reference and updates the information in the 2002 EIS. This section identifies past, present, and future actions that DOE considered to have

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[1]This is consistent with NRC regulations in 10 CFR 63.305(b) and EPA regulations in 40 CFR 197.15, which direct DOE not to project changes in society, the biosphere (other than climate), human biology, or increases or decreases of human knowledge or technology.

the potential to affect the same resources as those that would be affected by the repository. In Section 8.1.1, DOE states that the description of the existing environmental conditions in Chapter 3 of DOE's 2008 SEIS accounts for the impacts of past and present actions on the environment that the repository would affect. In Chapter 3 of that document, DOE describes the results of groundwater sampling to support its description of regional groundwater quality. DOE also provides information about contaminants in groundwater from past activities at the Nevada National Security Site (NNSS; formerly the Nevada Test Site). DOE used the baseline information in Chapter 3 to develop its assessment of the incremental environmental impacts of the proposed repository and, thus, its assessment of cumulative impacts.

The region of influence (or spatial boundary) DOE defined for its groundwater impacts assessment and used for its cumulative impacts assessment, as described in Section 4.1.3 of the 2002 EIS and referenced in Section 4.1.3 of the 2008 SEIS, includes "aquifers under the areas of construction and operations that DOE could use to obtain water, and downstream aquifers that repository use or long-term releases from the repository could affect." In its description of the groundwater environment in Chapter 3 of the 2002 EIS, DOE included the volcanic-alluvial aquifer and the lower carbonate aquifer as the aquifers that could be affected by radionuclide releases from the repository and by other Federal, non-Federal, and private activities. The NRC staff concludes that DOE's spatial boundary is appropriate for the purpose of identifying other past, present, and reasonably foreseeable future actions that could contribute to cumulative groundwater impacts because this area encompasses the flow path from the repository to potential discharge points and is thus consistent with the spatial boundary for groundwater impacts defined by the NRC staff in Section 4.2 of this supplement.

Other Federal, non-Federal, or Private Activities Identified by DOE

This section describes the actions DOE identified in its EISs as potential contributors to cumulative groundwater impacts.

Section 8.3.2 of the 2008 SEIS examines the cumulative impacts from past, present, and reasonably foreseeable future actions that have the potential to affect resources after repository closure. The actions DOE identified that could have the potential to contribute to long-term cumulative groundwater impacts are (i) past, present, and reasonably future actions at the NNSS, including nuclear weapons testing and radioactive waste management; and (ii) past and present actions at a low-level radioactive waste disposal facility and hazardous waste disposal facility located about 16 km [10 mi] southeast of Beatty, Nevada, or 15 km [9.3 mi] west of the proposed repository.

In its EISs, DOE did not identify mining as a potential contributor to cumulative groundwater impacts. Because there is currently mining activity within the spatial boundary for this analysis, the NRC staff determines that further assessment of these activities is needed. Section 4.4.2 provides more information about regional mining activity.

Additional Inventory Modules

Under the Nuclear Waste Policy Act (NWPA), the proposed repository would be a permanent disposal facility for up to 70,000 metric tons of spent nuclear fuel (SNF) and high-level radioactive waste (HLW). The NWPA requires the NRC to include in any construction authorization a condition prohibiting the emplacement of more than 70,000 metric tons of heavy metal or a quantity of solidified high-level radioactive waste resulting from the reprocessing of such a quantity of spent fuel in the first repository until a second repository is in operation

[NWPA, Section 114(d)]. DOE's proposed action, as described in its 2002 and 2008 EISs and in its Safety Analysis Report (SAR) (DOE, 2008b), is the construction of a repository and emplacement of up to 70,000 metric tons of spent nuclear fuel and high-level radioactive waste. In its 2002 EIS and 2008 SEIS analyses of cumulative impacts, DOE also included two RFFAs for the emplacement of waste beyond the 70,000-metric-ton limit, which DOE referred to as inventory modules. These modules accounted for the emplacement of additional SNF and other HLW, as well as Greater-Than-Class-C waste, at the Yucca Mountain repository. For this supplement, the NRC staff does not consider the inventory modules to be RFFAs because (i) DOE did not account for the additional waste inventories in its license application; and (ii) the NWPA prohibits both modules until such time as a second repository is in operation. Since no repository has been licensed, and no second repository is under consideration, the NRC staff concludes that a second repository is not reasonably foreseeable. The NRC staff further concludes that the modules are likewise speculative, therefore are not RFFAs, and are not considered further. If Congress enacts legislation that allows for the disposal of additional waste inventories at the Yucca Mountain repository before a second repository is in operation, any updated license application and associated environmental review would necessarily analyze the change in the proposed action.

NRC Staff Conclusions Regarding DOE's Identification of Other Actions

The NRC staff makes the following conclusions regarding the region of influence and identification of other actions in DOE's EISs:

- The NRC staff finds that the region of influence (spatial boundary) DOE used for identifying other actions that could affect groundwater is acceptable and reasonable because it extends throughout the area of the aquifer that could be affected by the repository or that would flow downstream to merge with groundwater flowing from the repository area, consistent with the description in Chapter 2 of the affected environment.

- The NRC staff has determined that in its EISs, DOE identified past, present, and reasonably foreseeable future actions that could affect groundwater along the flow path from the repository to the postclosure compliance location {18 km [11 mi] south of the repository site}. Specifically, the NRC staff finds that DOE appropriately identified the NNSS and the Beatty low-level radioactive waste disposal site as potential contributors to cumulative groundwater impacts after repository closure. The NRC staff concludes that the actions identified by DOE are reasonable for the evaluation of cumulative impacts at the postclosure compliance location and are acceptable for evaluation of cumulative impacts in this supplement because the actions may affect the regional groundwater flow system that would be affected by the repository.

- The NRC staff finds that the DOE EISs did not identify regional mining activity as a past, present, and reasonably foreseeable future action that could affect groundwater along the flow path from the repository to the postclosure compliance location. Therefore, the NRC staff has included information about regional mining in Section 4.4.2.

- For the reasons given in the previous section, the NRC staff concludes that the additional inventory modules are not reasonably foreseeable actions and does not address them further in this supplement.

- Because this supplement assesses groundwater impacts along the predominant groundwater flow path to the pumping location in Amargosa Farms and to surface

discharge locations in Death Valley, the NRC staff determines that further assessment is needed to determine whether there are (i) actions not identified by DOE, in addition to mining, that could affect groundwater downgradient from the postclosure compliance location and (ii) actions that could affect other resources at Amargosa Farms and at downgradient surface discharge locations, including those identified in DOE's EISs but not considered with the impacts identified in Chapter 3 of this supplement.

- DOE's analysis, as updated in the 2008 SEIS, is limited to actions already occurring or planned as of 2008. Thus, the NRC staff concludes that further supplementation is needed to describe actions planned or occurring since 2008 that could contribute to cumulative groundwater impacts, and to evaluate their potential cumulative impacts.

The results of the NRC staff's review are discussed in the next section.

4.4.2 NRC Staff Update and Supplementation of DOE EISs Identification of Other Actions

As discussed in the previous section, DOE's analysis included an assessment of impacts on groundwater at the postclosure compliance location. To address impacts on groundwater and from surface discharges of groundwater along the flow path beyond Amargosa Valley, the NRC staff supplements DOE's assessment by evaluating groundwater impacts at Amargosa Farms and at natural surface discharge locations in Death Valley. For this cumulative impacts assessment, the NRC staff has reviewed available information to determine whether other actions could affect the groundwater or resources at the surface discharge locations. In addition, the NRC staff has reviewed available information to determine whether actions planned or occurring after 2008 could have the potential to contribute to cumulative groundwater impacts.

The NRC staff consulted sources of publicly available information on existing and proposed activities, such as government websites, EISs, and resource management plans. The NRC staff also contacted Department of Interior (DOI), Bureau of Land Management (BLM) staff knowledgeable about RFFAs in the region.

Nevada National Security Site

DOE's National Nuclear Security Administration (NNSA) published its *Final Site-Wide Environmental Impact Statement for the Continued Operation of the Department of Energy/National Nuclear Security Administration Nevada National Security Site and Off-Site Locations in the State of Nevada (DOE/EIS-0426)* (NNSS SWEIS) in February 2013. The NNSS SWEIS assesses the potential environmental impacts of three alternatives for continued operations at the NNSS and operations at other DOE/NNSA-managed sites in southern Nevada. These alternatives are organized under three mission areas: (i) the National Security/Defense Mission, which addresses stockpile stewardship and management, nuclear emergency response, nonproliferation, counterterrorism, and other work; (ii) the Environmental Management Mission, which addresses waste management and environmental restoration; and (iii) the Nondefense Mission, which addresses general site support and infrastructure, conservation and renewable energy, and other research and development programs.

The sites in the spatial boundary of the NNSS SWEIS are the NNSS, the Tonopah Test Range {about 19 km [12 mi] north of the NNSS northern boundary}, and environmental restoration areas on the U.S. Air Force Nevada Test and Training Range (adjacent to the west, north, and

east of the NNSS). The three alternatives include similar types of programs, capabilities, projects, and activities, but differ primarily in their levels of operations and facility requirements. The NRC staff reviewed the December 30, 2014 Record of Decision (ROD) (79 FR 78421) and the NNSS SWEIS to determine whether any proposed or continuing activities could contribute to cumulative groundwater impacts within the spatial boundary of this analysis. The ROD and the NNSS SWEIS (DOE, 2013a; 2014c) state that DOE/NNSA would add new projects at the NNSS, including activities in the areas of nonproliferation and counterterrorism, high-hazard experiments involving explosives and nuclear materials, research and development, testing, renewable energy, and the disposal of a wide variety of wastes. Activities proposed for the Tonopah Test Range include the continuation of current activities (primarily weapons testing, experiments, and research and development) as well as improving infrastructure (such as communications, electrical transmission, and buildings) (DOE, 2013a; Table 3-3).

In addition, DOE/NNSA would continue or start new projects on the NNSS to manage or dispose of low-level radioactive waste (LLRW), LLRW mixed with hazardous waste (mixed LLRW), hazardous waste, solid waste, explosives ordnance, and site remediation wastes. With the exception of a proposed solid waste management facility that would be located in Area 25 (adjacent to the east of the Yucca Mountain site), all of these waste management activities are or would be located in the easternmost areas of the NNSS, more than 30 km [19 mi] from the proposed repository site. The depth to the water table in these eastern areas of the NNSS ranges from over 500 ft [152 m] to nearly 2,000 ft [610 m] (Winograd and Thordarson, 1975; DOE, 2013a; Section 4.1.6.2).

DOE/NNSA concludes that none of the proposed activities described in the NNSS SWEIS for the NNSS, the Tonopah Test Range, or the Nevada Test and Training Range would contribute to NNSS cumulative groundwater impacts (DOE, 2013a; Tables 3-4, 3-7). The NRC staff finds the conclusions of the NNSS SWEIS for these proposed new and continuing activities to be reasonable and acceptable, based on the NRC staff's understanding of the activities and that DOE/NNSS would continue managing the various types of wastes in compliance with applicable requirements, as described in Section 4.1.11 of the NNSS SWEIS.

Solar Energy Projects

DOI BLM has approved several renewable energy projects in Nevada and California in recent years as part of a larger, national effort to promote the growth of solar, wind, and geothermal energy generation. None of the approved solar, geothermal, or wind energy projects are located within the region of influence identified for this supplement (i.e., the geographic area overlying the area of the aquifer that could be affected by the repository or that would flow downstream to merge with groundwater flowing from the repository). However, three areas within the region of influence may be developed as solar energy facilities. Two of the areas could be developed as small (50-megawatt) photovoltaic energy facilities (Helseth, 2015). The third area is a larger zone designated recently by the BLM and DOE as a "solar energy zone" (SEZ), established as part of a BLM program to encourage solar energy development. This zone, named the Amargosa Valley SEZ, is located in the Amargosa Desert between the Funeral Mountains to the southwest and Yucca Mountain to the northeast. The SEZ is on BLM-administered land and the developable area within it is 8,479 acres [34.3 km^2]. There are no pending solar applications within the SEZ, but the BLM will encourage future interested parties to site projects within this zone (BLM, 2012a,b). Withdrawal of small amounts of water for construction {approximately 200 acre-ft [246,700 m^3] per photovoltaic facility} or operations {approximately 5 acre-ft [6,170 m^3] per photovoltaic facility per year} would be the principal impact on groundwater from the development of solar energy in this area (Helseth, 2015). The

NRC staff concludes that these solar projects would not regularly produce liquid wastes, with the exception of sanitary wastewater and, depending on the type and size of the facility, blowdown water from a steam boiler. Such wastewaters would be retained (e.g., in septic systems or evaporative ponds) and would not be discharged to groundwater (BLM, 2010; Section 5.9). Therefore, the NRC staff concludes that these activities would not result in groundwater contamination and would not contribute to cumulative groundwater impacts.

Mining Activities

The BLM administers the mineral estate on public lands in Southern Nevada. The BLM *Las Vegas and Pahrump Field Offices Draft Resource Management Plan/Environmental Impact Statement* (BLM, 2014) describes historic, current, and future trends in mining activities in various regions of southern Nevada and evaluates the potential environmental impacts. The BLM EIS describes mining activities that have occurred in the vicinity of the town of Beatty and in Amargosa Valley, which are limited in the number of operations. These areas are within the region encompassed by the groundwater flow paths considered in this supplement, as described in Section 2.2.2. The mining activities include current gold and silver mining in the Bare Mountain district in the vicinity of Beatty, Nevada. Current conditions include one open pit and two underground mines. BLM indicates the level of precious metal mining activity is linked to market conditions, and future mining trends are, therefore, difficult to forecast. Amargosa Valley (in both Nevada and California) produces nonmetallic resources, including magnesium clays (used as binding agents, thickeners, gels, and in filtering) and zeolites (used in filtration systems, cat litter, and animal feed). Current conditions include ongoing production that has been limited by the recent economic recession. BLM projects that production would improve as the local, regional, or global economy improves. The BLM EIS impact analysis states that mineral extraction has the potential to impact surface water and groundwater quality due to increased sedimentation from surface disturbances and the potential for releases of wastewater. BLM concludes that the degree of impacts would depend on the level of preplanning and analysis, the provision of bonding to ensure sufficient funds would be available to mitigate potential impacts, and the regulatory stipulations aimed at protecting wildlife and other resource values, which would also protect water resources. BLM concludes impacts could be negligible to moderate but would be addressed through best management practices and other mitigation. Based on the information provided in the BLM EIS, the NRC staff concludes that the extent of mining activity in the region of the groundwater flow path is limited, and the existing permitting and associated regulatory protections would limit potential groundwater impacts to minimal levels. Based on this review, the NRC staff concludes that the omission of mining activities from the DOE cumulative impact analysis is not likely to have affected impact conclusions; however, these activities are included in the NRC supplement.

The NRC staff evaluated the description of other land uses for the repository site provided in DOE's SAR (DOE, 2008b), and conducted an independent evaluation of the Yucca Mountain site description as part of its review (NRC, 2015a, Section 2.1.1.1.3.9; NRC 2014b, Sections 2.5.8 and 2.5.9). Based on the results of this review, the NRC staff has not identified other activities that would contribute to cumulative groundwater impacts.

4.5 Cumulative Impacts on Groundwater and from Surface Discharges

This section evaluates repository impacts on groundwater and from surface discharges when added to the aggregate effects of other past, present, and reasonably foreseeable future actions. As described in Chapter 3, the incremental impacts for all resource areas and locations would be SMALL. This section provides the NRC staff's review of the cumulative impact

assessment in DOE's EISs (Section 4.5.1) and the NRC staff's supplement to the cumulative impacts analyses in DOE's EISs for the impacts identified in Chapter 3 (Section 4.5.2).

4.5.1 Impact Assessment in DOE's EISs

In Section 8.3.2 of the 2002 EIS (as updated in Section 8.3.2 of DOE's 2008 SEIS), DOE assessed the potential cumulative impacts from other Federal, non-Federal, and private actions that could contribute to doses from modeled groundwater contamination at the postclosure compliance location, which is the location of the reasonably maximally exposed individual (RMEI), as defined in 40 CFR 197.21. DOE assessed the cumulative impacts associated with the NNSS and the Beatty waste management and disposal sites. A summary of DOE's assessments and the NRC staff's conclusions regarding DOE's assessments are provided in the sections that follow.

Nevada National Security Site

In the 2002 EIS, DOE made assumptions about the magnitude and timing of radiological releases from the NNSS (assuming, for example, that the peak groundwater concentrations of contaminants from the NNSS would coincide in time and space with the peak groundwater concentrations from repository contaminants). The NRC staff considers these assumptions to be conservative because the maximum concentrations of groundwater contaminants flowing from the repository and from multiple locations in the NNSS through a vast space for hundreds of thousands of years are unlikely to reach the same location at the same time. DOE also assumed that any contaminated groundwater from the NNSS would flow along the same paths as those for repository contaminants (DOE, 2002). The NRC staff also considers this to be a conservative assumption because the different groundwater flow paths for the NNSS contaminants are likely to cause dispersion of contaminants, depending on factors such as solubility, sorption rates, and the volume of groundwater flow. Based on available information about contamination migrating from the NNSS (DOE, 2013a), the NRC staff concludes that DOE's assumptions as described previously are reasonable and conservative in considering the potential cumulative groundwater impacts from the NNSS.

In assessing potential impacts from future LLRW disposal activities in Areas 3 and 5 of the NNSS, DOE summarized various ongoing and proposed LLRW and mixed LLRW activities in its 2002 EIS (Section 8.3.2.1.3). DOE concluded that the only possible groundwater impacts from these activities would be from a few hazardous chemicals (1,2-dichloroethane, methylene chloride, and benzene), but that these chemicals are not within the inventory of chemicals from the repository. The NRC staff agrees that these chemicals are not among those that would be released from the repository. Further, the depth to the water table in Areas 3 and 5 ranges from over 500 ft [152 m] to nearly 2,000 ft [610 m] (DOE, 2013a; Section 4.1.6.2; Winograd and Thordarson, 1975), and the NRC staff concludes that any small amount of contaminants leaking from these LLRW activities would be detected and remediated before they could affect groundwater. This conclusion is based on the NRC staff's assumption that DOE/NNSA would continue managing the LLRW and mixed LLRW wastes, in compliance with applicable requirements, as described in Section 4.1.11 of the NNSS SWEIS.

Beatty Low-Level Waste and Hazardous Waste Disposal Facilities

The Beatty LLRW facility, located on U.S. Highway 95 approximately 12 mi [19 km] south of the town of Beatty, stopped accepting radioactive waste in 1992 and is under the permanent custody of the Nevada Department of Health and Human Services Division of Public and

Behavioral Health. In Section 8.3.2 of the 2002 EIS, DOE provided an assessment of the quantity of radionuclides that could be available for groundwater transport and possibly contribute to cumulative groundwater impacts. DOE found the quantity of radionuclides at the Beatty site to be a small fraction of the quantity of radionuclides available for release and transport from initial failures of waste packages at the proposed Yucca Mountain repository. Therefore, DOE concluded that the Beatty LLRW site would be a small contributor to long-term cumulative impacts (DOE, 2002). The NRC staff finds DOE's conclusions about this site are supported by the available information and are therefore reasonable and acceptable.

Additionally, DOE noted that the co-located Beatty hazardous waste treatment, storage, and disposal facility is permitted under the Resource Conservation and Recovery Act and has engineered barriers and administrative controls that minimize the potential for offsite migration of hazardous constituents (DOE, 2002). This is consistent with the NRC staff's understanding of the management of these facilities. In particular, the Beatty facility is equipped with two liners, with leachate collection and removal systems placed between and above the liners; thus, any leakage from the facility would be collected and removed (NDEP, 2011; Section 7).

NRC Staff Conclusions Regarding DOE's Assessment

DOE's assumptions and analysis regarding the contribution to radiological and nonradiological groundwater contamination by the NNSS and the Beatty site are conservative for assessing the cumulative groundwater impacts at the postclosure compliance location. The NRC staff notes that a fire occurred at the Beatty low-level radioactive waste disposal site on October 18, 2015. An incident report (NDPS, 2015) determined that the fire was caused by openings in the cover that allowed water to infiltrate drums of metallic sodium. The report concluded that no injuries to personnel occurred, that the effects of the fire were contained to the immediate site, and that no radioactive materials were released due to the fire.

The NRC staff has determined that the groundwater flowing below Yucca Mountain is most likely to be impacted by those NNSS activities located in areas of the NNSS in the Alkali Flat-Furnace Creek Basin (Figure 2-3). Potential contaminants from NNSS activities in areas of the NNSS in the Pahute Mesa-Oasis Valley Basin (Figure 2-3) could also mix with groundwater from below Yucca Mountain in the Amargosa Desert area (see discussion in Section 2.2.1). Interactions of the Yucca Mountain flow path with water from the Ash Meadows Basin is much less likely (Section 2.2.2). Based on the potential contaminants that could be released from the NNSS and the Beatty waste disposal facilities and DOE's analysis, the NRC staff finds DOE's conclusions about the potential cumulative impact contribution of these sites to impacts at the postclosure compliance location to be reasonable. The NRC staff, therefore, concludes that DOE adequately addressed the possible contributions of radiological contaminants from the NNSS and the Beatty LLRW site to cumulative groundwater quality impacts. The NRC staff concludes that the NNSS and the Beatty LLRW and hazardous waste facilities are unlikely to contribute nonradiological contamination to groundwater. Further, the NRC staff concludes that while these sites could contribute to cumulative radiological impacts on groundwater along the flow path from the repository, the impacts would be reduced because of the attenuating effects of dispersion and radioactive decay as contaminants move through the groundwater flow path from the repository.

4.5.2 NRC Staff Supplementation of DOE EISs Cumulative Impacts Assessment

The following sections provide the NRC staff's supplementation to DOE's cumulative groundwater impacts analysis based on (i) the NRC staff's review of DOE's identification of

past, present, and future actions in Section 4.4.1; (ii) the NRC staff's review of DOE's assessment of cumulative impacts in Section 4.5.1; and (iii) the NRC staff's updated identification of past, present, and reasonably foreseeable future actions in Section 4.4.2. Updates are included, as necessary, for cumulative groundwater impacts discussed in the groundwater subsections of Sections 4.5.2.1 (for the Amargosa Farms area) and 4.5.2.2 (for natural surface discharge locations). Supplementation is provided for cumulative impacts on other affected resources at Amargosa Farms area in Sections 4.5.2.1 (soils, ecological resources, public health, and environmental justice) and surface discharge locations in 4.5.2.2 (soils, ecological resources, public health, environmental justice, and cultural resources).

4.5.2.1 Cumulative Impacts on Affected Resources at Amargosa Farms

This section discusses cumulative impacts on groundwater and from pumping and irrigation in the affected environment described in Chapter 2. The impacts at Amargosa Farms are reported separately from the natural discharge locations because Amargosa Farms is not a natural discharge location and the evaluation of impacts involves a consideration of different environmental processes and pathways. As in Chapter 3, the analysis of impacts considers both the present-day and future cooler/wetter climates.

4.5.2.2 Groundwater at Amargosa Farms

Section 3.1.1 describes the incremental impacts on groundwater (the estimated concentrations of contaminants in the groundwater) at the Amargosa Farms area, which is approximately 17 km [11 mi] beyond the postclosure compliance location, or approximately 35 km [22 mi] along the flow path from Yucca Mountain. Tables 3-1a and 3-1b show the estimated levels of contaminants in the aquifer environment beyond the postclosure compliance location up to Amargosa Farms and at Amargosa Farms, respectively. Using the estimated concentrations in the Amargosa Farms area as representative of the aquifer that is subject to groundwater withdrawal in that area, Table 3-2 lists the average estimated groundwater concentrations of radiological and nonradiological material from the repository in the aquifer at Amargosa Farms for both the present-day and future wetter climates. As shown in Table 3-2, the estimated total concentration of all of the radionuclides in groundwater at Amargosa Farms from releases at the repository are lower than the applicable EPA standards for drinking water. No standards have been established for the nonradiological contaminants listed in the table, but the concentrations of each are much lower than one part per million, and are comparable to natural levels in the water (Table 2-2). As stated in the Aquifer Environment section of Section 3.1.1, based on the NRC staff's analysis of the potential future accumulation of radiological and nonradiological material released from the repository to the aquifer environment between the postclosure compliance location and Amargosa Farms, the NRC staff finds that the incremental impact on the aquifer environment beyond the postclosure compliance location would be SMALL.

Based on the information provided in Sections 4.4.1 and 4.4.2 concerning other actions and the NRC staff's conclusions about DOE's assessment in its EISs of cumulative groundwater impacts in Section 4.5.1, the NRC staff has identified only regional mining activity as an additional action that was not already identified by DOE as a potential contributor to cumulative groundwater impacts. As described in Section 4.4.1, the NRC staff concluded the extent of mining activity in the region of the groundwater flow path is limited and considering existing regulatory protections, the potential groundwater impacts would be minimal. The NRC staff has also identified new information concerning groundwater contamination resulting from past NNSS activities, discussed as follows.

As discussed in Section 4.5.1, in its EISs, DOE identified groundwater contamination from the NNSS as a possible contributor to cumulative groundwater impacts. Since the 2008 SEIS was published, DOE has detected and described contamination migrating off the NNSS. DOE provided information on this contamination in the NNSS SWEIS (discussed in Section 4.4.2) and it is summarized here. In its NNSS SWEIS description of affected groundwater at the NNSS, DOE/NNSA reports that tritium was detected in two offsite wells. In 2009, DOE/NNSA detected tritium in Well ER-EC-11, which is less than one half-mile off the northwestern boundary of the NNSS on the Nevada Test and Training Range and about 23 km [14 mi] from the nearest public water source, a private well. The tritium concentration was 13,180 pCi/L, which is below the EPA's MCL of 20,000 pCi/L. In 2010, DOE/NNSA found low levels of tritium (48.3 pCi/L) in Well PM-3, located about 11,000 ft [3,353 m] west of the NNSS boundary on the Nevada Test and Training Range (DOE, 2013a).

DOE/NNSA concluded that tritium releases in this area could eventually flow to the southwest, possibly discharging in the Amargosa River area or in Death Valley (DOE, 2013a; Section 6.3.6.2). Based on the NRC staff's knowledge of groundwater flow, as described in Chapter 2, and the manner in which tritium moves through groundwater, the NRC staff finds the DOE/NNSA conclusion to be reasonable, but that the tritium releases are unlikely to lead to appreciable impacts. This is because the NNSS tritium releases would need to travel a long distance to the Amargosa Farms area, and because tritium migration identified to date is of limited extent. Additionally, as shown in Tables 3-1a, 3-1b, and 3-2, tritium is not a repository contaminant likely to reach the aquifer at this location due to the long delay for repository releases and the relatively short half-life of tritium (12.3 years). Therefore, the NRC staff concludes that tritium from the NNSS would likely decay to negligible levels before arriving at Amargosa Farms in conjunction with contaminants from the repository. Therefore, the NRC staff concludes that tritium contamination would not contribute cumulatively with the radionuclides from the repository.

Considering the information provided previously regarding regional mining activities, tritium releases from the NNSS, and the NRC staff's conclusions in Section 4.5.1 about DOE's analysis of cumulative groundwater impacts from the NNSS and the Beatty disposal sites, the NRC staff concludes that the cumulative impacts on groundwater at the Amargosa Farms area would be SMALL because any additional contaminants from these sites would likely not be detectable or would be so minor that they would not noticeably alter groundwater characteristics beyond the effects that could be attributed to the repository alone.

Soils at Amargosa Farms

Section 3.1.1 describes the potential accumulation from irrigation of radiological and nonradiological contaminants in irrigated soils at Amargosa Farms. Table 3-3 provides estimated concentrations in soils at 10,000 and one million years for the present-day and future wetter climates, as well as natural background concentrations and U.S. Environmental Protection Agency (EPA) screening levels for comparison purposes. As stated in Section 3.1.1, the calculated maximum soil concentrations for all of the contaminants are well below the EPA generic soil screening levels. Based on the NRC staff's analysis of the accumulation in soils at Amargosa Farms of radiological and nonradiological material released from the repository, the NRC staff finds that the incremental impact on soils at Amargosa Farms would be SMALL.

Based on the information provided in Sections 4.4.1 and 4.4.2 concerning other actions, the NRC staff has identified only regional mining activity impacts on groundwater and NNSS tritium releases as additional actions or impacts that could contribute to cumulative soils impacts at the

irrigated Amargosa Farms area. Given the NRC staff's assessment of cumulative groundwater impacts provided in the previous section, which indicates that potential mining impacts would be mitigated by regulatory controls and would have minimal impacts on groundwater, and the NRC staff's conclusions in Section 4.5.1 about DOE's analysis of cumulative groundwater impacts from the NNSS and the Beatty disposal sites, the NRC staff concludes that the cumulative impacts on soils at the Amargosa Farms area from irrigation would be minimal and would not noticeably alter the soils beyond the potential impacts that could be attributed to the repository alone.

Public Health at Amargosa Farms

Section 3.1.1 provides the potential impacts at the Amargosa Farms area of groundwater contaminants on public health associated with external exposure, inhalation of soil particles and from evaporative coolers, and ingestion of water, crops, animal products, fish, and soil. As stated in that section, the largest contributors to dose for both the present-day and future wetter climates at Amargosa Farms are I-129, Tc-99, Np-237, and Th-230. At 10,000 years, I-129 and Tc-99 are the primary contributors to dose. Table 3-4 lists the peak annual dose estimates. The peak dose of 1.3 mrem/yr [0.013 mSv/yr] (occurring at one million years for the wetter climate) is a small fraction of the dose from natural background levels of approximately 300 mrem/yr [3.0 mSv/yr] (including radon) for Amargosa Valley, and is much lower than the NRC annual dose standards for a Yucca Mountain repository in 10 CFR Part 63 {15 mrem [0.15 mSv] for the first 10,000 years, and 100 mrem [1 mSv] for one million years, after permanent closure}.

The NRC staff assessed human health impacts from nonradiological contaminants by comparing daily intakes with EPA's Oral Reference Dose standard. Table 3-5 provides the estimated values of peak daily intakes for each of the nonradiological contaminants for the one-million-year period and shows that these values are lower than the EPA Oral Reference Doses. The Oral Reference Doses are the levels below which no detectable health effects would occur. As stated in Section 3.1.1, based on the NRC staff's analyses of radiological and nonradiological material released from the repository to the Amargosa Farms area, the NRC staff finds that the incremental impact of contaminants released from the repository on public health at the Amargosa Farms area would be SMALL.

Based on the information provided in Sections 4.4.1 and 4.4.2 concerning other actions, the NRC staff has identified only regional mining activity impacts on groundwater and NNSS tritium releases as additional actions or impacts that could contribute to cumulative public health impacts at the Amargosa Farms area. The NRC staff's assessment above of cumulative groundwater impacts at Amargosa Farms notes that, because tritium released from the NNSS would need to travel a long distance to the Amargosa Farms area, tritium from the NNSS would likely decay to negligible levels before arriving at Amargosa Farms in conjunction with contaminants from the repository. Given the NRC staff's assessment of cumulative groundwater and cumulative soils impacts at Amargosa Farms provided in the previous sections, and the NRC staff's conclusions in Section 4.5.1 about DOE's analysis of cumulative groundwater impacts from the NNSS and the Beatty disposal sites, the NRC staff concludes that the cumulative impacts on public health at the Amargosa Farms area would be minimal and would not noticeably affect public health beyond the potential public health impacts from the repository alone.

Ecological Resources at Amargosa Farms

Section 3.2 discusses the incremental impacts on ecological resources in the Amargosa Farms area. The NRC staff evaluated the potential for nonhuman biota to be exposed to radionuclides at the Amargosa Farms area, based on the estimated magnitude of radioactivity in the environment as quantified by the human dose estimates provided in Sections 3.1.1 and 3.1.2. Because the human dose estimates are a small fraction of background radiation exposure, the NRC staff concludes in Section 3.2 that the estimated levels of radioactivity in the environment would be well below levels of concern for potential impacts to nonhuman biota.

The NRC staff also evaluated the potential for nonhuman biota to be exposed to potentially harmful levels of nonradiological chemicals at Amargosa Farms, based on the aquifer and soil concentrations in Sections 3.1.1 and 3.1.2 for present-day and future wetter climates and for both 10,000-year and one-million-year timeframes. The NRC staff compared the estimated aquifer and soil concentrations with ecological impact concentrations from available scientific data on the toxicity of the relevant chemicals. Table 3-15 compares estimated aquifer and soil concentrations at Amargosa Farms with ecological impact concentrations. The estimated water and soil concentrations of radiological and nonradiological contaminants at Amargosa Farms are below the ecological impact threshold concentrations; therefore, the NRC staff concludes that incremental environmental impacts to nonhuman biota from these constituents would be SMALL.

Based on the information provided in Sections 4.4.1 and 4.4.2 concerning other actions, the NRC staff has identified only regional mining activity and NNSS tritium releases as additional actions or impacts that could contribute to cumulative ecological resources impacts at the Amargosa Farms area. Given the NRC staff's assessment of cumulative groundwater, soil, and public health impacts at Amargosa Farms provided previously, and the NRC staff's conclusions in Section 4.5.1 about DOE's analysis of cumulative groundwater impacts from the NNSS and the Beatty disposal sites, the NRC staff concludes that the cumulative impacts on ecological resources at the Amargosa Farms area would be nonexistent or so small as to not be detectable or not noticeably affect nonhuman biota beyond the potential impacts from the repository alone.

Environmental Justice at Amargosa Farms

Section 3.4.2 provides the NRC staff's assessment of the potential for disproportionately high and adverse human health or environmental effects on minority and low-income populations in the Amargosa Valley area. Based on the information presented in Table 3-18, the NRC staff concludes that the low-income population in the Amargosa Valley Census County Division is a significant environmental justice population. Section 3.4.2 further states that based on the conclusions in Section 3.1.1 concerning impacts on groundwater, soils, and human health, that the NRC staff finds no environmental pathway that would physiologically affect minority or low-income populations differently from other segments of the general population. Therefore, the NRC staff concludes that no disproportionately high and adverse health or environmental impacts would occur to minority or low-income populations in the Amargosa Valley area.

Because the NRC staff has not identified any impacts related to environmental justice in the Amargosa Valley area, the NRC staff concludes that, likewise, no cumulative impacts related to environmental justice would occur in this area.

4.5.2.3 Cumulative Impacts on Affected Resources at Natural Surface Discharge Locations

This section evaluates cumulative impacts at current and potential future natural surface discharge locations (identified in Chapter 2). As in Chapter 3, the discussion of natural discharge locations considers both the present-day and future cooler/wetter climates. The potential future discharge locations are conservatively based on a future cooler/wetter climate.

Groundwater at Natural Surface Discharge Locations

In Chapter 3, the NRC staff assessed potential incremental groundwater impacts at the State Line Deposits/Franklin Well area (Section 3.1.2.1), the Furnace Creek springs area (Section 3.1.2.2), the Middle Basin area (Section 3.1.2.2), and at Alkali Flat (Section 3.1.2.3). Summaries of these impact assessments and the NRC staff's conclusions for these areas are provided as follows.

The State Line Deposits (paleospring deposits) are in the area where the Amargosa River and Fortymile Wash join and the Franklin Well area refers to the stretch of the Amargosa River channel at the southern extent of the State Line Deposits area. There is no current surface discharge at this location, except for limited evapotranspiration in a narrow band of vegetation at Franklin Well (Section 2.3.3). Paleospring deposits at this location indicate that surface springs and playas are likely in a future cooler/wetter climate (Section 2.3.4). Section 3.1.2.1 describes several features of the aquifer environment in this area (e.g., its location downstream of Amargosa Farms and dilution from mixing with uncontaminated groundwater) that lead the NRC staff to conclude that groundwater concentrations and accumulations of material sorbed onto sediments would be less than in the aquifer environment at Amargosa Farms. The NRC staff concludes that the incremental impact on groundwater at the State Line Deposits/Franklin Well area would be SMALL.

To estimate groundwater impacts at Furnace Creek, the NRC staff conservatively assumed that the entire groundwater contaminant plume would discharge to Furnace Creek (instead of discharging partially at this location and partially at Middle Basin). Table 3-9 presents the estimated average concentrations of important radionuclides and nonradiological elements in groundwater discharging at Furnace Creek. The NRC staff finds that the only radiological and nonradiological material reaching Furnace Creek would be small amounts of Tc-99, I-129, and Mo, and thus the NRC staff finds that the incremental groundwater impacts at Furnace Creek would be SMALL.

To estimate groundwater impacts at Middle Basin, the NRC staff conservatively assumed that the entire groundwater contaminant plume would discharge to Middle Basin (instead of discharging partially at the Basin and partially at Furnace Creek). The NRC staff concludes that groundwater concentrations of the elements listed in Table 3-9 (for Furnace Creek) would be similar for discharges at the Middle Basin, but it is unlikely that free-flowing water would appear in the wet playa environment. As discussed in Section 3.1.2.2, the only radiological and nonradiological material reaching Middle Basin would be small amounts of Tc-99, I-129, and Mo, and thus the NRC staff finds that the incremental groundwater impact at Middle Basin would be SMALL.

Conservatively assuming that there is limited or no pumping at the Amargosa Farms area, groundwater modeling indicates that the majority of contaminants transported from Yucca Mountain will be discharged at Furnace Creek (or the State Line Deposits area in a future

wetter climate) prior to reaching Middle Basin in Death Valley. The NRC staff concludes that only a small fraction of contaminants may be directed southward toward the Alkali Flat area. For this reason, as stated in Section 3.1.2.3, the NRC staff did not calculate estimates of contaminants in the groundwater at Alkali Flat. Rather, the NRC staff observes that the portion of the contaminant plume reaching Alkali Flat is less than 1 percent, and concludes that the incremental groundwater impacts at Alkali Flat would be a small fraction of those calculated for the other surface discharge areas. Therefore, incremental groundwater impacts for Alkali Flat would be SMALL.

Based on the information provided in Sections 4.4.1 and 4.4.2 concerning other actions, the NRC staff has identified only regional mining activity and NNSS tritium releases as additional actions or impacts that could contribute to groundwater impacts at surface discharge locations. Because tritium released from the NNSS would need to travel a long distance to these locations (further than for Amargosa Farms), tritium from the NNSS would likely decay to negligible levels before arriving at any surface discharge locations in conjunction with contaminants from the repository. Based on the NRC staff's conclusions in Section 4.5.1 about DOE's analysis of cumulative groundwater impacts from the NNSS and the Beatty disposal sites, and the NRC staff's assessment in Section 4.5.2.1 of cumulative groundwater impacts at the Amargosa Farms area, the NRC staff concludes that the cumulative impacts on groundwater at these surface discharge areas would be minimal and would not noticeably alter groundwater characteristics beyond the effects that could be attributed to the repository alone.

Soils at Natural Surface Discharge Locations

In Chapter 3, the NRC staff assesses potential incremental soil impacts at the State Line Deposits/Franklin Well area (Section 3.1.2.1), the Furnace Creek and Middle Basin areas (Section 3.1.2.2), and Alkali Flat (3.1.2.3). Summaries of the assessments and the NRC staff's conclusions for these areas are provided as follows.

Section 3.1.2.1 provides estimates of soil contaminant concentrations for the wet climate at the State Line Deposits/Franklin Well area because the NRC staff finds that contaminants would accumulate in soils only for the cooler/wetter climate state, when the water table could rise approximately 20 to 30 m [66 to 98 ft] above its present level. Table 3-6 provides estimates of the concentrations of radiological and nonradiological constituents in soil for this area under the cooler/wetter climate. At one million years, all contaminants remain below screening and impact levels, as shown in Table 3-6 and as described further in Section 3.1.2.1. Based on the NRC staff's analysis of the accumulation in soils of radiological and nonradiological material released from the repository, the NRC staff finds that the incremental impact on soils in the State Line Deposits/Franklin Well area would be SMALL.

Section 3.1.2.2 describes the accumulation of repository materials in soils at Furnace Creek and Middle Basin in Death Valley. Radionuclide contaminants would not reach either location in Death Valley within 10,000 years under the present-day climate, even with limited or no pumping. Over the longer time period, and in the cooler/wetter climate, only nonsorbing contaminants would reach Death Valley. Table 3-10 provides estimates of maximum soil/evaporite contaminant concentrations for radiological (I-129 and Tc-99) and nonradiological (Mo) constituents for these areas. Because the soil accumulations of radiological and nonradiological contaminants are very low, the NRC staff finds that incremental soil impacts associated with natural groundwater discharges at Furnace Creek springs and Middle Basin would be SMALL.

As stated in Section 3.1.2.3, the NRC staff did not specifically calculate estimates of contaminants in the groundwater at Alkali Flat and thus did not calculate concentrations in soils. Rather, the NRC staff observes that the portion of the contaminant plume reaching Alkali Flat is expected to be very small (less than 1 percent of the potential release reaching the postclosure compliance location) and concludes that the incremental groundwater impacts at Alkali Flat would be a small fraction of those calculated for the other surface discharge areas. Thus, the resulting impacts on soils at Alkali Flat would also be a small fraction of the impacts on soils at the other discharge locations. Therefore, incremental soil impacts for Alkali Flat would be SMALL.

Based on the information provided in Sections 4.4.1 and 4.4.2 concerning other actions, the NRC staff has identified only regional mining activity and NNSS tritium releases as additional actions or impacts that could contribute to cumulative soils impacts at the State Line Deposits/Franklin Well area, the Furnace Creek and Middle Basin areas of Death Valley, and at Alkali Flat. Given the NRC staff's assessment of cumulative groundwater impacts provided in the previous section and for the Amargosa Farms area (Section 4.5.2.1), and the NRC staff's conclusions in Section 4.5.1 about DOE's analysis of cumulative groundwater impacts from the NNSS and the Beatty disposal sites, the NRC staff concludes that the cumulative impacts on soils at these areas would be minimal and would not noticeably alter the soil composition beyond the potential impacts from the repository alone.

Public Health at Natural Surface Discharge Locations

In Chapter 3, the NRC staff assessed potential incremental public health impacts at the State Line Deposits/Franklin Well area (Section 3.1.2.1), the Furnace Creek springs and Middle Basin areas (Section 3.1.2.2), and at Alkali Flat (Section 3.1.2.3). Summaries of these assessments and the NRC staff's conclusions for these areas are provided as follows.

The largest contributors to dose for both the present-day and future cooler/wetter climates at the State Line Deposits area are I-129, Tc-99, Np-237, and Pu-242 (Figure 3-3). Combined-radionuclide peak dose (including all radionuclides) and body intake for nonradiological chemicals are provided in Table 3-7 for 10,000 and one million years for the future wetter climates. Section 3.1.2.1 states that estimates of dose and nonradiological body intake for the present-day climate are extremely small because of the small area affected (Franklin Well area) and the limited amount of evapotranspiration. For the future cooler/wetter climates, the peak dose of 0.34 mrem/yr [0.0034 mSv/yr] in Table 3-7 is a small fraction of the dose from natural background levels of approximately 300 mrem/yr [3.0 mSv/yr] (including radon) for Amargosa Valley and much lower than the NRC annual dose standards for a Yucca Mountain repository in 10 CFR Part 63 {15 mrem [0.15 mSv] for the first 10,000 years, and 100 mrem [1 mSv] for one million years, after permanent closure}. For all of the nonradiological contaminants at this location in the cooler/wetter climate, the estimates of body intake are significantly lower than the EPA Oral Reference Dose. Based on the NRC staff's analyses of radiological and nonradiological material released from the repository to the State Line Deposits/Franklin Well area, the NRC staff finds that the impact to public health would be SMALL.

Section 3.1.2.2 evaluates the public health impacts of estimated discharges at Furnace Creek and Middle Basin. Because of the longer flow path and sorption in the aquifer, only nonsorbing radionuclides reach the natural discharge locations in Death Valley. The primary contributors to dose at this location are the nonsorbing radionuclides Tc-99 and I-129. Table 3-11 in Section 3.1.2.2 provides the peak annual dose estimates for the Furnace Creek area. All

estimated doses for either climate state are below 1 mrem [0.01 mSv], which is a small fraction of the dose from natural background levels of approximately 300 mrem/yr [3.0 mSv/yr] (including radon) for Amargosa Valley and much lower than the NRC annual dose standards for a Yucca Mountain repository in 10 CFR Part 63 {15 mrem [0.15 mSv] for the first 10,000 years, and 100 mrem [1 mSv] for one million years, after permanent closure}. The only nonradiological contaminant from the repository determined to be present in groundwater discharging at Furnace Creek is Mo, because of the longer flow path and sorption in the aquifer (Mo is conservatively assumed to be nonsorbing in the NRC staff's analysis). Table 3-12 provides estimates of peak daily intake for Mo for the one-million-year period in both present-day and cooler/wetter climates. The estimated daily intake of approximately 3×10^{-3} parts per million is lower than the EPA Oral Reference Dose.

For Middle Basin, radiological contaminants that contribute to estimated dose are limited to those elements whose transport in groundwater is not impacted by sorption processes. Tc-99 and I-129 are the primary contributors to dose at Middle Basin, as at Furnace Creek springs. As groundwater flows to Middle Basin and evaporates, these elements are incorporated into the resulting evaporite mineral deposits. Table 3-13 summarizes the estimated peak annual doses for the Middle Basin area. All estimated doses are below 1 mrem [0.01 mSv], which is a small fraction of the dose from natural background levels of approximately 300 mrem/yr [3.0 mSv/yr] (including radon) for Amargosa Valley and much lower than the NRC annual dose standards for a Yucca Mountain repository in 10 CFR Part 63 {15 mrem [0.15 mSv] for the first 10,000 years, and 100 mrem [1 mSv] for one million years, after permanent closure}.

Compared to the dose estimates for the Furnace Creek area, peak annual dose estimates for Middle Basin are lower for both climate states, primarily due to the absence of a drinking water pathway at this location. Table 3-14 provides estimates of peak daily intake for Mo for the one-million-year period in both present-day and future wetter climates at Middle Basin. The estimated value of daily intake (from inhalation and ingestion of wind-blown contaminated soil, as there is no drinking water pathway) is lower than the EPA Oral Reference Dose. The NRC staff concludes that the incremental impacts from radiological and nonradiological contaminants associated with natural groundwater discharges at Furnace Creek and Middle Basin would be SMALL.

For Alkali Flat, the NRC staff did not calculate estimates of contaminants in the groundwater, and thus did not calculate concentrations in soils or potential doses to the public. There are no residents at Alkali Flat, and the potential exposure pathways are limited to inhalation and exposure to resuspended dust that may contain radiological and nonradiological contaminants precipitated from evaporating groundwater. The NRC staff observes that while the exposure pathways at Alkali Flat would be the same as those for Middle Basin, Alkali Flat is further from present population centers and has even fewer visitors or temporary occupants. Thus, the NRC staff concludes that the impacts at Alkali Flat would be a small fraction of those calculated for the other surface discharge locations and, thus, the incremental radiological and nonradiological public health impacts for Alkali Flat would be SMALL.

Based on the information provided in Sections 4.4.1 and 4.4.2 concerning other actions, the NRC staff has identified only regional mining activity and NNSS tritium releases as additional actions or impacts that could contribute to cumulative public health impacts at these areas. Given its assessment of cumulative groundwater and cumulative soils impacts provided in the previous sections, and based on the NRC staff's conclusions in Section 4.5.1 about DOE's analysis of cumulative groundwater impacts from the NNSS and the Beatty disposal sites, the NRC staff concludes that the cumulative impacts on public health at these areas would be

nonexistent or would be so small as to not be detectable or not noticeably affect public health beyond the potential public health impacts from the repository alone.

Ecological Resources at Natural Surface Discharge Locations

As discussed in Section 3.2, the NRC staff evaluates the potential for nonhuman biota to be exposed to radionuclides at the State Line Deposits/Franklin Wells, Furnace Creek springs, Middle Basin, and Alkali Flat based on the estimated magnitude of radioactivity in the environment as quantified by the human dose estimates provided in Sections 3.1.1 and 3.1.2 for present-day and future wetter climates and for both 10,000-year and one-million-year timeframes. Because the human dose estimates are a small fraction of background radiation exposure, the NRC staff concludes in Section 3.2 that the estimated levels of radioactivity in the environment would be well below levels for potential impacts to nonhuman biota.

The NRC staff also evaluates the potential for nonhuman biota to be exposed to potentially harmful levels of nonradiological chemicals based on the aquifer and soil concentrations in Sections 3.1.1 and 3.1.2 for present-day and future wetter climates and for both 10,000-year and one-million-year timeframes. The NRC staff compared the estimated aquifer and soil concentrations with ecological impact concentrations from available scientific data on the toxicity of the contaminant chemicals. Tables 3-16 and 3-17 compare estimated aquifer and soil concentrations at the State Line Deposits/Franklin Wells area and at Middle Basin and Furnace Creek, respectively, with ecological impact concentrations. The estimated water and soil concentrations of radiological and nonradiological contaminants at the State Line Deposits/Franklin Well area and Furnace Creek /Middle Basin are well below ecological impact concentrations, with the exception of Mo in the evaporite soil at Middle Basin. As discussed in Section 3.2, the evaporite soil at Middle Basin with the highest calculated Mo content corresponds to areas of sparse to no vegetation. This is because the high salinity in this soil is generally not conducive to plant growth. Therefore, the NRC staff concludes that it would be unlikely that a significant proportion of the diet for wildlife could be obtained from these areas, and that the actual exposure of local wildlife to Mo accumulated in soil would be negligible. Based on this analysis, the NRC staff concludes that the environmental impacts to nonhuman biota from radiological and nonradiological contaminants in these areas would be SMALL.

Because only a very small fraction of the contaminants are expected to reach Alkali Flat (see Section 3.1.2.3), impacts on nonhuman biota at Alkali Flat would be much lower than impacts at the other discharge areas identified previously. In addition, the NRC staff expects that Alkali Flat would remain a predominantly playa environment with sparse amounts of salt-tolerant vegetation growing in highly saline surficial material. Thus, the NRC staff concludes that impacts to nonhuman biota at Alkali Flat would also be SMALL.

Based on the information provided in Sections 4.4.1 and 4.4.2 concerning other actions, the NRC staff has identified only regional mining activity and NNSS tritium releases as additional actions or impacts that could contribute to cumulative ecological resources impacts at these areas. Given the NRC staff's assessment of cumulative groundwater and cumulative soils impacts provided previously in this section, and based on the NRC staff's conclusions in Section 4.5.1 about DOE's analysis of cumulative groundwater impacts from the NNSS and the Beatty disposal sites, the NRC staff concludes that the cumulative impacts on ecological resources at the State Line Deposits/Franklin Wells, Furnace Creek springs and Middle Basin, and Alkali Flat would be minimal and not noticeably affect non-human biota beyond the potential impacts from the repository alone.

Historic and Cultural Resources at Natural Surface Discharge Locations

Section 3.3 provides a discussion of the NRC staff's review of DOE's historic and cultural resources impact assessments in its EISs. The NRC staff concludes in Section 3.3.5 that DOE adequately addressed the potential impacts on historic and cultural resources in its EISs, given DOE's defined region of influence and given that some consultation processes were still ongoing at the time the final 2008 SEIS was published. Based on the region of influence DOE described in its EISs as being limited to the Operator-Controlled Area, the NRC staff concludes that the surface discharge locations considered in this supplement are outside the region of influence DOE considered in its EISs. Thus, the NRC staff concludes that DOE would need to assess whether further consultation and investigation are necessary to account for potential impacts and potential cumulative impacts on historic and cultural resources that may be located in surface discharge areas.

Environmental Justice at Natural Surface Discharge Locations

Section 3.4.2 provides the NRC staff's assessment of the potential for disproportionately high and adverse human health or environmental effects on minority and low-income populations in Death Valley National Park. Section 3.4.2 refers to the NRC staff's assessment in Section 3.1.2.2 of the impacts at the Furnace Creek area and Middle Basin of Death Valley because only those areas are within an identified population center (Death Valley National Park). Therefore, this cumulative impacts analysis also assesses potential cumulative impacts only for the Furnace Creek and Middle Basin areas. Based on the information presented in Table 3-19, the NRC staff concludes that the minority population in the Death Valley Census County Division is a significant environmental justice population. The population in Death Valley is characterized in part by the Timbisha Shoshone Tribe on a parcel of land in the Furnace Creek area. The NRC staff acknowledges the sensitivities and cultural practices of the Timbisha Shoshone Tribe concerning the use and purity of springs in the Furnace Creek area. Based on the conclusions in Section 3.1.1 concerning impacts on groundwater, soils, and human health, the NRC staff found no environmental pathway that would affect minority or low-income populations differently from other segments of the general population; therefore, the NRC staff concludes that no disproportionately high and adverse health or environmental impacts would occur to minority or low-income segments of the population in the Death Valley area.

Because the NRC staff has not identified environmental justice impacts in the Death Valley area, the NRC staff concludes that, likewise, no cumulative impacts related to environmental justice would occur in this area.

4.6 Conclusion

Cumulative impacts on groundwater and from surface discharges of groundwater include the potential impacts of the proposed repository when added to the aggregate effects of other past, present, and reasonably foreseeable future actions. As described in Chapter 3 of this supplement, the incremental impacts from the proposed repository on groundwater resources and from surface discharges of groundwater would be SMALL. The cumulative impacts from the proposed repository when added to other past, present, and reasonably foreseeable Federal and non-Federal activities, such as those activities at the NNSS, would also be SMALL.

5 SUMMARY OF ENVIRONMENTAL CONSEQUENCES

This report supplements the U.S. Department of Energy's (DOE's) 2002 Environmental Impact Statement (EIS) and 2008 Supplemental EIS (SEIS) for a proposed geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain, Nevada, by providing additional analyses of impacts on groundwater and from surface discharges of groundwater, as identified in the U.S. Nuclear Regulatory Commission (NRC) staff's "Adoption Determination Report (ADR) for the U.S. Department of Energy's Environmental Impact Statements for the Proposed Geologic Repository at Yucca Mountain" (NRC, 2008a). This chapter summarizes the impact conclusions from the NRC staff's supplemental analyses and evaluates whether any of these supplemental analyses have identified any additional: (i) unavoidable adverse impacts, (ii) considerations regarding the relationship between local short-term uses of the environment and the maintenance and enhancement of long-term productivity, or (iii) irreversible and irretrievable commitments of resources. DOE previously summarized these impacts in Chapter 10 of its 2008 SEIS.

The direct and indirect impacts of this supplement are described in Chapter 3 and the cumulative impacts are described in Chapter 4. As discussed in Chapter 1, and as applied throughout this supplement, significance categories for potential environmental impacts are based on NRC guidance (NRC, 2003) and are characterized as follows:

> **SMALL**—The environmental impacts are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource.
>
> **MODERATE**—The environmental impacts are sufficient to alter noticeably, but not to destabilize, important attributes of the resource.
>
> **LARGE**—The environmental impacts are clearly noticeable and are sufficient to destabilize important attributes of the resource.

Summary of Environmental Impacts

This NRC staff supplement evaluates the direct, indirect, and cumulative impacts on water and soil, public health, ecology, historic and cultural resources, and environmental justice for locations beyond the postclosure compliance location. The locations of the affected environment are described in Chapter 2, which include potential locations for groundwater pumping and natural surface discharge beyond the postclosure compliance location downstream along the groundwater flow path to Death Valley.

The NRC staff finds that all of the impacts on the resources evaluated in this supplement are SMALL. The NRC staff's analysis includes the impact of potential radiological and nonradiological releases from the repository on the aquifer and at surface discharge locations of groundwater beyond the postclosure compliance location. The peak annual individual radiological dose at any of the evaluated locations is 1.3 mrem [0.013 mSv] from pumping and irrigation at the Amargosa Farms area. The NRC staff concludes that all estimated radiological doses are SMALL because they are a small fraction of background radiation dose of 300 mrem/yr [3 mSv/yr] (including radon), and much lower than the NRC annual dose standards for a Yucca Mountain repository in title 10 of *Code of Federal Regulations* (CFR) Part 63 {15 mrem [0.15 mSv] for the first 10,000 years, and 100 mrem [1 mSv] for one million years, after permanent closure}. The NRC staff's peak dose estimates accounted for uncertainty in climate and in groundwater pumping at the Amargosa Farms area. Based on conservative

assumptions about the potential for health effects from exposure to low doses of radiation, the NRC staff expects that the estimated radiation dose would contribute only a negligible increase in the risk of cancer or severe hereditary effects in the potentially exposed population. Impacts to other resources at all of the affected environments beyond the postclosure compliance location from radiological and nonradiological (i.e., chemical) material from the repository would also be SMALL, based on low estimated levels of the evaluated constituents in those potentially affected areas.

The cumulative impact analysis in Chapter 4 of this supplement contains the NRC staff's evaluation of the cumulative impacts for direct and indirect impacts identified in Chapter 3 when aggregated with the impacts of other actions that could affect the same resources. The NRC staff also evaluates how its findings in Chapter 3 and cumulative impact findings in Chapter 4 affect the conclusions provided by DOE in its assessment of cumulative impacts on groundwater in Chapter 8 of its EIS (DOE, 2002) and Chapter 8 of its SEIS (DOE, 2008a).

Unavoidable Adverse Impacts

Unavoidable adverse impacts are the direct, indirect, or cumulative impacts that remain after any proposed or required mitigation that could lessen impacts have been applied. The NRC staff considers the direct, indirect, and cumulative impacts summarized in the previous section to be the unavoidable adverse impacts of the proposed repository because the impact analyses have already taken into account applicable mitigating factors.

Relationship between Short-term Uses of the Environment and the Maintenance and Enhancement of Long-Term Productivity

The NRC staff considered whether its supplemental impact analyses identify any additional potential impacts of short-term uses on long-term productivity from what DOE previously evaluated in its EISs. Because there are no changes to the proposed action under review, the NRC staff concludes there are no changes to the short-term uses of the environment, as assessed in DOE's EISs. Additionally, while this supplement considers potential repository impacts on the groundwater environment and from surface discharges along the groundwater flow path beyond the postclosure compliance location, the SMALL impact conclusions reached in this supplement entail no new and significant threats or contributions to the maintenance and enhancement of long-term productivity relative to the impacts previously described by DOE (2008a).

Irreversible and Irretrievable Commitments of Resources

The NRC staff considered whether this supplement identifies any additional irreversible and irretrievable commitments of resources. Because the analyses in this supplement do not change the proposed action or reveal any new and significant use or loss of finite resources, the NRC staff concludes that the supplement identifies no additional irreversible and irretrievable commitments of resources relative to the commitments that were previously described by DOE (2008a).

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7 GLOSSARY

Accessible environment: For this analysis, any point outside of the long-term controlled area of the repository at Yucca Mountain, including the atmosphere above the controlled area, land surface, and surface waters along the Yucca Mountain flow path. The specific definition used by the NRC for regulation of the repository at Yucca Mountain is given in 10 CFR 63.302.

Adsorption: The adhesion by chemical or physical forces of molecules or ions (of gases or liquids) to the surface of solid bodies. For example, the transfer of solute mass, such as radionuclides, in groundwater to the solid geologic surfaces with which it comes in contact. The term sorption is sometimes used interchangeably with this term.

Advection: The process in which solutes, particles, or molecules are transported by the motion of flowing fluid.

Alloy 22: A nickel-based, corrosion-resistant alloy containing approximately 22 weight percent chromium, 13 weight percent molybdenum, and 3 weight percent tungsten as major alloying elements. This alloy is used as the outer container material in U.S. Department of Energy's waste package design for the repository at Yucca Mountain, Nevada.

Alluvial sediments, alluvial fan: Pertaining to the process of moving sediment by running water. An alluvial fan is a wedge-shaped sedimentary deposit of alluvium formed at the base of a slope in arid regions.

Aquifer: An underground layer of permeable, unconsolidated sediments or porous or fractured bedrock that yields usable quantities of water to a well or spring.

Biosphere: The regions of the surface, atmosphere, and waters of the earth occupied by living organisms.

Biosphere dose conversion factor: For purposes of this analysis, the factor that is used to convert the concentration of radiological contaminants in groundwater to calculate the annual dose to the reasonably maximally exposed individual, or other receptor with similar characteristics, due to a specific radionuclide.

Biota: The living organisms of a geographic region or time period considered as a group.

Carbonate rock: Rocks composed primarily of calcium or magnesium carbonate minerals, most commonly, limestone or dolomite. Carbonate rocks underlie extensive portions of the Great Basin in Nevada and the Death Valley regional groundwater flow system.

Colloid: As applied to radionuclide migration, colloids are large molecules or very small particles, having at least one dimension with the size range of 10^{-6} to 10^{-3} mm [10^{-8} to 10^{-5} in] that are suspended in a solvent. Colloids in groundwater arise from clay minerals, organic materials, or (in the context of a proposed geologic repository) from corrosion of engineered materials.

Confining unit: In geology, a confining unit is a rock or sediment unit of relatively low permeability that retards the movement of water in or out of adjacent aquifers.

Contaminants: In this analysis, materials that could be released from the repository into the groundwater and could impact water quality. These include both radiological and nonradiological materials.

Corrosion: The deterioration of a material, usually a metal, as a result of a chemical or electrochemical reaction with its environment. Corrosion includes, but is not limited to, general corrosion, microbially influenced corrosion, localized corrosion, galvanic corrosion, and stress corrosion cracking.

Cultural resource (historic resource): The remains of past human activity, including prehistoric era and historic era archaeological sites, historic districts, buildings, or objects with an associated historical, cultural, archaeological, architectural, community, or aesthetic value. Historic and cultural resources also include traditional cultural properties that are important to a living community of people for maintaining their culture.

Death Valley Regional groundwater Flow System model (DVRFS model): A model of groundwater conditions and flow for the Death Valley region developed by the U.S. Geological Survey. The model can simulate steady-state groundwater conditions with no withdrawal by pumping, as well as different pumping rates over time.

Decay (radioactive): The process by which a radionuclide spontaneously transforms into another element, called a decay product. That decay product may undergo further decay.

Discharge (surface): The areas where groundwater leaves the ground. Discharge points typically occur as springs or seepage into wetlands, lakes, and streams. Discharge also occurs as evapotranspiration.

Dose: A general term that may be used to refer to the amount of energy absorbed by an object or person per unit mass. Known as the “absorbed dose,” this reflects the amount of energy that ionizing radiation sources deposit in materials through which they pass, and is measured in units of radiation-absorbed dose (rad). The related international system unit is the gray (Gy), where 1 Gy is equivalent to 100 rad.

Evaporite: Geologic deposits composed of water-soluble mineral sediments that result from the evaporation of surface water.

Evapotranspiration: The loss of water by evaporation from the soil and other surfaces, including evaporation of moisture emitted or transpired from plants.

Flux: The amount of fluid (or mass) that flows through a unit area per unit time.

Geologic repository: An excavated, underground facility that is designed, constructed, and operated for safe and secure permanent disposal of high-level radioactive waste. A geologic repository uses an engineered barrier system and a portion of the site's natural geology, hydrology, and geochemical systems to isolate the radioactivity of the waste.

Groundwater: The water found beneath the Earth’s surface, usually in porous rock formations (aquifers) or in a zone of saturation, which may supply wells and springs, as well as base flow to major streams and rivers. Generally, it refers to all water contained in the ground.

Half-life: The time in which one-half of the atoms of a particular radioactive substance disintegrate into another nuclear form. Measured half-lives vary from millionths of a second to billions of years. Also called physical or radiological half-life.

Hydraulic gradient (groundwater): The rate of change of hydraulic head per unit of distance of flow at a given point and in a given direction; the measure of steepness between two or more hydraulic head measurements over the length of a flow path. For this analysis, the hydraulic gradient is used to determine the direction and rate of groundwater movement.

Hydraulic head (groundwater): The height to which water would rise in an open well expressed in units of length, as a measure of water pressure above a reference elevation. For an unconfined aquifer, the hydraulic head at a location coincides with the water table elevation. Hydraulic head measurements over a region determine the potentiometric surface.

Hydrology: The study of water that considers its occurrence, properties distribution, circulation, and transport, and includes groundwater, surface water, and rainfall.

Infiltration: For this analysis, infiltration is the precipitation or irrigation water that is not lost to evapotranspiration or runoff and enters the groundwater system.

Latent cancer fatality: A death that results from cancer caused by ionizing radiation following a latent, or dormant, period between the time of a radiation exposure and the time the cancer cells become active.

Longitudinal dispersion: The mixing of groundwater and contaminants in the direction of groundwater flow as water flows in an aquifer. Dispersion is the process whereby some of the contaminants travel at a different rate than the average velocity of the water.

Low-income populations: Persons whose average family income is below the poverty line. The poverty line takes into account family size and age of individuals in the family. In 2013, the poverty line for a family of four with two children below the age of 18 was $23,624. For any family below the poverty line, all family members are considered to be below the poverty line.

Low-level radioactive waste (LLRW): A general term for a wide range of items that have become contaminated with radioactive material or have become radioactive through exposure to neutron radiation. The radioactivity in these wastes can range from just above natural background levels to much higher levels, such as those observed in parts from inside the reactor vessel in a nuclear power reactor.

Matrix diffusion: The exchange between the fast-flowing groundwater in fractures and faults with slow-flowing water in the rock matrix.

Nonradiological contaminants: Contaminants that could be released from the proposed repository after permanent closure, including chemically toxic metals such as molybdenum, nickel, and vanadium. These materials generally originate from construction materials of the repository and the waste packages. Uranium, while a radioactive element, is also evaluated for its chemical toxicity as a nonradiological contaminant.

Playa: A dry lake bed at the bottom of a desert basin, sometimes temporarily covered with water. Playas have little or no vegetation, and are highly saline (salty) due to evaporation of groundwater near or at the ground surface. This leads to precipitation of salt minerals.

Potentiometric surface: A hypothetical surface representing the level to which groundwater would rise if not trapped in a confined aquifer. The potentiometric surface is equivalent to the water table in an unconfined aquifer.

Radioactivity: The property possessed by some elements (e.g., uranium) of spontaneously emitting energy in the form of radiation as a result of the decay (or disintegration) of an unstable atom. Radioactivity is also the term used to describe the rate at which radioactive material emits radiation. Radioactivity is measured in curies (Ci) and becquerels (Bq).

Radionuclide: An unstable isotope of an element that decays or disintegrates spontaneously, thereby emitting radiation. Approximately 5,000 natural and artificial radioisotopes have been identified.

Radiological contaminants: Radionuclide contaminants that could be released from the proposed repository after permanent closure.

Radioactive decay and ingrowth: The decay of radioactive material over time, which in turn may generate new radioactive contaminants (daughter products). The rate of decay and daughter products depend on the type of radioactive material.

Recharge (groundwater): Water entering an aquifer where permeable soil or rock allows water to enter the ground and reach groundwater.

Saturated zone: The subsurface ground area where water fills all of the openings (pores) in the soil or rock. Water that seeps deep into the ground continues downward under the force of gravity until it reaches this area.

Sorption: The binding, on a microscopic scale, of one substance to another. Sorption is a term that includes both adsorption and absorption and refers to the binding of dissolved radionuclides onto geologic solids or waste package materials by means of close-range chemical or physical forces. Sorption is a function of the chemistry of the radioisotopes, the fluid in which they are carried, and the material they encounter along the flow path.

Sorption coefficient: A numerical means to represent how strongly one substance sorbs to another.

Specific discharge: In hydrology, the rate of discharge of groundwater per unit area of a porous medium measured normal to the direction of flow. Synonymous with Darcy velocity.

Steady state (groundwater): That point when all input rates to a groundwater system are balanced by all the output rates.

Unsaturated zone: The zone between the land surface and the regional water table.

Water table: The upper limit of the saturated zone (the portion of the ground wholly saturated with water). The upper surface of a zone of saturation above which the majority of pore spaces and fractures are less than 100 percent saturated with water most of the time (unsaturated zone) and below which the opposite is true (saturated zone).

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APPENDIX A

ANALYTICAL METHODS

APPENDIX A ANALYTICAL METHODS

This appendix provides a description of the analysis methods used to determine impacts to affected environments beyond the postclosure compliance location. Section A.1 of this appendix describes the U.S. Nuclear Regulatory Commission (NRC) staff's analysis framework for evaluating impacts over the period of geologic stability (approximately one million years). Section A.2 describes processes at potential discharge sites that may affect concentrations and exposures and how those processes are analyzed for surface discharge.

The use of conservative assumptions simplifies calculations without underestimating impacts, and is warranted when the estimated impacts are small. Many of the conservative assumptions in the analyses for this supplement are discussed throughout the text. Section A.3 summarizes the important conservative assumptions used in the analyses.

A.1 Analysis Framework

The overall analytical framework used in this supplement extends the framework used in previous analyses performed by the U.S. Department of Energy (DOE) in its earlier Environmental Impact Statements (EISs) (DOE, 2008a; 2002) and Safety Analysis Report (SAR) (DOE, 2008b). In this supplement, the framework is extended to analyze both radiological and nonradiological contaminants for one million years after closure of the repository, and to analyze impacts at locations beyond the postclosure compliance location using transport and biosphere models.

In the 2002 EIS (DOE, 2002) and 2008 Supplemental EIS (SEIS) (DOE, 2008a), DOE principally used its Total System Performance Assessment (TSPA) model for assessing the effects of release and transport processes. This model was designed to evaluate those features, events, and processes of the engineered and natural barrier systems that affect repository performance (DOE 2008b, Chapter 2; NRC, 2015a). TSPA is a probabilistic model. Results are generated through multiple iterations with different values for input parameters as a way to account for uncertainties (the results of an iteration are termed a model realization). The 2002 EIS and 2008 SEIS used the dose calculated in TSPA as the principal measure of radiological impacts on groundwater. This dose was calculated following the criteria given in 10 CFR 63.312 for the reasonably maximally exposed individual (RMEI) residing "in the accessible environment above the highest concentration of radionuclides in the plume of contamination," a location approximately 18 km [11 mi] south of the repository along the groundwater flow path (the postclosure compliance location). The RMEI exposure pathway includes the well withdrawal of contaminated groundwater for drinking and irrigation, as well as inhalation of surface dust potentially contaminated by well water. DOE provided TSPA dose results for the one-million-year period following permanent closure of the repository. In addition, in the 2002 EIS and 2008 SEIS, DOE provided TSPA results for the concentration of radionuclides in groundwater for the 10,000-year period following permanent closure of the repository.

In the 2002 EIS and 2008 SEIS, DOE considered impacts on groundwater at other locations beyond the postclosure compliance location to be no greater than those calculated by TSPA for the RMEI location. In the 2002 EIS, DOE applied fractional scaling factors to its TSPA results at the postclosure compliance location to provide estimates of impacts at more distant locations. These scaling factors accounted for increased dispersion of a contaminant plume downstream along the flow path to distances of 30 and 60 km [19 and 37 mi] from the repository location (DOE, 2002, Section 5.4.1; Appendix I.4.5), which approximately match the distances from the

proposed repository to Amargosa Farms and Alkali Flat, respectively. DOE's estimation of the scaling factors did not consider sorption along the flow path or other processes that could affect impacts. In the 2008 SEIS, DOE did not use the scaling factors, but instead stated that contaminant concentrations, and thus impacts, for any areas beyond the postclosure compliance location can be no greater than those estimated for the postclosure compliance location. In the Adoption Determination Report (ADR) (NRC, 2008a), the NRC staff concluded that this generic description of affected environments and impacts was not sufficient for adoption.

A description of the source terms for radiological and nonradiological (toxic chemicals) contaminants is given in Section A.1.1, followed by, in Section A.1.2, a description of the transport models the NRC staff used for modeling the two transport segments (i) from the repository to the postclosure compliance location, and (ii) beyond the postclosure compliance location along the flow path to discharge locations, including descriptions of processes that occur along the different transport segments.

A.1.1 Source Term and Mass Flux at the Postclosure Compliance Location

In the 2002 EIS and 2008 SEIS, DOE estimated the source term (the total inventory of potential contaminants) for radionuclides for one million years, and for toxic chemicals for 10,000 years. Here, the source term is the released contaminants from the repository. Mass flux for this analysis is the rate at which contaminants flow from the proposed repository to the postclosure compliance location, and then beyond the postclosure compliance location; for example, to Amargosa Farms or Furnace Creek in Death Valley along the groundwater flow path.

This supplement uses TSPA results for the mass flux of radionuclides reaching the postclosure compliance location as an input in the transport model, which analyzes the movement of contaminants to different locations along the flow path. Using this mass flux for this supplement is conservative because the safety case evaluated for Yucca Mountain conservatively used the highest concentration of a plume passing the postclosure compliance location. All other points in the plume would have lower potential contaminant concentrations. As stated in Section 3.1, the NRC staff found DOE's TSPA methodology to be acceptable as part of its safety evaluation (NRC, 2014a, Section 2.2.1.4.1).

Because the source terms for radionuclides and toxic chemicals are estimated using different approaches, they are discussed separately in the next two subsections. This section provides a brief summary of the method for calculating mass flux that was used in the 2008 SEIS for the postclosure compliance location for radionuclides, and a description of the NRC staff's revised approach used in this supplement that extends the analysis period for the mass flux of nonradiological contaminants at the postclosure compliance location to one million years, which was not part of DOE's 2008 SEIS. The mass flux at the postclosure compliance location is a function of the releases from the repository and the effects of transport to the postclosure compliance location. The mass flux at the postclosure compliance location over the one million year period is used as an input to the transport model for the migration of radiological and nonradiological contaminants along the flow path towards Death Valley. This is described in Section A.1.2 (Transport to Affected Environments Beyond the Postclosure Compliance Location). In addition, the NRC staff revised some values in Chapter 3 to reflect peak values during a period (e.g., during the million-year period) instead of values at the end of the period, and to reflect updated entries found in staff's consistency review of the analyses.

Source Term and Mass Flux at the Postclosure Compliance Location for Radionuclides

In the 2008 SEIS, DOE used mean results from the TSPA model to estimate the source term for radionuclides and transport to the postclosure compliance location. This supplement uses the same approach and results, but uses those results as inputs to the transport model that calculates movement of the contaminants beyond the postclosure compliance location (see Section A.1.2). The NRC staff found that the TSPA model and results were acceptable as part of its safety evaluation (NRC, 2014a; Section 2.2.1.4.1). The NRC staff also found, in its ADR (NRC, 2008a), that use of the TSPA results as a source term for the postclosure compliance location is appropriate. The amounts of radionuclides released from the repository over time are an intermediate result of the TSPA simulation. The simulations also include transport through the unsaturated and saturated zones below the repository to the postclosure compliance location approximately 18 km [11 mi] from the repository. The 2002 EIS also used this approach, but with an earlier version of the TSPA model. The analysis in this supplement tracks 31 radionuclides from the TSPA results as the source term for calculating radiological impacts in affected environments. These radionuclides were identified by DOE (2014a, Table B-3 and B-4) as important contributors to the calculated dose from repository releases. The NRC staff confirmed that these radionuclides are the important dose contributors in the NRC staff's safety evaluation (NRC, 2014a, Section 2.2.1.4.1).

DOE's mean TSPA results were determined by averaging the behavior of the repository performance over the range of uncertainty and variability used to represent the features, events, and processes (e.g., corrosion of the waste package, seismic events, geologic and hydrologic characteristics of the site, or future climate conditions). TSPA uses scenario classes to represent specific events, such as seismic events and igneous events. DOE's TSPA includes seismic activity and igneous activity as two categories of events with the potential to affect a large number of waste packages, and thus potentially to have a significant effect on releases. Seismic events are uncertain in both timing and magnitude. Therefore, TSPA considered an appropriate range of seismic events that could potentially occur throughout the one-million-year period (e.g., smaller magnitude seismic events occur much more frequently than very large seismic events). Thus, the TSPA results reflect the occurrence of a number of seismic events of different magnitudes that occur at different times throughout the million-year period, as reflected in the historical record for seismic events in the region and accounting for uncertainty associated with such events.

The use of TSPA results to estimate releases that can be reasonably expected to enter the aquifer from the repository will not underestimate environmental impacts by inclusion of releases due to unlikely events regardless of probabilities assigned to the unlikely events. The TSPA model is a probabilistic tool that models uncertainty and variability in many parameters, including the effects of future climate change.

In DOE's analysis, the probability of an igneous occurrence is slightly above one chance in 100 million. DOE's TSPA takes into account unlikely events like igneous disruption and large magnitude seismic events, as well as features, events, and processes that are expected to occur (e.g., corrosion of the waste package, seepage of water into the repository). The NRC staff's approach in using TSPA results for its evaluation in the supplement is therefore a credible representation of potential contaminant releases, which accounts for environmental impacts that are reasonably likely to occur, while including impacts from events that are much less likely to occur.

In the 2002 EIS and the 2008 SEIS, DOE used the transport submodels in the TSPA code to estimate radionuclide movement to the postclosure compliance location. The TSPA transport model incorporates the following five transport processes:

- ***Advection*** is the migration of contaminants by the rate of groundwater flow.
- ***Matrix diffusion*** is the exchange between the fast-flowing groundwater in fractures and faults with slow-flowing water in the rock matrix.
- ***Sorption*** is the exchange of contaminants between groundwater and rock surfaces; the sorption coefficient describes the partitioning of the contaminant between groundwater and the rock (solid phase); and the magnitude of sorption is dependent on the element, the rock, and the groundwater chemistry.
- ***Colloidal transport*** is the sorbing of contaminants onto colloidal particles, which can then be transported as undissolved species.
- ***Radioactive decay and ingrowth*** is the decay of radioactive material over time, which in turn may generate new radioactive contaminants (daughter products), depending on the type of radioactive material.

The transport model and outputs for radionuclides used for analyses in this supplement have not changed from those in the 2008 SEIS. These TSPA simulation outputs produced the mass fluxes of radionuclides arriving at the postclosure compliance location as a function of time for the one-million-year period. The NRC staff found these TSPA results acceptable as part of its safety evaluation (NRC, 2014a; Section 2.2.1.4.1). These results are used as the source term in this supplement for calculations of transport beyond the postclosure compliance location.

The TSPA model used for the license application was derived using the draft rule (70 FR 53313) for the licensing of a geologic repository at Yucca Mountain. The final rule (74 FR 10811), in addition to other changes not relevant to this supplement, incorporated a slightly different distribution for deep percolation (the amount of water moving from the surface to a great enough depth that it is not removed by evaporation or transpiration) than the draft rule. This distribution represents the effect of future climates for the period from 10,000 to one million years after repository closure, which is applicable to the cooler/wetter climate state used in this supplement. The revised distribution in the final rule led to a slightly larger mean value of percolation for the 10,000 to one million year period, which could potentially have affected TSPA results. The NRC staff concluded in the SER that the slight change in the mean and distribution of deep percolation in the final rule had no significant effect on repository performance (NRC, 2014a; Section 2.2.1.3.6.3.2), and therefore no significant effect on the release of radionuclides from the repository and transport to the postclosure compliance location, and hence, no significant effect on the source term used in this supplement for the postclosure compliance location.

Source Term and Mass Flux at the Postclosure Compliance Location for Nonradiological Contaminants

In its 2002 EIS and 2008 SEIS, DOE performed a screening analysis where it compared chemical contaminants of materials used in the construction of the repository (including waste package materials) with the U.S. Environmental Protection Agency (EPA) substance list from the Integrated Risk Information System (2002 EIS Section I-6; 2008 SEIS Section F.5). Besides toxicity information from the EPA substance list, a second component of DOE's screening

process was the consideration of the potential for each chemical to migrate to the accessible environment (in DOE's analysis, the postclosure compliance location). For nonradiological material, DOE only considered the first 10,000 years after closure in its screening analysis. The source term that DOE developed for nonradiological chemicals was based on the thickness of corroded material and the total surface area of repository construction and waste package material exposed to corrosion. Because only a few packages were predicted to fail in the first 10,000 years after permanent closure, chemically toxic materials from within the waste packages were not considered.

In the 2002 EIS and 2008 SEIS, DOE assumed the release rate due to corrosion was uniform over the entire 10,000-year period. In the 2002 EIS, the chemicals of concern resulting from the DOE screening analysis were chromium (Cr), molybdenum (Mo), nickel (Ni), and vanadium (V). In the 2008 SEIS, DOE screened out Cr on the basis that the expected predominant form would be Cr (III) (chromium in a valance state of +3) in the repository environment, which is nontoxic to humans and relatively insoluble; that is, significant levels would not be dissolved in water, and thus would not migrate into the groundwater. DOE stated that the more toxic form, Cr (VI), would not form by corrosion of the waste package material (Alloy 22) or stainless steel under repository conditions (2008 SEIS, Section F-5.1). If Cr (VI) forms from such corrosion in the repository, the DOE screening analysis in the 2008 SEIS found that Cr (VI) is efficiently and quickly reduced to Cr (III) (Eary and Rai, 1989; Palmer and Puls, 1994) in the expected repository environment. The NRC staff, in its safety evaluation, found the DOE description of the repository chemical environment to be acceptable (NRC, 2014a; Section 2.2.1.3.3). For nonradiological contaminants in the 2002 EIS and 2008 SEIS, DOE applied the quantity of nonradiological chemicals released from corrosion of construction and waste package materials directly to the pumping well at the postclosure compliance location, thus conservatively excluding any transport-related delays or reductions.

This appendix describes the estimation of mass flux of nonradiological contaminants applied to the postclosure compliance location over the entire one-million-year period, beyond the 10,000 year period evaluated by DOE. This description begins with the source term at the repository and adjusts for transport processes along the saturated flow path to estimate the one-million-year mass flux at the postclosure compliance location. The release of contaminants from the repository is conservatively applied directly to the unsaturated-saturated zone boundary below the repository. Because more waste packages are expected to fail during the one-million-year period, compared to the number of expected failures during the first 10,000 years, toxic chemical contaminants from fuel assemblies and other materials inside waste packages are considered in addition to the materials (e.g., stainless steel or Alloy 22) considered in the 2008 SEIS. From the inventory of material inside failed waste packages, uranium (U) is the only additional contaminant added to the list of toxic chemicals because of its large quantity and its high toxicity (DOE, 2014a). For U, the source term is derived from TSPA results for radionuclides as the sum of all U isotopes arriving at the postclosure compliance location (as all forms of U are radioactive) (DOE, 2014a). Based on this screening process, which considers mobility and toxicity (DOE, 2014a), no other contaminants from inside waste packages are added to the list. Therefore, total U is added to Mo, Ni, and V as the toxic chemicals considered in this supplement. The NRC staff reviewed the mobility and toxicity screening process used by DOE and finds no other elements in the construction and waste package materials that should be included in this supplement.

To estimate the mass flux reaching the postclosure compliance location, the source term from the repository is adjusted using a two-step procedure to account for delays and reductions during transport between the repository and the postclosure compliance location. First, a

simplified model is used for the release rate of nonradiological contaminants (Mo, V, Ni) from the repository to estimate the mass flux at the unsaturated-saturated boundary approximately 300 m [1,000 ft] below the repository. The release rate model approach is based on the analysis in DOE (2014a), which used the following assumptions and values:

- The materials that corrode to produce nonradiological contaminants include construction material, all waste package material, and internal fuel assemblies and spent fuel. The number of failed waste packages is taken from the TSPA output for the combined scenario case. As described earlier in this section, the combined case includes the nominal, early failure, igneous intrusion, and seismic ground motion-fault displacement scenario classes;

- The mobilization rate for each element is calculated based on the corrosion rate used in the DOE's SAR (DOE, 2008b) and the exposed area of all external material (from construction and waste packages) and internal material (exposed in failed waste packages). Note that DOE (2014a) allowed corrosion to proceed indefinitely; for this supplement the release ends when the thickest component has been completely corroded. More details on this release model are provided in the following paragraphs; and

- The mobilization rate is applied at the unsaturated-saturated zone boundary, and a transport model based on breakthrough curves from the TSPA (DOE, 2008b) is used to determine the mass flux reaching the postclosure compliance location 18 km [11 mi] from the repository.

The analysis in DOE (2014a) included an unrealistic assumption of the total amount of nonradiological contaminants that could be released from the repository. For the calculations in this supplement, the NRC staff constrained the total amount of the source of the nonradiological contaminants available in the repository, specifically the Alloy 22 (the high-nickel alloy that makes up the outer barrier of the waste packages) and the 316NG stainless steel (both exposed in the repository structures, and used in the internal components of the waste packages) such that the total release cannot exceed the amount in the repository. Using the corrosion rates from DOE's SAR, exposed stainless steel from rock bolts, tunnel and drift liners, and other installed rock supports would be completely corroded in 10,000 years. Internal waste package components would corrode over a period of 500,000 years (as exposed in failed waste packages), and Alloy 22 would corrode over 600,000 years. Figure A–1 (top) illustrates the mass flux mobilized by corrosion and applied directly to the unsaturated-saturated zone boundary below the repository.

The release rate calculated for each of the nonradiological contaminants is used to generate the mass flux at the unsaturated zone-saturated zone interface below the repository. This approach explicitly (and conservatively) neglects any delay or reduction potentially caused by transport out of the engineered barriers and through the unsaturated zone below the repository.

Sorption

Sorption is the process whereby contaminants are removed from the water through attachment to solid grains in the rock. For a continuous contaminant source, sorption causes a delay in the arrival of the peak contaminant levels at downstream locations, but does not reduce the peak contaminant level. The inclusion of longitudinal dispersion smooths sharp contaminant fronts (such as the pulse of the nonradiological contaminant release shown in the top of Figure A–1), and only affects the timing of the first arrival of the contaminant at downstream locations.

Next, the mass flux at the postclosure compliance location for nonradiological contaminants is calculated from the mass flux at the unsaturated zone-saturated zone boundary, modified to account for delays and reductions along the approximately 18-km [11-mi] flow path to the postclosure compliance location. Breakthrough curves from the TSPA are used to transfer the mass fluxes of Mo, Ni, and V from the unsaturated-saturated zone boundary below the repository to mass fluxes at the postclosure compliance location. Appropriate analog breakthrough curves were selected by matching sorption properties of the nonradiological contaminant with breakthrough curves derived for radiological contaminants with similar sorption properties. A breakthrough curve represents the arrival of a contaminant at a location as a function of time, and reflects the transport velocity and sorption characteristics of the contaminants for the various processes operating in the aquifer. The processes implemented in the TSPA model account for advection, matrix diffusion, dispersion, sorption, and colloidal processes. Together with the release rate from the repository (Section A.1.1), the breakthrough curve provides the mass of nonradiological contaminants at the postclosure compliance location as a function of time, which is used as input for the transport calculation beyond the postclosure compliance location described in the next subsection. The mass fluxes of nonradiological material at the postclosure compliance location are provided in Figure A–1 (bottom), which represents the nonradiological releases over the one-million-year period.

A.1.2 Transport to Affected Environments Beyond the Postclosure Compliance Location

In its 2002 EIS, DOE considered transport beyond the postclosure compliance location only through the use of fractional scaling factors for both radiological and nonradiological contaminants. These factors were applied to the TSPA outputs at the postclosure compliance location to assess impacts at more distant locations. These scaling factors nominally accounted for the increased dispersion of a contaminant plume migrating downstream from the approximately 18-km [11-mi] postclosure compliance location (DOE, 2002, Section 5.4.1 and Appendix I.4.5). In its 2008 SEIS, DOE stated that dose and concentration, and thus impacts, for areas beyond the postclosure compliance location can be no greater than those estimated for the postclosure compliance location.

In this supplement, the NRC staff uses the transport analysis in the U.S. Geological Survey's (USGS) Death Valley Regional Flow System (DVRFS) model (Belcher and Sweetkind, 2010). The DVRFS model uses the publicly available MODFLOW software (Harbaugh, 2005; Harbaugh et al., 2000), which is the most widely-used groundwater modeling software. The USGS has been developing the DVRFS model for more than 15 years (Belcher, 2004; Belcher and Sweetkind, 2010; D'Agnese et al., 1999). The NRC staff reviewed and accepted the DVRFS model as used in the SAR (DOE, 2008b; Section 2.3.9) in its safety evaluation (NRC, 2014a; Section 2.2.1.3.8). As used in this supplement, the DVRFS model was updated (SNL, 2014) by including additional years (1999–2003; in addition to original 1913–1999 data) of pumping data from Amargosa Farms. The DVRFS model (SNL, 2014) is used in this supplement to determine flow pathways and inputs for the transport model. The NRC staff reviewed the changes to the inputs and the resulting output, and determines that the DVRFS model (SNL, 2014) is acceptable for use in the analyses in this supplement. Based on the NRC staff's reviews of the DVRFS models described above, the NRC staff finds the DVRFS model to be a reasonable representation of the flow system in the Death Valley region, including the flow path from Yucca Mountain to Death Valley.

The next sections describe the transport approach used in this supplement to analyze the transport of radiological and nonradiological contaminants from the postclosure compliance

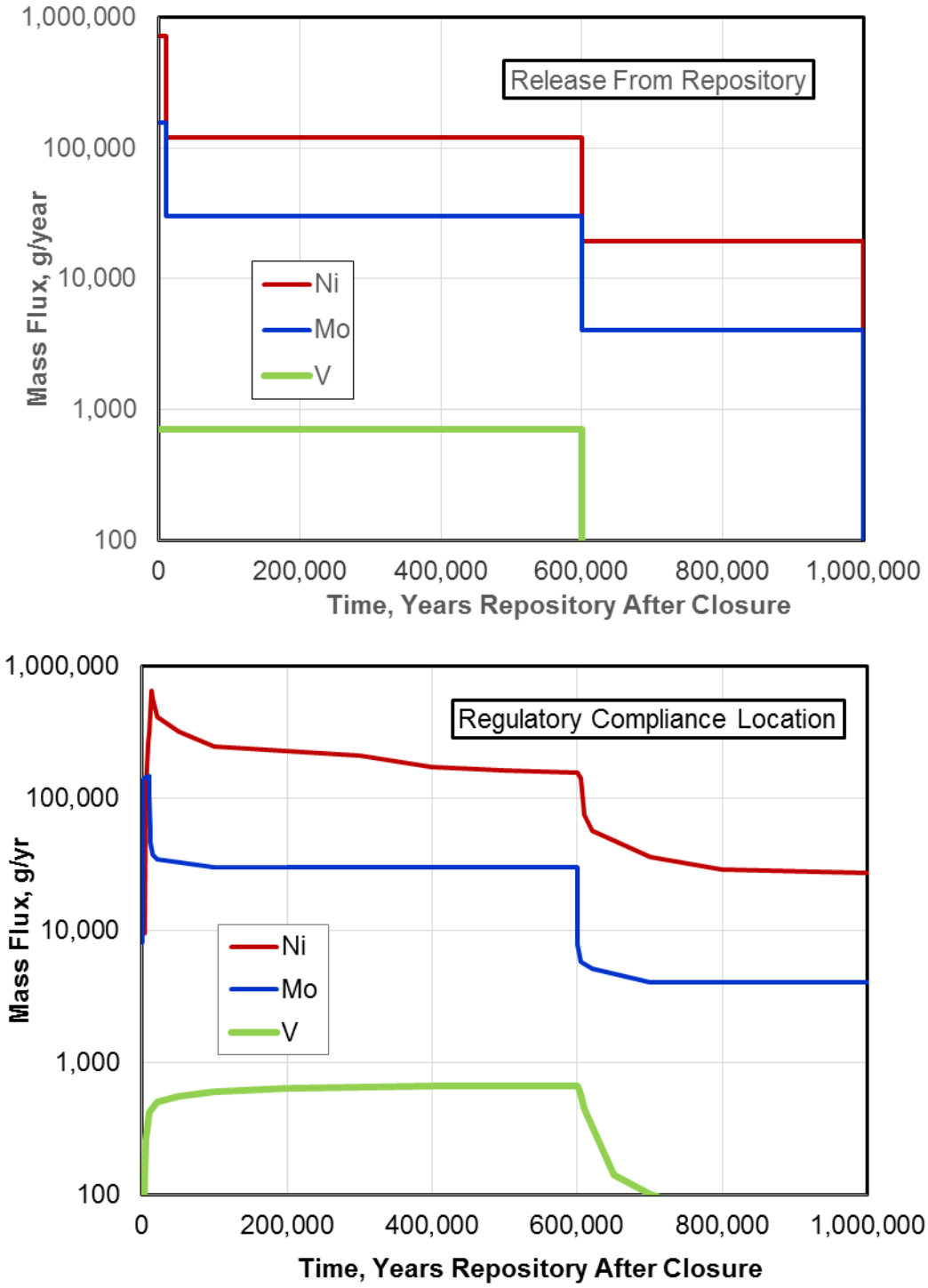

Figure A–1. Mass Flux for Mo, Ni, and V Released From Repository (Top) and Reaching the Postclosure Compliance Location (Bottom). To Plot All Three Metals on the Same Graph, a Logarithmic Mass Flux Scale Is Used.

location to affected environments along the groundwater flow path to Death Valley. The description includes the identification of the likely transport pathways and the transport model, including processes and properties.

Identification of Pathways

The model the NRC staff uses for identifying the transport pathways and determining the flow characteristics along those pathways is based on the DVRFS model [Belcher and Sweetkind (2010)], modified to include data on groundwater pumping from 1913 to 2003 (SNL, 2014). Implemented with the MODFLOW software (Harbaugh, 2005; Harbaugh et al., 2000), USGS's DVRFS model includes particle-tracking capabilities. Particle tracking is a technique commonly used to delineate flow pathways. Particles move through the model domain based on the flow direction and velocity at each cell in the model. Flow pathways are identified by releasing particles at the postclosure compliance location and tracking where the particles move within the DVRFS. Adsorption, colloidal filtering, decay, or other mechanisms that limit movement of the particles along with the water are neglected in this analysis for simplification and conservatism. In the DOE (2014a) analysis, 8,024 particles were released at the postclosure compliance location and tracked. The 8,024 particles used at the postclosure compliance location were derived from release of 10,000 particles from Yucca Mountain in the Yucca Mountain Site-Scale Flow Model (SNL, 2007a). When pumping is included in the DVRFS model, all particles are captured by the wells in Amargosa Farms. When no pumping is included (the pre-pumping model, representing groundwater conditions prior to 1913), particle tracking identifies two potential pathways downstream of Amargosa Farms. The strongly predominant path is approximately southward through Amargosa Farms, turning southwestward to westward beneath the Funeral Mountains, to the springs at Furnace Creek, and on to Middle Basin in Death Valley (DOE, 2014a; Figure 3-1). A potential alternative path (only two particles out of 8,024 leaving the postclosure compliance location took this course) is southward past Amargosa Farms to surface discharge at Alkali Flat (DOE, 2014a; Figure 3-2). For this analysis, these two particles represent the limited possibility that a small amount of contamination could divert from the predominant pathway.

Particle tracking results in the DVRFS model indicate that the contaminants would travel through several different water-bearing segments (parts of the aquifer) along the flow path. Each of these segments has different transport properties. For the analysis in this supplement, the length of transport segments along each identified pathway are estimated from the DVRFS model, using separate steady state simulations with and without pumping in Amargosa Farms (as in DOE, 2014a). The segment lengths represent flow in different rock formations. Flow beyond the postclosure compliance location is primarily in volcanic-alluvial or carbonate-hosted aquifers. For the nonpumping scenario, two different aquifer types predominate in the flow path to Death Valley (DOE, 2014a): (i) the volcanic-alluvial basin fill unit comprises 46 percent of the path; and (ii) the lower carbonate aquifer comprises 40 percent. For the pumping scenario, the entire path (from the postclosure compliance location to Amargosa Farms) is comprised of various basin fill volcanic-alluvial units (DOE, 2014a). The NRC staff finds that the DVRFS segment lengths and hydrogeological units along the flow paths as described by DOE are acceptable and reasonable because (i) the NRC staff found the DVRFS model an acceptable representation of groundwater flow in the region (see above), (ii) the NRC staff reviewed the flow segment lengths and found them to be reasonably consistent with distances from maps of the hydrogeological units, and (iii) the hydrogeological units and their spatial representation are direct inputs from the model developed by the USGS (Belcher and Sweetkind, 2010).

Transport Model

The mass flux at the postclosure compliance location was estimated from the release and transport of contaminants from the repository, as described in Section A.1.1. This section describes how the contaminants at the postclosure compliance location are modeled to move different distances downstream using a different transport model than that used for the transport between the repository and the postclosure compliance location.

> **Analytical Solutions for Transport Equations**
>
> An analytical solution to the transport equation is a mathematical solution in the form of mathematical expression. It is also called a closed-form solution. A numerical solution is an alternative method for solving the transport equation. Numerical solutions are needed for complex problems, but the results only approximate the solution to the transport equation. The choice of solution method generally is determined by the complexity of the problem, and by the intended usage and needs of the results.

For this supplement, transport in the saturated zone (i.e., the aquifer) downstream of the postclosure compliance location is modeled using the one-dimensional pipe model described in DOE (2014a). The entire contaminant plume is assumed to be contained in the pipe. As described below, a one-dimensional representation is conservative compared to a three-dimensional model because it neglects vertical and lateral dispersion, and thus likely overestimates maximum contaminant concentrations.

Transport in the pipe is based on an analytical solution of the advection-dispersion equation modified for sorption and decay. The exact solution to the equation (Lapidus and Amundsen, 1952; Equation 9) is simplified by dropping the term for short distances. The concentration-based solution is multiplied by the volumetric flux to convert it to a mass flux-based solution. In addition, a mathematical identity for the complementary error function in the solution is used to avoid potential computational difficulties which can occur with a numerical approach. Whereas the analytical solution for transport is valid for a constant source term, solutions for different magnitudes of the source term that occur at different times are additive. Because the mass flux at the postclosure compliance location changes with time, the solution approach is to break up the source term into step changes (of radionuclide and nonradiological contaminant mass fluxes) and solve the transport equation for each source term step. The solution for a location and time is then the sum of contributions from each source term step.

Transport processes of sorption, longitudinal (in the direction of the flow path) dispersion, and radioactive decay and ingrowth are incorporated in the model, but matrix diffusion and colloidal processes are not included. Neglecting matrix diffusion is conservative for estimating impacts because diffusion reduces concentrations of contaminants. DOE's TSPA includes these processes, so their effects are included in the mass of radionuclides calculated to arrive at the postclosure compliance location. Neglecting colloidal transport beyond this point may under-represent the mass flux to affected environments. However, the NRC staff reviewed the magnitude of colloidal transport included in the TSPA and determined that this process was not significant to dose, and hence the mass of radionuclides that is used to estimate that dose at the postclosure compliance location (NRC, 2014a; Section 2.2.1.4.1). Because the same radionuclides and transport processes in the TSPA are analyzed in this supplement, not including colloidal processes will not significantly affect the estimated impacts. The processes of radioactive decay and ingrowth are approximated by adjusting the input source term for the one-dimensional pipe model to account for decay or ingrowth that would take place between the postclosure compliance location and the downstream location (e.g., Amargosa Farms or Death Valley).

The primary inputs for the transport model are sorption properties for each contaminant and flow path characteristics from the DVRFS model. Sorption analyses in this supplement use values from DOE (2014a; Table B-1). For radionuclides in volcanic and alluvial rock units, DOE derived the sorption values from the low end of the range provided in the SAR (DOE, 2008b; Table 2.3.9-14), and updated them based on more recent literature (DOE, 2014a). Larger values of sorption coefficients lead to delayed arrivals of contaminants at downstream locations, such as delays in the time of peak concentrations. The NRC staff found that the values in DOE's SAR were acceptable as part of its safety evaluation (NRC, 2014a, Section 2.2.1.3.10). Further, sensitivity analyses using a set of significantly lower sorption values for all contaminants (except non-sorbing species where the sorption coefficient is zero) (DOE, 2014a, Table B-16; DOE, 2008b, Table 2.3.9-14) showed only a 15 percent increase in dose and body uptake impacts (DOE, 2014a). This small increase in impacts would not change the conclusions in Chapter 3 of this supplement. Therefore, the NRC staff finds the sorption properties in DOE (2014a, Tables B-1) reasonable for use in this supplement for the transport model.

Secular equilibrium for decay chain isotopes is a valid assumption when the sorption coefficients of parent and daughter products of radionuclides are similar in magnitude. In its 2002 EIS and 2008 SEIS, DOE assumed secular equilibrium for all radionuclides in decay chains. In DOE (2014a), DOE screened radionuclide decay chains for parent and daughter radionuclides with large differences in respective sorption coefficients. DOE identified the actinium, neptunium, thorium, and uranium series in the screening analysis (DOE, 2014a). The NRC staff reviewed the screening of radionuclide series for secular disequilibrium in the SAR, and found this same list acceptable for use in the SAR (NRC, 2014a; Section 2.2.1.3.9). In this supplement, the effect of secular disequilibrium is accounted for by applying a scaling factor to the dose conversion factors for radionuclides of parent-daughter pairs with different sorption characteristics. Any factor above one has the effect of increasing the estimated dose impact of the identified radionuclide species. Following the approach described in Olszewska-Wasiolek and Arnold (2011), the factors used in this supplement are 8.7 for Ra-228 and 1.8 for lead-210 (Pb-210) and Ra-226 (shown in DOE, 2014a, Tables B-3 and B-4).

For the flow path characteristics, DOE derived the following from the DVRFS model: (i) bulk density, porosity, and flow path length in each rock unit (referred to as flow segments), and (ii) specific discharge. The values for each flow path are provided in DOE (2014a, Table B-1), and their derivation is summarized below. The NRC staff finds the DVRFS hydrogeological properties of each flow segment along the flow paths acceptable and reasonable because (i) the NRC staff found the DVRFS model of Belcher and Sweetkind (2010) an acceptable representation of groundwater flow in the region in its safety evaluation (NRC 2014a; Section 2.2.1.3.8), (ii) the NRC staff reviewed the flow segment lengths in DOE (2014a) and found them to be reasonably consistent with distances from maps of the hydrogeological units (e.g., Belcher and Sweetkind, 2010), and (iii) the hydrogeological units and their spatial representation are direct inputs from the model developed by the USGS (Belcher and Sweetkind, 2010).

These parameters are derived as follows. Particle track modeling indicates the different hydrogeological units that water flows through along the paths from the postclosure compliance location to either Amargosa Farms or to Furnace Creek/Middle Basin. The distance the particle travels in each hydrogeological unit is the length of the flow segment, which, when summed, provides the total flow path length. For bulk density and porosity, a single value for the entire flow path length is derived using a distance-weighted average of the properties for the individual segments along the pathway. Specific discharge is calculated as the average travel time of

particles divided by the total length of the flow path. For the cooler/wetter climate state, the specific discharge rate is increased by a factor of 3.9 over that of the present-day climate to account for potentially faster groundwater flow under the wetter conditions. Whereas a cooler/wetter climate would lead to both a higher water table and faster flow rates, the NRC staff review in the SER (NRC, 2014a; Section 2.2.1.3.8) concluded that only the faster flow rates need be considered for the transport model. The factor of 3.9 was derived from simulations of wetter conditions using the DVRFS model (D'Agnese et al., 1999; SNL, 2008a, Table 6-5), and was used for the glacial-transition climate in TSPA model simulations (DOE, 2008b, Section 2.4). The NRC staff reviewed the basis for the factor of 3.9 and found it to be an acceptable representation of the glacial-transition climate and for the long-term climate change during the 10,000 to one million-year period in its safety evaluation (NRC, 2014a, 2.2.1.3.8).

A separate calculation is required to estimate contaminant concentrations in the aquifer environment between the postclosure compliance location and Amargosa Farms (see Section 3.1.1) because the one-dimensional pipe-model approximation does not account for the potential plume dimensions. The contaminant concentration for the aquifer environment is estimated as the difference between the amount of radiological or nonradiological mass at the postclosure compliance location and that at the Amargosa Farms divided by the volume of the aquifer environment. The volume of the aquifer environment is conservatively estimated by the dimensions of the particle tracking traces in DOE (2014a, Figure 3-1; 2008b, Figure 2.3.9-14). This volume estimate is conservative because particle tracking neglects lateral and vertical dispersion, which would lead to larger aquifer volumes and lower concentrations. From these values, representative dimensions of the plume are 3 km [1.9 mi] wide and 100 m [330 ft] thick. The third dimension of the volume is the distance between the postclosure compliance location and Amargosa Farms, which is 17 km [11 mi]. The next section provides a description of processes at surface discharge locations, for which the mass fluxes are used as input to estimate impacts at those locations.

A.2 Processes at Discharge Sites

For groundwater withdrawal for irrigation, a conceptual model for the recycling of irrigation water pumped to the surface was not included in DOE's 2002 EIS or 2008 SEIS. The irrigation recycling model used in this supplement is described in Section A.2.1. Processes that can affect accumulation, concentration, and potential remobilization of groundwater-borne contaminants, including the influence of different chemical conditions at natural discharge sites such as springs or evapotranspiration at wet playas, are discussed in Section A.2.2.

A.2.1 Groundwater Pumping, Recycling, and Irrigation

Groundwater may be discharged at the surface due to pumping or through natural discharge features, such as springs, seeps, and wet playas. In the Amargosa Farms region, a significant amount of shallow alluvial aquifer groundwater is pumped and used as a source of domestic and commercial water supply and for the irrigation of crops. As irrigation water is applied to soils, its chemical constituents can be taken up by crops, sorbed to soils, and concentrated by the effects of evaporation and transpiration. These processes can lead to the buildup of salts and other elements detrimental to continued farming and the broader ecosystem. In addition, in the Amargosa Farms region, excess irrigation water is applied to compensate for evaporation and to limit the buildup of salts in the root zone of the soil (DOE, 2014a). Excess irrigation is the practice of applying more irrigation water than is needed by the particular crop, thus enabling the excess water to recharge the water table while carrying the salts (and in this modeling case,

some of the contaminants) away from the upper soil layers. The water that reinfiltrates the aquifer then becomes available again for groundwater pumping.

This practice adds a complicating factor in assessing impacts from irrigation where irrigation water percolates deep into the subsurface and is recaptured and recycled at pumping locations. Where this occurs, the recycling process increases concentrations of contaminants in the groundwater and thus increases the concentrations of contaminants as they are reapplied to the surface during irrigation. Groundwater pumping at Amargosa Farms is on the order of 17,000 acre-ft/yr [21 million m^3/yr]. This high volume of irrigation indicates that use of an irrigation recycling model is warranted for the assessment of impacts at Amargosa Farms.

For this supplement, a mathematical analytical solution describing an equilibrium concentration is used to incorporate the impacts of irrigation recycling at the Amargosa Farms area, following the approach in DOE (2014a; SNL, 2007b). This mathematical solution, referred to hereafter as the special-case model, neglects the effects of radioactive decay. Neglecting decay overestimates radionuclide concentrations and, therefore, impacts. DOE (2014a) notes that more detailed irrigation recycling models have been developed (SNL, 2007b; Kalinina and Arnold, 2013), but that the special-case model represents a limiting case of the more detailed irrigation recycling models. The NRC staff finds that the irrigation recycling model in DOE (2014a) represents a reasonable, limiting case that would lead to conservative results for this analysis.

The output of the irrigation recycling model that is used in this supplement is used to increase the amount of recycled groundwater. The irrigation recycling model includes two factors to calculate the change in concentration of dissolved contaminants in groundwater resulting from irrigation recycling: (i) the amount of pumped water used for irrigation and (ii) the amount of irrigation water recaptured by pumping wells (DOE, 2014a). For the first factor, 86 percent of pumped groundwater on average in the Amargosa Farms area is used for irrigation (Moreo and Justet, 2008). For the second factor, this supplement conservatively assumes that 100 percent of the irrigation water is subsequently recaptured by the Amargosa Farms area wells, and also assumes no decay of the contaminants. In addition, this model also assumes that none of the contaminants in the plume are sorbed to the aquifer during deep percolation. As a result of these factors and assumptions, the model used in this supplement produces an increase in groundwater contaminant concentrations by a factor of 7.1, which is much larger than values (1.1 to 1.5) used to assess the impacts of irrigation recycling at the postclosure compliance location in the SAR (DOE, 2014a; Kalinina and Arnold, 2013; SNL, 2007b). The calculated changes in groundwater concentrations are then applied to the contaminant concentrations in the transport model for the Amargosa Farms area to incorporate the impact of irrigation recycling in the groundwater pumping scenario. The NRC staff finds the DOE implementation of the irrigation recycling model in DOE (2014a) acceptable and reasonable for use in this supplement because (i) the NRC staff reviewed the irrigation model in the SER and found it acceptable as part of its safety evaluation (NRC, 2014a; Section 2.2.1.2.1, FEP 1.4.07.03.0A); and (ii) the irrigation recycling model input for recapture was changed to a maximum possible value, and the percentage of pumped groundwater in Amargosa Farms was set to the actual value determined by Moreo and Justet (2008); and (iii) radioactive decay is conservatively neglected for the recaptured water.

Two forms of the irrigation recycling model used in this supplement are applied at two locations: Amargosa Farms and the State Line/Franklin Well area. Recycling is included for Amargosa Farms where wells that pump water for irrigation are generally located in the farm fields where the irrigation water is applied. Recycling is not included in the salt marsh model used for the

State Line/Franklin Well area because the water from springs and marshes would not be applied at the location it is discharged. In any potential irrigation at the State Line/Franklin Well area, fresh water from springs and marshes would be diverted to locations downstream from the extraction location where soils are not highly saline. In this type of environment, areas close to springs and marsh areas would contain high levels of salts, and thus would be unsuitable for agriculture.

A.2.2 Processes at Surface Discharge Locations that Could Affect Accumulation, Concentration, and Potential Remobilization of Contaminants

In the 2002 EIS and 2008 SEIS, DOE did not include an assessment of impacts from groundwater-borne contaminants downstream of the postclosure compliance location. Although potential groundwater flow paths downstream of the compliance location were discussed in the 2008 SEIS, there was limited description of groundwater-surface interaction processes and no quantitative assessment of impacts from groundwater discharging at the ground surface beyond the postclosure compliance location.

As discussed in Chapter 2, natural groundwater surface discharge features in the Yucca Mountain region include springs, seeps, evapotranspiration zones with near-surface water table levels, and wet and dry playas. For the analysis in this supplement, these are grouped into springs and wet playas, or are neglected because exposure pathways for evapotranspiration are much smaller than for springs or wet playas. Besides present-day features, there are also paleospring deposits (e.g., the State Line Deposits) along the groundwater pathway from Yucca Mountain that show surface discharge during past wetter climate periods (Section 2.3). The specific processes that occur at these different types of groundwater discharges are dependent on several factors, including the host rock lithology, the groundwater chemistry, the topographic setting, the rate of evaporation, and the ecology of the sites (e.g., Douglas, 2004; Hardie, 1968; Quade et al., 1995; Reynolds et al., 2007).

Springs and paleosprings in the Yucca Mountain region are often associated with brownish, fine-grained, silt-sand sediment deposits; variable carbonate cementing of sediments; and greenish clay deposits (Quade et al., 1995). Quade et al. (1995) classified the springs into two main types:

- Springs where the water table intersects with the ground surface (free-face discharge, exemplified by the State Line Deposits)

- Springs controlled by faulting or other geologic features (structure-controlled discharge, exemplified by springs at Furnace Creek)

In areas adjacent to both spring types, an ecological hierarchy is commonly developed in which plants transition from sparse xerophytes (plants adapted to very arid environments) upgradient of the spring, to large phreatophytes (deep-rooted plants that obtain water from the water table) near the spring, to grassy wet meadows downstream from the spring (Quade et al., 1995). These ecological zones trap different types of sediment and produce the brownish silts, green clays, and calcite-cemented crusts near the zone edges (Quade et al., 1995). When the water table is lowered, as in the present-day climate, erosion and channeling of the sediments deposited in the paleospring can occur, and the phreatophytes are replaced by xerophytes (Quade et al., 1995). This process can be observed in the Furnace Creek spring area. Because the regions near these springs would have limited agricultural activity, the analyses in this supplement do not include irrigation recycling for these areas. However, the analyses do

include potential exposure from use of the springs as a drinking water source, as well as impacts from exposure to sediments contaminated by groundwater.

As groundwater moves closer to the surface or is discharged at the surface, it is impacted by gas exchange with the atmosphere, sorption on minerals in the soil, and concentration effects. Groundwater in the subsurface typically has an elevated concentration of carbon dioxide (CO_2), relative to surface water in equilibrium with the atmosphere, due to chemical exchange with carbonate rocks in the aquifer. As the groundwater is discharged, it re-equilibrates with the atmosphere. Depending on the overall chemical composition of the groundwater, the loss of CO_2 may result in the precipitation of carbonate minerals, such as calcite. In the Yucca Mountain region, precipitation of calcite is observed at springs that originate from the carbonate aquifer, like those in Ash Meadows or Furnace Creek (Johannesson et al., 1997; Paces et al., 1997). Other effects from the loss of CO_2 may include an increase in pH (alkalinity) of the groundwater. Both pH and CO_2 concentration changes can affect the potential for sorption onto soil and other surface sediments. The modeling described in this supplement uses the sorption values reported in DOE (2014a) to calculate the retention of contaminants on soils and sediments. The mean values reflect a range of sorption values that capture the range of pH and CO_2 effects on sorption.

At wet playas, the upward movement of groundwater is not driven by water table interactions, but by capillary action that draws the groundwater upward. Nearer the surface, the groundwater is subject to evaporation and evapotranspiration. These processes tend to concentrate the chemical constituents in the groundwater and increase the total dissolved solids (TDS) content of the water. As more water is lost, the water becomes more saline, and solubility limits for minerals may be exceeded. Various carbonates, salts, and other evaporite minerals may precipitate. This action produces a soft surface of evaporite phases that are typically rich in minerals such as calcium carbonate, hydrated calcium sulfate, sodium chloride, and sodium sulfate (DOE, 2014a). The specific types of evaporite minerals that form are dependent on the initial groundwater chemistry and the extent of evaporation, and the deposits are often zoned (Hardie, 1968). The evaporite deposits are found both in the capillary fringe area and on the surface of a playa (DOE, 2014a); extreme evaporation in a closed basin can lead to thick, zoned sequences of relatively pure evaporite minerals, as in Badwater Basin in Death Valley (e.g., Hunt and Mabey, 1966). As the evaporite mineral crystals form, they also displace and mix with the rock-derived sediments (often fine silts and clays), expanding the sediments upward (DOE, 2014a; Reynolds et al., 2007). The playa deposits with evaporite minerals are often described as “fluffy” with large pore space and low density (Reynolds et al., 2007). At the surface, microbial activity may produce mats that trap additional sediment and control the types of mineral phases that form (Douglas, 2004). Sometimes a more compact, but still friable (easily crumbled) material forms, which contains a lower fraction of evaporate minerals (DOE, 2014a). These types of deposits are associated with lower rates of evaporation or lower salinity in the groundwater (DOE, 2014a). The residual water is highly mineralized. For example, at Alkali Flat (Franklin Lake Playa), stagnant water has TDS content of 70,000 to 80,000 ppm, and drainage paths have water with TDS content of 6,000 to 20,000 ppm (DOE, 2014a; Reynolds et al. 2007). For comparison, a maximum contaminant level of 500 ppm TDS is recommended for drinking water under the National Secondary Drinking Water Regulations (40 CFR 143.3).

The effect of evaporation and evaporite mineral formation on the contaminants is to concentrate them in the groundwater and eventually incorporate them into the evaporite mineral phases. The dose model in this supplement does not include assumptions about preferential retention or partitioning of contaminants into specific precipitated minerals. Although some preferential

partitioning is likely, this is a reasonable assumption that ensures all contaminants are available for subsequent dose assessments due to exposure to evaporite particulates from soil disturbances. If preferential partitioning occurred, contaminants would only be available for exposure pathways for some fraction of time. At other times, burial and precipitation of uncontaminated evaporates would lead to lesser or no impacts.

In this supplement, contaminant concentrations are estimated in the surficial materials at wet playas by using the ratio of the contaminant concentration to the observed TDS in the groundwater. This approach for estimating contaminant concentrations in surficial materials is conservative for several reasons. First, this approach conservatively assumes that evaporites are the only component of the surficial material; including the rock-derived component (e.g., silt, clay) of the surficial material would dilute the contaminant concentration. Second, the TDS in the groundwater is conservatively assumed to be 257 ppm, which is the TDS from the J-13 well. The J-13 well measured the volcanic aquifer below Fortymile Wash and upstream of the postclosure compliance location. Because TDS generally increases with the time or distance that water is below ground, the TDS from J-13 is lower than that in groundwater downstream of the postclosure compliance location. For comparison, the measured TDS of spring water at Furnace Creek is approximately 600 ppm TDS (Steinkampf and Werrell, 1998); using this value for TDS would decrease the contaminant concentration in evaporite to less than half that of the estimate provided in Chapter 3 of this supplement. Third, this approach for estimating evaporite concentrations is conservative because the evaporites, which include potential contaminants, can be redistributed by wind and rainfall. Since many of the evaporite minerals are highly soluble, they can be dissolved and redistributed during periods of water inundation and flow. Redistribution of the contaminated evaporite particulates would tend to disperse contaminants over a larger area and dilute their concentration.

A.2.3 Biosphere Exposure and Dose Conversion

This section provides a discussion of the biosphere model, which includes exposure pathways and the conversion of contaminant levels to a dose (for radionuclides) or a body uptake (for nonradiological contaminants) for each of those pathways.

For radiological and nonradiological contaminants that reach the biosphere (or accessible environment), either through groundwater pumping or natural surface discharge, the impacts to that environment are assessed by first determining the exposure pathways. The contaminant level (i.e., concentration) is then converted to an impact using a dose conversion factor for radionuclides or a body uptake factor for toxic chemicals. The dose conversion and body uptake factors depend on the exposure pathways in each environment. For radionuclides, the resulting annual dose to humans is compared against natural background levels and the criteria specified for safety in 40 CFR Part 197 and 10 CFR Part 63 for the RMEI. For nonradiological contaminants, body uptake is compared directly against an Oral Reference Dose (e.g., EPA, 1999a,b; 1997a,b; 1994).

In its 2002 EIS and 2008 SEIS, DOE assessed impacts using a conceptual biosphere model with a broad range of water uses and exposure pathways, as shown in Figure A–2. In this supplement, three environments with different exposure pathways are developed. These three environments are

- Environment 1: Irrigation Pumping and an Agricultural Community
- Environment 2: Surface Discharge as Springs with a Local Non-Farming Community
- Environment 3: Surface Discharge at Wet Playas

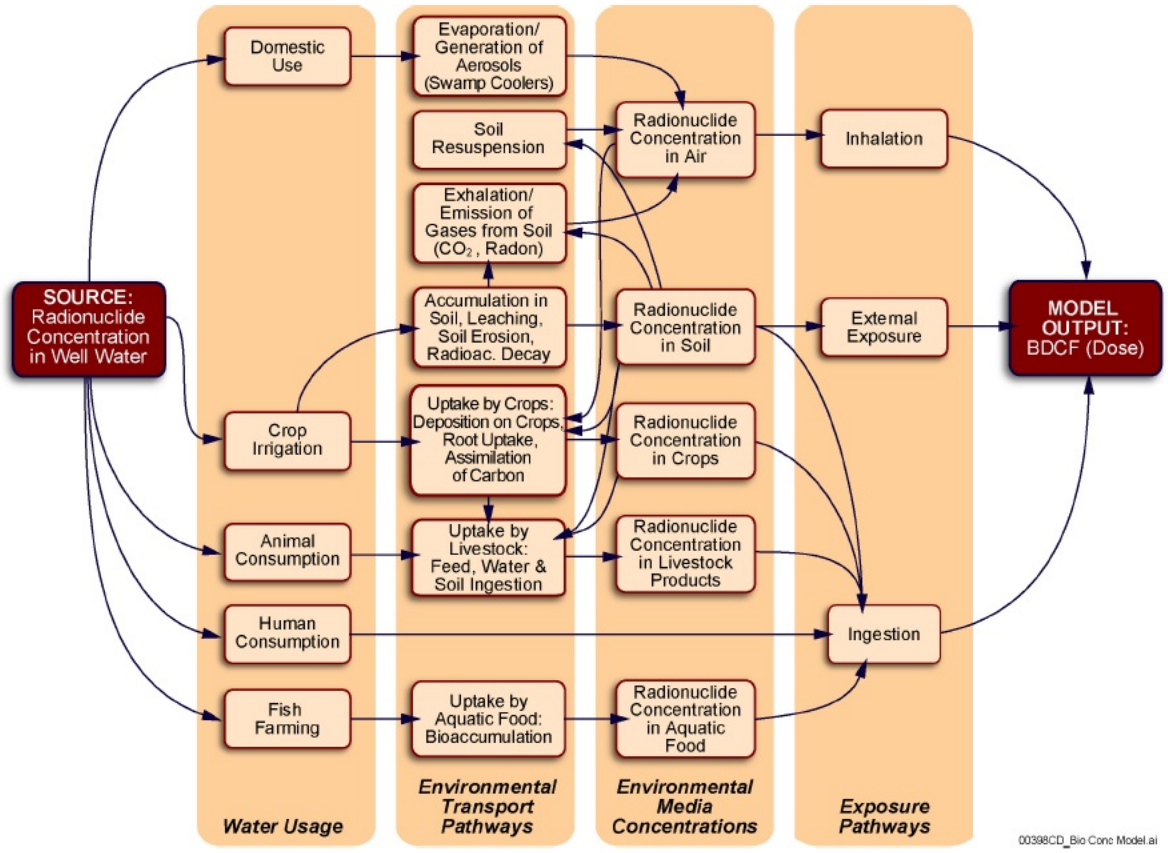

Figure A–2. Water Uses and Exposure Pathways in the Biosphere Conceptual Model. See Text for Discussion of Relevant Pathways for Each Environment. (Source: SNL, 2007c, Figure 6.3-3).

The biosphere exposure framework in Figure A–2 lists a range of potential pathways, but not all water uses and exposure pathways apply to each environment in this supplement. For the pathways for each environment, dose conversion factors were derived from SNL (2007c) for the 31 radionuclides that make up the source term from the repository (DOE, 2014a). The NRC staff, as part of its safety evaluation, found the biosphere exposure framework and dose conversion factors to be acceptable (NRC, 2014a; Section 2.2.1.3.14). The impacts from total U and the nonradiological contaminants Mo, Ni, and V are assessed by estimating the daily uptake amount.

Environment 1: Irrigation Pumping and an Agricultural Community

This environment includes groundwater pumping for irrigation and groundwater use for a domestic and commercial water supply in an agricultural community. Presently, Amargosa Farms is the only location along the flow path from Yucca Mountain where extensive groundwater pumping occurs. The population eats locally grown food, both plants grown in fields and animals raised in the area, and works and lives in areas where the soils could become contaminated by water pumped for irrigation. Some fraction of the contaminants can leach back into the aquifer and possibly be recaptured by pumping wells, and some fraction would escape by soil erosion. In addition, decay and ingrowth will affect radionuclide concentrations. These processes are captured in the irrigation recycling model described in

Section A.2.1. The recycling processes affect the source radionuclide concentration in well water, which is the input in Figure A-2.

The dose pathways for this environment (e.g., Amargosa Farms) are (i) external (body) exposure to contaminated soil, dust or water; (ii) inhalation of contaminated soil particles (including Ra-226) and vapor from evaporative coolers; and (iii) ingestion of water, crops, meat, fish, and soil. These pathways have not changed from those used in the 2002 EIS and 2008 SEIS. The dose conversion factors used in this supplement are from DOE (2014a, Table B-3), which were derived from the maximum values in the distributions provided in the SAR (DOE, 2008a; Table 2.3.10-12). The NRC staff found the dose conversion factors in the SAR acceptable in its safety evaluation (NRC, 2014a; Section 2.2.1.3.14). The dose conversion factors have been adjusted for secular disequilibrium for identified radionuclides as described in Section A.2.2.

The intake of toxic chemicals from the repository (Mo, Ni, V, and total U) at an agricultural community is based on daily intakes by a 70-kilogram [150-lb] person drinking 2 liters [8.5 cups] of water per day. The daily intake is equal to the water concentration times the daily amount consumed, divided by the weight of a person.

Environment 2: Surface Discharge at Springs with a Local Non-Farming Community

For Environment 2, groundwater is discharged in springs and lost by evapotranspiration. The spring water may be used for a local water supply. The areas surrounding springs are sites for evaporation and transpiration that could lead to evaporite minerals forming in contaminated soils, and potentially plants with contaminated uptake. Examples of spring environments along the groundwater flow path are Furnace Creek springs under the present-day and wetter climate states, or the State Line Deposits/Franklin Well area under a wetter climate state.

The biosphere model for a spring environment includes exposure pathways of (i) inhalation of contaminants in dust resuspended into the air and vapor from evaporative coolers, (ii) ingestion of water for drinking and inadvertent ingestion of soil, and (iii) external exposure from contaminant deposits at or near the ground surface. The model does not include groundwater pumping or ingestion of contaminated foods. The dose conversion factors used in this supplement are from DOE (2014a, Table B-4), which were derived from the maximum values in the distributions provided in the SAR (DOE, 2008a; Tables 2.3.10-11 and 2.3.10-12). The NRC staff found the dose conversion factors in the SAR acceptable in its safety evaluation (NRC, 2014a; Section 2.2.1.3.14). The dose conversion factors have been adjusted for secular disequilibrium for identified radionuclides, as described in Section A.2.2.

Intake of chemical contaminants at a springs-type environment is based on daily intakes by a 70-kilogram [150-lb] person drinking 2 liters [8.5 cups] of water per day. The daily intake is equal to the water concentration times the daily amount consumed, divided by the weight of a person.

Environment 3: Surface Discharge at Wet Playas

At playas, groundwater comes close to the ground surface and evaporates or transpires, leaving evaporite minerals in the surficial materials (soil and evaporite). The evaporite mineral content and percentage in the surficial materials can be highly variable. The nonevaporite material is comprised of soil present prior to playa formation, the windblown dust deposited concurrently with evaporite precipitation, and other sediment carried in from higher elevations by sporadic

flooding. Water in the surficial materials and at the surface can be highly variable in composition, but is often saline. Intermittent or local springs may also occur, but the amount of potable water is generally insufficient to support a local human population. The environment is not conducive to farming, and natural vegetation is typically sparse and composed of salt-tolerant species. Examples of playas without prominent springs are the Middle Basin of Death Valley and Alkali Flat. For future wetter climates, the State Line Deposits area would likely also have wet playas, but may also have springs, pools, and marshes.

The exposure pathway for playas includes (i) inhalation of resuspended contaminated dust, (ii) ingestion of contaminated water and inadvertent ingestion of evaporites, and (iii) external (body) exposure to contaminated water or evaporites. A full-time resident living at the discharge areas with the exposure pathways is conservatively assumed. To account for periodic airborne resuspension of surface contaminants without significant soil disruption (i.e., no heavy machinery causing dust resuspension), a value of 0.1 mg/m^3 [6×10^{-9} lb/ft^3] is used for the annual average airborne particle concentration. This represents a maximum long-term value for airborne particle concentrations in the affected environment. The value for resuspension is taken from the distribution provided in DOE (2008b; Table 2.3.10-10). The NRC staff finds this an acceptable and reasonable value, because the NRC staff found the distribution to be acceptable as part of its safety evaluation (NRC, 2014a; Section 2.2.3.1.14). The airborne particle concentration is used with a long-term average breathing rate and an assumed inhalation intake duration for the entire year. These assumptions conservatively overestimate both annual intakes of inhaled contaminants and annual doses. Dose conversion factors used for Environment 3 were derived from SNL (2007c, Tables 6.4-4 to 6.4-6), which the NRC staff found acceptable as part of its safety evaluation (NRC, 2014a; Section 2.2.1.3.14).

Intake of chemical contaminants is for a receptor who is active on the playa but not operating heavy machinery that would create dust. It is based on daily intakes by a 70-kilogram [150-lb] person inadvertently ingesting or breathing dust from contaminated evaporites. The amount inhaled is estimated from the concentration of suspended particles. The daily intake is equal to the evaporite concentration times the daily amount ingested and inhaled, and divided by the weight of a person.

Climate States

Biosphere dose conversion factors would differ for different climate states because groundwater use and resulting exposures vary with climate. For example, a cooler/wetter climate requires less irrigation and thus results in a lower concentration of radionuclides in fields due to the use of less (potentially contaminated) groundwater for irrigation. The present-day climate, which is characterized as the driest of the anticipated climate states, would have the highest biosphere dose conversion factors. For the calculations of impact in this supplement, biosphere dose conversion factors for the present-day climate were used for all of the climate scenarios for conservatism.

A.3 Conservative Assumptions Used in the Model Calculations

Many conservative assumptions were used in the calculations of impacts in Chapter 3. Because of these conservatisms, the NRC staff expects that the actual impacts would be smaller than those calculated in this supplement. The most notable conservatisms in the analyses in this supplement include:

- At each natural surface discharge location, it was assumed that the entire contaminant plume was discharged therein. This likely overestimates the impacts at any one location because contaminants from the repository would likely discharge at several discharge locations. For example, for the present-day climate with no pumping (Analysis Case 2), it is much more likely that some fraction of the plume would discharge at Furnace Creek springs, and that a larger fraction would continue to Middle Basin. Or, if pumping in Amargosa Farms is at some significantly lower rate than is used in Analysis Case 1, some portion of the contaminants could bypass Amargosa Farms irrigation wells and discharge instead at Furnace Creek and Middle Basin.

- The dose conversion factors for the Amargosa Farms area are derived for the characteristics of the RMEI (a hypothetical individual) in a manner that results in maximum annual and lifetime doses, which would not necessarily be representative of the population. The dose to the population in Amargosa Farms would be less than that to the maximally exposed hypothetical individual.

- The dose conversion factors are derived for the present-day climate and would be less for a future wetter climate. The dose conversion factors for the present-day climate were applied to both climates in the analyses for Section A.2.3, and thus likely overestimate dose for the future wetter climate.

- Natural surface discharge rates are likely underestimated for future climate conditions, which would affect estimates used for the no pumping scenario in Analysis Case 2. Model estimates of discharge flow rates are supported by indirect measurements, and were used at Middle Basin (evapotranspiration), Furnace Creek (spring flow), and Alkali Flat (evapotranspiration). However, current regional pumping likely lowers the natural surface discharge rates compared to what might be expected without pumping. Use of a lower surface discharge flow rate would overestimate the concentration of contaminants using the biosphere model described in Section A.2.3, and thus potentially overestimate impacts.

- Lateral and vertical dispersion are not considered along the flow path beyond the postclosure compliance location. Dispersion spreads out the plume and reduces the peak concentration wherever it would occur. Mixing of the contaminated plume with water from other aquifers along the path increases dispersion, such that the concentrations in the plume would decrease at each location where mixing occurs. Mixing of water from beneath Yucca Mountain with other components occurs at the (i) confluence of groundwater from east of Fortymile Wash into Amargosa Desert near Amargosa Farms (east of Fortymile Wash and west of Ash Meadows); (ii) confluence of Fortymile Wash with eastward-flowing groundwater in Amargosa Desert; and (iii) confluence with the carbonate aquifer south of Amargosa Farms, either under the Funeral Mountains or with groundwater from Ash Meadows in Carson Slough and Alkali Flat.

- The irrigation recycling model (see Section A.2.1) neglected radioactive decay and sorption of contaminants. This provides a conservative result because it does not include reductions in contaminant concentrations in the soil column during percolation back into the aquifer.

- The NRC staff's evaluation assumes that doses and intakes would be proportional to evaporite concentrations at playas. This is a conservative assumption because

(i) low-end estimates of dissolved solids in the water were used to estimate radiological and nonradiological concentrations in the precipitated evaporites, (ii) zonation of evaporation sequences and burial may reduce availability of contaminants for dust resuspension, and (iii) rock-based clastic soils and windblown dust would make up some of the surficial material, and therefore reduce the effective concentration of contaminants.

The magnitude of the effect of these conservative assumptions is not quantified in this model. Each of these assumptions serves to potentially overestimate the calculated potential impacts of contaminants on groundwater and the aquifer, and surface discharge sites to capture uncertainty and the range of potential impacts.

APPENDIX B

RESPONSES TO PUBLIC COMMENTS

APPENDIX B RESPONSES TO PUBLIC COMMENTS

This appendix contains comment summaries and responses.

B.1 Public Comment Process for the Draft Supplement

The U.S. Nuclear Regulatory Commission (NRC) staff published NUREG–2184, the draft "Supplement to the Department of Energy's Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada" (supplement) in August, 2015. The NRC staff also distributed the draft supplement to persons and organizations on the adjudicatory distribution list in the Yucca Mountain licensing proceeding, Federal and State government agencies and organizations, Native American tribes, and other interested stakeholders. The public comment period on the draft supplement began on August 21, 2015, and ended on November 20, 2015. As part of the process to solicit public comments on the draft supplement, the NRC staff took the following actions:

- placed the draft supplement *Federal Register* Notice on the NRC's Web site and on the Federal rulemaking Web site (www.regulations.gov) under Docket NRC2–015–0051
- advised stakeholders and published a press release on August 13, 2015, that the draft supplement was available for review and provided a link to the supplement on the NRC's Web site
- published a request for comment on the draft supplement in the *Federal Register* on August 21, 2015 (80 FR 50875)
- sent electronic or paper copies of the draft supplement to participants in the NRC's adjudication for the repository, members of the public, environmental interest groups and nongovernmental organizations, representatives of tribes, and Federal, State, and local government agencies
- announced and held a public meeting via teleconference on August 26, 2015, to explain the public comment process and respond to questions from stakeholders
- announced (via press releases, e-mails, and *Federal Register* notices) and held public meetings in Rockville, Maryland (three meetings, two of which were teleconference-only meetings); Las Vegas, Nevada; and Amargosa Valley, Nevada
- published on September 18, 2015, a *Federal Register* Notice of extension to the comment period from 60 to 91 days, which extended the comment period to November 20, 2015, (80 FR 56501)
- issued press releases announcing issuance of the draft supplement, the beginning of the comment period, the public meetings, and extension of the public comment period
- used the NRC's Web site at http://www.nrc.gov/waste/hlw-disposal/key-documents.html to aid public review of the draft supplement by posting the draft supplement and related announcements in the *Federal Register* and in press releases, meeting times and dates,

meeting materials (e.g., slides, transcripts, summaries, and webcast archives), and meeting handouts and posters

B.1.1 Public Meetings

During the 91-day public comment period, the NRC staff conducted five public meetings. The public meeting in Rockville, Maryland, on September 3, 2015, featured a live webcast and moderated teleconference line to accommodate remote participants. The meetings on October 15 and November 12, 2015, were teleconference-only meetings to ensure that stakeholders unable to participate in the previous public meetings were afforded another opportunity to present oral comments. In addition, the NRC staff held public meetings in Las Vegas, Nevada, and Amargosa Valley, Nevada. Approximately 265 people attended or participated in the public meetings. A certified court reporter recorded oral comments and prepared written transcripts of all five meetings, and the NRC staff prepared meeting summaries with a list of participants for each meeting. Meeting summaries and transcripts can be found in ADAMS under the accession numbers listed in Table B-1.

Notices for public meetings were included in *Federal Register* notices (80 FR 50875 and 80 FR 56501), on the NRC's Web site at http://www.nrc.gov/waste/hlw-disposal/key-documents.html and on the NRC's public meeting notification Web site at http://meetings.nrc.gov/pmns/mtg. The NRC staff also e-mailed meeting notices to the YMEIS_supplement@nrc.gov distribution list.

Table B-1. Draft Supplement Public Comment Meeting Summaries and Transcripts

Meeting Date	Meeting Location	Meeting Summary (Accession No.)	Meeting Transcript (Accession No.)
September 3, 2015	Rockville, Maryland	ML15253A663	ML15253A669
September 15, 2015	Las Vegas, Nevada	ML15272A405	ML15268A399
September 17, 2015	Amargosa Valley, Nevada	ML15280A279	ML15274A168
October 15, 2015	Teleconference	ML15302A184	ML15294A368
November 12, 2015	Teleconference	ML15321A424	ML15321A414

The NRC staff extended the original close of the public comment period from October 20, 2015, to November 20, 2015 (80 FR 56501), and added an additional public comment teleconference on November 12, 2015.

B.1.2 Public Comments on the Draft Supplement

During the public comment period for the draft supplement, the NRC staff received over 1,200 individual comments from 5 transcribed public meetings and more than 140 comment letters. All comment correspondence is available in ADAMS and on www.regulations.gov under docket ID NRC–2015–0051. The transcripts are available in ADAMS as indicated in Table B-1.

B.1.3 Disposition of Comments

At the conclusion of the comment period, the NRC staff reviewed the five public meeting transcripts and each comment letter. Many statements from public meetings or individual comment letters contained multiple individual comments, which were captured and processed separately, as appropriate. Each statement from a public meeting or comment letter was given a unique correspondence identification number, allowing the set of comments from a

commenter to be traced back to the transcript or comment letter in which the comments were recorded.

Table B-3 provides a list of individuals who submitted written and oral comments. The comment authors are identified by name, affiliation (if given), ADAMS accession number of their comment letter or the public meeting transcript, and the comment correspondence identification number. Each comment was assigned to a specific subject area (see Table B-2 for the list of comment categories), and similar comments were further grouped together and summarized. Finally, responses were prepared for each comment summary. This appendix contains comment summaries and the NRC staff responses to these summaries.

When comments resulted in a change to the text of the supplement, the corresponding response refers readers to the appropriate section of the supplement where the change was made. Throughout the final supplement—with the exception of this new Appendix B—revisions to the text from the draft supplement are indicated by vertical lines (change bars) in the margin beside the text. In addition, the NRC staff revised entries in the tables of Chapter 3 to reflect peak values (e.g., during the million-year period) instead of only providing values at the end of the period, as well as to reflect updated values based upon the NRC staff's consistency review of the analyses. The staff also revised low-income and minority population entries in Tables 3-18 and 3-19 to account for more recent data and to correct errors in the draft supplement.

The NRC staff categorized and consolidated comments according to subject area. Table B-2 lists the comment categories (i.e., subject areas) and the page where each general category begins.

Table B-2. Comment Categories

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	B.2.6.3 General Support	B–111

B.2 Comments and Responses

The following sections include summaries of the comments received on the draft supplement and responses to those summaries. Parenthetical numbers after each comment and response refer to the correspondence identification number. Comments can be tracked from the commenter and the source document through the correspondence identification numbers listed in Table B-3.

B.2.1 NEPA Process

B.2.1.1 Public Process

B.2.1.1.1 ***COMMENT***: *Many commenters requested an extension to the comment period for the draft supplement. Commenters expressed concern that the 60-day comment period provided for in the Federal Register Notice was insufficient to allow for the public to review the supplement and other documents in order to understand and comment on the supplement. Some commenters felt that the length of the comment period provided an advantage to the NRC. One commenter expressed concern that the comment period was too short when considering the very long timeframes addressed in the supplement. Some commenters expressed concern about the length of time that it takes for grassroots organizations to reach out to their communities and encourage participation, and about the lack of resources available to give their staffs adequate review time. Following the NRC's extension of the comment period by 31 days, the NRC received additional comments expressing appreciation for the extension, disappointment in the length of the extension, and requesting additional extensions.*

RESPONSE: The NRC staff acknowledges the concerns expressed by commenters about the length of the comment period. In response to requests received to extend the comment period, the NRC staff extended the original 60-day comment period to 91 days. Because of the limited scope of the supplement, the NRC staff believes that 91 days is sufficient time for members of the public to review the document and prepare comments. During the comment period, the NRC staff held five public meetings to explain the purpose and scope of the document, answer questions about the process, and to receive comments. The NRC staff appreciates the considerable number of comments that were received, and each of the comments was taken into consideration in the preparation of the final supplement. Appendix B contains the NRC staff's consideration and response to the comments received on the draft supplement.

(013, 014, 018, 022, 028, 031, 039, 040, 047, 053, 054, 055, 071, 075, 078, 080-16, 083, 085, 092, 093, 094, 101, 104, 107, 110, 111, 112, 130, 141, 146-01, 146-02, 146-05, 146-06, 146-07, 146-13, 147-03, 147-13, 147-14, 147-24, 150)

B.2.1.1.2. ***COMMENT****: Several commenters expressed appreciation for the NRC's holding of public meetings, particularly in-person meetings, seeking public input on the draft supplement, and listening to the public's concerns. Some commenters stated that it is important to exchange ideas, gain a better understanding of the topic, and for the voices of the stakeholders to be heard. One commenter noted that the NRC had provided extensive public participation opportunities.*

RESPONSE: The NRC staff acknowledges the comments in support of the public meetings that were held for this supplement. The NRC staff agrees that stakeholder input is vital to the NRC's decisionmaking process and appreciates the time and effort that stakeholders took to participate. Appendix B contains the NRC staff's consideration and response to the comments received on the draft supplement.

(034, 080-15, 095-03, 095-06,127, 143, 146-02, 147-02, 147-03, 147-04, 147-08, 147-17, 147-29, 148)

B.2.1.1.3. ***COMMENT****: Many commenters requested that additional public meetings be held in California and elsewhere across the country. Most of these commenters requested that these meetings be held near the transportation routes that could be used for shipment of spent nuclear fuel to the repository. Commenters requested a call-in option at all public meetings. One commenter asked if the reason for not holding public meetings on the supplement in California was due to lack of funding or because of lack of consideration for the area.*

RESPONSE: The NRC staff acknowledges the comments requesting additional public meetings and regrets that time and resources did not allow for public meetings to be held in every location requested by commenters. The NRC staff attempted to maximize participation in the public meetings by holding meetings at NRC headquarters that were accessible by teleconference, local meetings in Las Vegas and in Amargosa Valley, and two additional public teleconference meetings. Because the scope of this supplement is limited to impacts from the potential repository on groundwater and from surface discharges of groundwater at points beyond the postclosure compliance location, meeting locations were limited to areas near the potentially affected environment. Las Vegas was selected because it is the closest major population center near the affected environment. Amargosa Valley was selected because it is among the areas directly affected by the impacts discussed in the supplement and is within a few miles of the California/Nevada border. Commenters were also able to submit comments electronically. In response to comments, the NRC staff also extended the comment period from 60 to 91 days. From participation in public meetings and comment letters, the NRC received over 1,200 comments on the draft supplement.

No changes were made to the supplement as a result of these comments.

(013, 014, 022, 028, 031, 039, 040, 047, 053, 054, 055, 071, 075, 076, 078, 080-05, 80-16, 083, 085, 092, 093, 094, 101, 104, 107, 112, 146-07, 146-14, 147-15, 150)

B.2.1.1.4. ***COMMENT****: Two commenters expressed concern that many citizens and public officials are not sufficiently aware of the supplement and other NRC-related activities. One commenter stated that it is incumbent on the government to notify elected officials. Another commenter stated that it seems very few people are interested and may not realize the seriousness of the matters discussed.*

RESPONSE: The NRC staff acknowledges the concern that some citizens and public officials may not be fully aware of the NRC's activities. The NRC staff strives to provide clear and timely notification to affected units of local government and other stakeholders to maximize participation in public comment processes. Consistent with NRC practices, the supplement includes a distribution list for the supplement (Chapter 9). When the draft supplement was published, all individuals on the Yucca Mountain adjudicatory distribution list were notified, as well as many other individuals and organizations. In addition, the NRC issued a press release noting the availability of the supplement.

The NRC staff agrees that public participation is vital to the NRC's decisionmaking process and encourages interested stakeholders to view public participation opportunities on the NRC's Web site at http://www.nrc.gov/public-involve.html.

No changes were made to the supplement as a result of these comments.

(095-02, 095-10)

B.2.1.1.5. ***COMMENT****: Two commenters asked about the availability of information regarding the supplement and public meetings or about use of the www.regulations.gov. One commenter asked where to find transcripts of the public meetings and another asked where to find the slides from the teleconferences on the NRC Web site. One of the commenters also asked about technical issues with use of the www.regulations.gov Web site, including issues with tracking comments on the site, the allotted space for a comment, and determining if a comment has been received.*

RESPONSE: Information about the supplement, including the public meetings summaries, meeting materials, and transcripts can be found on the NRC's Web site at http://www.nrc.gov/waste/hlw-disposal/key-documents.html#er. The NRC staff regrets that commenters may have experienced difficulties with the regulations.gov Web site. All comments the NRC received on the draft supplement are accounted for in this appendix.

No changes were made to the supplement as a result of these comments.

(080-07, 122, 146-10)

B.2.1.1.6. ***COMMENT****: Several commenters expressed concern or disappointment with the NRC's public participation opportunities. One commenter asserted that their organization had not had any say in changes made to the nuclear waste program since DOE's Environmental Impact Statement (EIS) was published. Another commenter stated that the public has struggled to participate in the NRC's processes and obtain information. One commenter stated that NRC should be more sensitive about scheduling public meetings on or close to religious holidays. Another commenter was disappointed that the format of the meeting did not allow for a technical dialogue among participants.*

RESPONSE: The NRC staff acknowledges the comments concerning the public participation opportunities and recognizes the vital importance and value of stakeholder participation in the NRC's decisionmaking process. The NRC staff has attempted to provide ample notification of the availability of the draft supplement for comment, extended the public comment period to allow more time for commenters to provide their input, and provided multiple avenues for comment submission (online, in-person, by mail, and by teleconference). The NRC staff has

also attempted to maximize participation in public meetings by providing teleconference lines at several meetings, providing informational presentations at all public meetings, and holding open houses at the Nevada-area public meetings prior to the formal meeting. The NRC staff recognizes the importance of religious holidays and attempts to schedule meetings so as not to interfere with religious holidays, Federal holidays, or local events.

With regard to opportunities for public participation in the nuclear waste program since the publication of DOE's EIS, the preparation of this supplement is only one of several steps in the licensing process for the proposed repository. As discussed in Section 1.1 of the supplement, the adjudicatory proceeding for the proposed repository is currently suspended. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement as a result of these comments.

(080-10, 122, 146-03, 146-17, 147-12)

B.2.1.2 NEPA Process and the Supplement Scope

B.2.1.2.1. ***COMMENT****: Two commenters stated that the NRC should have conducted public scoping for the draft supplement. One commenter cited changed circumstances, the controversial nature of the Yucca Mountain project, and the passage of 7 years since the development of the NRC staff's Adoption Determination Report (ADR), as reasons to have conducted scoping. Another commenter stated the supplement does not acknowledge a January 20, 2015 letter from the Board of Lincoln County Commissioners to the NRC (Lincoln County, 2015) requesting additional scoping for the draft supplement. The commenter argued that the final supplement must disclose how any such comments may have influenced the supplement's scope.*

RESPONSE: The NRC staff disagrees that additional scoping should have been conducted for the supplement. Section 3.2.1.4.2.3 of the ADR states: "(g)iven the description in this report of the needed supplementation, and pursuant to 10 CFR 51.26(d), the staff would not conduct scoping for the supplement." The NRC Chairman responded to the Chair of the Board of Lincoln County Commissioners by a letter dated March 9, 2015 (NRC, 2015d). In the letter, the Chairman stated that the scope of the EIS was determined by DOE with full public involvement, including public scoping meetings and the publication of a draft EIS for notice and comment, and the scope was adopted by the NRC staff. The Chairman noted that the public was provided the opportunity to challenge the scope of the NRC staff's analysis by raising contentions before the agency's Atomic Safety and Licensing Board.

The letter also explains that the staff prepared the supplement at the direction of the Commission after the U.S. Court of Appeals for the District of Columbia Circuit issued its decision in *Aiken County*, 725 F.3d 255 (D.C. Cir. 2013). The Court directed the NRC to continue its licensing activities and use previously-allocated funds from the Nuclear Waste Fund. Once these funds are expended, the continuation of licensing activities is subject to Congressional appropriations and actions external to the NRC. Additional information concerning changed circumstances since DOE's EISs and the ADR were finalized can be found in comment responses in Sections B.2.1.2.6, B.2.1.2.29, and B.2.2.3.1.

No changes were made to the supplement as a result of these comments.

(118, 123)

B.2.1.2.2. ***COMMENT****: One commenter made several comments describing why the scope of the supplement is appropriate. The commenter stated that the scope is consistent with the areas defined in the NRC staff's ADR, NRC regulations in 10 CFR 51.109(c), and Supreme Court and Commission precedent.*

RESPONSE: The NRC staff acknowledges the comments in agreement with the scope of the supplement.

No changes were made to the supplement as a result of these comments.

(143)

B.2.1.2.3. ***COMMENT****: One commenter stated that the scope of the supplement is insufficient because it does not consider that costs may have changed since DOE developed its EIS. The commenter noted that on-site storage costs at San Onofre have exceeded the industry's estimates.*

RESPONSE: Comments regarding costs for on-site storage of spent fuel or high-level waste, or costs of a repository, are beyond the scope of this supplement, which concerns an assessment of the potential impacts to groundwater and from surface discharges of groundwater beyond the postclosure compliance location. The scope of the supplement is further described in the NRC staff's ADR (NRC, 2008a), and in the NRC's Notice of Intent to prepare the supplement (80 FR 13029).

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement as a result of this comment.

(080-15)

B.2.1.2.4. ***COMMENT****: Several commenters stated that the draft supplement is deficient because it artificially constrains the scope to a single issue. Others said the NRC erroneously eliminated issues that it considered previously and, therefore, failed to look at the whole picture. One commenter stated the NRC did not take a hard look at the national transportation infrastructure, including Federal regulations on the deterioration of rail infrastructure. Another commenter stated the NRC should consider the issues of high-burnup fuels and transportation canisters.*

RESPONSE: The NRC staff acknowledges the concerns raised about the limited scope of this supplement. The scope of the supplement is an assessment of the potential impacts to

groundwater and from surface discharges of groundwater beyond the postclosure compliance location, as described in detail in the NRC staff's ADR (NRC, 2008a) and the NRC's Notice of Intent to prepare the supplement (80 FR 13029).

The NRC Chairman stated in a letter to the Chair of the Board of Lincoln County Commissioners that participants in the adjudication may pursue their contentions before the Atomic Safety and Licensing Board, as well as raise new issues as new or amended contentions, upon resumption of the hearing (NRC, 2015d). The preparation of this supplement is only one of several steps in the NRC's licensing process for the proposed repository. Information may be identified in the future that requires further supplementation of DOE's 2002 and 2008 EISs. The completion of licensing activities is subject to Congressional appropriations and other actions external to the NRC. Specific comments about transportation are addressed in Sections B.2.4.6.6 and B.2.6.1.22 and comments about high-burnup fuels are addressed in Sections B.2.1.2.29, B.2.2.3.2, and B.2.6.1.23.

No changes were made to the supplement as a result of these comments.

(080-05, 080-08, 080-15, 146-02, 148)

B.2.1.2.5. ***COMMENT****: Two commenters made general statements that the scope of the document is too narrow. One of the commenters stated that the only areas that NRC found to critique are with regard to land ownership and water rights.*

RESPONSE: The NRC disagrees that the scope of the supplement is too narrow. The NRC staff identified the scope as a result of the staff's review of the DOE EISs, as documented in the NRC staff's ADR. That assessment defined two areas that needed supplementation: the potential impacts to groundwater and from surface discharges of groundwater beyond the postclosure compliance location. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

The commenter is correct that the NRC staff identified land ownership and water rights as areas of deficiency in DOE's license application. These deficiencies were identified in the NRC staff's safety review, as documented in the NRC staff's SER. The NRC staff concluded in the SER that DOE had not met regulatory requirements regarding ownership and control of certain land and water rights. Additional information about the results of the safety review can be found in Volume 5 of the SER (NRC, 2015b).

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement as a result of these comments.

(146-07, 147-21)

B.2.1.2.6. ***COMMENT****: Several commenters stated that the supplement and DOE's EISs need to be updated to reflect current science, data, and circumstances. The commenters stated that the narrow scope defined by the NRC staff's ADR deserves reconsideration under NRC*

regulations in 10 CFR 51.92 due to changed circumstances and new information that has arisen since 2008. Another commenter cited 10 CFR 51.109(c)(2), addressing "significant and substantial new information or new considerations," and the ADR's application of this regulation. One commenter also called for the NRC to develop a new safety evaluation report for the proposed repository. One commenter asked if the conclusions in the supplement are based on a "recycle of old data." Another commenter stated that the entire licensing process should restart from the beginning.

RESPONSE: The NRC staff acknowledges these comments requesting that the supplement and DOE's documents be updated to reflect new information or changed circumstances since 2008. This supplement concerns an assessment of the potential impacts from the proposed repository to groundwater and from discharges of groundwater at locations downstream of the postclosure compliance point. The NRC staff did not identify any new information about the affected environment beyond the postclosure compliance point pertinent to the scope of the supplement. However, the preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

Some of the commenters gave specific examples of developments since 2008, and these are addressed in further detail in Sections B.2.2.3 (repository inventory and canisters); B.2.1.2.29, B.2.2.3.2, and B.2.6.1.23 (high-burnup spent fuel); and B.2.1.2.6 (changed circumstances).

No changes were made to the supplement in response to these comments.

(116, 118, 121, 128, 141, 146-06, 147-23, 147-24, 148, 149-03, 149-10, 149-20)

B.2.1.2.7. ***COMMENT****: One commenter stated that the scope of the analysis (the timeframe of 1,000,000 years) is too broad, the methodology of the analysis is not quantifiable, and the document is confusing and lacks structure.*

RESPONSE: The NRC staff disagrees with the comment. Responses to comments about the timeframe are provided in Section B.2.2.1. The methodology for the analysis, as described in Chapter 3 of the supplement, employs modeling and other analysis techniques commonly used in environmental impact statements and other NEPA documents. The structure of the document is based on NUREG-1748, "Environmental Review Guidance for Licensing Actions Associated with NMSS Programs" (NRC, 2003). However, there are some differences in the structure of this supplement compared to other NRC environmental review documents due to the narrow scope of this supplement and because it supplements DOE EISs pursuant to an NRC regulation developed to address the NRC's environmental review process specifically for the Yucca Mountain repository (10 CFR 51.109) (NRC, 2003).

No changes were made to the supplement as a result of this comment.

(020)

B.2.1.2.8. ***COMMENT****: A few commenters expressed their concerns about the supplement's consideration of institutional controls for the proposed repository and the assumptions about institutional controls at storage sites in the no-action alternative scenarios in DOE's EISs. Some comments stated that the supplement is insufficient, because it fails to*

update DOE's assessment of a no-action alternative. The comments discussed the two scenarios in the DOE EISs, which include Scenario 1 (long-term storage of spent fuel at reactor and storage sites with institutional controls present) and Scenario 2 (long-term storage with loss of institutional controls). The comments asserted that the proposed action (construction of a repository at Yucca Mountain) was chosen because the Scenario 2 alternative would have large impacts by comparison. The comments also stated that the NRC's Generic EIS for Continued Storage (NUREG-2157) states that the no-action alternative Scenario 2 is contrary to the rule of reason and violates NEPA. The comments conclude that if Scenario 2 is eliminated from consideration, Yucca Mountain is not the preferred alternative under NEPA. Another commenter stated that the validity of the no-action alternative scenario in DOE's EIS that assumes no institutional controls is out of scope for this supplement, because the NRC staff did not raise this as an issue as a result of the staff's 2008 EIS adoption review. The commenter also states that DOE's other no-action scenario and the NRC's evaluations in the Waste Confidence EIS (Continued Storage GEIS) adequately address the Yucca Mountain no-action scenarios, and no further evaluation is necessary. Another commenter stated that the NRC mistakenly relies on institutional controls within the compliance boundary to protect the public from the impacts of contamination, whether those controls are active or passive.

RESPONSE: The comments regarding the consideration of institutional controls in DOE's EISs, the alternatives and no-action alternative in DOE's EISs, institutional controls at storage sites, and the evaluations in the NRC's Continued Storage GEIS (NUREG-2157) are beyond the scope of this supplement. The supplement concerns an assessment of the potential impacts to groundwater and from surface discharges of groundwater beyond the postclosure compliance location. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029), and in the NRC staff's ADR (NRC, 2008a). The alternatives to the proposed repository are discussed in DOE's 2002 and 2008 EISs, including institutional controls. The NRC staff's ADR concluded that it is practicable to adopt DOE's EISs (with supplementation related to groundwater impacts beyond the postclosure compliance location), and the NRC staff's review did not identify the need for supplementation concerning alternatives or institutional controls at the repository site.

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. As stated in Section 1.4 of the supplement, the supplement does not represent a change to the proposed action or alternatives presented by DOE. However, information may be identified that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement as a result of these comments.

(132, 138, 141, 146-06, 148)

B.2.1.2.9. ***COMMENT****: Three commenters raised questions or concerns about the alternatives considered in the supplement. Two of the commenters stated that a NEPA analysis would include an evaluation of alternatives to determine the best solution and with consideration of all relevant environmental factors. One commenter expressed concern that, because Yucca Mountain is the only site under consideration, the NEPA analyses for the proposed repository justify a foregone conclusion. Another commenter questioned whether other sites had been considered as alternatives to Yucca Mountain, or whether Yucca Mountain was the only site considered.*

RESPONSE: The analysis of alternatives is included in the DOE EISs for Yucca Mountain, which were assessed and adopted by the NRC staff, consistent with the Nuclear Waste Policy Act of 1982, as amended (NWPA), and with NRC regulations (10 CFR 51.109). The NRC staff's adoption of DOE's EISs is documented in its ADR (NRC, 2008a), which specified two areas that needed supplementation: impacts to groundwater and from surface discharges of groundwater beyond the repository compliance location. These areas constitute the scope of this supplement. As noted in Section 1.4 of the supplement, the supplement does not represent any change to the alternatives identified by DOE in its EISs. The NWPA, as amended, specifies Yucca Mountain as the only site for consideration and states in Section 114(a)(1)(D) that additional alternative sites need not be considered.

No changes were made to the supplement as a result of these comments.

(118, 146-04, 149-10)

B.2.1.2.10. ***COMMENT****: Three commenters provided input with regard to tribal consultation. One commenter quoted the draft supplement on page 4-20 to note that meaningful and ongoing tribal consultation is important. Another commenter pointed to the supplement's conclusion in Section 3.3 that "DOE would need to assess whether further consultation and investigation are necessary to account for potential impacts on cultural resources that may be located in areas where groundwater discharges to the surface," noting that this statement indicates the supplement evaluation is incomplete, and inquiring whether the staff plans to further address the issue*.

Another commenter highlighted the same conclusion in Section 3.3 of the supplement and noted the similar conclusion in Section 4.5.2.3 (page 4-19) of the supplement. The commenter stated that the supplement improperly excludes an analysis of the Timbisha Shoshone Tribe's interests in California, and that deferring such an analysis to an unknown future time prevents the tribe from meaningfully evaluating the supplement and presents the possibility that the analysis may never be conducted. The commenter cited a court decision [Conner v. Burford, 848 F.2d 1441, 1452 (9th Cir.1988)] in arguing that this exclusion is in violation of NEPA, because proceeding with the project without the information that would be provided by such an analysis amounts to conducting an interim action that could prejudice the ultimate decision on the project. The commenter concludes that, without this analysis, the Timbisha Shoshone Tribe's statutory rights to be consulted on these impacts is denied.

One commenter further noted that the supplement acknowledges that the Programmatic Agreement in place to govern project-related compliance under the National Historic Preservation Act is limited in scope to the repository site and the surrounding controlled area (i.e., the Project Operator-Controlled Area). The commenter pointed out that the Programmatic Agreement was executed in 2009 with a 10-year duration and includes a statement that impacts outside the Operator-Controlled Area are outside the scope of the Agreement and need to be considered separately. The commenter stated that the affected area in Nevada and California covered by the supplement is larger than the area covered by the Programmatic Agreement, and that the draft supplement is lacking an analysis of the short-term and long-term project effects in areas not covered by the Agreement.

RESPONSE: The NRC staff disagrees that its supplement is incomplete. However, the staff recognizes that tribes may not have had the opportunity to fully consult with DOE on potential impacts to cultural and historical resources at groundwater discharge locations because these areas were not fully considered in DOE's EISs. Section 3.3 of the supplement describes DOE's

activities related to tribal consultations and cultural and historic resources under the National Historic Preservation Act (NHPA) and DOE's Native American Interaction Program. The NRC staff also notes the commitment DOE made in its EISs to complete these activities for impacted areas within the scope of the proposed repository. The supplement also describes DOE's programmatic agreement with the Advisory Council on Historic Preservation and the Nevada State Historic Preservation Office. The NRC staff's supplement addresses groundwater discharge areas that were not specifically addressed in DOE's EISs or in the executed programmatic agreement.

As stated in Section 4.1 of the staff's ADR, DOE is the lead agency responsible for these activities. As stated in Section 2.3.2 of the supplement, cultural and historic resources may be located in or around these discharge areas. As noted in Section 3.3.5 of the supplement, DOE would need to assess whether further consultation and investigation are necessary to account for potential impacts on cultural resources that may be located in areas where groundwater discharges to the surface.

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified related to the commenters' concerns that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement in response to these comments.

(060, 080-04, 136)

B.2.1.2.11. ***COMMENT****: One commenter expressed a number of concerns about the evaluation of impacts documented in the supplement and in the DOE EIS documents of 2002 and 2008. Specific concerns addressed compliance of the supplement and DOE EISs with court rulings and regulations of the Council on Environmental Quality for implementation of NEPA, and the potential synergistic effects of metals (specifically, Cr^{6+} and V^{5+}) and radionuclides on the environment and human health.*

RESPONSE: The supplement was prepared in accordance with NEPA, the NRC's regulations that implement NEPA in 10 CFR Part 51, and staff guidance in NUREG-1748 (NRC, 2003). The staff's review of DOE's EISs is given in its ADR (NRC, 2008a), which discusses the basis for the adoption under 10 CFR 51.109, and the need for supplementation on the specific issues addressed in the supplement.

The supplement did not examine synergistic effects of metals and radionuclides, as these are unlikely due to the very low concentrations of the metals of interest calculated for the groundwater system. While it is correct that large amounts of metals, such as Cr and V, are present in the engineered materials of the repository, the metals would enter the groundwater system very slowly (corresponding to the slow corrosion rates) and result in low groundwater concentrations, as evaluated by the NRC staff in the SER (NRC, 2014a; Section 2.2.1.3.1). Even using the very conservative assumption in the supplement that all of the metal in the repository would ultimately be corroded and released, the calculated groundwater concentrations and from surface discharges of groundwater remain very low (see Section 3.1 and a discussion of the NRC staff's release model in Appendix A, Section A.1.1). The potential synergistic effects cited by the commenter appear to occur at much higher metal concentrations and radiation doses than would be present in the groundwater environments evaluated in the supplement.

No changes were made to the supplement as a result of these comments.

(116, 147-12)

B.2.1.2.12. ***COMMENT****: Two commenters stated that the supplement should be revised to recognize and incorporate applicable Nevada and California State laws into the analysis. One commenter cited Nevada water statutes [Nevada Revised Statutes (NRS) 532, 533, 534, and 445A] and the Nevada Water Pollution Control Law (enacted at NRS 445A; Sections 445A.400, 445A.405, 445A.415, and 445A.465), which the commenters stated collectively prohibit the discharge of radioactive materials into groundwater and the "artificially induced alteration" of the radiological integrity of groundwater. Another commenter stated that these laws provide protection beyond the regulations for the Clean Water Act and Safe Drinking Water Act and may not be preempted by Federal law. The commenter argued that the supplement should include a discussion of these laws and associated permitting requirements and should address groundwater impacts at the repository site rather than at a location 11 miles from the repository. The commenter also stated that an analysis of the project with respect to California laws on water quality and water rights is needed, because impacts to groundwater and surface discharge areas in the Death Valley area may occur. The commenter cites the California Water Code (§§ 13000, et. seq., Porter-Cologne Water Quality Act) and Article 10 Section 2 of the California Constitution. One of the commenters also stated that the supplement should account for how the scarcity of water in Nevada could exacerbate the impacts from contamination from the proposed repository, further limiting potential beneficial uses.*

One commenter also noted that the Yucca Mountain project may be required to have state-issued permits for discharges to surface waters and groundwaters of the State, including permits covering such activities as stormwater management, de minimis discharges, pesticide use, drainage wells, groundwater discharges, wastewater discharges, sewage management, underground injections, and other similar activities. The commenter also said that, additionally, DOE will be responsible for obtaining all other Federal, State, or local permits that may be required.

RESPONSE: DOE compliance with State laws and permits are beyond the scope of this supplement, which concerns an assessment of the potential impacts to groundwater and from surface discharges of groundwater beyond the postclosure compliance location. The scope is further described in the NRC staff's ADR (NRC, 2008a) and in the NRC's Notice of Intent to prepare the supplement (80 FR 13029).

The scope of the supplement does not include impacts on site at the repository, which were evaluated in the DOE EISs. In Chapter 11 of both the 2002 and 2008 EISs, DOE evaluated compliance with the Safe Drinking Water Act, the Clean Water Act, and Nevada statutes (including those cited by the commenter), noting that the Nevada primary drinking water standards are identical to the national standards. In the 2008 EIS, DOE also acknowledged that various permits would need to be obtained to comply with State and Federal laws and identified some of the permits that it had already obtained.

With regard to the request that the supplement discuss the scarcity of water and the potential for the scarcity to exacerbate impacts, the description of the affected environment in Chapter 2 of this supplement describes in detail the desert environment, current water quality, and water uses in the area. Chapter 3 of the supplement describes the impacts that may occur to groundwater and the potential contamination that could result from a repository beyond the

postclosure compliance location, as well as the potential different uses of the water under different future climate states. Chapter 4 discusses past, present, and reasonably foreseeable future actions that could contribute to cumulative impacts associated with the proposed repository. Considering amounts of water, baseline water quality, potential for contaminants to concentrate, and many other factors, the supplement concluded that the potential impacts to groundwater would be small.

The preparation of this supplement is one of several steps in the repository licensing process. Information may be identified that requires further supplementation of DOE's EISs in the future. The completion of licensing activities, however, is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement as a result of these comments.

(136, 146-69, 148)

NEPA Process

B.2.1.2.13. ***COMMENT****: Several commenters requested clarification or made statements regarding the licensing process and framework for the Yucca Mountain repository, and how the supplement fits within that framework. One commenter requested clarifications in two specific areas of the supplement: i) at Page 1-2 Line 6, requesting a summary of why the NRC's Atomic Safety and Licensing Board denied DOE's request to withdraw the license application; and ii) at Page 1-2 Line 19, requesting clarification on why the adjudicatory process remains suspended, also stating that it is due to lack of funding. One commenter asked what options stakeholders have to challenge the supplementing of documents that are out of date, asking whether an opportunity to challenge would be offered if the licensing proceeding were to continue, how the public would be notified if the proceeding were to continue, and whether additional parties to the proceeding could be added at that time. Another commenter noted that the NRC's and DOE's legal responsibilities would not be met if the licensing process does not continue and questioned how completion of the supplement relates to the hearing process.*

RESPONSE: The NRC staff recognizes the complexity of the process by which DOE would obtain a license to construct and operate a repository at Yucca Mountain, though the staff notes that these comments are outside the scope of this supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029), and in the NRC staff's ADR (NRC, 2008a).

The licensing process for a repository at Yucca Mountain has two major components, which inform the NRC's regulatory decision: an environmental review and a safety review. The framework for the NRC's environmental review for the repository is defined by NEPA, which requires that agencies consider environmental impacts in their decisionmaking. The NWPA requires that DOE prepare an EIS for the proposed repository and that the NRC adopt DOE's EIS to the extent practicable. DOE published its final EIS for the repository in 2002 and submitted the EIS with its site recommendation to the President of the United States in 2002. In 2008, DOE published a final supplemental EIS, which it submitted along with its 2002 EIS to the

NRC as part of its license application. The NRC staff reviewed the EISs and issued its ADR in September of 2008. As discussed in Section 1.2 of the supplement, the ADR describes the scope of this supplement.

The NRC maintains information about the status of the Yucca Mountain licensing proceeding on its Web site at http://www.nrc.gov/waste/hlw-disposal.html. Should the licensing process resume, the NRC would notify participants in the adjudication and would also notify the public through a press release, announcement on its Web site, E-mail communications, and a *Federal Register* notice.

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement as a result of these comments.

(046, 080, 149-02)

B.2.1.2.14. ***COMMENT****: Several commenters asked questions about the NRC staff's ADR. The commenters requested information about the history of the ADR, whether a record of decision is available, how the ADR fits into the decisionmaking process, and the qualifications of the NRC staff who made the decisions reflected in the ADR.*

RESPONSE: The ADR (NRC, 2008a) was developed by the NRC staff to document the staff's review of DOE's EISs for the proposed repository at Yucca Mountain. The Nuclear Waste Policy Act requires that DOE prepare an EIS for the proposed repository and that the NRC adopt DOE's EIS to the extent practicable. DOE published its final EIS for the repository in 2002. In 2008, DOE published a final supplemental EIS, which it submitted along with its 2002 EIS, to the NRC as part of its license application. The NRC staff reviewed the EISs and issued its ADR in September of 2008 (NRC, 2008a). The ADR defined the scope of this supplement, as discussed in Section 1.2 of the supplement.

Appendix A of the ADR lists the contributors to the review and their qualifications. A record of decision was not issued for the ADR, because it does not represent a final decision by the NRC. The NRC's final decision on the environmental review would follow completion of NRC adjudication on the construction authorization, and a record of decision would be issued in support of a construction authorization decision.

The preparation of this supplement is one of several steps in the licensing process for the proposed repository; the adjudicatory proceeding is currently suspended. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement as a result of these comments.

(146-02, 146-03, 146-05)

B.2.1.2.15. ***COMMENT****: Several commenters questioned whether the NRC is playing an appropriate role by developing this supplement instead of DOE, and whether a conflict of interest therefore exists. Some commenters stated that NRC authorship of the supplement compromises the integrity of the document and gives the perception that the regulator is not*

independent. One commenter stated that the NRC staff decision to prepare the supplement reverses the staff's previous position, is in contradiction to NEPA, and that the decision was made without a reason and without a prior opportunity for public input. The commenter stated that this decision violates 10 CFR 63.24(c), which provides that DOE must supplement its EIS to account for changes in its proposal or other significant new information, and that the Commission had stated that imposing this requirement on DOE was appropriate in the circumstances envisioned by the proposed regulation [54 Fed. Reg. 27864, 27867 (July 3, 1989)]. The commenter also stated that because the information identified in the NRC staff's ADR is an important information gap, the filling of that gap (the authoring of the supplement) is equally important. Thus, the commenter concluded, this supplement should have fallen into the "new and significant information" meaning of 10 CFR 63.24, which would require DOE to develop the supplement and would make the NRC's authorship unlawful.

RESPONSE: The NRC staff disagrees that development of the supplement by the NRC staff is inappropriate or compromises the supplement or the independence of the NRC in its review of the application for the proposed repository. The potential for the NRC to develop an EIS supplement for Yucca Mountain is specifically contemplated in 10 CFR 51.109 and is discussed in Section 3.2.1.4.2.3 of the staff's 2008 ADR. Also, as stated in Section 1.1 of the supplement, the Commission directed the staff to develop the supplement only after DOE informed the NRC, in response to a Commission request, that DOE would not prepare the supplement.

With respect to public participation, following the August 2013 decision by the U.S. Court of Appeals for the District of Columbia Circuit that directed the NRC to resume the licensing process for DOE's license application, the Commission provided an opportunity for participants in the adjudicatory proceeding to comment on how to proceed (NRC, 2013).

Concerning the requirement in 10 CFR 63.24(c) to update the EIS, DOE published a final supplement to the 2002 EIS in 2008.

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement as a result of these comments.

(146-04, 147-02, 147-14, 148, 149-13)

B.2.1.2.16. ***COMMENT****: One commenter made broad statements that the draft supplement violates both the "letter and spirit" of NEPA and the NWPA. The commenter went on to give several detailed explanations of their objections to the supplement, including NRC preparation of the supplement (instead of DOE); information that the commenter stated was significant new information having arisen since the ADR was published in 2008; and other concerns about scientific and legal deficiencies*.

RESPONSE: The NRC staff disagrees with the comment. The NRC staff has carefully complied with NEPA and the NRC's NEPA-implementing regulations and guidance in 10 CFR Part 51 and NUREG-1748 (NRC, 2003) in preparing this supplement. Furthermore, the staff prepared the supplement in compliance with the NWPA; this issue is discussed further in Section B.2.1.2.15. Issues regarding potential new information are addressed in

Section B.2.1.2.6. The commenter's other specific objections that followed this general statement are captured and addressed in specific topic areas throughout this appendix.

No changes were made to the supplement as a result of this comment.

(148)

B.2.1.2.17. ***COMMENT****: One commenter stated that the NRC previously indicated to the Appeals Court for the District of Columbia Circuit that it had limited resources to complete the Yucca Mountain license application review. The commenter asked whether sufficient resources were available to complete the groundwater analysis in this supplement and stated that if resources were not adequate, the NRC should note where additional funding could result in a more comprehensive analysis. Another commenter stated that a dissenting opinion in the court case in which the NRC was ordered to resume licensing activities [In Re Aiken County, 725 F.3d 255 (D.C. Cir.2013)] held that the amount of funding available for licensing activities was grossly insufficient. The commenter went on to say that the court case had left unresolved whether or not the NRC would have sufficient resources to lawfully complete the review process, and that regardless of availability of finances, nothing in the court's majority and dissenting opinions excuses any final decisionmaking on Yucca Mountain from fully complying with NWPA and NEPA.*

RESPONSE: Comments regarding the funding needed or available to complete the Yucca Mountain licensing review are beyond the scope of this supplement, which concerns an assessment of the potential impacts to groundwater and from surface discharges of groundwater beyond the postclosure compliance location. However, the NRC staff acknowledges that limited funds are available to complete the Yucca Mountain license application review. The 2013 decision by the Court of Appeals for the District of Columbia Circuit ordered the NRC to continue work on licensing activities as long as it had available funds. Following the NRC staff's publication of the SER, sufficient remaining funds were available for the staff to develop this supplement. The NRC staff agrees that all license review activities must be in accordance with the NWPA and NEPA and has conducted its reviews and analyses in accordance with the NWPA and NEPA.

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement as a result of these comments.

(018, 019, 148)

B.2.1.2.18. ***COMMENT****: Several commenters stated their objections to the completion of the document on a "fast track" or with missing information. Commenters stated the supplement schedule prevented a thorough scientific evaluation, did not provide transparency regarding the potential impacts, and did not provide an opportunity for meaningful public participation. Another commenter noted the NRC's responsibility to future generations, in the context of one-million-year compliance period, is more important than meeting a deadline. One commenter cited experiences at the WIPP facility, Savannah River site, and Hanford site as*

reasons for careful consideration. Two commenters stated that the supplement is premature because not all of the risk factors have been adequately characterized or evaluated.

RESPONSE: The NRC staff disagrees with commenters that there was not sufficient opportunity for public participation on the supplement. With regard to the development of the supplement, the NRC staff assessed the time and resources needed to obtain sufficient information to complete its required analyses, given the limited scope of the document. Furthermore, in recognition that public participation is important to the NEPA process, the NRC staff extended the comment period, giving members of the public additional time to evaluate the draft supplement and prepare comments. The NRC staff received over 1,200 individual comments from 5 transcribed public meetings and more than 140 comment letters.

While experiences at other sites such as WIPP and the Savannah River Site are beyond the scope of this document, which concerns groundwater impacts beyond the postclosure compliance location, the NRC staff acknowledges the commenters' concerns and carefully evaluated the potential impacts of the proposed repository beyond the postclosure compliance location.

No changes were made to the supplement as a result of this comment.

(111, 146-02, 146-12, 146-13, 146-16)

B.2.1.2.19. ***COMMENT****: Several commenters made statements about the lack of funding available for affected units of local government (AULGs) and affected Indian tribes to consider and comment on the draft supplement. One commenter expressed concern that the Timbisha Shoshone, a designated affected tribe, did not receive prior notification that the supplement was being issued. The commenter stated that the tribe did not have the time needed nor resources available to hire experts to conduct the needed thorough review, especially given the importance of potential contamination on tribal lands and the cultural and spiritual importance of water to the tribe. The commenter described its efforts to secure funding to conduct a review [from the Department of Interior (DOI), NRC, DOE, and the Central California Agency of the DOI's Bureau of Indian Affairs] but noted that it was unsuccessful. The commenter stated that the U.S. is bound by its own law to provide additional funding to the Timbisha to conduct a review, citing 42 U.S.C. § 10138(b) and 42 U.S.C. § 10199. The commenter described the supplement as an "abbreviated effort to assess impacts without meaningful tribal consultation," since no funding was provided. The commenter stated that the Timbisha has full statutory rights to consultation, and; therefore, the supplement should be rejected until funding and time are granted. The commenter also stated that the NRC cannot defer an assessment of potential impacts to Timbisha lands in California, which is discussed in Section B.2.6.1.4 and B.2.6.1.5.*

Two commenters stated that their respective organizations are at a disadvantage without having received funding to hire the technical experts necessary to adequately review the document. One of these commenters noted that had DOE completed the supplement, AULGs would have received funding, and that finalizing the document without proper AULG funding and involvement makes a mockery of the intent of NEPA and the intent of Congress in the NWPA. One commenter noted that the recent incidents at WIPP in New Mexico illustrate why potential impacts should not be viewed so far in the future that they are not important to local communities.

RESPONSE: The NRC staff acknowledges both the lack of funding available for AULGs and the concerns that this lack of funding has been a disadvantage to reviews of the supplement.

The Nuclear Waste Policy Act of 1982 provides that the Secretary of DOE shall make financial assistance available through grants to the State of Nevada, affected units of local governments, and to affected tribes, for the purpose of participating in the licensing process. This funding has been used by the State of Nevada, local governmental agencies, and tribes to fund participation in DOE's technical and environmental review process. The NRC is not granted authority under the Nuclear Waste Policy Act to provide funding for such participation. For this reason, the NRC is not able to provide funding to the State of Nevada, affected tribes, or affected units of local government.

The NRC staff provided its Notice of Intent to prepare the supplement in the *Federal Register* on March 12, 2015 (80 FR 13029). The NRC staff also issued a press release and notified the hearing participants and other stakeholders of the supplement's publication. The NRC staff made efforts to meet with members of the Timbisha Shoshone Tribe, including to discuss the draft supplement and respond to questions. The NRC staff also held multiple in-person public meetings and public teleconferences seeking stakeholder input on the draft supplement.

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement as a result of these comments.

(019, 060, 073, 138, 147-11, 147-14, 149-05, 149-08)

B.2.1.2.20. ***COMMENT****: One commenter requested that the NRC consider potential groundwater contamination from a holistic perspective. The commenter also requested that NRC consider utilizing unconventional land management perspectives by consulting with native peoples and protecting their knowledge as a resource.*

RESPONSE: The NRC staff acknowledges the commenter's concerns regarding the need for a thorough analysis of potential groundwater contamination. Some Native American tribes, as well as many local governments, have been participants throughout the Yucca Mountain licensing process either through formal consultations with DOE, by providing comments on DOE and NRC documents, or as parties to the NRC adjudication.

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities is subject to appropriations and other actions external to the NRC. Additional information about the status of tribal consultations can be found in Section B.2.1.2.10.

No changes were made to the supplement as a result of this comment.

(026)

B.2.1.2.21. ***COMMENT****: Two commenters stated that the draft supplement should not be finalized until contentions related to the Yucca Mountain licensing process are resolved. One commenter referenced a letter dated January 20, 2015, from Lincoln County to the NRC, which stated that the supplement should analyze the NEPA issues raised in the contentions that were*

admitted in the adjudicatory proceeding and conduct a public scoping process. Because the NRC did not include this information in the draft supplement, the commenter requested that the final supplement address these NEPA contentions. One commenter stated that the draft supplement is not complete and does not satisfy NEPA because the hearing contentions are not resolved. The commenter is also concerned that the State of Nevada's comments on the DOE EIS and the draft supplement are not fully addressed. The commenter noted that an accurate groundwater analysis is central to an evaluation of the repository's potential long-term risks. The commenter also noted that the NRC staff's SER does not consider TSPA-related contentions and argued that the use of these unresolved assumptions in the supplement renders the document invalid.

RESPONSE: The NRC staff disagrees that all contentions related to the Yucca Mountain licensing proceedings must be resolved before the supplement is finalized. The NRC staff acknowledges that contentions are currently pending in the suspended Yucca Mountain adjudicatory proceeding, including contentions that concern DOE's EISs. The NRC Chairman stated in a letter to the Chair of the Board of Lincoln County Commissioners (NRC, 2015d) that participants in the adjudication may pursue their contentions before the Atomic Safety and Licensing Board, as well as raise new issues as new or amended contentions upon resumption of the adjudication.

The NRC staff recognizes that groundwater analysis is an important component in evaluating the repository's potential long-term risks. Furthermore, the staff agrees that assumptions about the repository, including TSPA results, affect the assessment of impacts to groundwater in the supplement.

A number of commenters raised concerns related to the NRC staff's use of information from the DOE's Total System Performance Assessment (TSPA), which was part of DOE's license application for the proposed repository at Yucca Mountain and used as a primary input and as support for evaluating environmental impacts in this supplement. A discussion of the use of modeling in the supplement can be found in Section 1.2.2, Section B.2.2 of this appendix, and in Appendix A. The NRC staff's evaluation of information on these topics, as presented in the license application, is contained in the staff's Safety Evaluation Report (SER) for the Yucca Mountain repository license application (NRC, 2014a). As commenters note, several of the issues raised by commenters are the subject of contentions pending in the suspended adjudicatory proceeding.

Comments regarding the scope of the supplement are addressed in Section B.2.1.2.1.

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities, however, is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement as a result of these comments.

(123, 148)

B.2.1.2.22. ***COMMENT****: One commenter stated that NRC has not taken the "hard look" required by NEPA. The commenter stated that the NRC ignored available information on*

interactions between metals and radionuclides and did not properly address incomplete information, and, thus, violated NEPA, 10 CFR Part 63, and U.S. Supreme Court decisions.

RESPONSE: The NRC staff disagrees with the comments. The scope of NRC staff's analysis, as stated in the ADR (NRC, 2008a), is an assessment of the potential impacts to groundwater and from surface discharges of groundwater beyond the postclosure compliance location. This scope is detailed in the NRC's Notice of Intent to prepare the supplement (80 FR 13029). The staff specifically addresses potential metal and radionuclide interactions in Sections B.2.1.2.11, B.2.2.2.4, and B.2.2.2.5 of this appendix.

In addition, the NRC staff complied with the NRC's NEPA-implementing regulations in preparing the supplement. The staff evaluated the information in DOE's license application and EISs, the NRC staff's SER, and other sources of information.

The preparation of this supplement is only one of several steps in the licensing process for the proposed repository. Information may be identified in the future that could require supplementation of DOE's 2002 and 2008 EISs. The completion of licensing activities is subject to Congressional appropriations and other actions external to the NRC.

No changes were made to the supplement as a result of these comments.

(116)

B.2.1.2.23. ***COMMENT****: One commenter stated that the draft supplement demonstrates a lack of scientific rigor. First, the commenter stated that the NRC staff's June 2015 visit to the Yucca Mountain area did not produce information, analyses, conclusions, or a trip report. The commenter stated that the trip was undertaken to preempt the accusation that the supplement was prepared without a site visit being conducted. Second, the commenter pointed out that Figure 2-3 in the supplement is based on a U.S. Geological Survey paper published in 1979, suggesting the staff's analysis of "old" data is insufficient. The commenter further stated that relying on this information, which predates the Yucca Mountain license application, does not meet the NEPA requirement at 40 CFR 1506.5 that reviewing agencies independently review and verify information. Third, the commenter noted that in response to a Freedom of Information Act request for the data on which the map in Figure 2-3 is based, both the NRC and DOE responded that they do not possess that data, and this calls into question the accuracy and basis for relying on the map and figure.*

RESPONSE: The NRC staff disagrees that its analyses are not scientifically rigorous. The NRC undertakes in-person visits, as appropriate, to relevant geographic locations to enable technical staff to conduct visual inspections of sites and their characteristics. The first-hand knowledge obtained from site visits informs NRC staff analyses.

Figure 2-3 in the supplement is derived from Belcher and Sweetkind, 2010, and references cited therein. As noted by the commenter, the information in Figure 2-3 has been used in a variety of academic sources since 1979, and the NRC staff finds it appropriate for use in the supplement.

No changes were made to the supplement as a result of these comments.

(148)

B.2.1.2.24. ***COMMENT****: Several commenters requested that the supplement undergo an independent peer review. Some commenters stated that the draft supplement is subject to the Information Quality Act (IQA), as implemented by a January 14, 2005, OMB Bulletin and NRC Management Directive Section 3.17, because the supplement is a "highly influential scientific assessment" that is "scientifically and technically novel." Another commenter argued that the supplement is influential because it will affect national waste disposal policy and private sector decisions on continued storage of spent nuclear fuel. The commenter also noted that NRC Management Directive 3.17 states that information "may not be deemed 'influential' for the purposes of the guidelines 'because it is limited in its breadth.'" Another commenter stated that the NRC was originally the independent reviewer of the DOE EISs; however, this independent role was relinquished when the NRC developed the supplement, and, therefore, a separate independent review is needed. Other commenters expressed concerns about accountability and transparency and requested disclosure of the credentials of the authors and reviewers.*

RESPONSE: The supplement was prepared consistent with the IQA and OMB's guidelines concerning peer review. The NRC staff does not find that the supplement is "scientific information the agency reasonably can determine will have or does have a clear and substantial impact on important public policies or private sector decisions." (70 FR 2664). The supplement provides an assessment of potential impacts to groundwater and from surface discharges of groundwater beyond the postclosure compliance location, which extends 11 miles [18 km] beyond the Yucca Mountain project site.

The NRC's Notice of Intent to prepare the supplement (80 FR 13029) and the NRC staff's ADR (NRC, 2008a) describe the scope of the supplement in greater detail. The subject of the supplement is only one of many subject matter areas regarding the proposed repository that were analyzed in DOE's EISs, described in DOE's license application and associated reports, and evaluated in the NRC staff's SER. Importantly, the preparation of the supplement is only one of several steps in the licensing process for the proposed repository. Thus, this limited scope supplement will not determine national waste disposal policy or private-sector decisions about the storage of spent fuel.

The NRC staff has not relinquished its role of independent regulator with the development of the supplement. The NWPA and NRC's regulations at 10 CFR 51.109 anticipated the potential role for the NRC staff to develop an EIS supplement. The NRC staff has, consistent with 10 CFR Part 51, published the draft supplement for public review and comment, revised the supplement in response to comments, and published the final supplement to reflect revisions and responses in this appendix according to NEPA and the NRC's NEPA-implementing regulations. The public comment process provides accountability and transparency to the public and stakeholders. A list of contributors to this document and their credentials is provided in Chapter 8 of this supplement.

No changes were made to the supplement as a result of these comments.

(034, 124, 141, 146-02, 146-04, 146-05, 146-06, 146-13, 147-04, 148)

B.2.1.2.25. ***COMMENT****: One commenter stated that DOE's EIS is a minimalist environmental impact statement that ratifies a predetermined, politically driven outcome, and the supplement's reliance on DOE's information continues this sense of predetermination, even though DOE no longer supports construction of the repository.*

RESPONSE: The NRC staff disagrees with the comment. The NRC staff reviewed DOE's EISs and determined that, in accordance with the NWPA, it would be practicable to adopt the EISs with supplementation to address impacts to groundwater and from surface discharges of groundwater beyond the postclosure compliance location. While the NRC staff's analysis in the supplement relies in part on information provided by DOE, the NRC staff utilized multiple sources of information and conducted an independent evaluation, as documented in the supplement, to reach its conclusions.

No changes were made to the supplement as a result of this comment.

(148)

B.2.1.2.26. ***COMMENT****: Several commenters expressed concern with the impact determination descriptions used in the supplement, particularly the use of the term SMALL to describe impacts. Some commenters requested the use of quantitative rather than qualitative terms, with one commenter requesting that NRC explain why qualitative terms are appropriate and provide qualitative descriptions of the impacts. Another commenter stated that the definition of small varies among NRC NEPA documents, and requested clarification on how the determination relates to established regulatory limits. One commenter stated that use of the term SMALL has political implications and would be used by some parties to imply that there is no risk. One commenter, using a few examples in the document, stated that the term SMALL would be more accurate as "small and insignificant," or should be described as not detectable or very minor, so as not to destabilize or alter the resource. The same commenter also requested that NRC note that SMALL impacts do not require mitigation. Another commenter disagreed with the use of the term SMALL, stating that the supplement ignores devastating effects the repository would have on the Timbisha Shoshone Tribe's way of life, and that calling the impacts SMALL is contrary to NEPA, the NWPA, and the NRC's implementing regulations. Some of the comments also included statements about use of existing data, or radiological and toxicological effects.*

RESPONSE: The NRC staff acknowledges the commenters concerns about the way the impacts are described in the supplement. The terminology used in the supplement for impacts is consistent with NRC regulations (10 CFR Part 51) and guidance (NRC, 2003) for environmental impact assessments. To guide its assessment of environmental impacts for a proposed action or alternative actions, the NRC established standards of significance for environmental impacts using the CEQ terminology for significance (see 40 CFR 1508.27). Using this approach, the NRC established three levels of significance for potential impacts—SMALL, MODERATE, and LARGE—that provide a common framework for each of the resource areas assessed in NRC environmental evaluations, including this supplement. These significance levels provide a comparison tool that allows decisionmakers and interested parties to compare the relative significance of various environmental impacts. Each impact finding in the supplement is supported by substantial NRC staff analysis. Section 1.2.3 of the supplement also restates the definitions of the impact determinations. The terms SMALL, MODERATE, or LARGE are used in many NRC environmental review documents to draw attention to impact determinations.

Although the NRC staff concluded in the SER that the repository would meet regulatory limits specified for safety, the purpose of DOE's EISs and this supplement is to determine potential environmental impacts. In addition to concluding its constituent analyses with an impact determination (e.g., SMALL), the supplement provides specific concentration, dose, or other

appropriate impact information, where possible, associated with the particular resource evaluated in an analysis. Comments regarding impacts to tribes are further addressed in Sections B.2.4.4. and B.2.4.5. Comments about the use of existing data are further discussed in Section B.2.1.2.6, and comments about radiological and toxicological effects are further discussed in Section B.2.4.2.

No changes were made to the supplement as a result of these comments.

(019, 020, 046, 060, 116, 147-01, 147-12, 147-24)

Miscellaneous

B.2.1.2.27. ***COMMENT****: One commenter quoted the supplement on page 1-4, Line 25, "(t)his supplement does not reflect a change to DOE's proposed action or to DOE's purpose of or need for the proposed action" and noted that the purpose and need of the proposed action, as described in DOE's EIS, should be reiterated in the supplement to relay to readers the reason for the supplement.*

RESPONSE: The NRC staff acknowledges the request for a reiteration of DOE's statements of purpose and need and proposed action. The proposed action is stated in Section 1.4 in the supplement. For completeness, the NRC staff has added a brief statement of DOE's purpose and need within the same section of the document in response to this comment.

(020)

B.2.1.2.28. ***COMMENT****: One commenter stated that a section of text in the draft supplement (Page 1-5 Lines 25-38), which describes the relationship of the supplement to DOE's documents, is better suited for the introduction to the supplement because it is related to the purpose of the supplement. The commenter stated that the text after line 38 is more consistent with the title of the section, "Document Format."*

RESPONSE: The NRC staff agrees that additional clarity is needed in this section. The NRC staff has revised the title of Section 1.4 to "Document Purpose and Structure" to better reflect the content of that section.

(020)

Other Process Concerns

B.2.1.2.29. ***COMMENT****: Two commenters stated that the assumptions in the supplement should become binding license conditions because circumstances have changed since the documents were published. The commenters stated that a license would not be valid if new circumstances are not taken into account in the license application and the environmental analysis. As an example, a commenter expressed concern about the amount of high-burnup fuels being generated for disposal as different from what is presented in DOE's license application.*

RESPONSE: The licensing process for a repository at Yucca Mountain has two major components, which inform the NRC's regulatory decision: an environmental review and a safety

review. The NRC staff's conclusions in the SER were based on its review of the license application submitted by DOE, including their proposed design and inventory of spent nuclear fuel and high-level waste to be disposed of in the repository. The analysis in the supplement also includes assumptions about the performance of the repository, including its inventory, which are consistent with the design and inventory in DOE's Safety Analysis Report (supplement Section 1.2.2 and Sections B.2.2.2 and B.2.2.3 of this appendix). Changes to the information in DOE's license application would require appropriate review by the NRC, including appropriate supplemental environmental review.

In addition, the preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities is subject to appropriations and other actions external to the NRC. Comments concerning high-burnup fuels are specifically addressed in Sections B.2.1.2.29, B.2.2.2.1, B.2.2.3.1, B.2.2.3.2, and B.2.6.1.23.

No changes were made to the supplement as a result of these comments.

(146-01, 146-02)

B.2.1.2.30. ***COMMENT****: One commenter stated that the NRC's rulemaking process is flawed, and that NRC should consider the analyses of those opposed to the Yucca Mountain project.*

RESPONSE: The Yucca Mountain licensing decision is not a rulemaking, nor does the publication of this supplement represent a new rule or change to an existing rule. Rather, it documents an analysis of the potential impacts to groundwater and from surface discharges of groundwater beyond the postclosure compliance point for the proposed repository at Yucca Mountain. To develop this final supplement, the NRC staff has carefully considered the information and comments received on the draft supplement. The staff has reviewed, summarized, and responded to all comments, regardless of who submitted them and whether the comments agree or disagree with the NRC staff's initial for final analyses or conclusions.

To inform its decisionmaking processes, the NRC staff considers information from a variety of sources. Many of NRC's licensing processes include opportunities for public comment. For this supplement, the NRC received over 1,200 comments from 5 transcribed public meetings and over 140 comment letters. The NRC's rulemaking process also allows for public participation, and more information about public participation in the rulemaking process can be found on the NRC's Web site at http://www.nrc.gov/about-nrc/regulatory/rulemaking/public-involvement.html.

No changes were made to the supplement in response to this comment.

(081)

B.2.1.2.31. ***COMMENT****: Commenters questioned whether or not the NRC had followed NRC Management Directive 3.17 (NRC Information Quality Program), which provides guidance to the staff for implementing OMB Information Quality Guidelines (FR 67 8460). In particular, the commenters stated that the supplement violates the IQA because the NRC did not conduct an independent peer review for the supplement, which is required for influential information under the IQA.*

One of the commenters pointed to the NRC information guidelines in Management Directive 3.17 for ensuring quality in "influential analyses" of risks to human health, safety, and the environment, as discussed in the OMB guidelines implementing the IQA (67 FR 8460). The commenter asked why the NRC's guidelines in the Management Directive do not discuss quality principles in the Safe Drinking Water Act.

RESPONSE: The NRC staff prepared this supplement in accordance with the IQA and NRC Management Directive (MD) 3.17, which implements the OMB Information Quality Guidelines. As discussed in MD 3.17, "[I]t is the policy of the U.S. Nuclear Regulatory Commission to ensure the quality of all information it relies on for making decisions or disseminates to the public. The NRC's policies and practices are designed to ensure that the appropriate level of quality commensurate with the nature of the information is established and maintained."

The NRC's Handbook for MD 3.17 provides guidance for staff in implementing MD 3.17 for information quality. The Handbook describes the methods the NRC applies to its information products to ensure quality and defines specific categories of information that may be suitable for peer review. The supplement does not fall within these categories. The Handbook (Table 1) also describes broad categories of NRC Information Products, their level of data quality review, and ways in which the public can request corrections. The supplement fits within "Licensing EISs and EAs" that are reviewed for data quality by "Branch/Division/Office Concurrence" and are subject to public comment as a way to request corrections. Each of these processes was followed in preparing the supplement. In keeping with the guidance in the Handbook, the NRC staff determined that a peer review of the information in the supplement was not appropriate or necessary to ensure information quality.

No changes were made to the supplement as a result of these comments.

(141, 146-06, 148)

B.2.1.2.32. ***COMMENT****: One commenter referred to NEPA and other laws, stating that the EPA Administrator is tasked with developing new approaches to biomedical studies, including new approaches to study complex mixtures, such as mixtures found in drinking water. The commenter questioned why, given these requirements, regulatory agencies have not conducted research on the interactions of metals that could be released from the repository and the potential health implications.*

RESPONSE: The U.S. Environmental Protection Agency (EPA) supports research related to chemicals and microbes in drinking water that may result in human health effects. In addition, the EPA, not the NRC, has regulatory authority concerning nonradiological metal contaminants in drinking water. Section 2.5 of the supplement discusses the applicability of EPA drinking water standards, and Section 3.1 includes discussions about nonradiological contaminants (metals) with regard to the EPA Oral Reference Dose and maximum contaminant levels. Related discussions about metal and radiological interactions can be found in Sections B.2.1.2.11, B.2.2.2.4, and B.2.2.2.5 of this appendix.

No changes were made to the supplement as a result of these comments.

(116)

B.2.1.2.33. ***COMMENT****: A few commenters stated that the supplement does not adequately address the mitigation and remediation measures necessary to protect public health and safety and for consistency with NEPA. One commenter further noted the absence of an analysis of potential impacts from contaminants that may be released in the event of flooding of the repository site. Some commenters rejected DOE's approach to defer mitigation and remediation planning until unusual conditions are detected in the groundwater. On this issue, one commenter stated that the environmental documents do not describe a monitoring plan capable of detecting such unusual conditions, while another commenter indicated that the NRC staff's silence on this issue indicates concurrence with the DOE approach. These commenters also called for the inclusion of a groundwater well monitoring program and protocols for informing affected residents of potential contamination incidents. One commenter considered the DOE EIS insufficient because it does not address site reclamation if the repository project is shut down. A commenter also indicated in general that, per NRC regulations in 10 CFR 51.109(c)(2), significant and substantial new information exists that should be analyzed in the supplement (see Section B.2.1.2.15 for responses to comments regarding new information).*

RESPONSE: The NRC staff acknowledges the concerns expressed by several commenters regarding mitigation and remediation measures for the proposed repository. However, comments about the exclusion of potential impacts due to specific events, such as the release of contaminants in the event of flooding of the repository site, are beyond the scope of the supplement, which concerns the potential impacts to groundwater and on surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a). DOE considered potential flooding events during operations and approaches for mitigating flood control structures in its license application (DOE, 2008b, Section 1.6.3.4.9). The NRC staff review of this analysis is in its SER (NRC, 2015a, Chapter 3, Section 3.2.1.1.3).

The NRC staff's ADR evaluated the best management practices and management actions that DOE proposed in its EISs for mitigation of potential adverse impacts and for protecting public health and safety (NRC, 2008a, Section 3.2.1.4.1). These measures included a commitment to implementing an environmental management system program to monitor the effectiveness of mitigation measures and modify them as necessary, developing a mitigation action plan to identify specific commitments, and chartering one or more mitigation advisory boards to be led by governmental entities in Nevada. The NRC staff concluded in the ADR (2008a, Section 3.2.1.4.1) that these efforts and commitments meet NRC regulations.

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement in response to these comments.

(124, 142, 149-17)

B.2.1.2.34. ***COMMENT****: One commenter stated that the supplement is insufficient because it does not consider in its analysis the intended expenditures in the Amargosa Valley vicinity for emergency preparedness facilities. The commenter stated that the monies had not been spent on these developments, such as hospitals and police and fire services.*

RESPONSE: Comments regarding funding for facilities related to the proposed repository at Yucca Mountain, including emergency preparedness or response facilities, are beyond the scope of this supplement, which concerns an assessment of the potential impacts from repository releases to groundwater and from surface discharges of groundwater beyond the postclosure compliance location. The scope of the supplement is further described in the NRC staff's ADR (NRC, 2008a) and in the NRC's Notice of Intent to prepare the supplement (80 FR 13029). Emergency facilities are addressed in the DOE 2008 EIS (DOE, 2008a; Section 4.1.11) and were not identified in the ADR as needing supplementation.

No changes were made to the supplement as a result of this comment.

(149-17)

B.2.1.2.35. ***COMMENT****: One commenter stated that the Yucca Mountain licensing process is insufficient for having not considered the Trans-Pacific Partnership (TPP) treaty and potential implications that the U.S. may eventually become host to other countries' nuclear waste.*

RESPONSE: The NRC staff acknowledges the commenter's concern about whether the TPP may result in acceptance of nuclear waste from other countries. However, comments regarding the waste inventory of the repository are beyond the scope of this supplement, which concerns an assessment of the potential impacts to groundwater and from surface discharges of groundwater beyond the postclosure compliance location. The waste inventory assumptions used in the supplement were based on information in DOE's Safety Analysis Report (DOE, 2008b). In addition, DOE's Safety Analysis Report addressed disposal of 70,000 MTU in a repository at Yucca Mountain. Disposal of a greater quantity is not part of DOE's proposed action nor part of the licensing action under NRC consideration. The repository capacity of 70,000 MTU is defined in the NWPA and changing the capacity would require a change in the law.

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement as a result of this comment.

(080-07)

B.2.2 Supplement Assumptions

B.2.2.1 Climate and Long Timeframes

B.2.2.1.1. ***COMMENT****: Commenters expressed concerns about the representation of future climates in the draft supplement, including a general concern about accuracy and uncertainty in projections of long-term future climates. One commenter suggested that climate may change in ways we cannot predict. Another commenter suggested that the full range of climates was not adequately represented by the use of "average climate" states in the draft supplement, including climates not found in past records as a result of human or natural effects. This commenter stated that there were significant deficiencies with regard to methodologies and assumptions associated with the climate scenarios evaluated in the supplement, referring to cases and regulations that address the requirements of NEPA. The commenter goes on to say*

that NEPA requires analysis of the full range of climate conditions over the period studied, in this case one million years. The commenter contends that the range of conditions studied in the supplement is unlawfully truncated in that it assumes that physical conditions over the next million years will not resemble ones that existed in the area 26,000 years ago.

One commenter, referring to page 2-16 of the draft supplement, asked if the representation of future climate in the draft supplement is consistent with the hotter and drier man-made climate changes assumed by other Federal agencies (e.g., the Bureau of Land Management and the U.S. Fish and Wildlife Service). Another commenter stated that the supplement appropriately addresses human-induced climate change.

RESPONSE: Future climate change is treated differently in the supplement as compared with the TSPA. The TSPA incorporated a stochastic representation of four climates (DOE, 2008b, Section 2.3.1; NRC, 2014a, Section 2.2.1.3.5); present-day, monsoonal, glacial-transition, and full-glacial. As described in Sections 2.2.4 and 2.6 of the supplement, uncertainty in future climatic conditions is addressed by separately analyzing impacts for two climate states, one representing the hotter and drier present-day interglacial climate, and the other representing the cooler and wetter glacial-transition climate. The glacial-transition climate state resembles the climate 26,000 years ago when sections of the Amargosa River were likely perennial, and there was a paleo lake in Death Valley (Paces and Whelan, 2012). The supplement does not use an average climate over the 10,000-year or million-year periods, but rather, these two climate states reasonably capture the credible range of future conditions encompassing future climate change.

Presently available information about human-induced climate change from the release of greenhouse gases indicates that for this region, the most potentially significant long-term effect is that the present-day interglacial climate (hot and dry) would persist longer than it would in the absence of human-induced change. The NRC staff considered the effect of anthropogenic (human-induced) climate change in the SER (NRC, 2014a; Section 2.2.1.3.5). In the supplement, consideration of a persistent present-day climate represents an extended, hotter and drier climate.

The NRC staff's consideration of an extended present-day hotter and drier climate is also consistent with the climate analyses of other Federal agencies. The NRC staff notes that other Federal agencies, such as the Bureau of Land Management and the U.S. Fish and Wildlife Service consider climate change over scales of one hundred to several hundreds of years (e.g., 200 years in BLM, 2012c). The NRC staff, however, considers climate change in the supplement over the next several millennia, and up to one million years. Projections of climate change caused by man-made greenhouse gases for repository performance (NRC, 2014a; Section 2.2.1.3.5) and for impacts in the supplement are also consistent with the U.S. Global Change Research Program and its 3rd National Climate Assessment (Melillo et al., 2014).

No changes were made to the supplement in response to these comments.

(046, 138, 146-11, 148)

B.2.2.1.2. ***COMMENT****: One commenter was concerned with projections of human activity and community characteristics under wetter conditions in the future. The commenter indicated the need to consider additional surface water storage during future humid conditions, as exhibited by a lake in Death Valley 10,000 years ago, leading to a denser and larger human population that could be affected at discharge locations throughout Southern Nevada.*

RESPONSE: Projections of human activity, such as population shifts and associated changes in water use, are speculative. The NRC staff used the characteristics of the present-day population in the Town of Amargosa Valley to represent possible future populations that may be affected by releases from the repository, consistent with the description of the reasonably maximally exposed individual in 40 CFR 197.21 and 10 CFR 63.312. This approach is also consistent with recommendations of the National Academy of Sciences (NAS, 1995) on treatment of future populations for calculations over long time frames.

The NRC staff, considering the characteristics of the present-day community in the Amargosa Farms area, analyzed impacts accounting for uncertainty in future changes to climate conditions and to pumping rates. In order to represent uncertainty in future water usage, the supplement considers two analysis cases for future pumping in Amargosa Farms (pumping and no pumping scenarios). In addition, the supplement considers possible future climate conditions that may affect impacts. As discussed in the supplement, these conditions and other conservative assumptions reasonably represent the uncertainty in potential environmental impacts over the one-million-year period.

No changes were made to the supplement in response to these comments.

(019)

B.2.2.1.3. ***COMMENT****: Several commenters questioned the feasibility of projecting geological, climatic, and hydrological conditions and evaluating impacts over long time periods, such as for 100-year, 10,000-year or one-million-year periods. In addition, two commenters pointed to the potential for changes in society and the unknown direction of human evolution over one million years, comparing the analysis timeframe to other milestones in human and societal evolution over the past several millennia. Two of these commenters suggested that impacts for these long timeframes should be indeterminate, uncertain, or a best guess. Another commenter suggested the one-million-year analysis period is beyond the scope of what is reasonably foreseeable under CEQ regulations. Citing the release from the Waste Isolation Pilot Plant as an example, one commenter additionally expressed concern that, based on the supplement's conclusions, members of Congress may prematurely conclude that Yucca Mountain is an adequate repository site.*

RESPONSE: The NRC staff acknowledges that changes will occur in the future to the populations, climate, hydrology, and geology of the Yucca Mountain region and, furthermore, that uncertainty in these changes leads to uncertainty in estimated impacts. The staff, however, does not agree that future projections and estimates of impacts are not feasible. The staff believes that useful information to aid in decisionmaking is provided by models covering long timeframes. A National Academy of Sciences (NAS) 1995 report evaluated this topic. The report, "Technical Bases for Yucca Mountain Standards," provided guidance in the development of regulations for deep geologic disposal at Yucca Mountain. The NAS 1995 report concluded that scientifically justifiable analyses over many thousands of years in the future can be made.

For the analyses at Yucca Mountain, the report recommended that dose be analyzed for the first 10,000 years and peak dose be analyzed after 10,000 years but within the period of geologic stability.

The NRC staff selected the timeframes for the analysis in the supplement to be consistent with previous environmental assessments by DOE (2002, 2008a) and DOE's TSPA analyses in its

Safety Analysis Report (DOE, 2008b). The NRC staff's analysis of DOE's license application can be found in the staff's Safety Evaluation Report (NRC, 2010, 2014a,b; 2015a,b).

With regard to commenter concerns with projecting changes to future human society and evolution, climate, and seismic and volcanic activity, issues relating to the performance of the repository and natural environment up to the compliance location are outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surfaces discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029), and in the NRC staff's ADR (NRC, 2008a). As discussed in the supplement (Section 2.6), the NRC staff considers future changes to climate conditions and to pumping rates in the Amargosa Farms area. In order to represent uncertainty in future water usage, the supplement considers two analysis cases for future pumping in Amargosa Farms (pumping or no pumping scenarios). In addition, the supplement considers possible future climate conditions that may affect impacts. As discussed in the supplement, these conditions and other conservative assumptions reasonably represent the uncertainty in potential environmental impacts.

The potential direct effects of seismic and volcanic activity on repository performance are considered in the supplement through the use of the contaminant releases calculated by DOE's TSPA model, which includes such events. The supplement did not consider potential igneous or seismic events that may occur along the groundwater flow path beyond the postclosure compliance location. The specific locations, magnitudes, and changes to the affected environments would be speculative. While such events may themselves impact the environment, their occurrence is unlikely to significantly change the magnitude of the estimated impacts from contaminant releases because of the conservative assumptions made in the analyses, which are listed in Appendix A, Section A.3, including the assumption that the entire contaminant plume is discharged at each potential surface discharge location.

The NRC staff acknowledges the commenters' concerns with the proposed repository in light of recent releases at the WIPP facility during its operations. As previously noted, the supplement concerns the potential impacts of contaminants released from the repository to groundwater and surfaces discharges of groundwater beyond the postclosure compliance location. The NRC staff review of DOE's safety analysis for the Yucca Mountain repository design, operations and postclosure performance is contained in Volumes 2 and 3 of the staff's Safety Evaluation Report (NRC, 2014a, 2015a).

The preparation of this supplement one of several steps in the licensing process for the proposed repository. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement in response to these comments.

(018, 020, 080-06, 080-10, 082, 095-05, 095-08, 099, 146-15, 146-16, 147-16, 147-20, 147-24)

B.2.2.1.4. ***COMMENT****: One commenter expressed concern, in light of long time frames involved, with the safety of nuclear waste in dry casks, the transportation of waste across the country, and the disposal of the waste. The commenter pointed to the importance of the NAS*

study on low-level radiation (since discontinued), because of the recent shutdown of the San Onofre Nuclear Generating Stations and the implied need for decommissioning and storage of the waste.

RESPONSE: The NRC staff acknowledges the concerns expressed by the commenter about the safety of nuclear waste in dry casks, the transportation across the country, the discontinued National Academy of Sciences study on low-levels of radiation exposure, and disposal considering the shutdown and decommissioning of nuclear power plants. These comments are outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surfaces discharges of groundwater beyond the postclosure compliance location, which is 18 km (11 mi) from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029), and in the NRC staff's ADR (NRC, 2008a).

No changes were made to the supplement in response to these comments.

(080-15)

B.2.2.1.5. ***COMMENT****: Several commenters addressed the projections of groundwater pumping and water use in the Amargosa Farms area. Some commenters agreed with the supplement's approach in projecting volume used but not projecting changes in society or the types of water use. One commenter stated that the NRC made a reasonable assumption in basing the volume of water pumped on historical records at Amargosa Farms. Other commenters expressed concern about water use types, speculating that water use would shift from dominantly agriculture to municipal and industrial in the future.*

Some commenters mentioned the supplement's two analysis cases addressing the future pumping rates. The commenters stated the zero pumping analysis case is too conservative for calculating downstream impacts, and that using historical low levels of pumping instead would be a more reasonable reference. One of these commenters asked if likely future increases in groundwater pumping would be more or less conservative for Analysis Case #1.

One commenter indicated the draft supplement does not clearly account for combined water withdrawals by the RMEI at the compliance location or through other wells near the compliance location. This commenter recommended that the NRC state in the final supplement whether the analysis assumes that withdrawals occur at and near the compliance location.

Related to groundwater pumping and water use, some commenters speculated about future human population and activities in the area and their potential impacts. One commenter stated that the assumption that population and human activity near Yucca Mountain would remain unchanged most likely results in an underestimate of future harm. Another commenter argued it is unlikely that future society would lack the knowledge and technology to address potential contamination. This commenter suggested that the NRC was conservative in assuming that inhabitants would make extensive use of groundwater contaminated by releases from the repository.

RESPONSE: As described in the supplement, the analysis makes several assumptions regarding future climate, withdrawals of water, and population along the groundwater flow paths from Yucca Mountain. To consider uncertainty in future climate, the supplement analyzed impacts under two different climates states; one hot and dry, similar to the present-day climate, and the other cooler and wetter, similar to past glacial or glacial-transition climates. This is

discussed in Section 2.2.4 of the supplement. These climate states are based on geologic evidence for past climate changes in the region, and are consistent with the climatic conditions incorporated into DOE's analysis of repository performance. As discussed in the supplement in Section 2.2.4, the hot and dry climate also includes potential impacts for conditions that could occur from human-induced climate change. In conjunction with the two analysis cases for pumping in Amargosa Farms in Section 2.6 of the supplement, these climate states reasonably represent the conditions for consideration of future impacts.

The two analysis cases were chosen to capture the range of impacts in the affected environment. As noted in the supplement in Section 3.1, for each case, impacts at the surface are considered by assuming that the entire contaminant plume was captured in the particular water source (e.g., by pumping at Amargosa Farms or by natural surface discharge at a particular discharge location). Assumptions regarding future pumping rates and water uses at Amargosa Farms (Analysis Case 1) are based on historical records over the past several decades, as described in Sections 2.2.3 and 2.4 of the supplement. This approach is consistent with the recommendations by the National Academy of Sciences (NAS, 1995) to avoid speculative projections caused by difficulties in projecting future societal behavior. In addition, a present-day constraint on pumping rates includes the State of Nevada Engineer's order (Taylor, 2008) related to water levels in Devils Hole. Potential future changes to that order would also be speculative.

One commenter suggested that the supplement does not clearly account for combined water withdrawals at the postclosure compliance location and Amargosa Farms area. In the supplement, the pumping rate is based on historical records from wells in the Amargosa Farms area. Potential withdrawals at the postclosure compliance location are a convention for calculation purposes and are not included in the supplement analysis cases. It should be noted that if the entire contaminant plume were to be captured by groundwater withdrawal at the postclosure compliance location (as conservatively considered in NRC regulations), no contaminants would flow to Amargosa Farms or further downstream. Conversely, the assumption of no pumping at the postclosure compliance location is conservative with regard to impacts at Amargosa Farms because the entire plume is assumed captured at Amargosa Farms.

No changes were made to the supplement in response to these comments.

(046, 137, 138, 142, 145, 148)

B.2.2.2 Total System Performance Assessment and Other Modeling

A number of commenters raised concerns that the NRC staff is relying on DOE's TSPA, which was part of DOE's license application for the proposed repository at Yucca Mountain as a primary input and as support for evaluating environmental impacts in this supplement. In particular, commenters made the following points: (i) uncertainties in models used in the TSPA, including the one-million-year assessment period, raise concerns regarding the credibility of the estimated impacts, and (ii) TSPA calculates a probability-weighted dose and not simply a dose consequence.

The NRC staff's use of the results of DOE's TSPA as a primary input and as support for the analyses in the supplement is an appropriate means for evaluating environmental impacts. Use of the TSPA results is also an efficient and effective mechanism in that it uses existing information and minimizes the need for a duplicative analysis.

The TSPA is a model simulation that represents the performance of the repository system over time, including the potential releases from the repository to the environment and the potential effects on public health. The use of TSPA and other modeling assumptions is discussed in Section 1.2.2 and Appendix A of the supplement. The NRC staff's evaluation of information used in the TSPA, as presented in DOE's Safety Analysis Report, is given in the staff's Safety Evaluation Report for the Yucca Mountain repository license application (NRC, 2014a).

In its 2008 Supplemental EIS, DOE used mean results from the TSPA model to estimate the source term for radionuclides and transport to the postclosure compliance location. The supplement follows a similar approach, using the TSPA results as inputs to a transport model that calculates movement of the contaminants beyond the postclosure compliance location. The specific inputs are the mean amounts of radionuclides released from the repository over time, which are an intermediate result of the TSPA simulation. The mean TSPA release values are determined by averaging the behavior of the repository over the range of uncertainty and variability used to represent the features, events, and processes (e.g., corrosion of the waste package, seismic events, geologic and hydrologic characteristics of the site, and future climate conditions, among many other factors). The TSPA simulation uses scenario classes to represent unlikely events, such as large seismic events and igneous events, including events with a very low likelihood of occurrence (e.g., less than one chance in one million of occurring). Although DOE's TSPA includes unlikely events associated with igneous disruption of the repository and large-magnitude seismic events, the TSPA also includes features, events, and processes that are expected to occur (e.g., corrosion of the waste package and seepage of water into the repository). Use of the TSPA results, therefore, provides a credible representation of the potential contaminant releases, which accounts for the environmental impacts that are reasonably likely to occur while also including impacts from events that are much less likely to occur. The use of TSPA results to estimate releases that could enter the aquifer from the repository does not underestimate the potential environmental impacts, because the TSPA accounts for releases due to unlikely events, regardless of the probabilities of these events.

The NRC staff has revised text in Section 1.2.2 and in Appendix A, Section A.1.1 to further clarify the use of the results of DOE's TSPA as a primary input and as support for evaluating environmental impacts in this supplement.

Responses to specific comments concerning the TSPA or other aspects of performance assessment are provided below.

B.2.2.2.1. ***COMMENT****: Commenters expressed concern about the adequacy of DOE's TSPA model as a basis for impact evaluations in the draft supplement, including concerns about model and data validity; the analyzed quantity of high-burnup fuel; and the impacts of phenomena at or near the repository, including mechanical, natural, and chemical processes, as well as natural hazards. Many of these commenters expressed concerns that the TSPA does not reflect current information or assumptions about the repository, the waste inventory, or the surrounding environment, and that some aspects, such as waste inventory and canister design, are unresolved. Commenters noted that if the source term used in the analysis at or near Yucca Mountain is incorrect, then conclusions based upon that source term, including the findings in the supplement, would likewise be incorrect.*

One commenter claimed that most of the State of Nevada's contentions on the TSPA model were not addressed specifically in the NRC staff's SER, nor have they been subjected to an opportunity for public comment, per NEPA and CEQ regulations.

RESPONSE: The NRC staff acknowledges the commenters' concerns about how assumptions in the TSPA model may affect the conclusions in the supplement. Comments regarding the adequacy of DOE's TSPA model are beyond the scope of this supplement, which concerns the potential impacts to groundwater and on surface discharges of groundwater beyond the postclosure compliance location. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029), and in the NRC staff's ADR (NRC, 2008a).

The staff recognizes that the assumptions in the TSPA model affect the assessment in the supplement. DOE analyzed radiological impacts at the compliance location based on the results from the TSPA model submitted as part of its license application. In its safety evaluation, the NRC staff found that the TSPA model, methodology, and results were acceptable (NRC, 2014a). The NRC staff also found, in its ADR, that the TSPA results as reflected in DOE's license application and EISs could be used as a source term for the postclosure compliance location (NRC, 2008a). Based on this finding, the supplement used the TSPA results for the mass flux of radionuclides reaching the compliance location as an input in the analysis of radionuclide transport to different locations along the flow path beyond the postclosure compliance location.

Although the adjudication is currently suspended, participants in the adjudication may continue to pursue these contentions before the Atomic Safety and Licensing Board or raise new issues in the form of new or amended contentions, upon resumption of the adjudication. Information may be identified that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement as a result of these comments.

(001, 006, 061, 080-10, 080-16, 102, 104, 108, 115, 116, 121, 129, 133, 134, 138, 141, 146-02, 146-06, 148)

B.2.2.2.2. ***COMMENT****: A few commenters expressed concern about models used in the draft supplement and the general process for calculating impacts. One commenter stated that the draft supplement used an unproven EPA radiation groundwater model. One commenter cited the example of the groundwater model for the test site (NNSS) not being validated until 2030, and wondered how the groundwater model used in the draft supplement could reproduce groundwater conditions, particularly considering extreme conditions and future climate uncertainty. Another commenter asked how the models were validated and if current parameter values were used in the validation. One commenter stated that the scenarios used in the draft supplement are not realistic. Another commenter wanted confirmation that the NRC staff used DOE's analysis for releases up to the compliance location, and then used NRC staff analyses in the draft supplement to evaluate contaminant transport to downstream locations.*

RESPONSE: The commenters are correct that the NRC staff analysis in the supplement is generally derived from DOE's calculated releases from the repository and transport to the postclosure compliance location. DOE's analysis of radiological impacts at the postclosure compliance location, as presented in its EIS (DOE, 2008a), is based on groundwater flow and transport simulations included in its TSPA model as part of its license application. DOE's saturated zone flow and transport model is discussed in its safety analysis (DOE, 2008b; Section 2.3.9). The NRC staff review of this analysis is given in the staff's Safety Evaluation Report (NRC, 2014a; Chapters 11 and 12, Sections 2.2.1.3.8 and 2.2.1.3.9).

In its ADR, the NRC staff determined that it could adopt the approach DOE used in estimating releases from the repository and the impacts at the postclosure compliance location, but that the analysis needed to be supplemented to consider impacts on groundwater beyond that location. As discussed in the supplement (Sections 2.1, 3.1, and Appendix A), the NRC staff used the well-established Death Valley Regional Flow System (DVRFS) model to help define the affected environment and analyze the impacts on groundwater under different potential future climate and water use conditions. The DVRFS model has been calibrated and shown to provide a good fit to measured hydrologic conditions (Belcher and Sweetkind, 2010). The analysis cases in the supplement included both substantial and limited pumping of groundwater for irrigation purposes at Amargosa Farms under both wet and dry climate states. Modeling this combination of cases enabled the NRC staff to evaluate how the rate of pumping and volume of groundwater withdrawal could affect radionuclide concentrations in the groundwater and at the locations of potential surface discharge beyond the compliance location under a range of future conditions.

No changes were made to the supplement as a result of these comments.

(116, 146, 147-03, 147-12, 147-28, 148, 149-01, 149-15)

B.2.2.2.3. ***COMMENT****: Two commenters commented on the model that accounts for recycling of contaminants that are pumped from the aquifer and recharged back to the aquifer via irrigation used to assess impacts in the Amargosa Farms area. One commenter stated that there is an inconsistency between descriptions in Chapter 3 and Appendix A of the draft supplement regarding water uses, exposure pathways, and contaminant recapture fractions. This commenter provided a detailed discussion and asked the NRC to clarify this inconsistency in the final supplement. The other commenter suggested that the recycling analysis needs to be reasonable without being overly complex. The commenter suggested that the supplement's assumption of 100% groundwater capture at Amargosa Farms may be reasonable for any particular year but is unreasonably conservative when applied to longer time periods. The commenter further expressed disagreement with the use of the recycling model for estimating impacts at the postclosure compliance location. The commenter also questioned how the draft supplement can assume that salts can migrate through soil via excess irrigation water (as discussed in Appendix A, pages A-12 and A-13) and either be recaptured by pumping or migrate downstream, while also assuming that contaminants from the repository are not similarly flushed but rather are retained in the soil and recaptured by pumping.*

RESPONSE: The NRC staff's methodology for calculating the concentration of contaminants in water withdrawn from wells at Amargosa Farms is described in Section A.2.1 of the supplement. The method uses recycling and recapture factors along with the contaminant mass arriving at Amargosa Farms and volume of water withdrawn. DOE used a similar calculation in its irrigation recycling model for water withdrawal at the postclosure compliance location in its TSPA analyses (SNL, 2007b). The NRC staff's review of DOE's analysis can be found in the SER (NRC, 2014a, Section 2.2.1.2.1). As discussed in Appendix A, Section A.2.1, a simplification of the irrigation recycling model is used for analyzing impacts in the Amargosa Farms area. For the supplement analysis, the recapture factor is conservatively set to 1 as a simplifying assumption. This value means that all irrigation water that flows back in to (recharges) the aquifer is captured by a well in the Amargosa Farms area. This assumption is conservative in that all of the contaminants reaching Amargosa Farms contribute to calculated impacts. For the recycling factor, the fraction of groundwater withdrawal used for irrigation is set as 0.86, based on analysis of water use in Amargosa Farms (Moreo and Justet, 2008). For the analysis in the supplement, irrigation is considered to be the only water use that leads to overwatering, and thus the potential to recycle contaminants.

The schematic shown in supplement Figure A-2 (Water Uses and Exposure Pathways Biosphere Conceptual Model) does not include the irrigation recycling model. The analysis in the supplement uses the recycling and recapture factors associated with irrigation to calculate radionuclide concentration in well water, which is an input to the exposure pathway and dose model in Figure A-2. Thus, the analysis separates the calculation of irrigation effects on contaminant concentration from calculations for the exposure pathway and dose. The recycling and recapture factors of the irrigation recycling model are described in Appendix A, Section A.2.1, "Groundwater Pumping, Recycling, and Irrigation." The exposure pathways shown in Figure A-2 are described in Section A.2.3, "Biosphere Exposure and Dose Conversion."

The NRC staff agrees that the assumptions in the irrigation recycling model are conservative. The NRC staff notes, however, that conservative assumptions are reasonable where they allow for simplified models to be used for difficult-to-estimate input values where the impacts are nevertheless small.

In response to these comments, the NRC staff revised text in Section 3.1.1 of the supplement to clarify the distinction between recycling and recapture estimates for the postclosure compliance location and for the Amargosa Farms area. Also, Section A.2.3 in the supplement has been revised to emphasize the relationship between the irrigation recycling model and the exposure pathway schematic in Figure A-2.

(137, 138)

B.2.2.2.4. ***COMMENT****: A commenter expressed concerns about the representation of chemical processes or approaches used for the analyses in the draft supplement or as used in DOE's modeling for the license application. The commenter stated that sorption properties of individual radionuclides are not known, nor are competitive sorption properties known when two or more radionuclides or heavy metals are present. The commenter stated that research is needed, such as additional large-scale testing.*

The commenter also (i) expressed concern with unknown health hazards associated with mixtures of chemicals and radionuclides, (ii) stated that risks from canister corrosion is not resolved and asked why chloride and nitrate are included in the analysis, but sulfate is not, and (iii) asked why chromium is not mentioned for impacts in the Amargosa Farms area in the draft supplement, especially since there is so much chromium in the repository.

RESPONSE: The NRC staff acknowledges the commenter's concerns. Those comments that pertain specifically to the release rates of radionuclides from the repository, including the sorption of individual radionuclides near the repository and competitive sorption effects, are outside of the scope of this supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 miles] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

The commenter expressed concern with the treatment of chromium in the supplement. The rationale for excluding chromium from the analysis of impacts is discussed in Appendix A, Section A.1.1. In its 2002 EIS (DOE, 2002), DOE estimated the impact of chromium by conservatively assuming the presence of the fully oxidized state, chromium(VI) (chromium in a valence state of +6). In its 2008 EIS (DOE, 2008a; Sections 5.1.2 and F.5.1), DOE determined that chromium(III) would be the predominant chromium species present in the groundwater. If

chromium(VI) formed from corrosion of stainless steel and Alloy 22, DOE found that it would be efficiently and quickly reduced to chromium(III) in the expected repository environment. Chromium(III) is not toxic to humans. This chemical species readily sorbs onto solid surfaces and would not be mobile in the groundwater in the affected environment.

The commenter also expressed concern about the analysis in the supplement of impacts to the affected environment beyond the postclosure compliance location. These comments concern the sorption properties of radionuclides and nonradioactive metals in the saturated zone, health effects when multiple types of contaminants are present, and the behavior of chromium released from the repository. The sorption properties and dose conversion factors used in the NRC staff analysis are discussed in Appendix A, Section A.1.2. As stated in the supplement, these values are drawn from the DOE Safety Analysis Report (DOE, 2008b, Section 2.3.9), with subsequent updates based on further literature values (DOE, 2014a). The low concentrations of contaminants calculated in the groundwater indicate that any potential competitive sorption effects are not significant. The NRC staff is not aware of any new information on sorption properties of radionuclides, competitive sorption effects, or health effects when both radionuclides and nonradionuclide metals are present.

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified that requires further supplementation of DOE's EISs in the future.

No changes were made to the supplement as a result of these comments.

(116, 147-12)

B.2.2.2.5. ***COMMENT****: A commenter expressed concern with the uncertainty and health risks posed by the release of a large amount of metals from the repository as a result of corrosion of those materials in the repository. The commenter mentioned several mechanisms or particular environmental conditions that they believe have been neglected and cited studies that support higher corrosion rates than those used in the performance assessment.*

RESPONSE: The commenter raised concerns related to the NRC staff's use of information from the DOE's TSPA, which was part of DOE's license application for the proposed repository at Yucca Mountain, as a primary input and as support for evaluating environmental impacts in this supplemental EIS. A discussion of the use of modeling in the supplement can be found in Section 1.2.2, Appendix A, and Appendix B, Section B.2.2.2. The NRC staff's evaluation of information on these topics, as presented in the license application, is contained in the staff's Safety Evaluation Report for the Yucca Mountain repository license application (e.g., NRC, 2014a). In addition, several of the issues raised by commenters are the subject of contentions pending in the suspended adjudicatory proceeding.

As part of its license application, DOE conducted a performance assessment that identified and examined the effects of various features, events, and processes on the performance of the repository. The performance assessment included accounting for uncertainties in metal corrosion processes and rates that may affect the performance of the engineered barrier system. These uncertainties were analyzed by multiple simulations in the TSPA model using different corrosion rate input parameters (DOE, 2008b, Section 2.3.6). The NRC staff's review of this analysis is in its Safety Evaluation Report (NRC, 2014a; Chapter 4, Section 2.2.1.3.1). As explained in Section A.1.1 of the supplement, the analysis of impacts from nonradiological contaminants used release and transport rates based on the corrosion rates of the engineered

barrier components in the repository used in the TSPA. As discussed in the supplement, the release rates used are conservative in that they include all the potentially exposed surface area of the engineered barrier systems in the repository as subject to corrosion.

No changes were made to the supplement as a result of these comments.

(116)

B.2.2.2.6. ***COMMENT****: One commenter stated that accumulation of uranium-bearing minerals could occur near the repository and along the groundwater pathway wherever evaporation occurs. The commenter stated that the likelihood of accumulation is increased by the presence of vanadium and suggested several sources of vanadium in the natural environment (e.g., basaltic rock, reducing environments of swamp or marsh deposits) and in the materials used in repository construction. The commenter stated that the range of moisture conditions in the repository that may affect accumulation of radionuclide-bearing minerals should be expanded to include saturated conditions, such as perched water and intermittent flooding of the repository during wetter climates. The commenter stated that an analysis of the risk of criticality is needed for the possible accumulations of radionuclide-bearing minerals at locations in or downgradient of the repository.*

The commenter suggested deposits of uranium-vanadium-bearing minerals at Yeelirrie (Western Australia) and elsewhere, including southern Nevada, point to evaporation as an accumulation mechanism for uranium at the land surface. The commenter stated that the draft supplement should have considered radionuclides removed from the groundwater and deposited by sequential precipitation of minerals during evaporation or electrochemical reduction. The commenter suggested that accumulation of uranium-bearing minerals at groundwater discharge areas would result in ingestion, inhalation, and external exposure pathways that were not evaluated in the draft supplement.

RESPONSE: The aspects of these comments that pertain directly to the performance of the repository are out of the scope of this supplement. These aspects include criticality and uranium accumulation in or near the repository up to the postclosure compliance location. The scope of this supplement concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 11 mi [18km] downstream along the flow path from the Yucca Mountain site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

With respect to the comments concerning the potential for criticality and for health effects due to accumulation of carnotite or other uranium minerals beyond the compliance location, DOE considered the possibility of criticality of released fissionable material in the repository in its safety analysis and concluded that it could be excluded from analysis on the basis of very low probability (DOE, 2008b, Section 2.2.1). The NRC staff review of this analysis is given in its Safety Evaluation Report (NRC, 2014a, Chapter 2, Section 2.2.1.2.1). For similar reasons, the accumulation of sufficient U^{235} or other fissionable material in a configuration that facilitates criticality in deposited minerals along the groundwater pathway in Amargosa Desert or at groundwater discharge sites is also highly unlikely because the uranium released from commercial spent nuclear fuel is likely to be less than 1% U^{235}, and the chemical and physical conditions required for criticality are unlikely to form at these locations.

One commenter pointed to surficial uranium deposits in arid environments such as the Yeelirrie Deposit in Australia (e.g., IAEA, 1984) or those in the western United States as possible analogs to potential accumulations of repository contaminants in the aquifer or on the surface in the affected environment. The Yeelirrie Deposit was formed by periodic wetting and evaporation in an arid climate that led to the accumulation of a carnotite-bearing caliche (also called calcrete or hardpan) in soils at or near the ground surface. A similar environment and potential exposure pathway is described in the supplement in Appendix A, Section A.2.3, subsection titled Environment 3: Surface Discharge at Wet Playas. The primary exposure pathways for such a deposit are dust inhalation, ingestion, and external (skin) contact. As discussed in the supplement in Section 3.1.2.1 and Appendix A, Section A.2.2, the NRC staff analysis is conservative in its evaluation of the potential accumulation of contaminants at surface discharge sites. The evaporite soil model in the supplement assumes complete evaporation of discharged groundwater, forming evaporite minerals that concentrate contaminants. This approach makes no assumptions about the formation of specific minerals. Given the relatively low calculated contaminant concentrations in the evaporite soils, as detailed in Table 3-6 in the supplement, formation of significant amounts of uranium-vanadium mineral phases like those characteristic of the Yeelirrie Deposit is very unlikely. Formation of trace amounts of uranium-vanadium minerals within the soil would not lead to impacts greater than those evaluated in the supplement.

The commenter also suggested that accumulation of uranium and other contaminants could occur in reducing environments such as the “black mats” of organic-rich paludal (marsh) deposits. Paludal deposits may have formed within the alluvial sequence of Amargosa Desert under past wetter climatic conditions and may form at future spring and marsh environments such as those projected in the supplement for the State Line/Franklin Well area. Buried, isolated, sparse occurrences of thin layers with reducing conditions have been observed in boreholes in Amargosa Desert as well.

But the accumulation of radionuclide-bearing minerals at buried locations along the flow path would reduce the flux of radionuclides reaching a downstream receptor. In the supplement, the NRC staff analysis conservatively does not consider the possibility that some radionuclides would not reach an affected environment due to mineral accumulation along the groundwater pathway. Potential accumulation of contaminants in marsh deposits at surface discharge locations is discussed in the supplement in Sections 2.3.4 and 3.1.2.1. Calculated accumulations of contaminants in a marsh environment are evaluated and found to be very low (Table 3-6; Salt Marsh Soil Mode), as are the associated potential health effects (Table 3-7).

No changes were made to the supplement as a result of these comments.

(148)

B.2.2.2.7. ***COMMENT****: One commenter noted that assumptions in the draft supplement are overly conservative and result in an overestimation of potential impacts. This commenter further stated that groundwater flow inputs for the draft supplement that were derived from the TSPA are also conservative.*

RESPONSE: The NRC staff agrees that DOE’s impact analysis at the postclosure compliance location was based on results obtained from its performance assessment model, which included several conservative assumptions about features, events, and processes. Similarly, the analysis in the supplement makes several conservative assumptions to support the modeling and evaluation of potential impacts to groundwater and surface discharges beyond the

postclosure compliance location. The inclusion of conservative assumptions in these impact evaluations are a means for addressing uncertainties in the geologic setting for groundwater flow and radionuclide transport. Accordingly, conservative assumptions are used in the supplement to account for uncertainties in the groundwater model inputs.

No changes were made to the supplement as a result of this comment.

(138)

B.2.2.2.8. ***COMMENT****: One commenter stated that the impacts presented in the draft supplement represent risk rather than potential actual dose for a future scenario. The commenter noted that TSPA results used as input in the draft supplement do not represent dose consequences of events, were they to actually occur, but rather, they represent a dose weighted by the probability of the event occurrences (e.g., igneous intrusion into the repository). The commenter requested that the supplement present both consequence (dose) and probability of occurrence for the full range of scenarios and uncertainty.*

RESPONSE: As discussed in the NRC staff's ADR (NRC, 2008a) and in the supplement in Section 1.2.1, the NRC staff accepted the DOE analysis of releases from the repository, as calculated by DOE using their TSPA. The TSPA uses probabilistic methods to assess the performance of the repository and to estimate the doses that could result from releases from the repository following permanent closure. The NRC staff review of DOE's performance assessment is in its SER (NRC, 2014a). The NRC staff used results from DOE's TSPA on repository releases as representative of the likely types and levels of contaminants that could enter the groundwater system and be transported beyond the postclosure compliance location. As discussed in the supplement, the staff analysis used these results, along with conservative models and assumptions, to calculate potential impacts to the affected environment beyond the postclosure compliance location. This approach provides a reasonable means of quantifying potential impacts and is consistent with NRC regulations (10 CFR Part 51) and guidance (e.g., NRC, 2003) for analysis of environmental impacts. Additional information about the NRC staff's use of TSPA in the supplement can be found in Appendix A and Appendix B, Section B.2.2.2.

No changes were made to the supplement as a result of these comments.

(148)

B.2.2.2.9. ***COMMENT****: A commenter stated that the draft supplement relies too heavily on models used by DOE in its license application and, thus, does not address uncertainty and variability within and among the scenario classes. The commenter also stated that the supplement uses inappropriate data sets and statistical methods that have been challenged in contentions to the license application, such that uncertainties in radionuclide transport and radiological impacts are substantially underestimated in the supplement.*

RESPONSE: As discussed in the NRC staff's ADR (NRC, 2008a) and in the supplement in Section 1.2.1, the NRC staff accepted the DOE analysis of releases from repository, as calculated by DOE using its TSPA. The NRC staff review of DOE's performance assessment is in its Safety Evaluation Report (NRC, 2014a). The NRC staff used results from DOE's TSPA for repository releases as representative of the likely types and levels of contaminants that could enter the groundwater system and be transported beyond the postclosure compliance location. The supplement also used methods and parameters similar to those in the DOE models to

calculate potential health impacts at different locations under the different conditions described in the supplement. Specific challenges to the models and parameters used by DOE in its license application are pending in the adjudicatory proceeding, which is currently suspended.

As discussed in the supplement in Section 2.6, the NRC staff's analysis considered two analysis cases under different future climate conditions to provide a reasonable range of conditions to assess the affected environment and potential impacts. Uncertainties are addressed in the analysis through the use of the multiple conditions and conservatisms in the models and assumptions, as discussed in the supplement. The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified through the proceeding or otherwise that requires further supplementation of DOE's EISs in the future. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement as a result of these comments.

(148)

B.2.2.2.10. ***COMMENT****: Two commenters stated that criteria and rules for Yucca Mountain have changed over time, including those pertaining to groundwater travel times, point of compliance, dose levels, and the compliance period. One of the commenters stated that the rules and criteria changed because the earlier criteria would have been exceeded and would disqualify Yucca Mountain from further consideration as the site for a repository. The other commenter further stated that the supplement's evaluation ignores the populations most in need of protection from radioactivity, women and children.*

RESPONSE: The NRC staff acknowledges the commenters' concern about the requirements applicable to the proposed repository at Yucca Mountain. These comments are outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surfaces discharges of groundwater beyond the postclosure compliance location, which is 11 miles [18 km] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

The requirements that the NRC staff used for its evaluation in its Safety Evaluation Report are contained in the NRC regulation for Yucca Mountain (10 CFR 63), which under the NWPA, must be consistent with EPA's standards for Yucca Mountain (40 CFR 197). Both of these regulations were issued as proposed rules and finalized following consideration of public comments. The responses to public comments on 10 CFR Part 63 specifically addressed how the postclosure dose limit was protective of potentially more radiosensitive populations, such as children (66 FR 55732).

No changes were made to the supplement as a result of these comments.

(146-01, 147-23)

B.2.2.3 Repository Inventory, TADs, Drip Shields

B.2.2.3.1. ***COMMENT****: Commenters stated that many of the assumptions in the NRC staff's supplement and in DOE's EISs are no longer valid because they are based on assumptions in the license application DOE submitted to the NRC in 2008 that do not reflect the*

current state of affairs. Some commenters expressed concern that the proposed repository could not even hold the current inventory of spent commercial fuel, and that the supplement is incorrect to conclude that additional disposal beyond 70,000 MTU is not reasonably foreseeable. One commenter stated that DOE evaluated a larger repository (i.e., greater than 70,000 MTU) in its EIS, and the NRC should include, at a minimum, a qualitative discussion of possible impacts from an expanded repository in the final supplement. Other commenters pointed to the authorization by the President of the United States in 2015 for DOE to develop a repository for defense waste only, which would have the effect of removing defense waste from the Yucca Mountain repository, contrary to DOE's license application, which included both defense wastes and commercial wastes. Commenters also asserted that changes in thermal characteristics of the inventory due to changes in the inventory (e.g., no defense wastes, disposal of more high-burnup fuel, disposal of more 70,000 MTU at Yucca Mountain, changes to the storage canister characteristics) could affect repository performance and design and require new analyses to be performed for the supplement and the license application. One commenter asserted that because of this difference with respect to defense wastes, the application and associated environmental evaluations, including the supplement, violate the NWPA. One commenter stated that there is no inadequacy related to waste inventory in DOE's EIS for Yucca Mountain because DOE evaluated a representative quantity of SNF and HLW in its proposed action and evaluated much greater quantities of SNF and HLW that could exist in the future in its cumulative impacts evaluation.

RESPONSE: Comments regarding changes to the proposed repository's waste inventory are outside the scope of this supplement, are outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surfaces discharges of groundwater beyond the postclosure compliance location, which is 11 miles [18 km] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

The disposal of commercial SNF and defense HLW in separate repositories would change assumptions in the license application, and in DOE's EISs. If DOE changes its license application, the NRC staff would reevaluate the inventory assumptions in the process of updating its reviews. Regarding the potential disposal of more than 70,000 MTU at Yucca Mountain, DOE did not account for additional disposal in its license application; thus, this is neither part of DOE's proposed action nor part of the NRC's potential licensing action. Any proposal to dispose of more than the 70,000 MTU at a Yucca Mountain repository is contrary to the NWPA and would require a change in the law. This option is not reasonably foreseeable at this time.

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the EIS supplement as a result of these comments.

(001, 006, 018, 019, 042, 046, 080-06, 080-10, 102, 104, 117, 118, 128, 129, 133, 134, 138, 141, 146-01, 146-02, 146-06, 146-07, 146-14, 147-23, 147-24, 148)

B.2.2.3.2. ***COMMENT****: Commenters expressed concern that because the NRC has authorized many power plant licensees to burn fuel longer, the fuel that would go to Yucca*

Mountain does not match what DOE and the NRC staff evaluated in the application, TSPA, and associated environmental evaluations. Commenters stated that high-burnup spent fuel has higher thermal output and can increase degradation of the fuel cladding (e.g., through embrittlement), making the spent fuel more susceptible to damage during transportation and disposal. Additionally, commenters noted that longer storage times for spent nuclear fuel containing high-burnup fuel may require repackaging and separate containers for spent fuel assemblies. Commenters recommended that the supplement include analyses that evaluate the impacts of increasing amounts of high-burnup fuel. One commenter asked how much high-burnup fuel is planned for the repository.

RESPONSE: Comments regarding changes to the amount of high-burnup spent fuel included in the proposed repository's waste inventory are not within the scope of this supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location from the inventory proposed in DOE's license application. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

The waste inventory assumptions used in the supplement are based on information in DOE's license application. This inventory is also accounted for in DOE's EISs, which the staff determined to be adequate for adoption with further supplementation, as reflected in the ADR. In particular, DOE acknowledged in its license application that there was uncertainty in the actual amount of high-burnup fuel that would be shipped to the proposed repository, depending on whether the oldest or youngest fuel was shipped first. Thus, DOE accounted for differing amounts of high-burnup fuel by considering an average burnup ranging from 36 GWd/MTHM (gigawatt days per metric ton of heavy metal) if the oldest fuel is shipped first, to 49 GWd/MTHM if the youngest fuel is shipped first (DOE, 2008b, page 2.3.7-21). Additionally, DOE presented information in its license application supporting a range of burnups from 15 to 65 GWd/MTHM considered in modeling the degradation of spent fuel (DOE, 2008b, Rev. 1, page 2.3.7-41).

DOE's application includes a wet handling facility and its capabilities to receive, handle, and repackage failed spent nuclear fuel (DOE, 2008b; Section 1.2.5). If DOE updates its license application, the NRC staff would review the new information and update its reviews, as appropriate.

No changes were made to the supplement as a result of these comments.

(016, 062, 071, 072, 080-10, 080-16, 098, 108, 128, 133, 134, 146-01, 146-09, 146-16)

B.2.2.3.3. ***COMMENT****: Several commenters stated that the NRC staff's draft supplement, the technical basis for the repository performance assessment, and the DOE environmental impact statements are out of date and based on incorrect assumptions. These comments were attributed to DOE terminating work on the transport, aging, and disposal (TAD) canister concept prior to completing a design that would meet the NRC's performance requirements. The commenters also noted that the TAD concept is relied upon in DOE's application, including its EISs. Related to the lack of a TAD design, commenters stated that DOE assumptions about canister fuel capacity, number of canisters, canister performance, drip shield installation and performance, and other assumptions are likewise incorrect.*

RESPONSE: The NRC acknowledges the concerns expressed in these comments regarding the state of work on the concept and design of TAD canisters for use in the proposed geologic

repository and the use of information from DOE's TSPA to support impact evaluations in the supplement. However, these comments are outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

The NRC staff's use of information from the DOE's TSPA, which was part of DOE's license application for the proposed repository at Yucca Mountain, as a primary input and as support for evaluating environmental impacts in this supplemental EIS is discussed in Section 1.2.2 and Appendix A of the supplement. The NRC staff's evaluation of TSPA as presented in the license application, including the specific issues identified by commenters, is contained in the staff's Safety Evaluation Report for the repository license application (NRC, 2014a, Section 2.2.1.3.1). In addition, several of the issues raised by commenters are the subject of contentions pending in the suspended adjudicatory proceeding.

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement as a result of these comments.

(006, 062, 080-10, 080-08, 117, 118, 129, 133, 134, 141, 146-01, 146-06, 146-07, 147-06, 147-23, 148)

B.2.2.3.4. ***COMMENT****: Several commenters expressed concerns regarding the draft supplement's reliance on the assumption that titanium drip shields would be used in the repository. Some commenters questioned whether taxpayer dollars would be appropriated to fund installation of the drip shields and remarked that the drip shields may never be installed. Others questioned the design of the drip shields, the role of the drip shields in the engineered barrier system, and whether the technology would be available to install the drip shields correctly 100 years after repository closure. Some commenters also noted that the proposed canisters and other aspects of the DOE's analyses relied on by NRC in the supplement are obsolete assumptions.*

RESPONSE: The NRC staff acknowledges the concerns expressed in these comments regarding the use of titanium drip shields, including the future appropriation of funds for their installation in the proposed geologic repository. However, these comments are outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029), and in the NRC staff's ADR (NRC, 2008a).

A number of commenters raised concerns related to the design and future installation of the drip shields and the NRC staff's use of results from DOE's performance assessment to support evaluation of environmental impacts in this supplemental EIS. The NRC staff's evaluation of information on these topics, as presented in the license application, is contained in the staff's Safety Evaluation Report for the Yucca Mountain repository license application (NRC, 2015a;

Chapters 2 and 4). As discussed in the NRC staff's ADR (NRC, 2008a) and in the supplement in Section 1.2.1, the NRC staff accepted the DOE analysis of contaminant releases from the repository based upon DOE's TSPA model. Additional information on disposal assumptions can be found in responses to comments concerning waste containers and packages in Sections B.2.2.2.1, B.2.2.3.3, and B.2.4.6.3. A discussion of the use of the TSPA and other model results to support the supplement can be found in Section 1.2.2, Appendix A, and in Appendix B, Section B.2.2.2. Furthermore, several of the issues raised by commenters are the subject of contentions pending in the suspended adjudicatory proceeding.

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement as a result of these comments.

(034, 117, 147-04, 147-07, 147-15, 149-20)

B.2.3 Affected Environment

B.2.3.1 General Scope

B.2.3.1.1 ***COMMENT****: Commenters were concerned that the draft supplement focuses on impacts beyond the 11-mile postclosure compliance location and suggested that the supplement analysis be expanded to include estimates of impact to groundwater beneath the repository location, in the controlled area, and along the groundwater path to the point of compliance. These commenters stated that it is unreasonable to allow any level of groundwater contamination between the repository and the compliance location. One commenter stated that that ignoring such contamination is not consistent with how Nevada implements its laws. One commenter also stated that failing to disclose such impacts is not allowed under the Nuclear Waste Policy Act. Two commenters questioned the assumption that there will be no well drilling for water within the area between the repository and the compliance location; one commenter pointed out that DOE has already drilled for water within the controlled area, and another commenter stated that assumptions based on well drilling characteristics and pumping costs are unsupported. These commenters argued that it is implausible to assume that passive institutional controls will continue into the long-term future, and that population growth will be limited in the area near the repository site.*

RESPONSE: The NRC staff acknowledges these concerns regarding the spatial extent of the affected environment considered for the supplement analysis. These comments are outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029), and in the NRC staff's ADR (NRC, 2008a).

In its 2002 EIS and 2008 supplemental EIS, DOE described the affected environment and analyzed impacts for the area along the flow path from the repository to the postclosure compliance location. At the postclosure compliance location, DOE estimated the impacts for the reasonably maximally exposed individual (RMEI), consistent with the RMEI characteristics in 10 CFR Part 63. As described in its ADR, the NRC staff determined that it could adopt DOE's

evaluation of potential groundwater impacts from the repository to the postclosure compliance location. However, the NRC staff concluded that the affected environment and any impacts for areas beyond the postclosure compliance location were not adequately addressed in DOE's EISs for potential releases of radiological and nonradiological contaminants from the repository to groundwater and from surface discharges of groundwater.

No changes were made to the supplement text in response to these comments.

(080-10, 132, 148)

B.2.3.1.2. ***COMMENT****: One commenter stated that the draft supplement fails to adequately describe the affected environment, as required by NEPA. The commenter stated that the supplement text and figures do not indicate that the postclosure compliance location and Amargosa Farms pumping locations are within the town of Amargosa Valley, and that the groundwater impacts would be heavily concentrated within the town of Amargosa Valley. The commenter went on to state that this is an omission because the population of the town is larger than other populated areas shown on the maps (e.g., Beatty and Indian Springs). The commenter further asserted that the supplement does not acknowledge or describe potentially affected privately owned lands and associated water wells in the vicinity of the pumping location, nor does it describe the potential social and economic impacts on these resources. The commenter provided figures indicating the locations of privately owned lands and wells and stated that the final supplement must include a description of these resources.*

RESPONSE: The commenter is correct that the postclosure compliance location, located 18 km [11 mi] southeast of the repository site, as well as the Amargosa Farms area, lie within the boundaries of the unincorporated township of Amargosa Valley, which encompasses a large area of 1308 km^2 [505 mi^2]. While the DOE SEIS (DOE, 2008a) calculated groundwater impacts only at the postclosure compliance location, the supplement calculates impacts at additional locations within the affected environment, including for Amargosa Farms, 35 km [22 mi] southeast of the repository site, within the town of Amargosa Valley. As explained in the supplement in Section 3.1, this location was chosen to represent potential impacts from groundwater pumping for agricultural and other uses in Amargosa Valley. Consistent with NRC's NEPA-implementing regulations (10 CFR Part 51) and guidance (NRC, 2003), this location was chosen in order to focus on baseline conditions to assess impacts such that the detail incorporated is commensurate with the significance of the potential impacts. As discussed in the supplement, the NRC staff's analysis assessed impacts to the population and not impacts to individuals or groups within that population. For this analysis, specific consideration of privately owned lands and associated water wells in the vicinity of the pumping location is not necessary, given the representative nature of the NRC staff's calculations, the conservative assumption that the entire contaminant plume is captured by the well withdrawal, and the small impact on groundwater in Amargosa Valley calculated in the supplement.

The NRC staff used the characteristics of the present-day population in the town of Amargosa Valley to represent possible future populations that may be affected by releases from the repository, consistent with the description of the reasonably maximally exposed individual in 40 CFR 197.21 and 10 CFR 63.312. This approach also is consistent with recommendations of the National Academy of Sciences (NAS, 1995) on treatment of future populations for calculations over long time frames. The location for Amargosa Farms used in the supplement is conservative in that it represents the current population cluster along the groundwater flow path from Yucca Mountain in the area south of Highway 95 that is closest to the repository. Other current clusters of population and irrigation sites are farther down the groundwater flow path

and would therefore experience lesser estimated impacts for the same groundwater pumping assumptions.

In response to this comment, multiple changes have been made to the supplement text and figures to improve clarity. These changes include clarification of the relationship between the Amargosa Farms area and the town of Amargosa Valley, and modification of location labels on Figures 2-1, 2-3, and 2-5.

(148)

B.2.3.2 Water Resources

B.2.3.2.1. ***COMMENT****: One commenter stated that the groundwater flow paths will not be static and will migrate as Fortymile Wash is activated in future wetter climates. The commenter also suggested that (i) the draft supplement lacks analysis that would account for conditions resembling those in the region's geologic history, such as flowing river channels and a large lake in Death Valley sustained by runoff from Amargosa River; (ii) recharge during future wetter climates will cause the flow paths to shift – the commenter referred to a three-point solution presented in a contention (referred to as TIM-NEPA-004) that supports the flow path under Yucca Mountain shifting direction to the southwest from the current southeasterly flow; (iii) use of the DVRFS for modeling future flow pathways is not appropriate because the model does not adequately account for recharge and was calibrated to static conditions, not the dynamic conditions that the commenter states should be expected in future climates; and (iv) a regional watershed-based infiltration model should have been coupled with an appropriately modified DVRFS model to reflect future conditions.*

RESPONSE: The NRC staff agrees with the commenter that recharge occurs along channels during occasional flooding events in Fortymile Wash, and that in future wetter climatic conditions, recharge along the channel will increase due to seasonal or perennial channel flow. The NRC staff also agrees that the seasonal-to-perennial flow in the Amargosa River system, of which the Fortymile Wash is a tributary, along with increased groundwater discharge likely were the primary contributors to the formation of a paleolake in Death Valley during past wetter climates. The NRC staff, however, disagrees with the commenter with regard to the likelihood that recharge along Fortymile Wash during wetter climates could dramatically change the direction of the water table gradient beneath Yucca Mountain and Fortymile Wash because a water table rise to a planar surface is inconsistent with the hydrogeologic flow in the region, as discussed below. The term "water table" as used here is synonymous with the potentiometric surface for the uppermost aquifer as used by the commenter.

The commenter refers to a first-order (planar) three-point extrapolation of nominal sites of former surface discharge under wetter climates to support a dramatic change in flow direction (and thus impacts on groundwater) in a wetter future climate. As discussed in the supplement in Sections 2.3.4 and 2.4, the NRC staff analysis uses the regional water table reconstruction from Paces and Whelan (2012) and the hydrogeologic conceptual models developed over the past several decades by the U.S. Geological Survey (USGS) (Belcher and Sweetkind, 2010, and references therein). These studies support a flow system constrained by faults, changes in lithology, variably distributed recharge, and other hydrogeologic features that influence flow directions. The ability of the USGS models to reproduce water table positions measured in wells across the Death Valley region supports the hydrogeologic features upon which the numerical models are built.

The commenter also suggests that the estimates of recharge from a Maxey-Eakin elevation-controlled type model do not adequately reflect focused recharge along channels, and, thus, could not predict the water table rise indicated by the three-point solution. The commenter further states that recharge input for the groundwater flow model used in the supplement should have been estimated by a distributed watershed model, such as the Hevesi et al. (2003) infiltration model. The NRC staff notes that the Belcher and Sweetkind (2010) model used for the analyses in the supplement does not use a Maxey-Eakin relationship for estimates of recharge across the modeling domain, but rather, uses the Hevesi et al. (2003) model. The Hevesi et al. (2003) infiltration model indicates that recharge is highest at ridges and mountains (i.e., higher elevations) where soil layers are thin, and that recharge is lowest in alluvial basins.

In addition, the NRC staff disagrees with the commenter that the infiltration and saturated zone models need to be directly linked to produce results appropriate for use in the supplement, particularly considering the long time frames considered for the modeling (thousands to a million years). Use of average infiltration results is warranted by the large difference in time constants for infiltration and for saturated zone flow processes. For example, the long time-constant for saturated flow reflects the slow response of aquifers to variations in precipitation, compared to the fast response of infiltration to rain events.

In summary, the analysis presented in the supplement for the behavior of the flow system under a future cooler, wetter climate is supported by modeling and studies of the hydrogeologic system, as documented in the references cited in the supplement.

No changes were made to the supplement as a result of these comments.

(148)

B.2.3.2.2. ***COMMENT****: One commenter stated that groundwater transport pathways exist from Yucca Mountain eastward to Indian Springs Valley, under Sheep Creek Mountains, and into Coyote Springs Valley. The basis for the commenter's statement is uncertainty shown on Figure 2-3 on page 2-7 of the draft supplement for flows between basins to the east of Amargosa Desert in the DVRFS model. This commenter stated that the impacts to water users in Lincoln County must be evaluated in the draft supplement.*

RESPONSE: Section 2.2.2 and Figure 2-3 in the supplement describe the general direction of flow from Yucca Mountain as being southward along Fortymile Wash (in the Fortymile Canyon Section, 3a) and across Amargosa Desert (in the Amargosa River Section, 3b) to the eastern end of the Funeral Mountains, and then southwesterly into Death Valley (in the Funeral Mountain Section, 3d). As described in the supplement in Sections 2.6 and 3.1.1, when no pumping occurs in the Amargosa Desert, the potential contaminant plume from the repository continues into Death Valley. When pumping occurs in the Amargosa Farms area, the entire plume is assumed to be captured by the pumping. Within the Death Valley Regional Groundwater Flow System (Belcher and Sweetkind, 2010), water from Section 3a does not flow eastward into Sections 2e or 2f, and, therefore, contaminants from the repository would not reach Indian Springs Valley (Section 2c). The uncertainty expressed in Figure 2-3 of the supplement represents local uncertainty at the southern part of the boundary between Sections 2c and 2a. Coyote Springs Valley is on the eastern side of Sheep Range, and is partially contained within Section 2a. Based on the conceptualization in Belcher and Sweetkind (2010), and considering the areas contained on Figure 2-3 in the supplement, Coyote Springs Valley receives its groundwater from the north and from recharge in the Sheep Range. Therefore, the

NRC staff concludes that there would not be impacts to the Lincoln County groundwater system from a repository at Yucca Mountain.

No changes were made to the supplement in response to this comment.

(123)

B.2.3.2.3. ***COMMENT****: Many commenters stated that flow between basins as characterized in the DVRFS is misrepresented or uncertain, and thus affected environments or impacts were not properly considered in the draft supplement.*

Several commenters stated that new analyses presented in a report titled "2014 State of the Basin Report Amargosa River Basin" (Zdon and Associates, 2014) shows that groundwater flows from Amargosa Desert into the Southern Death Valley Subregion (SDVS), which includes the springs of Middle Amargosa Basin (Tecopa and Shoshone areas). A commenter provided a full copy of the report to the NRC. These commenters indicated that by misstating flow between Amargosa Desert and the SDVS, the draft supplement fails to analyze exposure pathways and impacts along the Amargosa River south of Alkali Flat, including impacts to ecology and communities over the one-million-year analysis period. The commenters further stated that the draft supplement failed to analyze potential changes associated with seismic activity over the one-million-year period.

Additionally, referencing Section 2.2.2 of the draft supplement, several commenters emphasized that the springs in the Middle Amargosa Basin are misrepresented in the draft supplement as small and intermittent. Noting line 19 on page 2-6 of the draft supplement, one commenter requested an estimate of the flow between the two basins in acre-feet/year.

Two commenters disagreed with the comments described above by stating that the groundwater flow pathways that contaminants from the repository would follow are not to Shoshone and Tecopa in the Lower Amargosa River Valley, but rather under the Funeral Mountains to Furnace Creek springs, as represented by the DVRFS-2010 model. Another commenter commended the NRC and DOE for credibly extending the analysis to the accessible environment and, in particular, by including analyses from the commenter's published reports on the Lower Carbonate Aquifer and Death Valley hydraulic studies.

RESPONSE: The analyses in Zdon and Associates (2014, 2015) are generally consistent with the conceptualization of flow in the supplement. In the description in the supplement (Section 2.2), groundwater from below the repository flows southward beneath Fortymile Wash and transitions at the junction with Amargosa River from the alluvial aquifer of the Amargosa Farms area to the carbonate aquifer at the eastern end of the Funeral Mountains. The groundwater pathway then follows the regional carbonate gradient southwesterly towards the springs near Furnace Creek and on to Middle Basin in Death Valley. The likelihood of flow through the carbonate blocks at the southeastern end of the Funeral Mountains was identified through research conducted by the USGS (Belcher and Sweetkind, 2010) and an Inyo County drilling program (Inyo County, 2007). Bredehoeft et al. (2008) defined properties of the relatively permeable carbonate units within the Funeral Mountains. Further support for the hydrologic connection between the southerly flowing alluvial aquifer in the Amargosa Desert and the carbonate aquifer beneath the Funeral Mountains is the presence of freshwater carbonates in the State Line paleospring deposits, as described in Paces and Whelan (2012). A likely

source of groundwater forming these deposits during wetter past climates are the carbonate blocks of the eastern end of the Funeral Mountains.

Zdon and Associates (2014) focused on identifying sources of water for springs in the Middle Amargosa River Basin. They conclude, besides the primary contributions from the east (e.g., the Spring Mountains), that the contribution from Amargosa Desert to the north was derived from Ash Meadows (see also Zdon et al., 2015; Zdon and Associates, 2015). The NRC staff notes that geographically, the Amargosa Desert encompasses both Ash Meadows and the Amargosa Farms area. However, as demonstrated in the Death Valley Regional Groundwater Flow System (Belcher and Sweetkind, 2010), these two areas are hydrologically separated by a large fault and coincident steep hydraulic gradient dipping approximately west to southwest. This feature was the primary basis for the NRC staff's conclusion in the supplement in Section 2.2.2 that the groundwater from below the repository flowing southward beneath Fortymile Wash does not enter the Ash Meadows area and would not, therefore, be a component of flow from Ash Meadows to the Middle Amargosa River Basin and the springs near Shoshone and Tecopa.

The Zdon and Associates (2014, 2015) reports contain isotopic, noble gas, major ion, and trace element data from multiple locations in the Middle Amargosa River Basin and adjacent areas in Nevada. Contrary to the assertions in some of the comments, the geochemical data presented in these reports are entirely consistent with previous interpretations of groundwater flow paths, recharge sources, and regions of mixing that are described in the supplement, including the separation between the predominant repository flow path and the flow from Ash Meadows towards the Middle Amargosa River Basin, and ultimately the Shoshone and Tecopa areas. The geochemical data, especially the stable isotope data, suggest that the source for the groundwater beneath the Amargosa River Valley is limited to either the Spring Mountains, or is a mixture of Ash Meadows, Spring Mountains, and Kingston Range groundwater (Davisson and Associates, 2014; Zdon and Associates, 2014, 2015; Larsen et al., 2001). These mixing and source waters do not travel along the relatively shallow alluvial system beneath the Amargosa River channel but through the regional carbonate aquifer system. From a comparison of isotopes in the groundwater near springs in the Tecopa area with data from an upstream well in Amargosa River channel sediments, Davisson and Associates (2014) suggest that an alluvial flow path beneath the river channel would be, at best, a minor contributor to the Amargosa River Valley groundwater system. Furthermore, Zdon and Associates (2015) and Davisson and Associates (2014) suggest that the springs at Tecopa are supported by water from a fracture flow system with a deep source of water, consistent with the helium isotope ratios and the extent of mixing from different sources. These data from the Zdon and Associates report from the springs in the Middle Amargosa River Basin reflect a strong influence of recharge from the Spring Mountains and provide additional evidence of contributions from the same recharge source that produces discharge at Ash Meadows (Davisson and Associates, 2014). These Zdon and Associates conclusions are entirely consistent with the conceptual model and analyses presented in the supplement.

The supplement considers the uncertainty in groundwater flow paths south of Amargosa Farms in the treatment of impacts in the no-pumping analysis case (Section 3.1.2). In addition to considering the conceptualization in the DVRGFS model (Belcher and Sweetkind, 2010) that most of the groundwater flow south of Amargosa Farms is under the Funeral Mountains, the supplement also discusses impacts for a limited amount of flow to Alkali Flat/Franklin Lake Playa. As discussed in the supplement in Sections 2.2.2 and 2.3.4, Alkali Flat/Franklin Lake Playa lies along the surface trace of the Amargosa River at the confluence with Carson Slough,

which flows from Ash Meadows. Most of the groundwater traveling along the Amargosa River pathway, as well as that along Carson Slough, is lost through evapotranspiration as it reaches the structural constriction associated with the Eagle Mountain pass. The supplement addresses potential impacts of contaminants reaching Alkali Flat/Franklin Lake Playa (Section 3.1.2.3), but as discussed in the supplement, there is no indication that a contaminant plume from the repository would persist in groundwater beyond that location towards the Middle Amargosa River Basin. This is consistent with the geochemical data in Davisson (2014) and Zdon and Associates (2014, 2015).

One commenter, referring to text on page 2-6 of the supplement, requested quantification of the volumetric groundwater flow (in acre-ft/yr) from Yucca Mountain in the Central Death Valley Subregion that reaches the location where the Amargosa River crosses into the Southern Death Valley Subregion, which is immediately south of Alkali Flat. While a tracer test to estimate this flow rate in the field is not feasible, in its groundwater reports, Sandia National Laboratory performed a particle tracking simulation using a flow field from the DVRFS model (Belcher and Sweetkind, 2010), essentially performing a numerically simulated tracer test. As described in Section 2.2.2 of the supplement, for 10,000 particles released at Yucca Mountain in an analysis by SNL (2009), 8,024 reached the postclosure compliance location. Only 2 particles reached Alkali Flat (SNL, 2009). This indicates that approximately 0.02 percent of the groundwater beneath Yucca Mountain reaches the Amargosa River at the boundary to the Southern Death Valley Subregion. The NRC staff considers this value to be uncertain, but reflective of the relative magnitude of flow from Yucca Mountain to Alkali Flat.

Uncertainties of flow patterns in southern Amargosa Desert may be reduced by future studies. The ongoing SAMM (USGS, 2016a) and LAV (USGS, 2016b) projects led by the U.S. Geological Survey both concern groundwater flow in the southern part of the Death Valley region. The Southern Amargosa eMbeddded Model (SAMM) is a modeling effort to refine the hydrogeologic framework and flow conceptualization for an area including Amargosa Farms and Ash Meadows and extending southward into eastern Funeral Mountains and Middle Amargosa River Basin. The SAMM project will include analysis of the hydrologic connection between Ash Meadows and Amargosa Farms. The LAV project focuses on the primary groundwater sources and generalized flow paths that support discharge in the Lower Amargosa Valley (Eagle Mountain to Tecopa section). These projects may provide additional information on pathways for flow southward from the alluvial aquifer in the Amargosa Farms area.

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. As a result of the in-progress studies or other developments, information may be identified that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

The NRC staff revised the description in Section 2.2.2 (subsection titled Alkali Flat and Southern Death Valley Subregion) to clarify that sections of the Amargosa River are perennially flowing due to springs along the Shoshone and Tecopa areas. The NRC staff revised the supplement text in Section 2.3.3 (subsection titled Discharge Locations along the Flow Path South from Amargosa Farms) to include the provided reference and discuss the additional data provided in the Zdon et al. (2015) and Zdon and Associates (2014, 2015) reports.

(042, 046, 061, 080-10, 121, 134, 142, 143, 149-10, 149-1601, 149-21)

B.2.3.2.4. ***COMMENT****: One commenter pointed out a discrepancy between the commenter's documented estimate of spring discharge in the Furnace Creek area and the estimate provided in the draft supplement. The commenter also noted a discrepancy in estimates of evapotranspiration, but indicated that the value used in the supplement is larger and represents a worst case for radionuclide transport.*

RESPONSE: The NRC staff appreciates the additional estimate of spring discharge provided by the commenter. Measurement of spring discharge at the Furnace Creek area and evapotranspiration at Middle Basin is uncertain because of the complex nature of the groundwater flow discharging at the ground surface. For spring discharge, the commenter suggested a value of 5 cfs [3,600 Ac-ft/yr; 4.4 x 10^6 m^3/d] combined for seven springs in the area and provided a report supporting that estimate (Jensen et al., 2004). The supplement utilized a value of 3.2 cfs [2,294 Ac-ft/yr; 2.8 x 10^6 m^3/d] that was derived from the three prominent springs (Travertine, Nevares, and Texas) reported in Belcher et al. (2010; Table C-2). The difference in the estimates is primarily due to differences in discharge estimates for each of the three prominent springs and not due to the inclusion of seven springs instead of three. As noted by the commenter, the use of the smaller value of discharge from the springs is conservative in that it leads to larger calculated values of contaminant concentration and dose.

The value of the evapotranspiration estimates provided in the supplement and that suggested by the commenter represent different quantities. The commenter's estimate of evapotranspiration was derived from irrigation demand in the Furnace Creek area, where water discharging from the springs is used for agricultural irrigation. In Section 3.1.2.2 of the supplement, the NRC staff analysis treats Middle Basin in Death Valley as a separate affected environment with different exposure pathways from that used for the Furnace Creek area. The evapotranspiration estimate in the supplement for Middle Basin represents evaporation of groundwater as the water table approaches the ground surface and transpiration from native plants such as creosote bush. The evapotranspiration estimate used in the supplement covers a broad area downslope of the Furnace Creek springs area and out to the salt pan of Death Valley.

In response to this comment, Section 2.3.3 of the supplement has been revised to acknowledge the larger value of spring discharge reported in Jensen et al. (2004). The discharge value from Belcher et al. (2010), however, is still used in the calculations of impacts at Furnace Creek area. No change was made in the supplement pertaining to the value of evapotranspiration at Middle Basin.

(142)

B.2.3.2.5. ***COMMENT****: Several commenters stated concerns related to the draft supplement's assumptions for groundwater pumping. One commenter questioned the statement in the draft supplement that current pumping rates in Amargosa Farms may not be sustainable because water levels at Devils Hole are approaching the level constrained by the State Engineer's order. The commenter maintained that estimates from the DVRFS model-derived estimates of declining water levels in Ash Meadows due to pumping in surrounding areas are inaccurate, and that nonpumping related consumptive use should be considered along with pumping in the DVRFS model calibration. The commenter provided a hydrograph of water levels at Devils Hole in Ash Meadows covering the past 50 years that indicates slightly increasing water levels over the past decade. Other commenters suggested that pumping in Amargosa Farms does not impact water levels in Ash Meadows because the areas are*

separated by a fault system. As with the previous commenter, these commenters noted that water levels are declining in the Amargosa Farms area and slightly increasing in Ash Meadows. One commenter suggested that it is unrealistic to rely on future restrictions of pumping for preservation of the Devils Hole pupfish, as indicated in the draft supplement, and further suggested that a wetter future climate will result in greater groundwater use because perennial yield[1] would increase. Another commenter pointed to potential changes in groundwater levels should water rights in Amargosa Farms be fully exercised or if the region's solar energy production potential is realized. Another commenter requested that during construction of the repository, the flow pathways should be thoroughly delineated along Fortymile Wash and through the Amargosa Farms area.

One commenter suggested that the DVRFS model used in the supplement could not appropriately represent the effects of future (continued) pumping in Amargosa Desert because it was calibrated to water levels observed in the mid-1990s, and that it is only capable of generating steady-state water levels that do not account for the impacts of pumping. The commenter cited Bredehoeft and King (2010), stating that continued pumping in Amargosa Desert would significantly decrease the vertical gradient between the carbonate and tuff aquifers below Yucca Mountain. Reversal of the gradient would lead to repository releases entering the carbonate aquifer and moving quickly to Death Valley.

RESPONSE: The effects of pumping on potentiometric conditions below Yucca Mountain, including the reversal of the vertical gradient between the carbonate and overlying volcanic aquifers is outside the scope of this supplement. The scope of the supplement concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

With respect to the effects of pumping on groundwater conditions and pathways beyond the postclosure compliance location, such as at Ash Meadows, assumptions regarding future pumping rates in the supplement are based on present and historical records over the past several decades. The NRC staff chose this approach for estimating future pumping rates to be consistent with discussions in the National Academy of Sciences 1995 report (NAS, 1995) to avoid speculative projections caused by difficulties in projecting future societal behavior. A present-day constraint on pumping rates includes the State of Nevada Engineer's order (Taylor, 2008) related to water levels in Devils Hole. The NRC staff considers it speculative to assume that the order will be rescinded. The NRC staff did not quantify the relationship between pumping rates in Amargosa Farms and water levels in Devils Hole because Ash Meadows is not part of the affected environment considered in the supplement. The NRC staff, however, agrees with the commenters that stated that a fault system that lies between Ash Meadows and Amargosa Farms influences the hydraulic connection between the two areas. The fault system and distribution of water table elevations across the fault inform the conclusion in the supplement in Section 2.2.2 that the groundwater flow pathway from Yucca Mountain does not include Ash Meadows. In addition, cumulative impacts from pumping and possible contamination related to potential solar projects in Amargosa Valley are considered in the supplement as possible cumulative impacts in Section 4.4.2.

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[1]Perennial yield is the maximum amount of groundwater that can be withdrawn over a period of time without depleting the groundwater reservoir.

With regard to the commenters' request for more thoroughly defined groundwater flow paths in Fortymile Wash and Amargosa Farms area, the designation of the Middle Amargosa River as a Wild and Scenic River has generated additional interest and research in groundwater flow in the southern extent of Amargosa Desert (e.g., development of the Southern Amargosa eMbedded Model, http://nevada.usgs.gov/water/studyareas/samm.htm) over the past years.

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified that requires further supplementation of DOE's 2002 and 2008 EISs in the future.

As discussed in the supplement in Section 1.2 and in the NRC staff's ADR (NRC, 2008a), the nature of the vertical gradient between the aquifers below Yucca Mountain is out of scope for this supplement. Nonetheless, the NRC staff notes that modeling reported in SNL (2009) provides relevant analysis using an updated version of the DVRFS model. As described in Section 2.4 of the supplement, SNL (2009, Table 8) provided results that suggest an insignificant effect on vertical gradients below Yucca Mountain when pumping for 500 years concurrently from both Amargosa Farms and from external basins (i.e., SNWA inter-basin transfers; see Section B.2.4.1.11). In addition, using a steady-state approximation, SNL (2009, Table 8) similarly showed an insignificant effect on the vertical gradient near Yucca Mountain. The commenter stated that their modeling of pumping in Amargosa Valley for 1,000 years into the future, using Belcher's (2004) DVRFS model, indicates a drop of 10 m [33 ft] in the potentiometric surface of the carbonate aquifer below Yucca Mountain [Bredehoeft and King, 2010]. The commenter did not, however, provide estimated hydraulic head changes for the overlying volcanic aquifers that would allow for calculation of changes to the vertical gradient between the two aquifers.

The same commenter suggested that the model used in the supplement was incapable of accounting for the effect of future pumping. Both the DOE and NRC environmental evaluations assess potential changes to the vertical gradient over the flow domain from Yucca Mountain to the Amargosa River. SNL (2009) used an updated version of the DVRFS model that included transient calibration of pumping and well data from 1913 to 2003. SNL (2009) did not use the DVRFS model to provide boundary conditions to the Site Scale Saturated Flow Model (DOE, 2008b, Section 2.3.9) for the analysis of future pumping effects. DOE's approach in its performance assessment (DOE, 2008b, Section 2.3.9), however, did link the DVRFS and Site-Scale Saturated Flow models. The NRC staff's discussion of groundwater modeling is in Section 2.4 of the supplement.

No changes were made to the supplement in response to these comments.

(046, 049, 142, 149-13, 149-18)

B.2.4 Environmental Impacts

B.2.4.1 Water Resources

B.2.4.1.1. ***COMMENT****: A commenter stated that the only significant exposure pathway occurs through groundwater that lies entirely within the Nye County community of Amargosa Valley, and that impacts for those pathways are small. The commenter noted that pumping in Amargosa Valley will likely continue in the future, and that it would capture all the contaminants that may be released from the repository. The commenter concluded that,*

therefore, no contamination would occur now or in the future at locations downstream of Amargosa Valley (e.g., to California and Death Valley). The commenter also provided a map that included groundwater flow path lines from the nuclear test areas to surface discharge areas. The commenter recommended visiting the Nye County Nuclear Waste Repository Project Office Web site for information about groundwater, based on data from 44 wells in Nye County.

RESPONSE: The NRC staff agrees with the commenter that the only significant exposure pathway would be in Amargosa Farms if pumping in that area continues at levels observed in the past several decades. However, the NRC staff considered the possibility that future pumping may decrease, whether as a result of the number of wells or the pumping rates at those wells. At some point, decreased levels of pumping may allow some contaminants in the groundwater to pass the Amargosa Farms area and continue downstream in the groundwater system. To evaluate the impacts from this possibility, the NRC staff assumed the extreme case of no pumping, which would maximize contaminant transport downstream of Amargosa Farms. The rationale for this assumption, as discussed in the supplement, is that if no pumping led to small impacts at affected environments downstream of Amargosa Farms, then pumping at some intermediate level would lead to less impacts. At an intermediate pumping level, some radionuclides and metals would be withdrawn in groundwater at Amargosa Farms (where pumping occurs) and others would continue to move downstream (e.g., Stateline Deposits area or Furnace Creek springs).

With regard to information from Nye County, the NRC staff acknowledges the map of groundwater flow path lines to surface discharge areas and appreciates Nye County making information from its drilling programs available on its Web site. Information from Nye County's past drilling programs has been helpful to the NRC staff for understanding the characteristics of groundwater flow in the Amargosa Desert.

No changes were made to the supplement as a result of these comments.

(106, 149-16)

B.2.4.1.2. ***COMMENT****: One commenter suggested that for surface water discharges described as potable, the supplement should refer to guidelines for total dissolved solids contained in the Environmental Protection Agency's National Secondary Drinking Water Regulations. The commenter noted that the secondary maximum contaminant level for TDS is 500 ppm.*

RESPONSE: The NRC staff agrees with the commenter that the maximum TDS level listed in the National Secondary Drinking Water Standards (NSDWS) set by the Environmental Protection Agency is the appropriate reference for the discussion of water quality at Alkali Flat in Section A.2.2 of the supplement. The NSDWS provide guidelines for aesthetic qualities (i.e., taste, smell, appearance) of drinking water. The TDS standard was changed from 250 to 500 ppm in Appendix A, Section A.2.2, and additional clarifying text was added in response to this comment.

(137)

B.2.4.1.3. ***COMMENT****: A commenter expressed concern that the postclosure compliance location is located 11 miles downstream of the repository site and stated that this distance is*

needed to reduce contamination through dilution. The commenter stated that the proposed repository could only meet legal requirements through this dilution of radioactivity for 11 miles, also noting that contamination would extend beyond the compliance point. The commenter argued that the groundwater flow is too low to provide sufficient dilution.

RESPONSE: The NRC staff acknowledges the concern expressed by two commenters about the 18-km [11-mi] postclosure compliance location and the extent of dilution that may reduce the concentration of radionuclides in the groundwater between the repository and the compliance location. These comments are outside the scope of this supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

The NRC staff reviewed groundwater flow and transport to the compliance boundary in the NRC staff's SER (2014a, Sections 2.2.1.3.8 and 2.2.1.3.9). DOE's use of the compliance location is a requirement in NRC regulations. The accessible environment begins at the postclosure compliance location and is any area outside of the controlled area. The controlled area in the direction of groundwater flow is defined in 10 CFR 63.302 as the location no further "(s)outh than 36°40'13.6661" North latitude." The NRC staff assessed DOE's calculation of radionuclide transport from the repository to the compliance location in Volume 3 of its SER (NRC, 2014a).

With respect to the commenters' claims regarding dilution to the postclosure compliance location, dilution is a natural process, the extent of which depends on the site-specific characteristics of the groundwater flow system. Dilution occurs when the groundwater carrying contaminants mixes with water flowing from other areas and thus is a mechanism that reduces concentrations of contaminants in the groundwater. At Yucca Mountain, radionuclides released from the repository would be carried downward through the unsaturated zone to meet a much larger volume of groundwater flowing horizontally in the underlying aquifer. The easterly to southeasterly flow in the aquifer below the repository converges with the much larger southerly flow in the aquifer below Fortymile Wash. Whereas the DOE models in the license application (DOE, 2008a,b) could have accounted for the characteristics of the groundwater flow system that may lead to dilution between the repository and the postclosure compliance location, DOE instead estimated the mass flux of radionuclides at the compliance location to facilitate estimation of dose, as required by NRC regulations. Dilution between the repository and compliance location is thus not considered in calculations of mass flux arriving at the postclosure compliance location. Because the regulations also include criteria for water quality, DOE calculated radionuclide concentrations in its application at the postclosure compliance location using the radionuclide mass flux and an annual water demand (e.g., water pumped from wells) of 3,000 acre-feet/year, as specified in the NRC regulations (10 CFR 63.312). The mass flux of radionuclides, which does not consider dilution effects as discussed above, is used as a source term for the calculations in the supplement.

Dilution downstream of the postclosure compliance location is similarly not calculated by characterizing the mixing of uncontaminated water with the contaminant plume, but rather is calculated in the supplement based only on the amount of discharge. The discharge at the affected environment is the pumping rate or seepage and evaporation of groundwater at the ground surface. The NRC staff conservatively assumes that the entire mass of radionuclides arriving at the affected environment is discharged with the water at each potential discharge location.

No changes were made to the supplement in response to these comments.

(095-12, 146-07)

B.2.4.1.4. ***COMMENT****: One commenter stated that there is insufficient information to evaluate impacts because the Death Valley Regional Flow System (DVRFS) model uses a grid (1.5 km by 1.5 km) that is too coarse to accurately and adequately represent transport from the repository through the system to California. The commenter further stated that (i) grid refinement is needed because the contaminant of concern (not specified by the commenter) is high risk, and its behavior should be assessed at a finer resolution; (ii) the use of average velocities for the groundwater flow paths reduces the ability of the higher velocity flow paths to move contaminants faster, such as may be observed in a more detailed model; (iii) the grid resolution could easily be refined within the existing framework without causing undue computational burdens; and (iv) the SAMM (Southern Amargosa eMbedded Model, which is expected to be completed in 2016) is an example of a model within the DVRFS with a finer grid resolution.*

RESPONSE: The NRC staff does not agree that an increased resolution of the grid of the DVRFS model would significantly change the estimates of impacts in the affected environments in the supplement.

The impacts presented in the supplement reflect the maximum estimate at each potentially affected environment. Refining the grid and potentially creating a faster flow path in the model would change the timing of the arrival of radionuclides but not change the maximum value of the mass flux of radionuclides. Therefore, the timing of the estimated maximum impact does not affect the impact conclusions in the supplement. The staff also notes that the entire plume is conservatively assumed to be captured at an affected environment (e.g., Furnace Creek springs), so preferential flow and transport similarly do not affect the impact conclusions in the supplement.

Also, the flow path from the repository to Death Valley includes some sections that are dominantly in fractured aquifers and other sections that are dominantly in granular aquifers. The commenter cited preferential flow and transport through aquifers composed of fractured rocks as an important reason to refine the DVRFS model grid. The first portion of the flow path covers flow through the fractured tuff aquifers from the repository to the compliance location where the flow path transitions into the alluvial aquifer of the Amargosa Desert. DOE's license application utilized the site-scale saturated zone flow model for this portion of the flow path. The site-scale saturated zone flow model is composed of grid cells that are significantly smaller than those of the DVRFS model and primarily reflects flow through the fault and fracture network in the volcanic tuff aquifers in the immediate vicinity of Yucca Mountain. In the supplement, the NRC staff used breakthrough curves that derive, in part, from the flow field characterized by the site-scale saturated zone flow model to transport metals from the repository to the compliance location. The NRC staff's evaluation of this approach can be found in NRC (2014a, Sections 2.2.1.3.8 and 2.2.1.3.9).

The next segment of the flow path is through the alluvial aquifers of Amargosa Desert. Fault and fracture flow is not a significant feature of the alluvial aquifers (alluvial sediments are a granular porous media). The last segment of the flow path, from eastern the Funeral Mountains to Furnace Creek springs and Middle Basin of Death Valley, is primarily through a carbonate aquifer. Fast travel times through this aquifer are reflected in the calculations in the supplement because the aquifer's low porosity is reflective of faults and fractures. Travel time is calculated

as the specific discharge divided by the porosity. In addition, the NRC staff assumed that the entire mass of radionuclides discharges to the ground surface at the springs of Furnace Creek for the no-pumping scenario. This is conservative in that it likely overestimates impacts at Furnace Creek, especially if preferential flow and transport are incorporated into the model, because some preferential pathways would bypass the springs.

The NRC staff is aware of the ongoing U.S. Geological Survey projects assessing flow patterns in the southern portion of Amargosa Desert. One of these, the Southern Amargosa eMbedded Model (USGS, 2016a) would use a refined grid and would be linked to the DVRFS model. The other project, Lower Amargosa Valley (USGS, 2016b), focuses on source areas for water contributing to flow in the Lower Amargosa River, specifically in the section south of Alkali Flat that includes Tecopa and Shoshone. These two projects have not yet been completed. The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement in response to this comment.

(124)

B.2.4.1.5. ***COMMENT****: Two commenters mentioned the potential for contamination of water flowing in the Amargosa River during floods or future wetter climates. One commenter described instances of rain followed by areal flooding and expressed concern about the potential for groundwater to contaminate surface water during floods. Another commenter noted that the draft supplement describes portions of the Amargosa River channel becoming perennial streams during future wetter climates and suggested that the supplement should consider how the greater volume of water at receptor locations would affect impacts. The commenter indicated that the greater water volume makes the assumption of 100 percent capture of contaminants too conservative for any one location.*

RESPONSE: For analyses in the supplement under present-day climatic conditions, the NRC staff considers areas where groundwater discharges to the ground surface and is the sole source of water during much of each year. These areas include the Furnace Creek springs and Middle Basin in Death Valley. The groundwater discharging in these affected environments may mix with the transient, short-lived, surface water flow during flooding events, which as discussed below, would dilute the concentration of contaminants and reduce estimated impacts.

For analyses in the supplement under future wetter climatic conditions, the NRC staff also considers discharge of groundwater to the ground surface at these Death Valley locations, as well as at the State Line Deposits area between the Amargosa River channel and the Amargosa Farms area. At the State Line Deposits area, some water from the past springs likely flowed into the Amargosa River channel during past wetter climates, thus contributing water to support perennial flow in the channel. Geologic evidence for hydrologic conditions in the past indicates that several sections of the Amargosa River were perennially flowing during past wetter climatic conditions, but do not support perennial flow over the entire length of the Amargosa River (Paces and Whelan, 2012).

In either of these climatic states, transient, short-term flood events or perennial flow in sections of the river channel, groundwater containing radionuclides that discharge into a flowing river

would be substantially diluted. One commenter recommended that this dilution be considered in the supplement because it would significantly reduce the estimate of impacts. The NRC staff conservatively chose not to consider this dilution. Instead, the supplement assumes that the entire mass flux of radionuclides was made available to the exposure pathway directly linked to the undiluted groundwater discharge location.

Additionally, the NRC staff interprets one commenter's description of a location where groundwater is discharging to a flowing river as being the Middle Amargosa River section that includes Tecopa and Shoshone. As discussed in the supplement in Section 2.2.2, the flow and transport models indicate that radionuclides from Yucca Mountain are not likely to reach the alluvial groundwater system below the channel of this section of the Amargosa River.

No changes were made to the supplement as a result of these comments.

(138, 149-12)

B.2.4.1.6. ***COMMENT****: A commenter stated that the draft supplement failed to consider how the temporary storage of hazardous materials and radioactive waste at surface facilities could result in contamination of the Amargosa River in the event of a flood. This commenter indicated that a mitigation or remediation plan would be needed prior to the active preclosure phase to protect the public health.*

RESPONSE: The NRC staff acknowledges the concerns expressed by the commenter about potential contamination of surface waters in the event of a flood during the preclosure operations phase at Yucca Mountain. This comment is outside the scope of the supplement, which concerns the potential impacts to groundwater and on surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

DOE considered potential flooding events during operations and plans for mitigating flood control structures in its Safety Analysis Report (DOE, 2008b, Section 1.6.3.4.9). The NRC staff review of this analysis is given in its SER (NRC, 2015a; Chapter 3, Section 3.2.1.1.3).

No changes were made to the supplement as a result of these comments.

(124)

B.2.4.1.7. ***COMMENT****: Several commenters suggested that Yucca Mountain was either permanently closed because it failed applicable requirements, or it failed specifications due to water flow through the mountain and the potential for ground and surface water contamination. Commenters expressed concerns about standards having been changed because Yucca Mountain did not meet initially established requirements. One commenter provided citations to two articles on changed standards. Another commenter wondered how drip shields would help in the event of a flood in the repository.*

RESPONSE: The NRC staff acknowledges commenters' concerns about the standards and regulatory requirements applicable to the proposed repository at Yucca Mountain. These comments are outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the

postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

The status of the Yucca Mountain project is described in Section 1.1 of the supplement. In 2010, the Secretary of Energy indicated that the Administration no longer intended to pursue a repository at Yucca Mountain. In 2011, Congress reduced funding for the NRC's review, which led to an orderly closure of the NRC staff's review of the license application and suspension of the adjudicatory proceeding. In August 2013, the U.S. Court of Appeals for the District of Columbia Circuit issued a decision directing the NRC to resume the licensing process for DOE's license application using funds previously appropriated from the Nuclear Waste Fund. The NRC staff completed the SER in 2015 (NRC, 2010; 2014a,b; 2015a,b).

The requirements that the NRC staff used for its evaluation in the SER are contained in the NRC regulation for Yucca Mountain (10 CFR 63), which are required to be consistent with EPA's standards for Yucca Mountain (40 CFR 197).

One commenter also referred to the use of man-made radioisotopes as tracers of water flow into the mountain, and that such information led to changes in standards for water entering the mountain. The NRC staff disagrees that the observations of radioisotopic tracers in the unsaturated zone at Yucca Mountain led to changes in criteria. Rather, DOE included the information from tracer studies in its safety analysis and indicated that they were consistent with its estimates and models of unsaturated flow and transport (DOE, 2008b, Section 2.3.2). The NRC staff review of this analysis is given in its SER (NRC, 2014a, Section 2.2.1.3.6)

Another commenter also expressed concern with the ability of titanium drip shields to protect waste packages during flooding events in the drifts. In DOE's design, the drip shields serve to divert water dripping from above away from the waste packages. DOE's analysis considered flooding of the drifts as a very low probability event that could be excluded (SNL, 2008b) from the postclosure safety performance assessment consistent with the regulations in 10 CFR Part 63. The NRC staff's evaluation can be found in its SER (NRC, 2014a, Section 2.2.1.2.1.3.2).

The preparation of this supplement is only one of several steps in the NRC's licensing process for the proposed repository. The completion of licensing activities is subject to Congressional appropriations and other actions external to the NRC.

No changes were made to the supplement in response to these comments.

(072, 086, 095-01, 095-04)

B.2.4.1.8. ***COMMENT****: One commenter stated that Clark County is searching for additional water supply in surrounding rural areas, and that groundwater impacts from the proposed repository would, therefore, impact the Clark County water supply.*

RESPONSE: Southern Nevada Water Authority's (SNWA) future plans include groundwater pumped from basins in Clark, Lincoln, White Pine, and northern Nye County, as summarized in SNWA (2015), which is described in more detail in Section B.2.4.1.11. Groundwater withdrawals and inter-basin water transfers from rural areas in eastern Nevada to Clark County were one part of SNWA's plans to address estimated future water demands in Las Vegas. As evaluated in Chapter 3 of the supplement, impacts from the proposed repository are identified in

Nye County at Amargosa Farms and the State Line Deposits/Franklin Well area, and in Inyo County at the Furnace Creek springs and Middle Basin of Death Valley. No impacts were identified in the areas listed in SNWA's plans (2015) (i.e., Clark, Lincoln, and White Pine counties, or northern Nye County).

The groundwater flow and transport pathway from Yucca Mountain is described in Chapter 2 of the supplement. As noted in Section B.2.3.2.2, the regional groundwater flow is southwesterly (Belcher and Sweetkind, 2010). Groundwater from Yucca Mountain is not projected to flow eastward or northeastward to Clark, Lincoln, White Pine, or northern Nye County. Section 2.2.2 and Figure 2-3 in the supplement describe the general direction of flow from Yucca Mountain as being southward along Fortymile Wash and across Amargosa Desert to the eastern end of the Funeral Mountains, and then southwesterly into Death Valley; this flow does not intersect any current or planned SNWA projects.

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement in response to these comments.

(147-14)

B.2.4.1.9. ***COMMENT****: Several commenters expressed concern about the siting of the repository in the unsaturated zone or about the supplement's description of flow through the unsaturated zone to the water table. One commenter referred to the criteria of 1,500 feet of overburden and 1,500 feet of underburden to the water table as providing protection above and below the repository. Another stated that the repository at Yucca Mountain is the only one in the world proposed to be built overlying a water table. Two commenters expressed concerns about the potential for fast-flowing water through the unsaturated zone or the potential for the upward flow of hot fluids towards the repository. A commenter requested a better description of how the radionuclide waste would reach groundwater*.

RESPONSE: The NRC staff acknowledges the comments on the siting of a repository in the unsaturated zone, and the importance of flow and transport in unsaturated zone at Yucca Mountain for estimating the source term used to calculate potential impacts to the affected environment in the supplement. Comments pertaining to the description or capability of the unsaturated zone to isolate waste and the potential release of contaminants from the repository, however, are outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

The commenter is correct that, in contrast to the proposed repository at Yucca Mountain, some deep geologic repositories for high-level radioactive waste in other countries are proposed to be in the saturated zone below the water table. The NRC staff notes that countries that are presently investigating deep geologic disposal focus on the geologic conditions existing within their borders, and few countries other than the U.S. have extensive regions with a deep (thick) unsaturated zone.

DOE analyzed in detail the flow and transport characteristics in the unsaturated zone at Yucca Mountain in its Safety Analysis Report (DOE, 2008b, Sections 2.3.2 and 2.3.8). DOE also analyzed the chemistry of water reaching the drifts and contacting waste packages in its SAR (DOE, 2008b, Section 2.3.5). In addition, DOE considered the likelihood of upwelling fluids flooding the repository drifts (SNL, 2008b, FEP 1.2.06.00.OA). The NRC staff review of these analyses is given in its SER (NRC, 2014a, Chapters 6, 9, 10, Sections 2.2.1.3.3, 2.2.1.3.6, 2.2.1.3.7).

No changes were made to the supplement in response to these comments.

(020, 041, 086, 095-01, 147-06, 147-25)

B.2.4.1.10. ***COMMENT****: Several commenters stated that water is a precious and scarce resource that must be protected from contamination. Several commenters stated that the risk of contamination is unacceptable, and one commenter suggested that the water is being poisoned. Several of the commenters voiced concerns about the importance of groundwater in the arid area surrounding Yucca Mountain. One commenter stated the need to maintain the purity of water for its healing properties.*

Several commenters stated concerns about contamination from the repository, while others pointed to existing contamination from the Nevada National Security Site and damage from geothermal fields that have already impacted resources and affected public health. Commenters stated that aquifers that would be contaminated by the project are irreplaceable, some with the same water in them for 100,000 years. Two commenters mentioned the interconnectedness of groundwater throughout the region and stated that contaminants migrate from one area to another. One commenter stated that the water had to be protected for visitors, for people who reside in the area, and for future generations. One commenter questioned the credibility of the supplement, considering the importance of water for drinking and other groundwater issues.

RESPONSE: The NRC staff agrees that water is a precious and scarce resource in the region and should be protected for use by local populations and visitors and for ecological, agricultural, and other purposes. The NRC staff notes that many designed and natural features of the repository would act to contain, reduce, and delay the release of waste emplaced in the repository, and the NRC staff's review of these aspects is documented in Volumes 2 and 3 of its SER (NRC, 2014a, 2015a).

Groundwater flow and transport of radionuclides and metals from the repository beyond the postclosure compliance location is assessed in the supplement. Many studies have been completed over the past decades to help understand the patterns and flow rates of groundwater flow in the Death Valley Region (Belcher et al., 2010, and references contained therein). The groundwater in the region is interconnected, although the connection between different groundwater basins may be weak, indirect, or strong. Based on its knowledge of the groundwater flow patterns and characteristics, the NRC staff estimated the direction and extent of metal and radioactive contamination that could transport downstream beyond the postclosure compliance location to affected environments at discharge locations, such as areas of groundwater pumping or natural springs. The NRC staff's determination in the supplement of small impacts in the affected environment is based on a comparison of estimated metal and radionuclide concentration and dose with natural background levels and exposures, soil and water standards, and other relevant criteria. The NRC staff used many conservative

assumptions in its calculation of impacts in the supplement; several of the more prominent conservative assumptions are discussed in Appendix A, Section A.3. These conservative assumptions provide the NRC staff with confidence that the impacts to the affected environments would be small and likely less than the values estimated.

The NRC staff agrees that groundwater has been contaminated at the Nevada National Security Site (NNSS; formerly, the Nevada Test Site), and that it may potentially reach the affected environments associated with a repository at Yucca Mountain. The NRC staff considered cumulative impacts in Chapter 4 of the supplement and found them to be small when considering sources from the repository and other areas, including those potentially from the NNSS groundwater contamination and other sources.

No changes were made to the supplement as a result of these comments.

(036, 070, 077, 095-02, 095-11, 095-12, 115, 146-18, 147-16, 147-18, 147-20, 147-27, 149-09, 149-13)

B.2.4.1.11. ***COMMENT****: One commenter pointed to a lack of analysis of groundwater pumping upgradient of Yucca Mountain, which the comment stated may reduce the potentiometric levels in the carbonate aquifer water in the Yucca Mountain area. The commenter pointed out that groundwater pumping in basins to the east and northeast of Yucca Mountain could reverse vertical gradients between the carbonate aquifer and the overlying aquifers below Yucca Mountain, and possibly draw contaminants down into the carbonate aquifer, resulting in faster transport to Death Valley. The commenter also stated that the draft supplement did not consider the Nevada State Engineer's ruling in 2005 on the SNWA's right to pump from the lower carbonate aquifer in two hydrographic basins east of Yucca Mountain (the Tikapoo and Three Lakes Valley basins). The commenter also noted that the Las Vegas Water Authority's 1989 application also included two other basins northeast of Yucca Mountain, two parts of the Railroad Valley. The commenter also suggested that the USGS 2014 model be used for modeling potential changes to groundwater conditions in the Yucca Mountain region caused by water withdrawal from basins to the east and northeast of Yucca Mountain.*

RESPONSE: The NRC staff acknowledges the importance to repository performance of maintaining the vertical gradient from the carbonate aquifer to the overlying volcanic aquifers beneath Yucca Mountain. However, these comments are outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a). Transport of radionuclides from the repository to the postclosure compliance location, as part of the performance assessment analyses of the repository, is described in Sections 2.3.8 and 2.3.9 in DOE (2008b) and reviewed by NRC staff in the SER (2014a, Chapters 10 and 12).

In the supplement, the NRC staff considered the effect on the groundwater and surface discharge areas beyond postclosure the compliance location caused by Nevada State Engineer permitted groundwater withdrawals in valleys to the east and northeast of Amargosa Desert. These impacts are discussed in Section 2.4 of the supplement. The NRC staff also notes that for its analysis, that the State of Nevada Engineer's order to maintain water levels at Devils Hole

is assumed to remain in force. Any pumping to the east and northeast of Yucca Mountain that would affect groundwater conditions in Amargosa Farms and south would also affect groundwater levels at Devils Hole, which are the subject of a State of Nevada Engineer order (Taylor, 2008).

The SNWA's future plans include groundwater pumped from basins in Clark, Lincoln, White Pine, and northern Nye County, as summarized in SNWA (2015). The groundwater withdrawals from rural areas in eastern Nevada and inter-basin water transfers were one part of SNWA's plans to address estimated future water demands in Las Vegas. For the applications submitted in 1989, Nevada State Engineer rulings led to permits being granted for groundwater withdrawals and transfers from six basins. Two of the basins are near Las Vegas (Garnet and Hidden Valleys). Groundwater withdrawals from the aquifer in these basins are unlikely to affect the groundwater levels or vertical gradients beneath Yucca Mountain or along the flow pathway to Death Valley due to the significant distance, regional groundwater flow direction to the southwest, and relatively weak hydrologic connections perpendicular to that regional flow direction (Brooks et al., 2014). The other four basins with granted permits for a total of 10,600 ac-ft/yr, are Tikapoo[2] Valley (north and south) and Three Lakes Valley (north and south). These two valleys are closer to the Yucca Mountain site than Garnet and Hidden Valleys and are in Clark and Lincoln Counties, approximately 75 miles northeast and east of Ash Meadows. Section 2.4 of the supplement describes modeling results from SNL (2009; comparison of Cases 4 and 5) that showed an insignificant effect on groundwater levels and on the vertical gradient in the Yucca Mountain or the Amargosa Farms areas caused by groundwater withdrawals from the Tikapoo and Three Lakes Valleys. The NRC staff considered the water rights permits granted by the Nevada State Engineer as representing reasonably foreseeable future actions, and, thus, included the potential effect of these groundwater withdrawals in its analysis.

The commenter provided a report (Zdon and Associates, 2015) that included analysis of the effect of groundwater withdrawal at Railroad Valley on the vertical gradients in the saturated zone below Yucca Mountain. This analysis used a U.S. Geological Survey regional model (Brooks et al., 2014) in steady state (i.e., pumping for a million years) mode with a groundwater withdrawal rate derived from the 1989 applications for Railroad Valley. Under these conditions, large drawdowns were predicted to occur across the entire NNSS and extending to Yucca Mountain and Ash Meadows. The authors acknowledge the limitations of the model, particularly because of large simulated drawdowns {>610m [2000 ft]} for the steady-state pumping case, but maintains that the concept warrants further analysis in the supplement. The NRC staff, however, considers the Railroad Valley (north and south parts) groundwater withdrawal plan speculative and not reasonably foreseeable, because (i) the 1989 applications have lapsed and must be resubmitted (SCN, 2010); (ii) if the applications are resubmitted, a Nevada State Engineer's ruling is needed for a permit to be granted; (iii) the amount of groundwater withdrawal in the application may change from the 1989 application; and (iv) SNWA has not advanced the application, and states that they intend to pursue the Railroad Valley development "when needed to supply future demands" (SNWA, 2015). Therefore, analysis of the effects of potential withdrawals from Railroad Valley is not included in the supplement.

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[2]Also referred to as Tikaboo Valley

For the group of Delamar, Dry Lake, Cave, and Spring Valleys in eastern Nevada, SNWA resubmitted applications in 2011 for these water rights, and the BLM completed an environmental impact statement (BLM, 2012c) analyzing impacts of the groundwater withdrawal and inter-basin water transfer project. The Nevada State Engineer ruled on the applications in 2012, but ongoing litigation has delayed issuance of the permits (SNWA, 2015). Modeling results of groundwater withdrawals in the BLM EIS (BLM, 2012c) indicate that these proposed withdrawals would not cause significant impacts to the groundwater system at Ash Meadows, Amargosa Valley, or beneath Yucca Mountain. This inter-basin transfer water project is also discussed in Section B.2.5.7.

With regard to the model recommended by the commenter, the NRC staff is aware of the recent and ongoing development of the U.S. Geological Survey (USGS) regional flow model (Brooks et al., 2014). This model covers the Great Basin carbonate and alluvial aquifer system extending from California to Idaho, including large portions of Nevada and Utah.

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

The NRC staff revised the discussion in Section 2.4 (subsection titled Effects of Pumping on Groundwater Conditions) in response to these comments. The discussion pertaining to the impacts of the planned Southern Nevada Water Authority groundwater withdrawals in eastern Nevada now specifically refers to the Tikapoo and Three Lakes Valleys.

(142)

B.2.4.1.12. ***COMMENT****: Several commenters stated that groundwater would be contaminated because the repository would be incapable of isolating the waste. Many of those commenters stated that there would be significant releases over the course of one million years, stating that significant impacts would occur over a broad region downstream and affect existing and potential new water users in Amargosa Valley, the Ash Meadows National Wildlife Refuge, and Death Valley. Other commenters stated that the draft supplement conflicts with the Blue Ribbon Commission's assessment of geologic repositories; that the NRC staff's predictions have no credibility over a one-million-year period; that water is scarce in the region; and that groundwater has already been contaminated by Nevada National Security Site operations. One commenter suggested that the probability of discharges of pollutants into the groundwater raises issues with respect to the Nevada Water Code and the Nevada Water Pollution Control Law.*

RESPONSE: The NRC staff acknowledges the concerns expressed by the commenters about potential radionuclide releases from Yucca Mountain and the magnitude of associated impacts over the course of a million years. Section B.2.2.1 of this appendix addresses commenters' concerns about the long timeframe under consideration in this supplement. Comments concerning the potential for leakage from the repository and transport of radionuclides to the compliance location are outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and from surface discharges of groundwater beyond the postclosure compliance location. The scope of the supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

Also out of scope for this supplement are comments concerning releases from the repository to the groundwater that commenters believe would violate the Nevada Water Code and the Nevada Water Pollution Control Law. This is also further discussed in Section B.2.1.2.12. DOE provided discussions in Chapter 11 of the 2002 and 2008 EISs regarding compliance with Federal and State statutes for discharge.

The NRC staff estimated in the supplement that radioactive contamination would spread downstream beyond the postclosure compliance location to affected environments at potential discharge locations, such as areas of groundwater pumping or natural springs. The NRC staff's determination of small impacts in the supplement is based on a comparison of estimated radionuclide concentration and dose with natural background levels and exposures, soil and water standards, and other recommended criteria. For example, as the estimated dose from releases from the repository (e.g., 0.21 and 1.3 mrem/yr at Amargosa Farms at 10,000 and million years, respectively) is a small fraction of the natural background radiation exposure (300 mrem/yr), the NRC staff concluded that the impact would be small. In addition, the estimated dose from repository releases is much less than the NRC dose standards for a Yucca Mountain repository in 10 CFR Part 63 {15 mrem/yr [0.15 mSv/yr] for the first 10,000 years, and 100 mrem/yr [1 mSv/yr] for one million years after permanent closure}.

The NRC staff disagrees with the comment that the supplement conflicts with the Blue Ribbon Commission (BRC, 2012) assessment of geologic repositories. The BRC was explicitly directed not to serve as a siting body, nor to evaluate Yucca Mountain or any other location as a potential site for the storage of spent nuclear fuel or disposal of high-level waste. Nor did the BRC take a position on the Administration's request to withdraw the Yucca Mountain license application. The BRC (2012) endeavored to recommend a sound waste management approach for disposal of spent nuclear fuel and other high-level nuclear wastes that "neither includes nor excludes Yucca Mountain as an option for a repository and can and should be applied regardless of what site or sites are ultimately chosen to serve as the permanent disposal facility."

The NRC staff agrees that groundwater has been contaminated at the Nevada National Security Site (NNSS; formerly, the Nevada Test Site), and that it may potentially reach the affected environments for the repository. The NRC staff considered cumulative impacts in Chapter 4 of the supplement and found these impacts to be small when considering sources from the repository and other areas, including the NNSS.

No changes were made to the supplement as a result of these comments.

(002, 003, 004, 008, 010, 011, 013, 014, 015, 022, 023, 028, 031, 039, 040, 043, 047, 048, 053, 054, 055, 057, 064, 066, 070, 071, 075, 076, 078, 079, 082, 083, 085, 092, 093, 094, 096, 101, 104, 112, 139, 146-07, 147-23, 148)

B.2.4.1.13. ***COMMENT****: Several commenters expressed concern regarding water leaking into and out of the potential repository at Yucca Mountain. One commenter stated that activities at the Nevada National Security Site are causing contamination in area groundwater, and asked whether contaminated groundwater would be decontaminated. Another comment referred to previous analyses on water flow through fractured rocks around Yucca Mountain and the relationship between the observed travel time of water through the rock and the travel times allowed for in guidelines that were eventually eliminated.*

RESPONSE: The NRC staff acknowledges the concerns expressed by the commenters about groundwater contamination and flow around the repository, both from the proposed repository and from other activities at the NNSS. These comments are outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

The NRC staff's evaluation of information on groundwater flow into and around the proposed repository is contained in Volume 3 of the staff's SER for the Yucca Mountain repository license application (NRC, 2014a, Chapters 6 and 9 through 12) and in the staff's ADR for the EISs prepared by DOE for the proposed repository. These documents are available on the NRC's Web site at http://www.nrc.gov/waste/hlw-disposal/key-documents.html.

No changes were made to the supplement as a result of these comments.

(080-03, 088, 108, 122, 147-19)

B.2.4.2 Public and Occupational Health

B.2.4.2.1. ***COMMENT****: Several commenters expressed general concerns about radiation and the health risks associated with exposure to radiation. One commenter asserted gamma radiation is not contained by structures, and that materials like rock, concrete, salt, or metal degrade with exposure to radiation. The commenter stated that future generations will be exposed to released radiation. Another noted that despite the draft supplement's conclusion that radioactive material releases from the repository would be small, there is no safe dose of radiation.*

Another commenter referenced a New York Times article from 1989 that suggested the National Academy of Sciences had stated in 1983 that because of the chemical characteristics of the water at Yucca Mountain, the waste would dissolve more easily there than at most other places. The commenter further stated that DOE scientists know that the steel waste canisters would dissolve long before the radiation hazards are gone.

RESPONSE: The dose limits for the proposed repository were set by the EPA as required by the NWPA, considering recommendations from the National Academy of Sciences and national and international standards-setting organizations, such as the International Commission on Radiological Protection (ICRP), National Council on Radiation Protection and Measurements (NCRP), and International Atomic Energy Agency (IAEA). The ICRP's and NCRP's recommendations are developed by recognized experts in the fields of radiation protection and health effects, including representatives from the NRC. In describing the final rule for 10 CFR Part 63, the NRC expressed confidence that the EPA's 0.15 mSv/yr [15 mrem/yr] limit is fully protective and that it provides an added margin of safety beyond what is necessary to ensure public health and safety (66 FR 55732). The radiation impacts identified in the supplement are also a small fraction of the average annual background radiation exposure received by the public each year in the U.S. from natural sources {3.1 mSv [310 mrem]} and all sources {6.2 mSv [620 mrem]} (NRC, 2015c).

One commenter asserted there is no safe dose of radiation. Although very small risks of health effects can be estimated from low doses of radiation, the NRC staff considers that doses within NRC limits are protective of public safety.

Section 3.1 of the supplement provides additional information about the NRC staff's bases and conservative approach for evaluating the potential health effects from exposure to low doses of radiation from the proposed repository.

A number of commenters raised concerns related to the NRC staff's use of information from DOE's TSPA, which was part of DOE's license application for the proposed repository at Yucca Mountain, as a primary input and as support for evaluating environmental impacts in this supplemental EIS. A discussion of the use of modeling in the supplement can be found in Sections 1.2.2 and 2.4, B.2.2.2, and Appendix A of the supplement.

The NRC staff's evaluation of these topics, as presented in the license application, is contained in the staff's SER for the Yucca Mountain repository license application (NRC, 2014a). Additional information on the relationship among the supplement's assumptions and approach and the TSPA can be found in Section B.2.2.2.

As stated in Section 3.1 of the supplement, the NRC staff found DOE's TSPA methodology to be acceptable as part of its safety evaluation (NRC, 2014a, Section 2.2.1.4.1). Additionally, in the ADR, the NRC staff identified only the DOE's evaluation of impacts downgradient of the postclosure compliance location as an area where supplementation is needed.

No changes were made to the supplement in response to these comments.

(025, 066, 076, 086)

B.2.4.2.2. ***COMMENT****: A commenter asked if the calculations in the draft supplement considered a catastrophic event occurring underground.*

RESPONSE: Comments concerning the potential occurrence of an underground catastrophic event are beyond the scope of this supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

As described in Appendix A of the supplement, the analytical framework used by the NRC staff extends the framework that DOE used for the analyses in its 2002 and 2008 EISs (DOE, 2008a; 2002) and license application (DOE, 2008b). In the 2008 SEIS, DOE used results from the TSPA model to estimate the source term for radionuclides and transport to the postclosure compliance location. Section B.2.2.2 further discusses the staff's use of information from the TSPA to inform the analyses in this supplement.

No changes were made to the supplement in response to this comment.

(095-08)

B.2.4.2.3. ***COMMENT****:* Several commenters expressed concerns about the representativeness of draft supplement dose calculations and, in particular, the modeled routes

of exposure to Native American peoples and other groups (i.e., exposure pathways). One commenter suggested that the draft supplement does not explain risks using a culturally appropriate context, inappropriately applies the "reasonably maximally exposed individual" (RMEI) modeling concept to Native Americans, and does not assess the cumulative risk to Native Americans living in the community. Other commenters stated that the environmental radiation protection standards for Yucca Mountain are not protective of the Newe Sogobia, and that their exposure would be significantly higher because of lifestyle differences, including religious practices, tribal laws, customs, and traditions. Another commenter suggested the public health impacts that could affect the Timbisha Shoshone people were not fully examined in the supplement, as required by NEPA, because the NRC staff had not evaluated the ingestion of crops, animal products, and fish as pathways for exposure in the Furnace Creek area (citing page 3-37 of the draft supplement). Another commenter noted that the traditional lifestyle of the Western Shoshone Indians has been in practice for thousands of years in the Yucca Mountain region, and includes hunting and gathering and the use of spring water for drinking. The commenter stated that this drinking water is being threatened by the proposed repository and disagreed with the 11-mile downgradient compliance location.

Another commenter stated that the public health impact conclusions in Chapter 5 of the draft supplement do not account for potential exposures (and protective protocols) to archaeologists, material culture experts, material scientists, conservators, and traditional artisans who extract materials from affected discharge areas. The commenter stated that these potential health consequences should be included in estimates of potential health impacts and further explored through tribal and public consultation. Another commenter wanted to know if the milk ingestion pathway is addressed in the dose calculations in the draft supplement.

RESPONSE: The public health impact analyses in the supplement broadly apply to any individuals in the region, including Native Americans. The NRC staff's analyses included several conservative assumptions, including regarding the use of groundwater for agricultural and domestic use, use of stream water for drinking, fishing, and exposure to the ground surface (Sections 3.1 and 3.4 and Appendix A, Section A.2.3). Additionally, the supplement evaluates environmental justice impacts and cumulative environmental justice impacts to the Timbisha Shoshone Tribe community in the Furnace Creek area in Sections 3.4.2 and 4.5.2.3.

Additional information about the NRC's radiation safety regulations can be found in Section B.2.4.2.1. Comments about the appropriateness and protectiveness of the NRC's regulations, the postclosure compliance location, and any other aspects of Yucca Mountain standards are beyond the scope of this analysis.

No changes were made to the supplement in response to these comments.

(024, 043, 046, 060, 080-16, 131, 136, 147-10, 148)

B.2.4.2.4. ***COMMENT****:* A few commenters expressed concerns about the description of dose results in the draft supplement. One commenter (citing page 3-14, lines 4-8, and page 3-20, lines 12-14) stated the impacts to the public are small and insignificant and requested the NRC compare the results to background radiation. The commenter also cited page 3-25, lines 31-36 and requested that the NRC report the peak dose, noting that the supplement text indicates the peak dose is lower than the regulatory standard, while Table 3-11 indicates the peak dose is less than 1 mrem/yr. Another commenter expressed the view that an independent review of the modeling in the draft supplement (Bredehoeft and King, 2015) determined the

radionuclide transport and dose modeling results in the draft supplement for the Death Valley Furnace Creek and lower section of Amargosa Valley areas are small and within EPA health standards.

RESPONSE: The information the commenters requested concerning calculated dose results in the context of background radiation is included in the supplement. Specifically, the supplement compares potential dose impacts to background dose in the paragraphs preceding the results in the two sections highlighted by the commenter. Peak dose values are provided in Table 3-11, which is referenced in Section 3.1.2.2 of the supplement. The NRC staff agrees with the commenters that stated the dose results are small, insignificant, and below EPA standards.

No changes were made to the supplement in response to these comments.

(046, 142)

B.2.4.2.5. ***COMMENT****: One commenter claimed the process of radiation health risk estimation used in the draft supplement is an oversimplification and is incorrect. The commenter drew a comparison between how chemicals and radionuclides affect human health. The NRC staff interprets the comment as suggesting that the NRC assumption that health risks from exposure to low doses of radiation are correlated with dose is a misapplication of principles that only apply to chemical toxicology. The commenter suggested that only chemicals have toxic thresholds and radiation does not, and that there is no safe radiation dose. The commenter concluded that the effects of dilution during transport from the repository to downgradient locations cannot be considered as a means of reducing the radiological impacts.*

Another commenter was concerned that the radiation health risk data used in the draft supplement was based only on one or two generations of health studies rather than the thousands of generations they asserted would be needed to address long-term genetic effects on exposed populations. The comment was expressed in the context of a broader concern that data from the Fukushima accident in Japan was not being used to update Yucca Mountain calculations. The commenter suggested, for example, that new information from Fukushima about the flammability of spent fuel cladding should also be incorporated into Yucca Mountain calculations.

RESPONSE: The NRC approach to estimating health risks from radiation conservatively assumes no threshold for effects, which is consistent with the recommendations of national and international standards-setting organizations, such as the ICRP and the NCRP. The ICRP's and NCRP's recommendations are developed by recognized experts in the fields of radiation protection and health effects, including representatives from the NRC.

The radiation protection community conservatively assumes that any amount of radiation may pose some risk for causing cancer and hereditary effect, and that the risk is higher for higher radiation exposures. The linear, no-threshold, dose-response relationship is used to describe the relationship between radiation dose and the occurrence of cancer. This dose-response model suggests that any increase in dose, no matter how small, results in an incremental increase in risk. The NRC accepts the linear, no-threshold hypothesis as a conservative model for estimating radiation risk. For additional information about radiation safety and NRC regulations, see Section B.2.4.2.1.

Concerns about spent fuel cladding performance estimates based on data from the Fukushima accident is beyond the scope of this supplement, which concerns an assessment of the

potential impacts of repository releases to groundwater and surface discharges of groundwater beyond the postclosure compliance location. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement in response to these comments.

(095-02, 146-15)

B.2.4.2.6. ***COMMENT****: A few commenters noted the draft supplement does not account for increased cancer incidence. One commenter added that the Environmental Protection Agency standards would limit the site's release of radiation to levels that will cause no more than 1,000 cancer deaths over 10,000 years. Another commenter asserted the supplement was not based on current science. They cited a study that they claimed showed an association between long-term low-dose radiation exposure and leukemia mortality and asserted the conclusions in the supplement that the low calculated doses result in a negligible increase in cancer risk was incorrect and misleading.*

RESPONSE: As noted in the supplement, the calculated annual doses are very low, consistent with the limits in 10 CFR Part 63, and are protective of human health and the environment. The summary of impacts in Chapter 5 of the supplement provides that the NRC staff expects that the estimated radiation dose from the proposed repository would contribute only a negligible increase in the risk of cancer or severe hereditary effects to the potentially exposed population. Additional information about the NRC's radiation protection standards and the scientific bases for evaluating health risks from exposure to radiation can be found in Section B.2.4.2.1.

No changes to the supplement were made in response to this comment.

(046, 086)

B.2.4.2.7. ***COMMENT****: A commenter cited newspaper articles describing previous studies that proposed alternative hypotheses of long-term repository performance resulting in large releases of radioactive materials. This included a 1995 hypothesis by a Los Alamos National Laboratory physicist that suggested wastes might erupt in a nuclear explosion. The commenter also referred to Charles Bowman and Francesco Venneri, who suggested failure of waste containers in the future will cause plutonium to disperse into surrounding rock. Additionally, the commenter mentioned former DOE geologist Jerry Szymanski, who suggested that catastrophic events are possible that would be greater than Chernobyl.*

RESPONSE: Long-term repository performance is beyond the scope of this supplement, which concerns an assessment of the potential impacts of repository releases to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

Additional information documenting the NRC staff's review of the DOE's TSPA, including the potential for disruptive events, is provided in the staff's SER (NRC, 2014a,b; 2015a,c).
No changes were made to the supplement in response to this comment.

(086)

B.2.4.2.8. ***COMMENT****: A commenter suggested the magnitude of the repository inventory of nonradiological constituents presents a potential health risk that should be investigated further. The commenter asserted the DOE groundwater analysis (DOE, 2009a) of nonradiological constituents that is referenced in the draft supplement contains errors. The commenter referred to Figure 1 of that report, which depicts the daily intakes of nonradiological contaminants at the Armargosa Farms area for the present climate. Describing chromium as a potent carcinogen, the commenter requested a basis for excluding chromium and vanadium from the daily intake calculations. The commenter stated that about 43,300 tons of chromium would be disposed of in the repository (citing the 2002 DOE EIS) and added that no data were provided for the area near the repository. The commenter also wanted to know whether the sorption of zeolite assumed in the calculations followed the order in which light elements replace heavy elements. The commenter also suggested the cited DOE report lacks credible evidence to support the DOE and NRC draft supplement conclusions that the impact of nonradiological elements on the human and groundwater environment would be minimal.*

RESPONSE: The NRC staff disagrees with the commenter that its chromium and vanadium analyses need to be revised or corrected. In Appendix A of the draft supplement, the NRC staff summarizes the NRC staff's basis for excluding chromium from the analysis. In the 2002 EIS, the chemicals of concern resulting from the DOE screening analysis were chromium (Cr), molybdenum (Mo), nickel (Ni), and vanadium (V). In the 2008 EIS, DOE screened out Cr on the basis that the expected predominant form would be Cr (III) (chromium in a valance state of +3) in the repository environment, which is nontoxic to humans and relatively insoluble; that is, significant levels would not be dissolved in water, and thus would not migrate into the groundwater. DOE found that the more toxic form, Cr (VI), would not form by corrosion of the waste package material (Alloy 22) or stainless steel under repository conditions (2008 EIS, Section F-5.1). If Cr (VI) forms from such corrosion in the repository, the DOE screening analysis in the 2008 EIS found that Cr (VI) is efficiently and quickly reduced to Cr (III) (Eary and Rai, 1989; Palmer and Puls, 1994) in the expected repository environment. The NRC staff, in its safety evaluation, found the DOE description of the repository chemical environment to be acceptable (NRC, 2014a; Section 2.2.1.3.3).

Regarding the commenter's question about how sorption was evaluated in the DOE's transport modeling, the DOE report (DOE, 2014) describes the technical bases for selection of distribution coefficients for radiological and nonradiological constituents, and uses distribution coefficients that reasonably represent radiological and nonradiological constituent retention on the composite material of the aquifer matrix. Additional information can be found in DOE, 2014 and in the supplement description of the transport model in Appendix A, Section A.1.2.

Potential impacts of nonradiological releases in the immediate vicinity of the repository is beyond the scope of the supplement, which concerns an assessment of the potential impacts of repository releases to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site.

No changes were made to the supplement in response to these comments.

(116)

B.2.4.2.9. ***COMMENT****: A commenter recommended the NRC provide carcinogenic risk coefficients for the receptors evaluated in the draft supplement based on EPA Federal Guidance Report No. 13 (EPA, 1999d), noting that the Interagency Steering Committee on Radiation Standards recommends the use of these radionuclide-specific risk coefficients.*

RESPONSE: The NRC staff's risk estimates in Sections 3.1, 3.5, and Chapter 5 of the supplement are based on the conversion factor for members of the public recommended by the International Committee on Radiological Protection (ICRP, 2007) that estimates the probability of a latent cancer fatality, nonfatal cancer, or severe hereditary effects from a 1.0 mrem/yr [0.01 mSv/yr] dose as 5.7×10^{-7}, or less than one in one million. Although the NRC staff considers both sources of risk factors appropriate, the health risk from the low mrem-level radiation dose calculated in the supplement is negligible for either reference.

No changes were made to the supplement in response to the comment.

(137)

B.2.4.2.10. ***COMMENT****: A commenter suggested that age and sex differences be addressed in radiation dosimetry because girls and women are between seven and two times more vulnerable than the standard man model used by Federal agencies to calculate radiation dose. The commenter suggested that the appropriate level of protection is subject to reevaluation and change.*

RESPONSE: While the NRC staff agrees that different individuals may have different radiosensitivity, the NRC's radiation protection standards for Yucca Mountain in 10 CFR Part 63 and 10 CFR Part 20 are protective of public health and include significant conservatism. This issue was addressed in detail in the development of the NRC standards for YM (66 FR 55732). Additional information about NRC radiation protection programs can be found in Section B.2.4.2.1.

No changes were made to the supplement in response to the comment.

(146-02)

B.2.4.3 Ecological Resources

B.2.4.3.1. ***COMMENT****: The NRC received several general comments about the diverse and unique wildlife species found in the potential surface discharge areas evaluated in the draft supplement. These commenters expressed concerns regarding radiation impacts and contaminated groundwater affecting wildlife. Other commenters expressed concern about potential impacts on the endangered pupfish at Devils Hole and Ash Meadows*.

RESPONSE: The potential radiological and chemical constituent effects on people and the environment from impacted soil, water, and ecology at discharge locations are evaluated in the supplement. The NRC staff's determination of small impacts on ecological resources in the supplement is based on a comparison of estimated chemical constituents and radionuclide concentrations and dose with natural background levels and exposures, soil and water

standards, and other applicable standards. As discussed in the supplement, the Nevada State Engineer is responsible for limiting groundwater withdrawal in the Ash Meadows area that may impact Devils Hole and the endangered Devils Hole pupfish.

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified related to ecological concerns that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities, however, is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement in response to these comments.

(025, 095-12, 147-20, 147-21, 149-12)

B.2.4.3.2. ***COMMENT****: One commenter stated that the draft supplement does not include an adequate analysis on impacts to endangered species in Ash Meadows, and suggested that NRC should determine the toxicity of the interaction between mixtures of metals and radionuclides on the pupfish at Ash Meadows.*

RESPONSE: The NRC staff acknowledges that the supplement does not evaluate potential impacts on endangered species listed under the Endangered Species Act (ESA) in the Ash Meadows area. As stated in Section 2.3.3 of the supplement (subsection titled Ash Meadows), Ash Meadows is not a discharge location for groundwater flowing from Yucca Mountain. The source of water to the springs at Ash Meadows is the regional carbonate aquifer, which is fed by recharge from the Spring Mountains, which flows from the east and northeast towards Ash Meadows. Therefore, impacts to endangered species in Ash Meadows are outside the scope of this supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified related to ecological resources that requires further supplementation of DOE's 2002 and 2008 EISs in the future, including evaluation of potential impacts to sensitive or endangered species. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement in response to these comments.

(116)

B.2.4.3.3. ***COMMENT****: Two commenters stated that the draft supplement does not include an adequate analysis or consultation for threatened and endangered species that could exist at the discharge locations, including the Amargosa Vole and least Bell's vireo. One commenter stated that NRC is required to consult with the U.S. Fish and Wildlife Service under Section 7 of the Endangered Species Act regarding potential impacts to threatened and endangered species that may be found at groundwater discharge locations evaluated in the draft supplement. The same commenter also suggested that NRC determine whether potential dose-related impacts on those species could occur at an individual, population, or community level*.

RESPONSE: The NRC staff acknowledges that the supplement does not evaluate potential impacts on specific species at discharge locations that may be listed under the Endangered Species Act (ESA). As noted in Section 4.2 of the staff's ADR, DOE stated that it is the lead agency for consulting with the U.S. Fish and Wildlife Service under Section 7 of the ESA. The NRC staff recognizes that the discharge areas assessed in this supplement are not addressed in the biological opinion reflecting DOE's prior Section 7 consultations.

The potential radiological and chemical constituent effects on people and the environment from impacted soil, water, and ecology at discharge locations are evaluated in the supplement. The NRC staff's determination of small impacts on ecological resources in the supplement is based on a comparison of estimated chemical constituents and radionuclide concentration and dose with natural background levels and exposures, soil and water standards, and other recommended criteria.

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified related to ecological resources that requires further supplementation of DOE's 2002 and 2008 EISs in the future, potentially including impacts to sensitive or endangered species. The completion of licensing activities, however, is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement in response to these comments.

*(*134, 142, 148, 149-10)

B.2.4.4 Historic and Cultural Resources

B.2.4.4.1. ***COMMENT****: The NRC received comments expressing opposition to the proposed repository at Yucca Mountain, stressing its impacts to cultural and historic resources. Several commenters stated that NRC did not adequately consider the cultural and spiritual values associated with groundwater and springs in the discharge locations and their contamination. One commenter lists impacts to living tribal lifeways; to freedom of religion and beliefs, tribal spiritual properties; to a shared sense of community; and to physical effects on medicinal plants, minerals, and water as among the potential impacts of the proposed repository. Some of the commenters stated that even perceived impacts on ground and surface water at discharge locations can affect the cultural healing properties of the water. One commenter provided examples of groundwater discharge locations that are culturally sensitive areas to the Timbisha Shoshone Tribe, and explained that those and other cultural and historic resources would be negatively impacted by the proposed repository. The same commenter suggested that additional studies are needed to comprehensively delineate the tribe's cultural and historic interests that could be impacted by the project. Another commenter stated that going forward with the project would be disrespectful to the Native American community.*

Another commenter suggested the NRC should consider potential effects from radioactive and nonradioactive materials on a variety of cultural resources in the soils that are found at either the pumping locations or water discharge locations. The commenter stated that NRC has not considered the attributes that afford a historic property its significance and integrity of location (e.g., design, setting, materials, workmanship, feeling, and association), including the perception of the Native American community that these locations are being spiritually tainted by the introduction of such materials.

RESPONSE: The NRC staff acknowledges the concerns expressed by many commenters about Native American perspectives and values associated with groundwater and springs, and potential impacts to cultural resources at discharge locations. Radiological and nonradiological effects on people and the environment from impacted soil, water, and ecological resources at discharge locations, including plants and water that could be used for cultural purposes, are evaluated in the supplement.

Section 2.3.2 of the supplement recognizes that cultural and historic resources may be located in the vicinity of discharge areas. Section 3.3 of the supplement describes DOE's activities related to tribal consultations and cultural and historic resources under the National Historic Preservation Act (NHPA) and its Native American Interaction Program. The NWPA identifies DOE as the lead agency responsible for these activities. The NRC staff also notes the commitment DOE made in its EISs to complete these activities for impacted areas within the scope of the proposed repository. The supplement also describes DOE's programmatic agreement with the Advisory Council on Historic Preservation and the Nevada State Historic Preservation Office. The NRC staff's supplement addresses groundwater discharge areas that are not addressed in DOE's EISs or in the executed programmatic agreement.

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified related to cultural resources and other Native American concerns that requires further supplementation of DOE's 2002 and 2008 EISs and the continuation of tribal consultations in the future. The completion of licensing activities, however, is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement in response to these comments.

(024, 036, 048, 060, 061, 070, 095-05, 095-11, 122, 131, 136, 146-07, 147-10, 147-20, 147-22)

B.2.4.4.2. ***COMMENT****: One commenter stated that NRC has not listened to the comments of the Native American community or addressed those concerns, including cumulative impacts. The commenter disagreed with the NRC staff's assessment of health effects from Yucca Mountain on the basis that the assumptions used in the TSPA model are flawed, and pointed out that the supplement does not consider spiritual and philosophical aspects of Native American cultural values. The commenter expressed that the Timbisha Shoshone Tribe is an affected tribe under the NWPA. The commenter further stated that the supplement does not address the major cultural, environmental, and health harm described by individual members of the Native American community that live in the affected area, including Western Shoshone and Southern Paiute people. The same commenter stated that the supplement failed to provide a map showing the groundwater discharges on Native American cultural and spiritual resources in the affected area under the no-pumping scenario. The commenter provided a copy of such a map in relation to both tribal lands and springs.*

RESPONSE: The NRC staff acknowledges the concerns expressed about radiation, the health risks associated with exposure to radiation, and the Native American perspective regarding cultural values of the groundwater and springs in the area of discharge locations. The NRC staff also acknowledges the Timbisha Shoshone's affected tribe status. The development of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified related to cultural resources and other Native American concerns that requires further supplementation of DOE's 2002 and 2008 EISs in the future. However, the completion of licensing activities is subject to appropriations and other actions external to the NRC.

Regarding the assumptions used in the TSPA model, Section B.2.2.2 of this appendix addresses comments on the TSPA model.

The NRC staff reviewed the map of tribal lands and springs that one commenter provided. In response to this comment, the NRC staff has added a new Figure 2-6 to Section 2.6 of the supplement. This figure shows the groundwater flow paths for the pumping and no-pumping scenarios, as indicated by particle tracking.

(148)

B.2.4.5 Environmental Justice

B.2.4.5.1. ***COMMENT****: Commenters stated that the potential for disproportionate impacts on minority or low-income populations from the Yucca Mountain project, especially members of the Timbisha Shoshone and Western Shoshone, is high due to current and traditional lifestyles. One commenter added that the rights and welfare of indigenous people must be respected and addressed.*

RESPONSE: The NRC staff acknowledges the commenters' concerns about the potential for disproportionate impacts on certain communities. Section 3.4.2 of the supplement assesses the potential human health and environmental effects that contaminated groundwater from the repository could have on minority and low-income populations. The staff determined that a repository at Yucca Mountain would not affect minority or low-income populations disproportionately, including impacts on historic and cultural resources.

The NRC staff recognizes that Native Americans use water for its spiritual, healing, and other qualities, and that many Native Americans believe that any impact to the water harms these qualities. Section 3.2.1.4.3 of the NRC staff's ADR notes that DOE committed to continue to work with tribes to identify mitigation measures to address tribal perspectives. The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement in response to these comments.

(002, 003, 004, 008, 013, 014, 022, 028, 031, 036, 039, 040, 047, 048, 053, 054, 055, 057, 071, 075, 076, 078, 079, 082, 083, 085, 092, 093, 094, 101, 104, 111, 112, 131, 139, 146-07)

B.2.4.5.2. ***COMMENT****: The NRC received several comments disagreeing with the NRC staff's environmental justice analysis. One commenter stated that NRC has failed to fully consult with the Timbisha Shoshone Tribe and meaningfully identify and consider the Timbisha's cultural and historic resources, which is further discussed in Sections B.2.1.2.10 and B.2.4.4. Other commenters expressed similar sentiments, stating that the NRC did not include in the supplement an adequate environmental justice consideration of the community of Tecopa, of Native American cultural and historic resources, and of the special meaning that water has for the tribes. One commenter stated that the inadequate funding, notice, and time provided to comment on the draft supplement also constitutes an environmental justice issue.*

RESPONSE: The NRC staff assessed the potential human health and environmental effects on minority and low-income populations in accordance with NRC environmental justice guidance.

The NRC staff evaluated potential impacts that may be unique to minority, low-income, and Native American communities. As the NRC staff explained in Section 3.3.5 of the supplement, the surface discharge locations considered in this supplement are outside the region of influence that DOE assessed in its EISs and in its programmatic agreement to address impacts on known cultural and historical resources and unanticipated finds under the National Historic Preservation Act. As also noted in the supplement in Section 3.3.2, consultation under the NHPA is not complete.

The NRC staff acknowledges commenters' concerns about the amount of notice commenters received before the draft supplement was published and the time provided to review the document. In March 2015, the NRC staff announced in the *Federal Register* its intent to develop the supplement. The NRC staff also provided this information via email in March to persons and organizations on the adjudicatory distribution list in the Yucca Mountain licensing proceeding, members of the Timbisha Shoshone Tribe, and other interested stakeholders. On August 13, 2015, the NRC staff advised stakeholders that the draft supplement was available for review and provided a link to the supplement on the NRC's public Web site. The NRC's public Web site also provided information about upcoming public meetings, which gave the public opportunities to provide oral comments on the supplement. The NRC staff also held a an initial, informational public meeting via a teleconference on August 26, 2015. At the August 26 meeting, the NRC staff explained how the public comment process works and responded to stakeholders' questions about the process. In response to requests from the public, the NRC staff extended the public comment period from 60 days to 91 days.

The NRC staff acknowledges commenters' concerns about the lack of financial assistance to certain stakeholders participating in the NRC's supplemental EIS process. The NWPA provides that the Secretary of DOE shall make financial assistance available through grants to the State of Nevada, affected units of local governments, and to affected Indian tribes, for the purpose of participating in the licensing process. This funding has been used by the State of Nevada, local governmental agencies, and Native Americans to fund participation in DOE's technical and environmental review process. The NRC is not granted authority under the NWPA to provide funding for such participation. For this reason, the NRC is not able to provide funding to the State of Nevada, affected tribes, or affected units of local government.

The consideration of Tecopa in the environmental justice analysis is explained in Section B.2.4.5.6.

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

The NRC staff has revised Section 3.4.2, and updated Tables 3-18 and 3-19, to reflect current census information, as well as to correct errors in the demographic data presented in the draft supplement. The revisions do not change the NRC staff conclusions in the supplement that impacts from the proposed repository would not affect minority and low-income populations disproportionately.

(060, 080-16, 121, 142, 146-03, 148)

B.2.4.5.3. ***COMMENT****: Several commenters oppose the Yucca Mountain project due to environmental justice concerns. Commenters expressed concerns that the Yucca Mountain*

project would contaminate land and water that the Native American community rely on for religious purposes. Two commenters expressed their view that DOE's process and policies of studying cultural and historic resources at Yucca Mountain is equivalent to environmental racism because, for example, the traditional Western Shoshone government of Newe Sogobia was not invited to participate. The commenters further stated that DOE ethnographic studies failed to identify the Newe, as governed by their own traditional form of tribal government. The commenters added that the Yucca Mountain project would violate the Treaty of Ruby Valley and the Proxmire Act.

RESPONSE: The NRC staff acknowledges commenters' concerns about environmental justice associated with the proposed repository. Those comments concerning the Genocide Convention Implementation Act (the Proxmire Act), the Treaty of Ruby Valley, and DOE's environmental justice policies and process are outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and from surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

The NRC staff reviewed DOE's evaluation of impact on Native Americans in Section 3.2.1.4.3 of its ADR. The NRC staff found that DOE's evaluation of those impacts was adequate. The staff's assessment concerning impacts to Native Americans and to cultural and historic properties can be found in Sections 3.3 and 3.4 of the supplement.

No changes were made to the supplement in response to these comments.

(010, 021, 024, 43, 108, 131, 147-10)

B.2.4.5.4. ***COMMENT****: One commenter suggested that because all communities in the area around the groundwater discharge locations rely upon groundwater and surface water, there is nothing unique about the Timbisha Shoshone Tribe in this respect.*

RESPONSE: The supplement considers annual groundwater withdrawal estimates and pumping rates to be part of the affected environment in Chapter 2 and assesses them in order to determine the potential effects of groundwater pumping on groundwater flow and conditions. The commenter refers to a statement in Section 2.1.1 of the supplement regarding the Timbisha Shoshone Tribe's Federal groundwater appropriation rights. This information is provided in the context of describing characteristics of population centers in Death Valley. The Timbisha Shoshone Tribe's groundwater rights are referenced in other places in the supplement in the context of establishing potential dose pathways (Section 3.1.2.2), potential effects on cultural resources (Section 2.3.2), and environmental justice communities (Section 3.4.2). The NRC staff recognizes that Native Americans use water for spiritual, healing, and other purposes. Section 3.4.2 of the supplement assesses the potential human health and environmental effects that contaminated groundwater from the repository could have on minority and low-income populations. The NRC staff determined there would be no disproportionately high and adverse human health or environmental effects, including impacts on historic and cultural resources, on any population from the uses or discharges of groundwater flowing from the repository beyond the postclosure compliance location.

No changes were made to the supplement as a result of this comment.

(046)

B.2.4.5.5. ***COMMENT****: The NRC received comments that radiological health and impacts from exposure to radiation are an environmental justice concern. The commenters expressed their views that no amount of radiation is safe and that any source of radiation represents a continuation of impacts already experienced by EJ communities as a result of nuclear weapons testing and other activities.*

RESPONSE: The NRC staff acknowledges that minority and low-income populations may have been affected disproportionately by past weapons testing. The staff also recognizes that radiological impacts should be considered in an environmental justice analysis. Section 3.4.2 of the supplement assessed the potential human health and environmental effects that contaminated groundwater from the repository could have on minority and low-income populations. In the supplement, the NRC staff determined that development of the Yucca Mountain repository would not have disproportionate effects on minority and low-income populations. In addition, in Chapter 4 of the supplement, the NRC staff considered the potential cumulative impacts of the proposed repository, when added to other reasonably foreseeable future actions, and likewise found those impacts not to disproportionately impact environmental justice communities.

The supplement concludes that the dose to members of the public would be small, and the doses calculated in the supplement are also a fraction of the average background radiation exposure received by the public each year.

The NRC staff has revised Section 3.4.2, and updated Tables 3-18 and 3-19, to reflect current census information, as well as to correct errors in the demographic data presented in the draft supplement. The revised text does not change the NRC staff conclusions in the supplement that impacts from the proposed repository would not affect minority and low-income populations disproportionately.

(024, 063, 146-12, 147-10)

B.2.4.5.6. ***COMMENT****: A commenter suggested that the NRC's environmental justice analysis does not recognize the community of Tecopa as disadvantaged. The commenter also stated that the community relies on ecotourism, which would be impacted negatively by a repository.*

RESPONSE: The NRC staff acknowledges that California designates Tecopa as a disadvantaged community, and that environmental justice planning programs of local governments include Tecopa. The NRC staff's environmental justice analysis is described in Section 3.4.2 of the supplement. The staff evaluated the potential for disproportionately high and adverse human health or environmental effects on minority and low-income populations from groundwater and surface discharges of groundwater downstream of the postclosure compliance location, consistent with NRC guidance for identifying those communities in NUREG-1748 (NRC, 2003). The NRC staff evaluated the characteristics of affected communities to determine if they might experience unique potential impacts. Tecopa, as well as other communities in Death Valley, is encompassed within the 12,217-km^2 [4,717-mi^2] Death Valley Census County Division (CCD) that the NRC staff evaluated. The Death Valley

CCD extends approximately from the southern boundary of Tecopa to Ubehebe Crater in the north, to the California/Nevada State line in the east, and Panamint Springs in the west.

The NRC staff has revised Section 3.4.2, and updated Tables 3-18 and 3-19, to reflect current census information, as well as to correct errors in the demographic data presented in the draft supplement. The revised text does not change the NRC staff conclusions in the supplement that impacts from the proposed repository would not affect minority and low-income populations disproportionately. Comments concerning tourism impacts are addressed in Section B.2.4.6.1.

(134, 149-10)

B.2.4.5.7. ***COMMENT****: A commenter expressed concern that the supplement does not consider people who are more susceptible to radiation exposures because of cultural practices or because they consume food and milk produced in the Amargosa Valley.*

RESPONSE: The NRC staff disagrees with the comment. The staff's dose calculations for members of the farming community in Amargosa Valley are based on conservative assumptions about the area and about agricultural practices, as further discussed in Section 3.1.1. For example, the radiological dose to an individual from well-pumping and irrigation at Amargosa Farms is calculated using the highest concentration of a plume within the postclosure compliance location. Appendix A of the supplement describes how the Amargosa Farms dose was calculated. The maximum dose calculated by the NRC staff is a peak annual dose of 1.3 mrem [0.013 mSv] per year. The maximum dose is only a small fraction of the background radiation dose of 300 mrem/yr [3.0 mSv/yr], which includes radon. Furthermore, the maximum dose is much less than the NRC annual dose standards for the Yucca Mountain repository published in 10 CFR Part 63. The regulatory limits are 15 mrem [0.15 mSv] for the first 10,000 years, and 100 mrem [1 mSv] from 10,000 years to one million years after permanent closure.

No changes were made to the supplement as a result of this comment.

(146-01)

B.2.4.5.8. ***COMMENT****: One commenter suggested that the minority population of Nye County, as presented in Table 3-18 of the supplement, is incorrect. The commenter did not provide a source for this information.*

RESPONSE: The NRC staff agrees that the draft supplement contained errors in the presented demographic data. The NRC staff has revised Section 3.4.2 and updated Tables 3-18 and 3-19 to reflect current census information and to correct errors in the demographic data presented in the draft supplement. The revised text does not change the NRC staff conclusions in the supplement that impacts from the proposed repository would not affect minority and low-income populations disproportionately.

(138)

B.2.4.6 Other Topics

Socioeconomics

B.2.4.6.1. ***COMMENT****: The NRC received comments about potential impacts on tourism in Las Vegas and on tourism and agriculture in Inyo County from transporting and storing spent nuclear fuel at Yucca Mountain. Commenters voiced concerns that tourism would be impacted for reasons related to security, accidents, contaminated groundwater, and public fear. One commenter stated that ecotourism in the Amargosa Valley area has increased since the decline of the mining industry. One commenter provided a reference to a 2010 socioeconomic impact study that predicted tourism and agriculture-related revenue decreases to Inyo County from the proposed Yucca Mountain high-level nuclear waste repository (Gruen Gruen & Associates, "A County at Risk: The Socio-economic Impacts of the Proposed Yucca Mountain High-level Nuclear Waste Repository," 2010). Another commenter stated that the area economy is vulnerable and can be affected by anything that affects Nevada.*

RESPONSE: The NRC staff acknowledges the concerns about potential impacts on tourism and agriculture. These comments are outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

Socioeconomic effects are addressed in the 2002 and 2008 environmental impact statements prepared by DOE. As documented in its ADR, the NRC staff determined that this portion of DOE's analysis is adequate and does not require supplementation.

No changes were made to the supplement as a result of this comment.

(034, 066, 127, 142, 147-03, 147-04, 147-18, 149-09, 149-11)

B.2.4.6.2. ***COMMENT****: One commenter stated that a lot of work remains to be done at Yucca Mountain facility and that completing the facility would provide employment for the many Nevada workers who are currently unemployed.*

RESPONSE: The NRC staff acknowledges that should the Yucca Mountain project resume, it could result in employment opportunities in the region. This comment is outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

Socioeconomic effects, including potential changes to employment from a repository at Yucca Mountain, are addressed in the 2002 and 2008 environmental impact statements prepared by DOE. As documented in its ADR, the NRC staff determined that this portion of DOE's analysis is adequate and does not require supplementation.

No changes were made to the supplement as a result of this comment.

(147-25)

General Safety Concerns

B.2.4.6.3. ***COMMENT****: Several commenters expressed concerns related to the integrity of the waste containers or their design. Some commenters cited the salinity of the Yucca Mountain environment and the oxidizing conditions of the repository as leading to enhanced corrosion. One commenter expressed concern that the proposed storage containers are not thick enough to withstand corrosion. Finally, a commenter suggested that casks on the surface could not survive an accidental or intentional aircraft crash without damage.*

RESPONSE: The NRC staff acknowledges the concerns expressed by the commenters about waste container safety, both at the proposed geologic repository operations area and in Yucca Mountain. These comments are outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and on surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

The NRC staff's evaluation of information on degradation of waste containers postclosure is contained in Volume 3 of the staff's SER for the Yucca Mountain repository license application (NRC, 2014a, Chapters 4 and 6). Information about the risks associated with aircraft crashes at the geologic repository operations area is contained in Volume 2 of the SER (NRC, 2015a, Chapter 3) and Section 3.2.1.4.4 of the NRC staff's ADR (NRC, 2008a). These documents are available on the NRC's Web site at http://www.nrc.gov/waste/hlw-disposal/key-documents.html.

No changes were made to the supplement as a result of these comments.

(080-01, 088, 095-08, 128, 147-15, 148)

B.2.4.6.4. ***COMMENT****: Commenters expressed general doubt or skepticism that the repository will be safe. While expressing their disapproval, some commenters also mentioned specific concerns about the suitability of the site and about transportation, terrorism, accidents, impacts to Native Americans, impacts to wildlife, the potential for leakage, and the long timeframes under consideration.*

RESPONSE: The NRC staff acknowledges the concerns expressed by the commenters. Comments concerning site suitability, transportation, terrorism, accidents, and the potential for leakage from the repository are outside the scope of the supplement, which concerns the potential impacts to groundwater and from surface discharges of groundwater beyond the postclosure compliance location. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a). Sections B.2.4.2, B.2.4.4, and B.2.4.5 of this appendix address comments about groundwater impacts on Native Americans, and Section B.2.4.3 addresses comments concerning wildlife. Section B.2.2.1 addresses comments about the long timeframe under consideration in this supplement.

The NRC staff's SER and ADR are available on the NRC's Web site at http://www.nrc.gov/waste/hlw-disposal/key-documents.html. In addition, the NRC's Web site at http://www.nrc.gov/waste.html provides information about various aspects of nuclear waste disposal.

No changes were made to the supplement as a result of these comments.

(008, 017, 034, 041, 044, 077, 086, 095-07, 107, 111, 146-01, 146-13, 147-06, 147-20, 148, 149-13)

B.2.4.6.5. ***COMMENT****: Several commenters expressed general concerns about the safety of the proposed Yucca Mountain repository and also expressed concerns and doubts about geologic, seismic, hydrologic, and container corrosion processes that could compromise repository safety. Other commenters expressed concerns about radionuclide releases, terrorism, and titanium drip shields. Other commenters stated that scientific studies of Yucca Mountain are flawed because of bias in favor of positive results or inadequate quality assurance. Some commenters stressed the considerable uncertainty associated with predicting the long-term behavior of the repository, referring in some cases to the Waste Isolation Pilot Plant, the accident Fukushima Dai'ichi, or Love Canal. One commenter labelled the conclusion that the potential impacts would be small "premature" because of these uncertainties.*

RESPONSE: The NRC staff acknowledges the concerns expressed by these commenters. Sections B.2.2.2, B.2.2.3, and B.2.4 of this appendix address comments on radionuclide releases from the repository. Section B.2.2.1 addresses comments on the long timeframe under consideration in this supplement. Comments regarding terrorism, drip shields, and processes in the environment that could affect repository integrity are outside the scope of the supplement, which concerns the potential impacts to groundwater and from surface discharges of groundwater beyond the postclosure compliance location. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

The NRC staff's evaluation of DOE's license application is contained in the staff's SER for the repository license application (NRC, 2010, 2014a,b, 2015a,b) and in its ADR (NRC, 2008a) for DOE's repository EISs. These documents are available on the NRC's Web site at http://www.nrc.gov/waste/hlw-disposal/key-documents.html. In addition, the NRC's Web site at http://www.nrc.gov/waste.html provides information about various aspects of nuclear waste disposal.

No changes were made to the supplement as a result of these comments.

(012, 015, 019, 045, 066, 067, 080-06, 086, 088, 090, 100, 108, 146-04, 147-03, 147-06, 149-14)

Transportation

B.2.4.6.6. ***COMMENT****: Commenters stated that the supplement should have addressed a number of issues related to the transportation of spent nuclear fuel to the proposed repository. Many commenters stated that the designation of the Great Basin Monument by President Obama in July 2015 would affect transportation routing of spent fuel to the proposed repository. The commenters requested that the analyses in the supplement be updated to consider possible changes in transportation routes. Several commenters raised concerns with the safety of spent fuel transportation, specifically whether emergency response capabilities and aging transportation infrastructure would be able to support spent fuel shipments. Other safety-related comments on transportation requested that new or updated analyses consider the impacts of spent fuel transportation accidents on Native American interests, the cumulative risks to the*

region of the transportation of radioactive materials, and the risks of transporting damaged fuel and high-burnup spent fuel to the repository. One commenter suggested the analyses be updated to reflect changes in spent fuel storage and transportation requirements. Several commenters expressed concern about the potential risk of accidents involving rail shipments of spent fuel and crude oil, and the possibility of a subsequent fire. Another commenter was concerned with the risk of accidents involving barge shipments of spent fuel and the challenges of responding to this type of accident.

Commenters suggested that the supplement should have analyzed the potential for national and local impacts from spent fuel transportation accidents and sabotage events on surface water and groundwater. One commenter objects to the use of probabilistic risk assessment methods in analyzing groundwater contamination scenarios, because these transportation risk assessments state extremely low probability rates, despite cancer risks. Another commenter noted that the entire area impacted by repository groundwater releases in Amargosa Valley and much of northern Death Valley overlaps the 50-mile region of influence for rail shipments along the Caliente and Mina rail alignments, as well as the route for truck shipments along US Highway 95. The commenter asserted that the evaluation of cumulative impacts in the draft supplement failed to consider the potential impacts of radiological releases from transportation accidents and sabotage events on surface and groundwater resources within the region of influence.

Commenters expressed concerns that the scope of the supplement is too narrow. One commenter suggested the importance of the supplement is being overlooked as it may lead to completing the DOE license application and issuing a construction authorization for the DOE facility. Two commenters noted that interstate transportation of nuclear waste warrants expanding the scope of this supplement to a national scope.

RESPONSE: The NRC staff acknowledges the concerns expressed by many commenters about the transportation of spent nuclear fuel to the proposed repository. These comments are outside the scope of the supplement, which concerns an assessment of the potential impacts of repository releases to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

Transportation impacts are addressed in DOE's 2002 and 2008 EISs (DOE, 2002; 2008). In the ADR, the staff determined that DOE considered spent fuel transportation impacts in its 2002 and 2008 EISs, in accordance with NRC regulations and applicable guidance. Moreover, the NRC staff did not identify portions of DOE's spent fuel transportation impact analyses that required supplementation. The NRC staff's ADR concluded that supplementation is necessary only to evaluate impacts to groundwater and from potential surface discharges of groundwater beyond the postclosure compliance location. The supplement examines the potential for subsurface groundwater transport of repository releases to downstream locations, which is an entirely different process than the transportation of spent fuel by truck, railcar, or barge to the proposed repository.

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement in response to these comments.

(006, 018, 019, 034, 048, 060, 069, 074, 080-05, 080-16, 084, 095-02, 095-11, 95-12, 118, 122, 123, 128, 138, 141, 146-02, 146-06, 146-13, 146-14, 147-15, 147-24, 147-25, 148)

Seismic and Volcanic Events

B.2.4.6.7. ***COMMENT****: Commenters expressed concern regarding seismic (earthquake) and/or tectonic risks in the Yucca Mountain area. Some commenters indicated that seismic studies have shown that Yucca Mountain is not a viable area in which to build a repository and provided information about local faults and earthquakes. Another commenter noted that a local Native American name for Yucca Mountain attests to its instability.*

One commenter stated that the results of peak ground motion studies applied to the Yucca Mountain area that were conducted after DOE submitted its license application to the NRC are lower than originally determined. The commenter stated that the possible impact of this on the EIS supplement results, when combined with recent determinations of smaller groundwater infiltration rates, would be a lowering of the estimated radionuclide doses from the repository. The commenter suggested that these results should be mentioned in the final supplement.

RESPONSE: The NRC staff acknowledges the concerns expressed by the commenters about seismic and tectonic events in the area of Yucca Mountain. These comments are outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

The NRC staff's evaluation of information relating to the geology and geologic hazards of the region around the repository is contained in Volume 2 of the staff's SER for the Yucca Mountain repository license application (NRC, 2015a, Chapters 1 and 3) and in the staff's ADR (NRC, 2008a) for DOE's EISs. These documents are available on the NRC's Web site at http://www.nrc.gov/waste/hlw-disposal/key-documents.html.

Preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement as a result of these comments.

(013, 080-13, 086, 088, 095-04, 127, 138)

B.2.4.6.8. ***COMMENT****: Commenters expressed concern regarding seismic (earthquake) and volcanic (igneous) risks of the Yucca Mountain area. A commenter stated that due to the volcanic and earthquake activity in the general vicinity of Yucca Mountain, disruptive events will take place but are estimated not to have severe effects. Other commenters expressed concern about the potential for damage to repository integrity or the contamination of groundwater as a result of earthquake or volcanic activity. One commenter suggested that earthquake or volcanic activity could produce an early waste package breach, and the commenter thus disagrees with*

the conclusion in the supplement that impacts to groundwater resources would be small. This commenter also expressed concern about the one million year timeframe for the analysis and questioned how the supplement could make conclusions about impacts over this length of time.

RESPONSE: The NRC staff acknowledges the concerns expressed by the commenters about seismic and volcanic events in the area of Yucca Mountain over a one-million-year period. These comments are outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

The NRC staff's evaluation of information relating to the geology, including seismicity and volcanism, of the region around the repository is contained in Volume 3 of the staff's SER for the Yucca Mountain repository license application (NRC, 2014a, Chapters 6 and 9 through 12) and in the staff's ADR for DOE's EISs (NRC, 2008a). These documents are available on the NRC's Web site at http://www.nrc.gov/waste/hlw-disposal/key-documents.html. Comments regarding the million-year timeframe are addressed in Section B.2.2.1.

No changes were made to the supplement as a result of these comments.

(019, 041, 066, 100, 128)

B.2.5 Cumulative Impacts

B.2.5.1. ***COMMENT****: Many commenters described what they believed to be past, present, or reasonably foreseeable future actions related to the NNSS (formerly the Nevada Test Site) operations that have a high potential to contribute to cumulative impacts. These actions include nuclear weapons tests, transportation and disposal of low-level radioactive waste at the NNSS, and remediation actions for the site.*

Commenters stated that atmospheric nuclear weapons tests were conducted in the vicinity of Yucca Mountain from 1951 to 1963, and that underground full-scale tests were conducted at the Nevada Test Site from 1963 to 1992. They asserted that many of these tests leaked radioactivity to the atmosphere and environment and contaminated regional groundwater. They stated that after 1992, nuclear weapons testing continued at the Nevada Test Site as subcritical experiments involving plutonium. One commenter suggested the supplement would not be complete unless it includes the environmental impacts of bomb test contamination and cited information in a report ["Focused Evaluation of Selected Remedial Alternatives for the Underground Test Area - DOE/NV465 (UC-700)"], published by the DOE Nevada Operations Office in Las Vegas, Nevada (DOE, 1997). Specifically, the commenter referred to Table 8-1 of the report, stating that ultimately the least expensive remedial alternative was selected (long-term monitoring under the "Institutional Control" alternative) until a permanent remediation solution is identified. The commenter argued that, therefore, contamination of the subsurface by at least one metric ton of plutonium-239 that is not being remediated and should cause the NRC staff to change the cumulative environmental impact conclusions in the supplement to LARGE.

Several commenters also expressed concerns that transportation and disposal of low-level radioactive waste (LLRW) at the NNSS would contribute to cumulative impacts. One commenter noted that waste from the Manhattan Project and other nuclear activities around the country has been transported to the NNSS for storage for several decades. The commenter

suggested spills and leaks have occurred at the NNSS. The commenter further noted the recent fire at the closed LLRW facility near Beatty, Nevada, has contributed to the legacy of nuclear activities in the vicinity of Yucca Mountain.

One commenter commended the NRC staff for the complete and thorough evaluation of activities that have occurred since DOE submitted its last EIS, as supplemented, in 2008.

RESPONSE: Cumulative impacts are evaluated in Chapter 4 of the NRC staff's supplement. Section 4.3 of the supplement describes the other past, present, and reasonably foreseeable future actions considered in the NRC staff's analysis of cumulative impacts. Section 4.4.1 of the supplement describes actions identified in DOE's 2002 and 2008 EISs (DOE, 2002; 2008a) and notes that DOE had considered information about contaminants in groundwater from past activities at the NNSS in its cumulative impact analysis. These past activities at the NNSS encompass the issues of concern raised by commenters, such as the impacts to groundwater from past nuclear weapons tests, disposal of LLRW, and remediation actions.

The impacts from the transportation of wastes to the NNSS are addressed in DOE's EIS for the site (DOE, 2013a). But these specific impacts, beyond their cumulative impacts, are outside the scope of the supplement (see responses to comments about Transportation and the scope of the supplement in Section B.2.4.6.6 of this Appendix)

In developing the supplement, the NRC staff identified and incorporated information about the NNSS (DOE, 2013a) that was unavailable when DOE developed its 2002 and 2008 EISs (supplement Sections 4.4.2 and 4.5). This information includes the most recent evaluations of potential impacts to groundwater from past, present, and reasonably foreseeable future actions at the NNSS, including nuclear weapons tests, disposal of LLRW, and remediation actions.

The NRC staff reviewed the DOE report on remedial action alternatives for the Underground Test Area at the Nevada Test Site (DOE, 1997) and found that remedial actions for the Underground Test Area were evaluated in DOE's NNSS EIS (DOE, 2013a), which was considered in the draft supplement.

The NRC staff does not agree that remedial actions requiring continued long-term monitoring of groundwater with institutional controls at the NNSS significantly increase the potential cumulative impacts of the proposed repository. Similar long-term caretaking approaches are in operation at other radioactively contaminated sites, including uranium mill tailings sites. Continued monitoring requires the long-term caretaker to track the movement of contaminants in groundwater over long periods and identify and mitigate potential future risks.

The conservative analyses in the supplement in Sections 4.5.1 and 4.5.2.2 provide the basis for the NRC staff's conclusion that the transport of tritium from NNSS could contribute to cumulative radiological impacts on groundwater along the flow path from the repository. However, these impacts would be negligible at the locations evaluated in the supplement because radioactive contaminants (including those potentially from other NNSS activities) will attenuate and decay as they move through the groundwater flow path from the repository. DOE considered cumulative impacts from NNSS in its 2002 EIS, and the supplement discusses this issue in Section 4.5.1. While the commenter mentions that large amount of radioisotopes, including Pu^{239}, are present below the surface of the NNSS from nuclear weapons testing, the NRC staff concludes that only a small fraction of this inventory is likely to move beyond the contaminated locations at the site (see also DOE, 2013a, Appendix H). The NRC staff also notes in

Section 4.4.2 of the supplement that DOE stated that it will continue its management of NNSS waste. The NRC staff discussion of concerns about the recent fire at the closed Beatty LLRW disposal site is in Section B.2.5.2.

The NRC staff revised Section 4.4.2 of the supplement in response to the comment. The staff's description of the scope of the NNSS EIS (DOE, 2013a) now includes DOE environmental management activities.

(002, 003, 004, 008, 013, 014, 022, 027, 028, 031, 039, 040, 047, 048, 053, 054, 055, 064, 069, 071, 075, 078, 079, 082, 083, 085, 092, 093, 094, 101, 104, 112, 138, 139, 139, 146-07)

B.2.5.2. ***COMMENT****: Commenters suggested the final supplement needs to account for the potential contribution to cumulative impacts of a fire that occurred in October 2015, at the LLRW disposal facility in Beatty, Nevada. One of the commenters further added that the draft supplement fails to provide a sufficient analysis of cumulative impacts associated with the movement of contaminants through groundwater into the Amargosa desert and Inyo County from the proposed repository in combination with contaminants from the NNSS and the Beatty low-level waste disposal site and hazardous waste facility.*

RESPONSE: The NRC staff acknowledges commenters' concerns about the fire at the LLRW disposal facility in Beatty, Nevada, on October 18, 2015. The potential impacts from the Beatty site, beyond their cumulative impacts, are outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. Additional information about the Beatty event is provided below. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

On December 30, 2015, the Nevada Department of Public Safety (NDPS), State Fire Marshal Division published an incident report (NDPS, 2015), which determined the fire was caused by settling of the waste that produced openings in the waste trench cover. The report notes that openings in the cover allowed water from a storm event to infiltrate into a disposal trench containing drums of metallic sodium. The report points out that the combination of water and metallic sodium caused an exothermic (heat-generating) chemical reaction producing hydrogen gas and heat. The heat generated by the sodium-water reaction ignited combustible metals in the immediate area, resulting in a fire that burned for several hours. The incident report concluded that no injuries to personnel occurred, that the effects of the fire were contained to the immediate site, and no radioactive materials were released due to the fire.

The joint agency investigation team led by the NDPS, State Fire Marshal Division, and including representatives from the Nevada Department of Health and Human Services, Radiation Control Program and the Nevada Department of Conservation and Natural Resources, Division of Environmental Protection, recommended the development of an interim action plan to promptly address cleanup of displaced materials and safeguard the facility against additional storm events. The team also recommended that a long-term action plan with a detailed evaluation of the existing LLRW facility and a proposal of measures to ensure long-term sustainability of the disposal facility be prepared. Interim repairs were completed prior to publication of the incident report; these include collecting displaced materials, replacing drums into the trench for burial, adding fill, and repairing the damaged portions of the cap to prevent the entry of moisture. The incident report indicates that local, State and Federal agencies are working on long-term solutions for stabilization of the site.

Section 4.5.1 of the supplement explains that DOE's cumulative impacts analysis was based on the small quantity of radionuclides at the Beatty facility in relation to the quantity that could be released by the repository. The NRC staff reviewed the NDPS's incident report and the investigation team's recommendations and finds that the NRC staff's evaluation in the supplement of the potential for cumulative impacts from the Beatty facility is not affected by the fire. This is because the analysis in the supplement is based on the small quantity of radionuclides that could be available for release over a long time frame and the attenuating effects of dispersion and radioactive decay along the long flow paths to the downgradient locations. In contrast, the fire has raised concerns about the stability of the site over a much shorter time frame than is considered in the supplement.

The supplement was modified in Section 4.5.1 to acknowledge the recent Beatty fire in response to these comments.

(142, 148)

B.2.5.3. ***COMMENT****: Two commenters expressed concerns that the cumulative impacts to Western Shoshone people from activities within the Yucca Mountain region, such as operation of the NNSS and regional LLRW disposal, were not considered in the supplement. They asserted that differences in aspects of their lifestyle, such as diet, mobility, and shelter, produce different risks for the Western Shoshone people. The commenters recommended investigation of these impacts as an early warning to protect human health.*

RESPONSE: These comments are similar to ones raised concerning the direct and indirect impact analyses in the draft supplement. Section B.2.4.2 of this appendix (Public and Occupational Health) addresses these issues. The NRC staff's cumulative impact analysis uses the same reasonable and conservative approach as the analysis of direct and indirect public health impacts in Sections 3.1.1 and 3.1.2 of the supplement to evaluate potential impacts to potentially affected communities.

No changes were made to the supplement in response to these comments.

(036, 057)

B.2.5.4. ***COMMENT****: One commenter suggested that DOE's and the NRC's cumulative impact analyses lack credible scientific data and, therefore, do not comply with the Council on Environmental Quality's regulation at 40 CFR 1508.27(b).*

RESPONSE: Section 4.1 discusses the standards with which the NRC staff's cumulative impacts analysis was developed. CEQ's regulation at 40 CFR 1508.27 defines "significantly" as involving considerations of both context and intensity. Section 1508.27(b) states that intensity refers to the severity of impact and includes (i) impacts that may be both beneficial and adverse, (ii) the degree to which the proposed action affects public health or safety, (iii) unique characteristics of the geographic area, and (iv) the degree to which the effects on the quality of the human environment are likely to be highly controversial. The NRC's NEPA guidance in NUREG-1748 (NRC, 2003) in Section 4.2.5.3 adopts these concepts for cumulative impact analysis. These concepts are incorporated in the supplement, as discussed in Section 4.1. The NRC staff's cumulative impact determinations are supported by relevant technical data and studies, including DOE's 2002 and 2008 EISs (DOE, 2002; 2008a); the DOE license application

(DOE, 2008b); the NNSS EIS (DOE, 2013a); the DOE postclosure groundwater impact analysis (DOE, 2014); and NRC's analyses of this information, including its SER, which was completed in January 2015 (NRC 2010, 2014a,b, 2015a,b).

No changes to the EIS supplement are needed to address the comment.

(116)

B.2.5.5. ***COMMENT****: Two commenters expressed concerns that the supplement should evaluate the cumulative impacts of transportation-related radiological exposure risks. One commenter asserted that the final supplement must identify DOE's proposed transportation of high-level radioactive waste as a foreseeable future action in its consideration of cumulative impacts and also account for the potential loss of the Caliente rail alignment as a route. Another commenter noted DOE's analyses of radiological impacts of transportation accidents or sabotage events in the 2008 final supplemental EIS for the repository and the EIS for the rail alignment "acknowledged that 'the region of influence was 80 km [50 mi] from the railroad or highway.'" The same commenter stated that the entire area impacted by repository groundwater releases in Amargosa Valley and much of northern Death Valley is located within this region of influence for rail shipments and for truck shipments. The commenter identified numerous surface water resources within this region of influence, noting the evaluation of cumulative impacts in the draft supplement failed to consider the potential impacts on these surface and groundwater resources from transportation accidents and sabotage events.*

RESPONSE: The NRC staff acknowledges the concerns expressed about spent fuel transportation accidents. Similar comments about transportation impacts are addressed in greater detail in Section B.2.4.6.6 of this appendix. However, these comments are outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement as a result of these comments.

(123, 148)

B.2.5.6. ***COMMENT****: One commenter stated that the evaluation of mining impacts in the draft supplement's cumulative impact analysis is not adequately supported by an analysis of future market conditions. The commenter suggests that the NRC staff ignored the potential impacts of future mining activities, described by the BLM, in its Draft Resource Management Plan, as potentially "negligible to moderate," by asserting that impacts would be addressed "through best management practices and other mitigation." The commenter stated that the supplement does not contain any meaningful analyses of future market conditions or industry practices to support its conclusion that impacts would remain low as a result of mitigation.*

RESPONSE: Section 4.4.2 of the supplement provides additional information about the potential impacts of mining in the analysis of cumulative impacts. The NRC staff's analysis considered the analyses and conclusions of the BLM Las Vegas and Pahrump Field Offices Draft Resource Management Plan/Environmental Impact Statement (BLM, 2014). In that report, the BLM describes historic, current, and future trends in mining activities in regions of southern Nevada and evaluates the potential environmental impacts. The range of impacts described by the NRC staff in the draft supplement (as negligible to moderate considering mitigation measures) are derived from its review of the information and conclusions in the BLM's Draft EIS. The NRC staff disagrees that BLM's impact conclusions highlighted by the commenter are not adequately analyzed and described in the SEIS.

No changes were made to the supplement in response to this comment.

(148)

B.2.5.7. ***COMMENT****: One commenter mentioned a Southern Nevada Water Authority plan to construct a large-capacity pipeline in Nevada's Great Basin that would extract groundwater in northern Nevada for use in southern Nevada. The commenter cited a 2009 BLM EIS (as BLM Document no: 8111 BLM NV040-09-1740B 2009, page 6-3) of the pipeline right-of-way and noted the potential for large impacts on flora and fauna from the proposed removal of groundwater. The commenter further noted that Nevada's Great Basin is located within Newe tribal lands and stated that the Southern Nevada Water Authority plan for the Great Basin would have consequences in northern Nevada that would be similar to the consequences in southern Nevada of activities at the NNSS. They added the impacts would affect the existence of the Newe Spiritual World and the Newe itself.*

RESPONSE: The NRC staff acknowledges the commenter's concerns about impacts from a major water project. However, these comments are outside the scope of this supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

The NRC staff was unable to locate the 2009 BLM document referenced by the commenter; however, the NRC staff believes the commenter is referring to the Southern Nevada Water Authority Groundwater Development Project for Clark, Lincoln, and White Pine Counties (SNWA, 2016). For this project, the Southern Nevada Water Authority proposed a buried pipeline system to convey groundwater from central and eastern Nevada to Southern Nevada to enhance the area's limited water resources. The stated purpose of the project is to reduce southern Nevada's reliance on water from the Colorado River, provide flexibility to respond to drought conditions in the river system, allow the Southern Nevada Water Authority to meet future projected water demand in Clark County, and to provide capacity for Lincoln County to convey water rights within Lincoln County.

BLM completed the final EIS for the right-of-way for this project in 2012 (BLM, 2012c). The BLM EIS evaluated the hydrographic basins within portions of Clark, Lincoln, and White Pine counties north of Las Vegas and a small portion of Nye County in the area north of Lincoln County. This region encompasses the Great Basin National Park and portions of surrounding areas. These areas are distant from the affected environment evaluated in the supplement, and

the BLM EIS indicates that these proposed withdrawals would not cause significant impacts to the groundwater system at Ash Meadows, Amargosa Valley, or beneath Yucca Mountain. This inter-basin transfer water project is also discussed in Section B.2.1.4.11.

No changes were made to the supplement in response to this comment.

(070)

B.2.5.8. ***COMMENT****: One commenter expressed concerns about how the potential for expansion of repository capacity was addressed in the cumulative impact assessment. The commenter noted that the draft supplement excludes consideration of emplacement of wastes in a Yucca Mountain repository beyond the 70,000 MTHM limit because the NWPA prohibits such emplacement until a second repository is in operation, and that the NRC staff regards a second repository as not reasonably foreseeable. The commenter noted that DOE included "detailed plans" for the expansion of repository capacity in its 2008 supplemental EIS and that this information contradicts the NRC staff's assertion that the expansion of repository capacity is speculative and not reasonably foreseeable.*

RESPONSE: Section 4.4.1 of the supplement explains that DOE's proposed action, as described in its 2002 and 2008 EISs (DOE, 2002; 2008a) and in its Safety Analysis Report (SAR) (DOE, 2008b), is the construction of a repository and emplacement of up to 70,000 metric tons of spent nuclear fuel and high-level radioactive waste. In these EIS analyses of cumulative impacts, DOE also described two future actions for the emplacement of waste beyond the 70,000-metric-ton limit. DOE referred to these scenarios as inventory modules and evaluated them as reasonably foreseeable. These inventory modules proposed for the Yucca Mountain repository would contain additional spent fuel, other high-level waste, and greater-than-class-C waste. The NRC staff does not consider the proposed inventory modules to be reasonably foreseeable future actions because (i) DOE did not evaluate the additional waste inventories in its license application; and (ii) both modules are prohibited by the NWPA until a second repository is built and in operation. The NRC staff concludes that a second repository is not reasonably foreseeable at this time because NRC has not yet licensed one repository, and a second repository is not under consideration.

No changes were made to the supplement in response to this comment.

(148)

B.2.5.9. ***COMMENT****: A commenter asked if there is a way to differentiate between the radioactive materials that could be released from the NNSS and the radioactive materials that could be released from Yucca Mountain.*

RESPONSE: Radionuclides present at the NNSS are also found in the commercial spent fuel that DOE proposes to emplace at Yucca Mountain. It may be possible to determine the origin of contaminants based on the relative abundance of different isotopes or other materials unique to each source of contaminants in a water sample; however, contaminant release and transport processes can obscure these distinctions. The current DOE environmental management program obligations described in the NNSS EIS (DOE, 2013a) include groundwater monitoring downgradient of sources of NNSS environmental radiological contamination that are upgradient of the Yucca Mountain flow path.

Sections 4.5.1 and 4.5.2.2 of the supplement explain that contamination from the NNSS has the potential to interact with Yucca Mountain flow paths. Based on the currently available information in the NNSS (DOE, 2013a), the NRC staff evaluated the potential for tritium from the NNSS to contribute to the cumulative impacts of the proposed repository. The NRC staff concludes that tritium from the NNSS would likely decay to negligible levels before arriving at Amargosa Farms and, therefore, would not contribute cumulatively to the impacts from contaminants from the repository.

No changes were made to the supplement in response to these comments.

(149-16)

B.2.6 Other Topics

B.2.6.1 Miscellaneous

B.2.6.1.1. ***COMMENT****: One comment suggested that the units for uranium concentration used in Table 3-2 in the draft supplement be made consistent with the units for uranium in the supplement text (i.e., ug/l).*

RESPONSE: The NRC staff corrected relevant text in Section 3.1.1 in response to this comment.

(137)

B.2.6.1.2. ***COMMENT****: Five commenters discussed various aspects of the Yucca Mountain project. One statement indicated that the author has no comments on the supplement. Other commenters recommended the NRC staff review certain information, including recent NRC consideration of greater-than-class-C waste. Two comments point to a movie ("Into Eternity") and a book ("About a Mountain") of which the commenter stated that NRC should be aware. Another commenter stated that there are many problems associated with the Yucca Mountain repository project and recommended that the "Engineering Tribute to the Presidential Inauguration of January 2017" offers an opportunity to discuss Yucca Mountain issues.*

RESPONSE: The NRC staff acknowledges the information provided by the commenters. These comments and references are outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

No changes were made to the supplement in response to these comments.

(80-01, 95-03, 126, 140, 146-11)

B.2.6.1.3. ***COMMENT****: Three comments addressed matters of location and population for the Amargosa Farms and Amargosa Valley area. One requested clarification of distances from the regulatory compliance point to the Amargosa Farms pumping area assumed in the supplement, and elsewhere. Other comments mention that the Amargosa area is shown as not populated on one of the maps in the draft supplement, and that this should be changed.*

RESPONSE: The NRC staff has revised Figures 2-1, 2-3, and 2-6 to show Amargosa Farms as a populated area. The staff also has revised the text in Section 3.1.1 to clarify that Amargosa Farms is not a single location, and that the distance between the postclosure compliance location and the groundwater pumping areas in Amargosa Valley of 17 km [11 mi] is based on a range of 14 to 20 km [9 to 12 mi] along the groundwater flow path.

There are residents and businesses between the primary farming areas and the postclosure compliance location. Most of the wells supplying water to these residents and businesses are close to the farming area. An isolated set of several wells is located just south of the junction of Highways 95 and 373, which is consistent with the DOE determination that that there were no permanent residents closer than 22 km [13.7 mi] from Yucca Mountain, as described in Section 2.1.1 of the supplement. Concerning the estimate of impacts for residential and business wells closer than 17 km [11 mi] to the compliance location, the NRC staff conservatively adopts the analysis in DOE's 2008 EIS for the RMEI.

Text in Section 3.1.1 was revised to clarify this distinction.

(149-01, 149-04, 149-13)

B.2.6.1.4. ***COMMENT****: Several commenters expressed opposition to the Yucca Mountain repository on the basis that ownership of the land is claimed by Native American tribes. One commenter noted that the strict standards (e.g., for land ownership) set by the NWPA are not being met. One commenter stated that the exterior boundaries of the Newe Sogobia land are defined by the 1863 Treaty of Ruby Valley, including Yucca Mountain, and the tribe does not consent to the inclusion of its lands into the jurisdiction or boundaries of the United States or any other State or territory. The commenter also stated that the tribal ownership of the land is a significant encumbrance, precluding licensing of the repository, and the tribe has informed the U.S. Government that the land is not for sale. Another commenter stated that Yucca Mountain is located on Shoshone land, and that the mountain is "swimming" west.*

RESPONSE: The NRC staff acknowledges the commenters' concerns about land ownership issues involving Native American tribes. These comments are beyond the scope of the supplement, which concerns an assessment of the potential impacts of repository releases to groundwater and from surface discharges of groundwater beyond the postclosure compliance location. The scope of the supplement is further described in the NRC staff's ADR (NRC, 2008a) in the NRC's Notice of Intent to prepare the supplement (80 FR 13029).

The NRC does not exercise statutory or regulatory authority over disputes concerning land ownership. NRC's regulations in 10 CFR 63.121 provide that lands within the geologic repository operations area must be under DOE's jurisdiction and control or be permanently withdrawn and reserved for DOE's use. The NRC staff concluded that DOE has not met the requirements in 10 CFR 63.121(a) and 10 CFR 63.121(d)(1) regarding the ownership of land and certain water rights, as discussed in Volume 4 of its SER (NRC, 2014).

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement as a result of these comments.

(012, 024, 080-01, 086, 131 147-01, 147-10)

B.2.6.1.5. ***COMMENT****: One commenter stated that NRC has failed to fulfill the Federal Government's trustee obligations to protect tribal lands and interests. The commenter states that because the proposed repository may impact lands set aside for the Timbisha (by the Timbisha Homeland Act, 16 U.S.C. § 104aa, Pub. L. 106-423, §§ 1-8, Nov. 1, 2000, 114 Stat. 1875) and because the land status of the reservation can only be changed by the Federal Government, the tribe has nowhere else to go if the land or groundwater become contaminated or rendered uninhabitable. The commenter stated that, therefore, the U.S. Government has an obligation to ensure that the Timbisha Shoshone's reservation remains livable and self-sustaining and that the tribal springs and groundwater sources remain free of radioactive contamination in perpetuity. The commenter further noted that the NRC is obligated to delay consideration or approval of the supplement until the Timbisha and the U.S. have fully analyzed the potential impacts to lands held in Trust.*

RESPONSE: The NRC staff acknowledges the concerns expressed by the commenter about potential impacts to groundwater and springs and cultural resources at discharge locations. The potential impacts to water in the Furnace Creek springs are discussed in Section 3.1.2.2 of the supplement. These springs provide water to the Timbisha Shoshone reservation in Death Valley. The potential concentrations of contaminants at this location are calculated to be very low, and the impacts on the aquifer, soil, and public health would be small.

In addition, Section 3.4.2 of the supplement assesses the potential human health and environmental effects that contaminated groundwater from the repository may have on minority and low-income populations. The staff assessment includes consideration of impacts to Native American communities. As stated in the supplement, the NRC staff determined that the proposed repository would not create disproportionate effects on minority and low-income populations.

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified related to cultural resources and other Native American concerns that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities, however, is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement as a result of these comments.

(060)

B.2.6.1.6. ***COMMENT****: One commenter stated that the Federal Government, including DOE and the NRC, needs to stop engaging in "radioactive racism." The commenter described situations in which he believes the U.S. Government unfairly treated Native American tribes with regard to Federal projects involving nuclear materials.*

RESPONSE: The NRC staff acknowledges that radiological impacts on Native American populations are an environmental justice concern. Section 3.4.2 of the supplement assesses the potential human health and environmental effects that contaminated groundwater from the repository could have on Native American communities and other minority and low-income

populations. As stated in the supplement, the staff determined that the proposed repository would not create disproportionate effects on minority and low-income populations. Section 3.2.1.4.3 of the NRC staff's ADR (NRC, 2008a) notes that DOE committed to work with tribes to identify mitigation measures to address tribal perspectives.

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified in future tribal consultations that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement as a result of this comment.

(095-12)

B.2.6.1.7. ***COMMENT****: Several commenters asserted that the siting of the Yucca Mountain repository was a political decision and they questioned the credibility of decisionmakers who designated the Yucca Mountain site. Several commenters indicated that the continued efforts to license the Yucca Mountain project are politically or financially motivated. Two commenters expressed concern that elected officials received monies from the nuclear industry and they believe the NRC is tied too closely to the nuclear industry. One commenter questioned whether government officials and scientists have been honest or given correct information about the potential effects of nuclear weapons testing and the accidents at Fukushima and Chernobyl on human health and the environment.*

RESPONSE: The NRC staff recognizes the difficulties that the U.S. has encountered in achieving political and social acceptance in siting and licensing a geologic repository. However, these comments, including those concerning national waste disposal policy, are outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

The NRC is an independent Federal agency established to ensure the safe use of radioactive materials for beneficial civilian purposes while protecting people and the environment. The NRC staff's review of the license application for the proposed repository, including the preparation of this supplement, is pursuant to the NWPA.

The NRC strives to conduct its regulatory responsibilities in an open and transparent manner, consistent with the NRC Approach to Open Government. To ensure objectivity and independence in its regulatory activities, the NRC and the U.S. Office of Government Ethics have stringent rules and procedures to ensure that employees of and advisors to the NRC are free of conflicts of interest and the appearance of conflicts of interest.

No changes were made to the supplement as a result of these comments.

(146-13, 146-18, 147-06, 147-23, 147-25, 149-14)

B.2.6.1.8. ***COMMENT****: Several commenters raised concerns about the storage of spent nuclear fuel on site at nuclear power plants, raising concerns about current storage in spent fuel*

pools and in casks. Some commenters expressed concern about storing spent fuel in pools, especially for very long timeframes, and a number of people support moving the fuel to dry storage. Several commenters support hardened on-site storage (HOSS) for spent fuel storage because they believe it would be safer than transporting fuel across the country to Yucca Mountain. Commenters also stated the need to store spent fuel in quality, tested dry casks. Two commenters opposed centralized storage facilities, with one commenter citing problems that occurred at the Waste Isolation Pilot Project. One commenter proposed several novel storage techniques that the commenter stated would improve safety.

Other commenters expressed concerns about the ability of dry casks to maintain adequate protection against leakage as a result of degradation, seismic events, or terrorist attacks. Two commenters raised questions about the use of dry storage casks that are not supplied by DOE, stating that this violates the Standard Contract Agreement for waste acceptance.

RESPONSE: The NRC staff acknowledges the commenters' concerns regarding onsite storage. However, these comments are outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

The NRC ensures that spent fuel is being stored safely in spent fuel pools and dry casks through its regulatory control and oversight of spent fuel storage. Additional information on the storage of SNF in spent fuel pools and dry casks is available on the NRC Web site at http://www.nrc.gov/waste/spent-fuel-storage.html.

No changes were made to the supplement as a result of these comments.

(035, 041, 080-06; 080-13, 080-14, 080-17, 086, 095-01, 095-04, 095-06, 095-07, 095-11, 100, 133, 134, 139, 146-09, 147-15, 149-14)

B.2.6.1.9. ***COMMENT****: One commenter suggested that information on Yucca Mountain as a nuclear waste repository and information relevant to the NRC should be topics included in the Engineering Tribute to the Presidential Inauguration of 2017. The commenter offered information about the Engineering Tribute and described ways to participate.*

RESPONSE: The NRC staff appreciates the commenter's recommendation; however, this comment is outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

No changes were made to the supplement as a result of this comment.

(080-02, 125)

B.2.6.1.10. ***COMMENT****: Two commenters stated concerns about the environmental contamination of Earth as a whole, suggesting that the problem of nuclear waste is much smaller by comparison*.

RESPONSE: The NRC staff acknowledges the comments concerning environmental contamination and degradation. The comments are general in nature, outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

No changes were made to the supplement as a result of these comments.

(147-02, 147-25)

B.2.6.1.11. ***COMMENT****: One commenter asked whether NRC and DOE should include a discussion of whether the Yucca Mountain repository would be a Superfund site under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980.*

RESPONSE: The potential for classification of Yucca Mountain as a Superfund site is outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

No changes were made to the supplement as a result of this comment.

(116)

B.2.6.1.12. ***COMMENT****: One commenter expressed concern about quality control in field work to collect data for Yucca Mountain evaluations, stating that core borings were improperly collected and labeled.*

RESPONSE: The NRC staff acknowledges the commenter's concern about the integrity of field samples. However, this comment is outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

The Yucca Mountain site and vicinity has been studied in detail for decades by private organizations, as well as local, State, and Federal agencies. The NRC implemented quality control programs during its field evaluations for Yucca Mountain. The NRC staff reviewed DOE's quality assurance programs and practices, as discussed in the NRC staff's SER. The NRC staff's evaluation of DOE's quality assurance program can be found in its SER (NRC, 2014b; Section 2.5.1).

No changes were made to the supplement as a result of this comment.

(095-02)

B.2.6.1.13. ***COMMENT****: One commenter recommended that rolling stewardship be instituted, instead of disposing of nuclear waste in a repository (i.e., abandoning the waste, which the commenter believes is unethical and unscientific). The commenter cited problems*

with cleaning up sites, the lack of certainty in mathematical models that predict performance, and historical radiological accidents at reactors and at disposal facilities as reasons for instituting rolling stewardship instead of geologic disposal.

RESPONSE: The NRC staff acknowledges the commenter's concern regarding long-term management of a geologic repository. The NRC does not establish policy for the *long-term management* of spent fuel and HLW in the U.S. This comment is outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

No changes were made to the supplement as a result of this comment.

(144)

B.2.6.1.14. ***COMMENT****: One commenter suggested that a visitors' center be established at the now decommissioned National Rocket Development Station. The commenter also suggested the showing of an educational video that illustrates the placement of spent fuel rods into canisters to demonstrate the safety of nuclear waste packaging.*

RESPONSE: The NRC staff acknowledges the commenter's concern about public education related to nuclear waste disposal. This comment is outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

More information about the storage of spent nuclear fuel can be found on the NRC's Web site at http://www.nrc.gov/waste/spent-fuel-storage.html.

No changes were made to the supplement as a result of this comment.

(147-05)

B.2.6.1.15. ***COMMENT****: Several commenters stated their concerns about the potential dangers of radiation. Some of these commenters expressed their belief that no amount of radiation is safe, with some commenters citing studies or other information. Two commenters expressed disapproval regarding the cessation of the National Academy of Sciences study evaluating the long-term cancer risks to communities near nuclear power plants, stating that funding would be well spent on continuation of this study. One commenter expressed concerns about the credibility of governing officials and about existing contamination near the Yucca Mountain site.*

RESPONSE: The NRC staff acknowledges commenters' concerns about radiation and its potential effects on human health and the environment. Concerns about the development of the NRC's radiation protection standards and the cessation of the NAS study are outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

The NRC staff agrees that groundwater has been contaminated at the NNSS (formerly the Nevada Test Site) and acknowledges commenters' concerns that it may reach the affected environments for the repository. The NRC staff considered cumulative impacts in Chapter 4 of the supplement and found these impacts to be small when considering sources from the repository and from other sources, including the NNSS.

The NRC's mission is to regulate the Nation's civilian use of radioactive materials to protect public health and safety, promote the common defense and security, and protect the environment. The NRC's regulatory standards for radiological protection are set to protect workers and the public from the harmful health effects (i.e., cancer and other biological impacts) of radiation in humans. Radiation standards reflect extensive scientific study by national and international organizations. The NRC actively participates in the work of these organizations. Additional information about the risks of radiation, including several background information sheets, can be found on the NRC's Web site at http://www.nrc.gov/about-nrc/radiation.html.

Additional information about the cessation of the National Academy of Sciences Cancer Risk Pilot study can be found at http://pbadupws.nrc.gov/docs/ML1525/ML15251A111.pdf.

No changes were made to the supplement as a result of these comments.

(080-15, 111, 120, 146-01, 147-15, 147-20, 147-23, 149-13, 149-14)

B.2.6.1.16. ***COMMENT****: Several commenters expressed different views about the siting of Yucca Mountain for a repository and about consent in the siting process. Two commenters stated that the repository should not be forced on Nevada or its residents, and one commenter called for an alternate location. One commenter stated that creating a new Federal authority to determine the feasibility of nuclear waste disposal in southern Nevada may facilitate gaining Nevada's consent. One commenter stated that Nevada politicians had previously provided their consent, but then withdrew it based on political and financial motivations. Another commenter suggested that the lack of consent has hindered the development of Yucca Mountain, but that a lack of consent and other difficulties may likewise arise for another site that may be identified. Several commenters voiced support for consent-based siting as recommended by the Blue Ribbon Commission on America's Nuclear Future. One commenter questioned the feasibility of consent-based siting, stating that the Blue Ribbon Commission's intent was for an interim storage site. This commenter also noted that more spent nuclear fuel exists than could be stored in Yucca Mountain. Another commenter stated that consent must be earned, and could be earned through scientific studies.*

RESPONSE: The NRC staff acknowledges that geologic repository siting has been a subject of political and social opposition. The Federal site-selection process is not within the NRC's statutory or regulatory authority and is outside the scope of the supplement, which concerns an

assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

DOE responded to the recommendations on repository site selection made in the January 2012 Blue Ribbon Commission Report on America's Nuclear Future (BRC, 2012). In January 2013, DOE released its *Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste* (DOE, 2013b) in response to the Blue Ribbon Commission Report. In this document, DOE stated that it planned to move "toward a sustainable program to deploy an integrated system capable of transporting, storing, and disposing of used nuclear fuel and high-level radioactive waste from civilian nuclear power generation." Since publication of this document, DOE stated that it is developing a consent-based siting process. The NRC staff continues to monitor DOE's efforts. Current information about DOE's consent-based siting process can be found at http://www.energy.gov/ne/consent-based-siting.

No changes were made to the supplement as a result of these comments.

(056, 066, 069, 095-09, 100, 147-03, 147-04, 147-09, 147-15, 147-17, 149-06, 149-16)

B.2.6.1.17. ***COMMENT****: Several commenters suggested alternative technologies or solutions for energy generation, and spent nuclear fuel management and disposal. These suggestions included transmutation, reduction of waste volumes using laser technology, or neutralization of the waste. Other commenters recommended construction of desalination plants and pipelines to provide water at a repository, or use of solar or hydroelectric power as alternative energy sources. Several commenters recommended that reprocessing be implemented, and one commenter stated their opposition to reprocessing*.

RESPONSE: The NRC staff acknowledges the comments calling for alternate energy generation and developing spent nuclear fuel management alternatives. However, these comments are outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

No changes were made to the supplement as a result of these comments.

(066, 069, 080-01, 087, 091, 095-06, 100, 103, 127, 147-02, 147-05, 147-20, 149-14)

B.2.6.1.18. ***COMMENT****: Several commenters urged continuation and completion of the licensing process, with some commenters requesting that the NRC seek funding from Congress to facilitate completion of the licensing process. Commenters noted that a repository is needed because of spent nuclear fuel accumulation around the country and because legal and contractual obligations under the Nuclear Waste Policy Act are not being met.*

RESPONSE: The NRC staff acknowledges the comments regarding further activities in the licensing process and the availability of funding. These comments outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km

[11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

The Commission directed the NRC staff to complete the supplement to DOE's EISs, along with other tasks, following the decision in 2013 by the Court of Appeals for the District of Columbia Circuit. The preparation of this supplement is one of several steps in the licensing process for the proposed repository. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement in response to these comments.

(051, 068, 135, 143, 145, 149-05)

B.2.6.1.19. ***COMMENT****: Several commenters made statements in support of nuclear power. Some of the commenters cited the lack of greenhouse gas emissions and concerns about the effects of other power sources on global climate change and land use. One commenter stated that the problem of spent fuel disposal hinders the further expansion of nuclear power.*

RESPONSE: Comments regarding the use of nuclear power are outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

The NRC is an independent regulator that does not promote nuclear or other types of energy. The NRC regulates commercial nuclear power plants, including the management of commercial spent nuclear fuel, and other civilian uses of nuclear materials, such as nuclear medicine, through licensing, inspection, and enforcement of its requirements.

No changes were made to the supplement as a result of these comments.

(038, 095-03, 126, 147-02, 147-25, 149-07, 149-16)

B.2.6.1.20. ***COMMENT****: Several commenters raised questions or concerns about the water and land rights that DOE would need to secure to receive a construction authorization for a repository at Yucca Mountain. Some of these commenters said that the project cannot or should not be licensed or further considered because the NRC's SER concluded that DOE has not yet obtained all the proper land or water rights required to license the project. One of the commenters contended that the supplement is insufficient because land and water rights were not included in the analysis. Another commenter noted that DOE does not have the proper rail access. One commenter also raised a concern about the tribal ownership of the land.*

RESPONSE: The NRC staff acknowledges the commenters' concerns about land ownership, water rights and rail access for the construction and operation of a repository at Yucca Mountain. These topics are outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater

beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

As discussed in the supplement (Chapter 1), this environmental analysis is based upon DOE's application, including its Safety Analysis Report (DOE, 2008b). The NRC staff's review of land ownership and water rights at the proposed Yucca Mountain repository is discussed in its SER (NRC, 2014b, Chapter 11, Section 2.5.8).

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. As discussed in Section 1.1 of the supplement, the adjudicatory proceeding for the proposed repository is currently suspended. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement as a result of these comments.

(021, 034, 056, 074, 117, 147-03, 147-04, 147-08, 147-09, 148, 149-17)

B.2.6.1.21. ***COMMENT****: Several commenters expressed concern about potential future funding and funding mechanisms for the Yucca Mountain project. Several commenters stated the nuclear industry should be responsible for the total costs of nuclear waste disposal. Other commenters stated the high costs of disposal creates an undue burden on taxpayers. Commenters also asserted that the full cost of the repository is difficult to calculate because Nevada anticipates delays due to years of litigation, and problems may arise in the future.*

Several commenters stated their opposition to the Price-Anderson Act, calling for it to be revoked and stating that the nuclear industry should be liable for nuclear accidents. One commenter stated that nuclear industry should not fund the campaigns of elected officials or hire former government workers because these actions create conflicts of interest. Other commenters pointed out that Congress has not appropriated funds to continue the Yucca Mountain repository licensing process in several years. They questioned whether funds will ever be made available, given the high cost of the facility, the shortage of funding for other public projects, and stakeholder opposition to the repository. A few commenters stated that even if Congress appropriated funds, the repository project would not bring revenues to nearby communities. One commenter also stated that monies from the Nuclear Waste Fund should not be used to fund an interim storage site.

RESPONSE: The NRC staff acknowledges that the NRC has limited funds available to complete the Yucca Mountain license application review. Comments regarding funding for the Yucca Mountain project or for NRC license review activities, financial liability, campaign funding, and industry hiring practices are outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

The 2013 decision by the Court of Appeals for the District of Columbia Circuit ordered the NRC to resume work on licensing activities as long as the agency had available funds from previous

appropriations. Following the NRC staff's publication of the SER, sufficient funds remained for the NRC staff to develop this supplement. The completion of licensing activities, however, is subject to further appropriations and other actions external to the NRC.

No changes were made to the supplement as a result of these comments.

(002, 095-10, 095-11, 098, 100, 102, 146-03, 146-13, 147-03, 147-06, 147-15, 149-20)

B.2.6.1.22. ***COMMENT****: Many commenters stated concerns about the transportation of nuclear waste to a repository at Yucca Mountain. Several commenters opposed any transportation of radioactive materials (by air, barge, roads, or rail). Many of the commenters stated concerns about potential radiation exposure to citizens and transportation workers and to watersheds and land areas adjacent to railways, waterways, and roadways during the transport of spent fuel, as well as from accidents during transportation.*

One commenter felt that storage at existing nuclear power plant sites is the safest option.

Commenters also raised concerns about the structural integrity of casks, canisters, and spent fuel assemblies before and during shipment, and during unloading. Several commenters questioned the bases underlying the models assessing cask damage in accident and sabotage situations. Many commenters raised concerns about the preparedness of emergency responders in accident situations. Others questioned whether casks can be so damaged as to hinder safe retrieval. The commenters cited the need to properly evaluate accident scenarios to assess the containment integrity of casks, the potential for high-temperature fire damage to casks, and the effects of aging on some parts of the national transportation infrastructure.

Other commenters requested casks' integrity be assessed for a possible terrorist attack or sabotage. Some of the commenters stated various reasons for their concern—including other nonradioactive transportation accidents and shipment experience in other countries, such as accidents involving the rail transportation of oil or other toxic or flammable substances—and expressed skepticism about claims that humans have not been harmed as a result of the transportation of nuclear materials historically.

RESPONSE: The NRC staff acknowledges the concerns about the transportation of radioactive waste and transportation accidents. These comments are outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

Regulatory oversight of radioactive materials shipments is the joint responsibility of the NRC and the U.S. Department of Transportation (DOT). The NRC oversees the safety of the transportation of nuclear materials through a combination of regulatory requirements, transportation package certification, inspections, and a system of monitoring to ensure that safety requirements are being met. Information about NRC regulation for these and other aspects of radioactive materials transportation can be found at http://www.nrc.gov/waste/spent-fuel-transp.html. The DOT has regulatory oversight for shipments while they are in transit. Comments related to transportation are addressed further in Section B.2.4.6.6 of this appendix.

No changes have been made to the supplement as a result of these comments.

(004, 012, 016, 025, 030, 032, 033, 034, 080-03, 080-13, 084, 086, 095-02, 095-04, 095-05, 095-07, 095-08, 095-10, 097, 098, 109, 117, 139, 146-08, 146-12, 146-18, 147-03, 147-04, 147-07, 147-19, 149-09)

B.2.6.1.23. ***COMMENT****: Several commenters stated their concern about the use, storage, and transportation of high-burnup fuel. Two commenters expressed concern about the lack of data to assess or mitigate the degradation of high-burnup spent fuel cladding. The commenters stated that properties of high-burnup fuel, such as the higher possibility of embrittlement in cladding, creates significant implications for storage in pools, movement of the fuel to dry storage, or transportation. One commenter called for the cessation of the use and NRC approval of high-burnup fuel and for rejection of NUREG-2125, "Spent Fuel Transportation Risk Assessment," for failing to consider high-burnup spent fuel (NRC, 2014c). Two commenters stated that no casks have been approved for transportation of high-burnup spent fuel; and therefore, the assumption that casks will exist to transport this fuel is invalid*.

RESPONSE: Comments about the use, storage, and transportation of high-burnup fuel are outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

The NRC staff acknowledges that high-burnup fuels are of concern to some stakeholders. The NRC continues to monitor international and national efforts to conduct research on high-burnup fuels, including degradation mechanisms, and is currently funding its own studies on high-burnup fuel, although the NRC staff notes that it has certified casks for the transportation and storage of high-burnup fuels. Additional information about the NRC's regulatory activities related to high-burnup fuels can be found at http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/bg-high-burnup-spent-fuel.html.

No changes were made to the supplement as a result of these comments.

(016, 072, 146-01)

B.2.6.2 General Opposition

B.2.6.2.1. ***COMMENT****: Several commenters expressed general concerns that there is currently no viable solution to the long-term management or disposal of spent nuclear fuel, and that radiological materials (including radioactive waste) are dangerous. The commenters cited historical and current issues at sites containing radiological materials, such as the NNSS, the Hanford site, and the Waste Isolation Pilot Project disposal site. Some of the commenters stated the need for robust scientific solutions for nuclear waste disposal.*

RESPONSE: The NRC staff acknowledges that difficulties have been encountered at the sites identified by the commenters. The evaluation of other long-term radioactive waste management and disposal options is outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the

postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

Comments addressing alternate solutions for nuclear waste, identifying the historical difficulties experienced at military nuclear facilities, or remarking on nonnuclear issues that occurred at the Waste Isolation Pilot Plant, however, are also beyond the scope of this supplement.

Likewise, comments stating that a viable solution for long-term management or disposal of spent nuclear fuel are also outside the scope of this supplement. The NRC staff's SER for the Yucca Mountain repository and the Continued Storage GEIS (NUREG-2157) provide recent NRC analyses on these subjects.

No changes were made to the supplement as a result of these comments.

(095-06, 095-08, 095-10, 146-05, 147-15, 149-13)

B.2.6.2.2. ***COMMENT****: Commenters expressed general disagreement with the approach, the scope, the information collection methods, and the conclusions reached in the NRC staff's supplement and called for withdrawal of the document. Some commenters provided specific reasons for their disagreement with the supplement. A few commenters stated that the supplement is deficient because the analyses rely on incomplete or inaccurate information. They also asserted that the supplement does not adequately characterize potential impacts from accidents, surface discharges of groundwater in the Amargosa Desert, transportation routes, and seismic activity. Three commenters stated that Native American communities in the Middle Amargosa Basin, specifically the towns of Shoshone and Tecopa, and the Timbisha Shoshone Tribe community in Death Valley, have not been fully analyzed in either the NRC's supplement or DOE's EIS documents. Several commenters question the supplement's conclusions and call for additional scientific studies and tribal consultations.*

RESPONSE: The NRC staff acknowledges the commenters' general disagreement with the nature of the supplement and its scope. Many of these comments are general or broadly question the basis for various assumptions or attributes of the analysis. The subject areas discussed generally by these commenters are addressed in greater detail in response to other comments throughout this appendix. Comments on Native American communities are addressed in Section B.2.4.2.3, B.2.4.4, and B.2.4.5; comments on groundwater resources and impacts are addressed in Sections B.2.3.2 and B.2.4.1; comments on transportation are addressed in Section B.2.4.6.6; and comments on seismicity are addressed in Sections B.2.4.6.7 and B.2.4.6.8. Comments about the accuracy and completeness of information and the assumptions are addressed in Section B.2.1.2 and B.2.2, respectively.

No changes were made to the supplement as a result of these comments.

(006, 060, 061, 062, 095-05, 095-10, 107, 108, 119, 124, 133, 134, 147-19, 149-10)

B.2.6.2.3. ***COMMENT****: Several commenters stated the NRC should withdraw or stop work on the supplement, because Yucca Mountain is an unsuitable location for a repository. Furthermore, they stated that continuing work on it is not a useful expenditure of time or financial resources. A number of commenters pointed out that Federal funds have not been appropriated for completion of the Yucca Mountain licensing. Several commenters stated that rather than using financial resources to complete the supplement or to continue to develop the*

Yucca Mountain repository, funds should be spent on workable solutions to store spent nuclear fuel and HLRW or on socially-oriented programs. Commenters also cited concerns about potential health effects from radioactive materials, and objected to expediting the supplement at the expense of accurate factual information. Commenters also expressed concern about the role of politics in the overall Yucca Mountain repository process.

RESPONSE: Comments opposing a repository at Yucca Mountain because of financial and social considerations are outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location, which is 18 km [11 mi] from the Yucca Mountain project site. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement as a result of these comments.

(015, 027, 034, 056, 074, 111, 147-03, 147-04, 147-08, 147-09, 147-19, 148)

B.2.6.2.4. ***COMMENT****: Commenters expressed broad opposition to the generation of nuclear waste and the continuation of nuclear power generation in the U.S. Many of the commenters stated that the U.S. should end the nuclear generation of electricity in order to stop producing spent nuclear fuel, because there is currently no solution for the waste. Some comments raised concerns about health risks and called for the shutdown of all nuclear power reactors and a moratorium on the construction of new nuclear plants. Other commenters referred to international radiological accidents and the accident at the Waste Isolation Pilot Plant. One commenter stated that the NRC should take its role of protecting the public more seriously. Other commenters expressed concern for the Earth and protecting future generations from nuclear waste.*

RESPONSE: The NRC staff acknowledges the comments raising general opposition to nuclear power, but notes that these comments are outside the scope of the supplement, which concerns an assessment of the potential impacts to groundwater and surface discharges of groundwater beyond the postclosure compliance location. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

Further, the NRC is an independent regulator that does not promote nuclear or other types of energy. The NRC was created to ensure the safe use of radioactive materials for beneficial civilian purposes while protecting people and the environment. The NRC regulates commercial nuclear power plants and other uses of nuclear materials, such as in nuclear medicine, through licensing, inspection, and enforcement of its requirements.

No changes were made to the supplement as a result of these comments.

(009, 011, 012, 023, 041, 048, 058, 062, 077, 080-01, 080-09, 080-11, 080-12, 080-13, 080-15, 090, 095-05, 095-06, 095-11, 097, 100, 102, 105, 109, 146-16, 147-16, 147-20, 149-15)

B.2.6.2.5. ***COMMENT****: Many commenters opposed the siting and operation of a repository at Yucca Mountain and stated various general reasons for their opposition. Commenters cited concerns about public health and safety, about whether the repository can adequately contain radioactive waste, that the State of Nevada and its residents have not consented to the siting of the facility, and that repository siting should be consent-based. Other commenters stated that DOE's plan is unworkable and represents a misuse of public resources. Several commenters opposed the decisionmaking process that designated the Yucca Mountain site as the repository location. A few commenters stated that the NRC is conspiring with the nuclear industry in evaluating Yucca Mountain for repository siting. Several commenters rejected the scientific and engineering studies and analyses conducted by DOE and the NRC. Some commenters asserted that these agencies misunderstand the technical issues or that information about Yucca Mountain has been misrepresented. Commenters generally questioned the accuracy and reliability of the long-term modeling underlying the environmental and safety conclusions made by DOE and the NRC. Other commenters opposed the project because of concerns about the ability to safely transport spent fuel and radiological materials to the repository. One commenter questioned the NRC staff's SER finding that the repository meets applicable performance standards and regulatory requirements and will protect public health and safety.*

RESPONSE: The NRC staff acknowledges the comments opposing a repository at Yucca Mountain; however, these comments are beyond the scope of this supplement, which concerns an assessment of the potential environmental impacts to groundwater and from surface discharges of groundwater beyond the postclosure compliance location. The scope of this supplement is further described in the NRC's Notice of Intent to prepare the supplement (80 FR 13029) and in the NRC staff's ADR (NRC, 2008a).

The SER and EIS supplement reflect the NRC staff's independent safety evaluations and analyses of DOE's license application and an assessment of DOE's environmental review. Commenters' concerns about transportation are discussed in Section B.2.4.6.6 and B.2.6.1.22.

The preparation and publication of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement as a result of these comments.

(002, 012, 021, 026, 029, 034, 044, 045, 048, 050, 052, 057, 059, 065, 066, 072, 074, 078, 079, 080-01, 080-06, 080-09, 080-10, 080-17, 081, 088, 089, 091, 095-06, 095-07, 095-08, 095-11, 098, 100, 102, 107, 108, 109, 114, 116, 117, 121, 127, 128, 134, 139, 144, 146-01, 146-13, -146-16, 146-17, 146-18, 147-03, 147-04, 147-06, 147-07, 147-08, 147-15, 147-16, 147-18, 147-27, 148, 149-14, 149-15, 149-20, 149-21)

B.2.6.3 General Support

B.2.6.3.1. ***COMMENT****: Several commenters expressed general support for the development of the supplement, or endorsed the conclusions in the supplement. Commenters stated that the NRC's findings were consistent with the scientific and environmental studies produced by Federal and State agencies and that the NRC used conservative assumptions in estimating environmental impacts, especially in estimating annual radiological dose.*

Commenters supported the NRC's findings that all of the impacts on the resources evaluated within would be small, including potential impacts on groundwater and from groundwater discharges of groundwater, stating that the supplement complies with all NEPA requirements.

Some commenters expressed support for the NRC's decision to develop the supplement in light of DOE's decision not to. Others commented on the thoroughness of the draft supplement, that the NRC's public involvement process was fair, and that the supplement demonstrates the technical feasibility of the Yucca Mountain repository. One commenter stated that the supplement scope was appropriate, properly focused on groundwater issues, and complemented DOE's environmental reports.

Some of these comments in support of the supplement also expressed general support for siting the repository at Yucca Mountain, arguing that the decision to license the repository should be based on science, which the commenter stated supports development of the project. Commenters also noted that the findings in the supplement support the NRC staff's SER conclusions that regulatory requirements would be met and provide further evidence that spent nuclear fuel and HLRW can be disposed of safely in a geologic repository at Yucca Mountain. Several commenters expressed confidence that the completion of the supplement would result in completion of a repository at Yucca Mountain. Some of these commenters urged the NRC to move forward with the licensing process under the Nuclear Waste Policy Act.

RESPONSE: The NRC staff acknowledges the comments stating general support for the development of the supplement and endorsing the conclusions in the supplement. The NRC staff agrees that conservative assumptions were used, that the supplement scope is appropriate, the supplement complies with NEPA, and that the conclusions reached in the supplement support the NRC staff's findings in the SER. The preparation of this supplement is one of several steps in the licensing process for the proposed repository. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement as a result of these comments.

(005, 046, 051, 068, 135, 138, 143, 145, 147-05, 147-17, 149-05, 149-11, 149-18)

B.2.6.3.2. ***COMMENT****: Several commenters expressed support for the Yucca Mountain project for a variety of reasons. Some commenters stated that disposing of spent nuclear fuel in a repository at Yucca Mountain is safer and more secure than storing the spent fuel at temporary storage facilities around the country, including in spent fuel pools and in dry casks. Several commenters expressed confidence in the safety and security of the proposed repository at Yucca Mountain, noting that the conclusions reached in the NRC staff's SER and the EIS supplement demonstrate its technical feasibility and safety. Commenters stated that Yucca Mountain was a preferred site for a repository for several reasons, including low groundwater flow or infiltration, the location of the repository away from water tables, low amounts of potential contamination compared to other sources, and the low potential for spills on site. Some commenters also stated that groundwater flowing in the area of the Yucca Mountain site is already contaminated by activities associated with the NNSS, and, therefore, Yucca Mountain, rather than an alternative uncontaminated site, should be the repository site. One commenter stated that a repository would provide good jobs in southern Nevada. Some of the commenters expressed support for the licensing process to continue, with two commenters noting that, by law, the process must be continued or that legal obligations are not being met.*

RESPONSE: The NRC staff acknowledges the comments in support of siting and developing a repository at Yucca Mountain. The NRC staff concluded in its SER that DOE's repository design meets the performance objectives to isolate radioactivity from the environment, as required by 10 CFR Part 63, Subpart E. The NRC staff also found that the proposed repository design meets the NRC's postclosure public and environmental standards for individual protection, human intrusion, and groundwater protection, as required by 10 CFR Part 63, Subpart L.

The preparation of this supplement is one of several steps in the licensing process for the proposed repository. Information may be identified that requires further supplementation of DOE's 2002 and 2008 EISs in the future. The completion of licensing activities is subject to appropriations and other actions external to the NRC.

No changes were made to the supplement as a result of these comments.

(007, 037, 038, 051, 069, 080-02, 080-03, 080-14, 125, 147-05, 147-11, 147-25, 147-26, 149-05, 149-07, 149-16, 149-19)

B.3 List of Commenters

Table B–3 lists individuals who provided comments on the draft supplement orally at meetings or through comment letters.

Table B-3. Individuals Who Submitted Written or Oral Comments

Commenter	Affiliation and Title (if provided)	Document Identification Number	ADAMS Accession Number
Anderson, Dorothy	Private Citizen	004	ML15343A213
Andrews, RD	Private Citizen	080-14	ML15294A368
Anonymous	Private Citizen	006	ML15343A017
Anonymous, Susan	Private Citizen	008	ML15343A211
Anonymous	Private Citizen	010	ML15343A214
Anonymous	Private Citizen	011	ML15343A422
Anonymous	Private Citizen	016	ML15344A301
Anonymous	Private Citizen	017	ML15344A302
Ashby, Kylee	Private Citizen	007	ML15313A016
Azarovitz, Janet	Private Citizen	009	ML15342A115
Barnes, Kathryn	Private Citizen	012	ML15323A408
Bechtel, Dennis	Private Citizen	018	ML15313A007
Bechtel, Dennis	Private Citizen	019	ML15343A390
Bechtel, Dennis	Private Citizen	147-24	ML15268A399
Belaski-Ashe, Meghan	Private Citizen	021	ML15343A384
Bell, Kevin	California Energy Commission, Senior Staff Counsel	147-13	ML15268A399
Bosold, Patrick	Private Citizen	001	ML15292A135
Bosold, Patrick	Private Citizen	002	ML15292A172
Bosold, Patrick	Private Citizen	112	ML15343A018
Bosta, John	Private Citizen	149-17	ML15274A168
Boudart, Jan	Nuclear Energy Information Service of Chicago	025	ML15344A205

Table B-3. Individuals Who Submitted Written or Oral Comments			
Commenter	**Affiliation and Title (if provided)**	**Document Identification Number**	**ADAMS Accession Number**
Boudart, Jan	Nuclear Energy Information Service of Chicago	030	ML15344A206
Boudart, Jan	Nuclear Energy Information Service of Chicago	032	ML15344A207
Boudart, Jan	Nuclear Energy Information Service of Chicago	033	ML15344A216
Boudart, Jan	Nuclear Energy Information Service of Chicago	095-04	ML15321A414
Brechin, Vernon	Private Citizen	027	ML15343A028
Bromm, Susan	EPA Office of Federal Activities, Director	137	ML15336A983
Brown, D.	Private Citizen	150	ML16013A310
Bryan, Richard	Nevada Commission on Nuclear Projects, Chairman	147-06	ML15268A399
Burton, Vic	Private Citizen	028	ML15344A217
Campbell, Bruce	Private Citizen	128	ML15344A095
Canfield, Skip and Ernstein, Julie	Nevada Division of State Lands, Program Manager Nevada State Historic Preservation Office (SHPO), Deputy State Historic Preservation Officer	136	ML15299A093
Carpenter, Susan	Cape Downwinders	080-06	ML15294A368
Carpenter, Susan	Cape Downwinders	095-08	ML15321A414
Carrigan, Milton	Private Citizen	042	ML15344A272
Cartwright, Lorie	New England Coalition	095-09	ML15321A414
Ciaran, C.	Private Citizen	058	ML15343A383
Cobb, Sandra	Private Citizen	003	ML15292A096
Cobb, Sandra	Private Citizen	063	ML15343A021
Collins, William	Private Citizen	064	ML15343A015
Corry, Ronit	Private Citizen	065	ML15323A405
Craig, Anne	Private Citizen	077	ML15292A132
Crater, Bruce	Private Citizen	149-19	ML15274A168
Crawford, Amena	Private Citizen	066	ML15323A407
D, Capt	Private Citizen	035	ML15343A387
D'Arrigo, Diane	Nuclear Information and Resource Service	146-01	ML15253A669
Damele, Ronald	Eureka County (Nevada), Public Works Director	118	ML15324A254
Darby, Forrest	Private Citizen	147-25	ML15268A399
Diamond, Brenda	Private Citizen	149-04	ML15274A168
Dirsa-DuBois, Margaret	Private Citizen	113	ML15342A116
Donnelly, Patrick	Amargosa Conservancy, Executive Director	149-10	ML15274A168

Table B-3. Individuals Who Submitted Written or Oral Comments			
Commenter	**Affiliation and Title (if provided)**	**Document Identification Number**	**ADAMS Accession Number**
Dubois, Gwen	Chesapeake Physicians for Social Responsibility	146-12	ML15253A669
Edwards, Gordon	Canadian Coalition for Nuclear Responsibility, President	144	ML15344A096
Erquiaga, Carl	Churchill County (Nevada), Vice-Chairman and Commissioner	046	ML15324A255
Esteve, Gregory	Private Citizen	117	ML15323A404
Evans, Matthew	Private Citizen	119	ML15313A019
Farber, Joan	Private Citizen	078	ML15275A161
Feldman, Jane	Sierra Club, Toiyabe Chapter, Energy Committee Chair	129	ML15313A011
Fettus, Geoffrey	Natural Resources Defense Council, Senior Attorney	132	ML15344A172
Fields, Sarah	Uranium Watch	080-08	ML15294A368
Forbes, Melinda	Private Citizen	114	ML15344A169
Foster, Beverly	Private Citizen	079	ML15275A158
Frank, Fred	Private Citizen	015	ML15292A133
Freelain, Kenneth	International Definition	080-02	ML15294A368
Freelain, Kenneth	International Definition	095-03	ML15321A414
Freelain, Kenneth	International Definition	125	ML15313A014
Freelain, Kenneth	International Definition	126	ML15336A941
Gaddis, Nicollee	Bureau of Land Management, Planning and Environmental Coordinator	020	ML15287A395
Gardner, Rose	Private Citizen	080-12	ML15294A368
Gedicks, Al	Private Citizen	022	ML15343A385
Gholson, George	Timbisha Shoshone Tribal Council, Chairman	052	ML15313A006
Gholson, George	Timbisha Shoshone Tribal Council, Chairman	060	ML15337A078
Gibson, Kenneth	Private Citizen	023	ML15342A118
Giese, Mark	Private Citizen	029	ML15313A018
Giese, Mark	Private Citizen	031	ML15343A419
Gilmore, Donna	San Onofre Safety	146-09	ML15253A669
Goedhart, Ed	Private Citizen	149-13	ML15274A168
Goodman, Carolyn	City of Las Vegas, Mayor	034	ML15313A010
Goodman, Carolyn	City of Las Vegas, Mayor	147-04	ML15268A399
Gotsch, Paula	Private Citizen	146-05	ML15253A669
Gotsch, Paula	Private Citizen	080-09	ML15294A368
Graham, Darlene	Private Citizen	036	ML15344A204
Gran, Gerhard	Private Citizen	037	ML15313A012
Gran, Gerhard	Private Citizen	038	ML15303A254
Gran, Gerhard	Private Citizen	149-07	ML15274A168
Graves, Caryn	Private Citizen	039	ML15292A170
Graves, Caryn	Private Citizen	040	ML15342A117

Table B-3. Individuals Who Submitted Written or Oral Comments			
Commenter	**Affiliation and Title (if provided)**	**Document Identification Number**	**ADAMS Accession Number**
Gray, Erica	Private Citizen	041	ML15344A170
Gray, Erica	Private Citizen	146-16	ML15253A669
Grecheck, Eugene	American Nuclear Society, President	005	ML15343A382
Hadeck, Jim	Private Citizen	147-26	ML15268A399
Halstead, Robert	Nevada Agency for Nuclear Projects, Executive Director	110	ML15243A454
Halstead, Robert	Nevada Agency for Nuclear Projects, Executive Director	147-01	ML15268A399
Halstead, Robert	Nevada Agency for Nuclear Projects, Executive Director	149-01	ML15274A168
Halstead, Robert	Nevada Agency for Nuclear Projects, Executive Director	149-20	ML15274A168
Halstead, Robert; Sandoval, Brian; Drozdoff, Leo; Gholson, George; and Zabarte, Ian	Nevada Agency for Nuclear Projects, Executive Director State of Nevada, Governor Nevada Department of Conservation and Natural Resources, Director Timbisha Shoshone Tribe, Chairman Government of Newe Sogobia, Principal Man for Foreign Affairs	148	ML15342A010
Harrison, Randy	Private Citizen	096	ML15342A114
Hart, Joshua	Inyo County (California), Planning Director	130	ML15275A159
Hays, Helen	Private Citizen	097	ML15323A410
Headington, Maureen	Stand Up Save Lives	095-10	ML15321A414
Headington, Maureen	Stand Up Save Lives	098	ML15344A219
Headington, Maureen	Stand Up Save Lives	146-13	ML15253A669
Hodin, Russell	Private Citizen	099	ML15344A218
Hoffman, Ace	Private Citizen	080-15	ML15294A368
Hoffman, Ace	Private Citizen	095-06	ML15321A414
Hoffman, Ace	Private Citizen	100	ML15343A389
Hoffman, Ace	Private Citizen	146-14	ML15253A669
Hoffman, Ace	Private Citizen	147-15	ML15268A399
Hoffman, Ace	Private Citizen	149-14	ML15274A168
Hoffman, Sharon	Private Citizen	147-16	ML15268A399
Hoffman, Sharon	Private Citizen	149-15	ML15274A168
Hofford, William	Private Citizen	104	ML15343A019
Hofmann, Sarah	Nuclear Waste Strategy Coalition, Chair	135	ML15342A006
Hollis, Gary	Private Citizen	106	ML15313A008
Hollis, Gary	Private Citizen	149-02	ML15274A168
Hollis, Gary	Private Citizen	149-16	ML15274A168
Hommel, Teresa	Private Citizen	107	ML15343A381

Table B-3. Individuals Who Submitted Written or Oral Comments			
Commenter	**Affiliation and Title (if provided)**	**Document Identification Number**	**ADAMS Accession Number**
James, HJ	Private Citizen	139	ML15299A099
Jensen, Pia	Private Citizen	081	ML15343A212
Jessee, Judy	Private Citizen	082	ML15292A171
Jessler, Darynne	Private Citizen	083	ML15342A009
Jim, Eddie	Pahrump Paiute Tribe, Chairman	147-22	ML15268A399
Johnson, Abby	Eureka County	146-10	ML15253A669
Kamps, Kevin	Beyond Nuclear	080-16	ML15294A368
Kamps, Kevin	Beyond Nuclear	095-12	ML15321A414
Kamps, Kevin	Beyond Nuclear	146-07	ML15253A669
Kasenow, Lisa	Private Citizen	084	ML15336A976
Keegan, Michael	Don't Waste Michigan	146-04	ML15253A669
Keegan, Michael	Don't Waste Michigan	080-17	ML15294A368
Kellen, Leonard	Private Citizen	080-11	ML15294A368
Kennedy, Joe	Private Citizen	147-20	ML15268A399
King, Mary	Private Citizen	149-12	ML15274A168
Kingsley, Matt	Inyo County (California) Board of Supervisors, Chairperson	142	ML15342A025
Kirschling, Karen	Private Citizen	085	ML15342A196
Kizzia, Toni	Private Citizen	149-21	ML15274A168
Klevorick, Phil	Clark County Nuclear Waste Division	147-14	ML15268A399
Kreisler, Leonard	Private Citizen	147-05	ML15268A399
Lacy, Darrell	Nye County Nuclear Waste Repository Project Office, Director	149-08	ML15274A168
Ladeira, Amber	Private Citizen	080-13	ML15294A368
LaForge, John	Nukewatch, Co-Director	086	ML15336A981
LaForge, John	Nukewatch, Co-Director	095-01	ML15321A414
Lazarus, Jay	Ponderosa Dairy, Consultant	049	ML15342A007
Leshinskie, Tony	Vermont Department of Public Service, State Nuclear Engineer	146-11	ML15253A669
Leneman, Cecile	Private Citizen	120	ML15342A197
Levin, Carol	Private Citizen	121	ML15343A388
Lewis, Marvin	Private Citizen	080-07	ML15294A368
Lewis, Marvin	Private Citizen	095-02	ML15321A414
Lewis, Marvin	Private Citizen	122	ML15336A980
Lewis, Marvin	Private Citizen	146-08	ML15253A669
Lingenfelter, Andrew	Private Citizen	147-29	ML15268A399
Lingenfelter, Andrew	Private Citizen	149-06	ML15274A168
Lish, Christopher	Private Citizen	101	ML15343A215
Mack, Webster	Private Citizen	103	ML15292A137
Mack, Webster	Private Citizen	147-02	ML15268A399

Table B-3. Individuals Who Submitted Written or Oral Comments			
Commenter	**Affiliation and Title (if provided)**	**Document Identification Number**	**ADAMS Accession Number**
Macks, Vic	Private Citizen	102	ML15344A271
Macks, Vic	Private Citizen	105	ML15343A026
Mahowald, Philip	Prairie Island Indian Community, General Counsel	051	ML15344A173
Malsch, Marty	Egan, Fitzpatrick, Malsch, & Lawrence PLLC	141	ML15292A094
Malsch, Marty	Egan, Fitzpatrick, Malsch, & Lawrence PLLC	146-06	ML15253A669
Malsch, Marty	Egan, Fitzpatrick, Malsch, & Lawrence PLLC	080-04	ML15294A368
McCullum, Rodney	Nuclear Energy Institute, Senior Director, Used Fuel & Decommissioning	143	ML15328A151
McCullum, Rodney	Nuclear Energy Institute, Senior Director, Used Fuel & Decommissioning	147-17	ML15268A399
McCullum, Rodney	Nuclear Energy Institute, Senior Director, Used Fuel & Decommissioning	149-11	ML15274A168
McFarland, Teresa	Private Citizen	094	ML15292A136
McMillan, Kristin; and Anderson, Hugh	Las Vegas Metro Chamber of Commerce, President and CEO Las Vegas Metro Chamber of Commerce, Government Affairs Committee Chairman	127	ML15344A098
Merritt, Dave	Private Citizen	149-03	ML15274A168
Michetti, Susan	Private Citizen	108	ML15336A978
Michetti, Susan	Private Citizen	111	ML15292A095
Miller, Conrad	Private Citizen	091	ML15344A091
Moradkhan, Paul	Las Vegas Metro Chamber of Commerce, Vice President of Government Affairs	147-27	ML15268A399
Mori, Gina	Private Citizen	090	ML15344A102
Morton, Jenna	Private Citizen	147-19	ML15268A399
Moss, Ben	Private Citizen	093	ML15342A008
Nakadegawa, Judy	Private Citizen	089	ML15343A386
Nelson, Dennis	Support and Education for Radiation Victims, Director	146-15	ML15253A669
Nelson, Scott	Private Citizen	092	ML15343A391
Nester, Dennis	Private Citizen	087	ML15287A394
Nichols, John	Private Citizen	088	ML15344A094

Table B-3. Individuals Who Submitted Written or Oral Comments			
Commenter	**Affiliation and Title (if provided)**	**Document Identification Number**	**ADAMS Accession Number**
Noel, Amy	Private Citizen	149-09	ML15274A168
O'Brien, Michael	Private Citizen	053	ML15275A160
Olson, Mary	Nuclear Information and Resource Service	146-02	ML15253A669
Olson, Mary	Nuclear Information and Resource Service	080-10	ML15294A368
Olson, Mary; and Donnelly, Patrick	Nuclear Information and Resource Service Amargosa Conservancy, Executive Director	134	ML15344A171
Parks, David	Nevada State Senate, Senator District 7	147-07	ML15268A399
Paz, Jacob	Private Citizen	116	ML15337A076
Paz, Jacob	Private Citizen	147-12	ML15268A399
Phillips, Kevin	Lincoln County (Nevada) Board of Commissioners, Chairman	123	ML15336A979
Pierman, Bette	Michigan Safe Energy Future	048	ML15344A275
Pierman, Bette	Michigan Safe Energy Future	095-05	ML15321A414
Pineda, Cecile	No Nuke Committee San Francisco	080-01	ML15294A368
Pitesa, Bill	Duke Energy, Chief Nuclear Officer	145	ML15323A409
Port, Patricia	U.S. Department of the Interior, Regional Environmental Officer	140	ML15299A094
Poulson, Judi	Fairmont, Minnesota Peace Group, Chair	050	ML15343A025
Regan, Robert	Private Citizen	149-18	ML15274A168
Regez, Hendrica	Private Citizen	057	ML15336A977
Reid, Harry	U.S. Senate, Senator for Nevada	056	ML15313A013
Reid, Harry*	U.S. Senate, Senator for Nevada	147-09	ML15268A399
Rivera, Ethyl	Private Citizen	095-07	ML15321A414
Ruby, Kenneth	Private Citizen	059	ML15292A173
Rude, Kathleen	Private Citizen	061	ML15344A093
Sachs, Gary	Private Citizen	146-17	ML15253A669
Sandoval, Brian	State of Nevada, Governor	074	ML15287A393
Sandoval, Brian*	State of Nevada, Governor	147-08	ML15268A399
Schinhofen, Dan	Nye County (Nevada), Commissioner	073	ML15313A009
Schinhofen, Dan	Nye County (Nevada), Commissioner	138	ML15328A152
Schinhofen, Dan	Nye County (Nevada), Commissioner	147-11	ML15268A399
Schinhofen, Dan	Nye County (Nevada), Commissioner	149-05	ML15274A168
Schlapfer, Edwin	Private Citizen	072	ML15344A300
Schoneberger, David	Private Citizen	080-05	ML15294A368

Table B-3. Individuals Who Submitted Written or Oral Comments			
Commenter	**Affiliation and Title (if provided)**	**Document Identification Number**	**ADAMS Accession Number**
Science Panel	Sustainable Fuel Cycle Task Force	068	ML15336A982
Seeley, Linda	San Luis Obispo Mothers for Peace	075	ML15344A273
Shapiro, Susan	Public Health and Sustainable Energy, LLC	133	ML15344A103
Shaw, Sally	Private Citizen	071	ML15343A016
Sheridan, Paul	Private Citizen	054	ML15292A134
Sims, Millicent	Private Citizen	109	ML15313A017
Spilsbury, Delaine	Great Basin Water Network, Member of Board of Directors	070	ML15337A077
Steadmon, Jason	Private Citizen	047	ML15343A022
Steele, Diane	Private Citizen	076	ML15343A020
Stevens, Barbara	Private Citizen	146-18	ML15253A669
Stremmel, Bill	Private Citizen	069	ML15313A015
Stremmel, Bill	Private Citizen	080-03	ML15294A368
Swanson, Lucy	Private Citizen	067	ML15344A099
Thabit, Nick	Private Citizen	045	ML15343A023
Thomas, Ruth	Environmentalists, Inc.	146-03	ML15253A669
Titus, Dina	U.S. House of Representatives, Congresswoman, Nevada 1st District	147-03	ML15268A399
Torrisi, Sharon	Private Citizen	044	ML15343A024
Travis, Terence	Private Citizen	055	ML15343A027
Treichel, Judy	Nevada Nuclear Waste Task Force, Executive Director	147-23	ML15268A399
Tsongas, Theodora	Private Citizen	043	ML15344A303
Valentine, Virginia	Nevada Resort Association	147-18	ML15268A399
Voeller, Estelle	Private Citizen	013	ML15344A270
Warren, Barbara	Citizens' Environmental Coalition	062	ML15344A100
Watts, Elizabeth	Private Citizen	014	ML15344A220
Weinman, Lissa	World Policy Institute	095-11	ML15321A414
Weisenmiller, Robert	California Energy Commission, Chair and State Liaison Officer to NRC	124	ML15344A101
Willoghby, Leonard	Private Citizen	147-29	ML15268A399
Wilvert, Rosemary	Private Citizen	115	ML15344A208
Woodward, Holly	Private Citizen	026	ML15344A097
Woodward, Holly	Private Citizen	147-21	ML15268A399
Zabarte, Ian	Government of Newe Sogobia, Principal Man for Foreign Affairs	024	ML15292A093
Zabarte, Ian	Government of Newe Sogobia, Principal Man for Foreign Affairs	131	ML15341A331
Zabarte, Ian	Government of Newe Sogobia, Principal Man for Foreign Affairs	147-10	ML15268A399

*Comments were read at a public meeting on behalf of these commenters

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(See instructions on the reverse)

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2. TITLE AND SUBTITLE
Supplement to the U.S. Department of Energy's Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada

Final Report

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U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

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Docket # 63-001

11. ABSTRACT (200 words or less)
This supplement evaluates the potential environmental impacts on groundwater and impacts associated with the discharge of any contaminated groundwater to the ground surface due to potential releases from a geologic repository for spent nuclear fuel and high-level radioactive waste at Yucca Mountain, Nye County, Nevada. This supplements the U.S. Department of Energy's (DOE's) 2002 Environmental Impact Statement (EIS) and its 2008 Supplemental EIS for the proposed repository in accordance with the findings and scope outlined in the U.S. Nuclear Regulatory Commission (NRC) staff's 2008 Adoption Determination Report for DOE's EISs. This supplement assesses the potential environmental impacts with respect to potential contaminant releases from the repository that could be transported through the volcanic-alluvial aquifer in Fortymile Wash and Amargosa Desert, and to the Furnace Creek/Middle Basin area of Death Valley. This supplement evaluates the potential radiological and nonradiological impacts on the aquifer environment, soils, ecology, and public health, as well as the potential for disproportionate impacts on certain populations. In addition, this supplement assesses the potential for cumulative impacts associated with other past, present, or reasonably foreseeable future actions. The NRC staff finds that the potential impacts on the resources evaluated in this supplement would be SMALL.

12. KEY WORDS/DESCRIPTORS (List words or phrases that will assist researchers in locating the report.)
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environmental impact statement (EIS)
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DOE or Department of Energy
Yucca Mountain
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