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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

Draft Report for Comment

Office of Nuclear Material Safety and Safeguards

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COMMENTS ON DRAFT REPORT

2 Any interested party may submit comments on this report for consideration by the U.S. Nuclear
3 Regulatory Commission (NRC) staff. Comments may be accompanied by additional relevant
4 information or supporting data. Please specify the report number **NUREG–2184** in your
5 comments, and send them by the end of the comment period specified in the *Federal Register*
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15 (RADB), Division of Administrative Services, Office of Administration, Mail Stop:
16 OWFN-12-H08, U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001.

17 For any questions about the material in this report, please contact: Christine Pineda, EIS
18 Supplement Project Manager, 301-415-6789, or by e-mail at YMEIS_Supplement@nrc.gov.

19 Please be aware that any comments that you submit to the NRC will be considered a public
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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 all 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 regulatory 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 regulatory 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 regulatory 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

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

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

13   The NRC staff finds that all of the impacts on the resources evaluated in this supplement would
14   be SMALL. The NRC staff's analysis includes the impact of potential radiological and
15   nonradiological releases from the repository on the aquifer and at surface discharge locations
16   of groundwater beyond the regulatory compliance location. The peak estimated annual
17   individual radiological dose over the one-million-year period at any of the evaluated locations is
18   1.3 mrem [0.013 mSv]. This maximum dose is associated with pumping and irrigation at the
19   Amargosa Farms area, and the estimated radiological dose at any other potential surface
20   discharge location is lower. The NRC staff concludes that the estimated radiological doses
21   are SMALL because they are a small fraction of the background radiation dose of 300 mrem/yr
22   [3.0 mSv/yr] (including radon), and much less than the NRC annual dose standards for a
23   Yucca Mountain repository in 10 CFR Part 63 {15 mrem [0.15 mSv] for the first 10,000 years,
24   and 100 mrem [1 mSv] for one million years, after permanent closure}. Based on conservative
25   assumptions about the potential for health effects from exposure to low doses of radiation, the
26   NRC staff expects that the estimated radiation dose would contribute only a negligible increase
27   in the risk of cancer or severe hereditary effects in the potentially exposed population. Impacts
28   to other resources at all of the affected environments beyond the regulatory compliance location
29   from radiological and nonradiological material from the repository would also be SMALL. The
30   cumulative impact analysis concludes that, when considered in addition to the incremental
31   impacts of the proposed action, the potential impacts of other past, present, or reasonably
32   foreseeable future actions would 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

FR   *Federal Register*

HLW   high-level radioactive waste

IAEA   International Atomic Energy Agency
I   iodine
ICRP   International Committee on Radiological Protection
LLRW   low-level radioactive waste

MCL   mean concentration limit
Mo   molybdenum
mrem   millirem
mSv   milliSieverts

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

ACRONYMS AND ABBREVIATIONS (continued)

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

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

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

21   1.1   Background—License Application and EIS Adoption
22   Review Process

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

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

42   After docketing the DOE license application and issuing the ADR in September 2008, the NRC
43   staff began its licensing review and development of its Safety Evaluation Report (SER). In

1 October 2008, the Commission issued a Notice of Hearing and Opportunity to Petition to
2 Intervene, which began the adjudicatory process (NRC, 2008b).

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

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

17 In January 2015, the NRC staff completed the five-volume SER (NRC, 2015a,b; 2014b;
18 2010). In February 2015, the Commission directed the NRC staff to prepare the EIS
19 supplement. The adjudicatory proceeding remains suspended.

20 **1.2   Scope and Assumptions**

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

25 **1.2.1   Need for Supplementation and Scope of the Analysis**

26 Section 3.2.1.4 of the ADR describes the NRC staff's evaluation of the adequacy of the
27 analyses in DOE's 2002 and 2008 EISs. Since the ADR was prepared (in 2008), the NRC staff
28 has not identified new information that would change the NRC staff's position described in detail
29 in the ADR.

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

39 This supplement provides the information the NRC staff identified as necessary in its ADR. Two
40 distinct but related aspects of potential impacts on the groundwater system are addressed in
41 this supplement. These are (i) the nature and extent of the repository's impacts on groundwater

1　in the aquifer and (ii) the potential impacts of the discharge of potentially contaminated
2　groundwater to the ground surface. These two aspects are described further below:

3　**Impacts on Groundwater**

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

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

10　•　　Estimates of contamination in the groundwater, given potential accumulation of
11　　　radiological and nonradiological contaminants.

12　**Impacts from Surface Discharges of Groundwater**

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

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

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

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

25　**1.2.2　　Analysis Assumptions**

26　The analyses in this supplement make the following assumptions:

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

35　•　　The current population in the area near Yucca Mountain and its distribution
36　　　(as discussed in NRC, 2015a; Section 2.1.1.1.3.2, Regional Demography) will continue
37　　　for the period analyzed in the supplement (approximately one million years). The

| 1 | supplement assumes the current range of human activities will also continue for this |
| 2 | period. This is consistent with 10 CFR Part 63, Subpart L. |

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

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

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

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

41 ### 1.2.3   Significance of Environmental Impacts

42 The NRC has established standards of significance for assessing environmental impacts. In
43 NRC environmental reviews, significance indicates the importance of potential environmental
44 impacts and is determined by considering two variables: (i) context and (ii) intensity. Context is
45 the geographic, biophysical, and social setting in which effects are expected to occur. Intensity

1 refers to the severity of the impact. The NRC uses a three-level standard of significance based
2 upon the President's Council on Environmental Quality guidelines in 40 CFR 1508.27 and as
3 provided in the NRC's environmental review guidance in NUREG–1748 (NRC, 2003):

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

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

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

1.3   Public and Agency Involvement

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

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

18 The NRC staff is providing a 60-day public comment period for this draft supplement. The
19 comment period begins on the date of publication of NRC's Notice of Availability of this draft
20 supplement and the U.S. Environmental Protection Agency's (EPA's) concurrent notice in the
21 FR. During the comment period, the NRC staff will conduct public meetings to describe the
22 results of the analysis in this supplement and accept comments. Comments received on the
23 draft supplement will be addressed in the final supplement.

1.4   Document Format

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

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

39 Chapter 2 of this supplement describes the potentially affected groundwater and surface
40 environments and the potentially affected resource areas for each environment. Chapter 3

1   describes the potential impacts of repository contamination of groundwater and from the surface
2   discharge of groundwater. Chapter 4 describes cumulative impacts associated with potential
3   repository contamination of groundwater and the surface discharge of that groundwater.
4   Chapter 5 provides a summary of the NRC staff's impact findings.

1 # 2 AFFECTED ENVIRONMENT

2 ## 2.1 Introduction

3 The U.S. Department of Energy's (DOE's) Environmental Impact Statement (EIS) (DOE, 2002,
4 Chapter 5) and Supplemental Environmental Impact Statement (SEIS) (DOE, 2008a, Chapter 5)
5 described the affected environment from the Yucca Mountain repository site to the location of
6 the reasonably maximally exposed individual (RMEI), or regulatory compliance location,[1] in the
7 Amargosa Desert using information from a model that DOE developed for its license application
8 (DOE, 2008b). The RMEI location is characterized using features of present-day conditions and
9 activities at Amargosa Farms (the south-central portion of Amargosa Desert, as shown in
10 Figure 2-1). Using these conditions, the location of the RMEI is approximately 18 km [11 mi]
11 from Yucca Mountain, along the flow path of the predominant groundwater flow, and
12 approximately at the southern boundary of the Nevada National Security Site (NNSS)
13 (NRC, 2014a). For locations beyond the regulatory compliance location, the analysis in DOE's
14 2002 EIS and 2008 SEIS scaled the results calculated for the regulatory compliance location to
15 generic locations at 30 km [19 mi] and 60 km [37 mi] from the repository in the predominant
16 direction of groundwater flow.

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

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

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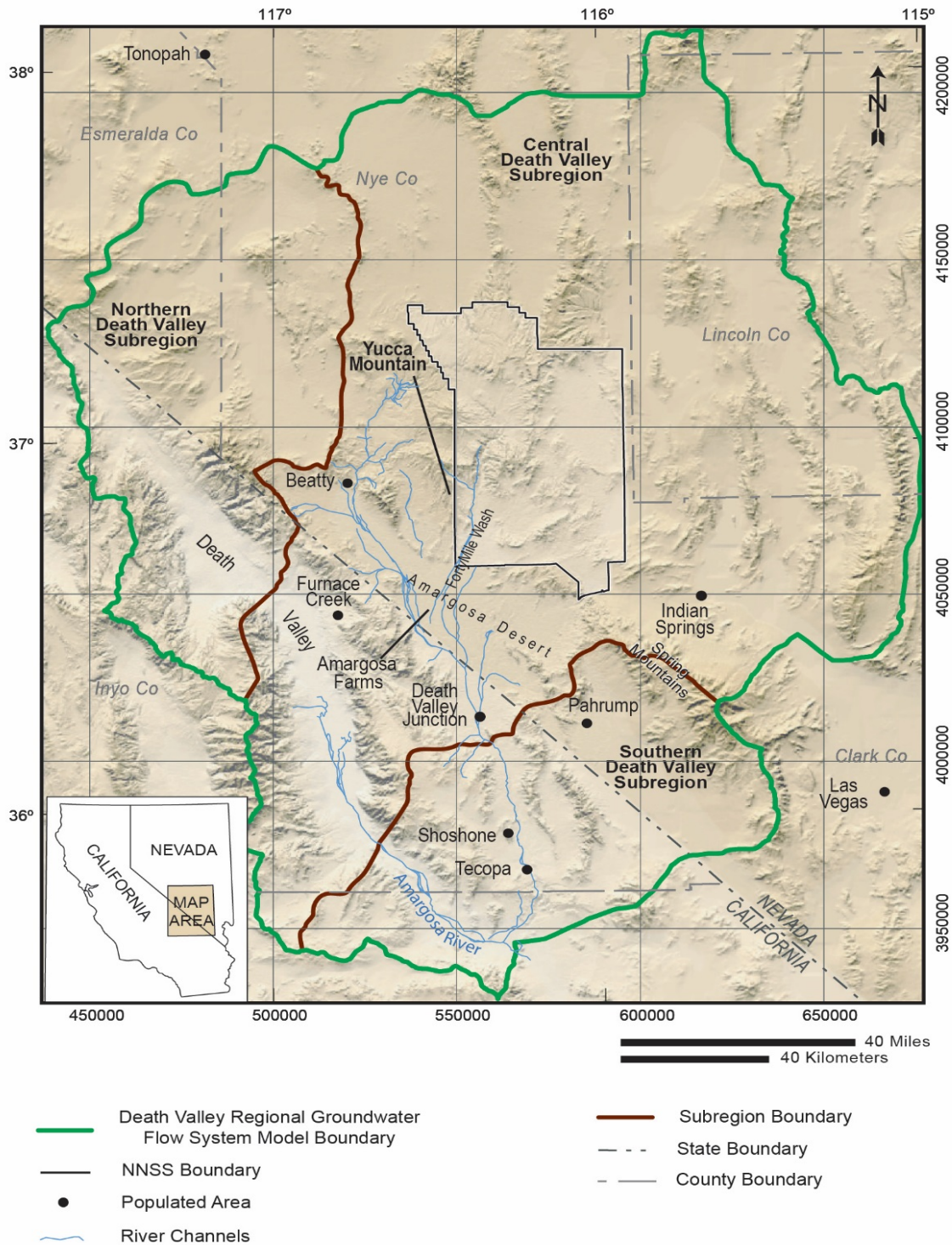
Figure 2-1. Location of Selected Geographical Features Within Death Valley Regional Groundwater Flow System. NNSS Is the Nevada National Security Site (Previously Called the Nevada Test Site). Modified From Belcher and Sweetkind (2010).

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

4   In particular, this chapter describes:

5   (i)   Groundwater Environment (Section 2.2)

6   —   Aquifers in the region potentially affected by releases from Yucca Mountain,
7   including aquifers along the flow path from Yucca Mountain to Death Valley

8   —   Effects of groundwater pumping on groundwater flow

9   —   Effects of the present and possible future climates on groundwater flow

10   (ii)   Surface Discharge Environment (Section 2.3)

11   —   Present-day discharge sites for releases from Yucca Mountain along potential
12   flow paths beyond the regulatory compliance location

13   —   Paleodischarge sites (areas of prehistorical, but not current surface discharge)
14   during wetter and cooler climates as indicators of potential future discharge

15   (iii)   Groundwater Modeling (Section 2.4)

16   —   Effects of pumping on groundwater conditions

17   —   Effects of climate on future flow paths

18   (iv)   Water Use and Quality (Section 2.5)

19   —   Water use along potential flow paths

20   —   Groundwater quality in the Yucca Mountain region

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

22   —   Present-day pumping levels (all potential contaminant releases are assumed to
23   be captured by pumping wells at the regulatory compliance location)

24   —   No future pumping (surface discharges downstream of the regulatory compliance
25   location under present and possible future climates)

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

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

1   with relatively young permeable basin fill sediments (mostly deposited by streams, also called
2   alluvium or alluvial deposits) in valleys across the DVRFS. These sediments comprise the
3   affected alluvial aquifer. The lowermost aquifer is a deep regional groundwater system formed
4   of thick sequences of older, highly permeable carbonate rocks that foster interbasinal
5   groundwater flow between basins that are topographically closed (Belcher and Sweetkind,
6   2010), as illustrated schematically in Figure 2-2. Regional groundwater flow in the DVRFS
7   through the carbonate rock sequence is affected by complex geologic structures caused by
8   regional faulting and fracturing. These geological structures can enhance or impede flow
9   (DOE, 2008b, Section 2.3.9). Although the carbonate aquifer is generally regionally connected
10 and fast flowing (Sweetkind et al., 2010; Winograd and Thordarson, 1975), there is also some
11 evidence from geochemical and temperature data that it may be locally compartmentalized
12 (e.g., Bushman, et al., 2010; Nye County NWRPO, 2009). The compartmentalized areas are a
13 possible consequence of a complex geological structure in the DVRFS, where local faulting may
14 intersperse less-permeable units.

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

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

31 Groundwater chemical compositions are used to understand groundwater flow paths and
32 identify areas in which groundwater mixing occurs. Groundwater chemistry is influenced by
33 interactions with the rock through which it flows. Interactions may include dissolution of
34 minerals, ion-exchange between the water and minerals, chemical alteration of mineral phases,
35 and precipitation of new mineral phases. Through these interactions, the groundwater develops
36 a chemical composition that is characteristic of a particular aquifer system. For example,
37 groundwater in the volcanic tuff aquifer system typically has relatively low ionic strength and has
38 higher concentrations of sodium, potassium, and silica derived from the volcanic source rocks.
39 In contrast, groundwater in the carbonate aquifer is dominated by dissolved calcium,
40 magnesium, and bicarbonate.

41 **Groundwater Subregions, Basins, and Sections**

42 To simplify modeling of the entire DVRFS and support modeling at different scales, the USGS
43 created a hierarchy of subregions, basins, and sections, from largest to smallest, respectively
44 (most recently described in Belcher and Sweetkind, 2010). DOE used earlier versions of the

EXPLANATION

| Phreatophytes | Groundwater flow |
| Approximate location of local, intermediate, and regional systems | Faults |
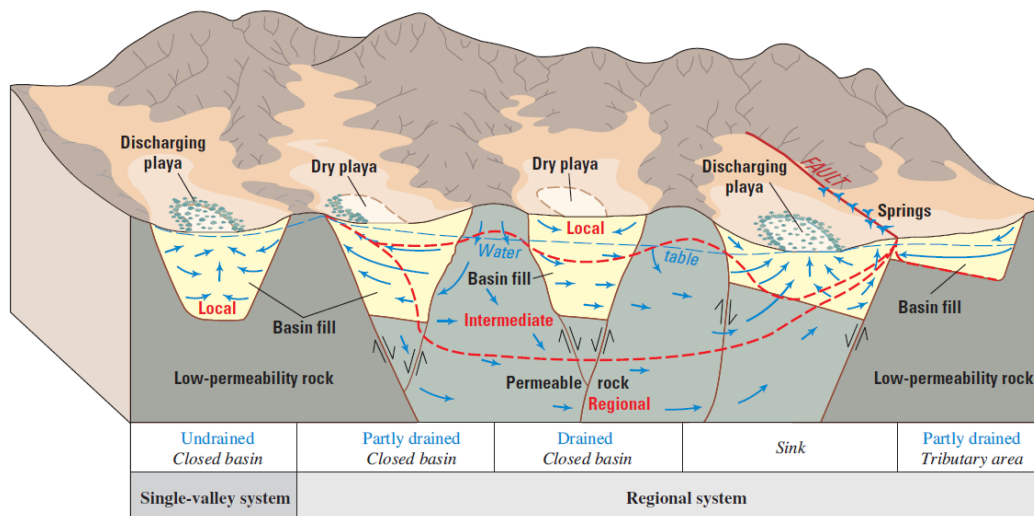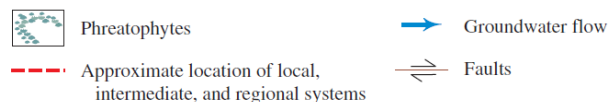
Figure 2-2. Schematic Block Diagram Illustrating the Structural Relations Among Mountain Blocks, Valleys, and Groundwater Flow in the Region (Modified from Eakin, et al., 1976). Taken From Belcher and Sweetkind (2010; Figure D-1).

1 USGS delineation of these groundwater flow areas (e.g., Belcher, 2004; Belcher, et al., 2002;)
2 at different scales in its EIS (DOE, 2002) and SEIS (DOE, 2008a). This delineation is a
3 reasonable method for conceptualizing the DVRFS, and this supplement utilizes the same
4 terminology. The delineation is reasonable because it is based on (i) an understanding of the
5 geology, including the rock units and structures that may influence groundwater flow;
6 (ii) observations or estimates of hydrologic information, including potentiometric surface
7 (for unconfined aquifers, the water table elevation is the potentiometric surface) and
8 hydrological properties of hydrogeological units; (iii) hydrogeochemical and thermal information;
9 and (iv) groundwater modeling that integrates all the hydrogeological information together.
10 Modeling the groundwater system involves characterizing the inflows and outflows for each
11 section, basin, and subregion. The inflows and outflows include recharge, lateral inflow and
12 outflow between areas, pumping, discharge related to springs, and evapotranspiration
13 (movement of water directly to air from ground surface and from plants).

14 Following the hierarchical delineation by the USGS, the DVRFS is divided at the largest scale
15 level into three subregions (Belcher and Sweetkind, 2010). The proposed repository site at
16 Yucca Mountain is in volcanic tuff and lies above part of the large volcanic aquifer in the
17 Central Death Valley Subregion (Figures 2-1 and 2-3). As discussed in the subsequent
18 sections, this Subregion contains the aquifers likely to be affected by contaminants released
19 from the repository. Some small portion of groundwater flow from beneath Yucca Mountain may
20 enter the Southern Death Valley Subregion to the south and east. The third subregion, to the
21 west and north of the Central Death Valley Subregion, is the Northern Death Valley Subregion,
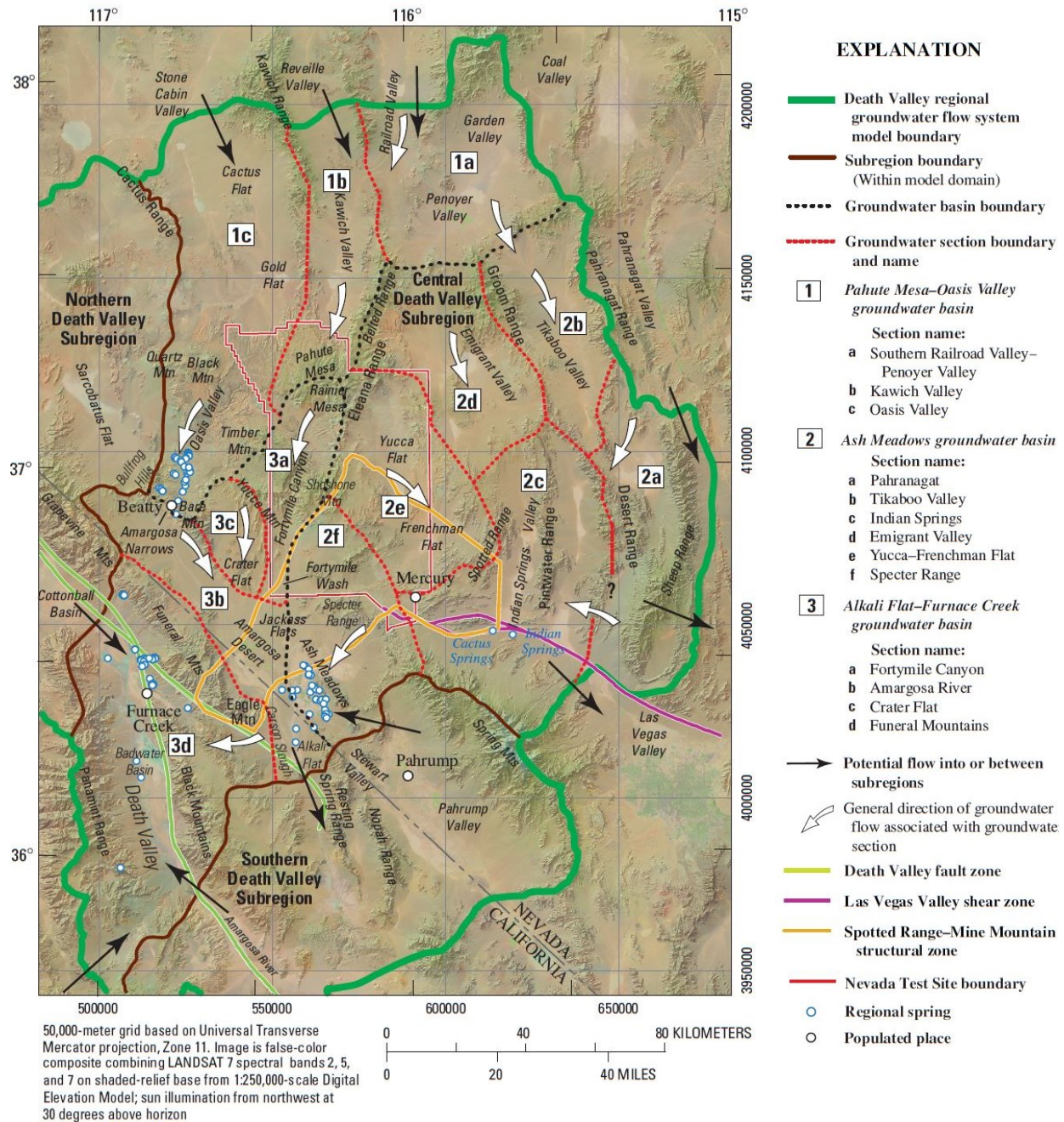
Figure 2-3. Death Valley Regional Groundwater Flow System (Outline in Green) with Further Delineations of Central Death Valley Subregion (Brown Line) Showing Basins (Black Dotted Lines), Numbered Sections (Numbered and Red Lines), and Flow Directions. Taken From Belcher and Sweetkind (2010; Figure D–7).

1

1 and is not affected by flow from beneath Yucca Mountain. The subregions are further
2 subdivided into basins, which themselves are subdivided into sections. Yucca Mountain falls in
3 the Fortymile Canyon Section, which is part of the Alkali Flat-Furnace Creek Basin, which is part
4 of the Central Death Valley Subregion, as shown in Figure 2-3.

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

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

11 **2.2.2   Aquifers Along the Flow Path From Yucca Mountain**

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

24 The flow system that passes below
25 Yucca Mountain trends southward along
26 Fortymile Wash in the Fortymile Canyon
27 Section (Figure 2-3). Beyond the regulatory
28 compliance location, it merges with
29 east-southeast flow in the Amargosa Desert
30 and continues south towards
31 Amargosa Farms. The next sections of this
32 chapter provide descriptions of the
33 groundwater flow path in the
34 Amargosa Farms area of the southcentral
35 portion of the Amargosa River Section, and

> **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).

36 between the Amargosa Farms area and Death Valley, predominantly westward through the
37 carbonate aquifer at the eastern Funeral Mountains (the Funeral Mountain Section of the flow
38 path). In addition, the potential, minor flow from Amargosa Farms to Alkali Flat is also
39 described. As discussed in the sections below, particle tracking analysis using the DVRFS
40 model indicates the possible pathways for contaminants from a repository at Yucca Mountain
41 past the Amargosa Farms area are westward through the Funeral Mountains to Death Valley, or
42 along the Amargosa River course to discharge at Alkali Flat.

1 **Fortymile Canyon Section**

2 The first portion of the flow path is in the Fortymile Canyon Section (Figure 2-3; labeled 3a). As
3 described in the 2008 SEIS, infiltrating water at Yucca Mountain passes through the
4 unsaturated zone, reaches the uppermost volcanic aquifer, and then flows east to southeast to
5 join the larger volume of groundwater flowing southward along Fortymile Wash towards
6 Amargosa Desert. The first part of this flow path is within the volcanic aquifer. Flow in these
7 volcanic rocks occurs predominantly in networks of fracture and fault zones. Along Fortymile
8 Wash, the strata (layers) of the volcanic aquifer thin and transition into the sediments of the
9 alluvial aquifer. The groundwater then exits the fractured volcanic tuffs and enters the relatively
10 unconsolidated granular porous media of the alluvial aquifer. This transition occurs in the
11 vicinity of the Highway 95 fault (a poorly-expressed west-northwest striking high-angle fault
12 zone that occurs just south of the southern boundary of NNSS, as shown in Figures 2-1 and
13 2-3, near the label "Jackass Flats"). The Highway 95 fault appears to be the southern boundary
14 of the volcanic aquifers, based on a fault zone geometry inferred from borehole and geophysical
15 data (DOE, 2008a; Nye County NWRPO, 2009). The fault juxtaposes fractured volcanic rocks
16 on the north side with less permeable alluvial sediments on the south side. Nye County
17 investigators proposed that contact with the less permeable alluvial sediments causes the
18 southward groundwater to flow up into an overlying alluvial aquifer system, which continues
19 to the Amargosa Desert (Nye County NWRPO, 2009). Hydraulic measurements conducted
20 by DOE and Nye County support a slight upward gradient in the alluvial aquifer (DOE, 2008a;
21 p. 3-33), which, when combined with the stratified alluvial sediments, indicates that a
22 groundwater plume emanating from Yucca Mountain would remain in the upper portion of the
23 uppermost alluvial aquifer in the Amargosa Desert. The transition from the Fortymile Canyon
24 Section to the Amargosa River Section coincides approximately with the regulatory compliance
25 location {approximately 18 km [11 mi]} along the flow path from the proposed repository site. In
26 this area, distributed recharge occurs in mountainous areas and focused recharge from
27 intermittent streamflow occurs in smaller washes. Losses from the aquifer are predominantly by
28 evapotranspiration.

29 **Amargosa River Section**

30 The next portion of the flow path is in the Amargosa River Section (Figure 2-3; labeled 3b). The
31 groundwater flow path from Yucca Mountain goes southward from Fortymile Wash into the
32 Amargosa Desert. Groundwater geochemical data indicate that the flow paths within the alluvial
33 aquifer of Fortymile Wash are readily identifiable along the length of Fortymile Wash and
34 southward across the Amargosa Desert (Figure 2-4) (Kilroy, 1991; SNL, 2007a).
35 Amargosa Farms is a small farming community which occupies the area where the alluvial fan
36 (a fan- or cone-shaped deposit of sediment built up by streams) from Fortymile Wash meets the
37 broad, dry Amargosa River bed in the Amargosa Desert, south of the regulatory compliance
38 location along the Yucca Mountain flow path (Figure 2-1). The Amargosa Farms area is not a
39 hydrographic area defined on Figure 2-3; it lies within the southcentral portion of the
40 Amargosa River Section. At present, extensive groundwater pumping for irrigation and
41 drinking water occurs in Amargosa Farms. Groundwater withdrawal contributes more to
42 losses within the Amargosa River Section than evapotranspiration. Groundwater
43 pumping, mostly in the Amargosa Farms area, has been on the order of 17,600 acre-ft/yr
44 [21.7 million m^3/yr] for the past several decades (DOE, 2014a, Table 2-1; NDWR , 2015). By
45 comparison, evapotranspiration losses from the Amargosa River Section were estimated to be
46 1,350 acre-ft/yr [1.67 million m^3/yr] (DOE, 2014a, Table 2-1). Due to groundwater pumping from
47 1952 to 1987, the maximum drawdown of the water table was more than 9 m [30 ft] over a
48 region more than 10 km [6 mi] across, east to west, centered on the irrigation wells distributed
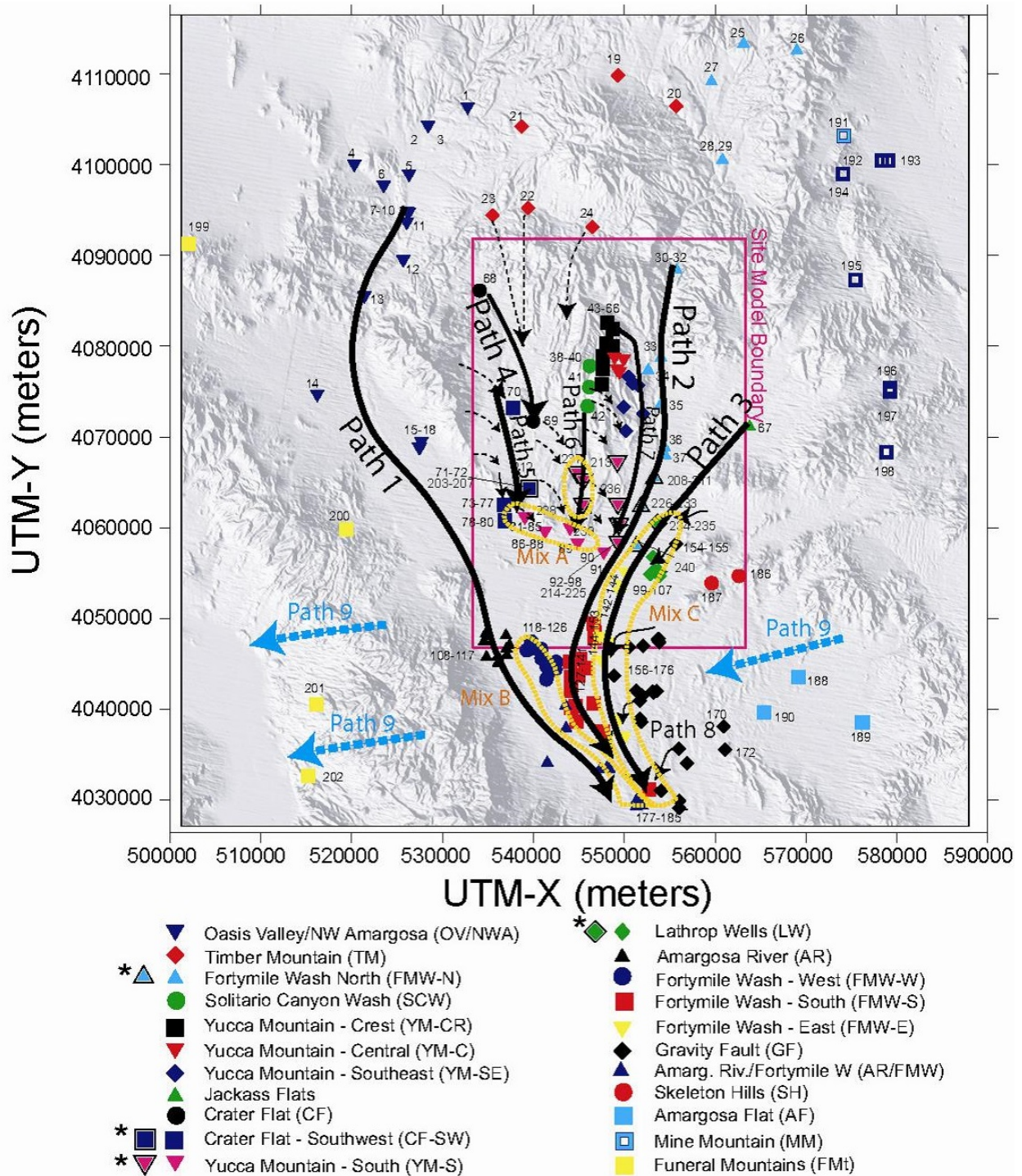
Figure 2-4. Groundwater Flow Paths Inferred From Groundwater Geochemical Analyses (From SNL, 2007a, Figure B6-15). Flow Path 2, Which Merges With Flow Path 7, Represents the Direction of Flow From Yucca Mountain. Flow Path 2 and Flow Path 1 (Amargosa River) Converge Near the Location of the State Line Deposits.

1

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

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

32 West of Ash Meadows, there is a steep hydraulic gradient coincident with the north-south
33 trending high-angle fault between the alluvial sediments of Amargosa Farms and the carbonate
34 rock exposed at the ground surface in Ash Meadows (Belcher and Sweetkind, 2010). All of the
35 present-day springs in Ash Meadows are in the area of the carbonate rocks. The surface
36 exposure of carbonate rocks in Ash Meadows is in sharp contrast to the hydrologic conditions in
37 the central portion of Amargosa Desert, where the carbonates are present far below the thick
38 sequence of alluvial sediments. The steep hydraulic gradient across the north-south trending
39 fault indicates little mixing of carbonate waters to the east with alluvial aquifer waters to the west
40 in the present-day climate. Given the direction of the hydraulic gradient, any connection
41 between the uppermost and underlying aquifers in this area is likely to be flow from the
42 carbonate aquifer of Ash Meadows to the alluvial aquifer in the Amargosa Farms area. Further
43 south, the waters of the two aquifers likely mix in the area between the Nevada-California state
44 line and Alkali Flat (Figure 2-3). This is because the north-south trending high-angle fault
45 appears to end further south near the Nevada-California state line (Belcher and Sweetkind,
46 2010; Figure B-26).

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

---

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).

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

12 Analysis of potential flow beyond Amargosa Farms, using a modification of the DVRFS model,
13 indicates that in the absence of pumping in Amargosa Farms over the last century, the flow path
14 would dominantly trend to the southwest under the eastern end of the Funeral Mountains
15 (DOE, 2014a). The model used was based on Belcher and Sweetkind (2010), modified to
16 include pumping data from 1913 to 2003 (SNL, 2014). Flow pathways can be identified in the
17 model by releasing nominal "particles" at the regulatory compliance location and tracking their
18 movement within the DVRFS. Adsorption, colloidal filtering, decay, or other mechanisms that
19 would preclude the particles from moving with the water are not included in this analysis, so the
20 particle tracking represents unrestrained movement of water-borne contaminants. In the model
21 runs, 8,024 particles were released and tracked from the regulatory compliance location. The
22 8,024 particles were derived from the release of 10,000 particles at repository locations in the
23 Yucca Mountain Site-Scale Flow Model (SNL, 2009). The NRC staff has found DOE's model for
24 saturated zone flow in the vicinity of the repository and its integration of the multiple models to
25 be acceptable as part of its safety evaluation (NRC, 2014a; Section 2.2.1.3.8).

26 When historic data for pumping are considered in the DVRFS model, all particles are captured
27 by the wells in Amargosa Farms. When no pumping is included (the prepumping model,
28 representing groundwater conditions prior to 1913), two pathways were identified (DOE, 2014a).
29 The predominant path identified was approximately southward through Amargosa Farms and
30 turning southwestward to westward beneath the Funeral Mountains to the springs at Furnace
31 Creek and on to Middle Basin in Death Valley (DOE, 2014a, Figure 3-1). A potential alternative,
32 but less likely, path was identified by 2 particles (out of the 8,024 particles) that traveled
33 southward to and discharged at Alkali Flat (DOE, 2014a, Figure 3-2). The flow path of the few
34 particles tracked to Alkali Flat arises from the uncertainties in the model parameters, and may
35 represent the possibility that a limited amount of water diverts from the predominant pathway.
36 The particle tracking approach is a recognized method for understanding contaminant transport
37 in hydrologic models (e.g., Faunt, et al., 2010b). The NRC staff concludes that the use of
38 particle tracking in the DVRFS model is a reasonable means of defining the potential paths that
39 contaminants may follow, consistent with the flow fields of the DVRFS. Further information on
40 the particle tracking model is given in Appendix A to this supplement.

41 The groundwater flow path from Amargosa Farms southwest through the Funeral Mountains
42 continues towards the springs near Furnace Creek and to Middle Basin in Death Valley. The
43 likelihood of flow through the carbonate blocks at the southeastern end of the Funeral
44 Mountains was identified through research conducted by the USGS (Belcher and Sweetkind,
45 2010) and Inyo County (2007); (Bredehoeft, et al., 2008), which defined the relatively permeable
46 carbonate units within the Funeral Mountains.

1   The likelihood of this southwesterly flow path differs from that identified in earlier DOE analysis
2   (2008 SEIS; p.3-31), which indicated that the majority of the water moved instead to the south
3   from the Amargosa Farms area, generally following the trace of the Amargosa River and
4   discharging at Alkali Flat, but did not include the presence of highly transmissive carbonate units
5   beneath the Funeral Mountains. Flow conditions in the absence of pumping in Amargosa
6   Farms are not well characterized, so some possible flow towards Alkali Flat cannot be excluded.
7   This alternate flow path is described further in the subsection on Alkali Flat and the Southern
8   Death Valley Subregion.

9   **Funeral Mountain Section**

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

21   The geochemistry of water at the Furnace Creek springs is similar to that at the springs of Ash
22   Meadows, and to that of the regional carbonate aquifer generally (DOE, 2014a; 2008a). The
23   chemistry of the water at the springs appears to have equilibrated (i.e., reflects the mineral
24   content of) with the surrounding carbonate rock as indicated by the calcium, magnesium, and
25   bicarbonate composition in the water. Further similarity of water discharging from the Furnace
26   Creek springs to water discharging at Ash Meadows is shown in their content of rare earth
27   elements (Johannesson, et al., 1997). In addition, strontium isotope measurements also
28   indicate that the groundwater interacted with older metamorphic or igneous rocks (Levich, et al.,
29   2000) in the central part of the Funeral Mountains. Furthermore, information from
30   potentiometric and structural geology maps and water temperature measurements also support
31   groundwater in the eastern regional carbonate aquifer flowing westward through Ash Meadows,
32   under the southern part of the Amargosa Desert and the eastern end of the Funeral Mountains,
33   to the springs at Furnace Creek. Geochemical and other data are consistent with the
34   interpretation that under present pumping conditions at Amargosa Farms, the Furnace Creek
35   springs do not include a significant component of water from the alluvial aquifer in that area.
36   The data from the Furnace Creek springs are also consistent with water from the alluvial aquifer
37   mixing with a larger volume of water flowing in the carbonate aquifer, or water that has
38   equilibrated with the carbonate rocks of the Funeral Mountains.

39   Evapotranspiration causes a much larger amount of groundwater loss than spring discharge in
40   the Funeral Mountain Section. Three large springs (Texas, Travertine, and Nevares) at Furnace
41   Creek together have a discharge of 2,300 acre-ft/yr [2.8 million m^3/yr] (DOE, 2014a; Table 2-1).
42   The annual estimate of evapotranspiration for the Funeral Mountain Section is approximately
43   10 times larger than this spring discharge (DOE, 2014a; Table 2-1). There is also a small
44   amount of groundwater pumping in the Funeral Mountain Section, but this pumping does not
45   occur near the groundwater flow path from Yucca Mountain, and thus does not impact the path
46   for potential contaminants.

1 **Alkali Flat and Southern Death Valley Subregion**

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

8 Based on the modeling results (DOE, 2014a), contaminant transport along the flow path beyond
9 Alkali Flat is unlikely. Past Alkali Flat, the groundwater flow path follows the trace of the
10 Amargosa River southward through the Shoshone-Tecopa Section and California Valley Section
11 of the Southern Death Valley Subregion, and then continues along the Amargosa River as it
12 turns westward through the Ibex Hills Section. Small, intermittent springs occur along the
13 predominantly dry Amargosa River in this section, although portions of the river are perennially
14 wet due to springs in the California Valley Section. Groundwater not lost to evapotranspiration,
15 the springs along the river, or pumping from two wells near the town of Tecopa, continues to the
16 flow path's endpoint at Badwater Basin, the lowest-elevation playa and salt pan in Death Valley.

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

25 In the Shoshone-Tecopa, California Valley, and Ibex Hills Sections, more groundwater is lost
26 through evapotranspiration {12,350 acre-ft/yr [15.2 million m^3/yr]} than through pumping
27 (DOE, 2014a; Table 2-1). Wells in these areas extract only on the order of 27 acre-ft/yr
28 [0.033 million m^3/yr] of groundwater (DOE, 2014a; Table 2-1).

29 ## 2.2.3   Effects of Groundwater Pumping on Flow

30 In the 2002 EIS and 2008 SEIS, DOE provided a discussion of pumping in the DVRFS with
31 additional detail for the Amargosa Desert. In the 2008 SEIS, DOE reported pumping rates
32 based on irrigation estimates generated by the Nevada Division of Water Resources [(NDWR),
33 see LaCamera, et al., 2005)]. Analyses in this supplement use pumping rates from DOE
34 (2014a), which were generated by the USGS using a different approach for estimating irrigation
35 (Moreo and Justet, 2008) that led to somewhat higher estimates of pumping rates. For
36 example, for the period from 1994 to 2003, the pumping rates in the Amargosa Desert
37 estimated by the NDWR are 72 to 84 percent of those estimated by the USGS. The different
38 methods are described further in Section 2.4 (Groundwater Modeling). This section of the
39 supplement provides a brief description of pumping rates for all water uses in the DVRFS,
40 including the updated rates provided in DOE (2014a).

41 **Groundwater Pumping in DVRFS**

42 Significant pumping in the region started in 1913 and increased from the 1940s to 1960s. The
43 pumping rates varied at approximately the same levels from the 1970s to the present-day for

1   the DVRFS (Moreo and Justet, 2008; Figure 2). There are three major groundwater pumping
2   areas within the DVRFS: Amargosa Valley, Pahrump Valley, and Penoyer Valley. In
3   Amargosa Valley, an average of 16,800 acre/ft [20.7 million m^3] of groundwater was withdrawn
4   annually from 1994 to 2003, of which 85 percent was used for irrigation and 13 percent was
5   used for mining, domestic, and commercial purposes. Annual pumping variations are
6   generally a result of crop and irrigation cycles. In Pahrump Valley, the largest groundwater
7   withdrawal area in the DVRFS, annual pumping estimates ranged from approximately 20,000 to
8   33,000 acre-ft [25 to 41 million m^3] from 1994 to 2003. Compared to Amargosa Valley, a larger
9   fraction of the pumped water in Pahrump Valley was used for domestic purposes and the public
10   water supply, rather than agriculture. Water used for irrigation ranged from approximately
11   50 percent to 75 percent during the period 1993 to 2003, and this fraction decreased over time.
12   Groundwater withdrawal in the Penoyer Valley (northeastern portion of DVRFS, outside of
13   the area that influences groundwater flow from beneath Yucca Mountain) was about
14   12,600 acre-ft/yr [15.5 million m^3/yr] and was used primarily for irrigation with the pumping rate
15   holding relatively steady from 1994 through 2003. Over the entire DVRFS for 2003, about
16   55,700 acre-ft [68.7 million m^3] of groundwater was pumped, of which 69 percent was used for
17   irrigation; 13 percent for domestic; and 18 percent for public supply, commercial, and mining
18   activities (Moreo and Justet, 2008). Comparable data for the entire DVRFS for more recent
19   years are not readily available, but the available records for the area from the State of Nevada
20   Division of Water Resources suggest that these volumes and fractions have not changed
21   significantly (NDWR, 2015).

22 **Groundwater Pumping in Amargosa Valley**

23   Historically, agricultural irrigation used 80 percent of annual groundwater withdrawal in
24   Nye County, Nevada, which includes both Pahrump and Amargosa Valleys. Domestic and
25   mining water supplies used the majority of the remaining 20 percent (DOE, 2014a). Outside of
26   Pahrump Valley, the primary irrigation area is Amargosa Farms, in the south-central portion of
27   Amargosa Valley. In the Amargosa Valley, total annual groundwater withdrawals averaged
28   16,800 acre-feet [20.7 million m^3] from 1994 through 2003, with a minimum and maximum of
29   14,100 and 21,100 acre-ft [17.4 and 26 million m^3] (Moreo and Justet, 2008). Estimates of
30   pumping rates since 2003 are available from the State of Nevada's Division of Water
31   Resources (NDWR, 2015). For Amargosa Valley[2], the State of Nevada estimates of
32   groundwater withdrawal rates from 2006 to 2012 range from 15,400 to 18,000 acre-ft/yr
33   [19 million to 22.2 million m^3/yr] with an average of 16,700 acre-ft/yr [20.6 million m^3/yr].

34   In its 2008 SEIS and in DOE (2014a), DOE suggested that present-day pumping rates for the
35   Amargosa Farms areas may not be sustainable due to proximity to Devils Hole and the potential
36   impact of pumping on water levels there. As DOE described in its 2002 EIS and 2008 SEIS,
37   strict limits on groundwater withdrawal in the Ash Meadows area have been instituted to protect
38   the water level in Devils Hole and the endangered Devils Hole pupfish. Withdrawals from within
39   Ash Meadows are a very small portion (less than 1 percent) of the total withdrawals from the
40   Amargosa Desert Hydrographic Basin (DOE, 2008a). Information provided at a State of
41   Nevada administrative hearing in 2007 (Taylor, 2008) showed that the water level in Devils Hole
42   was within 0.7 ft [0.2 m] of the minimum threshold. Accordingly, the Nevada State Engineer
43   issued an order (Taylor, 2008) that would deny any water rights applications within 25 mi

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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.

1 [40 km] of Devils Hole, and any change applications that place the point of diversion to within
2 25 mi [40 km] of Devils Hole (with some exceptions). This 25-mi [40 km] radius encompasses
3 the Amargosa Farms area. The State Engineer's order essentially limits future pumping rates in
4 areas beyond Ash Meadows that may impact Devils Hole. These restrictions may also render
5 the present-day pumping rates at the Amargosa Farms area unsustainable, as further analysis
6 (SNL, 2009) indicates that the protected water level at Devils Hole could be reached by 2016,
7 assuming only the continuation of current groundwater pumping.

8 2.2.4   Past and Future Climates

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

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

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

31 These reconstructions of past climate states are the best indicators of expected future climates.
32 Using paleoclimate reconstructions as a basis, DOE has defined three climate states in addition
33 to the present-day interglacial climate that are expected to occur over the next million years
34 (DOE, 2008b, Section 2.3.1). These are (i) a monsoonal climate that is warm and wetter
35 compared to the present-day interglacial climate, with a shift in the seasonality of precipitation;
36 (ii) a glacial-transition climate with cooler and wetter conditions compared to the present-day
37 climate; and (iii) a full-glacial climate, which represents the maximum extent of cool conditions
38 recorded in paleorecords. DOE included the interglacial, monsoonal, and glacial-transition
39 climate states in its performance assessment for the repository over the first 10,000 years
40 following permanent closure, and used a prescribed deep percolation rate (the amount of
41 water reaching the repository) for the remainder of the one million year period, as provided in
42 10 CFR 63.342 (DOE, 2008b, Section 2.3.1.2). The NRC staff found DOE's model for future
43 climate states to be acceptable as part of its safety evaluation (NRC, 2014a; Section 2.2.1.3.5).

44 For this supplement, the most significant considerations for groundwater are the overall flow
45 paths and flow rates, and potential changes in the water table that could affect locations of

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

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

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

38 Presently available information about human-induced climate change from the release of
39 greenhouse gases indicates that, for this region, the most notable effects on groundwater would
40 be increased heat and aridity in the near term, and over longer term, potentially extending the
41 duration of the present-day interglacial climate (hot and dry) for longer than it would persist in
42 the absence of human-induced change (e.g., Garfin, et al., 2014). The principal effects of a
43 climate that is warmer and drier than the present-day climate is to delay the release and
44 transport of contaminants from a repository. This is because releases depend on water entering
45 the repository by infiltration and percolation, and transport depends on the amount and rate of
46 water flow through the unsaturated and saturated zones (DOE, 2008b, Enclosure 8;
47 NRC, 2014a, Section 2.2.1.3.5). Therefore, the impacts from potential human-induced climate

1   change are captured within the range of conditions for climate and water use considered in
2   this supplement.

3   ## 2.3   Surface Discharge Environments

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

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

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

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

1 **2.3.1   Ecology at Surface Discharge Sites**

2   The region south of Yucca Mountain, where the surface water discharge locations discussed in
3   this supplement are located, is within the Mojave Basin and Range ecoregion (Bryce, et al.,
4   2003; Griffith, et al., 2011;). The Mojave Basin and Range ecoregion is composed of broad
5   basins and scattered mountains that are generally lower, warmer, and drier than those of the
6   Central Basin and Range located north of the Mojave Basin and Range ecoregion (north of
7   Beatty, Nevada). The broader Mojave Basin and Range ecoregion is further subdivided into
8   smaller ecoregions: State Line/Franklin Well, Ash Meadows, and Alkali Flat, which are located
9   within the Amargosa Desert ecoregion, and Furnace Creek Springs and Middle Basin, which
10 are located within the Death Valley/Mojave Central Trough ecoregion (Bryce, et al., 2003;
11 Griffith, et al., 2011).

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

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

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

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

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

25 **2.3.2   Cultural Resources at Surface Discharge Sites**

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

1   The affected environments considered in this supplement are outside of the nominally
2   controlled area considered by DOE in its previous assessments, and could include historic and
3   cultural resources. For example, members of the Timbisha Shoshone Tribe reside on a
4   314-acre [1.27-km^2] parcel of trust land located in the Furnace Creek area of Death Valley,
5   near Furnace Creek springs. As previously noted, the tribe has federally appropriated rights
6   to 92 acre-feet per year [0.113 million m^3/yr] of surface and groundwater in the area
7   (DOE, 2014a; 16 U.S.C. 410aaa). Section 3.3 is the NRC staff's consideration of impacts on
8   cultural resources.

9   ## 2.3.3   Present-Day Discharge Sites

10   This section describes present-day sites of natural surface discharge near or along the flow path
11   from Yucca Mountain to Death Valley in terms of the groundwater flow pathways discussed in
12   Section 2.2. Table 2-1 provides annual estimates of surface discharge for six different areas
13   discussed in the text. Figure 2-5 shows the locations discussed in the text.

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

19   **Discharge Locations along the Flow Path Southwest from Amargosa Farms**

20   The springs at Furnace Creek in Death Valley (Figure 2-5) discharge groundwater that has
21   flowed under the Funeral Mountains. The springs in the Furnace Creek area appear to be
22   controlled by major structural features (Fridrich, et al., 2012). The Texas, Travertine, and
23   Nevares Springs at Furnace Creek are surrounded by shrubs and grasses. The discharge is
24   predominantly a calcium-magnesium-bicarbonate water reflective of the regional carbonate
25   aquifer. Engineered structures have been built at several of the Furnace Creek springs to
26   manage the water for use in Death Valley. Section 2.5.1 provides more information on
27   water use.

28   Middle Basin (Figure 2-5) is a local low point in Death Valley that is down gradient from Furnace
29   Creek. Groundwater that does not discharge at the three Furnace Creek springs, or that
30   re-infiltrates after discharging from the springs, flows down an alluvial fan to the salt pan at
31   Middle Basin. Along the alluvial fan, there are numerous small springs surrounded by a variety
32   of desert shrubs, trees, and grasses. Direct evaporation occurs in the salt pan at the bottom of
33   the alluvial fan. As a salt pan, Middle Basin is a low point or depression in the ground in which
34   saline water has evaporated, leaving salt deposits.

35   **Discharge Locations along the Flow Path South from Amargosa Farms**

36   Alkali Flat, also known as the Franklin Lake Playa, is a broad area south of Amargosa Farms
37   along the dry bed of the Amargosa River (Figure 2-5). Deposits at the site reflect intermittent
38   spring discharge and wet and dry playas (Reynolds, et al., 2007). Salt pan, soft and fluffy wet
39   playa deposits, and hard and compacted dry playa deposits are distributed near or intermixed
40   with channel deposits at the confluence of Carson Slough (an ephemeral stream that
41   intermittently flows south from Ash Meadows) and the Amargosa River. The present-day water
42   table at Alkali Flat varies from 0 to 4 m [0 to 13 ft] below the ground surface. Water is supplied

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	—

1   to the flat from Ash Meadows along Carson Slough and from the Amargosa River. Surface
2   discharge is dominated by loss to evaporation and, to some extent, transpiration by scattered
3   low scrub vegetation, although intermittent surface flow can occur during brief wetter periods
4   such as major rainfall events (e.g., Beck and Glancy,1995; Tanko and Glancy, 2001). Surface
5   water in the wet playa portion primarily flows off the playa and continues along the
6   Amargosa River bed (Reynolds, et al., 2007); little standing water has been observed in this
7   area. Chemistry of the water varies widely, from dilute to highly saline. Water in the thin alluvial
8   sediments is confined to those sediments. Two springs in the northern part of the flat have
9   relatively dilute water; water emanating from a well and from a spring have 1,000 mg/l [ppm]
10 and <5,000 mg/l [ppm], respectively, of total dissolved solids. By contrast, total dissolved solids
11 reaches 80,000 mg/l [ppm] in water from the wet playa portions of the flat. The water at Alkali
12 Flat is of insufficient quantity and too saline to be of beneficial human use (Czarnecki and
13 Stannard, 1997).

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

20 The Shoshone and Tecopa portions of the Amargosa River, south of Alkali Flat, are perennial
21 under the present-day climate (Menges, 2008). Water that does not discharge at Alkali Flat
22 flows in the alluvial sediments of the Amargosa River valley. The quantity of groundwater
23 discharge is sufficient to maintain a flowing river year-round for a short stretch near Shoshone
24 and a longer stretch {about 8 km [5 mi]} south of Tecopa.

25 **Other Discharge Locations in the Amargosa Farms Area**

26 Evidence of paleosprings in the Amargosa Farms area is found in the State Line Deposits,
27 which extend southward from the Amargosa Farms area and span a section of the dry
28 Amargosa River bed. The surface exposures of these deposits consist of a complex distribution
29 of Holocene playa sediments and older freshwater limestone rocks interspersed with channel
30 and alluvial fan deposits (Kilroy, 1991). At present, this area is not likely to have significant
31 water loss by evapotranspiration, as described in Belcher and Sweetkind (2010, Chapter C),
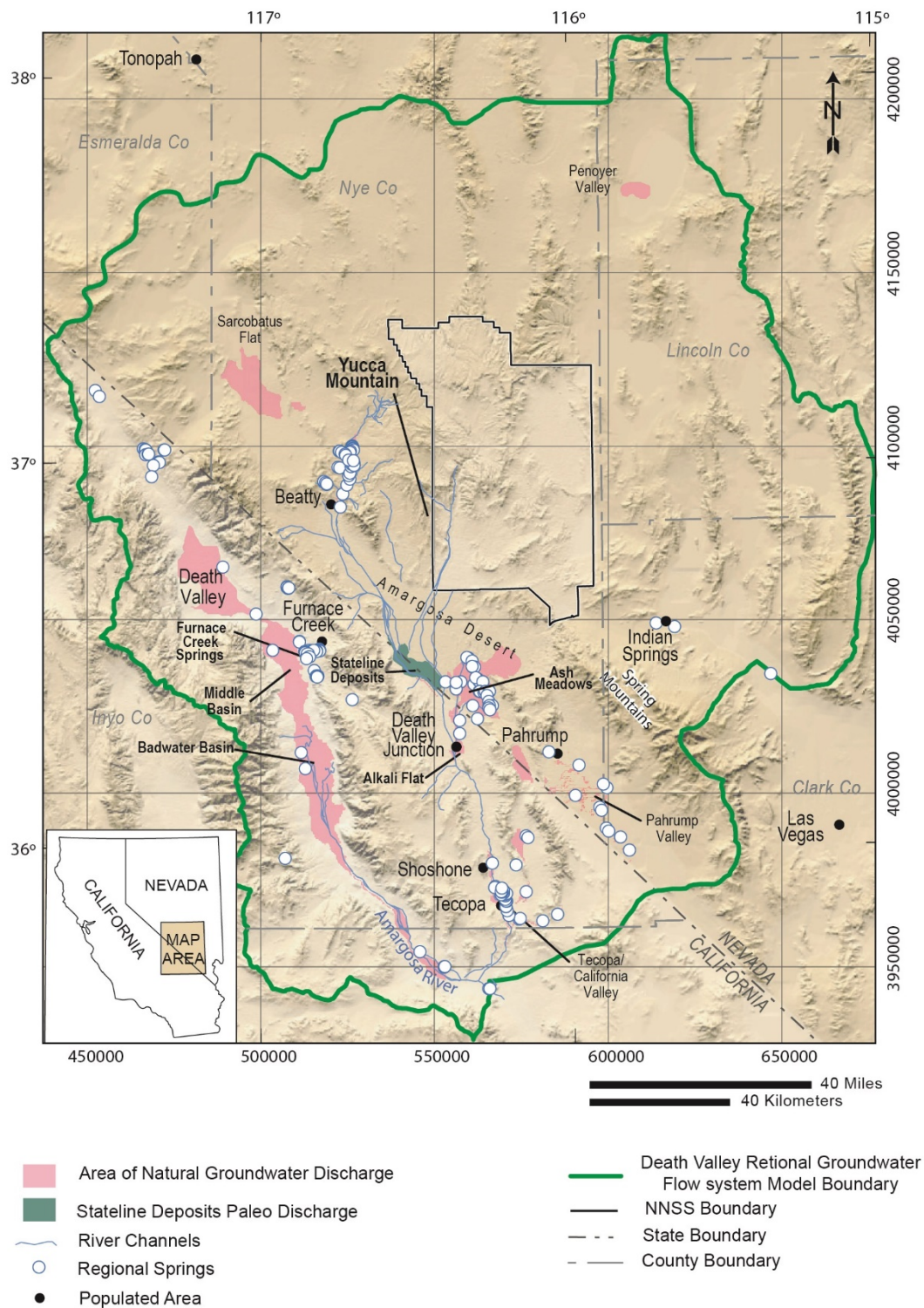
Figure 2-5. Location of Natural Groundwater Discharge Areas, Including Springs and Playas, in the Death Valley Regional Groundwater Flow System. Modified From Belcher and Sweetkind (2010).

1   except for the limited Franklin Well area, as discussed below. The water table in the State Line
2   Deposits area varies from 1.8 to 10 m [6 to 33 ft] below the surface, based on well
3   measurements from the 1980s (Kilroy, 1991; Paces and Whelan, 2012). The water table is
4   closest to the ground surface immediately to the southwest of the deposits, in the vegetated
5   Franklin Well area. In the area of the State Line Deposits, the water table depth is within the
6   range of a potential wet playa environment. Groundwater drawdown from pumping in the
7   Amargosa Farms area over the last century may have extended to parts of the State Line
8   Deposits area, and thus, in the absence of pumping at Amargosa Farms, evaporation may
9   occur over a larger area in the State Line Deposits wherever the water table is within 5 m [16 ft]
10 of the ground surface (following the delineation by Reynolds, et al., 2007). The State Line
11 Deposits area could be a potential minor discharge location for water flowing from
12 Yucca Mountain under the present-day climate (or in a future cooler/wetter climate), but only if
13 pumping in the Amargosa Farms area is significantly reduced. However, there is no evidence of
14 recent springs in the State Line area, and the youngest dated State Line spring deposits formed
15 approximately 30,000 years ago (Paces and Whelan, 2012).

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

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

32 **Ash Meadows**

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

42 Ash Meadows is a well-studied desert wetland ecosystem encompassing over 23,000 acres
43 [93 km^2] of spring-fed wetlands surrounded by sparse, relatively dry grassland interspersed with

1   sparse to moderately dense stands of trees and shrubs (Belcher, et al., 2012). According to
2   Laczniak, et al. (1999, pp. 7–8):

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

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

21 **2.3.4   Paleodischarge Sites**

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

27 Evidence of paleodischarge sites found in Amargosa Desert and across the DVRFS serve both
28 to identify possible future discharge locations and to constrain the potential increases in the
29 elevation of the water table. These sites provide calibration targets[3] for groundwater flow
30 models and are useful in identifying or precluding other potential discharge sites. Notably,
31 results of numerical groundwater modeling, as discussed in Section 2.4, suggest that even
32 though flow rates and discharge locations may vary, the flow path does not significantly change
33 between drier and wetter periods.

34 **Amargosa Desert Sites**

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

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

1   As described in Section 2.2.2, the State Line Deposits area (Figure 2-5) falls directly along the
2   path of groundwater flowing from Yucca Mountain (DOE, 2014a). Observations from the
3   discharge deposits show a complex interplay of surface flow and spring discharge in the
4   southern part of the Amargosa Desert (Belcher and Sweetkind, 2010). The discharge deposits
5   indicate that the groundwater generally reflects the mineral content of the volcanic-derived
6   alluvial sediments of Amargosa Valley. The deposits also indicate contributions from (i) the
7   lower carbonate aquifer, as indicated by the freshwater limestone deposits and (ii) older
8   metamorphic rocks to the south in the Funeral Mountains, as indicated by the strontium isotopic
9   composition (Paces and Whelan, 2012; Paces, et al., 1997). Based on the areal distribution of
10   discharge deposits at the ground surface and at depth, and the present-day topography, the
11   water table rise in a cooler/wetter climate would likely be no more than 30 m [98 ft] in this part of
12   the southern Amargosa Desert (Paces and Whelan, 2012). Information from the fossils,
13   mineralogy, and stratigraphy (relative relations of the rock layers) indicates that these ancient
14   discharge sites existed in a diverse wetland environment fed by springs and perennial or
15   seasonal flow along the Amargosa River (Paces and Whelan, 2012). This wetland environment
16   included wet ground, seeps, marshes, flowing channels, and open pools. Surrounding areas
17   supported phreatophyte (deep-rooted) vegetation with associated discharge by
18   evapotranspiration. Isotopic dating of the deposits indicates that the springs were active at
19   several times during the transition into the last glacial maximum, with measured ages of roughly
20   100,000 and 40,000 years before present.

21   Several small areas of paleodischarge deposits, marked in Figure 2-5, occur northeast of the
22   State Line Deposits, but west of Ash Meadows. These are much more limited in extent and
23   have not been studied in as much detail as the State Line Deposits. Given their locations, these
24   deposits are more likely related to groundwater from Ash Meadows during past wetter climates,
25   rather than the southward flowing volcanic-alluvial aquifer system in Fortymile Wash. The
26   present depth-to-water table at this location is greater than the possible water table rise in the
27   alluvial aquifer during wetter climate conditions (Paces and Whelan, 2012). For these reasons,
28   these locations are not likely to represent potential future discharge sites for groundwater from
29   the Yucca Mountain flow system.

30   Three paleodischarge deposits are present at the southern end of Crater Flat (Figure 2-5), on a
31   smaller scale and with much less carbonate deposition compared to the State Line Deposits
32   (Paces and Whelan, 2012). All three deposits have geochemical signatures of water
33   equilibrated with alluvial sediments derived from tuff (volcanic rock) and a lesser amount of
34   carbonate rock (Paces, et al., 1997). Differences in the stratigraphy at the three sites, together
35   with those in the State Line Deposits area, suggest that these deposits formed in local ponds
36   and marshes, rather than in a large lake across the Amargosa Desert (Paces, et al., 1997).
37   Diatomites (deposits composed of fossil diatoms, microscopic organisms with a silica shell) are
38   present at all the Amargosa discharge sites, though only the Lathrop Wells site has a thick
39   sequence. The presence of diatomites, along with other fossils (shells of ostracodes and
40   mollusks) indicate a paleoenvironment of open water such as flowing springs, pools, and
41   wetlands (Paces and Whelan, 2012). The three Crater Flat deposits occur at elevations of
42   790 to 835 m [2,591 to 2,739 ft] (Paces and Whelan, 2012). These elevations indicate the water
43   table elevation exiting Crater Flat during the wetter periods. Nye County research wells indicate
44   that the present-day depth to the water table ranges from 8 to 31 m [2.4 to 9.5 ft] at the three
45   paleodischarge sites (Paces and Whelan, 2012). Importantly, geochemical data and age
46   determinations indicate flow at the Crater Flat paleodischarge locations was active during
47   roughly the same time periods as at the State Line location (Paces and Whelan, 2012;
48   Paces, et al., 1997), indicating that the discharge was likely related to regional climate effects.
49   However, none of the three Crater Flat sites is located along a present or past flow path from

1   Yucca Mountain, based on an analysis of the elevations and potential extent of water table rise
2   at Yucca Mountain (Paces, et al., 1997; SNL, 2007a). Instead, particle tracking model results
3   for future wetter climates indicate that flow from the northwest below Crater Flat was the likely
4   source for the Crater Flat discharge deposits (Winterle, 2005).

5   **Alkali Flat to Death Valley**

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

19   **2.3.5   Summary of Surface Discharge Environments**

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

25   **2.4   Groundwater Modeling**

26   In the 2008 SEIS, DOE provided a description of the two groundwater flow models of different
27   scales that were used to quantify flow in and around the DVRFS. The small-scale model covers
28   Yucca Mountain and southward to Amargosa Desert (the Yucca Mountain Site Scale model).
29   This model remains unchanged since 2008 in DOE (2014a). The Yucca Mountain Site Scale
30   model provides flow information for groundwater conditions near Yucca Mountain, which DOE
31   used to support its evaluation of repository performance in its SAR (DOE, 2008b). The DVRFS
32   model is the larger scale model used by DOE in its SAR; it provides information about areas
33   beyond those in the Yucca Mountain Site Scale model. As previously noted, the NRC staff has
34   found DOE's integration of the multiple models for saturated zone flow to be acceptable as part
35   of the NRC's safety evaluation (NRC, 2014a; Section 2.2.1.3.8). For its 2002 EIS and 2008
36   SEIS analysis, DOE used the DVRFS model and its representation of groundwater flow beyond
37   the regulatory compliance location and along the flow path to Death Valley. The 2008 SEIS
38   describes the DVRFS model, as documented by the USGS in Belcher (2004). The USGS has
39   since updated the documentation of the DVRFS model (Belcher and Sweetkind, 2010), but the
40   information about the model in the updated report is substantively unchanged (Belcher and
41   Sweetkind, 2010).

42   DOE used a slight modification of the Belcher and Sweetkind (2010) model in its 2014 analyses
43   (DOE, 2014a). DOE used the 2004 DVRFS model to calculate the groundwater conditions
44   (e.g., water table position) present before extensive pumping in Amargosa Farms (nominally for

1   conditions in 1913). The model input parameters were then adjusted to match the transient
2   (changing) conditions that account for groundwater pumping from the period of 1913 to 1998
3   (Belcher and Sweetkind, 2010). DOE (2014a) incorporated an expanded pumping data set from
4   Moreo and Justet (2008) that accounted for the period 1913 to 2003, to further update the
5   DVRFS model. As previously noted in Section 2.2.3, pumping records since 2003 indicate little
6   change in the past decade, so this update and analysis capture current pumping rates
7   (NDWR, 2015). This update and DOE's observations from modeling several scenarios are
8   described below, especially as they pertain to the affected environment beyond the regulatory
9   compliance location.

10   **Effects of Pumping on Groundwater Conditions**

11   As described in Section 2.2.3 (Groundwater Pumping), substantial pumping in the area began in
12   1913 and has increased markedly in the past several decades. Evaluation of groundwater
13   conditions without pumping is an important starting point for comparisons with paleorecords for
14   calibrations to account for transient conditions caused by pumping, and for analyzing the
15   groundwater impacts if no pumping were to occur in the future.

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

31   The Belcher (2004) model was first calibrated to account for steady-state groundwater levels
32   prior to 1913, before significant pumping occurred in the area of the DVRFS. This no-pumping
33   condition provides an estimate of the water table position and flow path directions in the
34   Amargosa Farms area without the water table decrease caused by pumping. The model was
35   then calibrated for transient conditions using values for water level, spring flows,
36   evapotranspiration, and pumping as they changed over time from 1913 to 1998 (DOE, 2014a).
37   The results of these calibrations were compared with measured water table positions as they
38   changed until 1998.

39   Uncertainties in future pumping rates were considered in DOE (2014a), especially concerning
40   the effect on the water level in Devils Hole and on the positive vertical gradient from the regional
41   carbonate aquifer to the overlying alluvial aquifer in the Amargosa Farms area. Using the
42   USGS DVRFS model, DOE conducted simulations of long-term pumping, up to 500 years, at
43   the 2003 groundwater pumping rates. These simulations were done both with and without an
44   additional 10,600 acre-ft/yr [13.1 million m^3/yr] of withdrawal from the lower carbonate and
45   alluvial aquifers, as proposed by the Southern Nevada Water Authority for additional supply
46   wells east of the NNSS (SNL, 2009). The modeling results suggested that the upward hydraulic

1 gradient in the lower carbonate aquifer would be maintained after 500 years of additional
2 pumping and would be within 3 percent of that predicted for no-pumping steady-state
3 conditions. Simulation results with the additional annual withdrawal quantity proposed by the
4 SNWA indicated little additional impact on water levels beyond that calculated without the
5 SNWA-proposed withdrawal (SNL, 2009). In any case, continued heavy pumping from the
6 shallow alluvial aquifers would result in an increase in the upward vertical gradient of the lower
7 carbonate aquifer in the Amargosa Desert (SNL, 2009), at least until the pumping rate triggered
8 the restrictions discussed in Section 2.2.3 regarding impacts on the water levels at Devils Hole.

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

18 **Effects of Climate on Future Flow Paths**

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

37 ## 2.5   Water Use and Quality

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

40 In the 2002 EIS and 2008 SEIS, DOE provided a description of water use and the biosphere for
41 the Yucca Mountain area and south to the regulatory compliance location, approximately 18 km
42 [11 mi] along the flow path. Beyond the regulatory compliance location, water from wells or
43 springs is used in Amargosa Farms, and Furnace Creek. Amargosa Farms and Furnace Creek
44 are along the primary flow path for groundwater from Yucca Mountain. The 2002 EIS and 2008
45 SEIS list water uses in the Amargosa Valley as irrigation, mining (mostly in western Amargosa

1   Valley), livestock, and for quasi-municipal, commercial, or domestic water supply. DOE (2014a)
2   states that water from the Furnace Creek springs (Texas, Travertine, and Nevares) is used to
3   support Death Valley National Park and the Timbisha Shoshone Tribe, which occupies several
4   hundred acres within Death Valley National Park. The springs support the commercial and
5   domestic water supplies, including a small commercial date farm.

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

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

21   ## 2.6   Analysis Cases for Assessing Impacts

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

30   •   Analysis Case 1: Pumping in Amargosa Farms for current uses at current rates

31   •   Analysis Case 2: Natural surface discharge at and downstream from Amargosa Farms
32   with limited or no pumping in Amargosa Farms

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

40   Analysis Case 2 accounts for surface discharges beyond the regulatory compliance location in
41   the case of limited or no pumping in Amargosa Farms. In this case, contaminants could reach
42   locations further along the flow path, as far as Death Valley. With little or no pumping in
43   Amargosa Farms, contaminants from a repository could discharge to the surface at areas

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.			

1   similar to the State Line Deposits or Alkali Flat, or to Furnace Creek Springs and Middle Basin in
2   Death Valley.

3   As discussed in Section 2.3.2, paleodischarge sites from water flowing beneath Yucca Mountain
4   have not been identified along the flow path upgradient from Amargosa Farms. Although the
5   future flow path is subject to some uncertainty, analyses suggest that it would not change
6   appreciably (Section 2.4). For this reason, natural discharge of contaminated water is not
7   expected between Yucca Mountain and Amargosa Farms, even under future cooler and wetter
8   climates, thus possible impacts from natural discharge are not considered for that area.

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

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

3   ENVIRONMENTAL IMPACTS

The affected environment described in Chapter 2 includes the aquifer and the surface discharge sites beyond the regulatory 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 regulatory compliance location at approximately 18-km [11-mi] distance along the flow path from the repository. At the regulatory 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 regulatory compliance location would be less than those at the regulatory 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 regulatory compliance location, but concluded that the affected environment and any impacts for areas *beyond* the regulatory 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 regulatory 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 regulatory 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 regulatory 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

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

7   In the 2002 EIS, but not in the 2008 SEIS, DOE scaled results from the regulatory compliance
8   location to account for dispersion in the groundwater system to estimate impacts 30 and 60 km
9   [19 and 37 mi] downstream from the repository. These distances from Yucca Mountain
10 approximate the distances to Amargosa Farms and to Alkali Flat, respectively. In the 2002 EIS
11 and 2008 SEIS, DOE provided chemical toxicity impacts in terms of a bounding analysis at the
12 RMEI location only for the first 10,000 years after repository closure.

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

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

27 Analysis Case 1: Pumping at Amargosa Farms

28   –   Present-day and future cooler and wetter climate states

29 Analysis Case 2: Surface Discharge Downstream of Amargosa Farms

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

32 The first analysis case assumes that the pumping rate and well distribution in Amargosa Farms
33 is comparable to the present-day and is sufficient to extract any contaminants released from the
34 repository to the groundwater system. It also assumes that the present-day pumping rates will
35 continue into the future. Both present-day climate and a future cooler/wetter climate are
36 considered in the pumping scenario of Analysis Case 1 (Section 3.1.1). The second analysis
37 case assumes that limited or no pumping occurs in Amargosa Farms and, thus, all
38 contaminants would migrate to natural discharge locations along the path from Amargosa
39 Desert to Death Valley (Section 3.1.2). Downstream natural surface discharge locations
40 considered in Analysis Case 2 include natural spring discharges in the State Line
41 Deposits/Franklin Well area, Furnace Creek, and the playa/salt pan of Middle Basin of
42 Death Valley. An additional potential flow path to surface discharge to a playa/salt pan
43 environment at Alkali Flat is also considered (see Section 2.3.3). Analysis Case 2 also

1   addresses both present-day and future cooler/wetter climates. The methods used in this
2   analysis are summarized in the next section, and described in more detail in Appendix A.

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

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

20   **Analysis Method**

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

34   The results of these calculations and impacts at each location for the analysis cases are
35   provided for 10,000 and one million years in tables and plots in the following sections. In some
36   cases, the peak values for contaminants at a given location do not occur at the 10,000- or
37   one-million-year times, due to the pattern of the releases from the repository over time and the
38   effects of sorption during transport. This is particularly apparent for some of the nonradiological
39   contaminants (e.g., nickel), where conservative assumptions in the model for release from
40   the repository and significant sorption during transport strongly affect the peak values
41   (see Figure A–1 and Appendix A for further details). Specific cases for times of peak
42   contaminant concentrations at each location are discussed in the following sections.

1   **Mass Balance Description**

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

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

16   **Impacts of Calculated Contaminant Levels**

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

20   On average, Americans receive a radiation dose of approximately 620 mrem/yr [6.2 mSv/yr]
21   (NRC, 2015c). Half {310 mrem/yr
22   [3.1 mSv/yr]} comes from man-made
23   sources of radiation, including
24   medical, commercial, and industrial
25   sources. The other half of this dose
26   comes from natural background
27   radiation, which is predominantly due
28   to exposure to radon in air.[1] In
29   general, a yearly dose of 620 mrem
30   [6.2 mSv] has not been shown to
31   cause humans any harm (NRC,
32   2015c). The natural background
33   radiation, excluding radon, for a
34   resident of Amargosa Valley is 96
35   mrem/yr [0.96 mSv/yr] (DOE 2002,
36   Table 3-30). For this supplement, a
37   total natural background radiation
38   exposure at Amargosa Farms of
39   approximately 300 mrem/yr

> **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.

40   [3.0 mSv/yr] (including radon) is used as a comparison to the estimated doses for populations at
41   affected environments along the flow path from Amargosa Farms to Death Valley.

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[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).

1   Further context for the dose values provided in this supplement is the average annual dose
2   estimated for the regulatory compliance location from the 2008 SEIS. DOE calculated
3   maximum average annual dose for the RMEI at the regulatory compliance location to be
4   0.24 mrem/yr [0.0024 mSv/yr] for the initial 10,000 years after repository closure, and the
5   maximum average annual dose one million years after closure to be 2.0 mrem/yr [0.02 mSv/yr]
6   (DOE, 2008a, Section 2.4.1). The NRC staff has found DOE's calculations to be acceptable
7   as part of its safety evaluation (NRC, 2014a, Section 2.2.1.4.1). The regulatory safety
8   standards in 40 CFR Part 197 and 10 CFR Part 63 for the RMEI are 15 and 100 mrem/yr
9   [0.15 and 1.0 mSv/yr] for the 10,000 and one million year periods, respectively.

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

17 For nonradiological chemical contaminants, impacts to human health are compared to the
18 U.S. Environmental Protection Agency (EPA) Oral Reference Dose (EPA, 1999a,b; 1997a,b;
19 1994), which is the chemical level below which no
20 detectable human health effects would occur. In this
21 supplement, uranium (U) is evaluated for both
22 radiological and nonradiological contaminants,
23 because in addition to being radioactive, it has a
24 notable toxicity as a heavy metal. For
25 nonradiological analysis, U concentrations are given
26 as a sum of the U isotopes from the radionuclide
27 calculations, since the chemical risk of U does not
28 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.

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

41 **3.1.1   Analysis Case 1: Pumping at Amargosa Farms**

42 In the 2002 EIS and 2008 SEIS, DOE provided estimates of impacts for the RMEI at the
43 regulatory compliance location. In its ADR, the NRC staff found this impact assessment for the
44 RMEI location to be acceptable for adoption (NRC, 2008a). In this supplement, impacts are
45 estimated at the nearest population center to the repository location, Amargosa Farms, which is
46 approximately 17 km [10.5 mi] beyond the regulatory compliance location, or approximately

1 35 km [22 mi] along the flow path from Yucca Mountain. Because the RMEI dose pathways
2 identified by DOE in its EISs were based on activities and lifestyles of residents in
3 Amargosa Farms, the same pathways are appropriate for the analysis of impacts at
4 Amargosa Farms in this supplement. Amargosa Farms is a community that uses groundwater
5 pumping for irrigation and for its commercial and domestic water supply. The dose pathways for
6 a resident of Amargosa Farms are external (body) exposure, inhalation, and ingestion of crops,
7 meat, and soil. Details of these pathways are described in Appendix A and in
8 DOE (2014a, Table B-2).

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

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

25 • The mass flux of radiological and nonradiological material from the repository
26   reaching wells at Amargosa Farms is calculated using the 2003 pumping rate of
27   16,828 acre-feet/year [20.7 million m^3/year] taken from Moreo and Justet (2008). This
28   pumping rate is more than five times larger than the value used in the 2008 SEIS for the
29   RMEI, which calculated contaminant concentrations based on a withdrawal rate of
30   3,000 acre-feet/year [3.7 million m^3/year].

31 • Transport in the aquifer to Amargosa Farms is calculated using a value of
32   0.00613 m/day [0.020 ft/day] for the specific discharge (flow rate) along the 17 km
33   [11 mi] path in the present-day climate (see Appendix A, Section A.1.2). For the wetter
34   climate, the specific discharge is multiplied by a factor of 3.9 (DOE, 2014a; 2008b,
35   Section 2.3.9). An average porosity in the aquifer of 0.16 is used for both climate states.

36 • Contaminated water extracted by pumping can be recycled into the aquifer through
37   irrigation and other uses, as water pumped to the surface can infiltrate, reach the water
38   table, and be pumped again (see Appendix A, Section A.2.1 for details of the irrigation
39   recycling model). The analysis in this supplement uses a value of 86 percent for the
40   recycling fraction (the amount of water pumped to the surface that reaches the water
41   table), and a value of 100 percent for the recapture fraction (the fraction of that water
42   which is then captured by pumping and returned to the surface). These values are
43   conservative in that they assume that contaminants are brought to the affected
44   environment with high efficiency. These values result in an overall factor of 0.86 for
45   contaminant recycling through well pumping, compared to the value of 0.11 used in
46   previous recycling analyses (DOE, 2014a; Kalinina and Arnold, 2013; SNL, 2007b).

1   A larger value for this factor leads to greater calculated contaminant concentrations in
2   the exposure pathways, greater estimates of dose and body intake, and greater
3   calculated values of contaminants accumulating in soils.

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

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

25 **Aquifer Environment**

26 This section describes the total amount of contaminants from the repository in the aquifer
27 environment between the regulatory compliance location and the Amargosa Farms area. This
28 amount changes over time, as contaminants are released from the repository and are
29 transported by water to the aquifer and then downstream along the flow path. The
30 concentration of these contaminants in the groundwater at Amargosa Farms is then calculated
31 from the amount of contaminants present in the groundwater, and the volume of water affected
32 by the pumping. The amount of contaminants in the aquifer, and the contaminant concentration
33 in the groundwater, represent the impacts on the aquifer.

34 The term "aquifer environment" includes both the subsurface rock (porous media, predominantly
35 alluvial sediments) and water within the pores of the rock, and is used here to include the
36 contaminants both dissolved in the water and sorbed onto the rock. The amount of the
37 contaminants in the aquifer environment between the regulatory compliance location and the
38 Amargosa Farms area, based on mass balance calculations, is provided in Table 3-1a. The
39 values in Table 3-1a result from calculating the difference between the mass of the
40 contaminants that reach the regulatory compliance location and the contaminants that
41 accumulate in the Amargosa Farms area, using values from DOE (2014a, Tables B-6 and B-7).
42 These values were calculated from the releases from the repository over time, the amounts
43 transported downstream, and the amounts retained within the aquifer by sorption on rock
44 surfaces, following the methodology used in DOE's TSPA for repository performance
45 (DOE, 2008b, Section 2.4.1). The NRC staff has found DOE's TSPA methodology to be
46 acceptable as part of its safety evaluation (NRC, 2014a, Section 2.2.1.4.1). For U and Th, a

1   combined value is reported that includes all the identified isotopes in the source term and
2   daughter products. The mass of contaminants includes the effects of radioactive decay
3   over time.

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

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

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

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

30   Table 3-2 provides concentrations of radiological and nonradiological material calculated for the
31   groundwater in the vicinity of Amargosa Farms. The concentrations are calculated by dividing
32   the mass flux to the Amargosa Farms area by the pumping rate from all wells in the area.
33   Consistent with their behavior in the overall repository performance assessment, Tc-99 and
34   I-129 are present in relatively higher quantities than other radiological contaminants because of
35   their transport characteristics (i.e., they do not sorb). The amount of U reflects its high
36   abundance in the repository waste inventory. As shown in Table 3-2, a cooler/wetter climate
37   has variable effects on the calculated groundwater concentrations at Amargosa Valley. For
38   some contaminants, a wetter climate leads to slightly higher concentrations compared to the
39   drier climate (e.g., I-129 and Tc-99 at 10,000 years), as these nonsorbing contaminants move
40   more rapidly along the flow path. In others, the calculated concentrations show little or no
41   difference (e.g., Mo, V, and Ni), as the amount of contaminant moving through the system (the
42   mass flux) is not strongly affected by the groundwater flow rates.

Table 3-1a. Amount of Selected Radiological and Nonradiological Material From the Repository in the Aquifer Environment Between the Regulatory 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	316	1.5	90
Th isotopes (Ci)	0.18	178	0.18	51
Np-237 (Ci)	1.4	147	1.4	42
I-129 (Ci)	0.0042	0.23	0.0038	0.021
Tc-99 (Ci)	7.6	105	1.4	26
Se-79 (Ci)	5.8	83	5.8	22
Mo (kg)	1.3×10^5	2.6×10^5	1.1×10^5	2.7×10^5
Ni (kg)	1.7×10^7	1.7×10^7	1.7×10^7	1.2×10^7
V (kg)	2.2×10^3	9.7×10^3	2.2×10^3	5.7×10^3

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)	1.6×10^{-15}	101	1.5×10^{-10}	123
Th isotopes (Ci)	2.3×10^{-14}	61	1.2×10^{-11}	74
Np-237 (Ci)	7.1×10^{-17}	43	7.1×10^{-17}	54
I-129 (Ci)	2.4	134	2.5	134
Tc-99 (Ci)	125	2,270	126	2,280
Se-79 (Ci)	1.6×10^{-15}	121	1.6×10^{-15}	182
Mo (kg)	1.3×10^6	2.1×10^7	1.3×10^6	2.1×10^7
Ni (kg)	0	1.3×10^8	0	1.3×10^8
V (kg)	0	4.7×10^5	0	4.1×10^5

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. Average 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	0.063	7.1×10^{-12}	0.073
Th isotopes (pCi/L)	0	0.005	4.2×10^{-13}	0.002
Np-237 (pCi/L)	0	0.051	0	0.007
I-129 (pCi/L)	0.007	0.088	0.013	0.088
Tc-99 (pCi/L)	4.3	2.1	5.3	2.1
Se-79 (pCi/L)	0	0.016	0.009	0.017
Mo (mg/L)	7.3×10^{-3}	1.9×10^{-4}	7.1×10^{-3}	1.9×10^{-4}
Ni (mg/L)*	0	1.4×10^{-3}	0	1.3×10^{-3}
V (mg/L)	0	2.1×10^{-9}	0	2.1×10^{-9}
*calculated peak concentration value of 0.02 mg/L for Ni occurs at 74,000 years after repository closure. U = uranium, Th = thorium, Np = neptunium, I = iodine, Tc = technetium, Se = selenium, Mo = molybdenum, Ni = nickel, V = vanadium				

1   Overall, the concentrations of radionuclides and other contaminants from the repository for
2   groundwater at Amargosa Farms are uniformly very low. For example, the EPA Maximum
3   Contaminant Level (MCL)[2] for alpha-particle emitting radionuclides in drinking water is 15 pCi/L,
4   compared to the calculated total for all alpha-emitting radionuclides in Table 3-2 of less than
5   0.1 pCi/L.

6   The highest calculated total uranium concentration in the groundwater at Amargosa Farms
7   corresponds to less than 1 µ/L; for comparison, the EPA MCL for U in drinking water is 30 µ/L.
8   While no MCLs have been established for the metals Mo and V, the calculated groundwater
9   concentrations for these potential contaminants are all much lower than one part per million,
10 which is comparable to the levels occurring naturally at present (Table 2-2). The calculated
11 peak concentration of Ni in groundwater at Amargosa Farms, for each climate state, does not
12 occur at 10,000 years or one million years after repository closure. The peak concentration for
13 Ni in groundwater at this location is 0.02 mg/L, and is estimated to occur at 74,000 years for the
14 cooler/wetter climate. This concentration is much lower than the EPA National Recommended
15 Water Quality Criteria level for Ni of 0.61 mg/L (EPA, 2014).

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

[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.

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 both climate states occurs approximately 270,000 years after repository closure. The calculated peak soil concentration at that time is 4 ppm. After that time, 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 repository would be minimal and either not result in a difference from background levels or otherwise not noticeably affect soil. 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

Table 3-3. Estimates of 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	1.5×10^{-3}	0	1.0×10^{-4}	—	—
Pu-242	0	1.9×10^{-11}	0	2.8×10^{-5}	—	—
U-235	0	9.6×10^{-4}	4.7×10^{-14}	5.8×10^{-4}	—	—
Th-230	0	7.2×10^{-6}	3.2×10^{-16}	1.4×10^{-6}	—	—
U-238	0	0.042	2.0×10^{-12}	0.025	—	—
U-233	0	1.1×10^{-5}	4.6×10^{-16}	6.5×10^{-6}	—	—
Mo	0.007	1.9×10^{-4}	0.007	1.9×10^{-4}	—	390
Ni	0	0.29	0	0.27	17.8	1500
V	0	1.2×10^{-4}	0	1.2×10^{-4}	22.4	390
U (all isotopes)	0	0.043	2.0×10^{-12}	0.026	3.9	230

Np = neptunium, Pu = plutonium, U = uranium, Th = thorium, Mo = molybdenum, Ni = nickel, V = vanadium
Peak soil radionuclide concentrations are derived from estimates in DOE (2014a, Tables B-13 and B-14), assuming the contamination is in the top 0.25 m [0.82 ft] of soil and the soil bulk density is 1,500 kg/m³ [94 lb/ft³]
*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)

1   adjustments for secular disequilibrium. Dose conversion factors for the present-day climate
2   were used for both the present-day and future cooler/wetter climate. This approach is
3   conservative because dose conversion factors for cooler and wetter climates would be expected
4   to be lower than those for the present-day climate (Appendix A, Section A.2.3).

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

14   Peak doses, considering all radionuclides, are shown in Table 3-4 for 10,000 and
15   one million years for both climate states. The peak dose of 1.3 mrem/yr [0.013 mSv/yr] in
16   Table 3-4 is lower than the dose from natural background levels of approximately 300 mrem/yr
17   [3.0 mSv/yr] (including radon) for Amargosa Valley, and lower than that calculated for the RMEI
18   at the regulatory compliance location closer to the repository (DOE, 2008b). Furthermore, the
19   peak values estimated for 10,000 and one million years for the present-day and cooler/wetter
20   climate are much lower than the NRC annual dose standards for a Yucca Mountain repository in
21   10 CFR Part 63 {15 mrem [0.15 mSv] for the first 10,000 years, and 100 mrem [1 mSv] for
22   one million years, after permanent closure}.

23   Potential health effects from the nonradiological contaminants are considered for a nominal
24   body intake from ingestion of contaminated water, assuming daily intake for a 70-kilogram
25   person drinking 2 liters of water daily. Human health impacts of the nonradiological
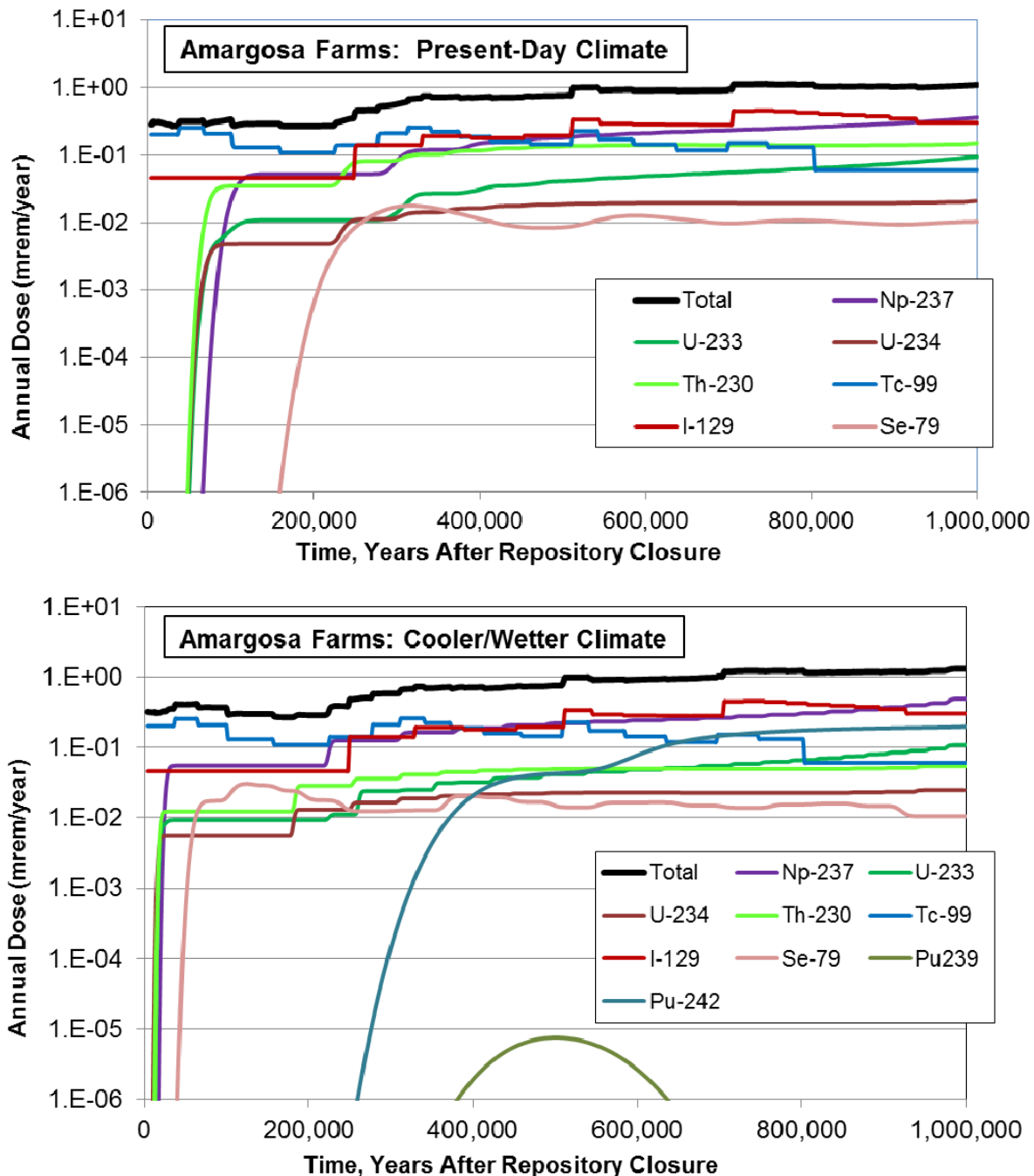
Figure 3-1. Dose History of Selected Radionuclides at Amargosa Farms for the Present-Day (Top) and Cooler/Wetter (Bottom) Climates. [Modified from DOE (2014a)].

1   contaminants are assessed by comparing daily intakes with EPA's Oral Reference Dose
2   standard (EPA, 1999a,b; 1997a,b; 1994). Estimated values of peak daily intakes for each of the
3   nonradiological contaminants are summarized in Table 3-5 for the one-million-year period. In
4   accord with the calculations for the aquifer environment between the regulatory compliance
5   location and Amargosa Farms, the peak daily intake for Ni is estimated to occur at
6   74,000 years. The peak value of 0.004 mg/kg body weight/day corresponds to the peak values

Table 3-4. Peak Annual Dose Estimates for the Amargosa Farms Area. Values From DOE (2014a, Table 3-1).

	Peak Annual Dose (mrem/yr)*	
	10,000 years	1 million years
Present-day Climate	0.21	1.1
Cooler/Wetter Climate	0.25	1.3
*Note: 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}	4.5×10^{-5}	1.5×10^{-3}	4.1×10^{-5}	5.0×10^{-3}
Ni*	0	2.9×10^{-4}	0	2.7×10^{-4}	2.0×10^{-2}
V	0	4.7×10^{-7}	0	4.5×10^{-7}	9.0×10^{-3}
U (all isotopes)	0	3.5×10^{-6}	0	3.8×10^{-6}	3.0×10^{-3}
*calculated peak daily intake of 0.004 mg/kg body weight/day for Ni occurs at 74,000 years after repository closure. Mo = molybdenum, Ni = nickel, V = vanadium, U = uranium					

1 in groundwater Ni concentration for the cooler/wetter climate. The calculated peak daily intake
2 for Ni for the present-day climate is lower than that estimated for the cooler/wetter climate. The
3 estimated values of daily intake are all much lower than the EPA Oral Reference Doses.

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

9 ## 3.1.2   Analysis Case 2: Surface Discharge Downstream of
10   Amargosa Farms

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

16 In the 2002 EIS, DOE scaled results from the RMEI location to account for groundwater
17 dispersion to estimate impacts at 30 and 60 km [19 and 37 mi] from the repository, which are
18 approximately the distances from the repository to Amargosa Farms and Alkali Flat,
19 respectively. In the 2002 EIS and 2008 SEIS, DOE stated that the contaminants would

1   discharge to the surface at Alkali Flat, but the DOE discussion of these impacts is limited to a
2   statement that no detrimental radiological impacts on plants and animals are expected.

3   In this supplement, impacts at natural discharge sites along the groundwater pathway beyond
4   the regulatory compliance location are analyzed. This Analysis Case addresses discharge of
5   contaminants by springs or playas at the State Line Deposits/Franklin Well area (which would
6   occur under a cooler/wetter climate only), the springs at Furnace Creek, and the playa/salt pan
7   at Middle Basin of Death Valley. Results from the DVRFS groundwater model indicate that in
8   the absence of pumping of the aquifer at Amargosa Farms, the predominant discharge site of
9   contaminants transported from Yucca Mountain for the present-day climate would be Middle
10   Basin in Death Valley (Chapter 2; see also Belcher and Sweetkind, 2010). Along the way to
11   Middle Basin, some amount of groundwater contaminants may be discharged at the springs in
12   the Furnace Creek area. In a future wetter climate, another potential location for natural
13   discharge is springs in the State Line Deposits/Franklin Well area. In addition, groundwater
14   modeling indicates that beyond the State Line area, a very small fraction (2 out of 8,024
15   modeled particles, or 0.03 percent) of contaminants may move southward toward Alkali Flat,
16   rather than Middle Basin (Chapter 2). This discharge location is considered as an alternative
17   pathway to the expected pathway (State Line–Furnace
18   Creek–Middle Basin).

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

26   **3.1.2.1   State Line Deposits/Franklin Well Area**

27   As discussed in Chapter 2, the State Line Deposits area is located approximately 21 km [13 mi]
28   beyond the regulatory compliance location, or 39 km [24 mi] from the repository along the
29   Yucca Mountain flow path. These paleospring deposits occur where the Amargosa River and
30   Fortymile Wash join. The water table approaches the ground surface in the present-day
31   climate, and reached the ground surface during past wetter climates to produce deposits that
32   formed in playas, springs, marshes, and ponds (Section 2.3.4). The Franklin Well area refers to
33   the narrow band of dense vegetation along the Amargosa River channel at the southern extent
34   of the State Line Deposits area. In the present-day climate, the Amargosa River only flows after
35   significant precipitation events in most of Amargosa Desert, including in the Franklin Well area.
36   For the present-day climate, a small amount of natural discharge occurs at the Franklin Well
37   area as evapotranspiration from a dominantly mesquite thicket along the river channel.

38   To estimate impacts in the State Line/Franklin Well area, the transport and biosphere model
39   inputs and assumptions are derived from the present hydrologic characteristics and
40   environmental inferences from the paleospring deposits observed in the region. In the
41   present-day climate, discharge occurs at the Franklin Well area only as evapotranspiration in
42   the Amargosa River channel. For a cooler/wetter climate, discharge is projected to occur in the
43   entire State Line Deposits/Franklin Well area in a combination of springs, pools, marshes, and
44   wet and dry playas. The discharge rate during a future cooler/wetter climate can be estimated
45   based on the extent of the deposits and similar modern springs in the region. One modern
46   analog, albeit on a larger scale, may be Ash Meadows. The present-day Ash Meadows area of

1 springs, marshes, pools and playas is approximately twice the area of the State Line deposits,
2 and has similar types of discharge to that indicated for the State Line Deposits area.
3 Present day discharge at Ash Meadows is estimated to be 60,372 m^3/day [17,865 acre-ft/yr]
4 (Belcher and Sweetkind, 2010, Table F-4). Prior to water use restrictions related to Devils Hole,
5 water was diverted from pools and ponds, and was pumped from the ground for agriculture in
6 Ash Meadows. Whereas limited water diversion for agriculture at a future, wetter State Line
7 Deposits area is possible, extensive agriculture in the area of the State Line Deposits is unlikely
8 due to the high concentrations of salts in the soils. Therefore, biosphere and dose pathway
9 modeling for a cooler/wetter climate at the State Line Deposits/Franklin Well area includes
10 (i) inhalation of resuspended dust from wet and dry playas, (ii) ingestion of water and soil, and
11 (iii) subsistence farming using water diverted from less saline pools and springs. Recycling and
12 recapture of irrigated water are not applicable for water diverted from pools and springs for
13 agriculture because unlike the case of well-pumping irrigation, any irrigation water diverted from
14 springs or pools is typically used downstream from its source, and thus the contaminants pass
15 only once through the local soil. Transport properties for the State Line Deposits/Franklin Well
16 area, except for the distance, are the same as used for the calculations for Amargosa Farms, as
17 the characteristics of the aquifer are the same. For the estimated impacts at the State Line
18 area, the NRC staff conservatively assumes that the entire plume discharges to that location.

19 **Aquifer Environment**

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

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

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

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

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

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

1 **Soil**

2 This section describes the accumulation of repository materials in soils at the State Line
3 Deposits/Franklin Well area for the wetter climate. Because of the very limited area where the
4 water table is potentially close enough to the ground surface for contaminants to enter the soil in
5 present-day climate conditions, an insignificant amount of precipitation of radiological and
6 nonradiological contamination from the repository is expected to occur. However, in a
7 cooler/wetter climate state where the water table could rise approximately 20 to 30 m
8 [66 to 98 ft] (Section 2.3.4), a larger area would be affected and soil concentrations of
9 contaminants could be greater.

10 The NRC staff uses two approaches to estimate the soil concentration of contaminants for the
11 cooler/wetter climate to account for the range of processes that occur in this type of
12 environment. These approaches are for contaminants in evaporite minerals at a wet playa-type
13 discharge setting, and for contaminants in sediments collecting in a salt marsh-type discharge
14 setting. These are the environments inferred from the paleospring deposits in this location
15 (Section 2.3.4). In the first approach, evaporation from a wet playa-type of discharge site is
16 conservatively assumed for the entire State Line Deposits/Franklin Well area. This approach
17 leads to the greatest calculated contaminant concentration in soils at the State Line
18 Deposits/Franklin Well area, as it assumes extensive formation of evaporite minerals in
19 playa-type areas, which strongly concentrates contaminants from groundwater. The
20 concentrations of contaminants in soil and evaporite deposits within the wet playa are calculated
21 using the estimated concentrations of the contaminant and total dissolved solids (TDS) content
22 of the groundwater. This model for soil concentration assumes that as water is lost by
23 evaporation, contaminants in groundwater are incorporated into newly formed evaporite
24 minerals. The contaminant concentration is higher in evaporites formed from relatively dilute
25 water (low TDS) than from water with the same concentration of contaminants but a greater
26 initial content of (noncontaminant) dissolved material, as a greater amount of evaporation is
27 needed to form evaporites from water with a low amount of TDS. These calculations
28 conservatively use water with a relatively low TDS [257 ppm, as measured in groundwater from
29 well J-13 in Fortymile Wash (DOE, 2014a)]. An additional conservatism is that the model
30 assumes that the "soil" is composed entirely of minerals formed by evaporation of the
31 groundwater. While this can be observed in some local areas of extreme aridity (for example, in
32 salt pans in Death Valley), wet and dry playas typically contain significant amounts of
33 nonevaporite material, with mineral grains transported to the playa by wind or running water
34 (like the playa environments indicated by the paleospring deposits in the State Line area;
35 Section 2.3.4). This assumption thus represents a conservative means of estimating
36 contaminant concentrations in the soil.

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

45 The calculated soil concentrations in Table 3-6 show similar patterns to Amargosa Farms for
46 sorbing and nonsorbing radionuclides and metals. Estimates of sorbing radionuclide (Np-227
47 and U isotopes) and metal (Ni and V) contaminants are essentially zero at the State Line

Table 3-6. Soil Concentrations of Radiological and Nonradiological Contaminants at the State Line/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	5.2×10^{-5}
U-235	0	3.1×10^{-3}	0	2.9×10^{-4}
U-238	0	0.13	0	0.013
U-233	0	3.4×10^{-4}	0	3.3×10^{-6}
Tc-99	3.0×10^{-3}	8.9×10^{-4}	2.5×10^{-6}	7.5×10^{-7}
I-129	5.5×10^{-4}	3.6×10^{-3}	7.8×10^{-6}	5.1×10^{-5}
Mo	52	1.4	3.6×10^{-3}	4.9×10^{-5}
Ni	0	9.6	0	0.069
V	0	0.016	3.2×10^{-5}	3.2×10^{-5}
U (all isotopes)	0	0.14	0	0.013

*calculated peak concentration value of 1 ppm for Ni occurs at 88,000 years after repository closure.
U = uranium, Th = thorium, Np = neptunium, I = iodine, Tc = technetium, Se = selenium, Mo = molybdenum, Ni = nickel, V = vanadium

1 Deposits/Franklin Well area at 10,000 years, for both calculation models. The nonsorbing
2 contaminants (I-129, Tc-99, and Mo) are estimated to be present in low concentrations at
3 10,000 years. As expected, the calculated concentrations are significantly greater for the
4 more-conservative evaporite model, particularly for the nonsorbing contaminants, but are still
5 very low.

6 At one million years, the calculations show all of the contaminants from the repository present in
7 the soils at the State Line Deposits/Franklin Well area, with most concentrations still very low.
8 As expected, the more conservative evaporite model gives a greater calculated concentration
9 than the salt marsh model for those contaminants estimated to occur in the soil. Even using the
10 evaporite model, the values calculated for all contaminants are all very low for both time
11 periods. As was the case for Amargosa Farms, the estimated peak soil concentration for Ni at
12 this location for either climate state occurs between 10,000 and one million years after
13 repository closure, at approximately 88,000 years, and reaches a maximum of 1 ppm for a short
14 period of time before decreasing. The estimated concentrations for all of the nonradiological
15 contaminants are lower than the EPA generic soil screening levels (Table 3-3).

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

20 **Public Health**

21 Combined radionuclide peak dose (considering all radionuclides) and body intake for
22 nonradiological contaminants are given in Table 3-7 for 10,000 and one million years for the
23 cooler/wetter climate, and the contributors to radiological dose are shown in Figure 3-2. The
24 largest contributors to radiological dose for both the present-day and the wetter climate at the
25 State Line Deposits area are I-129, Tc-99, Np-237, and Pu-242 (Figure 3-2). At 10,000 years,

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	7.0×10^{-5}	2.0×10^{-2}
V (mg/kg body-weight/day)	0	1.6×10^{-7}	9.0×10^{-3}
U (mg/kg body-weight/day)	0	1.0×10^{-6}	3.0×10^{-3}

*Note: 1.0 mrem/yr = 0.01 mSv/yr
†calculated peak daily intake of 0.001 mg/kg body weight/day for Ni occurs at 88,000 years after repository closure
Mo = molybdenum, Ni = nickel, V vanadium, U = uranium
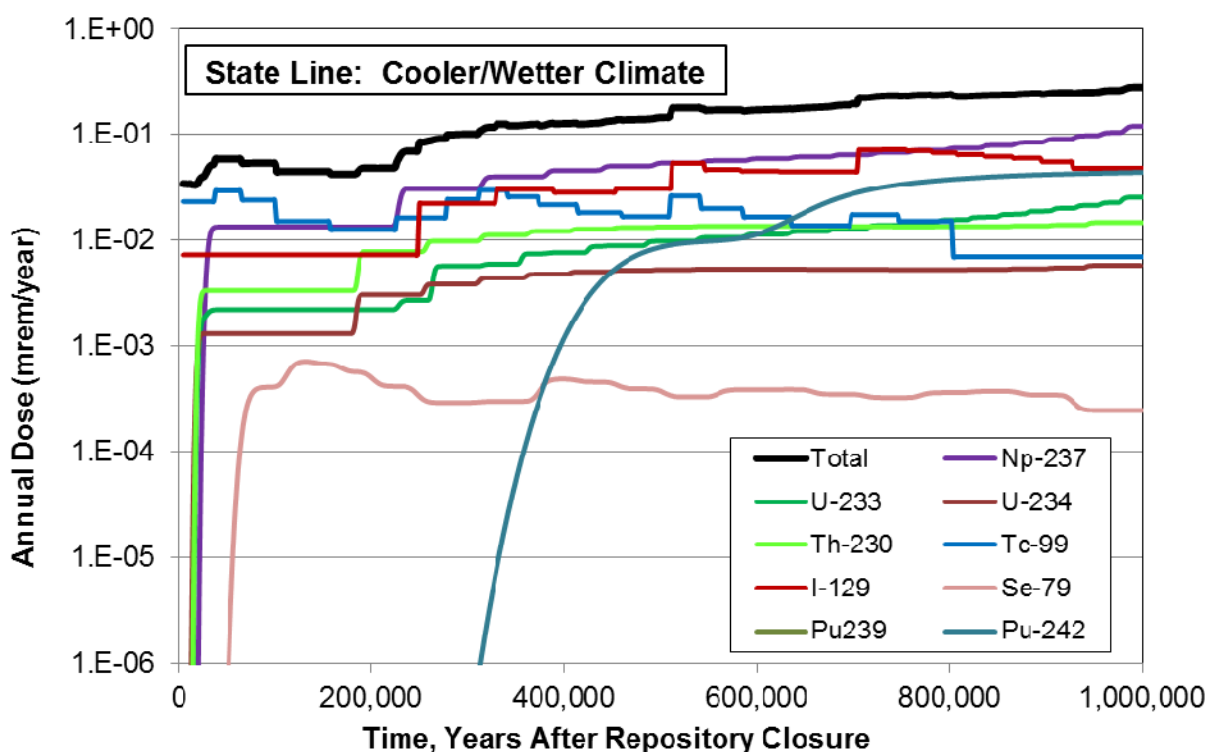
Figure 3-2. Dose History of Selected Radionuclides at State Line Deposits/Franklin Well Area for the Cooler/Wetter Climate

1   I-129 and Tc-99 are the primary contributors to dose. They do not sorb onto rock grains, but
2   rather remain dissolved in water. The other radionuclides in Figure 3-2 sorb to various degrees,
3   and thus arrive later.

4   Estimates of dose and body intake for the present-day climate are extremely small because of
5   the small area affected (Franklin Well area) and limited amount of evapotranspiration. For the

1   cooler/wetter climate, the peak dose of 0.28 mrem/yr [0.0028 mSv/yr] is substantially lower
2   than the dose from natural background levels {approximately 300 mrem/yr [3.0 mSv/yr],
3   including radon} for Amargosa Valley. Peak values estimated for 10,000 and one million years
4   for the cooler/wetter climate are much lower than the NRC annual dose standards for a
5   Yucca Mountain repository in 10 CFR Part 63 {15 mrem [0.15 mSv] for the first 10,000 years,
6   and 100 mrem [1 mSv] for one million years, after permanent closure}.

7   The peak daily intake value for Ni at the State Line Deposits/Franklin Well area corresponds to
8   its maximum groundwater and soil concentration at this location. The maximum of 0.001 mg/kg
9   body weight/day occurs at approximately 88,000 years after repository closure. For all of the
10   nonradiological contaminants at this location, the estimates of body intake are significantly lower
11   than the EPA Oral Reference Dose.

12   Based on the analyses above of radiological and nonradiological material potentially released
13   from the repository to the State Line Deposits/Franklin Well area, the NRC staff finds that the
14   impact to public health would be SMALL.

15   ## 3.1.2.2   Furnace Creek and Middle Basin

16   The Furnace Creek area and Middle Basin of Death Valley are located approximately 56 km
17   [35 mi] beyond the regulatory compliance location. As discussed in Section 2.2.2, under
18   scenarios in which there is no pumping at the Amargosa Farms area, groundwater modeling
19   indicates that the majority of contaminants transported from Yucca Mountain would be
20   discharged in Middle Basin of Death Valley (Belcher and Sweetkind, 2010). Contaminated
21   groundwater could also discharge at the springs in the Furnace Creek area, a short distance
22   upgradient from Middle Basin (Belcher and Sweetkind, 2010; DOE, 2014a). For the estimated
23   impacts at Furnace Creek or Middle Basin, the NRC staff conservatively assumes that the entire
24   plume discharges at that location. For these locations, the impact types are the same as for
25   Amargosa Farms (Section 3.1.1): (i) the amount of contaminants from the repository in the
26   groundwater system, (ii) the concentration of contaminants in the groundwater, (ii) the
27   concentration of contaminants in soils, and (iv) the radiological dose and body intake of
28   contaminants for the relevant exposure pathways. Biosphere dose conversion factors for the
29   Furnace Creek and Middle Basin areas are based on exposures to full-time residents in the
30   local environments (see Appendix A, Section A.2.2).

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

34   •   The mass flux of radiological and nonradiological material reaching the potential
35   discharge locations at Furnace Creek or Middle Basin is calculated using observations of
36   spring discharge and evaporation losses. Total discharge from the springs at Furnace
37   Creek is 2,294 acre-ft/yr [2.83 million m³/yr]. Discharge in the playa environment at
38   Middle Basin occurs through evaporation, and observed evaporation losses were
39   1,962 acre-ft/yr [2.4 million m³/yr] at that location (Belcher and Sweetkind, 2010;
40   Table F-4).

41   •   Transport in the aquifer to Furnace Creek is calculated using a value of 0.00046 m/day
42   [0.0015 ft/day] for the specific discharge (flow rate) along the 56 km [35 mi] path in the
43   present-day climate (see Appendix A, Section A.1.2). For the wetter climate, the specific

1   discharge is multiplied by a factor of 3.9 (DOE, 2014a; 2008b, Section 2.3.9). An
2   average porosity in the aquifer of 0.11 is used for both climate states.

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

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

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

23 **Aquifer Environment**

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

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

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

Table 3-8. Amount of Radiological and Nonradiological Material (From the Repository) in the Aquifer Environment Between the Regulatory 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	791	0.18	791
Np-237 (Ci)	1.4	581	1.4	581
I-129 (Ci)	2.5	65	2.2	15
Tc-99 (Ci)	1,260	1,520	1,160	435
Se-79 (Ci)	5.8	204	5.8	204
Mo (kg)	1.4×10^6	4.6×10^5	1.4×10^6	3.0×10^5
V (kg)	2.2×10^3	4.2×10^5	2.2×10^3	4.2×10^5
Ni (kg)	1.7×10^7	1.3×10^8	1.7×10^7	1.3×10^8
U = uranium, Th = thorium, Np = neptunium, I = iodine, Tc = technetium, Se = selenium, Mo = molybdenum, Ni = nickel,				

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

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

16   At Furnace Creek, the maximum concentration of Mo in the groundwater occurs approximately
17   58,000 years after repository closure for the present-day climate (under the cooler/wetter
18   climate, the peak arrives at 20,000 years after closure, at a lower concentration). The major
19   release of this contaminant from the repository occurs fairly early after repository closure
20   (see Appendix A), and as a nonsorbing element, transport of Mo is not significantly delayed in
21   the aquifer. The estimate of the maximum Mo concentration in the groundwater is 0.04 mg/L
22   and declines after this time. As noted previously, EPA has not set an MCL or National
23   Recommended Water Quality Criteria level for Mo, but the peak concentration is much lower
24   than 1 ppm and near the detection limit for Mo for the levels given in Table 2-1.

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

Table 3-9. Average 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	0.65	0.02	0.17
Tc-99 (pCi/L)	0	13.5	9.3	3.8
Se-79 (pCi/L)	0	0	0	0
Mo (mg/L)*	0	0.001	0	3.7×10^{-4}
V (mg/L)	0	0	0	0
Ni (mg/L)	0	0	0	0

*calculated peak concentration of 0.04 mg/L for Mo occurs at 58,000 years after repository closure
U = uranium, Th = thorium, Np = neptunium, I = iodine, Tc = technetium, Se = selenium, Mo = molybdenum,
V = vanadium, Ni = nickel

1 **Soil**

2 This section describes the accumulation of potential contaminants from the repository in soils at
3 Middle Basin or Furnace Creek. The concentrations of contaminants in soil and evaporite
4 deposits within the wet playa are calculated using the estimated concentrations of the
5 contaminant and TDS content of the groundwater, as in the evaporite model calculation for the
6 State Line Deposits area (Section 3.1.2.1). Essentially, as water is lost due to evaporation,
7 forming evaporites and other minerals, the contaminants in groundwater are incorporated into
8 the newly formed solids. The concentration of the contaminant in the resulting solid is
9 calculated by dividing the contaminant concentration in the groundwater by the TDS of the
10 groundwater. The same conservative low value of TDS (257 ppm) is used here as in the
11 previous evaporite model calculations (Section 3.1.2.1). The measured values of spring
12 discharge waters at Furnace Creek are approximately 600 ppm TDS (Steinkampf and Werrell,
13 1998). Using this value for TDS in the evaporite model would decrease the calculated
14 concentration in the soil to less than half that of the present estimate. Table 3-10 provides the
15 calculated concentrations of radiological and nonradiological contaminants in soil and evaporite
16 at Middle Basin. These values are derived from estimates in DOE (2014a, Table B-15) and the
17 observed evaporation-driven discharge rates at Middle Basin (Belcher and Sweetkind, 2010).
18 The values calculated for Middle Basin are limiting for possible soil accumulations at
19 Furnace Creek. This is because any potential soil contamination from natural spring discharge
20 at Furnace Creek would likely occur in a marsh/pool environment, rather than the wet playa
21 environment in the topographic low at Middle Basin. As discussed in Section 3.1.2.1, modeling
22 contaminant accumulation as a process that forms evaporites is very conservative, and results
23 in greater concentrations than would form in an environment with less extreme evaporation.
24 Potential accumulations of contaminants in soil at Furnace Creek are therefore expected to be
25 less than those shown in Table 3-10 for the Middle Basin playa.

26 No radionuclide contaminants reach Middle Basin within 10,000 years in the present-day
27 climate state, even with no pumping in Amargosa Farms. In the cooler/wetter climate state,
28 I-129 and Tc-99 are present in Death Valley groundwater at 10,000 years, and therefore would

Table 3-10. 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	0.017	0.0005	0.004
Tc-99 (ppm)	0	0.004	0.002	0.001
Mo (ppm)*	0	6.5	2.1×10^{-6}	1.6
*calculated peak concentration of 208 ppm for Mo occurs at 58,000 years after repository closure I = Iodine, Tc = technetium, Mo = molybdenum				

1   be found in Middle Basin soils, although at very low levels. Due to radioactive decay, maximum
2   Tc-99 soil/evaporite concentration is reached at about 500,000 years for the present-day climate
3   and at about 100,000 years in the cooler/wetter climate. The I-129 concentration continues to
4   increase slowly over the one-million-year period in both climate states.

5   For nonradiological contaminants, only the nonsorbing element Mo reaches Middle Basin.
6   Under both climate scenarios, Mo reaches a maximum soil/evaporite concentration at about
7   58,000 years. The estimated maximum value is 208 ppm under the present-day climate state.
8   The maximum value occurs slightly earlier for the cooler/wetter climate, but is lower. The
9   maximum value decreases in the soil as the groundwater concentration decreases over time.
10 This maximum is lower than the EPA soil screening level of 390 ppm for Mo in residential soils
11 (Table 3-3). Studies of evaporation pits collecting irrigation water in the San Joaquin Valley
12 have measured similar amounts of natural Mo concentrations (up to 94 ppm in soil/evaporite) as
13 observed in the wetter climate scenario (Tanji, et al., 1992). As discussed for the evaporite
14 model results at the State Line Deposits area (Section 3.1.2.1), the environments where
15 evaporites form are generally inhospitable due to the high salt concentrations and lack of
16 potable water.

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

23 **Public Health**

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

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

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

21 **Furnace Creek Radiological Contaminants**

22 Peak annual dose estimates for Furnace Creek are given in Table 3-11 for both climate states.
23 As discussed in the previous sections on impacts on the aquifer and soil, only a limited amount
24 of radionuclides reach the natural discharge locations in Death Valley. The principal
25 radionuclides that contribute to dose at Furnace Creek are Tc-99 and I-129 (Figure 3-3). The
26 contribution from Tc-99 begins to decrease at about 400,000 years after repository closure due
27 to its shorter half-life than I-129 (~200,000 years compared to 15.7 million years). Under the
28 lower flow volumes associated with the present-day climate, no radiological contaminants reach
29 the Furnace Creek area before 10,000 years after repository closure. Estimated peak annual
30 doses at one million years are slightly greater for the present-day climate state because there is
31 less dilution of the contaminants in the groundwater. Although the contaminants arrive at
32 Furnace Creek earlier in the cooler/wetter climate state, the peak dose is lower due to the lower
33 groundwater contaminant concentrations. The estimated peak annual doses are much lower
34 than the NRC annual dose standards for a Yucca Mountain repository in 10 CFR Part 63 {15
35 mrem [0.15 mSv] for the first 10,000 years, and 100 mrem [1 mSv] for one million years, after
36 permanent closure}.

37 **Furnace Creek Nonradiological Contaminants**

38 Peak daily intakes of the nonradiological contaminant Mo at Furnace Creek are given in
39 Table 3-12 for both climate states. As discussed in the previous sections on impacts on the
40 aquifer and soil, Mo is the only nonradiological contaminant present in groundwater discharging
41 from springs at Furnace Creek, and only at the one million year period. The calculated peak
42 daily intake at Furnace Creek correlates with the maximum peak concentration in groundwater
43 and soil approximately 58,000 years after repository closure for the present-day climate state
44 and is 1.3×10^{-3} mg/kg body-weight/day (as with the groundwater, the maximum for the
45 cooler/wetter climate occurs slightly earlier and is a lower value). Human health impacts of the
46 nonradiological contaminants are assessed by comparing daily intakes with EPA's Oral

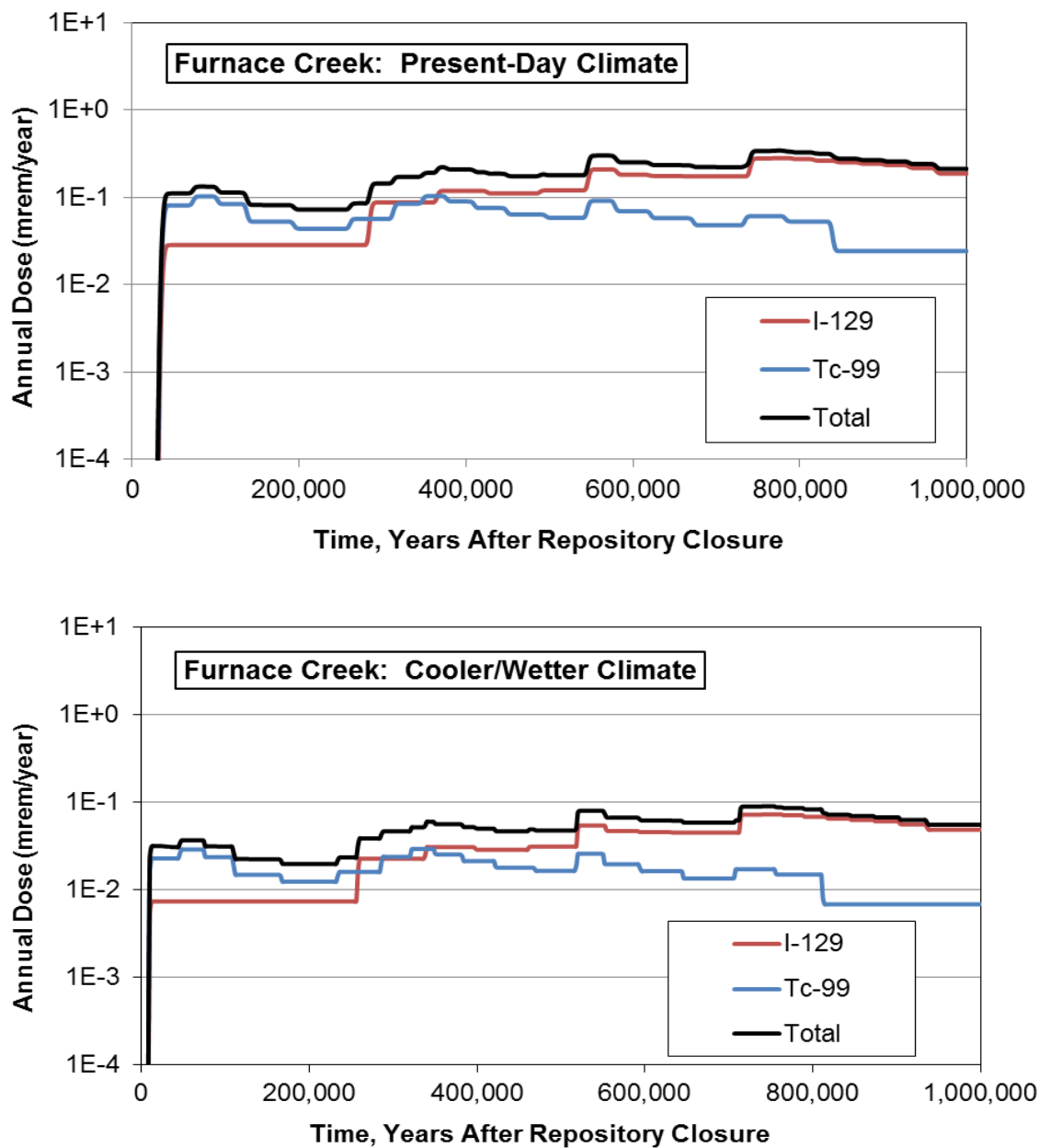| Table 3-11. Peak Annual Dose Estimates for the Furnace Creek Area		
	Peak Annual Dose (mrem/yr)*	
	10,000 years	1 million years
Present-day Climate	0.0	3.4×10^{-1}
Cooler/Wetter Climate	2.3×10^{-2}	8.9×10^{-2}
* Note: 1.0 mrem/yr = 0.01 mSv/yr		

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			

1   Reference Dose standard (EPA, 1999a,b; 1997a,b; 1994). For ingestion of potentially
2   contaminated water, daily intake is estimated for a 70-kg person drinking 2 L [0.53 gal] of water
3   daily. The estimated maximum value of daily intake is lower than the EPA Oral Reference
4   Dose.

5   **Middle Basin Radiological Contaminants**

6   Peak annual dose estimates for Middle Basin are given in Table 3-13 for both climate states.
7   As at the Furnace Creek area, the radiological contaminants that contribute to estimated dose in
8   Middle Basin of Death Valley are limited to those elements whose transport in groundwater is
9   not delayed due to sorption processes. As groundwater flows to Middle Basin and evaporates,
10 these elements are incorporated into the resulting evaporite mineral deposits. Again, Tc-99
11 and I-129 are the primary contributors to dose (Figure 3-4). As at the Furnace Creek area
12 (Figure 3-3), the contribution from Tc-99 decreases beginning at about 400,000 years after
13 repository closure due to its shorter half-life than that of I-129. Similar to the results at the
14 Furnace Creek area, dose estimates are greatest at one million years under the present-day
15 climate scenario because of the dilution of the radiological contaminants in the larger
16 groundwater flow volume under the cooler/wetter climate state, although the contaminants
17 arrive sooner under the cooler/wetter conditions.

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

25 **Middle Basin Nonradiological Contaminants**

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

31 Human health impacts of nonradiological contaminants are assessed by comparing daily
32 intakes with EPA's Oral Reference Dose standard (EPA, 1999a,b; 1997a,b; 1994). At this
33 location, the principal pathway is ingestion and inhalation of contaminated soil, as the water at
34 this location is not potable. As previously noted, the peak concentration for molybdenum occurs
35 approximately 58,000 years after repository closure for the present-day climate (the peak is
36 lower for the cooler/wetter climate, but occurs earlier). The peak Mo daily intake at Middle

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	1.6×10^{-1}
Cooler/Wetter Climate	1.5×10^{-2}	4.2×10^{-2}
* Note: 1.0 mrem/yr = 0.01 mSv/yr		

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
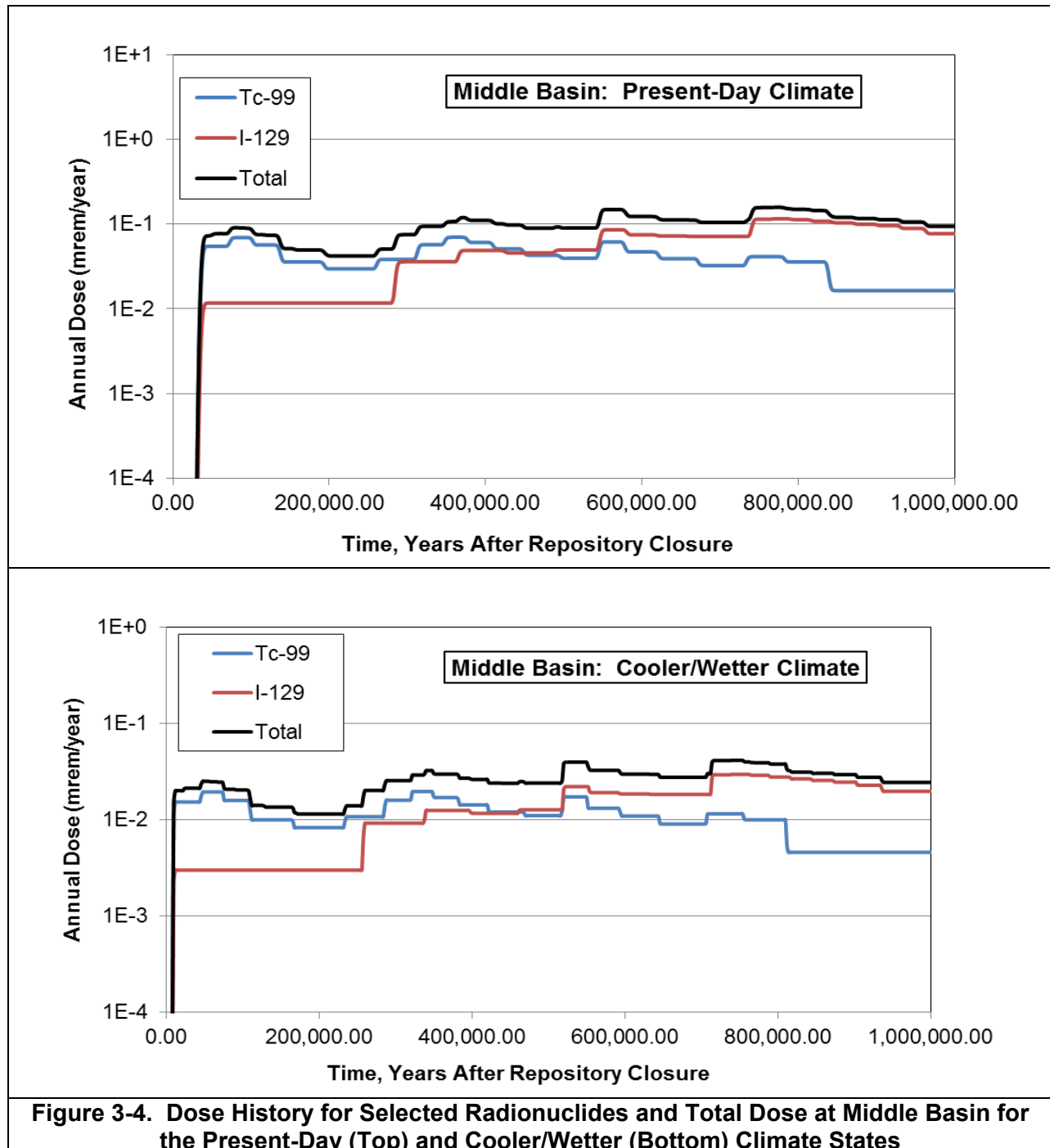
Table 3-14. Peak Daily Intake for Mo at Middle Basin			
Peak Daily Intake* (mg/kg body-weight/day)	**Present-Day Climate**	**Cooler/Wetter Climate**	**Oral Reference Dose**
Mo	3.0×10^{-4}	1.8×10^{-5}	5.0×10^{-3}
*calculated peak daily intake for Mo occurs at 58,000 years after repository closure for the present-day climate, and at 20,000 years for the cooler/wetter climate. Mo = molybdenum			

1 Basin is estimated to be 3×10^{-4} mg/kg body weight/day. The estimated values of daily intake
2 in Table 3-14 and the peak value are both lower than the EPA Oral Reference Dose.

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

9 **3.1.2.3   Alkali Flat**

10 Alkali Flat is located approximately 45 km [28 mi] from the regulatory compliance location, or
11 63 km [39 mi] from the proposed repository. The groundwater at Alkali Flat is a combination of
12 groundwater flowing from Ash Meadows and groundwater from western Amargosa Desert and
13 Fortymile Wash. As discussed in Section 2.2.2, under scenarios in which there is no pumping in
14 the Amargosa Farms area, groundwater modeling indicates that the majority of contaminants
15 transported from Yucca Mountain will be discharged in Middle Basin, and to a lesser extent, at
16 Furnace Creek (or the State Line Deposits area in a wetter climate) prior to reaching
17 Middle Basin (Belcher and Sweetkind, 2010; DOE, 2014a). DVRFS modeling indicated that
18 only a small fraction of contaminants could be directed southward toward the Alkali Flat area
19 (Belcher and Sweetkind, 2010; DOE, 2014a).

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

26 Estimates of groundwater, soil, and surface discharge mass and concentration at Alkali Flat
27 were not explicitly calculated for this supplement, as the impacts can be estimated from the
28 estimates for the other, more-likely discharge areas. Alkali Flat is similar to Middle Basin in its
29 dominantly playa environment, and in its inhospitable conditions and lack of habitation. But
30 Alkali Flat is more distant from present population centers, and is less likely to have visitors or
31 temporary occupants. The exposure pathways and biological dose conversion factors used for
32 a playa at Middle Basin are therefore applicable (and conservative) for Alkali Flat. The
33 fraction of the contaminant plume reaching Alkali Flat is expected to be very small (less than
34 one percent of the potential release reaching the regulatory compliance location, based on
35 DVRFS modeling). Thus, the results in Section 3.1.2.2 for release of the entire plume at
36 Middle Basin are likely to overestimate the contaminants in the groundwater or accumulated in

1 soil at Alkali Flat (even though the transport path is marginally shorter from the repository to
2 Alkali Flat). For these reasons, the NRC staff finds that the impacts at Alkali Flat would be a
3 small fraction of those calculated for Middle Basin under both climate states, which were found
4 to be SMALL, above. Therefore, the aquifer environment, soil, and public health (radiation dose
5 and body intake of chemicals) impacts for Alkali Flat would be SMALL.

6 ## 3.2   Ecological Impacts

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

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

29 The NRC staff evaluated the potential for nonhuman biota to be exposed to potentially harmful
30 levels of chemical constituents at Amargosa Farms, State Line Deposits/Franklin Well area, and
31 Furnace Creek/Middle Basin based on the aquifer and soil concentrations in Sections 3.1.1 and
32 3.1.2 for present-day and cooler/wetter climates and for both the 10,000 year and one-million-
33 year time-frames. Comparisons of the estimated groundwater and soil concentrations for the
34 nonradiological contaminants to ecological impact concentrations are given for the three areas
35 in Tables 3-15, 3-16, and 3-17. The water and soil concentrations shown in these tables are for
36 the climate state showing the greatest concentration over the one million year time period for
37 each area. Two approaches are used in Section 3.1.2.1 to estimate contaminant concentrations
38 in surficial material: the evaporite model for playas and the salt marsh model for areas near and
39 downstream from springs and pools. The values in Table 3-16 are derived from the salt marsh
40 model because biota would dominantly be associated with springs and pools; and would be
41 sparse on the saline playas.

42 The ecological impact values shown in Tables 3-15, 3-16, and 3-17 are derived from various
43 data, depending on the applicability and availability of information and considering the wildlife
44 that are representative of the region. Water concentration values are based on EPA aquatic life
45 criteria (EPA, 2014) (available only for Ni) or the reported ranges of adverse ecological effect
46 concentrations in scientific literature compilations. The threshold range for U in water is the

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	0.007	100–500
Ni	0.02	0.052	4.0	38–280
V	2.1×10^{-9}	0.835–200	1.2×10^{-4}	7.8–280
U (all isotopes)	$1.9 \times 10^{-4‡}$	0.0026–69	0.043	5–200

Mo = molybdenum, Ni = nickel, V = vanadium, U = uranium
*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.

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	3.6×10^{-4}	100–500
Ni	<0.02	0.052	0.99	38–280
V	$<2.1 \times 10^{-9}$	0.835–200	3.6×10^{-5}	7.8–280
U (all isotopes)	$<1.9 \times 10^{-4‡}$	0.0026–69	0.013	5–200

Mo = molybdenum, Ni = nickel, V = vanadium, U = uranium
*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.
[#] Soil concentrations are based on values from the irrigation recycling model approach, Section 3.1.2.1
[†] Sources as in Table 3-15.
[‡] Concentration of U in water calculated from total uranium activity per liter from Table 3-2.

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	0.13	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

Mo = molybdenum, Ni = nickel, V = vanadium, U = uranium
*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.

1   range of reported guideline values in Hinck, et al. (2010). The ranges for Mo and V in water are
2   from Sample, et al. (1996). The ecological impact values for soil concentrations of Ni and V are
3   the EPA ecological soil screening levels (EPA, 2007; 2005). These EPA levels were developed
4   to support screening analyses to identify potential ecological concerns at Comprehensive
5   Environmental Response, Compensation, and Liability Act (CERCLA) sites that may need
6   further, more detailed, evaluation (e.g., ecological risk assessment). EPA stated that it
7   expected that any federal, state, tribal or private environmental assessment could use the
8   values to screen soil contaminants (EPA, 2003). The soil range for Mo is based on dietary
9   concentrations where adverse effects have been observed in the most sensitive applicable
10   organisms (rabbits and birds) (Eisler, 1989). This dietary concentration is compared with the
11   estimated soil concentration, based on the assumption that the plants consumed by the
12   organisms would be in equilibrium with the estimated soil concentration. The U range is the soil
13   concentration-based guidance levels reported by Hinck, et al., 2010).

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

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

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

33   ## 3.3   Historic and Cultural Resources

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

3.3.1   Assessments in the DOE Environmental Impact Statements

2   DOE's historic and cultural resource analyses in its EISs for the proposed repository at
3   Yucca Mountain focused on the repository site and the surrounding controlled area.
4   Section 4.1.5 of the 2002 EIS contains DOE's evaluation of the potential environmental impacts
5   of the proposed repository on historic and cultural resources. DOE updated its historic and
6   cultural resources impact assessment in Sections 4.1.5 and 4.3.2.5 of the 2008 SEIS.
7   Section 4.1.5 of the 2008 SEIS provides an update to the expected historic and cultural
8   resources impacts, accounting for new information and an expanded region of influence,
9   including land that DOE had proposed for an access road from U.S. Highway 95 and land where
10 DOE would construct offsite facilities. Section 4.3.2.5 of the 2008 SEIS assesses the potential
11 historic and cultural resource impacts of proposed infrastructure improvements, such as the
12 construction or replacement of roads, the installation of transmission lines, and various
13 on-site improvements.

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

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

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

30 •   DOE had been consulting with the Nevada SHPO and the ACHP to develop a
31   programmatic agreement for the proposed repository.

32 •   DOE indicated its intent to have continuing discussions with Native American tribes
33   through its Native American Interaction Program and proposed establishing a "mitigation
34   advisory board" to explore ways to address concerns about adverse impacts.

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

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

12 ### 3.3.3   DOE's Programmatic Agreement (2009)

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

30 ### 3.3.4   Additional DOE Analysis (2014)

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

37 ### 3.3.5   NRC Staff Evaluation

38 The NRC staff concluded in its ADR that DOE adequately addressed the potential impacts on
39 historic and cultural resources in its EISs, given DOE's defined region of influence and given
40 that some consultation processes were still ongoing at the time the final 2008 SEIS was
41 published. Based on the region of influence DOE described in its EISs (DOE, 2008a; 2002), the
42 NRC staff concludes that the affected environments considered in this supplement are outside
43 the region DOE evaluated in its EISs' assessments of these impacts, and that the NRC staff
44 found acceptable in its ADR. The NRC staff acknowledges that DOE has developed a
45 programmatic agreement to specifically address impacts on historic properties under the NHPA.

1 However, the NRC staff notes that the agreement scope does not include areas outside the
2 Operator-Controlled Area and that the agreement states that any impacts outside this area
3 would need to be addressed separately. In addition, the DOE programmatic agreement focuses
4 on proposed activities within the state of Nevada, and some of the affected areas identified in
5 this supplement (and in DOE, 2014a) are in California. Thus, the NRC staff concludes that DOE
6 would need to assess whether further consultation and investigation are necessary to account
7 for potential impacts on cultural resources that may be located in areas where groundwater
8 discharges to the surface.

9 ## 3.4 Environmental Justice

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

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

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

32 ### 3.4.1 Assessments in DOE's Environmental Impact Statements

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

39 ### 3.4.2 NRC Staff Assessment

40 This section assesses the potential for disproportionately high and adverse human health or
41 environmental effects on minority and low-income populations that could result from
42 groundwater containing contaminants from the repository. As stated in Section 2.1.1, the NRC
43 staff incorporates by reference its SER assessment and DOE's license application description of

1   regional demography. For this analysis, the affected area consists of population centers located
2   along the groundwater flow path from Yucca Mountain. Section 2.1.1 describes population
3   centers within an 84-km [52-mi] radius of Yucca Mountain, comprising parts of Clark,
4   Esmeralda, Lincoln, and Nye Counties in Nevada, and Inyo County in California. Within that
5   radius, there are two population centers that the NRC staff has determined are located along
6   the groundwater flow path from Yucca Mountain. The potentially-affected population centers
7   are the town of Amargosa Valley in Nye County, Nevada, and Death Valley National Park in
8   Inyo County, California (NRC, 2015a; Section 2.1.1.1.3.2., Population Centers). The NRC
9   staff's analysis of potential environmental justice impacts at these two locations is
10   provided below.

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

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

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

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

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

Table 3-18. 2010 Minority Populations and 2009-2013 5-Year Poverty Estimates for the Amargosa Valley Area			
	Amargosa Valley Census County Division	Nye County	Nevada
Percent Minority (Including Hispanic and Latino Ethnicity)*	37	72	40
Percent of Persons Below the Poverty Level	38	19	15

Source: U.S. Census Bureau American Fact Finder <http://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml> (accessed June 26, 2015)
Percentages are rounded to the nearest whole number.
*Minority population includes persons of Hispanic/Latino origin who are considered an ethnic minority and may be of any race (USCB, 2001).

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

1

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

5 Consistent with NRC guidance, the NRC staff considers the minority population in the
6 Death Valley CCD to be a significant environmental justice population (NRC, 2003). As noted in
7 Section 2, the population in Death Valley includes the Timbisha Shoshone Tribe community
8 located on a 314-acre [1.27-km^2] parcel of land in the Furnace Creek area, which is located
9 within the Death Valley CCD. The Tribe has federally appropriated rights to 92 acre-ft/year
10 [0.113 million m^3/yr] of surface and groundwater. The springs in the Furnace Creek area,
11 including the Furnace Creek, Texas, Travertine, and Salt Springs, are of traditional and cultural
12 importance to the Tribe (DOE, 2014a).

13 Section 3.1.2 describes the impacts of surface discharges, assuming no pumping at
14 Amargosa Farms, for both the present-day and cooler/wetter climate states. The assumption of
15 no pumping at Amargosa Farms models the maximum quantity of groundwater, and potential
16 contaminants, to discharge at surface locations in Death Valley (as discussed in Chapter 2; with
17 present pumping rates at Amargosa farms, no contaminants from the repository would reach
18 Death Valley). The sites where discharges of radiological and nonradiological contaminants
19 could occur are springs at the State Line Deposits/Franklin Well area (under a wetter climate
20 only), springs at Furnace Creek, and the playa/salt pan at Middle Basin of Death Valley. The
21 NRC staff estimated the peak impact at these two areas by conservatively assuming that the
22 entire contaminant plume would discharge at each location. Biosphere dose conversion factors
23 for these areas are based on exposures to full-time residents. As stated in Section 3.1.2.2, the
24 dose pathways for a resident in these areas include external exposure, inhalation of
25 soil/evaporite particulates and water vapor from evaporative coolers, and ingestion of water and
26 soil/evaporite particulates. The NRC staff did not evaluate the ingestion of crops, animal
27 products, and fish as pathways because there is little current agricultural production near the
28 Furnace Creek area, and the NRC staff does not expect that wet playas would be used for
29 agriculture. Likewise, for the Middle Basin wet playa, the NRC staff did not include the ingestion
30 of water and exposure from evaporative coolers as pathways because the saline content of the
31 water is unsuitable for such uses. Even in wetter climates, the wet playa water would be
32 unsuitable for use as drinking water or in agriculture.

Table 3-19. 2010 Minority Populations and 2009-2013 5-Year Poverty Estimates for the Death Valley Area			
	Death Valley Census County Division	Inyo County	California
Percent Minority (Including Hispanic and Latino Ethnicity)*	78	55	37
Percent of Persons Below the Poverty Level	12	13	16
Source: U.S. Census Bureau American Fact Finder http://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml (accessed June 26, 2015) Percentages are rounded to the nearest whole number *Minority population includes persons of Hispanic/Latino origin who are considered an ethnic minority and may be of any race (USCB, 2001).			

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

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

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

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

1 ### 3.4.3　　　　NRC Staff Conclusion

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

8 ## 3.5　　　　Summary

9 In its 2008 SEIS, DOE determined that the waterborne pathway (groundwater flow to discharge
10 locations downstream) would dominate potential postclosure impacts of a repository at
11 Yucca Mountain. DOE found that its estimated mean annual individual dose at the regulatory
12 compliance location was a small fraction of the 15 mrem/yr [0.15 mSv/yr] standard in
13 40 CFR Part 197 (for the first 10,000 years after closure). Similarly, DOE found that the
14 estimated annual dose for the one–million-year period was a small fraction of the annual limit.
15 DOE also found that significant human impacts from chemicals and anticipated adverse impacts
16 to biological resources would be unlikely.

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

19 The peak radiological dose from estimates for all locations evaluated in this supplement is
20 1.3 mrem/yr [0.013 mSv/yr], which occurs in the Amargosa Farms area for Analysis Case 1
21 (pumping). The NRC staff finds that the calculated radiological doses are SMALL because they
22 are much lower than the NRC annual dose standards for a Yucca Mountain repository in
23 10 CFR Part 63 {15 mrem [0.15 mSv] for the first 10,000 years, and 100 mrem [1 mSv] for one
24 million years, after permanent closure}. The peak dose estimates considered uncertainty in
25 climate and pumping rates. Based on conservative assumptions about the potential for health
26 effects from exposure to low doses of radiation, the estimated radiation dose is expected to
27 contribute a negligible increase in the risk of cancer or severe hereditary effects in the
28 potentially exposed population.

29 Impacts to all of the affected environments beyond the regulatory compliance location from
30 nonradiological (chemicals) material from the repository were also found to be SMALL, as were
31 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 10 CFR § 51.91 and in 10 CFR Part 51, Subpart A, Appendix A, and that the EISs are generally consistent with NRC's 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

1 and guidance described in NRC environmental review guidance (NRC, 2003), which
2 incorporates by reference CEQ's *Considering Cumulative Effects under the National*
3 *Environmental Policy Act* (CEQ, 1997) and EPA's *Consideration of Cumulative Impacts in EPA*
4 *Review of NEPA Documents* (EPA, 1999c). Based on the review of applicable portions of these
5 documents and the NRC's regulations for implementing NEPA in 10 CFR Part 51, the NRC staff
6 used the following methodology for assessing cumulative impacts in this supplement:

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

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

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

4.2   Spatial and Temporal Boundaries for Cumulative
Groundwater Impacts

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

28 The temporal boundaries for cumulative impacts include impacts from past actions and extend
29 to one million years after repository closure. The descriptions of the affected environment
30 provided by DOE (2014a; 2008a; 2002), as supplemented by the NRC staff (Chapter 2), already
31 encompasses the impacts of past human actions that may have previously affected
32 groundwater. The affected area includes vast and remote areas of limited human activity in a
33 predominantly naturally occurring state. Thus, the NRC staff concludes that the description of
34 the affected environment in Chapter 2 provides a reasonable baseline for the assessment of
35 cumulative groundwater impacts. The long duration of the temporal boundary is necessary
36 because, as described in Section 3.1.2, DOE and the NRC staff's analyses indicate that
37 contaminants released gradually from the repository would travel through the aquifer and
38 potentially reach ground surface locations over a very long timeframe after repository closure.
39 The analyses cover a period of one million years following repository closure, the nominal
40 "period of geologic stability" used as a basis for defining the regulatory compliance period
41 (70 FR 53,313). The NRC staff conducted a review to identify any near-term activities that
42 could contribute to long-term cumulative groundwater impacts. However, the NRC staff
43 concludes that using unsupportable assumptions about human activities occurring over the next

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

3   4.3   Potentially Affected Resources

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

7   •   Groundwater in the volcanic-alluvial aquifer, described in Section 2.2.

8   •   Resources associated with pumping and irrigation at Amargosa Farms, described in
9   Sections 2.2 and 2.3. The resources potentially affected at groundwater pumping
10   locations include groundwater, soils, ecological resources, and public health
11   (including environmental justice concerns).

12 •   Resources at current natural surface discharge locations (springs and playas) and
13   potential future sites of natural surface discharge under a reasonably foreseeable wetter
14   climate state, described in Section 2.3. The resources potentially affected at surface
15   discharge locations include groundwater, soils, ecological resources, public health
16   (including environmental justice concerns), and cultural resources.

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

21   4.4   Other Past, Present, and Reasonably Foreseeable
22   Future Actions

23   This section summarizes the other past, present, and future actions identified by DOE in the
24   2002 and 2008 EISs (Section 4.4.1) and by the NRC staff for this supplement (Section 4.4.2).
25   As described by the Council on Environmental Quality (CEQ), identifying RFFAs is a critical
26   component of a cumulative impacts analysis (CEQ, 1997). However, CEQ also recognizes that
27   agencies should not engage in speculation in an effort to identify all actions that could contribute
28   to overall potential cumulative effects. Given the long timeframes considered in this
29   supplement, as described in Chapter 2, it is not possible to identify or reasonable to speculate
30   about all potential public and private projects that could contribute to cumulative groundwater
31   impacts over the course of the next one million years. Therefore, the NRC staff reviewed
32   available information for the spatial boundary, including information in NEPA analyses and
33   resource management plans, which together provide a reasonable picture of potential present
34   or foreseeable future actions.

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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.

1 ### 4.4.1   Actions Identified in DOE's EISs

2 Section 8.1 of the 2008 SEIS incorporates by reference and updates the information in the
3 2002 EIS. This section identifies past, present, and future actions that DOE considered to have
4 the potential to affect the same resources as those that would be affected by the repository. In
5 Section 8.1.1, DOE states that the description of the existing environmental conditions in
6 Chapter 3 of DOE's 2008 SEIS accounts for the impacts of past and present actions on the
7 environment that the repository would affect. In Chapter 3 of that document, DOE describes the
8 results of groundwater sampling to support its description of regional groundwater quality. DOE
9 also provides information about contaminants in groundwater from past activities at the Nevada
10 National Security Site (NNSS; formerly the Nevada Test Site). DOE used the baseline
11 information in Chapter 3 to develop its assessment of the incremental environmental impacts of
12 the proposed repository and, thus, its assessment of cumulative impacts.

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

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

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

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

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

41 **Additional Inventory Modules**

42 Under the Nuclear Waste Policy Act (NWPA), the proposed repository would be a permanent
43 disposal facility for up to 70,000 metric tons of spent nuclear fuel (SNF) and high-level

1 radioactive waste (HLW). The NWPA requires the NRC to include in any construction
2 authorization a condition prohibiting the emplacement of more than 70,000 metric tons of heavy
3 metal or a quantity of solidified high-level radioactive waste resulting from the reprocessing of
4 such a quantity of spent fuel in the first repository until a second repository is in operation
5 [NWPA, Section 114(d)]. DOE's proposed action, as described in its 2002 and 2008 EISs and
6 in its Safety Analysis Report (SAR) (DOE, 2008b), is the construction of a repository and
7 emplacement of up to 70,000 metric tons of spent nuclear fuel and high-level radioactive waste.
8 In its 2002 EIS and 2008 SEIS analyses of cumulative impacts, DOE also included two RFFAs
9 for the emplacement of waste beyond the 70,000-metric-ton limit, which DOE referred to as
10 inventory modules. These modules accounted for the emplacement of additional SNF and other
11 HLW, as well as Greater-Than-Class-C waste, at the Yucca Mountain repository. For this
12 supplement, the NRC staff does not consider the inventory modules to be RFFAs because
13 (i) DOE did not account for the additional waste inventories in its license application; and (ii) the
14 NWPA prohibits both modules until such time as a second repository is in operation. Since no
15 repository has been licensed, and no second repository is under consideration, the NRC staff
16 concludes that a second repository is not reasonably foreseeable. The NRC staff further
17 concludes that the modules are likewise speculative, therefore are not RFFAs, and are not
18 considered further. If Congress enacts legislation that allows for the disposal of additional
19 waste inventories at the Yucca Mountain repository before a second repository is in operation,
20 any updated license application and associated environmental review would necessarily
21 analyze the change in the proposed action.

22 **NRC Staff Conclusions Regarding DOE's Identification of Other Actions**

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

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

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

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

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

4 • Because this supplement assesses groundwater impacts along the predominant
5   groundwater flow path to the pumping location in Amargosa Farms and to surface
6   discharge locations in Death Valley, the NRC staff determines that further assessment is
7   needed to determine whether there are (i) actions not identified by DOE, in addition to
8   mining, that could affect groundwater downgradient from the regulatory compliance
9   location and (ii) actions that could affect other resources at Amargosa Farms and at
10 downgradient surface discharge locations, including those identified in DOE's EISs but
11 not considered with the impacts identified in Chapter 3 of this supplement.

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

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

17 ## 4.4.2   NRC Staff Update and Supplementation of DOE EISs Identification of
18   Other Actions

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

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

33 **Nevada National Security Site**

34 DOE's National Nuclear Security Administration (NNSA) published its *Final Site-Wide*
35 *Environmental Impact Statement for the Continued Operation of the Department of*
36 *Energy/National Nuclear Security Administration Nevada National Security Site and Off-Site*
37 *Locations in the State of Nevada (DOE/EIS-0426)* (NNSS SWEIS) in February 2013. The
38 NNSS SWEIS assesses the potential environmental impacts of three alternatives for continued
39 operations at the NNSS and operations at other DOE/NNSA-managed sites in southern
40 Nevada. The sites in the spatial boundary are the NNSS, the Tonopah Test Range
41 (about 19 km [12 mi] north of the NNSS northern boundary), and environmental restoration
42 areas on the U.S. Air Force Nevada Test and Training Range (adjacent to the west, north, and
43 east of the NNSS). The three alternatives include similar types of programs, capabilities,

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

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

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

28 **Solar Energy Projects**

29 DOI BLM has approved several renewable energy projects in Nevada and California in recent
30 years as part of a larger, national effort to promote the growth of solar, wind, and geothermal
31 energy generation. None of the approved solar, geothermal, or wind energy projects are
32 located within the region of influence identified for this supplement (i.e., the geographic area
33 overlying the area of the aquifer that could be affected by the repository or that would flow
34 downstream to merge with groundwater flowing from the repository). However, three areas
35 within the region of influence may be developed as solar energy facilities. Two of the areas
36 could be developed as small (50-megawatt) photovoltaic energy facilities (Helseth, 2015). The
37 third area is a larger zone designated recently by the BLM and DOE as a "solar energy zone"
38 (SEZ), established as part of a BLM program to encourage solar energy development. This
39 zone, named the Amargosa Valley SEZ, is located in the Amargosa Desert between the Funeral
40 Mountains to the southwest and Yucca Mountain to the northeast. The SEZ is on BLM-
41 administered land and the developable area within it is 8,479 acres [34.3 km^2]. There are no
42 pending solar applications within the SEZ, but the BLM will encourage future interested parties
43 to site projects within this zone (BLM, 2012a,b). Withdrawal of small amounts of water for
44 construction {approximately 200 acre-ft [246,700 m^3] per photovoltaic facility} or operations
45 {approximately 5 acre-ft [6,170 m^3] per photovoltaic facility per year} would be the principal
46 impact on groundwater from the development of solar energy in this area (Helseth, 2015). The
47 NRC staff concludes that these solar projects would not regularly produce liquid wastes, with

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

6   **Mining Activities**

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

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

41   **4.5   Cumulative Impacts on Groundwater and from Surface**
42   **Discharges**

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

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

3   **4.5.1   Impact Assessment in DOE's EISs**

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

12   **Nevada National Security Site**

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

28   In assessing potential impacts from future LLRW disposal activities in Areas 3 and 5 of the
29   NNSS, DOE summarized various ongoing and proposed LLRW and mixed LLRW activities in its
30   2002 EIS (Section 8.3.2.1.3). DOE concluded that the only possible groundwater impacts from
31   these activities would be from a few hazardous chemicals (1,2-dichloroethane, methylene
32   chloride, and benzene), but that these chemicals are not within the inventory of chemicals from
33   the repository. The NRC staff agrees that these chemicals are not among those that would be
34   released from the repository. Further, the depth to the water table in Areas 3 and 5 ranges from
35   over 500 ft [152 m] to nearly 2,000 ft [610 m] (DOE, 2013; Section 4.1.6.2; Winograd and
36   Thordarson, 1975), and the NRC staff concludes that any small amount of contaminants leaking
37   from these LLRW activities would be detected and remediated before they could affect
38   groundwater. This conclusion is based on the NRC staff's assumption that DOE/NNSA would
39   continue managing the LLRW and mixed LLRW wastes, in compliance with applicable
40   requirements, as described in Section 4.1.11 of the NNSS SWEIS.

41   **Beatty Low-Level Waste and Hazardous Waste Disposal Facilities**

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

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

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

16   **NRC Staff Conclusions Regarding DOE's Assessment**

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

38   **4.5.2   NRC Staff Supplementation of DOE EISs Cumulative Impacts**
39   **   Assessment**

40   The following sections provide the NRC staff's supplementation to DOE's cumulative
41   groundwater impacts analysis based on (i) the NRC staff's review of DOE's identification of
42   past, present, and future actions in Section 4.4.1; (ii) the NRC staff's review of DOE's
43   assessment of cumulative impacts in Section 4.5.1; and (iii) the NRC staff's updated
44   identification of past, present, and reasonably foreseeable future actions in Section 4.4.2.
45   Updates are included, as necessary, for cumulative groundwater impacts discussed in the
46   groundwater subsections of Sections 4.5.2.1 (for the Amargosa Farms area) and 4.5.2.2

1   (for natural surface discharge locations). Supplementation is provided for cumulative impacts
2   on other affected resources at Amargosa Farms area in Sections 4.5.2.1 (soils, ecological
3   resources, public health, and environmental justice) and surface discharge locations in 4.5.2.2
4   (soils, ecological resources, public health, environmental justice, and cultural resources).

5   **4.5.2.1   Cumulative Impacts on Affected Resources at Amargosa Farms**

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

12   **4.5.2.2   Groundwater at Amargosa Farms**

13   Section 3.1.1 describes the incremental impacts on groundwater (the estimated concentrations
14   of contaminants in the groundwater) at the Amargosa Farms area, which is approximately
15   17 km [10.5 mi] beyond the regulatory compliance location, or approximately 35 km [22 mi]
16   along the flow path from Yucca Mountain. Tables 3-1a and 3-1b show the estimated levels of
17   contaminants in the aquifer environment beyond the regulatory compliance location up to
18   Amargosa Farms and at Amargosa Farms, respectively. Using the estimated concentrations in
19   the Amargosa Farms area as representative of the aquifer that is subject to groundwater
20   withdrawal in that area, Table 3-2 lists the average estimated groundwater concentrations of
21   radiological and nonradiological material from the repository in the aquifer at Amargosa Farms
22   for both the present-day and future wetter climates. As shown in Table 3-2, the estimated total
23   concentration of all of the radionuclides in groundwater at Amargosa Farms from releases at the
24   repository are lower than the applicable EPA standards for drinking water.   No standards have
25   been established for the nonradiological contaminants listed in the table, but the concentrations
26   of each are much lower than one part per million, and are comparable to natural levels in the
27   water (Table 2-2). As stated in the Aquifer Environment section of Section 3.1.1, based on the
28   NRC staff's analysis of the potential future accumulation of radiological and nonradiological
29   material released from the repository to the aquifer environment between the regulatory
30   compliance location and Amargosa Farms, the NRC staff finds that the incremental impact on
31   the aquifer environment beyond the regulatory compliance location would be SMALL.

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

41   As discussed in Section 4.5.1, in its EISs, DOE identified groundwater contamination from the
42   NNSS as a possible contributor to cumulative groundwater impacts. Since the 2008 SEIS was
43   published, DOE has detected and described contamination migrating off the NNSS. DOE
44   provided information on this contamination in the NNSS SWEIS (discussed in Section 4.4.2)
45   and it is summarized here. In its NNSS SWEIS description of affected groundwater at the

1   NNSS, DOE/NNSA reports that tritium was detected in two offsite wells. In 2009, DOE/NNSA
2   detected tritium in Well ER-EC-11, which is less than one half-mile off the northwestern
3   boundary of the NNSS on the Nevada Test and Training Range and about 23 km [14 mi] from
4   the nearest public water source, a private well. The tritium concentration was 13,180 pCi/L,
5   which is below the EPA's MCL of 20,000 pCi/L. In 2010, DOE/NNSA found low levels of tritium
6   (48.3 pCi/L) in Well PM-3, located about 11,000 ft [3,353 m] west of the NNSS boundary on the
7   Nevada Test and Training Range (DOE, 2013).

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

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

29   **Soils at Amargosa Farms**

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

39   Based on the information provided in Sections 4.4.1 and 4.4.2 concerning other actions, the
40   NRC staff has identified only regional mining activity impacts on groundwater and NNSS tritium
41   releases as additional actions or impacts that could contribute to cumulative soils impacts at the
42   irrigated Amargosa Farms area. Given the NRC staff's assessment of cumulative groundwater
43   impacts provided in the previous section, which indicates that potential mining impacts would be
44   mitigated by regulatory controls and would have minimal impacts on groundwater, and the NRC
45   staff's conclusions in Section 4.5.1 about DOE's analysis of cumulative groundwater impacts
46   from the NNSS and the Beatty disposal sites, the NRC staff concludes that the cumulative

1   impacts on soils at the Amargosa Farms area from irrigation would be minimal and would not
2   noticeably alter the soils beyond the potential impacts that could be attributed to the
3   repository alone.

4   **Public Health at Amargosa Farms**

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

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

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

39   **Ecological Resources at Amargosa Farms**

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

1 NRC staff concludes in Section 3.2 that the estimated levels of radioactivity in the environment
2 would be well below levels of concern for potential impacts to nonhuman biota.

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

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

24 **Environmental Justice at Amargosa Farms**

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

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

38 **4.5.2.3   Cumulative Impacts on Affected Resources at Natural Surface
39   Discharge Locations**

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

1 **Groundwater at Natural Surface Discharge Locations**

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

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

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

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

36 Conservatively assuming that there is limited or no pumping at the Amargosa Farms area,
37 groundwater modeling indicates that the majority of contaminants transported from
38 Yucca Mountain will be discharged at Furnace Creek (or the State Line Deposits area in a future
39 wetter climate) prior to reaching Middle Basin in Death Valley. The NRC staff concludes that
40 only a small fraction of contaminants may be directed southward toward the Alkali Flat area.
41 For this reason, as stated in Section 3.1.2.3, the NRC staff did not calculate estimates of
42 contaminants in the groundwater at Alkali Flat. Rather, the NRC staff observes that the portion
43 of the contaminant plume reaching Alkali Flat is less than 1 percent, and concludes that the
44 incremental groundwater impacts at Alkali Flat would be a small fraction of those calculated for
45 the other surface discharge areas. Therefore, incremental groundwater impacts for Alkali Flat
46 would be SMALL.

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

13   **Soils at Natural Surface Discharge Locations**

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

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

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

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

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

11   **Public Health at Natural Surface Discharge Locations**

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

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

33   Section 3.1.2.2 evaluates the public health impacts of estimated discharges at Furnace Creek
34   and Middle Basin. Because of the longer flow path and sorption in the aquifer, only nonsorbing
35   radionuclides reach the natural discharge locations in Death Valley. The primary contributors to
36   dose at this location are the nonsorbing radionuclides Tc-99 and I-129. Table 3-11 in
37   Section 3.1.2.2 provides the peak annual dose estimates for the Furnace Creek area. All
38   estimated doses for either climate state are below 1 mrem [0.01 mSv], which is a small fraction
39   of the dose from natural background levels of approximately 300 mrem/yr [3.0 mSv/yr]
40   (including radon) for Amargosa Valley and much lower than the NRC annual dose standards for
41   a Yucca Mountain repository in 10 CFR Part 63 {15 mrem [0.15 mSv] for the first 10,000 years,
42   and 100 mrem [1 mSv] for one million years, after permanent closure}. The only nonradiological
43   contaminant from the repository determined to be present in groundwater discharging at
44   Furnace Creek is Mo, because of the longer flow path and sorption in the aquifer (Mo is
45   conservatively assumed to be nonsorbing in the NRC staff's analysis). Table 3-12 provides
46   estimates of peak daily intake for Mo for the one-million-year period in both present-day and

1   cooler/wetter climates. The estimated daily intake of approximately 3×10^{-3} parts per million is
2   lower than the EPA Oral Reference Dose.

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

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

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

32   Based on the information provided in Sections 4.4.1 and 4.4.2 concerning other actions, the
33   NRC staff has identified only regional mining activity and NNSS tritium releases as additional
34   actions or impacts that could contribute to cumulative public health impacts at these areas.
35   Given its assessment of cumulative groundwater and cumulative soils impacts provided in the
36   previous sections, and based on the NRC staff's conclusions in Section 4.5.1 about DOE's
37   analysis of cumulative groundwater impacts from the NNSS and the Beatty disposal sites, the
38   NRC staff concludes that the cumulative impacts on public health at these areas would be
39   nonexistent or would be so small as to not be detectable or not noticeably affect public health
40   beyond the potential public health impacts from the repository alone.

41   **Ecological Resources at Natural Surface Discharge Locations**

42   As discussed in Section 3.2, the NRC staff evaluates the potential for nonhuman biota to be
43   exposed to radionuclides at the State Line Deposits/Franklin Wells, Furnace Creek Springs,
44   Middle Basin, and Alkali Flat based on the estimated magnitude of radioactivity in the
45   environment as quantified by the human dose estimates provided in Sections 3.1.1 and 3.1.2 for

1   present-day and future wetter climates and for both 10,000-year and one-million-year
2   timeframes. Because the human dose estimates are a small fraction of background radiation
3   exposure, the NRC staff concludes in Section 3.2 that the estimated levels of radioactivity in the
4   environment would be well below levels for potential impacts to nonhuman biota.

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

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

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

39   **Historic and Cultural Resources at Natural Surface Discharge Locations**

40   Section 3.3 provides a discussion of the NRC staff's review of DOE's historic and cultural
41   resources impact assessments in its EISs. The NRC staff concludes in Section 3.3.5 that DOE
42   adequately addressed the potential impacts on historic and cultural resources in its EISs, given
43   DOE's defined region of influence and given that some consultation processes were still
44   ongoing at the time the final 2008 SEIS was published. Based on the region of influence DOE
45   described in its EISs as being limited to the Operator-Controlled Area, the NRC staff concludes
46   that the surface discharge locations considered in this supplement are outside the region of

1   influence DOE considered in its EISs. Thus, the NRC staff concludes that DOE would need to
2   assess whether further consultation and investigation are necessary to account for potential
3   impacts and potential cumulative impacts on historic and cultural resources that may be located
4   in surface discharge areas.

5   **Environmental Justice at Natural Surface Discharge Locations**

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

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

27   # 4.6   Conclusion

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

5 SUMMARY OF ENVIRONMENTAL CONSEQUENCES

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

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

19   **SMALL**—The environmental impacts are not detectable or are so minor that they will
20   neither destabilize nor noticeably alter any important attribute of the resource.

21   **MODERATE**—The environmental impacts are sufficient to alter noticeably, but not to
22   destabilize, important attributes of the resource.

23   **LARGE**—The environmental impacts are clearly noticeable and are sufficient to
24   destabilize important attributes of the resource.

Summary of Environmental Impacts

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

32 The NRC staff finds that all of the impacts on the resources evaluated in this supplement are
33 SMALL. The NRC staff's analysis includes the impact of potential radiological and
34 nonradiological releases from the repository on the aquifer and at surface discharge locations of
35 groundwater beyond the regulatory compliance location. The peak annual individual
36 radiological dose at any of the evaluated locations is 1.3 mrem [0.013 mSv] from pumping and
37 irrigation at the Amargosa Farms area. The NRC staff concludes that all estimated radiological
38 doses are SMALL because they are a small fraction of background radiation dose of
39 300 mrem/yr [3 mSv/yr] (including radon), and much lower than the NRC annual dose standards
40 for a Yucca Mountain repository in 10 CFR Part 63 {15 mrem [0.15 mSv] for the first
41 10,000 years, and 100 mrem [1 mSv] for one million years, after permanent closure}. The NRC
42 staff's peak dose estimates accounted for uncertainty in climate and in groundwater pumping at
43 the Amargosa Farms area. Based on conservative assumptions about the potential for health

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

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

13   **Unavoidable Adverse Impacts**

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

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

21   The NRC staff considered whether its supplemental impact analyses identify any additional
22   potential impacts of short-term uses on long-term productivity from what DOE previously
23   evaluated in its EISs. Because there are no changes to the proposed action under review, the
24   NRC staff concludes there are no changes to the short-term uses of the environment, as
25   assessed in DOE's EISs. Additionally, while this supplement considers potential repository
26   impacts on the groundwater environment and from surface discharges along the groundwater
27   flow path beyond the regulatory compliance location, the SMALL impact conclusions reached in
28   this supplement entail no new and significant threats or contributions to the maintenance and
29   enhancement of long-term productivity relative to the impacts previously described by DOE
30   (2008a).

31   **Irreversible and Irretrievable Commitments of Resources**

32   The NRC staff considered whether this supplement identifies any additional irreversible and
33   irretrievable commitments of resources. Because the analyses in this supplement do not
34   change the proposed action or reveal any new and significant use or loss of finite resources, the
35   NRC staff concludes that the supplement identifies no additional irreversible and irretrievable
36   commitments of resources relative to the commitments that were previously described by DOE
37   (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.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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10 INDEX

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 regulatory 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 regulatory 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 regulatory 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 regulatory 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 regulatory 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

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

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

14   ## A.1.1   Source Term and Mass Flux at the Regulatory Compliance Location

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

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

29   Because the source terms for radionuclides and toxic chemicals are estimated using different
30   approaches, they are discussed separately in the next two subsections. This section provides a
31   brief summary of the method for calculating mass flux that was used in the 2008 SEIS for the
32   regulatory compliance location for radionuclides, and a description of the NRC staff's revised
33   approach used in this supplement that extends the analysis period for the mass flux of
34   nonradiological contaminants at the regulatory compliance location to one million years, which
35   was not part of DOE's 2008 SEIS. The mass flux at the regulatory compliance location is a
36   function of the releases from the repository and the effects of transport to the regulatory
37   compliance location. The mass flux at the regulatory compliance location over the one million
38   year period is used as an input to the transport model for the migration of radiological and
39   nonradiological contaminants along the flow path towards Death Valley. This is described in
40   Section A.1.2 (Transport to Affected Environments Beyond the Regulatory Compliance
41   Location).

42   **Source Term and Mass Flux at the Regulatory Compliance Location for Radionuclides**

43   In the 2008 SEIS, DOE used mean results from the TSPA model to estimate the source term for
44   radionuclides and transport to the regulatory compliance location. This supplement uses the

1   same approach and results, but uses those results as inputs to the transport model that
2   calculates movement of the contaminants beyond the regulatory compliance location
3   (see Section A.1.2). The NRC staff found that the TSPA model and results were acceptable as
4   part of its safety evaluation (NRC, 2014a; Section 2.2.1.4.1). The NRC staff also found, in its
5   Adoption Determination Report (ADR) (NRC, 2008a), that use of the TSPA results as a source
6   term for the regulatory compliance location is appropriate. The amounts of radionuclides
7   released from the repository over time are an intermediate result of the TSPA simulation. The
8   simulations also include transport through the unsaturated and saturated zones below the
9   repository to the regulatory compliance location approximately 18 km [11 mi] from the
10 repository. The 2002 EIS also used this approach, but with an earlier version of the TSPA
11 model. The TSPA model is a probabilistic tool that models uncertainty and variability in many
12 parameters, including the effects of future climate change. The TSPA model also includes
13 probability-weighted scenario classes, which represent different events or processes that can
14 cause failure of the engineered barriers (such as drip shields or waste packages) and cause the
15 release of contaminants from the repository. In the 2008 SEIS, mean results for 300 TSPA
16 realizations were used to construct a combined scenario case that included the nominal, early
17 failure, igneous intrusion, and seismic ground motion-fault displacement scenario classes.
18 This supplement tracks 31 radionuclides from the TSPA results as the source term for
19 calculating radiological impacts in affected environments. The NRC staff reviewed the list in
20 DOE (2014a, Table B-3 and B-4) and found that the list included the most important contributors
21 to dose as part of the NRC staff's safety evaluation (NRC, 2014a; Section 2.2.1.4.1).

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

25 •   *Advection* is the migration of contaminants by the rate of groundwater flow;

26 •   *Matrix diffusion* is the exchange between the fast-flowing groundwater in fractures and
27   faults with slow-flowing water in the rock matrix;

28 •   *Sorption* is the exchange of contaminants between groundwater and rock surfaces; the
29   sorption coefficient describes the partitioning of the contaminant between groundwater
30   and the rock (solid phase); the magnitude of sorption is dependent on the element, the
31   rock, and the groundwater chemistry;

32 •   *Colloidal transport* is the sorbing of contaminants onto colloidal particles, which can
33   then be transported as undissolved species; and

34 •   *Radioactive decay and ingrowth* is the decay of radioactive material over time, which
35   in turn may generate new radioactive contaminants (daughter products), depending on
36   the type of radioactive material.

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

1 The TSPA model used for the license application was derived using the draft rule (70 FR 53313)
2 for the licensing of a geologic repository at Yucca Mountain. The final rule (74 FR 10811), in
3 addition to other changes not relevant to this supplement, incorporated a slightly different
4 distribution for deep percolation (the amount of water moving from the surface to a great enough
5 depth that it is not removed by evaporation or transpiration) than the draft rule. This distribution
6 represents the effect of future climates for the period from 10,000 to one million years after
7 repository closure, which is applicable to the cooler/wetter climate state used in this supplement.
8 The revised distribution in the final rule led to a slightly larger mean value of percolation for the
9 10,000 to one million year period, which could potentially have affected TSPA results. The NRC
10 staff concluded in the SER that the slight change in the mean and distribution of deep
11 percolation in the final rule had no significant effect on repository performance (NRC, 2014a;
12 Section 2.2.1.3.6.3.2), and therefore no significant effect on the release of radionuclides from
13 the repository and transport to the regulatory compliance location, and hence, no significant
14 effect on the source term used in this supplement for the regulatory compliance location.

15 **Source Term and Mass Flux at the Regulatory Compliance Location for**
16 **Nonradiological Contaminants**

17 In its 2002 EIS and 2008 SEIS, DOE performed a screening analysis where it compared
18 chemical contaminants of materials used in the construction of the repository (including waste
19 package materials) with the U.S. Environmental Protection Agency (EPA) substance list from
20 the Integrated Risk Information System (2002 EIS Section I-6; 2008 SEIS Section F.5). Besides
21 toxicity information from the EPA substance list, a second component of DOE's screening
22 process was the consideration of the potential for each chemical to migrate to the accessible
23 environment (in DOE's analysis, the regulatory compliance location). For nonradiological
24 material, DOE only considered the first 10,000 years after closure in its screening analysis. The
25 source term that DOE developed for nonradiological chemicals was based on the thickness of
26 corroded material and the total surface area of repository construction and waste package
27 material exposed to corrosion. Because only a few packages were predicted to fail in the first
28 10,000 years after permanent closure, chemically toxic materials from within the waste
29 packages were not considered.

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

1   This appendix describes the estimation of mass flux of nonradiological contaminants applied to
2   the regulatory compliance location over the entire one-million-year period, beyond the
3   10,000 year period evaluated by DOE. This description begins with the source term at the
4   repository and adjusts for transport processes along the saturated flow path to estimate the
5   one-million-year mass flux at the regulatory compliance location. The release of contaminants
6   from the repository is conservatively applied directly to the unsaturated-saturated zone
7   boundary below the repository. Because more waste packages are expected to fail during the
8   one-million-year period, compared to the number of expected failures during the first 10,000
9   years, toxic chemical contaminants from fuel assemblies and other materials inside waste
10 packages are considered in addition to the materials (e.g., stainless steel or Alloy 22)
11 considered in the 2008 SEIS. From the inventory of material inside failed waste packages,
12 uranium (U) is the only additional contaminant added to the list of toxic chemicals because of its
13 large quantity and its high toxicity (DOE, 2014a). For U, the source term is derived from TSPA
14 results for radionuclides as the sum of all U isotopes arriving at the regulatory compliance
15 location (as all forms of U are radioactive) (DOE, 2014a). Based on this screening process,
16 which considers mobility and toxicity (DOE, 2014a), no other contaminants from inside waste
17 packages are added to the list. Therefore, total U is added to Mo, Ni, and V as the toxic
18 chemicals considered in this supplement. The NRC staff reviewed the mobility and toxicity
19 screening process used by DOE and finds no other elements in the construction and waste
20 package materials that should be included in this supplement.

21 To estimate the mass flux reaching the regulatory compliance location, the source term from the
22 repository is adjusted using a two-step procedure to account for delays and reductions during
23 transport between the repository and the regulatory compliance location. First, a simplified
24 model is used for the release rate of nonradiological contaminants (Mo, V, Ni) from the
25 repository to estimate the mass flux at the unsaturated-saturated boundary approximately
26 300 m [1,000 ft] below the repository. The release rate model approach is based on the
27 analysis in DOE (2014a), which used the following assumptions and values:

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

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

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

45 The analysis in DOE (2014a) included an unrealistic assumption of the total amount of
46 nonradiological contaminants that could be released from the repository. For the calculations in

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

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

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

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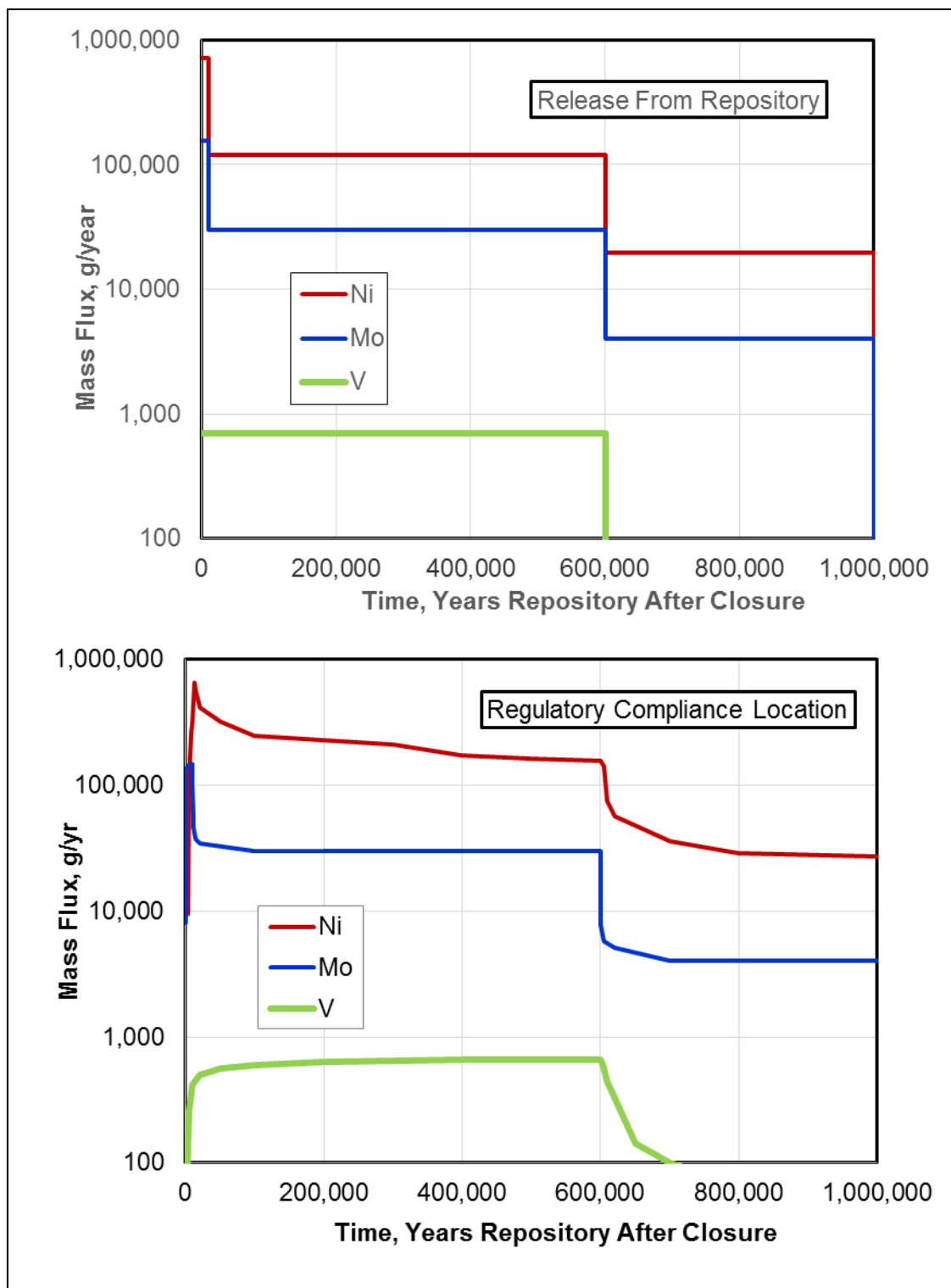
**Figure A–1. Mass Flux for Mo, Ni, and V Released From Repository (Top) and Reaching
the Regulatory Compliance Location (Bottom). To Plot All Three Metals on
the Same Graph, a Logarithmic Mass Flux Scale Is Used.**

1

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

In its 2002 EIS, DOE considered transport beyond the regulatory 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 regulatory 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] regulatory 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 regulatory compliance location can be no greater than those estimated for the regulatory compliance location.

In this supplement, the NRC staff uses the transport analysis is 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 regulatory compliance 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 regulatory 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 regulatory compliance location and tracked. The 8,024 particles used at the regulatory compliance location were derived from release of 10,000 particles from Yucca Mountain in the Yucca Mountain Site-Scale

1   Flow Model (SNL, 2007a). When pumping is included in the DVRFS model, all particles are
2   captured by the wells in Amargosa Farms. When no pumping is included (the pre-pumping
3   model, representing groundwater conditions prior to 1913), particle tracking identifies two
4   potential pathways downstream of Amargosa Farms. The strongly predominant path is
5   approximately southward through Amargosa Farms, turning southwestward to westward
6   beneath the Funeral Mountains, to the springs at Furnace Creek, and on to Middle Basin in
7   Death Valley (DOE, 2014a; Figure 3-1). A potential alternative path (only two particles out of
8   8,024 leaving the regulatory compliance location took this course) is southward past Amargosa
9   Farms to surface discharge at Alkali Flat (DOE, 2014a; Figure 3-2). For this analysis, these
10   two particles represent the limited possibility that a small amount of contamination could divert
11   from the predominant pathway.

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

30   **Transport Model**

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

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

1   Transport in the pipe is based on an analytical solution of the advection-dispersion equation
2   modified for sorption and decay. The exact solution to the equation (Lapidus and Amundsen,
3   1952; Equation 9) is simplified by
4   dropping the term for short distances.
5   The concentration-based solution is
6   multiplied by the volumetric flux to convert
7   it to a mass flux-based solution. In
8   addition, a mathematical identity for the
9   complementary error function in the
10   solution is used to avoid potential
11   computational difficulties which can occur
12   with a numerical approach. Whereas the
13   analytical solution for transport is valid for
14   a constant source term, solutions for
15   different magnitudes of the source term
16   that occur at different times are additive.
17   Because the mass flux at the regulatory
18   compliance location changes with time,
19   the solution approach is to break up the
20   source term into step changes (of radionuclide and nonradiological contaminant mass fluxes)
21   and solve the transport equation for each source term step. The solution for a location and time
22   is then the sum of contributions from each source term step.

> **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.

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

39   The primary inputs for the transport model are sorption properties for each contaminant and flow
40   path characteristics from the DVRFS model. Sorption analyses in this supplement use values
41   from DOE (2014a; Table B-1). For radionuclides in volcanic and alluvial rock units, DOE
42   derived the sorption values from the low end of the range provided in the SAR (DOE, 2008b;
43   Table 2.3.9-14), and updated them based on more recent literature (DOE, 2014a). Larger
44   values of sorption coefficients lead to delayed arrivals of contaminants at downstream locations,
45   such as delays in the time of peak concentrations. The NRC staff found that the values in
46   DOE's SAR were acceptable as part of its safety evaluation (NRC, 2014a, Section 2.2.1.3.10).
47   Further, sensitivity analyses using a set of significantly lower sorption values for all
48   contaminants (except non-sorbing species where the sorption coefficient is zero) (DOE, 2014a,
49   Table B-16; DOE, 2008b, Table 2.3.9-14) showed only a 15 percent increase in dose and body

1   uptake impacts (DOE, 2014a). This small increase in impacts would not change the
2   conclusions in Chapter 3 of this supplement. Therefore, the NRC staff finds the sorption
3   properties in DOE (2014a, Tables B-1) reasonable for use in this supplement for the transport
4   model.

5   Secular equilibrium for decay chain isotopes is a valid assumption when the sorption
6   coefficients of parent and daughter products of radionuclides are similar in magnitude. In its
7   2002 EIS and 2008 SEIS, DOE assumed secular equilibrium for all radionuclides in decay
8   chains. In DOE (2014a), DOE screened radionuclide decay chains for parent and daughter
9   radionuclides with large differences in respective sorption coefficients. DOE identified the
10   actinium, neptunium, thorium, and uranium series in the screening analysis (DOE, 2014a). The
11   NRC staff reviewed the screening of radionuclide series for secular disequilibrium in the SAR,
12   and found this same list acceptable for use in the SAR (NRC, 2014a; Section 2.2.1.3.9). In this
13   supplement, the effect of secular disequilibrium is accounted for by applying a scaling factor to
14   the dose conversion factors for radionuclides of parent-daughter pairs with different sorption
15   characteristics. Any factor above one has the effect of increasing the estimated dose impact of
16   the identified radionuclide species. Following the approach described in Olszewska-Wasiolek
17   and Arnold (2011), the factors used in this supplement are 8.7 for Ra-228 and 1.8 for lead-210
18   (Pb-210) and Ra-226 (shown in DOE, 2014a, Tables B-3 and B-4).

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

31   These parameters are derived as follows. Particle track modeling indicates the different
32   hydrogeological units that water flows through along the paths from the regulatory compliance
33   location to either Amargosa Farms or to Furnace Creek/Middle Basin. The distance the particle
34   travels in each hydrogeological unit is the length of the flow segment, which, when summed,
35   provides the total flow path length. For bulk density and porosity, a single value for the entire
36   flow path length is derived using a distance-weighted average of the properties for the individual
37   segments along the pathway. Specific discharge is calculated as the average travel time of
38   particles divided by the total length of the flow path. For the cooler/wetter climate state, the
39   specific discharge rate is increased by a factor of 3.9 over that of the present-day climate to
40   account for potentially faster groundwater flow under the wetter conditions. Whereas a
41   cooler/wetter climate would lead to both a higher water table and faster flow rates, the NRC staff
42   review in the SER (NRC, 2014a; Section 2.2.1.3.8) concluded that only the faster flow rates
43   need be considered for the transport model. The factor of 3.9 was derived from simulations of
44   wetter conditions using the DVRFS model (D'Agnese, et al., 1999; SNL, 2008, Table 6-5), and
45   was used for the glacial-transition climate in TSPA model simulations (DOE, 2008b, Section
46   2.4). The NRC staff reviewed the basis for the factor of 3.9 and found it to be an acceptable
47   representation of the glacial-transition climate and for the long-term climate change during the
48   10,000 to one million-year period in its safety evaluation (NRC, 2014a, 2.2.1.3.8).

1   A separate calculation is required to estimate contaminant concentrations in the
2   aquifer environment between the regulatory compliance location and Amargosa Farms
3   (see Section 3.1.1) because the one-dimensional pipe-model approximation does not account
4   for the potential plume dimensions. The contaminant concentration for the aquifer environment
5   is estimated as the difference between the amount of radiological or nonradiological mass at the
6   regulatory compliance location and that at the Amargosa Farms divided by the volume of the
7   aquifer environment. The volume of the aquifer environment is conservatively estimated by the
8   dimensions of the particle tracking traces in DOE (2014a, Figure 3-1; 2008b, Figure 2.3.9-14).
9   This volume estimate is conservative because particle tracking neglects lateral and vertical
10 dispersion, which would lead to larger aquifer volumes and lower concentrations. From these
11 values, representative dimensions of the plume are 3 km [1.9 mi] wide and 100 m [330 ft] thick
12 The third dimension of the volume is the distance between the regulatory compliance location
13 and Amargosa Farms, which is 17 km [10.5 mi]. The next section provides a description of
14 processes at surface discharge locations, for which the mass fluxes are used as input to
15 estimate impacts at those locations.

A.2   Processes at Discharge Sites

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

A.2.1   Groundwater Pumping, Recycling, and Irrigation

24 Groundwater may be discharged at the surface due to pumping or through natural discharge
25 features, such as springs, seeps, and wet playas. In the Amargosa Farms region, a significant
26 amount of shallow alluvial aquifer groundwater is pumped and used as a source of domestic
27 and commercial water supply and for the irrigation of crops. As irrigation water is applied to
28 soils, its chemical constituents can be taken up by crops, sorbed to soils, and concentrated by
29 the effects of evaporation and transpiration. These processes can lead to the buildup of salts
30 and other elements detrimental to continued farming and the broader ecosystem. In addition, in
31 the Amargosa Farms region, excess irrigation water is applied to compensate for evaporation
32 and to limit the buildup of salts in the root zone of the soil (DOE, 2014a). Excess irrigation is the
33 practice of applying more irrigation water than is needed by the particular crop, thus enabling
34 the excess water to recharge the water table while carrying the salts (and in this modeling case,
35 some of the contaminants) away from the upper soil layers. The water that reinfiltrates the
36 aquifer then becomes available again for groundwater pumping.

37 This practice adds a complicating factor in assessing impacts from irrigation where irrigation
38 water percolates deep into the subsurface and is recaptured and recycled at pumping locations.
39 Where this occurs, the recycling process increases concentrations of contaminants in the
40 groundwater and thus increases the concentrations of contaminants as they are reapplied to
41 the surface during irrigation.   Groundwater pumping at Amargosa Farms is on the order of
42 17,000 acre-ft/yr [21 million m^3/yr].   This high volume of irrigation indicates that use of an
43 irrigation recycling model is warranted for the assessment of impacts at Amargosa Farms.

44 For this supplement, a mathematical analytical solution describing an equilibrium concentration
45 is used to incorporate the impacts of irrigation recycling at the Amargosa Farms area, following

1   the approach in DOE (2014a; SNL, 2007b). This mathematical solution, referred to hereafter as
2   the special-case model, neglects the effects of radioactive decay. Neglecting decay
3   overestimates radionuclide concentrations and, therefore, impacts. DOE (2014a) notes that
4   more detailed irrigation recycling models have been developed (SNL, 2007b; Kalinina and
5   Arnold, 2013), but that the special-case model represents a limiting case of the more detailed
6   irrigation recycling models. The NRC staff finds that the irrigation recycling model in
7   DOE (2014a) represents a reasonable, limiting case that would lead to conservative results for
8   this analysis.

9   The output of the recycling irrigation model that is used in this supplement is used to increase
10   the amount of recycled groundwater. The irrigation recycling model includes two factors to
11   calculate the change in concentration of dissolved contaminants in groundwater resulting from
12   irrigation recycling: (i) the amount of pumped water used for irrigation and (ii) the amount of
13   irrigation water recaptured by pumping wells (DOE, 2014a). For the first factor, 86 percent of
14   pumped groundwater on average in the Amargosa Farms area is used for irrigation
15   (Moreno and Justet, 2008). For the second factor, this supplement conservatively assumes that
16   100 percent of the irrigation water is subsequently recaptured by the Amargosa Farms area
17   wells, and also assumes no decay of the contaminants. In addition, this model also assumes
18   that none of the contaminants in the plume are sorbed to the aquifer during deep percolation.
19   As a result of these factors and assumptions, the model used in this supplement produces an
20   increase in groundwater contaminant concentrations by a factor of 7.1, which is much larger
21   than values (1.1 to 1.5) used to assess the impacts of irrigation recycling at the regulatory
22   compliance location in the SAR (DOE, 2014a; Kalinina and Arnold, 2013; SNL, 2007b). The
23   calculated changes in groundwater concentrations are then applied to the contaminant
24   concentrations in the transport model for the Amargosa Farms area to incorporate the impact of
25   irrigation recycling in the groundwater pumping scenario. The NRC staff finds the DOE
26   implementation of the irrigation recycling model in DOE (2014a) acceptable and reasonable for
27   use in this supplement because (i) the NRC staff reviewed the irrigation model in the SER and
28   found it acceptable as part of its safety evaluation (NRC, 2014a; Section 2.2.1.3.14); and (ii) the
29   irrigation recycling model input for recapture was changed to a maximum possible value, and
30   the percentage of pumped groundwater in Amargosa Farms was set to the actual value
31   determined by Moreo and Justet (2008); and (iii) radioactive decay is conservatively neglected
32   for the recaptured water.

33   Two forms of the irrigation recycling model used in this supplement are applied at two locations:
34   Amargosa Farms and the State Line/Franklin Well area. Recycling is included for Amargosa
35   Farms where wells that pump water for irrigation are generally located in the farm fields where
36   the irrigation water is applied. Recycling is not included in the salt marsh model used for the
37   State Line/Franklin Well area because the water from springs and marshes would not be
38   applied at the location it is discharged. In any potential irrigation at the State Line/Franklin Well
39   area, fresh water from springs and marshes would be diverted to locations downstream from the
40   extraction location where soils are not highly saline. In this type of environment, areas close to
41   springs and marsh areas would contain high levels of salts, and thus would be unsuitable
42   for agriculture.

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

46   In the 2002 EIS and 2008 SEIS, DOE did not include an assessment of impacts from
47   groundwater-borne contaminants downstream of the regulatory compliance location.

1   Although potential groundwater flow paths downstream of the compliance location were
2   discussed in the 2008 SEIS, there was limited description of groundwater-surface interaction
3   processes and no quantitative assessment of impacts from groundwater discharging at the
4   ground surface beyond the regulatory compliance location.

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

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

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

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

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

37   As groundwater moves closer to the surface or is discharged at the surface, it is impacted by
38   gas exchange with the atmosphere, sorption on minerals in the soil, and concentration effects.
39   Groundwater in the subsurface typically has an elevated concentration of carbon dioxide (CO_2),
40   relative to surface water in equilibrium with the atmosphere, due to chemical exchange with
41   carbonate rocks in the aquifer. As the groundwater is discharged, it re-equilibrates with the
42   atmosphere. Depending on the overall chemical composition of the groundwater, the loss of
43   CO_2 may result in the precipitation of carbonate minerals, such as calcite. In the Yucca
44   Mountain region, precipitation of calcite is observed at springs that originate from the carbonate
45   aquifer, like those in Ash Meadows or Furnace Creek (Johannesson, et al., 1997; Paces, et al.,

1   1997). Other effects from the loss of CO_2 may include an increase in pH (alkalinity) of the
2   groundwater. Both pH and CO_2 concentration changes can affect the potential for sorption onto
3   soil and other surface sediments. The modeling described in this supplement uses the sorption
4   values reported in DOE (2014a) to calculate the retention of contaminants on soils and
5   sediments. The mean values reflect a range of sorption values that capture the range of pH and
6   CO_2 effects on sorption.

7   At wet playas, the upward movement of groundwater is not driven by water table interactions,
8   but by capillary action that draws the groundwater upward. Nearer the surface, the groundwater
9   is subject to evaporation and evapotranspiration. These processes tend to concentrate the
10 chemical constituents in the groundwater and increase the total dissolved solids (TDS) content
11 of the water. As more water is lost, the water becomes more saline, and solubility limits for
12 minerals may be exceeded. Various carbonates, salts, and other evaporite minerals may
13 precipitate. This action produces a soft surface of evaporite phases that are typically rich in
14 minerals such as calcium carbonate, hydrated calcium sulfate, sodium chloride, and sodium
15 sulfate (DOE, 2014a). The specific types of evaporite minerals that form are dependent on the
16 initial groundwater chemistry and the extent of evaporation, and the deposits are often zoned
17 (Hardie, 1968). The evaporite deposits are found both in the capillary fringe area and on the
18 surface of a playa (DOE, 2014a); extreme evaporation in a closed basin can lead to thick,
19 zoned sequences of relatively pure evaporite minerals, as in Badwater Basin in Death Valley
20 (e.g., Hunt and Mabey, 1966). As the evaporite mineral crystals form, they also displace and
21 mix with the rock-derived sediments (often fine silts and clays), expanding the sediments
22 upward (DOE, 2014a; Reynolds, et al., 2007). The playa deposits with evaporite minerals are
23 often described as "fluffy" with large pore space and low density (Reynolds, et al., 2007). At the
24 surface, microbial activity may produce mats that trap additional sediment and control the types
25 of mineral phases that form (Douglas, 2004). Sometimes a more compact, but still friable
26 (easily crumbled) material forms, which contains a lower fraction of evaporate minerals
27 (DOE, 2014a). These types of deposits are associated with lower rates of evaporation or lower
28 salinity in the groundwater (DOE, 2014a). The residual water is highly mineralized. For
29 example, at Alkali Flat (Franklin Lake Playa), stagnant water has TDS content of 70,000 to
30 80,000 ppm, and drainage paths have water with TDS content of 6,000 to 20,000 ppm (DOE,
31 2014a; Reynolds et al. 2007). For comparison, water with less than 250 ppm TDS is generally
32 considered to be potable.

33 The effect of evaporation and evaporite mineral formation on the contaminants is to concentrate
34 them in the groundwater and eventually incorporate them into the evaporite mineral phases.
35 The dose model in this supplement does not include assumptions about preferential retention or
36 partitioning of contaminants into specific precipitated minerals. Although some preferential
37 partitioning is likely, this is a reasonable assumption that ensures all contaminants are available
38 for subsequent dose assessments due to exposure to evaporite particulates from soil
39 disturbances. If preferential partitioning occurred, contaminants would only be available for
40 exposure pathways for some fraction of time. At other times, burial and precipitation of
41 uncontaminated evaporates would lead to lesser or no impacts.

42 In this supplement, contaminant concentrations are estimated in the surficial materials at wet
43 playas by using the ratio of the contaminant concentration to the observed TDS in the
44 groundwater. This approach for estimating contaminant concentrations in surficial materials is
45 conservative for several reasons. First, this approach conservatively assumes that evaporites
46 are the only component of the surficial material; including the rock-derived component (e.g., silt,
47 clay) of the surficial material would dilute the contaminant concentration. Second, the TDS in
48 the groundwater is conservatively assumed to be 257 ppm, which is the TDS from the J-13 well.

1   The J-13 well measured the volcanic aquifer below Fortymile Wash and upstream of the
2   regulatory compliance location. Because TDS generally increases with the time or distance that
3   water is below ground, the TDS from J-13 is lower than that in groundwater downstream of the
4   regulatory compliance location. For comparison, the measured TDS of spring water at Furnace
5   Creek is approximately 600 ppm TDS (Steinkampf and Werrell, 1998); using this value for TDS
6   would decrease the contaminant concentration in evaporite to less than half that of the estimate
7   provided in Chapter 3 of this supplement. Third, this approach for estimating evaporite
8   concentrations is conservative because the evaporites, which include potential contaminants,
9   can be redistributed by wind and rainfall. Since many of the evaporite minerals are highly
10   soluble, they can be dissolved and redistributed during periods of water inundation and flow.
11   Redistribution of the contaminated evaporite particulates would tend to disperse contaminants
12   over a larger area and dilute their concentration.

A.2.3   Biosphere Exposure and Dose Conversion

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

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

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

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

34   The biosphere exposure framework in Figure A–2 lists a range of potential pathways, but not all
35   water uses and exposure pathways apply to each environment in this supplement. For the
36   pathways for each environment, dose conversion factors were derived from SNL (2007c) for the
37   31 radionuclides that make up the source term from the repository (DOE, 2014a). The NRC
38   staff, as part of its safety evaluation, found the biosphere exposure framework and dose
39   conversion factors to be acceptable (NRC, 2014a; Section 2.2.1.3.14). The impacts from total U
40   and the nonradiological contaminants Mo, Ni, and V are assessed by estimating the daily
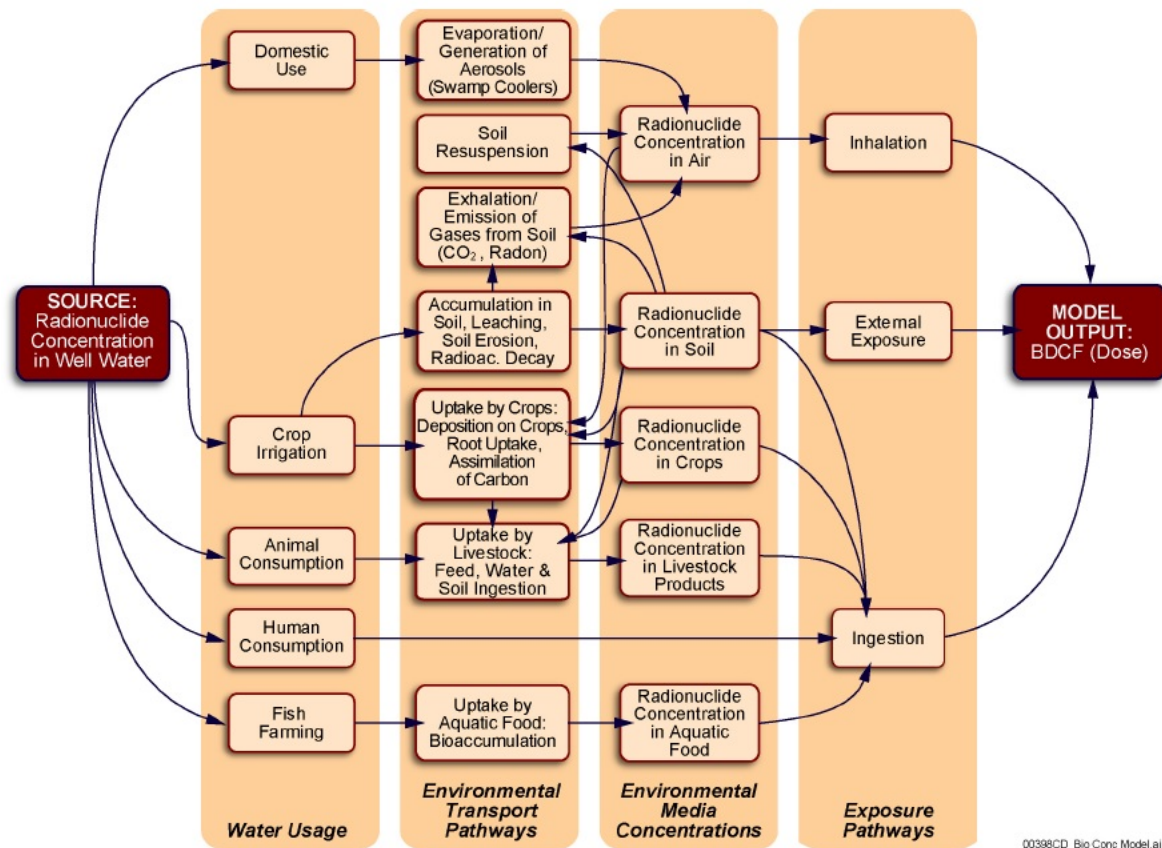41   uptake amount.

42

43

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).

1 **Environment 1: Irrigation Pumping and an Agricultural Community**

2 This environment includes groundwater pumping for irrigation and groundwater use for a
3 domestic and commercial water supply in an agricultural community. Presently,
4 Amargosa Farms is the only location along the flow path from Yucca Mountain where extensive
5 groundwater pumping occurs. The population eats locally grown food, both plants grown in
6 fields and animals raised in the area, and works and lives in areas where the soils could
7 become contaminated by water pumped for irrigation. Some fraction of the contaminants can
8 leach back into the aquifer and possibly be recaptured by pumping wells, and some fraction
9 would escape by soil erosion. In addition, decay and ingrowth will affect radionuclide
10 concentrations. These processes are captured in the recycling irrigation model described in
11 Section A.2.1.

12 The dose pathways for this environment (e.g., Amargosa Farms) are (i) external (body)
13 exposure to contaminated soil, dust or water; (ii) inhalation of contaminated soil particles
14 (including Ra-226) and vapor from evaporative coolers; and (iii) ingestion of water, crops, meat,
15 fish, and soil. These pathways have not changed from those used in the 2002 EIS and 2008
16 SEIS. The dose conversion factors used in this supplement are from DOE (2014a, Table B-3),
17 which were derived from the maximum values in the distributions provided in the SAR
18 (DOE, 2008a; Table 2.3.10-12). The NRC staff found the dose conversion factors in the SAR

1 acceptable in its safety evaluation (NRC, 2014a; Section 2.2.1.3.14). The dose conversion
2 factors have been adjusted for secular disequilibrium for identified radionuclides as described in
3 Section A.2.2.

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

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

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

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

25 Intake of chemical contaminants at a springs-type environment is based on daily intakes by a
26 70-kilogram [150-lb] person drinking 2 liters [8.5 cups] of water per day. The daily intake is
27 equal to the water concentration times the daily amount consumed, divided by the weight of
28 a person.

29 **Environment 3: Surface Discharge at Wet Playas**

30 At playas, groundwater comes close to the ground surface and evaporates or transpires, leaving
31 evaporite minerals in the surficial materials (soil and evaporite). The evaporite mineral content
32 and percentage in the surficial materials can be highly variable. The nonevaporite material is
33 comprised of soil present prior to playa formation, the windblown dust deposited concurrently
34 with evaporite precipitation, and other sediment carried in from higher elevations by sporadic
35 flooding. Water in the surficial materials and at the surface can be highly variable in
36 composition, but is often saline. Intermittent or local springs may also occur, but the amount of
37 potable water is generally insufficient to support a local human population. The environment is
38 not conducive to farming, and natural vegetation is typically sparse and composed of salt-
39 tolerant species. Examples of playas without prominent springs are the Middle Basin of
40 Death Valley and Alkali Flat. For future wetter climates, the State Line Deposits area would
41 likely also have wet playas, but may also have springs, pools, and marshes.

42 The exposure pathway for playas includes (i) inhalation of resuspended contaminated dust,
43 (ii) ingestion of contaminated water and inadvertent ingestion of evaporites, and (iii) external

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

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

21 **Climate States**

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

30 # A.3 Conservative Assumptions Used in the Model Calculations

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

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

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

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

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

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

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

34 • The NRC staff's evaluation assumes that doses and intakes would be proportional
35   to evaporite concentrations at playas. This is a conservative assumption because
36   (i) low-end estimates of dissolved solids in the water were used to estimate radiological
37   and nonradiological concentrations in the precipitated evaporites, (ii) zonation of
38   evaporation sequences and burial may reduce availability of contaminants for dust
39   resuspension, and (iii) rock-based clastic soils and windblown dust would make up
40   some of the surficial material, and therefore reduce the effective concentration
41   of contaminants.

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

APPENDIX B

RESPONSES TO PUBLIC COMMENTS

1 **APPENDIX B—RESPONSES TO PUBLIC COMMENTS**

2 This appendix is intentionally left blank in the draft supplement. In the final supplement, this
3 appendix will include comments and responses received on the draft supplement.

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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.

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