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

Readers Guide and Summary

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

DOE/EIS-0250

February 2002

ACRONYMS AND ABBREVIATIONS

To ensure a more reader-friendly document, the U.S. Department of Energy (DOE) limited the use of acronyms and abbreviations in this environmental impact statement. In addition, acronyms and abbreviations are defined the first time they are used in each chapter or appendix. The acronyms and abbreviations used in the text of this document are listed below. Acronyms and abbreviations used in tables and figures because of space limitations are listed in footnotes to the tables and figures.

CFR	Code of Federal Regulations
DOE	U.S. Department of Energy (also called *the Department*)
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
FR	*Federal Register*
LCF	latent cancer fatality
MTHM	metric tons of heavy metal
NEPA	National Environmental Policy Act, as amended
NRC	U.S. Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act, as amended
PM_{10}	particulate matter with an aerodynamic diameter of 10 micrometers or less
$PM_{2.5}$	particulate matter with an aerodynamic diameter of 2.5 micrometers or less
REMI	Regional Economic Models, Inc.
RMEI	reasonably maximally exposed individual
Stat.	United States Statutes
TSPA	Total System Performance Assessment
U.S.C.	United States Code

UNDERSTANDING SCIENTIFIC NOTATION

DOE has used scientific notation in this EIS to express numbers that are so large or so small that they can be difficult to read or write. Scientific notation is based on the use of positive and negative powers of 10. The number written in scientific notation is expressed as the product of a number between 1 and 10 and a positive or negative power of 10. Examples include the following:

Positive Powers of 10
$10^1 = 10 \times 1 = 10$
$10^2 = 10 \times 10 = 100$
and so on, therefore,
$10^6 = 1{,}000{,}000$ (or 1 million)

Negative Powers of 10
$10^{-1} = 1/10 = 0.1$
$10^{-2} = 1/100 = 0.01$
and so on, therefore,
$10^{-6} = 0.000001$ (or 1 in 1 million)

Probability is expressed as a number between 0 and 1 (0 to 100 percent likelihood of the occurrence of an event). The notation 3×10^{-6} can be read 0.000003, which means that there are three chances in 1,000,000 that the associated result (for example, a fatal cancer) will occur in the period covered by the analysis.

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WHY A READERS GUIDE?

The Proposed Action for this environmental impact statement (EIS) – to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain in Nevada – is complex. The EIS evaluates not only impacts associated with constructing, operating, and closing a repository, but also those associated with transporting the materials to the Yucca Mountain Repository site. In addition to evaluating the near-term impacts of those activities, the EIS evaluates impacts that could occur hundreds of thousands of years in the future.

The No-Action Alternative is also complex, involving estimated impacts of allowing spent nuclear fuel and high-level radioactive waste to remain at 72 commercial and 5 U.S. Department of Energy (DOE, or the Department) sites across the United States.

In addition to the Draft EIS, DOE issued a Supplement to the Draft EIS. The Department received thousands of comments on the Draft EIS and the Supplement, and considered each comment in preparing the Final EIS. DOE has prepared this guide to help the reader understand the Final EIS, its different parts, and the approach the Department followed in moving from Draft EIS to Final EIS.

WHY DID DOE CHANGE THE EIS?

The Proposed Action for this EIS has not changed. With that in mind, and in accordance with Council on Environmental Quality regulations under the National Environmental Policy Act of 1969, as amended, DOE relied on three criteria for introducing changes to information presented in the Draft EIS and the Supplement to the Draft EIS in the preparation of this Final EIS. The Department changed the EIS (1) in response to public comments as appropriate, (2) to correct errors in the Draft EIS or the Supplement to the Draft EIS, and (3) to provide new information or improved analyses relevant to the EIS. For example, DOE changed the EIS to identify its preferred transportation mode (mostly rail nationally and in Nevada), to incorporate 2000 Census data, to address the final Environmental Protection Agency standards and Nuclear Regulatory Commission rule related to Yucca Mountain, and to add Appendix M to provide general transportation information not specifically related to the transportation analysis considered in Chapter 6 and Appendix J.

DOE issued the Draft EIS in August 1999 and requested comments on it. The Department received more than 11,000 comments in letters, e-mails, faxes, and transcripts of public hearings at 21 locations across the country. As described below, Volume III of this EIS contains all of those comments individually or in summary form, and the DOE responses to them. Some of those comments led DOE to change or update the EIS, primarily to enhance understanding, but also to correct errors that readers found.

In addition to errors pointed out by the public during the comment periods on the Draft EIS and the Supplement to the Draft EIS, DOE internal reviewers found typographical or editorial errors. These errors have been corrected in the Final EIS.

Finally, DOE has included new information and related analyses in the Final EIS. The primary example concerns the evolving nature of the repository design. In May 2001, DOE issued for public comment the Supplement to the Draft EIS to address the repository design evolution. This Final EIS incorporates the design information from the Supplement and, in some cases, updates that information. These changes occur throughout the EIS, but primarily in Chapters 2, 4, and 5. DOE made other changes to the EIS in response to the more than 1,900 public comments it received on the Supplement.

HOW DID DOE CHANGE THE EIS?

This Final EIS is based on the Draft EIS and the Supplement to the Draft EIS. Although not required by regulations, DOE has chosen to indicate substantive changes (additions and deletions) to the scientific and technical analyses of impacts with "change bars" in the margins of the affected pages. These change bars indicate new or revised information acquired since the publication of the Draft EIS or the Supplement, information based on revised analyses, and information included as the result of public comments. DOE did not use change bars for editorial changes (including references) or rephrased (but technically unchanged) information from the Draft EIS or the Supplement to the Draft EIS.

As mentioned above, changes and updates to the EIS came about for a variety of reasons. The primary reason was the evolving nature of the repository design, which was the basis for the preparation of the Supplement to the Draft EIS. This Final EIS incorporates new analyses based on the flexible design higher- and lower-temperature repository operating modes introduced in the Supplement and now described in Chapter 2 and the resultant environmental impacts, as described in Chapters 4 (preclosure impacts) and 5 (postclosure impacts). The design evolution also affected the analyses described in Chapter 8 (cumulative impacts) and Chapter 6 (transportation impacts related to shipments of additional repository components and construction materials).

A number of commenters on the Draft EIS or on the Supplement to the Draft EIS requested DOE to make changes, and DOE did so where appropriate. However, some suggested changes were inappropriate because they would have introduced errors or because they were not germane to the Proposed Action. Other than the three types of changes described above, the Department did not alter the EIS.

The following list highlights areas of change incorporated in this Final EIS:

- More information regarding potential impacts, particularly impacts associated with transportation of spent nuclear fuel and high-level radioactive waste within Nevada

- Use of a "representative" fuel assembly in the accident analysis

- Use of updated data, particularly population data in the impact analyses

- A more detailed discussion of the issue of potential impacts associated with negative perceptions about the repository project

- Use of updated versions of computer models for assessing human health and transportation impacts

- Corrections or editorial changes for accuracy and clarity

- Addition of an appendix that contains general information about transportation of radioactive materials not specifically used in the analysis, but provided for public information

- Addition of the U.S. Fish and Wildlife Service Biological Opinion as an appendix to the Final EIS

- Addition of a Readers Guide to help readers understand the Final EIS

Readers will notice a change in the way this Final EIS presents references. In the Draft EIS, a reference appeared in the form, for example, DOE 1998a, p. 5. In the Final EIS, the same reference appears as DIRS 101779-DOE 1998, p. 5. Because of the large number of references cited in the Final EIS, DOE has introduced the Document Input Reference System (DIRS) to ensure that each citation is appropriate and proper. In addition, to aid the reader, DOE decided to put the reference list for each chapter at the end of that chapter and to not use a single list (which appeared in the Draft EIS as Chapter 12).

WHAT DOES THE FINAL EIS LOOK LIKE?

This *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* has four parts:

- Readers Guide and Summary
- Volume I – Impact Analyses, Chapters 1 through 15
- Volume II – Appendixes A through O
- Volume III – Comment-Response Document
- Volume IV – Additional information available upon written request to the DOE EIS Document Manager.

The purpose of the Summary is to present a condensed discussion of the analyses and impacts related to the Proposed Action and the No-Action Alternative, derived from the descriptions in Volumes I and II and from comments and responses contained in Volume III. The Summary stresses the major conclusions, areas of controversy, and issues to be resolved.

In developing the outline for Volume I, DOE adapted the EIS outline suggested by the Council on Environmental Quality (see 40 CFR 1502.10). The EIS outline is as follows:

Chapter 1 – Purpose and Need for Agency Action – establishes the need for DOE to take action.

Chapter 2 – Proposed Action and No-Action Alternative – describes what DOE proposes to do and the alternative of not building and operating a repository at Yucca Mountain.

Chapter 3 – Affected Environment – presents information on the 13 resource areas that the Proposed Action could affect at Yucca Mountain and along potential transportation routes, and on the affected environment of commercial and DOE sites to provide an analytical basis for the No-Action Alternative.

Chapter 4 – Environmental Consequences of Repository Construction, Operation and Monitoring, and Closure – describes potential impacts of the Proposed Action described in Chapter 2 on the Yucca Mountain environment described in Chapter 3. Chapter 4 also describes potential impacts of the offsite manufacturing of components that DOE would use in the repository.

Chapter 5 – Environmental Consequences of Long-Term Repository Performance – describes potential impacts of the Proposed Action described in Chapter 2 on the Yucca Mountain environment described in Chapter 3 after repository closure.

Chapter 6 – Environmental Impacts of Transportation – describes potential impacts of transportation activities nationally and in Nevada, as described in Chapter 2, on the transportation-related affected environment described in Chapter 3.

Chapter 7 – Environmental Impacts of the No-Action Alternative – describes potential impacts of the No-Action Alternative described in Chapter 2.

Chapter 8 – Cumulative Impacts – describes potential impacts of the Proposed Action described in Chapter 2 in combination with the impacts of other past, present, and reasonably foreseeable future actions.

Chapter 9 – Management Actions to Mitigate Potential Adverse Environmental Impacts – describes actions DOE could take to lessen the potential impacts described in Chapters 4, 5, 6, and 8.

Chapter 10 – Unavoidable Adverse Impacts; Short-Term Uses and Long-Term Productivity; and Irreversible and Irretrievable Commitment of Resources – describes impacts that would remain after the application of the mitigation measures described in Chapter 9.

Chapter 11 – Statutory and Other Applicable Requirements – discusses the regulatory and other guidelines for which DOE would be responsible in implementing the Proposed Action.

Chapter 12 – References – **To facilitate ease of use of this Final EIS, DOE has removed this chapter and placed a list of references at the end of each of Chapters 1 through 11. Information regarding the availability of these references can be found in the DOE Reading Rooms (as listed in Appendix D) or on the internet at the Yucca Mountain Project website at *http://www.ymp.gov*.**

Chapter 13 – List of Preparers, Contributors, and Reviewers – lists the persons involved in the preparation of the Final EIS.

Chapter 14 – Glossary – contains definitions of terms used in the Final EIS. Words or phrases defined in the glossary are italicized the first time they are used in the text.

Chapter 15 – Index.

Volume II contains a number of appendixes related to the Proposed Action and the No-Action Alternative, as follows:

Appendix A – Inventory and Characteristics of Spent Nuclear Fuel and High-Level Radioactive Waste and Other Materials – describes the inventory and characteristics of the spent nuclear fuel, high-level radioactive waste, and other highly radioactive material that DOE could dispose of at Yucca Mountain.

Appendix B – *Federal Register* Notices – contains notices published in the *Federal Register* regarding DOE's intent to prepare an EIS, EIS availability, and other matters related to this Proposed Action.

Appendix C – Interagency and Intergovernmental Interactions – describes consultations and other interactions between DOE and other agencies in relation to the Proposed Action.

Appendix D – Distribution List – includes the persons or organizations listed in the EIS distribution database at the time of publication of this Final EIS.

Appendix E – Environmental Considerations for Alternative Design Concepts and Design Features for the Proposed Monitored Geologic Repository at Yucca Mountain, Nevada – discusses features of the repository design as documented in Chapter 2.

Appendix F – Human Health Impacts Primer and Details for Estimating Health Impacts to Workers from Yucca Mountain Repository Operations – provides the basis for the information in Chapters 4 and 8 on human health impacts resulting from the Proposed Action.

Appendix G – Air Quality – provides the basis for the estimates in Chapters 4 and 8 of air quality impacts that would result from the Proposed Action.

Appendix H – Potential Repository Accident Scenarios: Analytical Methods and Results – provides the basis for potential impacts from the accident scenarios analyzed in Chapters 4, 5, 6, and 8.

Appendix I – Environmental Consequences of Long-Term Repository Performance – provides the basis for the potential impacts discussed in Chapter 5.

Appendix J – Transportation – provides the basis for potential impacts related to national and Nevada transportation, as discussed in Chapter 6.

Appendix K – Long-Term Radiological Impact Analysis for the No-Action Alternative – provides the basis for the potential impacts described in Chapter 7.

Appendix L – Floodplain/Wetlands Assessment for the Proposed Yucca Mountain Geologic Repository – describes floodplains near the Yucca Mountain site and along candidate transportation corridors and routes in Nevada.

Appendix M – Transportation Supplemental Information – In response to public comments, this new appendix provides general information not specifically related to the transportation analysis considered in Chapter 6 and Appendix J.

Appendix N – Are Fear and Stigmatization Likely, and How Do They Matter – In response to public comments, this new appendix addresses perceived risk and stigma, as discussed in Section 2.5.4.

Appendix O – Final Biological Opinion for the Effects of Construction, Operation and Monitoring, and Closure of a Geologic Repository at Yucca Mountain, Nye County, Nevada – This new appendix contains the text of the Biological Opinion issued by the U.S. Fish and Wildlife Service.

Volume III, the Comment-Response Document, contains the comments that DOE received on the Draft EIS and on the Supplement to the Draft EIS and the DOE responses to those comments. The Introduction to Volume III describes how DOE solicited comments on the Draft EIS and the Supplement to the Draft EIS, the methodology it used to extract, categorize, and respond to public comments, a summary of the key issues raised in the comments, a discussion on how to use the Comment-Response Document, and index tables that list organizations and individuals who submitted comments. The Introduction also lists the chapters in Volume III, which relate to the following topics:

- Proposed Action
- Nuclear Waste Policy Act
- National Environmental Policy Act
- Other Legal, Regulatory, and Policy Issues
- Alternatives
- Spent Nuclear Fuel and High-Level Radioactive Waste
- Repository Design, Performance, and Affected Environment
- Transportation Modes, Routes, Affected Environment, and Impacts
- No-Action Alternative
- Cumulative Impacts

- Impact Mitigation and Compensation
- DOE Credibility
- Comments Outside the Scope of the Environmental Impact Statement and the Yucca Mountain Site Characterization Project

The chapters in Volume III contain every comment received on a timely basis (see the Introduction to the Comment-Response Document) on each topic, and, in some cases, subtopic. Because a number of comments were similar in nature, DOE summarized them. The chapters also contain the DOE responses to all the comments, either individual or summarized.

Final

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Summary

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COVER SHEET

RESPONSIBLE AGENCY: U.S. Department of Energy (DOE)

TITLE: *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250)

CONTACT: For more information on this Final Environmental Impact Statement (EIS), write or call:

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Information on this EIS is available on the Internet at the Yucca Mountain Project web site at *http://www.ymp.gov* and on the DOE National Environmental Policy Act (NEPA) web site at *http://tis.eh.doe.gov/nepa/*.

For general information on the DOE NEPA process, write or call:

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U.S. Department of Energy
1000 Independence Avenue, S.W.
Washington, D.C. 20585
Telephone: (202) 586-4600, or leave a message at (800) 472-2756

ABSTRACT: The Proposed Action addressed in this Final EIS is to construct, operate and monitor, and eventually close a geologic repository at Yucca Mountain in southern Nevada for the disposal of spent nuclear fuel and high-level radioactive waste currently in storage or projected to be generated at 72 commercial and 5 DOE sites across the United States. The EIS evaluates (1) projected impacts on the Yucca Mountain environment of the construction, operation and monitoring, and eventual closure of the geologic repository; (2) the potential long-term impacts of repository disposal of spent nuclear fuel and high-level radioactive waste; (3) the potential impacts of transporting these materials nationally and in the State of Nevada; and (4) the potential impacts of not proceeding with the Proposed Action. The preferred alternative is to proceed with the Proposed Action and to use mostly rail, both nationally and in Nevada, to transport spent nuclear fuel and high-level radioactive waste.

PUBLIC COMMENTS: In preparing this EIS, DOE considered comments received by letter, electronic mail, facsimile transmission, and oral and written comments given at public hearings at 21 locations across the United States on the Draft EIS, and at 3 locations in Nevada for the Supplement to the Draft EIS.

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OVERVIEW

The purpose of this environmental impact statement (EIS) is to provide information on potential environmental impacts that could result from a Proposed Action to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at the Yucca Mountain site in Nye County, Nevada. The EIS also provides information on potential environmental impacts from an alternative referred to as the No-Action Alternative, under which there would be no development of a geologic repository at Yucca Mountain.

U.S. Department of Energy Actions

The Nuclear Waste Policy Act, enacted by Congress in 1982 and subsequently amended, establishes a process leading to a decision by the Secretary of Energy on whether to recommend that the President approve Yucca Mountain for development of a geologic repository. As part of this process, the Secretary of Energy is to:

- Undertake site characterization activities at Yucca Mountain to provide information and data required to evaluate the site.

- Decide whether to recommend approval of the development of a geologic repository at Yucca Mountain to the President.

If the Secretary recommends the Yucca Mountain site to the President, the Nuclear Waste Policy Act, as amended in 1987 (the EIS refers to the amended Act as the NWPA), requires that a comprehensive statement of the basis for the recommendation, including the Final EIS, accompany the recommendation. The Department of Energy (DOE) has prepared this Final EIS so the Secretary can consider it, including the public input on the Draft EIS and on the Supplement to the Draft EIS, in making a decision on whether to recommend the site to the President.

The NWPA requires DOE to hold hearings in the vicinity of Yucca Mountain to provide the public with opportunities to comment on the Secretary's possible recommendation of the Yucca Mountain site to the President. If, after completing the hearings and site characterization activities, and after considering other information, the Secretary decided to recommend that the President approve the site, the Secretary would notify the Governor and Legislature of the State of Nevada accordingly. No sooner than 30 days after any such notification, the Secretary may submit the recommendation to the President to approve the site for development of a repository.

Presidential Recommendation and Congressional Action

If, after a recommendation by the Secretary, the President considered the site qualified for application to the Nuclear Regulatory Commission for a construction authorization, the President would submit a recommendation of the site to Congress. The Governor or Legislature of Nevada may object to the recommendation of the site by submitting a notice of disapproval to Congress within 60 days of the President's action. If neither the Governor nor the Legislature submits such a notice within the 60-day period, the site designation would become effective without further action by the President or Congress. If, however, the Governor or the Legislature submits such a notice, the site would be disapproved unless, during the first 90 days of continuous session of Congress after the notice of disapproval, Congress passed a joint resolution of repository siting approval and the President signed it into law.

Actions To Be Taken after Site Designation

If a site designation became effective, the NWPA provides that the Secretary of Energy shall submit to the Nuclear Regulatory Commission an application for a construction authorization for a repository no later than 90 days after the date on which the recommendation of the site designation becomes effective. The NWPA requires the Nuclear Regulatory Commission to adopt DOE's Final EIS to the extent practicable as part of the Nuclear Regulatory Commission's decisionmaking on the License Application.

Decisions Related to Potential Environmental Impacts Considered in the EIS

This EIS analyzes a Proposed Action to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. The EIS also analyzes a No-Action Alternative, under which DOE would not build a repository at the Yucca Mountain site, and spent nuclear fuel and high-level radioactive waste would remain at 72 commercial and 5 DOE sites across the United States. The No-Action Alternative is included in the EIS to provide a basis for comparison with the Proposed Action.

As part of the Proposed Action, which DOE has identified as its preferred alternative, the EIS analyzes the potential impacts of transporting spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site from 77 sites across the United States. This analysis includes information on such matters as the comparative impacts of truck and rail transportation nationally and in Nevada, as well as impacts in Nevada of alternative intermodal (rail-to-truck) transfer stations, associated routes for heavy-haul trucks, and alternative corridors for a branch rail line.

DOE believes that the EIS provides the environmental impact information necessary to make certain broad transportation-related decisions, namely the choice of a national mode of transportation outside Nevada (mostly rail or mostly legal-weight truck), the choice among alternative transportation modes in Nevada (mostly rail, mostly legal-weight truck, or heavy-haul truck with use of an associated intermodal transfer station), and the choice among alternative rail corridors or heavy-haul truck routes with use of an associated intermodal transfer station in Nevada.

DOE has identified mostly rail as its preferred mode of transportation, both nationally and in the State of Nevada. At this time, however, the Department has not identified a preference among the five potential rail corridors in Nevada.

If the Yucca Mountain site was approved (designated), DOE would issue at some future date a Record of Decision to select a mode of transportation. If, for example, mostly rail was selected (both nationally and in Nevada), DOE would then identify a preference for one of the rail corridors in consultation with affected stakeholders, particularly the State of Nevada. In this example, DOE would announce a preferred corridor in the *Federal Register* and other media. No sooner than 30 days after the announcement of a preference, DOE would publish its selection of a rail corridor in a Record of Decision. A similar process would occur in the event that DOE selected heavy-haul truck as its mode of transportation in the State of Nevada. Other transportation decisions, such as the selection of a specific rail alignment within a corridor, would require additional field surveys, State and local government and Native American tribal consultations, environmental and engineering analyses, and appropriate National Environmental Policy Act reviews.

S.1 The National Environmental Policy Act

DOE prepared the *Draft 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* to provide the background, data, and analyses to help decisionmakers and the public understand the potential environmental impacts of the proposed repository. The Department issued the Draft EIS, dated July 1999, for public comment; a 199-day comment period began August 13, 1999, and ended on February 28, 2000. In May 2001, DOE issued the *Supplement to the Draft 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,* which was the subject of a public comment period that ended on July 6, 2001. The comment period was extended to August 13, 2001, for about 700 reviewers inadvertently omitted from the mailing list. In Volume III of this EIS, DOE has presented and responded to all comments on the Draft EIS and the Supplement to the Draft EIS received by August 31, 2001. All comments received by DOE after August 31, 2001, were responded to as time and resources permitted. However, all comments received after August 31, 2001, whether or not responded to, were considered by the Department. Based on this consideration, the Department concluded that none raised new issues not already reflected in timely comments and already considered. DOE has prepared this *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* consistent with the National Environmental Policy Act (NEPA) and the Nuclear Waste Policy Act, as amended. This Final EIS updates information in the Draft EIS and Supplement, provides additional information, and responds to public comments.

S.2 Purpose and Need for Agency Action

S.2.1 PURPOSE AND NEED

For many years civilian and defense-related activities have produced spent nuclear fuel and high-level radioactive waste. These materials have accumulated—and continue to accumulate—at 72 commercial and 5 DOE sites across the United States. Figure S-1 shows the locations of these sites and Yucca Mountain.

In passing the Nuclear Waste Policy Act in 1982, Congress affirmed that the Federal Government is responsible for the permanent disposal of spent nuclear fuel and high-level radioactive waste. In the 1987 amendments to the Act, Congress directed the Secretary of Energy to determine whether to recommend that the President approve the Yucca Mountain site for development of a repository for the permanent disposal of these materials.

S.2.2 BACKGROUND

DOE is responsible for implementing a permanent solution for the management of spent nuclear fuel and high-level radioactive waste. *Spent nuclear fuel* is fuel that has been withdrawn from a nuclear reactor following irradiation; it consists mostly of uranium, and is usually intensely radioactive because it also contains a high level of radioactive nuclear fission products. Commercial spent nuclear fuel was used in civilian nuclear reactors to produce electricity. The majority of DOE spent nuclear fuel comes from defense production reactors, naval propulsion plant reactors, and test and experimental reactors. In addition to conventional uranium fuel, DOE is responsible for the disposition of weapons-usable plutonium that is surplus to national security needs. This EIS includes analysis of surplus weapons-usable plutonium that DOE plans to convert to mixed-oxide (uranium and plutonium) fuel as part of the commercial spent nuclear fuel inventory and surplus weapons-grade plutonium that DOE plans to immobilize and include as part of the high-level radioactive waste inventory.

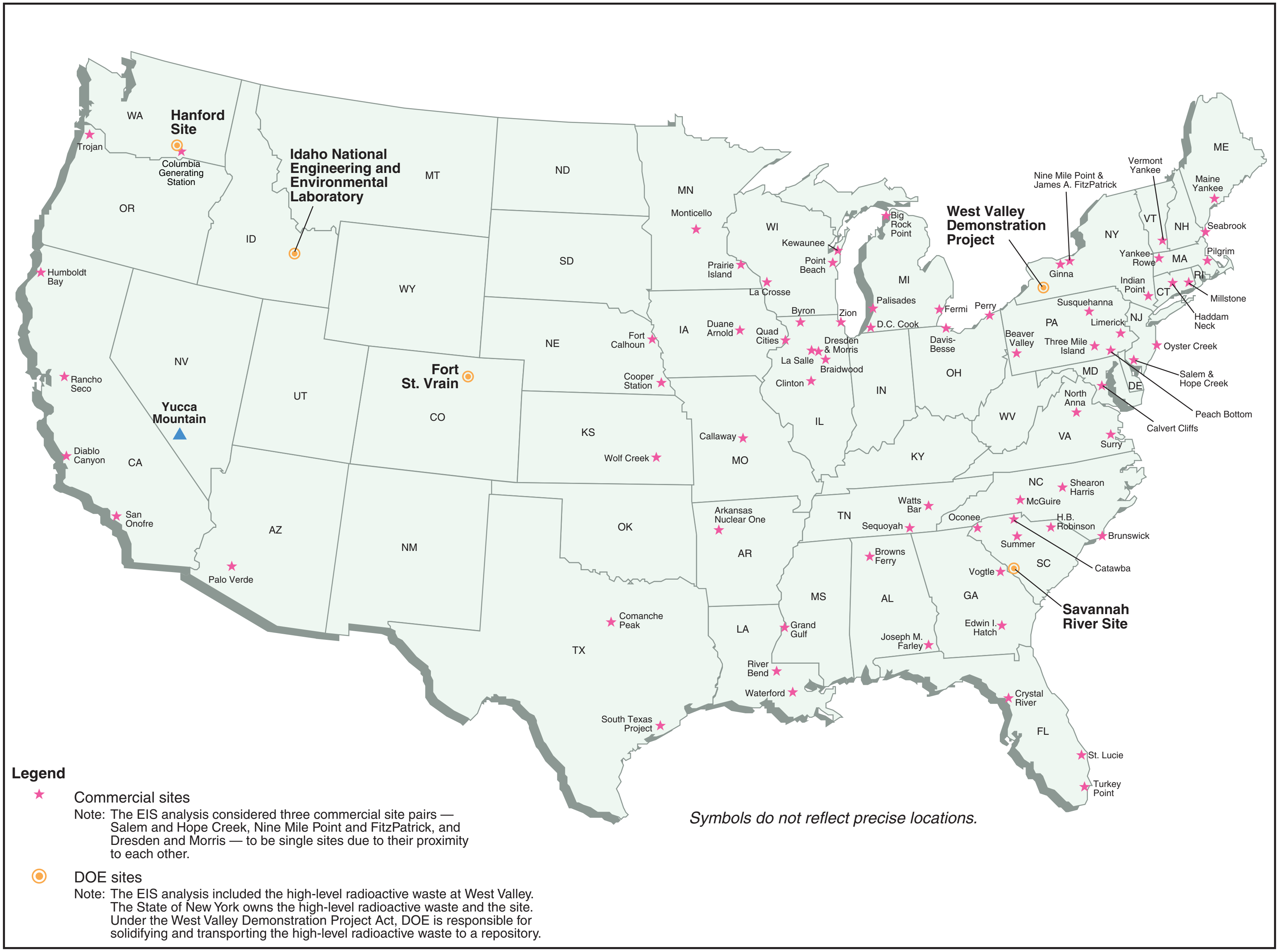


Figure S-1. Locations of commercial and DOE sites and Yucca Mountain.

When the DOE production reactors were operating, they used a controlled fission process to irradiate nuclear fuel and produce materials for nuclear weapons. After the spent nuclear fuel was removed from the reactors, chemical processes extracted the weapons-usable materials from the spent nuclear fuel. This is called *reprocessing*.

The byproduct remaining after reprocessing is *high-level radioactive waste*. High-level radioactive waste also resulted from the reprocessing of naval reactor fuels and some commercial reactor fuels, some DOE test reactor fuels, and some non-DOE research reactor fuels.

The Proposed Action includes disposal of spent nuclear fuel and high-level radioactive waste. In addition, DOE is responsible for the disposal of other waste types, referred to as *Greater-Than-Class-C* and *Special-Performance-Assessment-Required* wastes. These waste types are low-level radioactive wastes that have high radionuclide concentrations. They could become eligible for disposal in a geologic repository in the future, so DOE has analyzed the cumulative environmental impacts associated with the potential disposal of these wastes in a repository at Yucca Mountain.

MATERIALS EVALUATED IN THIS EIS

Spent nuclear fuel is fuel that has been withdrawn from a reactor following irradiation.

- **Commercial** – from civilian nuclear powerplants that generate electricity (including mixed-oxide fuel)
- **DOE** – from DOE production reactors, naval reactors, test and experimental reactors, and research reactors (including some non-DOE reactors)

High-level radioactive waste is primarily waste that resulted from the chemical extraction of weapons-usable materials from the spent nuclear fuel. Immobilized surplus weapons-usable plutonium is part of the high-level radioactive waste inventory.

Greater-Than-Class-C waste is low-level radioactive waste generated by commercial nuclear reactors that does not meet shallow land burial disposal limits.

Special-Performance-Assessment-Required waste is low-level radioactive wastes generated in DOE production reactors, research reactors, reprocessing facilities, and research and development activities that exceed the Nuclear Regulatory Commission Class C shallow-land burial disposal limits.

S.2.2.1 Legislative History

Methods to dispose of radioactive wastes have been studied since the late 1950s. In 1980, President Carter declared that the safe disposal of radioactive waste generated by both defense and civilian nuclear activities is a national responsibility. In the *Environmental Impact Statement, Management of Commercially Generated Radioactive Waste* (DOE/EIS-0046, 1980), DOE analyzed the environmental impacts that could occur if it implemented alternative strategies for the management and disposal of spent nuclear fuel. The disposal alternatives included mined geologic disposal, very deep hole waste disposal, disposal in a mined cavity that results in rock melting, island-based geologic disposal, subseabed disposal, ice sheet disposal, well injection disposal, transmutation, space disposal (for example, launching waste into orbit around the sun), and no action. The Record of Decision for that EIS, issued in 1981, announced the DOE decision to pursue the mined geologic disposal alternative.

In 1982, Congress enacted the Nuclear Waste Policy Act in recognition of the need to provide for the permanent disposal of spent nuclear fuel and high-level radioactive waste in the United States. This Act established the Federal Government's responsibility to provide permanent disposal of the Nation's spent nuclear fuel and high-level radioactive waste and set forth a process and schedule for the disposal of these materials in a geologic repository. In 1986, following the process outlined in the original Nuclear Waste Policy Act, DOE narrowed the number of potentially acceptable sites for a geologic repository to three: Deaf Smith County in Texas; the Hanford Site in Washington; and Yucca Mountain. President Reagan approved the DOE recommendation of these sites as suitable for site characterization. In 1987, Congress amended the Nuclear Waste Policy Act and directed the Secretary of Energy to characterize only Yucca Mountain as a potential location for a geologic repository, setting forth a process for the Federal Government to decide whether to designate Yucca Mountain as the site for a repository.

The site characterization program consists of scientific, engineering, and technical studies and activities. Site investigations and evaluations include the construction of the Exploratory Studies Facility, which is a large underground laboratory consisting of a long tunnel or *main drift* and side tunnels and rooms inside the mountain; investigations of the hydrology and geology of the site; studies of socioeconomics, cultural resources, and terrestrial ecosystems; and monitoring of air quality, meteorological, radiological, and water resource data.

SITE CHARACTERIZATION OF YUCCA MOUNTAIN

DOE has had a program of investigations and evaluations to assess the characteristics of Yucca Mountain as a potential monitored geologic repository and to provide information for this environmental impact statement. Data from site characterization activities have been used to describe the existing environment at the Yucca Mountain site and to assess the potential impacts of the proposed repository.

S.2.2.2 Related Activities and Decisions

Decision Process for Site Recommendation. Under the NWPA, DOE is required to hold hearings in the vicinity of Yucca Mountain to provide the public with opportunities to comment on the Secretary's possible recommendation of the site to the President. If, after completion of the hearings and site characterization activities, the Secretary decides to recommend that the President approve Yucca Mountain, the Secretary would notify the Governor and Legislature of the State of Nevada accordingly. No sooner than 30 days after the notification, the Secretary may submit the recommendation to the President to approve the site for development of a repository. The NWPA further requires that the Secretary's recommendation to the President be based on the record of information developed through the site characterization program, as well as other sources, including the Final EIS. The Secretary will consider the Final EIS, as well as comments from Federal, state, local, and tribal governments, other organizations, and interested individuals on the Draft EIS and the Supplement to the Draft EIS in making a determination on whether to recommend the site to the President.

If the Secretary recommends the Yucca Mountain site to the President, the NWPA requires that a comprehensive statement of the basis for the recommendation, including the Final EIS, accompany the recommendation. Since issuing the Draft EIS and the Supplement to the Draft EIS, DOE has issued several publicly available documents that would form part of this comprehensive statement. These documents address such topics as:

- Baseline postclosure models for Total System Performance Assessment
- Preliminary engineering specifications, including definitions of repository operating modes
- Preclosure safety analysis
- Sensitivity studies using alternative models and data

- Analyses of unquantified uncertainties
- Updates of scientific information and analysis of long-term performance of the lower-temperature repository operating mode
- Preliminary evaluation of the suitability of the Yucca Mountain site for a repository

The key documents that were issued for public review and comment in support of a potential site recommendation include:

- *Yucca Mountain Science and Engineering Report: Technical Information Supporting Site Recommendation Consideration,* May 2001
- *Preliminary Preclosure Safety Assessment for Monitored Geologic Repository Site Recommendation,* July 2001
- *FY01 Supplemental Science and Performance Analysis,* July 2001
- *Yucca Mountain Preliminary Site Suitability Evaluation,* August 2001
- *Total System Performance Assessment-Analyses for Disposal of Commercial and DOE Waste Inventories at Yucca Mountain-Inputs to Final Environmental Impact Statement and Site Suitability Evaluation, August 2001.*

DOE has established guidelines (10 CFR Part 963) for evaluating the suitability of the Yucca Mountain site by assessing how specific design concepts would work within the natural system and by comparing the results of these assessments to the applicable regulatory standards. As required by the NWPA, DOE would apply these guidelines in determining the suitability of Yucca Mountain as a site for a repository.

REGULATORY STANDARDS

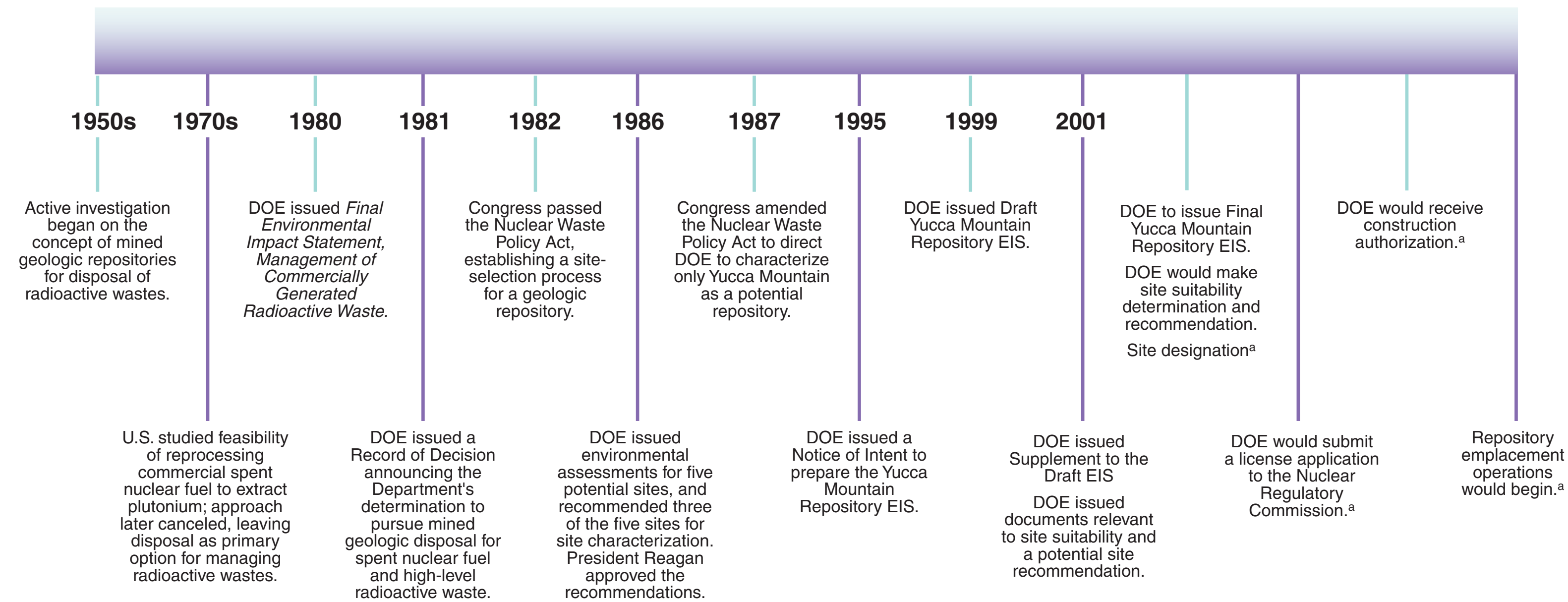
40 CFR Part 197: *Public Health and Environmental Radiation Protection Standards for Yucca Mountain, NV* issued by the Environmental Protection Agency.

10 CFR Part 63: *Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, NV* issued by the Nuclear Regulatory Commission.

10 CFR Part 963: *General Guidelines for Nuclear Waste Repositories*; Yucca Mountain Site Suitability Guidelines issued by DOE.

Decision Process for U.S. Nuclear Regulatory Commission Licensing. If the Yucca Mountain site is approved, DOE will submit a License Application to the Nuclear Regulatory Commission for authorization to construct a geologic repository. The NWPA directs the Commission to adopt the Final EIS to the extent practicable in its decision on whether to issue a construction authorization and license for such a repository.

The Nuclear Regulatory Commission has issued requirements governing its licensing of DOE to construct a geologic repository and to receive and possess nuclear material at that repository (10 CFR Part 63). As mandated by law, these requirements are required to be consistent with the final standards for Yucca Mountain issued by the Environmental Protection Agency (40 CFR Part 197). Figure S-2 shows the sequence of past disposal decisions and projected activities.



a. If Yucca Mountain was approved.

Figure S-2. Sequence of past disposal decisions and future repository activities.

S.3 Proposed Action and No-Action Alternative

S.3.1 PROPOSED ACTION

Under the Proposed Action, DOE would construct, operate and monitor, and eventually close a geologic repository for the disposal of 70,000 metric tons of heavy metal (MTHM) of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. The Proposed Action would include the transportation of spent nuclear fuel and high-level radioactive waste from commercial and DOE sites to the Yucca Mountain site.

DEFINITION OF METRIC TONS OF HEAVY METAL

Quantities of spent nuclear fuel are traditionally expressed in terms of *metric tons of heavy metal* (typically uranium), without the inclusion of other materials such as cladding (the tubes containing the fuel) and structural materials. A metric ton is 1,000 kilograms (1.1 tons or 2,200 pounds). Uranium and other metals in spent nuclear fuel (such as thorium and plutonium) are called *heavy metals* because they are extremely dense; that is, they have high weights per unit volume. One metric ton of heavy metal disposed of as spent nuclear fuel would fill a space approximately the size of a typical household refrigerator.

DOE would dispose of spent nuclear fuel and high-level radioactive waste in the repository using the natural geologic features of the mountain and engineered barriers as a total system to help ensure the long-term isolation of the materials from the accessible environment. DOE would build the repository inside Yucca Mountain, at least 200 meters (660 feet) below the surface and at least 160 meters (530 feet) above the present-day water table. Figure S-3 shows the location of the proposed repository at Yucca Mountain.

In addition, the Proposed Action would include the use of active institutional controls (controlled access, inspection, and maintenance, etc.) through the end of the closure period, and the use of passive institutional controls (markers, engineered barriers, etc.) after the completion of closure. The purpose of the passive institutional controls would be to prevent inadvertent intrusion by and exposures to members of the public.

S.3.1.1 Repository and Waste Package Design

The repository would be a large underground excavation with a number of interconnecting tunnels (called drifts) that DOE would use for waste emplacement. Figure S-4 shows the proposed repository concept.

The Draft EIS evaluated the preliminary design concept described in the 1998 *Viability Assessment of a Repository at Yucca Mountain.* DOE recognized when it published the Draft EIS that plans for a repository would continue to evolve during any development of a final repository design and as a result of any licensing review of the repository by the Nuclear Regulatory Commission. Later, DOE

PREFERRED ALTERNATIVE

DOE's preferred alternative is to proceed with the Proposed Action to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain.

DOE has also identified a preferred mode (the mostly rail scenario) of transporting spent nuclear fuel and high-level radioactive waste to the proposed repository. The smaller number of shipments required to transport 70,000 MTHM of spent nuclear fuel and high-level radioactive waste by the mostly rail scenario, coupled with the correspondingly reduced environmental impacts, form the basis for DOE's preference of the mostly rail scenario, both nationally and in Nevada.

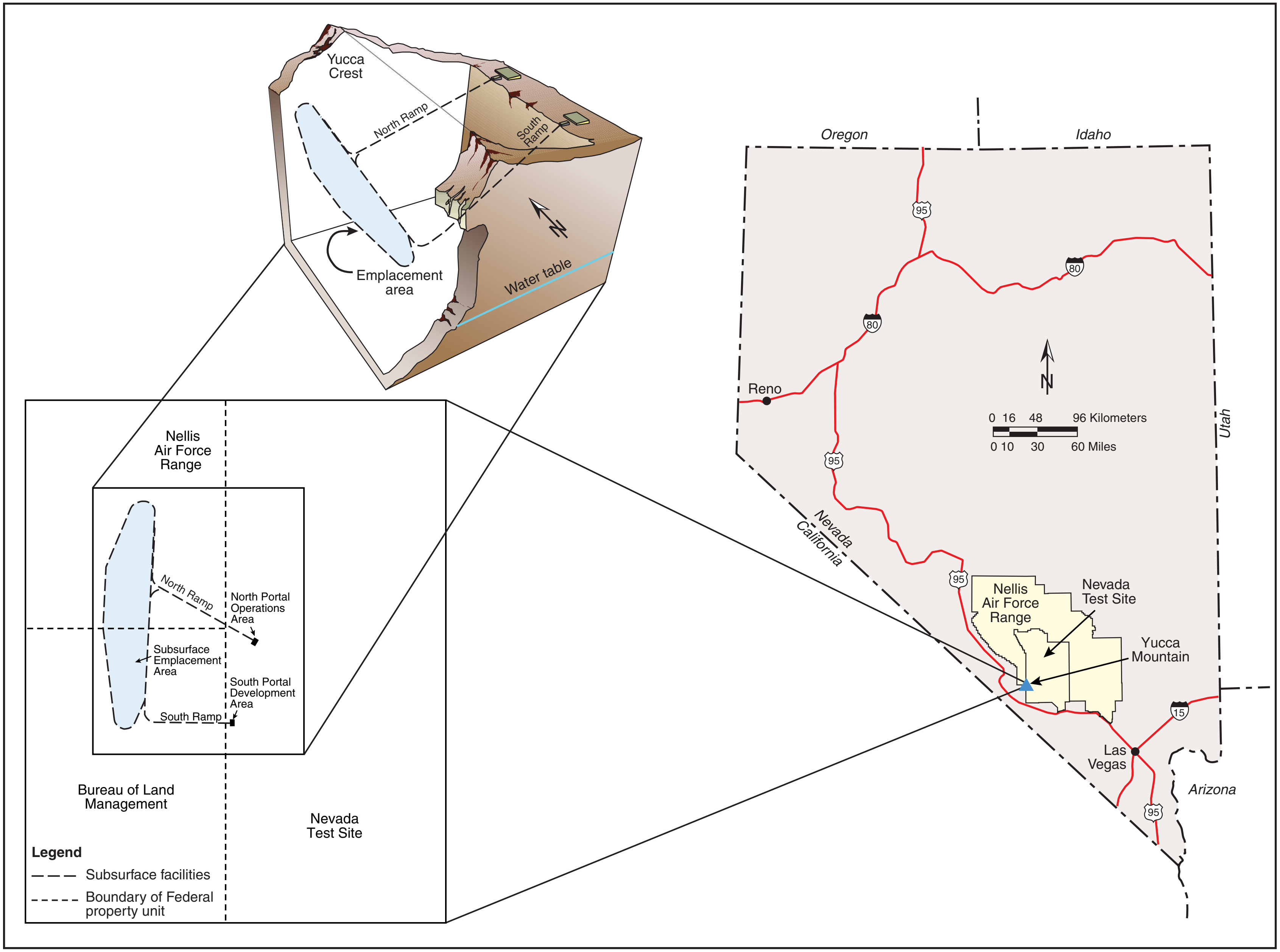


Figure S-3. Location of the proposed repository at Yucca Mountain.

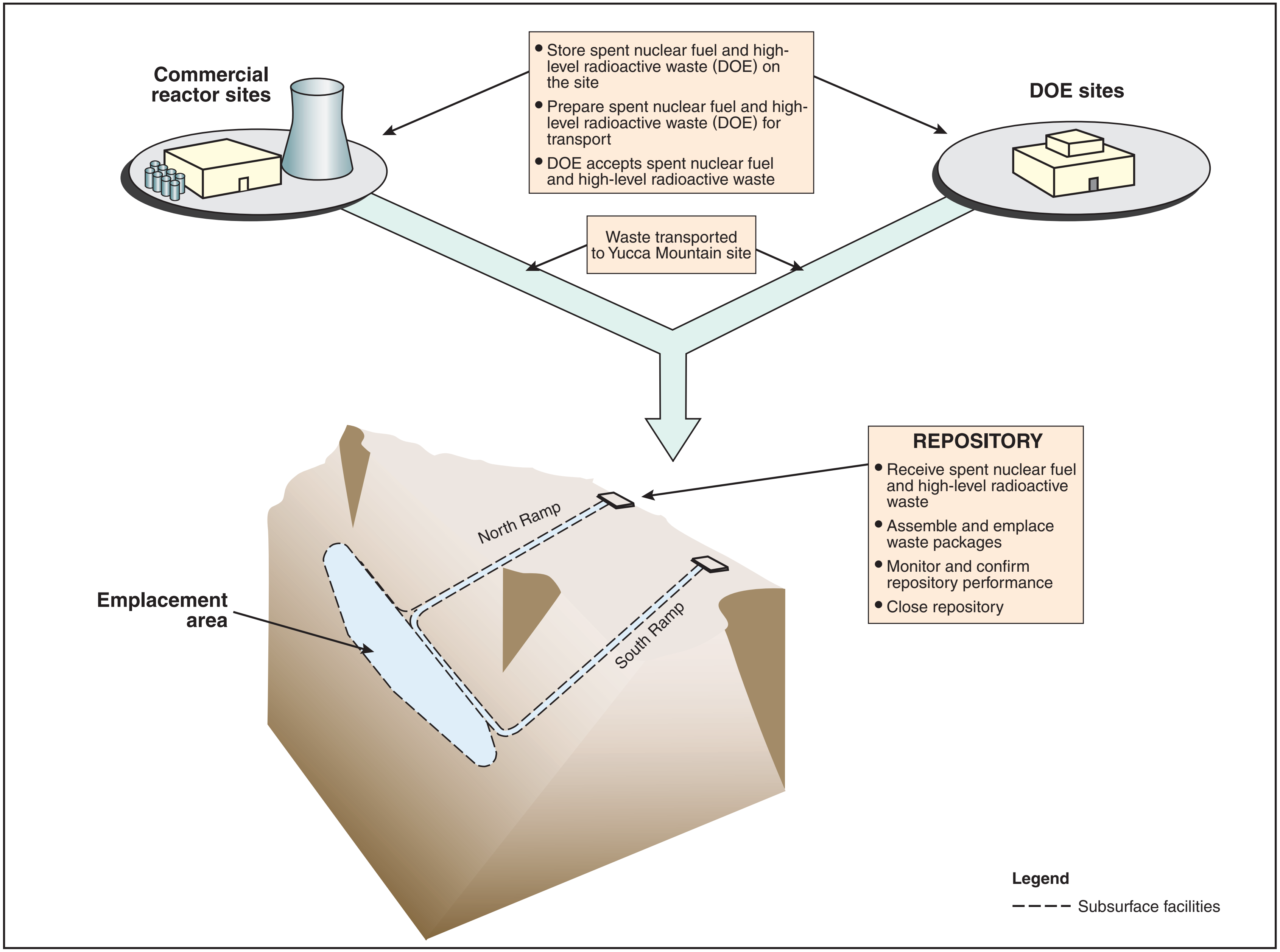


Figure S-4. Spent nuclear fuel and high-level radioactive waste handling, transportation, and disposal.

issued the Supplement to the Draft EIS that evaluated the repository design described in the *Yucca Mountain Science and Engineering Report: Technical Information Supporting Site Recommendation Consideration,* which it issued in May 2001. The flexible design analyzed in the Supplement includes an improved understanding of the interactions of potential repository features with the natural environment, the addition of design features for enhanced waste containment and isolation, and evolving regulatory requirements. Rather than analyzing the three thermal load scenarios (high, intermediate, and low thermal loads) as in the Draft EIS, the Final EIS analyzes a range of operating modes (higher- to lower-temperature) for the flexible design. Because (1) thermal load is no longer the descriptive parameter for specifying thermal management scenarios for the proposed repository, and (2) an effort was made in the Final EIS to avoid confusion and to clarify the impacts of the Proposed Action, DOE has not carried the earlier thermal load scenarios through to the Final EIS. (A comparison between the thermal load scenarios and the repository operating modes for the flexible design is provided in the Supplement to the Draft EIS.)

FLEXIBLE DESIGN

The flexible design includes the ability to operate the proposed repository in a range of operating modes that are characterized by higher and lower temperatures and associated humidity conditions. *Higher-temperature* means that at least a portion of the emplacement drift rock wall would have a maximum temperature above the boiling point of water at the elevation of the repository. The ranges analyzed for the *lower-temperature* operating mode include conditions under which the drift rock wall temperatures would be below the boiling point of water, and under which the surface temperature of the waste package would not exceed 85°C (185°F).

Modifications from the repository design introduced in the Draft EIS and analyzed in the Supplement to the Draft EIS include:

- The ability to blend hotter and cooler commercial spent nuclear fuel assemblies (the assemblies produce most of the heat generated by waste materials in a geologic repository) to control the heat generation of waste packages
- The flexibility to include a facility on the surface for aging (that is, cooling) of hotter commercial spent nuclear fuel to control the heat of waste packages
- Increased ventilation (forced and natural) to enable a cooler repository
- Increased spacing between emplacement drifts to allow a moisture pathway between drifts
- The operational flexibility to vary the spacing between the waste packages in a drift to manage the heat load
- Modified waste packages and the addition of titanium drip shields to improve overall performance and divert moisture

The purpose of the flexible design is to improve the long-term performance of the proposed repository, and reduce associated uncertainties.

DOE would receive materials at the repository in one of three configurations: uncanistered fuel (spent nuclear fuel placed directly in a shipping cask), dual-purpose canisters (containers designed to store and transport commercial spent nuclear fuel), or disposable canisters (canisters for spent nuclear fuel or high-level radioactive waste with multiple specialized overpacks to enable their storage, transportation, and emplacement in a repository). All DOE materials (spent nuclear fuel and high-level radioactive waste) would be received in disposable canisters. Commercial spent nuclear fuel would be received in any of the three packaging configurations. DOE cannot predict the particular combination of uncanistered fuel, dual-purpose canisters, or disposable canisters it would receive at a repository because the managers of the commercial sites would determine the canister type, if any, they will use. For that reason, in the Draft EIS the Department analyzed two fuel packaging scenarios [mostly uncanistered and mostly canistered (including dual-purpose canisters and disposable canisters)] that cover the possible range of repository and transportation impacts to human health and the environment. DOE's analysis shows that the mostly uncanistered fuel packaging scenario would result in the highest short-term impacts, with the exception of (1) the empty dual-purpose canisters that some commercial sites could use that would require disposal or recycling, and (2) some attributes of offsite manufacturing of disposable canisters. To simplify the presentation in this Final EIS, the impacts throughout this document include those associated with the mostly uncanistered fuel packaging scenario, plus the impacts of the waste management and offsite manufacturing impacts, which are also included to represent potential impacts associated with the canistered scenario. This approach ensures that the impacts presented in this Final EIS would bound the impacts of any packaging scenario ultimately selected.

DEFINITIONS OF PACKAGING TERMS

Shipping cask: A vessel that meets applicable regulatory requirements for shipping spent nuclear fuel or high-level radioactive waste.

Dual-purpose canister: A metal vessel suitable for storing (in a storage facility) and shipping (in a shipping cask) commercial spent nuclear fuel assemblies. At the repository, dual-purpose canisters would be removed from the shipping cask and opened. The spent nuclear fuel assemblies would be removed from the canister and placed in a disposal container or in the fuel pool to accommodate blending. The opened canister would be recycled or disposed of offsite as low-level radioactive waste.

Disposable canister: A metal vessel for commercial or DOE spent nuclear fuel assemblies or solidified high-level radioactive waste suitable for storage, shipping, and disposal. At the repository, the disposable canister would be removed from the shipping cask and placed directly in a disposal container. The disposable canister is sometimes referred to as a multi-purpose canister in discussions of repository design.

Uncanistered spent nuclear fuel: Commercial spent nuclear fuel placed directly into shipping casks. At the repository, spent nuclear fuel assemblies would be removed from the shipping cask and placed in a disposal container or in the fuel pool to accommodate blending.

Disposal container: A container for spent nuclear fuel and high-level radioactive waste consisting of the barrier materials and internal components. The filled, sealed, and tested disposal container is referred to as the *waste package*, which would be emplaced in the repository.

Waste package: The filled, sealed, and tested disposal container that would be emplaced in the repository.

Material received at the repository would be unloaded from the shipping casks and placed in disposal containers called *waste packages*. To control the heat generation of the waste packages, the flexible design includes thermal blending of commercial spent nuclear fuel assemblies. Remote-controlled transporters would place the waste packages in emplacement drifts.

DOE considered waste packages containing two layers—a corrosion-resistant Alloy-22 shell on the outside and a stainless-steel inner shell to provide structural support. The highly corrosion-resistant outer material of the waste package would protect the underlying structural material from corrosive degradation, while the extremely strong internal structural material would support the thinner corrosion-resistant material. A drip shield of titanium (also extremely corrosion-resistant) with a nominal thickness of 1.5 centimeters (0.6 inch) would be placed over the waste packages during the closure phase. With the titanium drip shield and the Alloy-22 outer cylinder, there would be two different corrosion barriers protecting the waste from contact with water. Further, the use of two distinctly different corrosion-resistant materials would reduce the probability that a single mechanism could cause failure in both materials. The waste packages, together with the titanium drip shields, would be the primary part of an engineered barrier system in the repository. This system would, in combination with the natural features of this site, help slow the release of radioactive material to the accessible environment for long periods.

NATURAL AND ENGINEERED FEATURES

Water is the primary means by which radionuclides disposed of at Yucca Mountain could reach the accessible environment. The natural features of the very dry climate, large distance to the water table, and geology of the site would act to limit the amount of water that entered the repository. The engineered features, including drip shields and waste packages made from corrosion-resistant material, would deter releases of radioactive material, even in the presence of any water that reached the emplacement area.

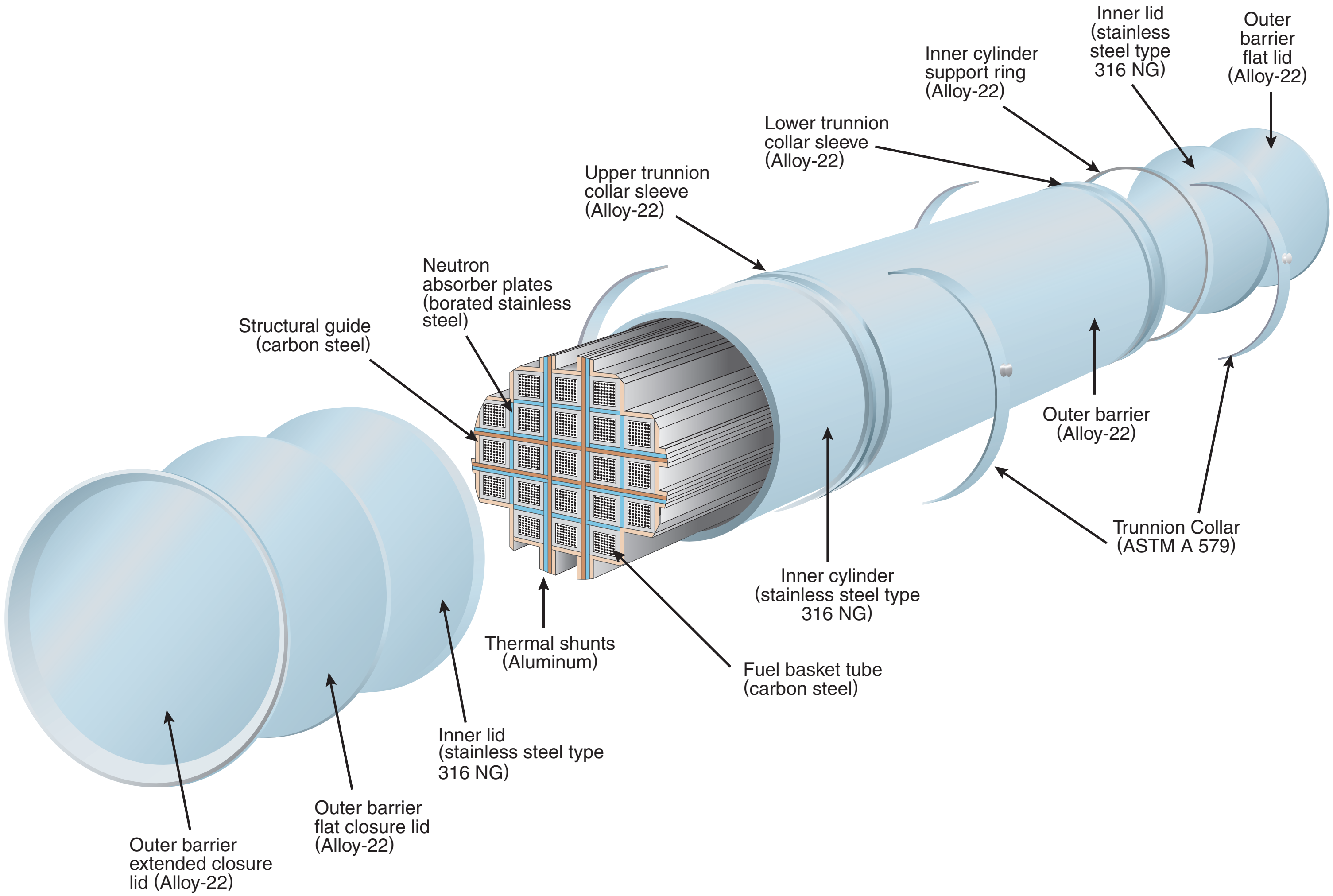
Under the Proposed Action, DOE would emplace approximately 11,000 to 17,000 waste packages containing no more than 70,000 MTHM of spent nuclear fuel and high-level radioactive waste in the repository. Of that amount, 63,000 MTHM would be spent nuclear fuel assemblies that would be shipped from commercial sites to the repository. The remaining 7,000 MTHM would consist of about 2,333 MTHM of DOE spent nuclear fuel and the equivalent of 4,667 MTHM of high-level radioactive waste, currently estimated to be approximately 8,315 canisters, that DOE would ship to the repository from DOE sites. The inventory includes surplus weapons-usable plutonium. At present, DOE expects two-thirds of the plutonium would be converted into mixed-oxide fuel, which is included as part of the commercial spent nuclear fuel inventory. DOE expects the remaining third of the plutonium to be immobilized and included in the high-level radioactive waste inventory.

Figure S-5 shows potential waste package designs for commercial spent nuclear fuel. Figure S-6 shows waste packages in an emplacement drift.

S.3.1.2 Preconstruction Testing and Performance Confirmation, Construction, Operation and Monitoring, and Closure

DOE would construct and operate surface facilities at the repository site to receive, prepare, and package spent nuclear fuel and high-level radioactive waste for emplacement in underground drifts. The surface and subsurface facilities developed for site characterization activities at Yucca Mountain would be incorporated into the repository design to the extent practicable. Figures S-7 and S-8 show conceptual designs of the surface and subsurface facilities, respectively. Figure S-9 shows the sequence for repository development at Yucca Mountain.

Preconstruction Testing and Performance Confirmation. The preconstruction Testing and Performance Confirmation Program would continue many of the same types of activities performed during site characterization and would include tests, experiments, and analyses that DOE would conduct to evaluate the long-term performance of the repository. Before the start of repository construction, this program would assume responsibility for activities now being performed as part of site characterization. Those activities would continue until closure of the repository.



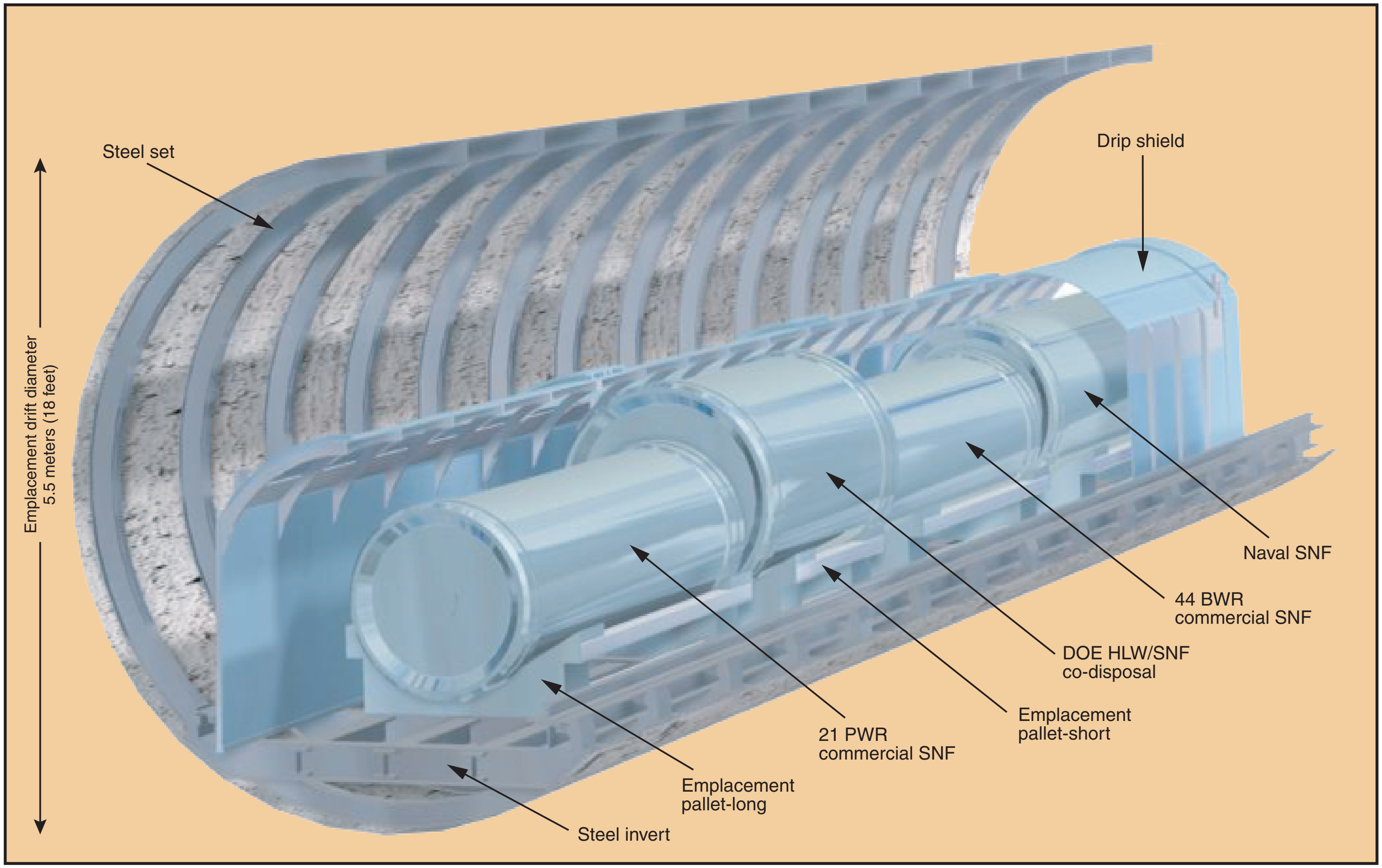
Legend

ASTM	American Society for Testing and Materials
NG	Nuclear grade stainless steel

Notes: Glossary contains definitions of terms.

Drawing not to scale.

Figure S-5. Waste package for commercial spent nuclear fuel (pressurized-water reactor waste package).



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Legend

BWR	Boiling-water reactor
DOE	U.S. Department of Energy
HLW	High-level radioactive waste
PWR	Pressurized-water reactor
SNF	Spent nuclear fuel

Figure S-6. Typical section of emplacement drift with waste packages and drip shields in place.

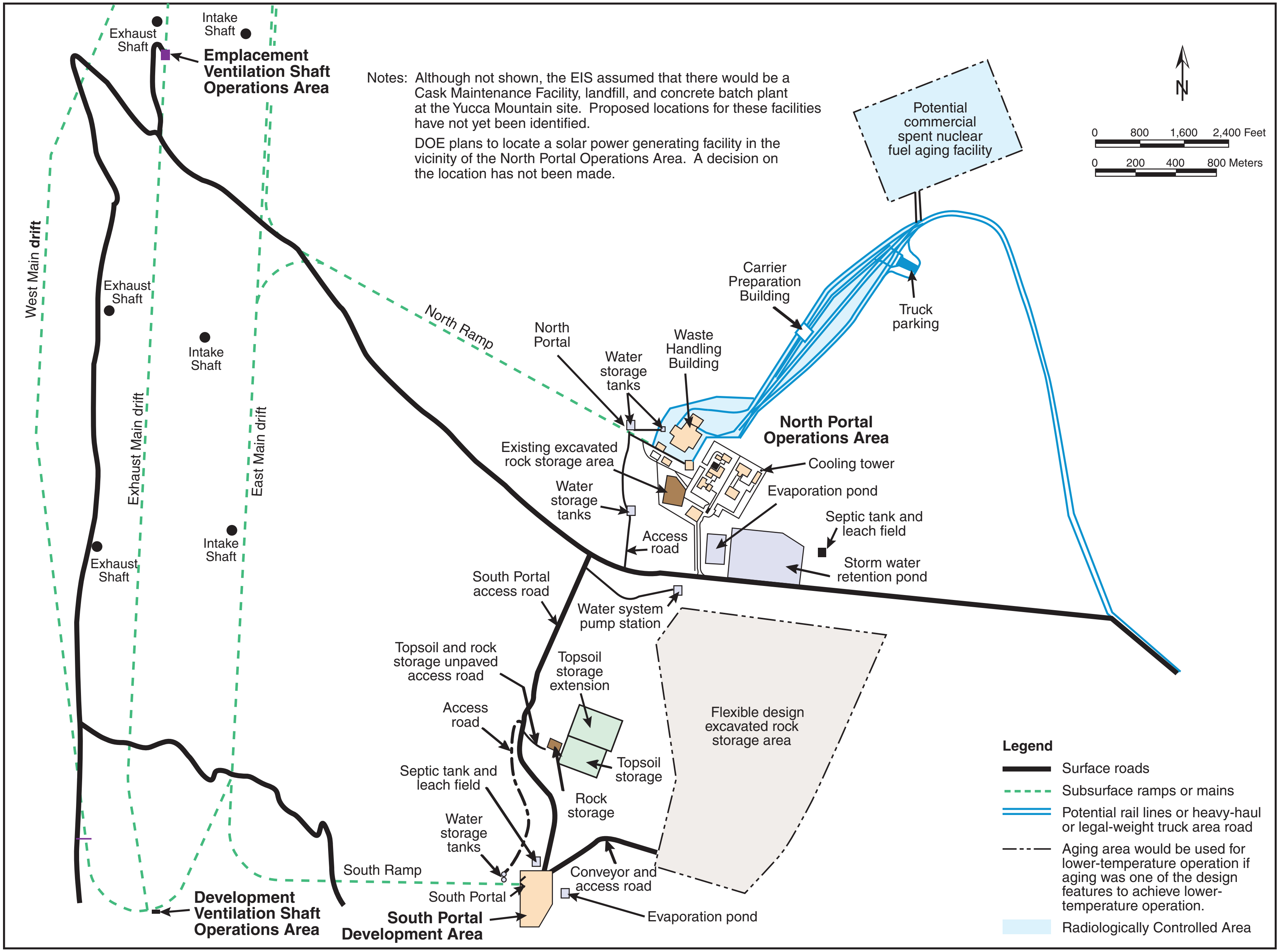
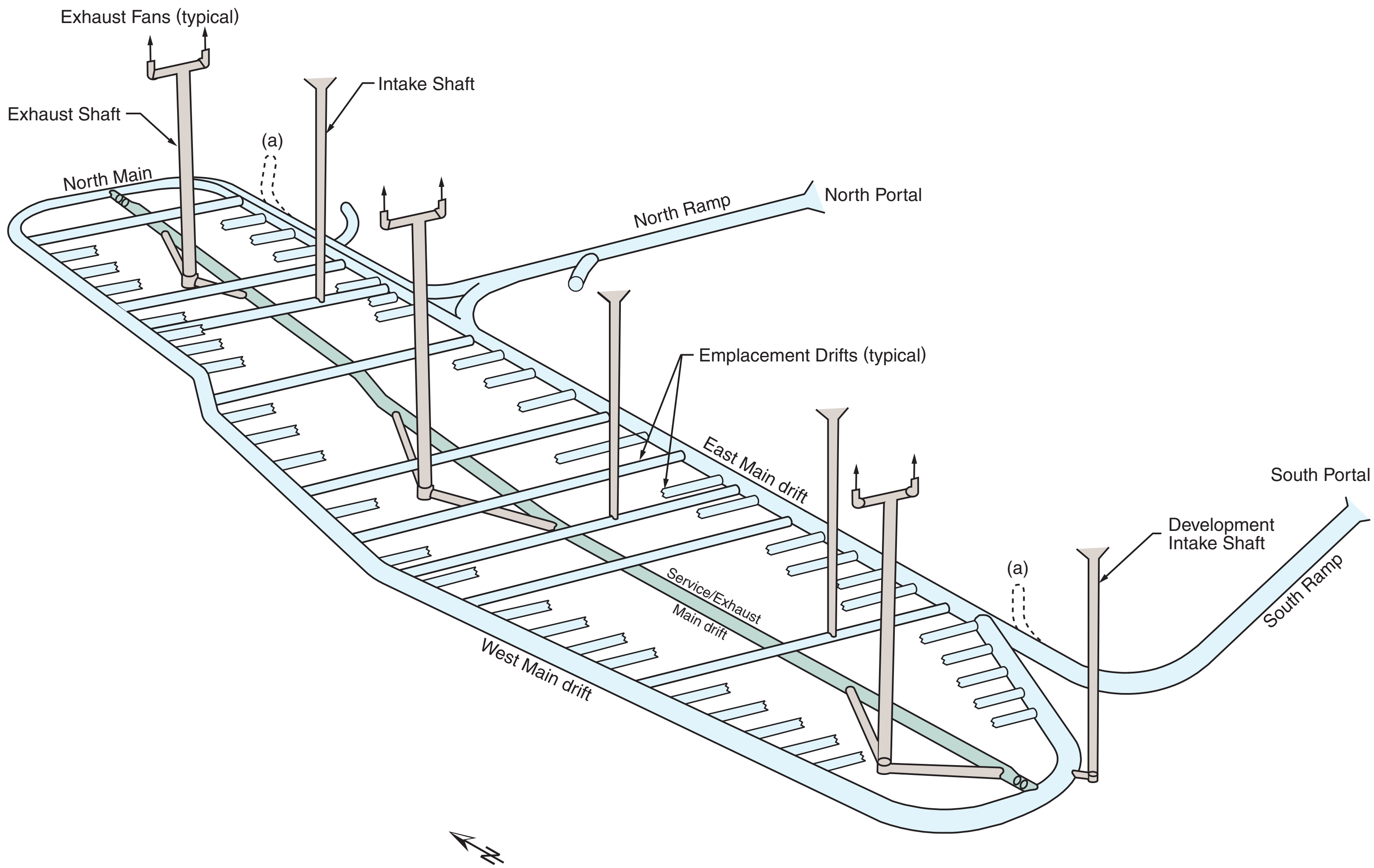


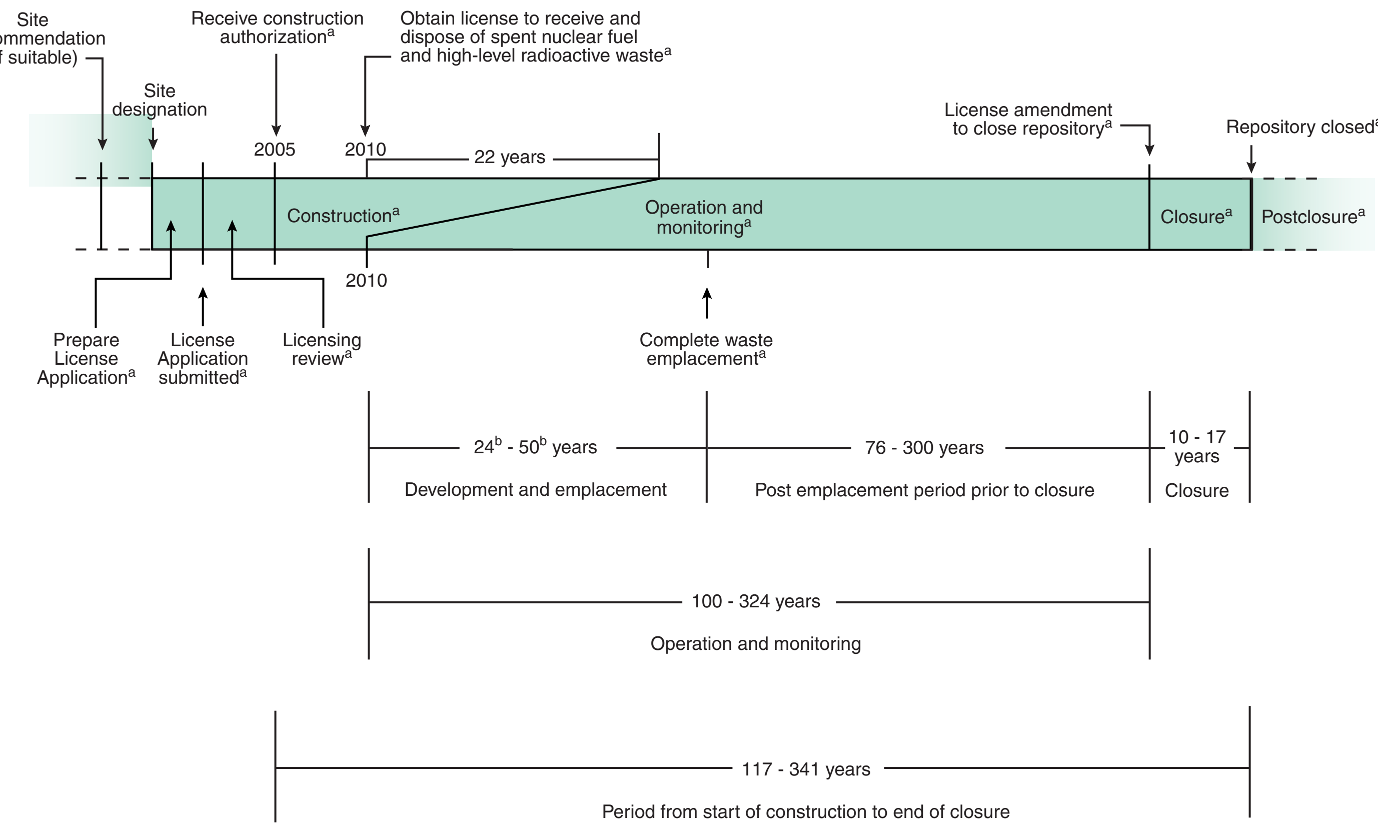
Figure S-7. Potential repository surface facilities site plan.



Note: (a) Potential connection to lower block

Drawing not to scale.

Figure S-8. Repository subsurface facility plan (higher-temperature repository operating mode).



a. If Yucca Mountain is approved.

b. Analysis without aging assumed that waste emplacement would occur over a 24-year period and analysis with aging assumed that waste emplacement with commercial spent nuclear fuel aging would occur over a 50-year period.

Figure S-9. Monitored geologic repository range of milestones used for analysis.

Construction. The construction of repository surface and subsurface facilities could begin after the receipt of construction authorization from the Nuclear Regulatory Commission. For analytical purposes, DOE assumed that construction would begin in 2005. The Department would build the repository surface facilities, main drifts, ventilation system, and initial emplacement drifts in about 5 years, from 2005 to 2010. Construction of the emplacement drifts would continue after emplacement began.

Surface facilities would receive, prepare, and package spent nuclear fuel and high-level radioactive waste for emplacement, and would support the construction of subsurface facilities. The primary surface facilities would be the *North Portal Operations Area* (including the *Waste Handling Building* and a *surface aging facility* if DOE employed aging of commercial spent nuclear fuel in conjunction with the lower-temperature repository operating mode), the *South Portal Development Area* (supporting subsurface facility development), and a 3-megawatt *solar power generating facility* that DOE would use to meet some of the electrical energy requirements of the repository.

Subsurface facilities would include the drifts developed during site characterization activities. During construction, additional underground excavation would occur. Excavation in the subsurface facilities would include gently sloping *access ramps* for the movement of construction and waste package vehicles, *main drifts* for the movement of construction and waste package vehicles, *emplacement drifts* for the placement of waste packages, *exhaust mains* to transfer air in the subsurface area, and *ventilation shafts* to transfer air between the surface and the subsurface. The higher-temperature repository operating mode would require three emplacement intake shafts, one development intake shaft, and three exhaust shafts to support the full emplacement of 70,000 MTHM. The lower-temperature repository operating mode could require three to seven emplacement intake shafts, one development intake shaft, and five to nine exhaust shafts. *Performance confirmation drifts* would contain instrumentation to monitor emplaced waste packages.

Operation and Monitoring. Repository operations would begin after the Nuclear Regulatory Commission granted a license to "receive and possess" spent nuclear fuel and high-level radioactive waste. For planning purposes, DOE assumed that the receipt and emplacement of these materials would begin in 2010. Based on a total emplacement of 70,000 MTHM at approximately 3,000 MTHM each year, waste emplacement would end after approximately 24 years.

Under the lower-temperature repository operating mode, DOE could place commercial spent nuclear fuel on a surface aging pad in Nuclear Regulatory Commission-licensed storage casks. This aging was assumed to occur during a 50-year period and would allow the heat generated by radioactive decay to be reduced before emplacing the waste packages into the repository.

The construction of emplacement drifts would continue for approximately 22 years during operation and monitoring. The repository design would enable simultaneous construction and emplacement operations, but it would physically separate construction or development activities from emplacement activities. Ventilation barriers would create airlocks to separate the emplacement and development sides of the repository, and the ventilation system would be designed to maintain the emplacement side at a lower pressure than the development side. This would ensure that no air leakage would occur from the emplacement side to the development side.

Monitoring and maintenance activities would begin with the first emplacement of waste packages and would continue until repository closure. The monitoring period, as defined for analytical purposes, would begin after the completion of emplacement. During the monitoring period, DOE would maintain the repository facilities, including the ventilation system and utilities (air, water, electric power) that would enable the continued monitoring and inspection of waste packages, continued investigations of long-term repository performance, and the retrieval of waste packages, if necessary. Immediately after

RETRIEVAL

Section 122 of the NWPA requires DOE to maintain the ability to retrieve emplaced materials. Because of this requirement, the EIS includes an analysis of the impacts of retrieval. Although the EIS analyzes it, DOE does not believe that retrieval would be necessary, and it is not part of the Proposed Action. DOE would maintain the ability to retrieve the spent nuclear fuel and high-level radioactive waste for at least 100 years and possibly for as long as 300 years in the event of a decision to retrieve the materials to protect public health and safety or the environment or to recover constituent parts of spent nuclear fuel.

the completion of emplacement, DOE would decontaminate and close the nuclear facilities on the surface to eliminate potential radioactive material hazards. However, the Department would maintain the Waste Handling Building for the possible retrieval of waste.

Closure. For the higher-temperature operating mode, the EIS analysis assumed repository closure would begin 100 years after the start of emplacement (76 years after the completion of emplacement) and would take 10 years. Repository closure for the lower-temperature operating mode would begin 125 to 300 years after the completion of emplacement and would take between 11 and 17 years, depending on the waste package spacing. The longer time required for the lower-temperature operating mode would ensure that the repository temperature would remain below boiling after closure.

Repository closure would occur after DOE received a license amendment from the Nuclear Regulatory Commission. Closure activities would include installing the titanium drip shields and closing the subsurface facilities, decommissioning the surface facilities, sealing openings into the mountain (access ramps, ventilation shafts, boreholes), performing reclamation activities at the site, and establishing institutional controls such as permanent monuments to mark and identify the area.

S.3.1.3 Transportation

DOE would transport spent nuclear fuel and high-level radioactive waste from commercial and DOE sites around the country to the Yucca Mountain site, either by rail or by truck. The Department analyzed two transportation scenarios (*mostly legal-weight truck* and *mostly rail*) that cover the reasonably foreseeable range of transportation impacts to human health and the environment.

The mostly legal-weight truck scenario assumes that DOE would transport most of the spent nuclear fuel and high-level radioactive waste to the repository by legal-weight truck. The trucks would travel from the 77 sites to the Yucca Mountain site primarily on the U.S. Interstate Highway system, as shown in Figure S-10. An exception to this scenario would be the naval spent nuclear fuel, which the Navy would transport from the Idaho National Engineering and Environmental Laboratory to Nevada by rail, as decided in the *Record of Decision for a Dry Storage Container System for the Management of Naval Spent Nuclear Fuel.*

The mostly rail scenario assumes that DOE and the Navy would transport most of the spent nuclear fuel and high-level radioactive waste to Nevada by rail, with the exception of material from commercial nuclear generating sites that initially would not have the capability to load

NEVADA TRANSPORTATION IMPLEMENTING ALTERNATIVES

Rail corridors
- Caliente
- Carlin
- Caliente-Chalk Mountain*
- Jean
- Valley Modified

Intermodal transfer station locations and heavy-haul truck routes
- Caliente
  - – Caliente route
  - – Caliente/Chalk Mountain route*
  - – Caliente/Las Vegas route
- Sloan/Jean (one route)
- Apex-Dry Lake (one route)

* Nonpreferred

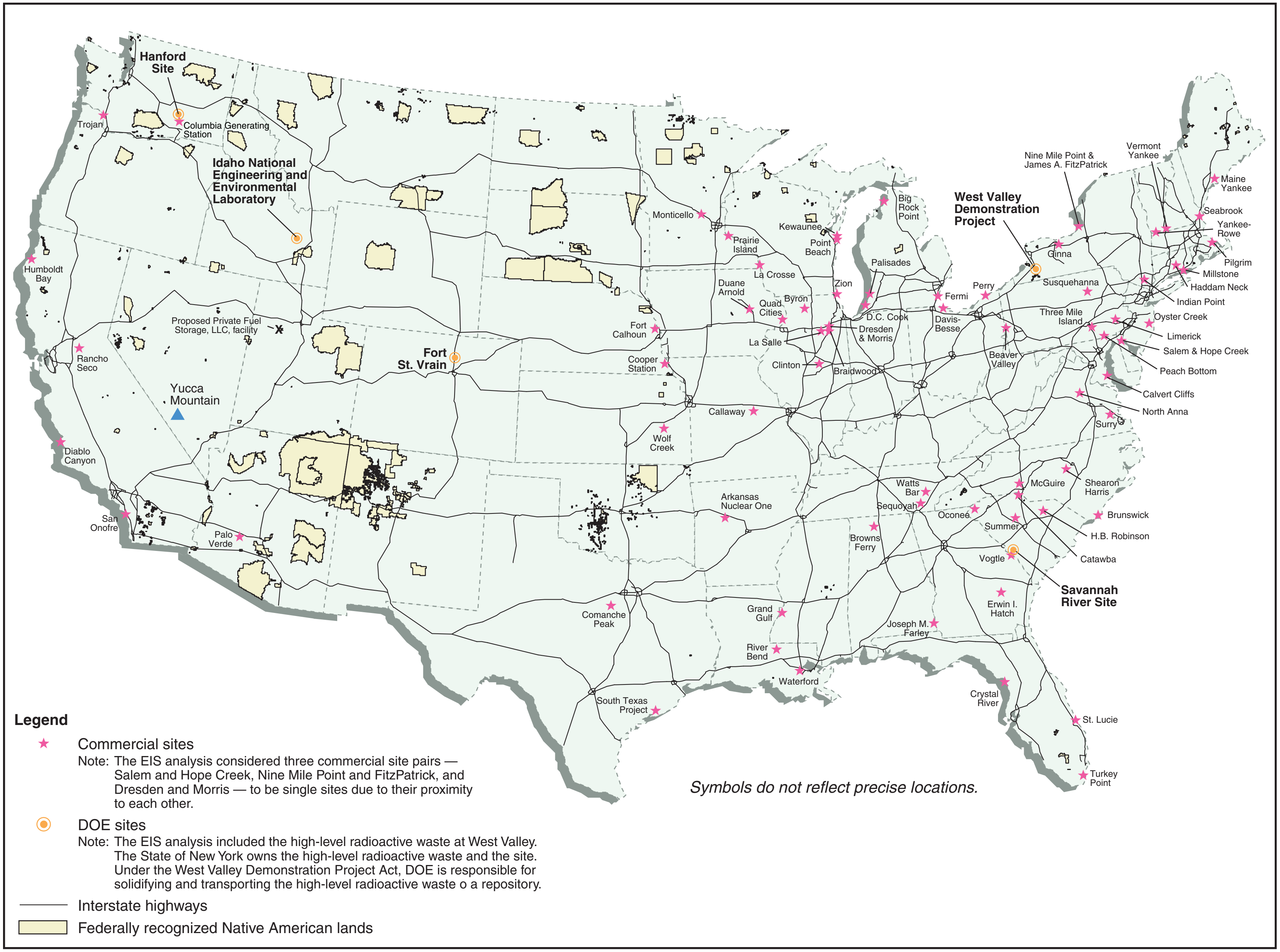


Figure S-10. Commercial and DOE sites and Yucca Mountain in relation to the U.S. Interstate Highway System.

DEFINITIONS FOR TRUCK TRANSPORTATION

Legal-weight trucks: trucks with a gross vehicle weight (both truck and cargo weight) of less than 36,300 kilograms (80,000 pounds), which is the loaded weight limit for commercial vehicles operated on public highways without special state-issued permits.

Heavy-haul trucks: overweight, overdimension vehicles that must have permits from state highway authorities to use public highways.

large-capacity rail shipping casks. Those sites would use legal-weight trucks to ship material to the repository. Commercial sites with the capability to load the rail shipping casks but that did not have rail access could use heavy-haul trucks or barges to ship spent nuclear fuel to the nearest rail line. Figure S-11 shows the commercial and DOE sites and Yucca Mountain in relation to the U.S. railroad system over which the railcars could travel.

In the State of Nevada, waste that traveled from the commercial and DOE sites by legal-weight truck would continue to the repository in the same manner. Figure S-12 shows the southern Nevada highways over which the legal-weight trucks could travel. Potential routes for legal-weight truck shipments in Nevada comply with U.S. Department of Transportation regulations (49 CFR 397.101) for selecting "preferred routes" and "delivery routes" for motor carrier shipments of Highway Route-Controlled Quantities of Radioactive Materials. Based on these regulations, those shipments would arrive in Nevada on Interstate-15, travel over the planned Las Vegas Beltway, and then proceed north on U.S. Highway 95 to Yucca Mountain. The State of Nevada could designate alternative routes as specified in 49 CFR 397.103.

REPOSITORY ANALYSIS

Repository Facilities and Operations

Packaging scenarios
- Mostly uncanistered fuel
- Mostly canistered fuel

Operating mode
- Higher-temperature
- Lower-temperature

Transportation Activities

National transportation scenarios
- Mostly legal-weight truck
- Mostly rail

Nevada transportation scenarios
- Mostly legal-weight truck
- Mostly rail with a new branch rail line (five corridors)
- Mostly rail with heavy-haul truck from a new intermodal transfer station (five routes)

At this time there is no rail access to the Yucca Mountain site. This means that material traveling by rail would have to continue to the repository on a new branch rail line or transfer to heavy-haul trucks at an intermodal (that is, from rail to truck) transfer station in Nevada and then travel on existing highways that could need to be upgraded. DOE is considering implementing alternatives for the construction of either a new branch rail line or an intermodal transfer station with associated highway improvements. The Department has identified five alternatives for rail corridors, each of which has alignment variations (Figure S-13), and three alternative locations for an intermodal transfer station and five associated highway routes for heavy-haul trucks (Figure S-14). Figure S-15 shows how the national and Nevada transportation scenarios relate.

S.3.1.4 Costs

DOE estimates that the total cost of the Proposed Action, including the transportation of spent nuclear fuel and high-level radioactive waste to the repository, would be about $42.8 billion to $57.3 billion (in 2001 dollars). These costs include:

- $31.5 billion to $43.1 billion for construction and operation of the repository.
- $4.3 billion for waste acceptance, storage, and transportation.

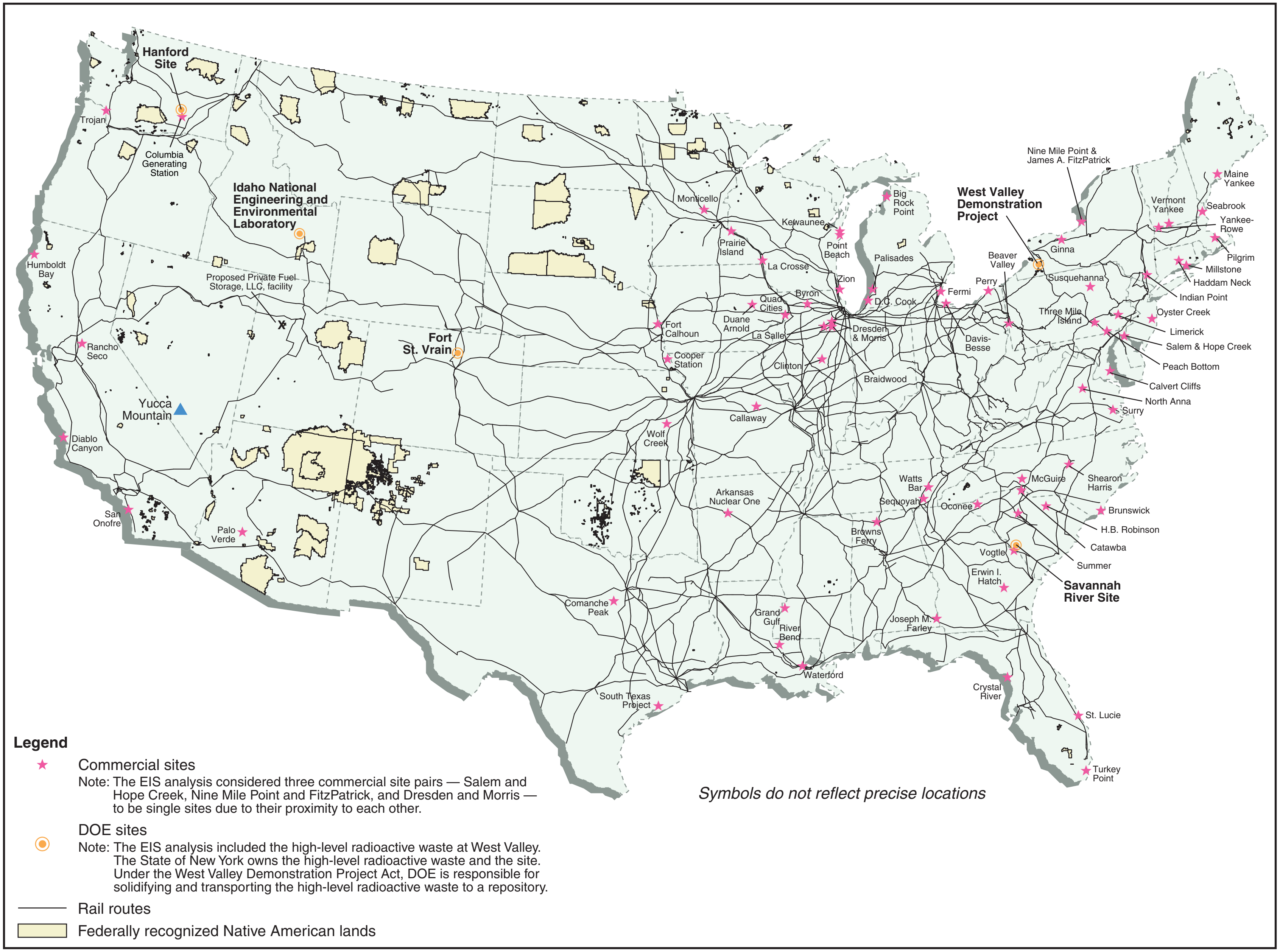


Figure S-11. Commercial and DOE sites and Yucca Mountain in relation to the U.S. railroad system.

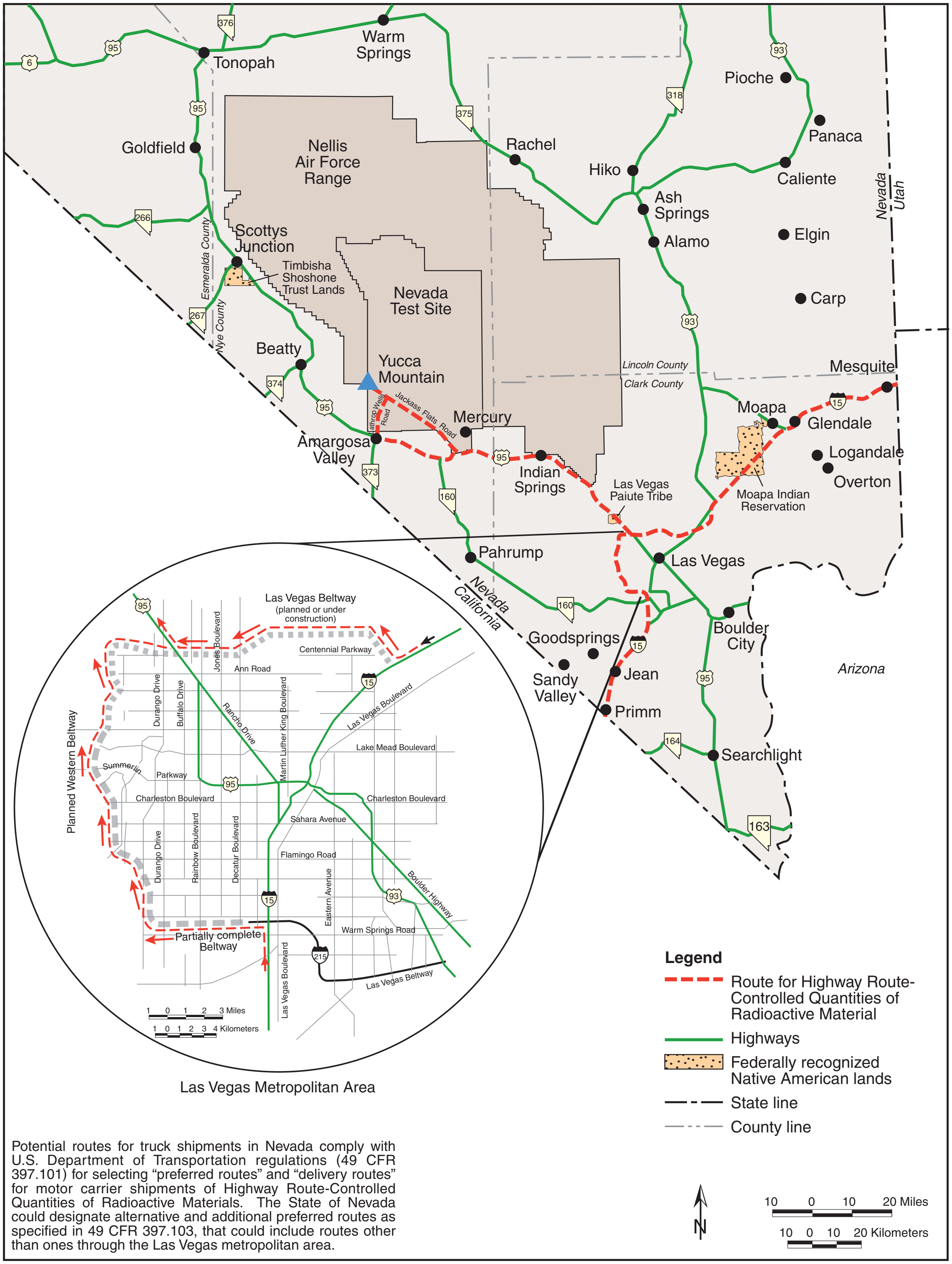


Figure S-12. Potential Nevada routes for legal-weight truck shipments of spent nuclear fuel and high-level radioactive waste to Yucca Mountain.

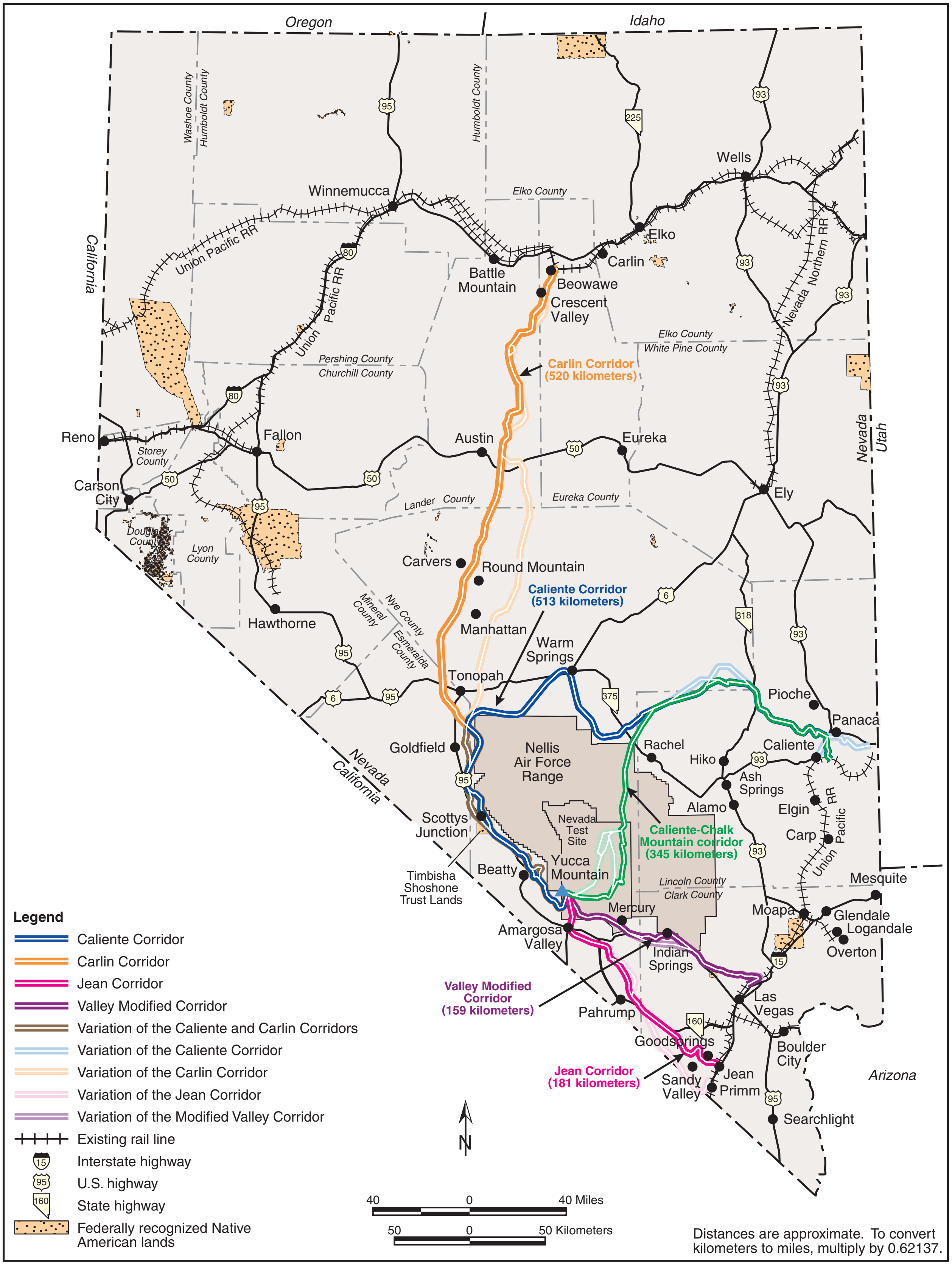


Figure S-13. Potential Nevada rail routes to Yucca Mountain.

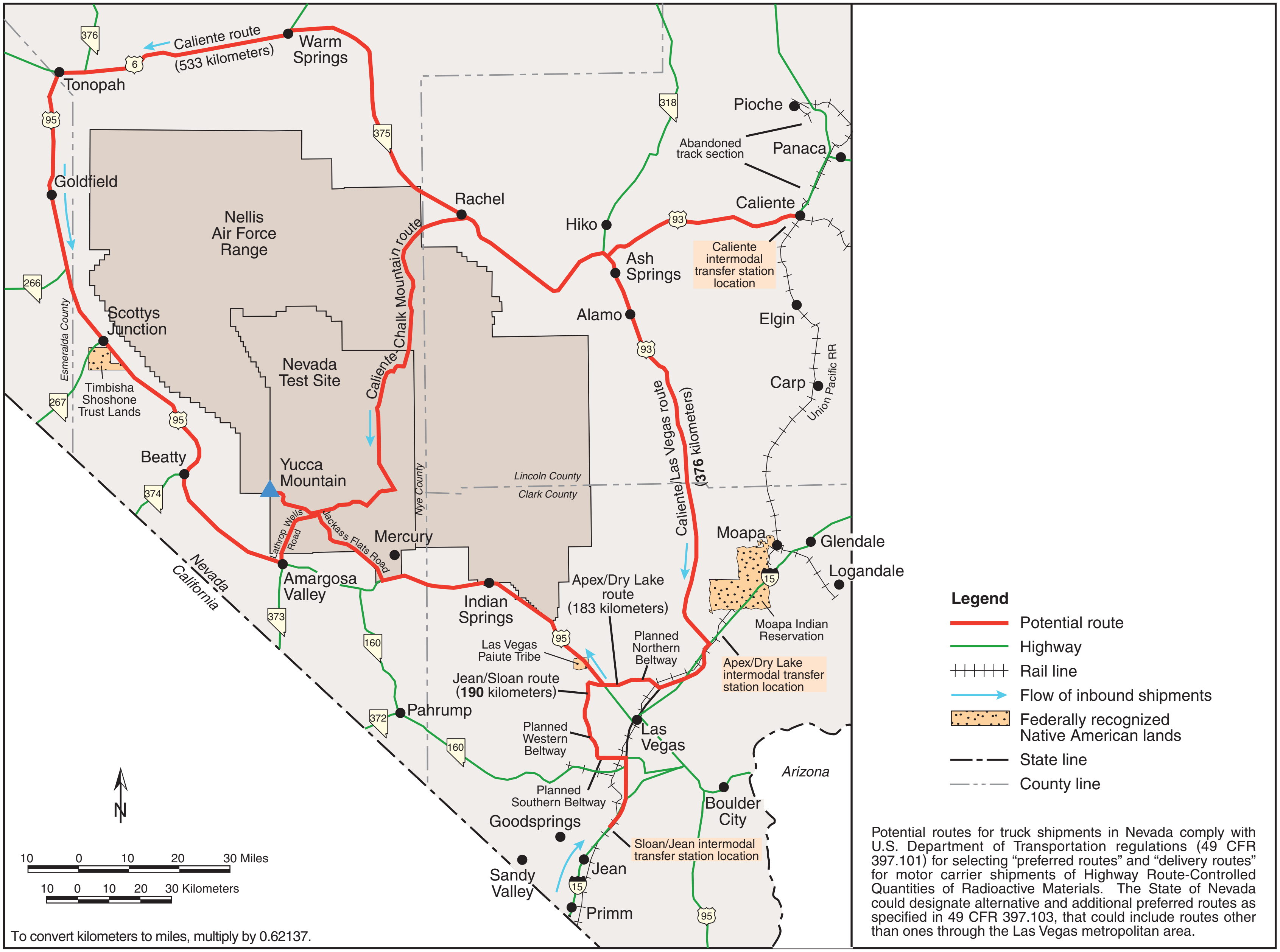


Figure S-14. Potential intermodal transfer station locations and potential routes in Nevada for heavy-haul trucks.

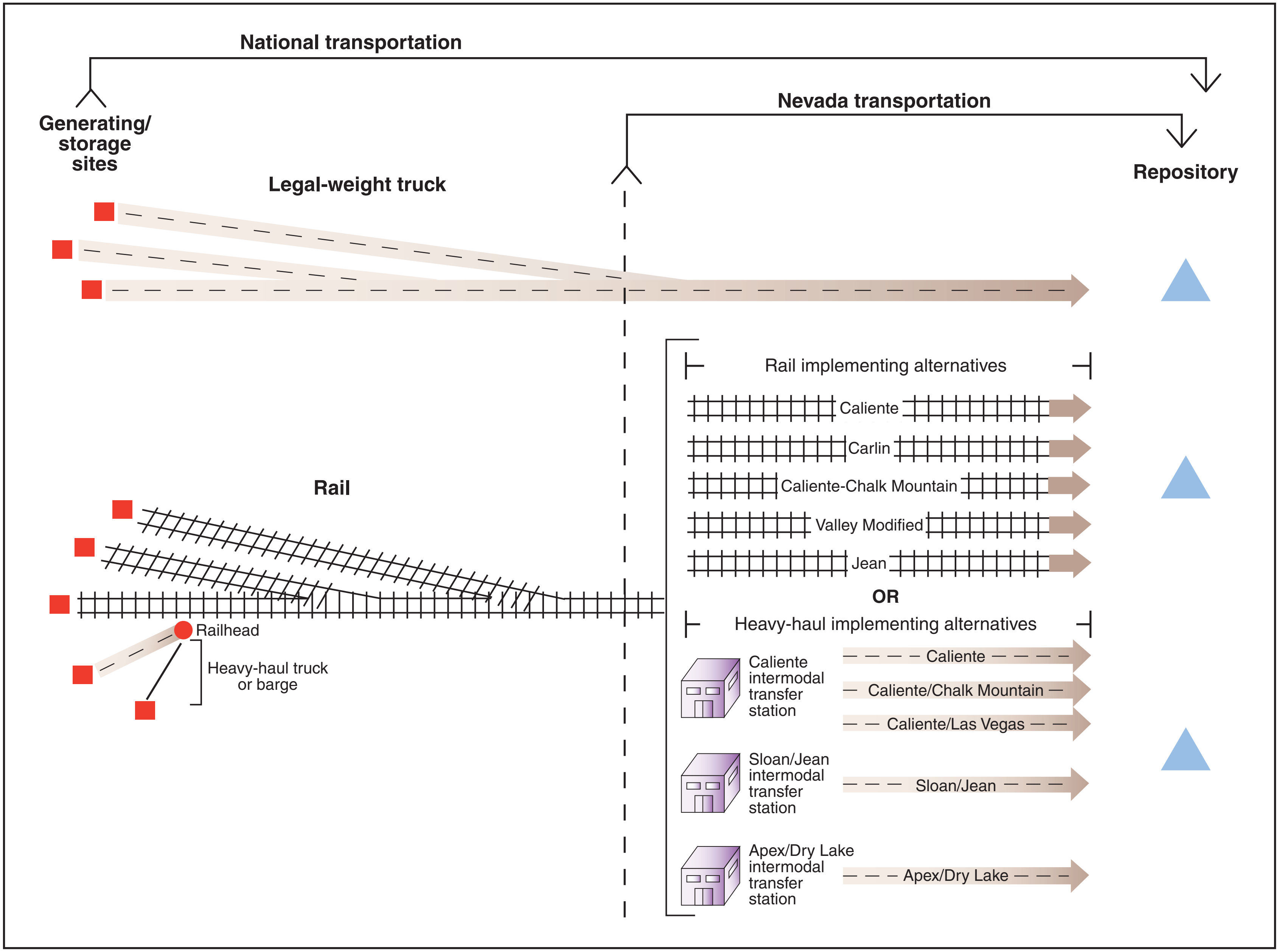


Figure S-15. Relationship of Nevada and national transportation.

- Up to $800 million for Nevada transportation, including construction of a potential branch rail line.
- $6.1 billion to $9.1 billion for program integration and institutional programs. These would include quality assurance, program management, costs associated with the Nuclear Regulatory Commission, Nuclear Waste Technical Review Board, and financial assistance for transportation planning.

The most recent estimates show that approximately 70 percent of the repository-related costs would be paid from the Nuclear Waste Fund (fees collected by nuclear utilities from ratepayers) and about 30 percent from taxpayer revenues (primarily to pay for disposal of DOE spent nuclear fuel and high-level radioactive waste).

S.3.2 NO-ACTION ALTERNATIVE

Under the No-Action Alternative, DOE would end site characterization activities at Yucca Mountain and undertake site reclamation to mitigate adverse environmental impacts from those activities. The commercial nuclear power utilities and DOE would continue to store spent nuclear fuel and high-level radioactive waste. Because it would be highly speculative to attempt to predict future events, DOE decided to illustrate one set of possibilities by focusing its analysis of the No-Action Alternative on the potential impacts of two scenarios:

- Scenario 1 assumes that spent nuclear fuel and high-level radioactive waste would remain at the 72 commercial and 5 DOE sites under institutional control for at least 10,000 years.
- Scenario 2 assumes that spent nuclear fuel and high-level radioactive waste would remain at the 77 sites in perpetuity, but under institutional control for only about 100 years. This scenario assumes no effective institutional control of the stored spent nuclear fuel and high-level radioactive waste after 100 years.

INSTITUTIONAL CONTROL

Monitoring and maintenance of storage facilities to ensure that radiological releases to the environment and radiation doses to workers and the public remain within Federal limits and DOE Order requirements.

DOE recognizes that neither scenario would be likely if there were a decision not to develop a repository at Yucca Mountain; however, they are part of the EIS analysis to provide a basis for comparison to the Proposed Action. There are a number of possibilities that the Nation could pursue, including continued storage of the material at its current locations or at one or more centralized location(s); the study and selection of another location for a deep geologic repository; development of new technologies; or reconsideration of other disposal alternatives to deep geologic disposal. One such centralized storage possibility, the proposed Private Fuel Storage Facility for commercial spent nuclear fuel in Utah, is currently in the Nuclear Regulatory Commission licensing process. The Commission issued a Final EIS in January 2002, however, that document was unavailable for use during the preparation of this Final EIS. The Commission has yet to issue a decision on whether to grant a license. Under any future course that would include continued storage, both commercial and DOE sites have an obligation to continue managing the spent nuclear fuel and high-level radioactive waste in a manner that protects public health and safety and the environment.

S.3.2.1 Reclamation and Decommissioning at Yucca Mountain

Under the No-Action Alternative, site characterization activities would end at Yucca Mountain. DOE would start site decommissioning and reclamation. These activities would include the removal or shutdown of all surface and subsurface facilities, and the restoration of the lands disturbed during site characterization. DOE would fill and seal drill holes to meet Nevada requirements.

S.3.2.2 Continued Storage at Commercial and DOE Sites

Under the No-Action Alternative, the 72 commercial and 5 DOE sites would continue to store spent nuclear fuel and high-level radioactive waste. For purposes of analysis, the No-Action Alternative assumes that those sites would treat and package the materials, as necessary, for their safe onsite management. It also assumes that the amount of spent nuclear fuel and high-level radioactive waste stored would be the same as that shipped under the Proposed Action (70,000 MTHM).

The EIS analysis assumed that spent nuclear fuel and high-level radioactive waste would be placed in dry-storage canisters inside reinforced concrete storage modules. Both the canister and the concrete storage module would provide shielding against the radiation that the material would emit, although the concrete module would provide the primary shielding. The dry configuration would enable outside air to circulate and remove the heat of radioactive decay. As long as spent nuclear fuel, high-level radioactive waste, canisters, and storage modules were properly maintained, this would provide safe storage.

No-Action Scenario 1. Spent nuclear fuel and high-level radioactive waste would remain in dry storage at the commercial and DOE sites and would be under institutional control for at least 10,000 years. Institutional control at these facilities would ensure the protection of workers and the public in accordance with Federal regulations. For purposes of analysis, DOE assumed that the storage facilities would undergo one major repair during the first approximately 100 years, and complete replacement after the first 100 years and every 100 years thereafter.

No-Action Scenario 2. Spent nuclear fuel and high-level radioactive waste would remain in dry storage at the commercial and DOE sites and would be under institutional control for approximately 100 years (as in Scenario 1). This scenario, however, assumes no effective institutional control after 100 years, and that the storage facilities at 72 commercial and 5 DOE sites would begin to deteriorate after 100 years. The facilities would eventually release radioactive materials to the environment, contaminating the atmosphere, soil, surface water, and groundwater for the 10,000-year period analyzed.

The assumption for Scenario 2 that there would be no effective institutional control after approximately 100 years is based on a review of generally applicable requirements that discount altogether the consideration of institutional control after 100 years for purposes of conducting performance assessments [U.S. Environmental Protection Agency regulations (40 CFR Part 191); U.S. Nuclear Regulatory Commission regulations for disposal of low-level radioactive material (10 CFR Part 61); and the National Research Council report on standards for the proposed Yucca Mountain Repository]. Thus, in addition to its inherent conservatism, the assumption that no institutional control would be in place after 100 years provides a consistent analytical basis for comparing the No-Action Alternative and the Proposed Action.

If the institutional control period assumed for the analysis of the No-Action Scenario 2 was extended to 300 years, consistent with the lower-temperature repository operating mode of the Proposed Action, the short-term environmental impacts during the period would increase by as much as 3 times.

Figure S-16 shows conceptual timelines for activities at the commercial and DOE sites for Scenarios 1 and 2.

S.3.2.3 Costs

DOE estimates that the total cost of Scenario 1 or 2 for the first 100 years, including the decommissioning and reclamation of the Yucca Mountain site, would range from $55.7 billion to $61.3 billion (in 2001 dollars), depending on the need to replace the dry-storage canisters in addition to replacing the storage facilities during that time. If the institutional control period was extended to 300 years to be consistent

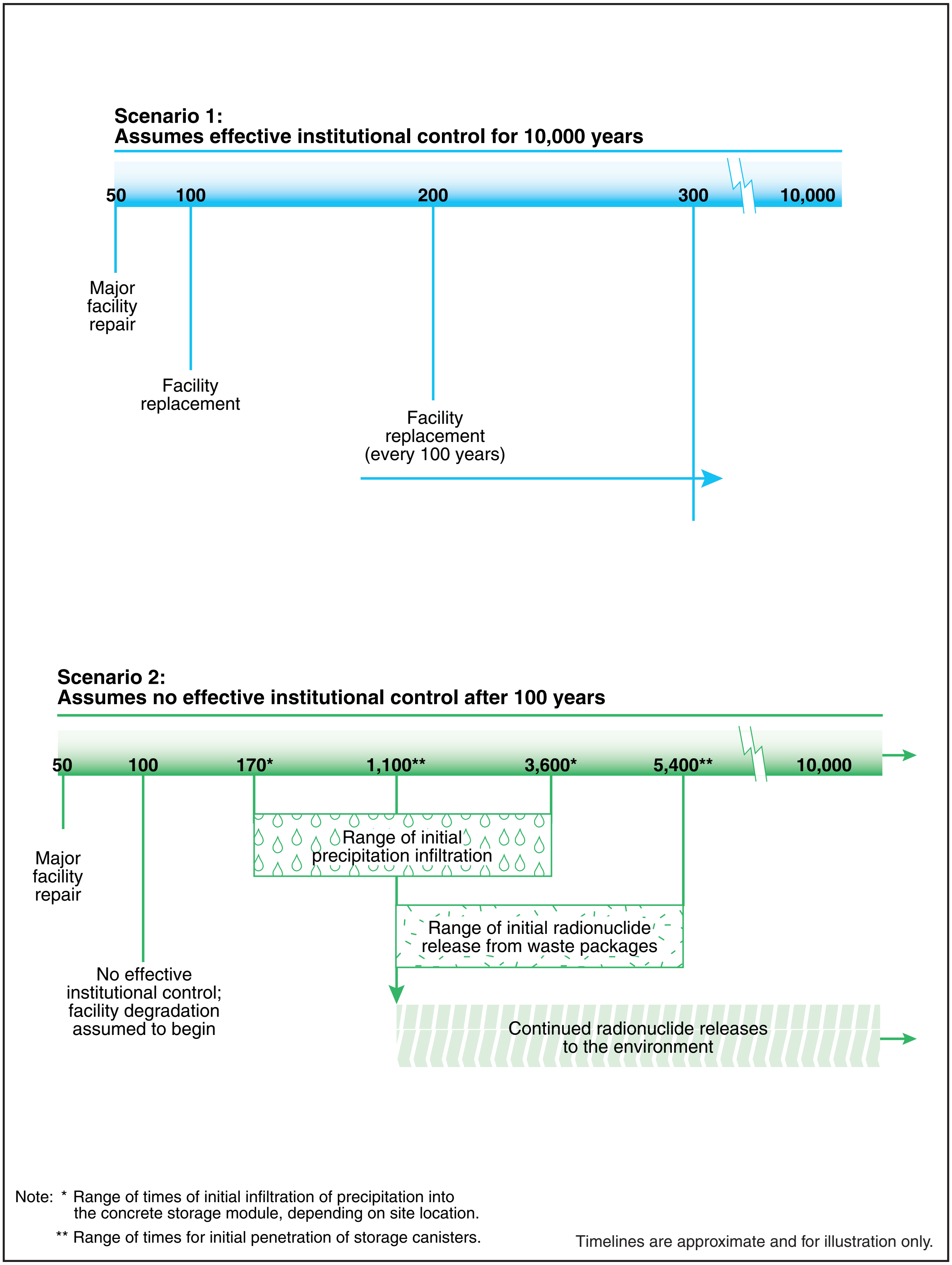


Figure S-16. Conceptual timelines for events at commercial and DOE sites for No-Action Scenarios 1 and 2.

with an extended monitoring period at the repository, the range values would triple to $167 billion to $184 billion (in 2001 dollars). The estimated cost for the remaining 9,700 to 9,900 years of Scenario 1 would range from $519 million to $572 million per year. There would be no costs under Scenario 2 after the first 100 years because that scenario assumes no effective institutional control after that time.

S.4 Issues Raised by the Public

S.4.1 Issues Raised in Public Scoping

DOE solicited written comments and held 15 public scoping meetings across the country between August 29 and October 24, 1995, to enable interested parties to present comments on the scope of this EIS.

During the public scoping process, a number of commenters asked that the EIS discuss the history of the Yucca Mountain site characterization program and requirements of the NWPA, address DOE's responsibility to begin accepting waste in 1998, describe the potential decisions that the EIS would support, and examine activities other than construction, operation and monitoring, and closure of a repository at Yucca Mountain. Other comments raised during public scoping addressed the consistency of the proposed repository with existing land uses, effects of earthquakes and volcanism, health and safety impacts, long-term impacts, and sabotage. In response to the public's input, DOE included discussions and analyses of these issues in the EIS. DOE also received comments noting that the Nation will have more than 70,000 MTHM of spent nuclear fuel and high-level radioactive waste, although the NWPA directs that the maximum amount allowed for repository disposal is 70,000 MTHM of these materials until a second repository is in operation. Commenters encouraged DOE to evaluate the disposal of the entire anticipated inventory of spent nuclear fuel and high-level radioactive waste and other waste types that might also require permanent isolation. For this reason, the EIS analyzes cumulative environmental impacts that could occur from the disposal at Yucca Mountain of the country's total projected inventory of spent nuclear fuel and high-level radioactive waste, as well as Greater-Than-Class-C and Special-Performance-Assessment-Required wastes. In response to other public scoping comments, DOE added an additional transportation corridor and route in Nevada to the analysis.

Many other public scoping comments presented views and concerns not related to the scope or content of the Proposed Action. Examples of these comments include statements in general support of or opposition to a repository at Yucca Mountain, geologic repositories in general, and nuclear power; lack of public confidence in the Yucca Mountain program; perceived inequities and political aspects of the siting process by which Congress selected Yucca Mountain for further study; the constitutional basis for waste disposal in Nevada; legal issues involving Native American land claims and treaty rights; and unrelated DOE activities. DOE considered and recorded these concerns, but has not included analyses of these issues in the EIS.

S.4.2 Issues Raised on the Draft EIS and the Supplement to the Draft EIS

During the public comment process for the Draft EIS and the Supplement to the Draft EIS, commenters raised a variety of key issues. DOE identified issues as "key" based on factors such as:

- The extent to which an issue concerned fundamental aspects of the Proposed Action
- The nature of the comments as characterized by the commenter
- The extent to which DOE modified the EIS in response to the issue
- The number of comments received on a particular issue

The Comment-Response Document contains the comments received on the Draft EIS and on the Supplement to the Draft EIS and the DOE responses to those comments. The following summaries illustrate some of the key issues and DOE's responses.

- *Nuclear Waste Policy Act – Why is Yucca Mountain the only site that DOE is studying?*

  The Nuclear Waste Policy Act of 1982 provided for a process for selecting sites for technical study as potential geologic repository locations. In accordance with this process, DOE identified nine candidate sites, the Secretary of Energy nominated five of the nine sites for further consideration, and DOE issued environmental assessments for the five sites. DOE recommended three of the five sites, of which Yucca Mountain was one, for possible study as candidate repository sites. In 1987, Congress amended the Nuclear Waste Policy Act of 1982, directing the Secretary of Energy to perform site characterization activities only at the Yucca Mountain site, and, if the site was found suitable, to make a determination whether to recommend that the President approve the site for development of a repository.

- *DOE's site suitability guidelines – Why did DOE change its guidelines for determining the suitability of the Yucca Mountain site?*

  The Nuclear Waste Policy Act of 1982 directed the Secretary of Energy to issue general guidelines for the recommendation of sites for characterization, in consultation with certain Federal agencies and interested governors, and with the concurrence of the Nuclear Regulatory Commission. These guidelines (issued in 1984 at 10 CFR Part 960) included factors related to the comparative advantages among candidate sites located in various geologic media, and other considerations such as population density and distribution.

  In 1987, amendments to the Nuclear Waste Policy Act specified Yucca Mountain as the only site DOE was to characterize. For this reason, DOE proposed in 1996 to clarify and focus its 10 CFR Part 960 guidelines to apply only to the Yucca Mountain site. In 1999, DOE proposed further revisions to these guidelines principally to reflect the then-proposed regulations and criteria of the Environmental Protection Agency (40 CFR Part 197) and the Nuclear Regulatory Commission (10 CFR Part 63), and to provide a technical basis to assess the performance of a geologic repository at Yucca Mountain to isolate spent nuclear fuel and high-level radioactive waste from the environment.

  In 2001, DOE promulgated its final guidelines (10 CFR Part 963), establishing the methods and criteria to determine the suitability of the Yucca Mountain site for the location of a geologic repository. The Final EIS describes these final guidelines.

- *Repository design – Why design a repository that would release radioactive materials into the environment?*

  Given the current state of technology, it is virtually impossible to design and construct a geologic repository that would provide a reasonable expectation that there would never be any releases of radioactive materials. DOE would design and construct a repository that would meet public health and safety radiation protection standards and criteria established by the EPA and the NRC. In part, the EPA standards (40 CFR Part 197) and NRC criteria (10 CFR Part 63) prescribe radiation exposure limits that the repository, based on a performance assessment, must be designed not to exceed during a 10,000-year period after closure.

  In the EIS, DOE has evaluated the environmental impacts of the proposed repository's natural and engineered barrier system, which is designed to isolate radioactive materials from the environment for thousands of years. As a result of this evaluation, DOE would not expect the repository to result in impacts to public health beyond those that could result from the prescribed radiation exposure and activity concentration limits during the 10,000-year period after closure.

- *Public participation process – Commenters stated that the public comment processes for scoping, the Draft EIS, and the Supplement to the Draft EIS were inadequate.*

  DOE's public involvement process during the development of the EIS is consistent with Council on Environmental Quality and DOE regulations implementing NEPA, and reflects DOE guidance on public participation during the preparation of EISs.

  For the scoping process and in advance of the Notice of Intent, DOE notified its stakeholders of its plans to prepare the EIS and its approach to the scoping process. When the Notice of Intent was published in the *Federal Register,* DOE mailed a series of information releases to stakeholders, sent press releases and public service announcements to the media, and provided information on the Internet and in its reading rooms. Fifteen public scoping meetings were held during a 120-day public scoping period.

  In August 1999, DOE distributed the Draft EIS to more than 3,400 stakeholders and held 21 public hearings across the Nation during a 199-day public comment period. DOE placed advertisements in local newspapers and distributed public service announcements and press releases to more than 175 local and national stakeholder and media outlets to publicize information about the Draft EIS and public comment process.

  In May 2001, DOE distributed the Supplement to the Draft EIS to more than 4,000 stakeholders and held three public hearings in Nevada during the 57-day public comment period. During this period, the Department discovered that it had inadvertently not sent the Supplement to about 700 stakeholders who had requested and received a copy of the Draft EIS. DOE acknowledged this oversight, provided copies of the Supplement to the Draft EIS, and provided a separate 45-day comment period for these stakeholders.

  In Volume III of this EIS, DOE has presented and responded to all comments on the Draft EIS and the Supplement to the Draft EIS received by August 31, 2001.

- *Need for another Draft EIS or a Supplemental EIS – The Draft EIS did not provide sufficient information or analysis and, thus, was deficient and should be withdrawn.*

  The level of information and analyses, the analytical methods and approaches used to represent conservatively the reasonably foreseeable impacts, and the use of bounding assumptions to address incomplete or unavailable information or uncertainties provide an assessment of environmental impacts consistent with all applicable requirements.

  The EIS, which DOE prepared using the best reasonably available data, analyzes a variety of implementing alternatives and scenarios. These alternatives and scenarios reflect potential repository design and operating modes, waste packaging approaches, and transportation options for shipping spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site. DOE included a No-Action Alternative that analyzed two scenarios to provide a basis for comparison with the Proposed Action and to reflect the range of impacts that could occur.

  In the Draft EIS, DOE discussed ongoing site characterization activities and design evaluations, and the potential for resulting changes to repository design. Since the publication of that document, DOE improved its understanding of the interactions of potential repository features with the natural environment, and the advantages of a number of design features to enhance waste containment and isolation. DOE published the Supplement to the Draft EIS to address the most recent design enhancements, including various operating modes to manage heat generated by emplaced spent nuclear fuel and high-level radioactive waste.

This Final EIS evaluates the Proposed Action based on the design considered in the Supplement to the Draft EIS.

- *Range of alternatives – DOE should have considered a range of alternatives, such as other sites, treatment technologies, and alternatives to geologic disposal.*

  In 1980, DOE evaluated alternatives to mined geologic disposal in an EIS, and decided in 1981 in the subsequent Record of Decision to develop mined geologic repositories for the disposal of spent nuclear fuel and high-level radioactive waste. Furthermore, the NWPA provides that DOE need not consider in this EIS the need for a geologic repository and alternatives to isolating spent nuclear fuel and high-level radioactive waste in a repository. The NWPA also provides that this EIS does not have to consider any site other than Yucca Mountain for development as a repository. For these reasons, DOE did not analyze alternatives other than the Proposed Action and the No-Action Alternative.

- *The Proposed Action – DOE has failed to define its Proposed Action clearly.*

  In response to this concern, DOE has modified the EIS to promote an improved understanding of the potential environmental impacts from a more specifically defined Proposed Action. DOE has identified its preferred alternatives, simplified aspects of the Proposed Action, and modified its analyses and presentation of information to illustrate the full range of potential environmental impacts that could occur under any reasonably foreseeable repository design and operating mode or mode of transportation.

- *Preferred alternative – DOE should identify its preferred alternatives and scenarios.*

  In the Draft EIS, DOE indicated its preferred alternative was to proceed with the Proposed Action to construct, operate and monitor, and eventually close a repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. In this Final EIS, DOE has identified mostly rail as its preferred mode of transportation, both nationally and in the State of Nevada.

  DOE has not identified a preference among the five candidate rail corridors in Nevada. If the Yucca Mountain site was approved, DOE would issue at some future date a Record of Decision to select a mode of transportation. If, for example, mostly rail was selected (both nationally and in Nevada), DOE would then identify a preference for one of the rail corridors in consultation with affected stakeholders, particularly the State of Nevada.

  DOE has not identified other preferences under the various scenarios presented in this Final EIS. Specific details of operating the repository and related features would be resolved only in the context of developing a License Application for review by the NRC.

- *No-Action Alternative – Why did DOE evaluate a No-Action Alternative that includes unreasonable scenarios?*

  If the Yucca Mountain site was not approved, DOE would, as required by the NWPA, prepare a report to Congress, with the Department's recommendations for further action to ensure the safe, permanent disposal of spent nuclear fuel and high-level radioactive waste, including the need for new legislative authority. In this event, the generator sites, commercial utilities, and DOE would have to continue managing spent nuclear fuel and high-level radioactive waste in a manner that protected public health and safety and the environment. However, the future course that Congress, DOE, and the commercial utilities would take is uncertain, and a number of possibilities could be pursued.

In light of these uncertainties, DOE decided to illustrate the range of potential environmental impacts by analyzing two No-Action Alternative scenarios that could occur without additional legislation—long-term storage of spent nuclear fuel and high-level radioactive waste at the current sites with effective institutional control for at least 10,000 years, and long-term storage with no effective institutional control after about 100 years. Although the Department agrees that neither of these scenarios is likely, it selected them for analysis because they provide a basis for comparison to the impacts of the Proposed Action and because they reflect a range of the impacts that could occur.

- *Decisionmaking – DOE cannot base decisions on this EIS.*

  DOE believes that the EIS adequately analyzes the potential environmental impacts that could result from the Proposed Action. This belief is based on the level of information and analysis, the analytical methods and approaches used to represent conservatively the reasonably foreseeable impacts, and the use of bounding assumptions where information is incomplete or unavailable, or where uncertainties exist.

  For the same reasons, if the site was approved, DOE believes that the EIS provides the environmental impact information necessary to make certain broad transportation-related decisions, namely the choice of a national mode of transportation outside Nevada (mostly rail or mostly legal-weight truck), the choice among alternative transportation modes in Nevada (mostly rail, mostly legal-weight truck, or heavy-haul truck with use of an associated intermodal transfer station), and the choice among alternative rail corridors or heavy-haul truck routes with use of an associated intermodal transfer station in Nevada. However, follow-on implementing decisions, such as the selection of a specific rail alignment in a corridor, would require additional NEPA reviews.

- *Premature decisionmaking – DOE has decided to recommend the Yucca Mountain site in advance of the Final EIS and other documentation.*

  At the time DOE prepared this Final EIS, it had not made a decision on the proposed repository at Yucca Mountain. The Secretary of Energy will make a determination on whether to recommend the site to the President on the basis of a number of different types of information, including that contained in the Final EIS. Any recommendation would be accompanied not only by the Final EIS, but also by other information designated in the NWPA.

- *Population data – Why does DOE use outdated population data?*

  When DOE prepared the Draft EIS, it based the Nevada population estimates on the then-most-recently available information (1996-1997) from the U.S. Bureau of the Census. The Department used these data in its economic and demographic forecasting model to project population growth in the regions of influence and to evaluate socioeconomic impacts from the Proposed Action. For its transportation health and safety analyses, however, DOE relied on 1990 population data, which were the then-most-recent data incorporated in the standard models used for such analyses.

  In response to comments and recently available information, DOE has updated its population estimates in the regions of influence to reflect the most recent state and local information, as well as the Bureau of the Census 2000 population summary data for Nevada. To update the health and safety analyses associated with transportation in Nevada, DOE used the baseline population for each county in the region of influence and forecast the population to 2035 and scaled the impacts accordingly. To update the health and safety analyses on a national basis, DOE scaled the 1990 population-based impacts upward to reflect the relative state-by-state population growth to 2035. The projections are based on 2000 Census data.

- *Risk perception and stigma – Why didn't DOE analyze the impacts associated with the negative perceptions attached to a potential repository at Yucca Mountain?*

  During scoping for the EIS, DOE received comments saying the EIS should analyze perception-based and stigma-related impacts. Perception-based impacts would not necessarily depend on the actual physical impacts or risks from repository operations or transportation. Further, people do not consistently act in accordance with negative perceptions, and thus the connection between public perception of risk and future behavior would be uncertain or speculative at best. For these reasons, DOE determined that including analyses of perception-based and stigma-related impacts in the Draft EIS would not provide meaningful information.

  Nevertheless, in light of the comments received on the Draft EIS, DOE commissioned an examination of relevant studies and literature on perceived risk and stigmatization of communities to determine whether the state of the science in predicting future behavior, based on perceptions, had advanced sufficiently to allow DOE to quantify the impact of public risk perception on economic development or property values. Based on this examination, DOE has concluded that:

  1. While in some instances risk perceptions could result in adverse impacts on portions of a local economy, there are no reliable methods whereby such impacts could be predicted with any degree of certainty,

  2. Much of the uncertainty is irreducible, and

  3. Based on a qualitative analysis, adverse impacts from perceptions of risk would be unlikely or relatively small.

  While stigmatization of southern Nevada can be envisioned under some scenarios, it is not inevitable or numerically predictable. Any such stigmatization would likely be an aftereffect of unpredictable future events, such as serious accidents, which are not anticipated to occur. As a consequence, DOE did not attempt to quantify any potential for impacts from risk perceptions or stigma in this Final EIS.

- *Native American viewpoints – DOE did not adequately consider Native American viewpoints or incorporate these viewpoints in the analyses and resulting conclusions.*

  DOE believes that it appropriately considered Native American viewpoints by incorporating in the EIS the Native Americans' own identification of potential impacts to historic and other cultural resources important to sustaining and preserving their cultures. During the preparation of the EIS, DOE supported the American Indian Writers Subgroup of the Consolidated Group of Tribes and Organizations in its preparation of a separate report, the results of which are included in the EIS.

  Based on the results of the report, DOE acknowledges in the EIS that people from many Native American tribes have used the area proposed for the repository as well as nearby lands; that the lands around the site contain cultural, animal, and plant resources important to those tribes; and that the implementation of the Proposed Action would continue restrictions on free access to the area around the repository site. Furthermore, the presence of a repository would represent an intrusion into what Native Americans consider an important cultural and spiritual area. These concerns notwithstanding, DOE and the Consolidated Group of Tribes and Organizations recognize that restrictions on public access to the area have been generally beneficial and protective of cultural resources, sacred sites, and traditional cultural properties.

- *Ruby Valley Treaty – DOE should honor the Ruby Valley Treaty of 1863 with the Western Shoshone Nation.*

  The Western Shoshone people maintain that the Ruby Valley Treaty of 1863 gives them rights to 97,000 square kilometers (37,000 square miles) in Nevada, including the Yucca Mountain region. In 1977, the Indian Claims Commission granted a final award to the Western Shoshone people, who dispute the Commission's findings and have not accepted the monetary award for the lands in question. In 1985, the Supreme Court ruled that even though the money has not been distributed, the United States has met its obligations with the Indian Claims Commission's final award and, as a consequence, the aboriginal title to the land has been extinguished.

- *Approach to environmental justice transportation analysis – DOE's two-staged assessment process masks significant impacts to minorities and low-income populations, and its failure to identify either specific locations or specific characteristics of affected communities demonstrates the inadequacy of the analysis.*

  The approach to environmental justice analysis in this EIS is consistent with the Council on Environmental Quality guidance. The goal of this approach is to identify whether any high and adverse impacts would fall disproportionately on minority and low-income populations. The approach first analyzes the potential impacts on the general population as a basis for comparison. Second, based on available information, the approach assesses whether there are unique exposure pathways, sensitivities, or cultural practices that would result in high and adverse impacts on minority and low-income populations. If high and adverse impacts on a minority or low-income population would not appreciably exceed the same type of impacts on the general population, no disproportionately high and adverse impacts would be expected.

  In response to comments, DOE has reevaluated available information to determine whether the Draft EIS overlooked any unique exposure pathways or unique resource uses that could create opportunities for disproportionately high and adverse impacts to minority and low-income populations. Although DOE identified additional unique pathways and resources, none revealed a potential for disproportionately high and adverse impacts.

  DOE also updated and refined information germane to its environmental justice analysis. Based on the additional information and resulting analysis, DOE has concluded that disproportionately high and adverse impacts from the construction and operation of a rail line or intermodal transfer station would be unlikely.

- *Rail and highway routes – Why didn't DOE identify the specific rail and highway routes that would be used to ship spent nuclear fuel and high-level radioactive waste?*

  Because it is impossible to predict which highway routes or rail lines DOE could use in advance of actual shipments, the Department selected potential highway routes for analysis in accordance with U.S. Department of Transportation regulations, which require the use of preferred routes (typically highways and bypasses that are part of the Interstate Highway System). The Department based its selection of potential rail routes on current rail practices, because there are no comparable Federal regulations applicable to the selection of rail routes for the shipment of radioactive materials.

In response to public comments, DOE has included maps of the representative highway routes and rail lines it used for analysis in the Final EIS. It also included potential health and safety impacts associated with shipments for each state through which shipments could pass.

- *Transportation public health and safety impacts – The transportation-related health and safety analysis was inadequate because DOE did not consider community-by-community population characteristics.*

  DOE does not believe that it is necessary or appropriate to consider population characteristics on a community-by-community basis to determine potential public health and safety impacts from the transportation of spent nuclear fuel and high-level radioactive waste. The use of widely accepted analytic tools, latest reasonably available information, and cautious but reasonable assumptions if there are uncertainties, offer the most appropriate means to arrive at conservative estimates of transportation-related public health impacts.

  In this EIS, DOE used computer models it has used in previous EISs and other studies. These models, such as RADTRAN 5, are widely accepted by the national and international scientific and regulatory communities.

  In addition, DOE has either incorporated information that has become available since the publication of the Draft EIS or modified existing information to accommodate conditions likely to be encountered over the life of the Proposed Action. For example, in this Final EIS DOE has scaled impacts upward to reflect the relative state-by-state population growth to 2035, using 2000 Census data.

  Not all aspects of incident-free transportation or accident conditions can be known with absolute certainty, and so DOE has relied on conservative assumptions that tend to overestimate impacts. For instance, DOE assumed that a hypothetical individual, the “maximally exposed individual,” would be a resident living 30 meters (100 feet) from a point where all truck shipments would pass (this individual would receive a dose of about 6 millirem). Although it can be argued that individuals could live closer to these shipments, it is highly unlikely that an individual would be exposed to all shipments over the 24-year period of shipments to the repository, even though DOE incorporated this highly conservative assumption in the analysis.

  In response to comments, DOE has considered locations at which individuals could reside nearer the candidate rail corridors and heavy-haul truck routes in Nevada as a way of representing conditions that could exist anywhere in potentially affected communities. For example, an individual residing as close as 4.9 meters (16 feet) to a potential heavy-haul truck route would receive an estimated dose of about 29 millirem if exposed to all shipments.

  The doses from these exposures would be well below those received from natural background radiation and would not be discernible even if the doses could be measured.

- *Transportation accident conditions – Why didn’t DOE analyze a range of accidents that reflect real-life conditions?*

  “Real-life conditions” that would involve various types of collisions, various natural disasters, specific locations (such as mountain passes), or various infrastructure accidents (such as track failure) in effect constitute a combination of cask failure mechanisms, impact velocities, and temperature ranges, which the EIS does evaluate. Accident scenarios are modeled in this fashion to accommodate the almost infinite number of variables that any given accident could involve. In the Draft EIS, for example, DOE evaluated the ability of large aircraft components (engines and engine shafts) to penetrate shipping casks. DOE considered both small military aircraft and commercial aircraft at velocities representative of takeoffs and landings and at higher velocities. DOE found that, at lower velocities, these aircraft components would not penetrate a shipping cask sufficiently to cause a release of radioactive materials. Recent analysis of this event at higher velocities, however, indicate an increased potential for seal failure of the shipping casks. If seal failure were to occur, impacts to an urban area would be less than 1 latent cancer fatality in the exposed population.

Based on its revised analyses, DOE has concluded in the EIS that casks would continue to contain spent nuclear fuel fully in more than 99.99 percent of all accidents (of the thousands of shipments over the last 30 years, none has resulted in an injury due to release of radioactive materials). This means that of the approximately 53,000 truck shipments, there could be 66 accidents, each having less than a 0.01-percent chance that radioactive materials would be released. The chance of a rail accident that would cause a release from a cask would be even less. The corresponding chance that such an accident would occur in any particular locale would be extremely low.

- *Cask testing – Will DOE conduct full-scale testing of transportation casks?*

The NWPA requires DOE to use casks certified by the NRC when transporting spent nuclear fuel and high-level radioactive waste to a repository. A cask's ability to survive the tests prescribed by the regulations (10 CFR Part 71) can be demonstrated either through component analysis or through scale-model and full-scale testing to demonstrate and confirm the performance of the casks. The NRC would decide which level of physical testing or analysis was appropriate for each cask design submitted.

- *Repository design – Why didn't DOE analyze the latest design in the Draft EIS?*

In the Draft EIS, DOE evaluated a preliminary design that focused on the amount of spent nuclear fuel (and associated thermal output) that DOE would emplace per unit area of the repository (called *areal mass loading*). Areal mass loading was represented in the Draft EIS by three thermal load scenarios. The purpose of these scenarios was not to place a limit on the choices among alternative designs because, as stated in the Draft EIS, DOE expected the repository design to continue to evolve in response to ongoing site characterization and design-related evaluations. Rather, DOE selected these analytical scenarios to represent the range of foreseeable design features and operating modes, and to ensure that it considered the associated range of potential environmental impacts.

Since issuing the Draft EIS, DOE has continued to evaluate design features and operating modes. The result of the design evolution process was the development of the *flexible design* (which the Supplement to the Draft EIS called the Science and Engineering Report Flexible Design). Although this design focuses on controlling the temperature of the rock between the waste emplacement drifts (as opposed to areal mass loading), the basic elements of the Proposed Action to construct, operate and monitor, and eventually close a geologic repository at Yucca Mountain remain unchanged since the Draft EIS.

- *Hydrologic setting – DOE lacks an understanding of the hydrologic setting and should continue to study the site and surrounding region before making any decisions.*

DOE believes that it has sufficient information and understanding of the hydrologic setting to make an adequate determination of the potential environmental impacts from the Proposed Action. DOE, the U.S. Geological Survey, and others have been evaluating and assessing the hydrologic setting and associated characteristics at the Yucca Mountain site and nearby region for more than two decades. During this time, DOE has modified its site characterization program to reflect new information and assessments and to accommodate reviews by independent parties. Nevertheless, DOE recognizes that additional information would refine its understanding of the regional groundwater flow system, and would reduce uncertainties associated with flow and transport in the alluvial, volcanic, and carbonate aquifers.

To obtain additional information, DOE has supported Nye County in the Early Warning Drilling Program to characterize further the saturated zone along possible groundwater pathways from Yucca Mountain as well as the relationships among the volcanic, alluvial, and carbonate aquifers. DOE also has installed a series of test wells along the groundwater flow path between the Yucca Mountain site and the Town of Amargosa Valley as part of an alluvial testing complex.

After completion of site characterization, DOE would institute a *Testing and Performance Confirmation Program*, elements of which would address the hydrologic system. The program would continue through closure of the repository.

- *Site disqualification – The Yucca Mountain site should be disqualified under 10 CFR Part 960 because subsurface fracturing would allow contaminated groundwater to reach the environment in less than 1,000 years.*

  DOE's original 1984 site suitability guidelines (10 CFR Part 960) have been superseded by Yucca Mountain-specific guidelines (10 CFR Part 963) promulgated by DOE in 2001. In any event, information and analyses do not support a finding that the site would have been disqualified under the groundwater travel time disqualifying condition at 10 CFR 960.4-2-1(d). Under that condition, a site would be disqualified if the expected groundwater travel time from the disturbed zone (the area in which properties would change from construction or heat) to the accessible environment would be less than 1,000 years along any pathway of likely and significant radionuclide travel. The definition of groundwater travel time in 10 CFR 960.2 specifies that the calculation of travel time is to be based on the average groundwater flux (rate of groundwater flow) as a summation of travel times for groundwater flow in discrete segments of the system. As a practical matter, this definition provides for consideration of the rate at which most of the water moves.

  DOE estimates that the median groundwater travel times would be about 8,000 years, and average groundwater travel times would be longer. These models indicate that small amounts of water potentially moving in "fast paths" from the repository to the accessible environment could do so in less than 1,000 years. However, the models and corroborating physical evidence indicate that most of the water would take more than 1,000 years to reach the accessible environment. Given this, DOE believes that the site would not have been disqualified under the groundwater travel condition at 10 CFR 960.4-2-1.

- *Repository performance – How can DOE possibly predict repository performance given data uncertainties, untested computer models, and the chaotic nature of the long-term processes?*

  DOE acknowledges that it is not possible to predict with absolute certainty what will occur thousands of years into the future. The NRC regulations (see 10 CFR Part 63) acknowledge that absolute proof is not to be had in the ordinary sense of the word, and the EPA has determined (see 40 CFR Part 197) that reasonable expectation, which requires less than absolute proof, is the appropriate test of compliance.

  DOE has designed its performance assessment to be a combination of mathematical modeling, and natural analogs. Performance assessment explicitly considers the spatial and temporal variability and inherent uncertainties in geologic, biologic, and engineered components of the disposal system. In this way, DOE is confident that its approach to performance assessment addresses and compensates for various uncertainties, and provides a reasonable estimation of potential impacts over thousands of years.

- *Disruptive natural phenomena – Commenters stated that earthquakes and volcanoes will cause releases of radioactive waste.*

  DOE has analyzed the potential public health and safety impacts that could arise from natural events such as earthquakes and volcanic activity. The disruptive natures of earthquakes and volcanic activity differ materially, both in terms of probabilities (likelihood of occurrence) and the possible disruptive nature of the events themselves. Volcanism over the long-term life of the repository, with eruptions and magma flow, would be highly unlikely, while seismic activity and its consequent ground motion would be more likely to occur.

  While the occurrence of events cannot be predicted exactly, risks can be estimated statistically. Computer simulations allow DOE to estimate risks from natural events. Thus, the EIS contains an analysis of the probabilities and effects of such events on radionuclide release, and the resultant potential human health impacts to the public.

  Although DOE would design repository structures to withstand the ground movement associated with severe earthquakes, it estimated the impacts that could result from a "beyond-design-basis" seismic event that would result in the collapse of the Waste Handling Building and consequent damage to spent nuclear fuel assemblies. DOE determined the resulting impacts associated with this scenario would be small (primarily due to the physical form of the assemblies, reduced releases due to the building rubble, and distance to the nearest population). The underground engineered barriers would be far less susceptible to damage.

  DOE also estimated the impacts of volcanic eruptions that could result in the release of volcanic ash and entrained waste into the atmosphere. DOE estimated the potential impacts on the nearest population, conservatively assuming (tending to overestimate) the direction and speed of wind transport of an ash plume, and determined that the potential for public health and safety impacts would be very small. DOE also determined that magma flows would have minimal impacts on the long-term performance of the repository.

S.4.3 Changes Made in the Final EIS

As a result of public comments and the availability of new and updated information, changes were made to the Draft EIS and Supplement to the Draft EIS and are reflected in the Final EIS. Examples of these changes are the inclusion of:

- More information regarding potential impacts, particularly impacts associated with transportation of spent nuclear fuel and high-level radioactive waste within Nevada
- Use of a "representative" fuel assembly in the accident analysis
- Use of updated data, particularly population data in the impact analyses
- A more detailed discussion of the issue of potential impacts associated with negative perceptions about the repository project
- Use of updated versions of computer models for assessing human health and transportation impacts
- Corrections or editorial changes for accuracy and clarity
- Addition of an appendix that contains general information about transportation of radioactive materials not specifically used in the analysis, but provided for public information

- Addition of the U.S. Fish and Wildlife Service Biological Opinion as an appendix to the Final EIS
- Addition of a Readers Guide to help readers understand the Final EIS

As stated in the Supplement to the Draft EIS, "The fundamental aspects of the repository have not changed." The differences in environmental impacts due to the changes noted above were minor. In most environmental resource areas, the impacts either stayed the same or were smaller than those presented in the Draft EIS or the Supplement to the Draft EIS. In those cases where the impacts were larger than previously presented (generally driven by the larger population used for analysis in the Final EIS), the increases were not materially larger.

S.5 Environmental Consequences of the Proposed Action

To analyze the potential environmental impacts associated with the Proposed Action, DOE compiled baseline information for various environmental resource areas and examined how the construction, operation and monitoring, and eventual closure of a repository at Yucca Mountain could affect each of those environmental resources, and resulting impacts on human health. In considering the impacts on human health, DOE analyzed both routine operations and accident scenarios.

ENVIRONMENTAL CONSEQUENCES

Under the regulations implementing the procedural provisions of the National Environmental Policy Act, an EIS should include a discussion of the *environmental consequences* of the Proposed Action and alternatives. The discussion of environmental consequences must include:

- Environmental *impacts* or *effects* (impacts are synonymous with effects under the regulations)
- Any adverse environmental impacts that cannot be avoided
- The relationship between short-term uses of the environment and the maintenance and enhancement of long-term productivity
- Any irreversible or irretrievable commitment of resources

Short-term consequences are those that could occur in the period before the completion of repository closure. DOE analyzed potential short-term impacts that could occur in resource areas as a result of performance confirmation, construction, operation and monitoring, closure, and transportation activities.

Long-term consequences are those that could occur after repository closure. DOE analyzed potential long-term impacts that could occur to human health and biological resources from radiological and chemical groundwater contamination for 10,000 years after repository closure. In addition, peak dose to 1 million years was estimated.

DOE conducted a broad range of studies to obtain or evaluate the information needed for the assessment of Yucca Mountain as a geologic repository. These studies have provided in-depth knowledge about the Yucca Mountain site and vicinity and provide sufficient information to aid in DOE decisionmaking. The Department used the information from these studies in the analyses described in this EIS. However, because some of these studies are ongoing, some of the information is incomplete. Further, the complexity and variability of the natural system at Yucca Mountain, the long period evaluated (10,000 years), and incomplete information or the unavailability of some information have resulted in uncertainty in the analyses and findings. Throughout the EIS, DOE notes both the use of incomplete information if complete information is unavailable, and the existence of uncertainty, to enable the reader to better understand EIS findings.

The following paragraphs describe the potentially affected resources at the Yucca Mountain site and vicinity and a summary of the extent to which the Proposed Action could affect those resources.

S.5.1 YUCCA MOUNTAIN SITE AND VICINITY

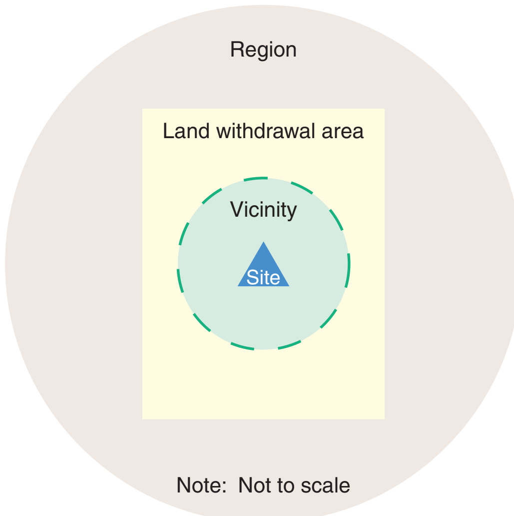
SITE-RELATED TERMS

Yucca Mountain site (the site): The area on which DOE has built or would build the majority of facilities or cause the majority of land disturbances related to the proposed repository.

Yucca Mountain vicinity: A general term used in nonspecific discussions about the area around the Yucca Mountain site. The EIS also uses terms such as area, proximity, etc., in a general context.

Land withdrawal area: An area of Federal property set aside for the exclusive use of a Federal agency. For the analyses in this EIS, DOE used an assumed land withdrawal area of 600 square kilometers, or 150,000 acres.

Region of influence (the region): A specialized term indicating a specific area of study for each of the resource areas that DOE assessed for the EIS analyses.



Controlled Area (as defined in 40 CFR Part 197) *(not shown on illustration):* The area surrounding the repository that is restricted to public access for the long term, as identified by passive institutional controls that DOE would install at closure. The controlled area could include as much as 300 square kilometers (about 120 square miles) surface and subsurface area. It would extend no more than 5 kilometers (3 miles) in any direction from the repository footprint except in the predominant direction of groundwater flow, where the controlled area would extend no farther south than 36 degrees, 40 minutes, 13.6661 seconds North latitude, the present latitude of the southwest corner of the Nevada Test Site [about 18 kilometers (11 miles)].

The Yucca Mountain site has several characteristics that would limit or restrict possible long-term impacts from the disposal of spent nuclear fuel and high-level radioactive waste. The site is isolated from concentrations of human population and human activity and is likely to remain so. The climate is arid and conducive to evapotranspiration (the loss of water by evaporation from the soil and other surfaces, including evaporation of moisture emitted or transpired from plants), resulting in a relatively small volume of water that can move through the mountain, contact waste materials, and move down to the water table. The groundwater table is at least 160 meters (530 feet) below the level at which DOE would emplace spent nuclear fuel and high-level radioactive waste, providing additional separation between water sources and emplaced materials. Groundwater from Yucca Mountain flows into a closed, sparsely populated hydrogeologic basin.

The Yucca Mountain site is on Federal land in a remote area of the Mojave Desert in Nye County in southern Nevada, about 160 kilometers (100 miles) northwest of Las Vegas, Nevada. The Yucca Mountain region is sparsely populated and receives only about 170 millimeters (7 inches) of precipitation each year. The Yucca Mountain Repository land withdrawal area would occupy about 600 square kilometers (230 square miles or 150,000 acres) of land currently under the control of DOE, the Department of Defense (U.S. Air Force), and the Department of the Interior (Bureau of Land Management).

Surface repository facilities would occupy as much as 6.0 square kilometers (2.3 square miles or 1,500 acres) of the Yucca Mountain site. The remainder of the site would be used to locate support facilities, and for continued performance confirmation and testing activities (for example, wells) and to separate repository facilities from other human activities. Performance confirmation and testing activities would take place on and in the vicinity of the site. The existing environment at the site includes the structures and physical disturbances from DOE-sponsored activities that took place from 1977 to 1988 related to the selection of Yucca Mountain for site characterization, and continuing site characterization activities that began in 1989 to determine the suitability of the site for a repository.

S.5.1.1 Land Use and Ownership

The Yucca Mountain site is in the southwest corner of the DOE Nevada Test Site, partially on and adjacent to the Nellis Air Force Range. The lands in the region include Bureau of Land Management special-use areas excluded from development that would require terrain alterations, unless the alterations would benefit wildlife or public recreation. The Fish and Wildlife Service of the U.S. Department of the Interior manages the Desert National Wildlife Range and the Ash Meadows National Wildlife Refuge, which are about 50 kilometers (30 miles) east and 39 kilometers (24 miles) south of Yucca Mountain, respectively. These areas provide habitat for a number of resident and migratory animal species in relatively undisturbed natural ecosystems. The National Park Service manages Death Valley National Park, which at its closest point is about 35 kilometers (22 miles) southwest of Yucca Mountain. The National Park Service also manages the small Devils Hole Protective Withdrawal in Nevada adjacent to the east-central boundary of Ash Meadows.

State-owned lands are limited in the vicinity of the proposed repository. There are scattered tracts of private land in and near communities such as Beatty and Indian Springs in Nevada. There are larger private tracts in the agricultural areas of the Las Vegas Valley, near

RUBY VALLEY TREATY ISSUE

The Western Shoshone people maintain that the Ruby Valley Treaty of 1863 gives them land rights to approximately one-third of the State of Nevada (including the Yucca Mountain region), along with portions of California, Utah, and Idaho. The Western Shoshone filed a claim in the early 1950s alleging that the Government had taken the tribe's land. The Indian Claims Commission found that Western Shoshone title to the land had gradually been extinguished, and set a monetary award as payment for the land. In 1976, the Commission entered its final award to the Western Shoshone people. The Western Shoshone dispute these findings, and have not accepted the monetary award for the lands in question. The tribe maintains that no payment has been made and that Yucca Mountain is on Western Shoshone land. Although DOE recognizes the sensitivity of this issue, a 1985 Supreme Court decision (United States v. Dann) held that the Western Shoshone claim to the land associated with the Ruby Valley Treaty has been extinguished, and that fair compensation has been made. The Supreme Court ruled that even though the monetary award has not been distributed, the United States has met its obligation and the aboriginal title to the land has been extinguished. DOE is aware that among the Native American community there is significant disagreement with the Court rulings.

Pahrump, and in the south-central portion of the large area that makes up the Amargosa Valley community. The closest year-round housing is at the location formerly known as Lathrop Wells, about 22 kilometers (14 miles) south of the site. This location is now part of the unincorporated Town of Amargosa Valley. There are farming operations about 30 kilometers (19 miles) south of the proposed repository. Figure S-17 shows the land use and ownership in the Yucca Mountain region.

Only Congress has the power to withdraw Federal lands permanently for the exclusive purposes of specific agencies. If the Yucca Mountain site was approved for development as a repository, a permanent land withdrawal would be necessary to isolate the land designated for the site from public access to satisfy Nuclear Regulatory Commission licensing requirements. The EIS analysis assumed the use of an area of approximately 600 square kilometers (150,000 acres) on Bureau of Land Management, U.S. Air Force, and DOE lands in the vicinity of the proposed repository. Figure S-18 shows the land withdrawal area that DOE used for analytical purposes. Proposed Action activities would require the use of as much as about 6.0 square kilometers (1,500 acres) of noncontiguous areas within the 600-square-kilometer (150,000-acre) area. These activities would not conflict with land uses on adjacent lands.

S.5.1.2 Air Quality

The evaluation of air quality impacts considered potential atmospheric releases of nonradiological pollutants and radiation doses from releases of radionuclides at the Yucca Mountain site. Nonradiological pollutant air concentrations were evaluated at the location of the maximally exposed individual member of the public and compared to National Ambient Air Quality Standards for criteria pollutants. Radiation doses were estimated for the maximally exposed individuals and populations of the public and workers.

Nonradiological Impacts. Principal nonradiological pollutants evaluated are the criteria pollutants nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter with a diameter less than 10 micrometers (PM_{10}). Emission of the gases nitrogen dioxide, sulfur dioxide, and carbon monoxide comes primarily from fuel combustion by vehicles, construction equipment, and boilers. PM_{10} is released mainly as a component of fugitive dust from land and excavation activities, as well as in smaller quantities from fuel combustion.

Exposures of the maximally exposed individual to airborne pollutants would be a small fraction of National Ambient Air Quality Standards. The highest concentrations of gaseous criteria pollutants (nitrogen dioxide, sulfur dioxide, and carbon monoxide) would be less than 1 percent of standards in all cases. Concentrations of PM_{10} were estimated to be relatively higher, less than 6 percent of the 24-hour limit and less than 2 percent of the annual limit during some project phases. These PM_{10} concentrations were estimated without considering common fugitive dust suppression measures, so actual concentrations would likely be lower.

The proposed site of the Yucca Mountain repository is in an area considered by the Environmental Protection Agency to be in attainment with Clean Air Act requirements. Therefore, Clean Air Act general conformity requirements do not apply to activities at the Yucca Mountain site.

Radiological Impacts. Radiological air quality impacts were evaluated as the radiation doses that could occur from airborne releases of radionuclides. The primary radionuclide released from Yucca Mountain would be naturally occurring radon-222 and its radioactive decay products. Releases of very small quantities of manmade radionuclides (krypton-85 and other noble gases) would occur only during the operations period, when spent nuclear fuel assemblies would be removed from transportation casks in the Waste Handling Building.

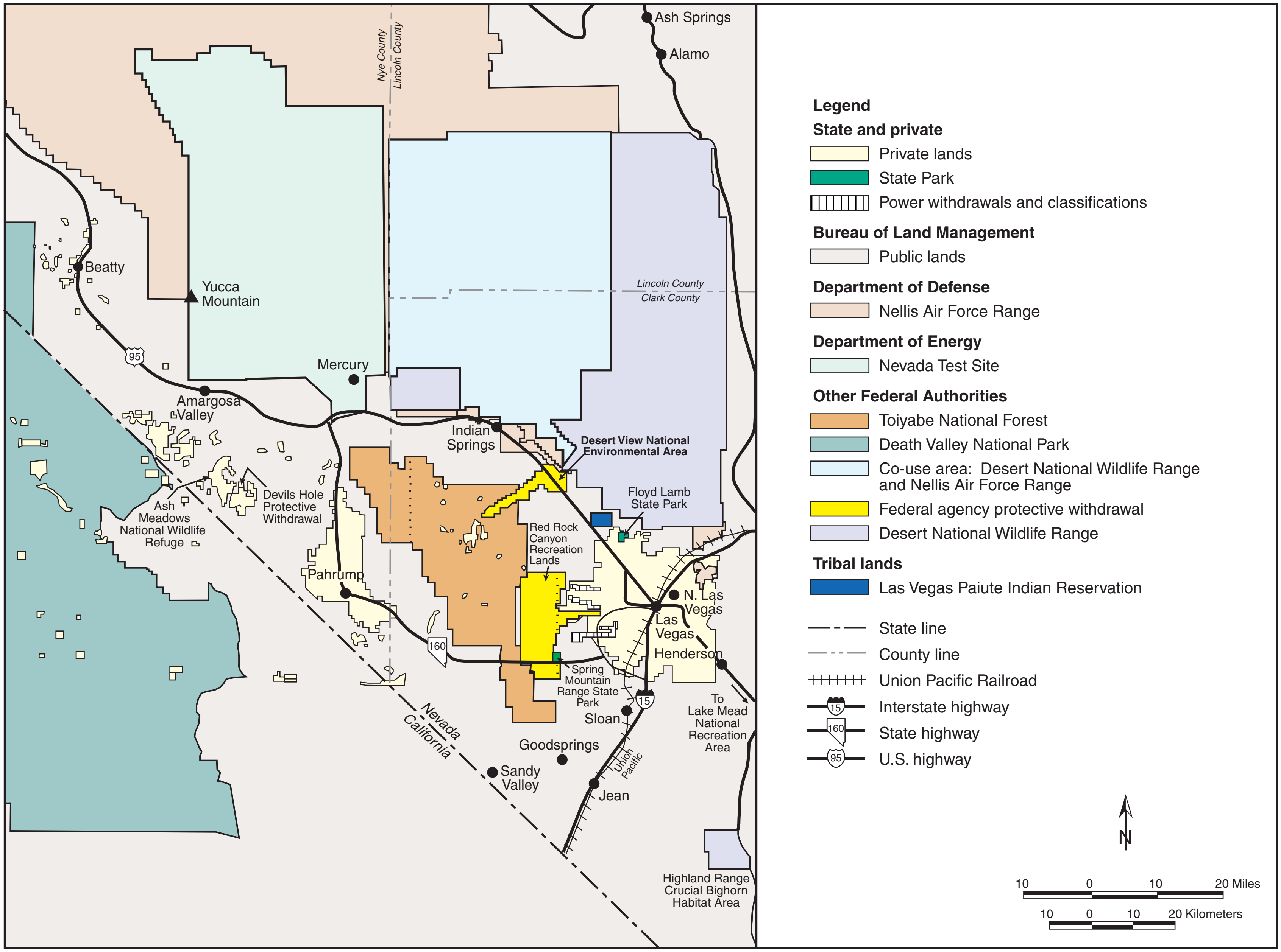


Figure S-17. Land use and ownership in the Yucca Mountain region.

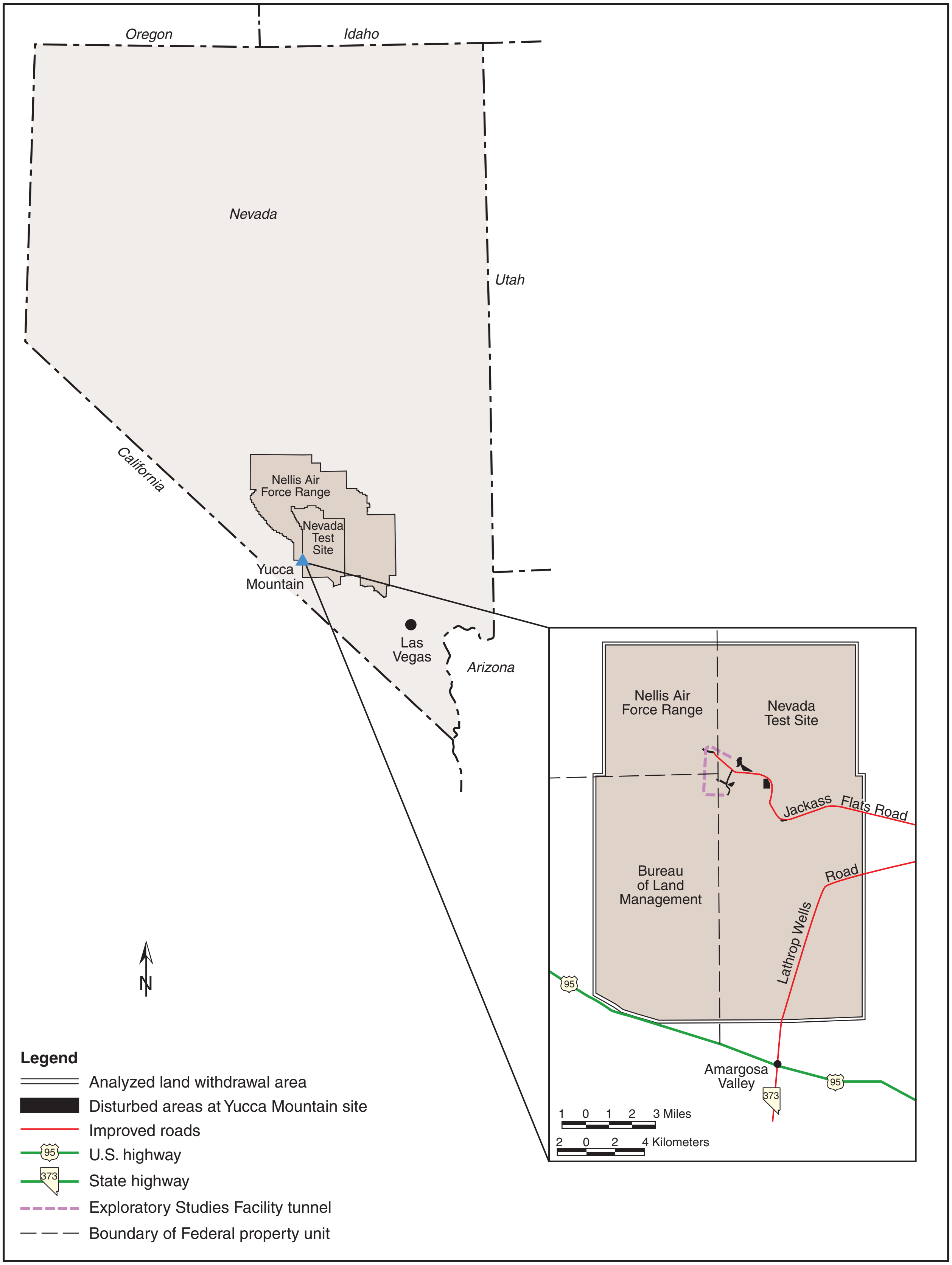


Figure S-18. Land withdrawal area used for analytical purposes.

RADIATION

In the United States, people are inevitably exposed to three sources of ionizing radiation: natural sources unaffected by human activities, such as cosmic radiation from space and natural radiation in the ground (for example, that from radon); sources of natural origin but affected by human activities, such as air travel and tunneling through rocks as at Yucca Mountain; and manmade sources, such as medical X-rays and consumer products. In the Yucca Mountain region, individuals are typically exposed to a 340- to 390-millirem radiation dose from natural and manmade sources each year, compared to about 300 millirem for the average person living in other areas of the United States.

When a person is exposed to ionizing radiation, the amount absorbed by the body is called the radiation *dose*. Dose is often described in measurement units of *rem*, which take into account how different types of radiation affect the body (the biological effectiveness). Small doses are described in *millirem*, each of which is one one-thousandth of a rem.

To analyze the short-term impact of exposure to radiation, DOE used a *maximally exposed individual* (member of the public, involved worker, or noninvolved worker), defined as the individual whose location and habits result in the highest potential total radiation dose from a particular source for all exposure routes (inhalation, ingestion, direct exposure). For long-term impacts, DOE used a *reasonably maximally exposed individual* (member of the public), defined as a hypothetical individual whose location and habits would place this individual among those with the highest total radiological or chemical exposure (and thus dose) from a particular source for all exposure routes (for example, inhalation, ingestion, direct exposure).

The maximum annual dose to the maximally exposed individual member of the public would range from about 0.73 millirem per year to 1.3 millirem per year, depending on the operating mode. The range in dose is due primarily to the varying size of the repository, with a larger repository having higher radon release and resulting in higher dose. Greater than 99.99 percent of the annual dose would be from radon-222 and radon decay products. The preclosure Public Health and Environmental Standard found at 10 CFR 63.204 is 15 millirem per year to a member of the public. Maximum annual doses from repository activities would range from about 5 to 9 percent of this standard. The average individual in the United States receives 200 millirem per year from exposure to naturally occurring radon and its decay products, so Yucca Mountain releases would be expected to add less than 0.7 percent to the natural background dose from radon.

Radiation doses from radionuclides released to air were also estimated for the general population within 80 kilometers (50 miles) of the site, the maximally exposed noninvolved worker, and the noninvolved worker population at Yucca Mountain. There are no applicable air quality standards for these exposure groups and individuals. However, these radiation doses are used to estimate the potential human health impacts presented in Section S.4.1.7. Estimates of health impacts to members of the public are converted directly from these air quality dose estimates. The doses to noninvolved workers from airborne exposures would be very small compared to other occupational doses; therefore, the doses estimated here would contribute minimally to the estimates of health impacts to noninvolved workers presented in Section S.4.1.8.

S.5.1.3 Geology

Yucca Mountain originated from volcanism and faulting that occurred 14 million to 11.5 million years ago. The mountain is bordered on the north by Pinnacles Ridge and Beatty Wash, on the west by Crater Flat, on the south by the Amargosa Desert, and on the east by the Calico Hills and by Jackass Flats, which contains Fortymile Wash. Beatty Wash is one of the largest tributaries of the Amargosa River and drains the region north and west of Pinnacles Ridge, a part of Yucca Mountain that is north of the proposed repository. Fortymile Wash is the most prominent drainage through Jackass Flats to the Amargosa River. The river is dry along most of its length most of the time. Figure S-19 shows the physiographic subdivisions and characteristic land forms in the region of influence for geology.

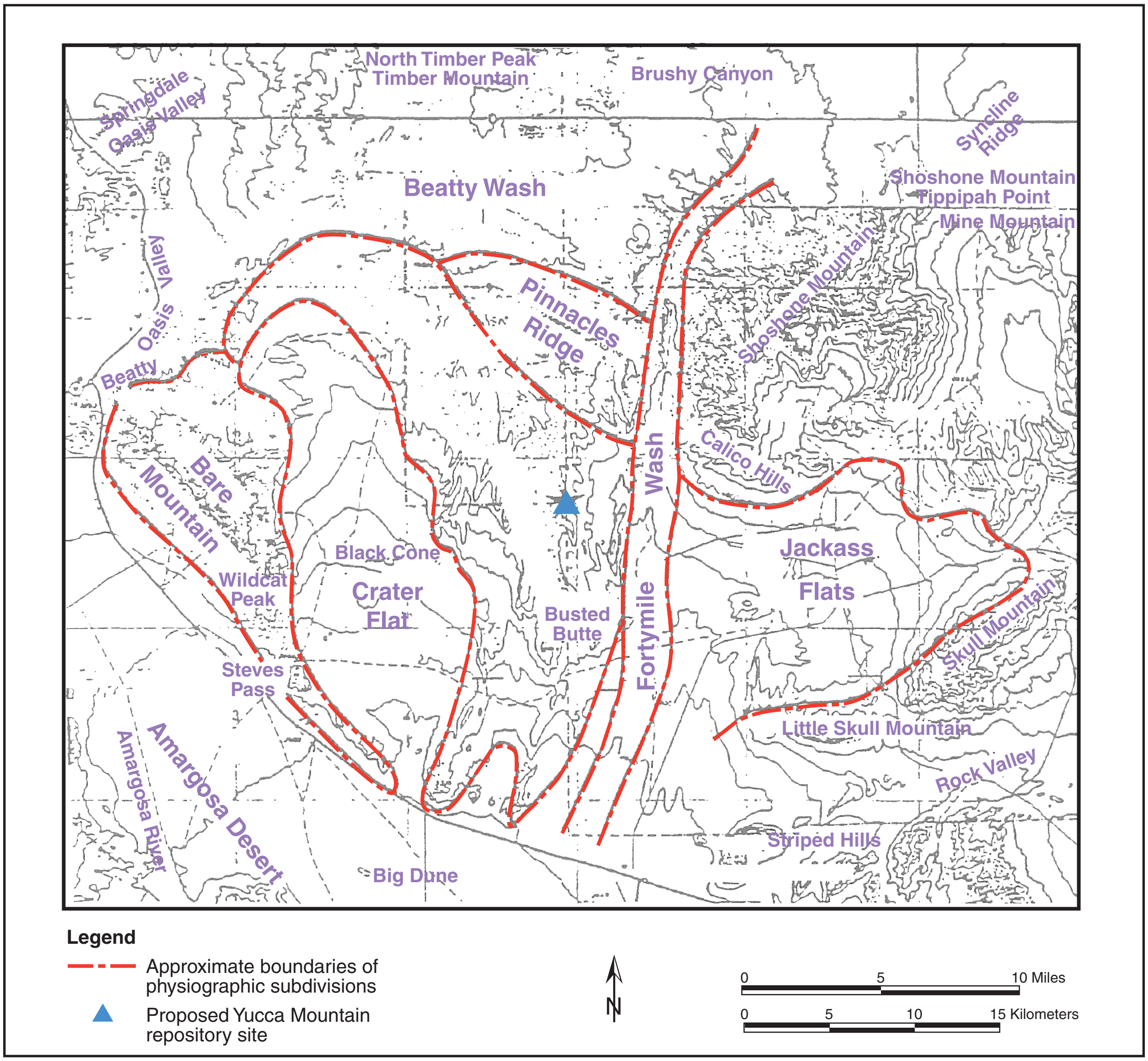


Figure S-19. Physiographic subdivisions of the Yucca Mountain area.

DOE would build the proposed repository and emplace the waste packages in a mass of volcanic rock (welded tuff) known as the Topopah Spring Tuff. This formation was formed by a volcanic ash-flow from the calderas north of Yucca Mountain 12.8 million years ago and has not been disturbed by volcanic activity since then. The volcanic activity that produced these rocks is complete and, based on the geology of similar volcanic systems in the region, additional silicic volcanic activity would be unlikely. (Younger, small-volume basaltic volcanoes to the south, west, and northwest of Yucca Mountain have been the focus of extensive study by DOE.) DOE chose the Topopah Spring Tuff as the potential repository emplacement area because of (1) its depth below the ground surface that would protect nuclear materials

VOLCANISM

Differing views on the risks of volcanism near Yucca Mountain result from uncertainty in the volcanic hazard assessment. To address these uncertainties, DOE has conducted extensive volcanic hazard assessments, considered alternative interpretations of the geologic data, and consulted with recognized experts. In 1995 and 1996, DOE convened a panel of recognized experts representing other Federal agencies (for example, the U.S. Geological Survey and national laboratories) and universities (for example, the University of Nevada and Stanford University) to assess uncertainties associated with the data and models used to evaluate the potential for disruption of the proposed Yucca Mountain Repository by a volcanic intrusion. The panel estimated that the chance of a volcanic disruption at or near the repository during the first 10,000 years after closure would be 1 in 7,000.

from exposure to the environment, (2) its extent and characteristics that would enable the construction of stable openings and the accommodation of a range of temperatures, (3) its location away from major faults that could adversely affect the stability of underground openings and could provide pathways for water flow, eventually leading to radionuclide release, and (4) its location well above the present water table.

North-trending seismic faults are the characteristic geological structural elements at Yucca Mountain. The Solitario Canyon Fault along the west side of Yucca Mountain and the Bow Ridge Fault along the east side are the major block-bounding faults that bracket the area under consideration for the proposed repository. The proposed repository has been configured such that there would be no block-bounding faults in the emplacement zone. Between the major north-trending, block-bounding faults there are intrablock or subsidiary faults. One intrablock fault, called the Ghost Dance Fault, is in the area of the proposed repository and one relatively short, northwest-trending subsidiary fault, the Sundance Fault, transects the area of the proposed repository. Studies at Yucca Mountain indicate that individual faults have very long recurrence intervals between the types of earthquakes that would be powerful enough to cause surface displacements. Strain can accumulate on these faults over long periods between surface-rupturing earthquakes. Little or no seismic activity might occur during this long strain buildup.

EARTHQUAKES

Experts have evaluated site data and other relevant information to assess where and how often future earthquakes could occur, how large they could be, how much offset could occur at the Earth's surface, and how much ground motion could diminish with distance. DOE would design the repository to withstand the effects of earthquakes that might reasonably occur in the future.

DOE has monitored seismic activity at the Nevada Test Site since 1978. In 1992, an earthquake measuring 5.6 on the Richter scale occurred at Little Skull Mountain, about 20 kilometers (12 miles) southeast of Yucca Mountain. It caused no detectable damage in tunnels or characterization facilities at the Yucca Mountain site, but did cause some minor damage at the Field Office Center in Jackass Flats about 5 kilometers (3 miles) north of the epicenter.

S.5.1.4 Hydrology

Yucca Mountain is in the Alkali Flat-Furnace Creek groundwater basin, which is within the larger Death Valley Regional Groundwater Flow System). This area is characterized by a very dry climate, limited surface water, and generally deep aquifers. The Death Valley basin is a closed hydrologic basin, which means its surface water and groundwater can leave only by evaporation from the soil and other surfaces and transpiration from plants. Surface-water resources include drainages and streambeds, streams, springs, and playa lakes. The groundwater system includes recharge zones (where water infiltrates from the surface and reaches the saturated zone and aquifers), discharge points (where groundwater reaches the surface), unsaturated zones (above the water table), saturated zones (below the water table), and aquifers (water-bearing layers of rock that can provide water in usable quantities).

Surface Water. Yucca Mountain and the Death Valley Basin, like other areas in the southern Great Basin, generally lack perennial streams and other surface-water bodies. The Amargosa River system drains Yucca Mountain and the surrounding areas. Although referred to as a river, the Amargosa and its tributaries (the washes that drain to it) are dry along most of their lengths most of the time.

Activities associated with the Proposed Action could cause minor impacts to surface hydrology at the Yucca Mountain site. The potential for contaminants to reach surface water generally would be limited to spills or leaks followed by a rare precipitation or snow melt event large enough to generate runoff. The most likely sources of potential surface-water contaminants would be the fuels (diesel and gasoline) and lubricants (oils and greases) needed for equipment. Because these materials would be used and stored inside buildings or appropriate containment structures and managed in accordance with standard best management practices, there would be little potential for contamination to spread to surface water.

Disturbing the land surface probably would alter the rate at which water could infiltrate the surface. Of the approximately 4.3 to 6.0 square kilometers (1.7 to 2.3 square miles or 1,060 to 1,500 acres) needed for surface repository facilities, construction and operation and monitoring activities probably would disturb about 2.8 to 4.5 square kilometers (690 to 1,100 acres). The amount of newly disturbed land would vary depending on the operating mode used. The high end of the range would be attributed to the lower-temperature operating mode with maximum waste package spacing and surface aging. However, DOE expects the resulting change in the amount of runoff actually reaching the drainage channels to be relatively minor because repository activities would disturb a relatively small amount of the natural drainage area. The eventual removal of structures and impermeable surfaces, with mitigation (soil reclamation) and rehabilitation of natural plants in disturbed areas, would decrease runoff from these areas.

Facilities at which DOE would manage radioactive materials would be able to withstand the probable maximum flood (the most severe flood that is reasonably foreseeable). The foundations would be built up as necessary so the facilities would be above the flood level. Other facilities would be designed and built to withstand a 100-year flood, consistent with common industrial practice. The water levels expected from a 100-year, 500-year, or probable maximum flood would be unlikely to reach the North or South Portal entrances to the subsurface facilities, but some of the support facilities outside the North Portal would be within the level of the probable maximum flood. Access routes to the North Portal Operations Area and the South Portal Development Area would cross the lower magnitude flood areas as well.

Portions of the transportation system probably would be in the 100-year floodplains of Midway Valley Wash, Drillhole Wash, Busted Butte Wash, and/or Fortymile Wash. Structures that might be constructed in a floodplain could include one or more bridges to span the washes, one or more roads that could pass through the washes, or a combination of roads and culverts in the washes. Based on an initial assessment, potential impacts from such activities would be minor.

Groundwater. The groundwater flow system of the Death Valley region is very complex, involving many groundwater basins, as shown in Figure S-20. Over distance, aquifers and confining units in the groundwater flow system vary in their characteristics or even their presence. In some areas, confining units allow considerable movement between aquifers; in other areas confining units are sufficiently tight to support artesian conditions (where water in a lower aquifer is under pressure in relation to water in an overlying aquifer).

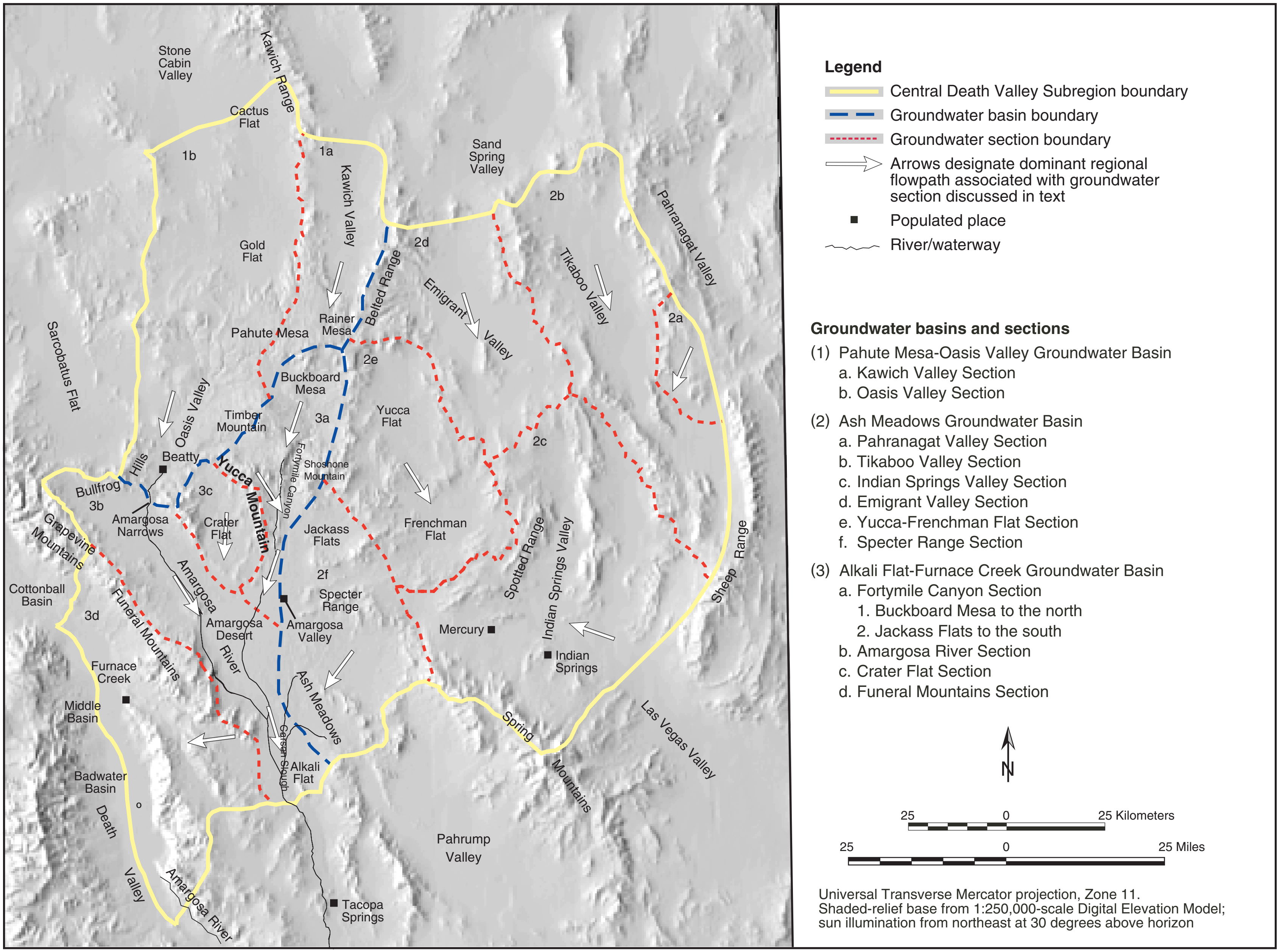


Figure S-20. Groundwater basins in the Yucca Mountain vicinity.

Groundwater in aquifers below Yucca Mountain and in the surrounding region flows generally south toward discharge areas in the Amargosa Desert and Death Valley. This broad area is called the Death Valley regional groundwater flow system. The area around Yucca Mountain is in the central subregion of the Death Valley regional groundwater flow system, which has three groundwater basins: (1) Pahute Mesa-Oasis Valley, (2) Ash Meadows, and (3) Alkali Flat-Furnace Creek.

> **GROUNDWATER**
>
> **Aquifer:** A subsurface saturated rock unit of sufficient permeability to transmit groundwater and capable of yielding usable quantities of water to wells and springs.
>
> **Confining unit:** A rock or sediment layer that restricts the movement of water into or out of adjacent aquifers.
>
> **Spring:** A point (sometimes a small area) through which groundwater emerges from an aquifer to the ground surface.

There is scientific uncertainty about the exact locations of the groundwater flow boundaries between the three groundwater basins in the central Death Valley subregion. All interpretations of the available data, however, place the aquifers below Yucca Mountain in the central Alkali Flat-Furnace Creek groundwater basin. In the region of influence for hydrology, the primary sources of groundwater recharge are infiltration on Pahute Mesa, Rainier Mesa, Timber Mountain, and Shoshone Mountain to the north, and the Grapevine and Funeral Mountains to the south. Recharge in the immediate Yucca Mountain vicinity is small in comparison and consists of water reaching Fortymile Wash as well as precipitation that infiltrates the surface. DOE studies indicate that the quantity of water that might move through a repository area of 10 square kilometers (2,500 acres), assuming 4.7 millimeters (0.2 inch) of infiltration per year, would be about 0.2 percent of the estimated 23.4 million cubic meters (19,000 acre-feet) that moves from the Amargosa Desert to Death Valley on an annual basis.

To pose a threat to groundwater during the construction, operation and monitoring, or closure phase of the Proposed Action, a contaminant such as a hazardous material would have to be spilled or released and then carried down either by its own weight or by infiltrating water. The depth to groundwater [at least 160 meters (530 feet)] and the arid environment would combine to reduce the potential for contaminant migration during the preclosure period of repository operations.

The most likely way to affect infiltration rates and, thus, groundwater recharge would be as the result of a land disturbance that caused additional runoff from the facilities to accumulate in areas like Fortymile Wash. That is, the additional runoff could increase groundwater recharge. However, given the dry climate and relatively small amount of potentially disturbed area in relation to the surrounding unchanged areas, the net change in infiltration would be small. After closure, the implementation of soil reclamation and revegetation would accelerate a return to more natural infiltration conditions.

DOE would meet the water demand for the Proposed Action by pumping from the groundwater in the Jackass Flats area. Estimates of perennial yield of the aquifer (the quantity of groundwater that can be withdrawn annually without depleting the reservoir, also referred to as safe yield) in the Jackass Flats area ranges from 1.1 million to 4.9 million cubic meters (880 to 4,000 acre-feet). The highest demand during the repository construction phase and the operation and monitoring phase [as high as 360,000 cubic meters (290 acre-feet) per year], added to the demand from ongoing Nevada Test Site activities, would be below the lowest estimate of the area's perennial yield.

Maximum repository water demands would occur during emplacement and development activities and, when combined with the baseline demands from Nevada Test Site activities, would approach (but still be below) the lowest perennial yield estimate. None of the water demand estimates would approach the high estimates of perennial yield.

S.5.1.5 Biological Resources and Soils

The plants and animals in the Yucca Mountain vicinity are typical of species in the Mojave and Great Basin Deserts. No plants listed as *threatened* or *endangered*, that are proposed for listing, or that are candidate species under the Endangered Species Act occur in the land withdrawal area analyzed in this EIS. No plant species classified as *sensitive* by the Bureau of Land Management are known to occur in the analyzed land withdrawal area. Several species of cacti and yucca protected from commercial collection by the State of Nevada occur throughout the Yucca Mountain region, including the analyzed land withdrawal area. Neither the removal of vegetation from the area required for the repository nor the impacts to some species would affect regional biological diversity and ecosystem function. Repository construction activities in areas of undisturbed vegetation could result in additional areas where colonization by exotic (non-native) plant species could occur. Reclamation would enhance the recovery of native vegetation in disturbed areas and reduce colonization by exotic species.

One animal species that lives at the Yucca Mountain site, the desert tortoise, is listed as *threatened* under the Endangered Species Act. Yucca Mountain is at the northern edge of the range of the desert tortoise, and the presence of tortoises at the site is infrequent in comparison to other portions of its range. DOE anticipates that the deaths of small numbers of individual tortoises from vehicle traffic and activities could occur during the repository construction, operation and monitoring, and closure phases. Although these losses would cause a small decrease in the abundance of desert tortoises in the immediate vicinity of the repository site, they would not affect long-term survival of the local or regional population of the species. DOE would continue to work with the Fish and Wildlife Service and would implement the terms and conditions established by the Service in its Biological Opinion to minimize impacts to desert tortoises at the site. There is no critical habitat in the analyzed land withdrawal area.

Five animal species classified as *sensitive* by the Bureau of Land Management (two bats, a lizard, an owl, and a beetle) occur at the Yucca Mountain site. These species are unlikely to be affected by repository activities because loss of individuals would be rare or a small amount of habitat would be disturbed, depending on the species.

There would be small quantities of routine releases of radioactive materials from the repository during the preclosure period. These releases would consist of gases, principally naturally occurring radon, and krypton from spent nuclear fuel handling. The small quantities released would result in small doses to plants and animals as the gases dispersed in the atmosphere. The estimated doses would be unlikely to cause measurable detrimental effects in populations of even the more radiosensitive species in terrestrial ecosystems.

There are no naturally occurring wetlands on the proposed repository site, so no impacts to such areas would occur as a result of repository construction, operation and monitoring, or closure. Soils at the site are from underlying volcanic rocks and mixed alluvium (sand, silt, or clay deposited on land by water) dominated by volcanic material, and in general have low water-holding capabilities. The potential for soil impacts such as erosion would increase slightly as a result of land-disturbing activities at the site, but DOE would use erosion control techniques to minimize impacts.

DOE also considered whether, during the postclosure period, the repository would affect biological resources at Yucca Mountain on the repository footprint through the heating of the ground surface and through radiation exposure to species from contaminant migration through groundwater to discharge points. After closure under the higher-temperature operating mode, heat from the decay of radionuclides in the waste would cause temperatures in the rock near the disposal containers to rise above the boiling point of water. The time that the subsurface temperature could remain above the boiling point would vary up to a few thousand years. Conduction and the flow of heated air and water through the rock would carry the heat away from the waste packages through the rock. The heat would spread to the surface above and to the aquifer below.

Although the atmosphere would remove excess heat when it reached the ground surface, the temperature of near-surface soils could increase slightly. As reported in the Draft EIS for the hotter, high thermal load scenario, surface soil temperatures were estimated to increase by as much as approximately 3°C (5.4°F) in dry soil at a depth of 1 meter (3.3 feet), which could affect root growth and the growth of microbes or nutrient availability. The range of repository operating modes now being considered would provide a cooler repository than the high thermal load analyzed in the Draft EIS, so any soil temperature increases would be less than those cited above. Potential impacts from the repository on biological resources could consist of an increase of heat-tolerant species and a decrease of less heat-tolerant species. In general, areas affected by repository heating could experience a loss of shrub species and an increase in annual species. A shift in the plant community could also lead to localized changes in the animal community that depends on the plant community for food and shelter. The effects of repository heat on the surface soil temperatures would gradually decline with distance from the repository out to about 500 meters (1,640 feet). DOE expects any shift in species composition to be limited to that general area.

In the distant future (many thousands of years) groundwater would contain small quantities of radionuclides and chemically toxic substances. Doses to humans from exposure to this water would be very small; doses to plants and animals would be even smaller, and unlikely to have adverse impacts on the population of any species.

Impacts to surface soils at Yucca Mountain in the postclosure period would be possible. If vegetation cover decreased as a result of the presence of the repository, the amount of rainfall runoff and the amount of erosion and subsequent sedimentation could be higher. In rare cases of significant runoff, this could change the quality of surface water in the Yucca Mountain area.

S.5.1.6 Cultural Resources

Land disturbances associated with the Proposed Action could have direct impacts on cultural resources around Yucca Mountain. Archaeological investigations in the immediate vicinity of the proposed surface facilities during characterization studies and infrastructure construction combined with other cultural resource investigations in the area have identified 830 archaeological and historic sites in the analyzed land withdrawal area. Most of the archaeological sites are small scatters of stone artifacts. None of the sites has been listed on the *National Register of Historic Places,* but 150 are potentially eligible.

Repository development would disturb no more than about 4.5 square kilometers (1,100 acres) of previously undisturbed land at the site. Before repository development activities began, DOE would identify and evaluate archaeological or cultural resources sites for their importance and eligibility for inclusion on the *National Register of Historic Places*. DOE would avoid such sites if possible or, if avoidance were not possible, DOE would conduct a data recovery program in cooperation with tribal representatives and other appropriate officials and would document the findings. Artifacts and knowledge from the site would be preserved. Improved access to the area could lead to indirect impacts, which could include unauthorized excavation or collection of artifacts. Training, which is ongoing during site characterization activities, would continue to be provided to workers on the laws and regulations related to the protection of cultural resources.

Studies have described several Native American sites, areas, and resources in or immediately adjacent to the analyzed land withdrawal area. DOE recognizes that Native Americans have concerns about protecting traditions and the spiritual integrity of the land in the Yucca Mountain region, and that these concerns extend to the propriety of the Proposed Action. The Consolidated Group of Tribes and

Organizations in the area surrounding the Yucca Mountain site value the cultural resources in the area, viewing them in a holistic manner. They believe that the water, animals, plants, air, geology, sacred sites, and artifacts are interrelated and dependent on each other for existence. Because of the general level of importance attributed to the land by these Native Americans, and because they regard the land as part of an equally important integrated cultural landscape, these Native Americans consider the intrusive nature of the repository to be an adverse impact to all elements of the natural and physical environment. The establishment of the land withdrawal boundary and construction of the repository would continue to restrict their free access to these areas. Figure S-21 shows traditional boundaries and locations of tribes in the region.

S.5.1.7 Socioeconomics

Southern Nevada has been one of the fastest-growing areas in the country, with its economy being driven by the growth of the hotel and gaming industry. Most of the Yucca Mountain Project and Nevada Test Site onsite employees live in Clark (93 percent of employees) and Nye (4 percent) Counties. Between 1990 and 2000, the population in the region of influence (Clark, Lincoln, and Nye Counties), led by Clark County, grew by 88 percent, compared to 66.3-percent population growth in Nevada and 13.1-percent population growth in the United States as a whole. Clark County reached a population of about 1.4 million in 2000 and added an average of more than 38,000 new jobs a year during the 1990s. Similarly, Nye County experienced an 83-percent growth rate for the decade, while Lincoln County's population increased by about 10 percent between 1990 and 2000. Although new jobs have been added to the region's economy each month, some potential employees lack necessary job skills. As a result, Clark County has maintained an unemployment rate that remains near State and national averages. In 2000, Nye and Lincoln Counties had unemployment rates above the State and national averages. In addition, the residential housing market is strong and steady; steady employment and population growth are spurring the demand for housing. Public services such as education, health care, law enforcement, and fire protection are adequate. However, these services likely will require expansion if the general growth in the economy and population continues.

The DOE evaluation of impacts to the socioeconomic environment in communities in the vicinity of the proposed repository considered changes to employment, population, economic measures, housing, and public services. For all five socioeconomic parameters evaluated, the impacts would be very small, less than 1 percent of the baselines for the region. For example, the largest change in population would range from less than 1 percent in Clark County and Nye County, to as high as 2.4 percent in Lincoln County (assuming the selection of a rail or heavy-haul transportation route in Lincoln County).

The lower-temperature repository operating mode with surface aging would have the highest potential socioeconomic impact due to the longer operation period. This scenario would result in a maximum of 0.3-percent increase in direct and indirect employment in the peak construction year (2006). Population increases caused by the increased employment opportunities would peak in 2030 at about 5,700, or less than 0.25 percent of the baseline for that year.

In light of public comments received on the Draft EIS concerning perceived risk and stigmatization, DOE reexamined relevant studies and literature to determine whether the state of the science in predicting future behavior based on perceptions had advanced sufficiently to allow DOE to quantify the impacts of public risk perception on economic development or property values in potentially affected communities. The following conclusions were reached from evaluation of these literature reviews plus scientific and social studies carried out in the past few years:

- While in some instances risk perceptions could result in adverse impacts on portions of a local economy, there are no reliable quantitative methods whereby such impacts could be predicted with any degree of certainty.

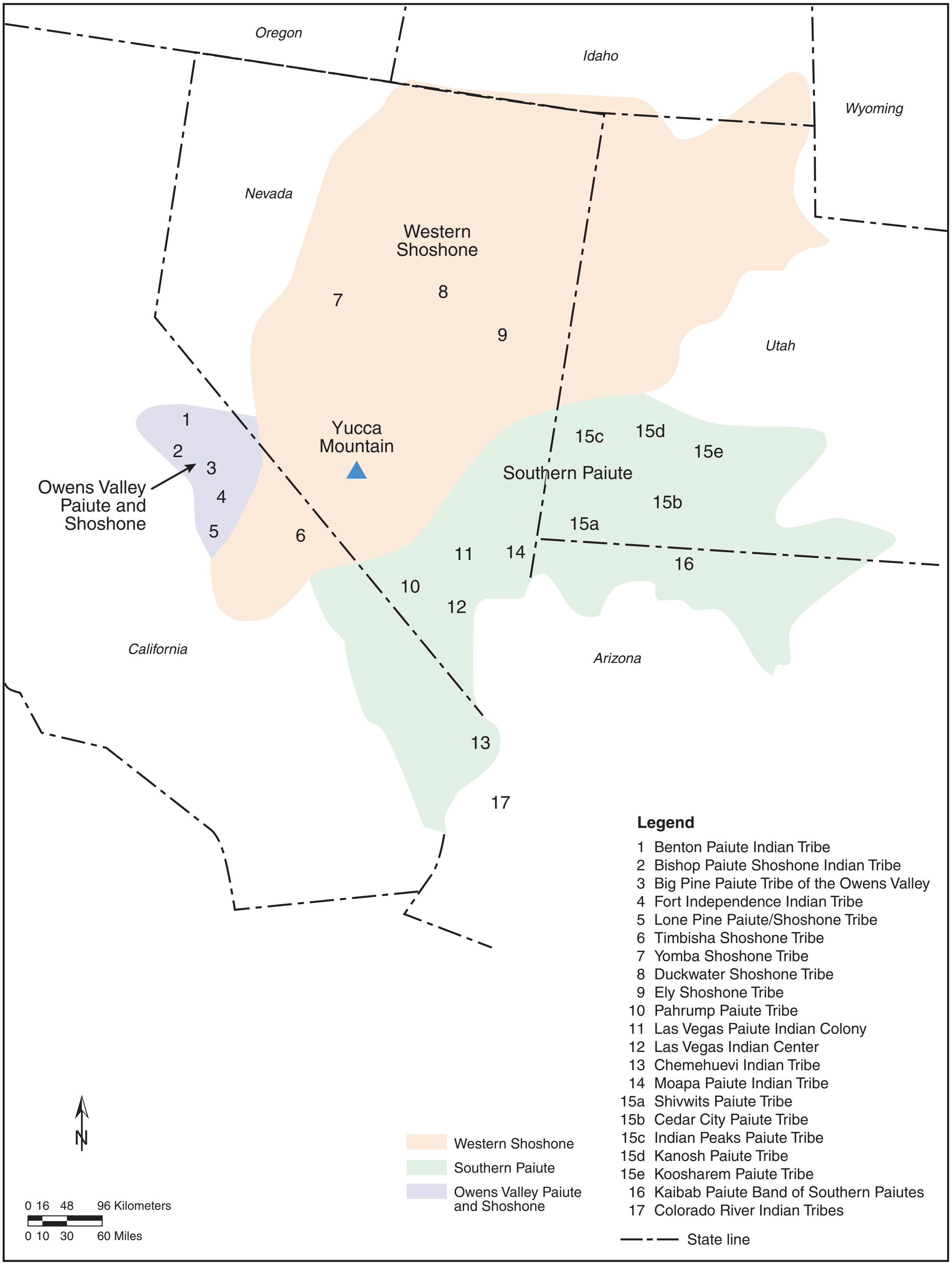


Figure S-21. Traditional boundaries and locations of tribes in the Yucca Mountain region.

- Much of the uncertainty is irreducible, and
- Based on a qualitative analysis, adverse impacts from perceptions of risk would be unlikely or relatively small.

S.5.1.8 Occupational and Public Health and Safety

The analysis of occupational and public health and safety considered short-term (prior to closure) health impacts from routine operations (1) to workers from hazards that are common to similar industrial settings and excavation operations, such as falling or tripping (referred to as industrial hazards), (2) to workers and the public from naturally occurring nonradiological materials in the rock under Yucca Mountain, (3) to workers as a result of radiation exposure during their work activities, and (4) to the public from airborne releases of radionuclides (estimated doses are described in Section S.4.1.2). The analysis separately considered involved workers (those who would participate in a particular activity) and noninvolved workers (those who would be on the site but would not participate directly in the activity in question).

Impacts to Workers from Industrial Hazards. Workers would be subject to industrial hazards during all phases of the Proposed Action. Examples of the types of industrial hazards that could present themselves include tripping, being cut on equipment or material, dropping heavy objects, and catching clothing in moving machine parts. Most impacts would be the result of fuel handling in the Waste Handling Building during the operations period. The next biggest component of industrial hazards would be the result of the subsurface excavation.

The estimated number of workplace fatalities from industrial hazards over the project life would range from 2.0 for the higher-temperature repository operating mode to between 2.2 and 3.3 for the lower-temperature operating mode.

Nonradiological Impacts to Workers and the Public. DOE would use engineering controls during subsurface work to control exposures of subsurface workers to dust that might contain cristobalite, a form of crystalline silica. If engineering controls could not keep dust concentrations below established limits, administrative controls such as respiratory protection would be used until engineered controls could reduce concentrations. Similar controls would be applied for surface workers if necessary. DOE expects that exposure of subsurface and surface workers to cristobalite would be well below applicable regulatory limits and that potential impacts to these workers would be low. Cristobalite concentrations at the site boundary would be small and unlikely to pose impacts to the public.

HEALTH AND SAFETY IMPACTS (AFFECTED INDIVIDUALS)

Workers
- Industrial hazards
  - Involved workers
  - Noninvolved workers
- Nonradiological impacts
  - Involved workers
  - Noninvolved workers
- Radiological impacts
  - Involved workers
  - Noninvolved workers

Public
- Nonradiological impacts
  - Maximally exposed individual
  - Population
- Radiological impacts
  - Maximally exposed individual
  - Population

Radiological Impacts to Workers. Radiological impacts to workers are reported both in terms of the increase in likelihood of a latent cancer fatality for an individual, and the increase in the total number of latent cancer fatalities for the total worker population. The probability of the maximally exposed worker incurring a latent cancer fatality from repository-related radiation exposure would range from about 0.0072 to 0.012 (7 to 12 chances in 1,000) for a 50-year working lifetime. The total estimated number of

LATENT CANCER FATALITIES

As used in this EIS, a latent cancer fatality is a death resulting from cancer that has been caused by exposure to ionizing radiation. There is typically a latent period between the time of radiation exposure and the time the cancer cells become active. Exposure to radiation that results in a 1-rem (1,000-millirem) lifetime dose causes an estimated 0.0005 chance of incurring a fatal cancer.

In a population of 10,000 people, national statistics indicate that about 2,224 people would die from cancer of one form or another. Using information developed by the International Commission on Radiological Protection, if all 10,000 people received a dose of 200 millirem during their lifetimes (in addition to the normal background radiation dose), an estimated 1 additional cancer fatality would occur in that population. However, we would not be able to tell which of the 2,225 fatal cancers was caused by radiation and, possibly, the additional radiation would cause no fatal cancers.

Sometimes, calculations of the number of latent cancer fatalities associated with radiation exposure do not yield whole numbers, and, especially in environmental applications, may yield numbers less than 1.0. For example, if each individual in a population of 100,000 received a total dose of 0.001 rem, the collective dose would be 100 person-rem and the corresponding estimated number of latent cancer fatalities would be 0.05 (100,000 persons × 0.001 rem × 0.0005 latent cancer fatality per person-rem). How should one interpret a nonintegral number of latent cancer fatalities, such as 0.05? The answer is to interpret the result as a statistical estimate. That is, 0.05 is the *average* number of deaths that would result if the same exposure situation were applied to many different groups of 100,000 people. For most groups, no one would incur a latent cancer fatality from the 0.001 rem dose each member would have received. In a small fraction of the groups, 1 latent fatal cancer would result; in exceptionally few groups, 2 or more latent fatal cancers would occur. The *average* number of deaths over all of the groups would be 0.05 latent fatal cancer (just as the average of 0, 0, 0, and 1 is 1/4, or 0.25). The most likely outcome for any single group is 0 latent cancer fatalities.

latent cancer fatalities that could occur in the repository workforce from the radiation dose received over the entire project would be about 4.0 for the higher-temperature repository operating mode. For the lower-temperature operating mode, the number of latent cancer fatalities would range from 4.4 to 6.8 for the project duration, depending on the length of time before closure.

About 70 percent of the radiological impacts to workers for the Proposed Action would occur during the operations period. The principal contributor to these operations impacts would be surface facility operations, which would involve receipt, handling, and packaging of spent nuclear fuel and high-level radioactive waste for emplacement. The second largest contributor to worker impacts would be subsurface monitoring, which would increase proportionately with the length of time monitoring would be carried out.

Preclosure Radiological Impacts to the Public. Short-term radiological health impacts to the public for Yucca Mountain construction, operation and monitoring, and closure would be small. (Impacts from transportation are discussed in Section S.4.2.) More than 99.9 percent of the potential health impact would be from naturally occurring radon-222 and its decay products released in exhaust ventilation air. The highest annual dose would range from 0.73 to 1.3 millirem, less than 1 percent of the annual 200-millirem dose that members of the public in Amargosa Valley would receive from ambient levels of naturally occurring radon-222 and its decay products.

The maximally exposed individual would have an increase in the probability of incurring a latent cancer fatality ranging from about 0.000016 to 0.000031 (from 16 to 31 chances in 1,000,000) from exposure to radionuclides released from repository facilities over a 70-year lifetime. The total estimated number of latent cancer fatalities in the potentially exposed population would range from 0.46 for the higher-temperature operating mode to 0.97 to 2.0 for the lower-temperature repository operating mode.

For the sake of comparison, statistics published by the Centers for Disease Control indicate that, during 1998, 24 percent of all deaths in the State of Nevada were attributable to cancer of some type and cause. Assuming this mortality rate would remain unchanged for the estimated population in 2035 of about 76,000 within 80 kilometers (50 miles) of the Yucca Mountain site, about 18,000 members of this population would be likely to die from cancer-related causes unrelated to the Proposed Action. During the time the project was active (100 to 324 years), the number of cancer deaths unrelated to the project would range from 30,000 to 89,000 in the general population. Estimated project-related impacts (0.46 to 2.0) would be a very small increase (0.007 percent or less) over this baseline.

Long-Term Radiological Health Impacts. DOE considered potential long-term human health impacts for 10,000 years from the start of emplacement. The analysis estimated potential human health impacts due to processes and events such as corrosion of waste packages, dissolution of waste forms, seismic events, and changing climate. In addition, it considered the effects of such disturbances as exploratory drilling or volcanic events.

UNCERTAINTY IN LONG-TERM PERFORMANCE

Uncertainty is associated with estimates of long-term repository performance. The uncertainty regarding a repository's long-term performance was handled in two ways. First, where the uncertainty was considered very important to the outcome, conservative assumptions were used that tended to overstate the risks that would be obtained by a more realistic model. Second, ranges of data were used in a probabilistic sampling routine to produce ranges of results that reflected the effect of the range of inputs.

The heat generated by spent nuclear fuel and high-level radioactive waste could affect both the short-term (before repository closure) and the long-term performance of the repository (that is, the ability of the engineered and natural barrier system to isolate the emplaced waste from the accessible environment for long periods). The temperature of the repository after emplacement of spent nuclear fuel and high-level radioactive waste could have a direct effect on the corrosion rate and integrity of the waste packages. Further, the repository temperature could affect the geochemistry, hydrology, and mechanical stability of the emplacement drifts, which in turn could influence groundwater flow and the transport of radionuclides from the engineered and natural barrier systems to the environment.

For the range of repository operating modes, radioactive materials that entered the groundwater would produce the primary impacts from the repository to human health in the far future. Figure S-22 shows the potential movement of contaminants from the repository to the accessible environment. The analysis estimated human health impacts from the groundwater pathway at three locations in the Yucca Mountain region: water wells approximately 18 and 30 kilometers (11 and 19 miles) from the repository and the nearest surface-water discharge point, which is about 60 kilometers (37 miles) away. The estimated health impact is expressed as the probability of a resulting latent cancer fatality from lifetime use of the contaminated water.

Under the entire range of repository operating modes, less than 1 latent cancer fatality would be likely over the 10,000-year analysis period. The analysis indicated that the higher-temperature operating mode would have a low, but nonetheless higher, annual dose [0.00002 millirem at 18 kilometers (11 miles)] and correspondingly greater health effects on the reasonably maximally exposed individual (lifetime probability of a latent fatal cancer of 6×10^{-10}) than the range of lower-temperature modes. In addition, concentrations of chemically toxic materials were found to be lower than identified Maximum

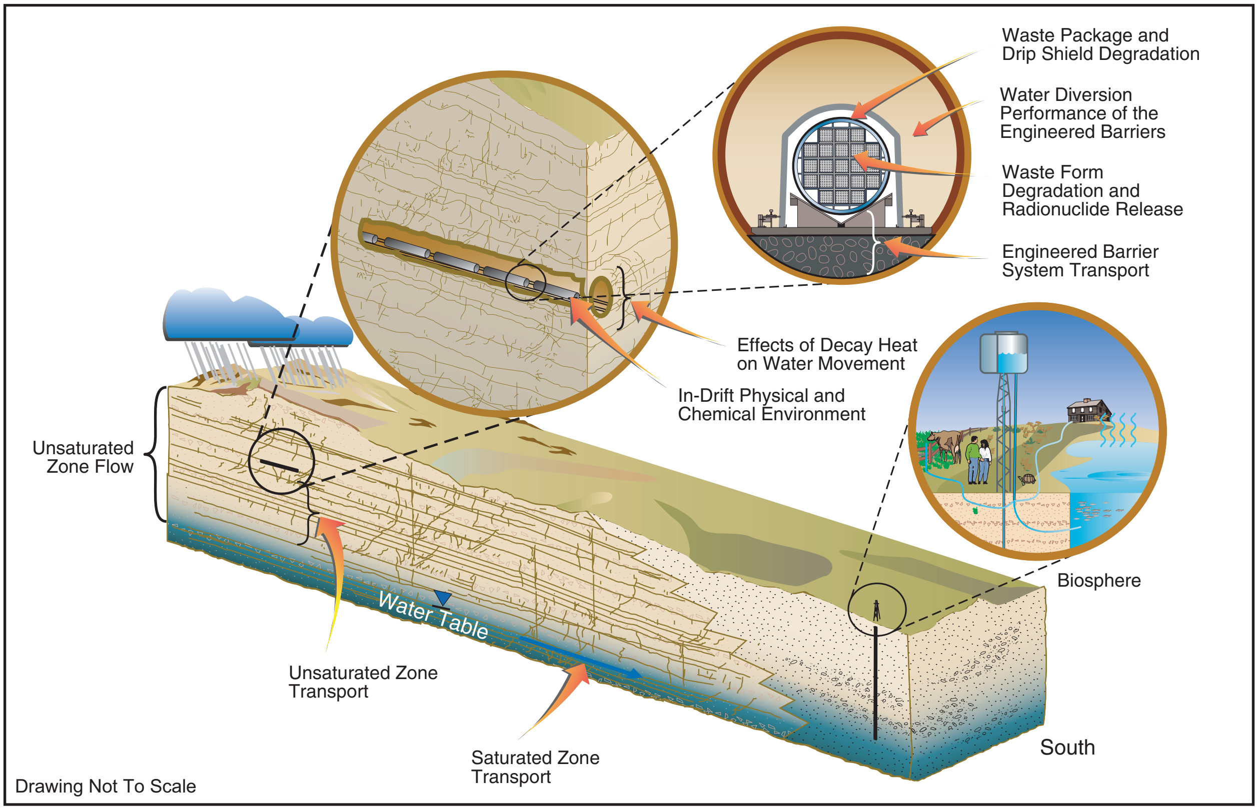


Figure S-22. Schematic illustration of the processes modeled for Total System Performance Assessment.

Contaminant Level Goals. Where no levels or goals have been established were found to be very low. Therefore, DOE does not anticipate detrimental impacts to water quality or human health from toxic materials.

In addition, DOE estimated the annual dose for 1 million years after repository closure. For the higher-temperature repository operating mode, the peak annual dose would be 150 millirem to a reasonably maximally exposed individual approximately 18 kilometers (11 miles) from the repository, occurring 480,000 years after closure (120 millirem under the lower-temperature operating mode). Variations in the peak annual dose to a reasonably maximally exposed individual among the range of operating modes would be caused by earlier waste package failures under the higher-temperature operating mode, placement of waste packages in different areas of the repository, and different amounts of water infiltrating through the different repository areas.

The analysis of a drilling intrusion event occurring at 30,000 years indicated a peak of the mean annual dose to the reasonably maximally exposed individual approximately 18 kilometers (11 miles) downstream of the repository would be 0.002 millirem, occurring a short time after 100,000 years. The analysis of an igneous activity scenario, including a volcanic eruption event and igneous intrusion event indicated a peak of the mean annual dose to the reasonably maximally exposed individual approximately 18 kilometers downstream of the repository would be 0.1 millirem.

Congress, in the Energy Policy Act of 1992, directed the Environmental Protection Agency to develop public health and safety standards for the protection of the public from releases of radioactive materials stored or disposed of in a repository at the Yucca Mountain site. Congress also directed the Nuclear Regulatory Commission to publish criteria for licensing a repository that would be consistent with the radiation protection standards established by the Environmental Protection Agency. In part, the

Environmental Protection Agency standards (40 CFR Part 197) and Nuclear Regulatory Commission criteria (10 CFR Part 63) prescribe radiation exposure limits that the repository, based on a performance assessment, cannot exceed during a 10,000-year period after closure.

In the EIS, DOE has evaluated the environmental impacts of a natural and engineered barrier system designed to isolate radioactive materials from the environment for thousands of years. As a result of this evaluation, DOE would not expect the repository to result in impacts to public health beyond those that could result from the prescribed radiation exposure and activity concentration limits during the 10,000-year period after closure.

S.5.1.9 Accident Scenarios

> **ACCIDENT**
>
> An unplanned event or sequence of events that results in undesirable consequences.

The evaluation of accident scenarios associated with the Proposed Action included the potential for radiological accidents and accidents involving exposure to hazardous and toxic substances before repository closure. The potentially affected individuals considered include (1) the maximally exposed individual, a hypothetical member of the public at the point on the site boundary who would receive the largest dose, (2) the involved worker who would be handling the spent nuclear fuel or high-level radioactive waste when the accident occurred, (3) the noninvolved worker near the accident but not involved in handling the material, and (4) members of the public living within about 80 kilometers (50 miles) of the repository. The accident scenario analysis examined consequences under both median (50th-percentile) meteorological conditions and highly unfavorable meteorological conditions (95th-percentile, or those that would not be exceeded more than 5 percent of the time) that tend to maximize potential radiological impacts.

Initiators of radiological accident scenarios could be external or internal. External initiators originate outside a facility and affect its ability to confine radioactive material. They include human-caused events such as aircraft crashes, external fires and explosions, and natural phenomena such as seismic disturbances and extreme weather conditions. Internal initiators occur inside a facility and include human errors, equipment failures, or combinations of the two. DOE analyzed initiating events applicable to repository operations to define subsequent sequences of events that could result in releases of radioactive material or radiation exposure. For each event in these accident sequences, the analysis estimated and combined probabilities to produce an estimate of the overall accident probability for the sequence. In addition, the analysis used bounding (maximum reasonably foreseeable) accident scenarios to represent the impacts from groups of similar accidents. Finally, it evaluated the consequences of the postulated accident scenarios by estimating the potential radiation dose and radiological impacts.

The radionuclide source term for various accident scenarios could involve several different types of radioactive materials. These would include commercial spent nuclear fuel from both boiling- and pressurized-water commercial reactors, DOE spent nuclear fuel, high-level radioactive waste incorporated in a glass matrix, and weapons-grade plutonium either immobilized in a high-level radioactive waste glass matrix or as mixed-oxide fuel. In addition, the analysis examined accident scenarios involving the release of low-level waste generated and handled at the repository, primarily in the Waste Treatment Building.

In a change from the analysis in the Draft EIS, DOE used a "representative fuel assembly" for all accident analyses for the repository. The Draft EIS used average fuel assemblies that were aged approximately 26 years out of the reactor. Based on a relative hazard index, the representative fuel assemblies analyzed in the Final EIS are only about 14 years out of the reactor and have a higher burnup, meaning they contain a higher concentration of radionuclides than those used in the Draft EIS analyses, and therefore result in more conservative impact estimates than those presented in the Draft EIS.

After a screening to determine the internal and external initiators that would be applicable to the repository and that are considered reasonably foreseeable, 10 accident scenarios were analyzed in detail. These accidents include both low-probability/high-consequence events and high-probability/low-consequence events. These scenarios bound the risks of credible accidents at the repository. They include accidents in the Cask Handling Area, the Canister Transfer System, the Assembly Transfer System, the Disposal Container Handling Area, the Surface Aging Facility, and the Waste Treatment Building. The scenarios consider drops and collisions involving shipping casks, bare fuel assemblies, low-level radioactive waste drums, and the waste package transporter. The maximum reasonably foreseeable accident (a credible accident scenario with the highest foreseeable consequences) was determined to be a beyond-design-basis seismic event. For this accident, using unfavorable weather conditions, the impacts to the maximally exposed offsite individual would be 38 millirem and would result in an estimated 0.011 additional latent cancer fatality for the population within 80 kilometers (50 miles) of the repository.

Impacts to the noninvolved worker from the reasonably foreseeable accidents would result in a maximum dose of 25 rem during the beyond-design-basis seismic event. This maximum dose would correspond to a 1-percent chance of incurring a latent cancer fatality. Severe accidents would be likely to result in the deaths of some involved workers.

DOE evaluated the likelihood of an accidental crash of aircraft (military and commercial) into the surface aging facility. The analysis determined that the aircraft would not penetrate the storage modules and a release of radioactive materials would not occur.

In response to public comments and to provide further information about accident risks, DOE analyzed an accident scenario in which a large commercial jet aircraft would crash into the repository facilities. The probability of this accident is less likely than the threshold considered reasonably foreseeable (1 in 10 million). However, if the accident occurred, the estimated consequences would include a dose of 4.5 rem to the maximally exposed offsite individual and a corresponding likelihood of 0.0023 that this individual would incur a fatal cancer. The consequences to the population for this event would be 78 person-rem and an estimated 0.039 latent cancer fatality. In addition, passengers on board the aircraft and any workers in the vicinity of the crash could perish.

A release of hazardous or toxic (nonradiological) materials during accidents involving spent nuclear fuel or high-level radioactive waste at the repository, however, would be very unlikely. The repository would not accept hazardous waste, although some potentially hazardous metals such as arsenic or mercury could be present in the high-level radioactive waste. Because such waste would be contained in a glass or ceramic matrix, exposure of workers or members of the public from any accident would be highly unlikely. In any event, because of the large quantity of radioactive material, radiological considerations would outweigh nonradiological concerns under most accident conditions.

S.5.1.10 Noise and Vibration

Background noise at Yucca Mountain is caused by natural phenomena such as rain and wind and noise from people, including vehicles from site characterization activities and from occasional low-flying military jets. Sound-level measurements recorded in May 1997 at areas adjacent to and at the Yucca Mountain site were consistent with noise levels associated with industrial operations (sound levels from 44 to 72 decibels). Background levels of ground vibration at Yucca Mountain are also low. Other than site characterization activities, there is a lack of sources of ground vibration impacts (pile-driving, heavy earthmoving equipment, blasting).

Repository activities during construction, operation, and closure that could generate elevated noise levels would include use of heavy equipment, ventilation fans, diesel generators, transformers, and a concrete batch plant.

Workers at the repository site could be exposed to elevated levels of noise. However, worker exposures to elevated noise levels during all repository phases would be controlled by the use of protective equipment, so impacts from noise would be unlikely.

The distance from the Yucca Mountain site to the nearest housing is about 22 kilometers (14 miles). Based on an estimated maximum noise level from repository operations, DOE calculated that noise from the repository would be at the lower limit of human hearing at 6 kilometers (3.7 miles). For this reason, DOE expects that noise impacts to the public from repository construction and operations would be small.

S.5.1.11 Aesthetics

Yucca Mountain has visual characteristics fairly common to the region, and the visibility of the site from publicly accessible locations is low or nonexistent. The intervening Striped Hills and the low elevation of the southern end of Yucca Mountain and Busted Butte would obscure the view of repository facilities from the south near the Town of Amargosa Valley, approximately 22 kilometers (14 miles) away. There is no public access to the north or east of the repository site to enable viewing of the facilities. The only structures that could potentially be visible from the west that exceed the elevation of the southern ridge of Yucca Mountain [1,500 meters (4,900 feet)] would be the exhaust ventilation stacks and support structures that would be constructed along the crest of the mountain.

DOE would provide lighting for operation areas at the repository that could be visible from public access points. However, there would not be significant visual impacts due to repository lighting to users of Death Valley National Park. The Towns of Amargosa Valley, Beatty, and Pahrump, located between the park and the proposed repository, would probably cause greater impacts to the nightly viewshed than operational lighting at the repository site. The visual impact of the lighting from Las Vegas would also be more significant in the region than that of the repository. The use of shielded or directional lighting at the repository would limit the amount of light that could be seen from outside the repository area. Closure activities, such as dismantling facilities and reclaiming the site, would restore the visual quality of the landscape, as viewed from the site itself.

S.5.1.12 Utilities, Energy, Materials, and Site Services

The scope of the analysis included electric power use, fossil-fuel consumption, consumption of construction materials, and onsite services such as emergency medical support, fire protection, and security and law enforcement. Overall, DOE does not expect large impacts to residential water, energy, materials, and emergency services from the Proposed Action.

Electricity. The repository demand for electricity would be well within the expected regional capacity for power generation. The current electric power supply line has a capacity of 10 megawatts. During the early stages of repository operations, when emplacement activities would be occurring while new drifts were being developed, the peak electric power demand would be between 40 and 54 megawatts, depending on the operating mode. Therefore, DOE would need to enhance the electric power delivery system to the Yucca Mountain site. The solar power generating facility, which could produce as much as 3 megawatts of power, would be a dual-purpose facility, serving as a demonstration of photovoltaic power generation and augmenting the overall repository electric power supply (as much as 7 percent).

Fossil Fuel. Fossil fuel would include diesel fuel, gasoline, and fuel oil. Yearly repository use during construction would be less than 1 percent of the current use in Clark, Lincoln, and Nye Counties, and should result in only small impacts to fossil-fuel supplies.

Fossil-fuel use during the operation and monitoring phase would be highest during emplacement and development operations and would decrease substantially during monitoring and maintenance activities.

The highest annual use would be less than 5 percent of the 1996 use in Clark, Lincoln, and Nye Counties. Thus, the projected use of liquid fossil fuels should be within the available regional capacity and should result in only small impacts to fossil-fuel supplies. Hydraulic oils and lubricants and nonfuel hydrocarbons would be used to support equipment operation. These materials would be recycled and reused.

Construction Materials. The primary materials needed to build the repository would be concrete, steel, and copper. Concrete, which consists of cement and aggregate, would be used for tunnel liners in main drifts and ventilation shafts and the construction of surface facilities. DOE would use regionally available aggregate for concrete, and would purchase cement regionally. The lower-temperature repository operating mode would require the largest amount of concrete (up to 1.4 million cubic meters or 1.8 million cubic yards), which would be less than about 3 percent of the amount used in Nevada in 1998. Because steel and copper have worldwide markets, DOE expects little or no impact from an increased demand for steel and copper in the region.

Site Services. An emergency response system would be established to respond to accidents at the repository site. The capabilities would include emergency and rescue equipment, communications, facilities, and trained professionals to respond to fire, radiological, mining, industrial, and general accidents above or below ground. The onsite service capabilities would be able to respond to most events, including underground events, without outside support. Therefore, a large impact on the emergency services of surrounding communities or counties would be unlikely.

S.5.1.13 Waste Management

The evaluation of waste management impacts considered the quantities of nonhazardous industrial, sanitary, hazardous, and radioactive wastes that repository-related activities would generate. DOE would build onsite facilities to accommodate construction and demolition debris, sanitary and industrial solid wastes, sanitary sewage, and industrial wastewater, or could use a landfill at the Nevada Test Site. DOE would use less than 4 percent of the existing available offsite capacity for low-level radioactive waste disposal at the Nevada Test Site and a smaller fraction of the available hazardous waste disposal capacity.

S.5.1.14 Environmental Justice

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, directs Federal agencies to work to achieve "environmental justice" by identifying and addressing the potential for their activities to cause disproportionately high and adverse impacts to minority and low-income populations. As part of this process, DOE has identified the minority and low-income communities in Clark, Lincoln, and Nye Counties, using U.S. Bureau of the Census population designations to determine areas with high concentrations of minority or low-income populations.

DOE considered the potential for disproportionately high and adverse impacts to minority and low-income populations under both normal and accident conditions using the identified potential impacts to the general population and an assessment of potential unique pathways, sensitivities, or cultural practices that could

POPULATIONS

Minority: individuals who are American Indian or Alaskan Native; Asian or Pacific Islander; Black, not of Hispanic origin; or Hispanic. For this EIS, a minority community is one in which the percent of the population of a racial or ethnic minority is 10 percentage points higher than the percent found in the population as a whole.

Low income: individuals with an income below the poverty level defined by the U.S. Bureau of the Census. A low-income population is one in which 20 percent or more of the persons in the population live in poverty.

result in high and adverse impacts on minority and low-income populations. The EIS analyses determined that the impacts that could occur to public health and safety would be small for the population as a whole for all phases of the Proposed Action, and that no subsections of the population, including minority or low-income populations, would receive disproportionately high and adverse impacts. The Department recognizes, however, that Native American tribes in the region consider the intrusive nature of the repository and continuation of restrictions on access to lands where the repository would be located to have an adverse impact on all elements of the natural and physical environment and to their way of living within that environment.

S.5.1.15 Sabotage

In the aftermath of the tragic events of September 11, DOE is continuing to assess measures that it could take to minimize the risk or potential consequences of radiological sabotage or terrorist attacks against our Nation's proposed monitored geologic repository.

Over the long term (after closure), deep geologic disposal of spent nuclear fuel and high-level radioactive waste would provide optimal security by emplacing the material in a geologic formation that would provide protection from inadvertent and advertent human intrusion, including potential terrorist activities. The use of robust metal waste packages to contain the spent nuclear fuel and high-level radioactive waste more than 200 meters (660 feet) below the surface would offer significant impediments to any attempt to retrieve or otherwise disturb the emplaced materials.

In the short term (prior to closure), the proposed repository at Yucca Mountain would offer certain unique features from a safeguards perspective: a remote location, restricted access afforded by Federal land ownership and proximity to the Nevada Test Site, restricted airspace above the site, and access to a highly effective rapid-response security force.

Current Nuclear Regulatory Commission regulations (10 CFR 63.21 and 10 CFR 73.51) specify a repository performance objective that provides "high assurance that activities involving spent nuclear fuel and high-level waste do not constitute an unreasonable risk to public health and safety." The regulations require that spent nuclear fuel and high-level radioactive waste be stored in a protected area such that:

- Access to the material requires passage through or penetration of two physical barriers. The outer barrier must have isolation zones on each side to facilitate observation and threat assessment, be continually monitored, and be protected by an active alarm system.
- Adequate illumination must be provided for observation and threat assessment.
- The area must be monitored by random patrol.
- Access must be controlled by a lock system, and personnel identification must be used to limit access to authorized persons.

A trained, equipped, and qualified security force is required to conduct surveillance, assessment, access control, and communications to ensure adequate response to any security threat. Liaison with a response force is required to permit timely response to unauthorized entry or activities. In addition, the Nuclear Regulatory Commission requires (10 CFR Part 63, by reference to 10 CFR Part 72) that comprehensive receipt, periodic inventory, and disposal records be kept for spent nuclear fuel and high-level radioactive waste in storage. A duplicate set of these records must be kept at a separate location.

DOE believes that the safeguards applied to the proposed repository should involve a dynamic process of enhancement to meet threats, which could change over time. Repository planning activities would continue to identify safeguards and security measures that would further protect fixed facilities from terrorist attack and other forms of sabotage. Additional measures that DOE could adopt include:

- Facilities with thicker reinforced walls and roofs designed to mitigate the potential consequences of the impact of airborne objects
- Underground or surface bermed structures to lessen the severity of damage in cases of aircraft crashes
- Additional doors, airlocks, and other features to delay unauthorized intrusion
- Additional site perimeter barriers to provide enhanced physical protection of site facilities
- Active denial systems to disable any adversaries, thereby preventing access to the facility

Although it is not possible to predict if sabotage events would occur, and the nature of such events if they did occur, DOE examined various accident scenarios that approximate the types of consequences that could occur. These accidents and their consequences are discussed in Section S.5.1.9.

S.5.2 TRANSPORTATION

The loading and shipping of spent nuclear fuel and high-level radioactive waste would take place at 72 commercial and 5 DOE sites. Legal-weight trucks and trains would travel on the Nation's highways and railroads. Barges and heavy-haul trucks could be used for the short-distance transport of spent nuclear fuel from some commercial sites to nearby railroads. Shipments of spent nuclear fuel and high-level radioactive waste arriving in Nevada would travel to the Yucca Mountain site by legal-weight truck, rail, or heavy-haul truck. Legal-weight truck shipments would use existing highways in accordance with U.S. Department of Transportation regulations. Figures S-13 and S-14 show the alternatives for rail corridors and intermodal transfer station locations and associated heavy-haul truck routes, respectively, in the State of Nevada.

DOE analyzed the impacts of transporting these materials to the repository under the mostly legal-weight truck and mostly rail scenarios. Under the mostly legal-weight truck scenario, most of the spent nuclear fuel and high-level radioactive waste would be shipped to Nevada by legal-weight truck, while naval fuel would be shipped by rail. Under the mostly rail scenario, commercial spent nuclear fuel from most sites and DOE and naval spent nuclear fuel and high-level radioactive waste would arrive in Nevada by rail. However, commercial fuel from a few commercial sites would initially be shipped by legal-weight truck because those sites do not currently have the capability to load a rail cask.

At present, there is no rail access to the Yucca Mountain site. If material was shipped by rail, a branch line that connected an existing main line to the Yucca Mountain site would have to be built or the material would have to be transferred to heavy-haul trucks at an intermodal transfer station and transported over existing highways that might need upgrading. DOE examined the environmental impacts that would be associated with a new branch rail line (five alternative rail corridors) and with an intermodal transfer station (three alternative locations) and heavy-haul truck routes (five alternative routes).

S.5.2.1 National Transportation Impacts

National transportation includes the impacts of transporting spent nuclear fuel and high-level radioactive waste from the commercial and DOE sites to the Yucca Mountain site. Much of the difference in the impacts between the mostly legal-weight truck and mostly rail scenarios would result from the differing number of shipments over the 24-year transportation period and differences in the characteristics of the truck and rail modes of transport. The mostly legal-weight truck scenario would involve about

53,000 shipments (2,200 annually), and the mostly rail scenario would involve approximately 10,700 shipments (450 annually). Primarily because of the larger number of shipments, the mostly legal-weight truck scenario would have greater incident-free radiological impacts (latent cancer fatalities), even though each individual truck shipment would carry less radioactive material than a rail shipment.

The EIS analysis considered potential accidents based on the 19 truck and 21 rail accident cases presented in NUREG-6672, *Reexamination of Spent Fuel Shipment Risk Estimates.* In addition, the analysis estimated impacts of postulated releases from accidents in three population zones—urban, suburban, and rural—under a set of meteorological (weather) conditions that represent the national average meteorology. The analysis used state-specific accident data, the lengths of routes in the population zones in states through which the shipments would pass, and the number of shipments that would use the routes to determine accident probabilities.

ESTIMATED NATIONAL TRANSPORTATION IMPACTS (for 24 years of operation)

Impact	Mostly legal-weight truck scenario	Mostly rail scenario
Incident-free latent cancer fatalities		
Involved worker	12	3
Public[a]	3	1
Latent cancer fatalities from accidents		
Public	0.00023	0.00045
Traffic fatalities[b]	5	3
Latent cancer fatalities from maximum reasonably foreseeable accident	0.55	5
Frequency of occurrence per year	2.3×10^{-7}	2.8×10^{-7}

a. These latent cancer fatalities would result from very low doses to a very large population.

b. Does not include 10 to 17 fatalities that could occur from repository workers commuting and transporting construction materials to the repository.

In addition to the risk due to accidents involving a release of radioactive material, the analysis examined the impacts of loss-of-shielding accidents. The loss-of-shielding scenarios range from an accident with no loss of shielding to a low-probability severe accident involving both a loss of shielding (and any increased direct exposure) and a release of some of the contents of the cask.

The EIS analysis also estimated impacts from an unlikely but severe accident called a *maximum reasonably foreseeable accident* to provide perspective about the consequences for a population that might live nearby. For maximum reasonably foreseeable accidents, the consequences were estimated for each of the accidents and for both truck and rail casks from the spectrum of accidents presented in NUREG-6672. For each accident, the possible combinations of weather conditions, population zones, and transportation modes were considered. The accidents were then ranked according to those that would have a likelihood greater than 1 in 10 million per year and that would have the greatest consequences.

Real life transportation accidents involve collisions of many kinds, such as with other vehicles and along-the-route obstacles, involvement in fires and explosions, inundation, and burial. These accidents are caused, in turn, by a variety of initiating events including human error, mechanical failure, and natural causes such as earthquakes. Accidents occur in many different kinds of places including mountain passes and urban areas, rural freeways in open landscapes, and rail switching yards.

Thus, there are as many different kinds of unique initiating events and accident conditions as there are accidents. Analyzing each accident that could occur would not be practical. However, it is practical to analyze a limited number of accidents, each of which represents a grouping of initiating events and conditions having similar characteristics. For example, the EIS analyzes the impacts of a collection of collision accidents in which a cask would be exposed to impact velocities in the range of 97 to 145 kilometers (60 to 90 miles) per hour. The EIS also analyzes a maximum reasonably foreseeable accident in which a collision would not occur but where the temperature of a rail cask containing spent nuclear fuel would rise to between 750°C and 1,000°C (between 1,400°F and 1,800°F). The conditions of the maximum reasonably foreseeable accident analyzed in the EIS envelop conditions reported for the Baltimore Tunnel fire (a train derailment and fire that occurred in July 2001 in a tunnel in Baltimore, Maryland). Temperatures in that fire were reported to be as high as 820°C (1,500°F), and the fire was reported to have burned for up to 5 days.

DOE also evaluated the potential consequences of an accidental crash of a large jet aircraft into a truck cask or rail cask. The analysis determined that penetration of the cask would not occur; however, potential seal failure could result in releases of radiological materials. The consequences associated with this event would be less than 1 latent cancer fatality in an urban population.

The consequences of the maximum reasonably foreseeable transportation accident (an accident with the highest consequence for human health that can be reasonably foreseen) would be higher under the mostly rail scenario (5 latent cancer fatalities) than under the mostly legal-weight truck scenario (1 latent cancer fatality) principally because the amount of material in a rail shipment would be larger than that in a legal-weight truck shipment.

The Nuclear Regulatory Commission has developed a set of rules specifically aimed at protecting the public from harm that could result from sabotage of spent nuclear fuel casks. Known as physical protection and safeguards regulations (10 CFR 73.37), these security rules are distinguished from other regulations that deal with issues of safety affecting the environment and public health. The objectives of the physical protection and safeguard regulations are to:

- Minimize the possibility of sabotage
- Facilitate recovery of spent nuclear fuel shipments that could come under control of unauthorized persons

The cask safety features that provide containment, shielding and thermal protection also provide protection against sabotage. The casks would be massive. The spent nuclear fuel in a cask would typically be only about 10 percent of the gross weight; the remaining 90 percent would be shielding and structure.

It is not possible to predict whether sabotage events would occur and, if they did, the nature of such events. Nevertheless, DOE examined various accidents, including an aircraft crash into a transportation cask. The consequences of both the maximum reasonably foreseeable accident and the aircraft crash are presented above for the mostly truck and mostly rail transportation scenarios and can provide an approximation of the type of consequences that could occur from a sabotage event. In addition, DOE analyzed the potential consequences of a saboteur using a device on a truck or rail cask. The results of this analysis indicate that the risk of the maximally exposed individual incurring a fatal cancer would increase from approximately 23 percent (the current risk of incurring a fatal cancer from all other causes) to about 29 percent. The same event could cause 48 latent cancer fatalities in an assumed population of a large urban area.

Because of the terrorist attack of September 11, 2001, the Department and other agencies are reexamining the protections built into their physical security and safeguards systems for transportation shipments. As dictated by results of this reexamination, DOE would modify its methods and systems as appropriate.

S.5.2.2 Nevada Transportation Impacts

The analysis of national transportation includes the analysis of transportation from 77 generation sites to Yucca Mountain. This includes transportation in the State of Nevada. To present a more focused description of impacts in Nevada, the EIS discusses Nevada transportation separately as well. Spent nuclear fuel and high-level radioactive waste shipped to the repository by legal-weight truck would continue in the same vehicles to the Yucca Mountain site. Material that traveled by rail would either continue to the repository on a newly constructed branch rail line or transfer to heavy-haul trucks at an intermodal transfer station that DOE would build in Nevada for shipment on existing highways that could require upgrades. Selection of a specific rail alignment within a corridor, or the specific location of an intermodal transfer station or the need to upgrade the associated heavy-haul truck routes, would require additional field surveys; environmental and engineering analysis; State, local, and Native American government consultation, and National Environmental Policy Act reviews.

Rail Corridor Implementing Alternatives. DOE assessed five rail implementing alternatives—the Caliente, Carlin, Caliente-Chalk Mountain, Jean, and Valley Modified corridors (see Figure S-13). The assessment considered the impacts of constructing a branch rail line in one of the five 400-meter (0.25-mile)-wide corridors including variations of the corridors. Each corridor would connect the Yucca Mountain site with an existing mainline railroad in Nevada.

Intermodal Transfer Station and Heavy-Haul Truck Route Implementing Alternative. DOE assessed alternative intermodal transfer station locations at rail terminals near Caliente, Apex/Dry Lake, and Sloan/Jean (see Figure S-14). The intermodal transfer station would transfer casks containing spent nuclear fuel and high-level radioactive waste from railcars to heavy-haul trucks and empty casks from heavy-haul trucks to railcars. In addition, DOE assessed three alternative heavy-haul truck routes from a Caliente intermodal transfer station—Caliente, Caliente/Chalk Mountain, and Caliente/Las Vegas—and one route each from the Apex/Dry Lake and Sloan/Jean locations. This implementing alternative probably would include an average of 110 legal-weight truck shipments of commercial spent nuclear fuel each year from the six sites that do not currently have the capability to load rail casks.

Estimated impacts for any of the five alternative rail corridors or five heavy-haul truck routes over the 24 years of transport operations would include the following:

- The incident-free collective dose to members of the public would result in less than 1 latent cancer fatality.
- The cumulative radiological accident risk would be less than 0.0002 latent cancer fatality, taking into account both the probability of accident occurrence and the resulting consequences if an accident were to occur.
- The likelihood of the maximum reasonably foreseeable accident in an urbanized area nationally is about 2.3 to 2.8 chances in 10 million per year; if such an accident were to occur, from 1 to 5 latent cancer fatalities could result.
- From 1 to 5 fatalities would be likely to occur due to traffic accidents.
- The amount of land disturbed (for an intermodal transfer station and mid-route stops) would be small, generally less than 0.3 square kilometer (75 acres).

RAIL CORRIDOR IMPACTS

Caliente

- 513 kilometers (319 miles) long, requiring about 10 hours to complete a one-way trip.
- Would disturb 18 square kilometers (4,500 acres) of land.
- 842 new jobs (direct and indirect) could be created during 46 months of construction.
- Estimated life-cycle cost is $880 million (2001 dollars).
- Other: One potential alignment would pass through Timbisha Shoshone Trust Lands.

Carlin

- 520 kilometers (323 miles) long, requiring about 9 hours to complete a one-way trip.
- Would disturb 19 square kilometers (4,900 acres) of land.
- 783 new jobs (direct and indirect) could be created during 46 months of construction.
- Estimated life-cycle cost is $821 million (2001 dollars).
- Other: One potential alignment would pass through Timbisha Shoshone Trust Lands.

Caliente-Chalk Mountain

- 345 kilometers (214 miles) long, requiring about 8 hours to complete a one-way trip.
- Would disturb 13 square kilometers (3,000 acres) of land.
- 647 new jobs (primary and secondary) could be created during 43 months of construction.
- Estimated life-cycle cost is $622 million (2001 dollars).
- Nonpreferred alternative: Strongly opposed by the U.S. Air Force because of the adverse effect on security and operations at Nellis Air Force Range.

Jean

- 181 kilometers (114 miles) long, requiring about 4 hours to complete a one-way trip.
- Would disturb 9 square kilometers (2,000 acres) of land.
- 526 new jobs (direct and indirect) could be created during 43 months of construction.
- Estimated life-cycle cost is $462 million (2001 dollars).
- Other: Could affect scenic quality lands and habitat for desert tortoise; would pass near the Las Vegas metropolitan area.

Valley Modified

- 159 kilometers (98 miles) long, requiring about 3 hours to complete a one-way trip.
- Would disturb 5 square kilometers (1,240 acres) of land.
- 245 new jobs (direct and indirect) could be created during 40 months of construction.
- Estimated life-cycle cost is $283 million (2001 dollars).
- Other: Could affect Desert National Wildlife Range on Nellis Air Force Range, would pass near Las Vegas Paiute Indian Reservation; would pass near the Las Vegas metropolitan area.

- Impacts to biological resources due to habitat disturbance and loss of individuals of affected species would be small. In particular, the activities associated with constructing a branch line, building an intermodal transfer station, or upgrading and maintaining a heavy-haul truck route to Yucca Mountain would be likely to adversely affect a few individual desert tortoises; these activities would not negatively affect regional populations of desert tortoises, jeopardize the continued existence of the species, or result in adverse modification of designated critical habitat.

- Based on an assessment, potential impacts from activities in floodplains and wetlands would be small.

HEAVY-HAUL TRUCK ROUTE IMPACTS

Caliente

- 533 kilometers (331 miles) long, requiring 2 days to complete a one-way trip.
- 856 new jobs (direct and indirect) could be created during 35 months of construction.
- Estimated life-cycle cost is $669 million (2001 dollars).
- Other: Could have visual impacts to Kershaw-Ryan State Park; would pass adjacent to Timbisha Shoshone Trust Lands.

Caliente/Chalk Mountain

- 282 kilometers (175 miles) long, requiring 2 days to complete a one-way trip.
- 751 new jobs (primary and secondary) could be created during 26 months of construction (levels of employment reflect assumption of $463-million estimate to complete the northern portion of the Las Vegas Beltway).
- Estimated life-cycle cost is $548 million (2001 dollars).
- Nonpreferred alternative: Strongly opposed by the U.S. Air Force because of the adverse effect on security and operations at the Nellis Air Force Range.
- Could have visual impacts to Kershaw-Ryan State Park.

Caliente/Las Vegas

- 377 kilometers (234 miles) long, requiring 2 days to complete a one-way trip.
- 1,979 new jobs (direct and indirect) could be created during 46 months of construction.
- Estimated life-cycle cost is $607 million (2001 dollars).
- Other: Could have visual impacts to Kershaw-Ryan State Park and would pass near the Las Vegas metropolitan area; would pass near the Moapa Indian Reservation and through the Las Vegas Paiute Indian Reservation.

Sloan/Jean

- 188 kilometers (118 miles) long, requiring one-half day to complete a one-way trip.
- 3,047 new jobs (direct and indirect) could be created during 48 months of construction (levels of employment reflect assumption of $790 million estimate to complete the Southern and Western portions of the Las Vegas Beltway).
- Estimated life-cycle cost is $444 million (2001 dollars).
- Other: Would pass near the Las Vegas metropolitan area; would pass through the Las Vegas Paiute Indian Reservation.

Apex/Dry Lake

- 183 kilometers (114 miles) long, requiring one-half day to complete a one-way trip.
- 1,882 new jobs (direct and indirect) could be created during 28 months of construction (levels of employment reflect assumption of $790-million estimate to complete the northern portion of the Las Vegas Beltway).
- Estimated life-cycle cost is $387 million (2001 dollars).
- Other: Would pass near the Las Vegas metropolitan area; could pass near the Moapa Indian Reservation and through the Las Vegas Paiute Indian Reservation.

- There could be visual impacts from the existence of the branch rail line, access road, and borrow pits in the landscape and the passage of trains to and from the repository along any rail corridor.

- There would be no effect on the general availability of gasoline, diesel fuel, steel, or concrete.

- There would be no disproportionately high and adverse impacts to minority and low-income populations. DOE considered impacts that would be associated with potential routes for rail and legal-weight and heavy-haul trucks that would pass through or near the Moapa and Las Vegas Paiute Indian Reservations and the newly established Timbisha Shoshone Trust Lands.

The factors that differ among the alternative transportation corridors and routes are length and associated time of travel, land use or disturbance, industrial safety impacts, job creation, and cost. The U.S. Air Force has informed DOE that it strongly opposes the Caliente-Chalk Mountain Corridor because it could adversely affect national security-related activities of the Nellis Air Force Range (now called the Nevada Test and Training Range). The State of Nevada and the City of Las Vegas have expressed specific concerns about shipments through or near the Las Vegas metropolitan area, which would occur if either the Jean or Valley Modified Corridor or the Caliente-Las Vegas, Apex/Dry Lake, or Sloan/Jean heavy-haul truck route was selected.

S.6 Environmental Consequences of the No-Action Alternative

Under the No-Action Alternative, DOE would terminate site characterization activities at the Yucca Mountain site. Long-term storage of spent nuclear fuel and high-level radioactive waste would continue at 77 sites.

DOE analyzed the potential impacts of two no-action scenarios: long-term storage with institutional controls (Scenario 1) and long-term storage with no effective institutional control after about 100 years (Scenario 2). The Department recognizes that neither of these scenarios is likely to occur if there is a decision not to develop a repository at Yucca Mountain, but any other scenarios would be too speculative for meaningful analysis. DOE therefore chose to include the two scenarios because they provide a basis for comparison to the impacts from the Proposed Action.

Activities at the Yucca Mountain site would be the same under either Scenario 1 or 2, as would impacts at the commercial and DOE sites during the first 100 years. After about 100 years and for as long as the 10,000-year analysis period and beyond, Scenario 2 assumes that the storage facilities at the 72 commercial sites and 5 DOE sites would deteriorate and that the radioactive materials in the spent nuclear fuel and high-level radioactive waste would eventually escape to the environment, contaminating the atmosphere, soil, surface water, and groundwater.

S.6.1 RECLAMATION AND DECOMMISSIONING AT THE YUCCA MOUNTAIN SITE

Under the No-Action Alternative, DOE would end characterization and construction activities at the Yucca Mountain Repository site and would complete site decommissioning and reclamation. Land ownership and control would revert to the original controlling authority. Adverse impacts to any resource would be unlikely as a result of these activities.

The overall impact of the No-Action Alternative would be the loss of approximately 4,700 jobs in the Yucca Mountain region of influence, out of approximately 840,000 jobs in the region. Most of the lost jobs would be in disciplines (construction, engineering, administration, support, etc.) that are not unique or unusual and are similar to those in the region. However, some of the jobs would be in unique disciplines (nuclear engineering, nuclear safety, etc.) that might not otherwise be needed in the region. Fatalities from industrial hazards would be unlikely, as would latent cancer fatalities from worker or public exposure to naturally occurring radionuclides released by decommissioning and reclamation activities. Resources important to Native American interests would be preserved, although the integrity of archeological sites and resources could be threatened by increased public access if roads were open and site boundaries were not secure.

S.6.2 CONTINUED STORAGE AT COMMERCIAL AND DOE SITES

The No-Action Alternative assumes that the spent nuclear fuel and high-level radioactive waste would remain at the sites at which it is being generated and stored. For the EIS analysis, DOE divided the 72 commercial and 5 DOE sites among five regions of the country to organize the analysis into a framework that would promote an understanding of comparative impacts, and configured a single hypothetical site in each region. Such sites do not exist but are mathematical constructs for analytical purposes. Using this approach, DOE was able to estimate the potential release rate of the radionuclide inventory from the spent nuclear fuel and high-level radioactive waste, based on anticipated interactions of the environment (for example, rainfall and freeze-thaw cycles) with the concrete storage modules in which the nuclear materials would be stored.

The potential occupational and public health and safety impacts associated with the No-Action Alternative are described below. For purposes of this analysis, the potential occupational and public health and safety impacts are the most relevant for comparison with the impacts of the Proposed Action.

S.6.2.1 No-Action Scenario 1

Under this scenario, releases of contaminants to the ground, air, or water would be extremely small under normal conditions. Workers would perform routine industrial maintenance and maintenance unique to a nuclear materials storage facility to minimize releases of contaminants to the environment and exposures to workers and the public. These activities could result in worker exposures to industrial hazards, and worker and public exposures to radiological releases.

IMPACTS FROM NO-ACTION SCENARIO 1

Industrial hazards

- 2 worker fatalities in the first 100 years, and 320 in the next 9,900 years
- 760 fatalities in the public and worker population from worker commuting and transportation of maintenance materials over 10,000 years.

Radiological

- 3.0 latent cancer fatalities in exposed public population over 10,000 years (compared to 3.3 million from other causes in the areas immediately surrounding the 77 sites)
- 10 latent cancer fatalities in involved worker population over 10,000 years (compared to 37,600 from other causes)
- 16 latent cancer fatalities in involved and noninvolved worker population over 100 years, after which noninvolved workers would not be present at the site (compared to 18,800 from other causes)
- No radiological releases would be expected in the event of a severe accident (a postulated aircraft crash at the relatively low velocities encountered during takeoffs and landings) because of the integrity of the concrete storage modules. Consequences of impacts at higher velocities have not been evaluated by DOE for these Nuclear Regulatory Commission-licensed facilities.

S.6.2.2 No-Action Scenario 2

Under this scenario, after 100 years the facilities storing the materials at 72 commercial and 5 DOE sites would begin to deteriorate and would continue to do so over time. Eventually, radioactive materials from failed facilities and storage containers and exposed radioactive materials would contaminate the land surrounding the storage facilities, potentially rendering it unfit for human habitation or agricultural uses for hundreds or thousands of years. Contaminants would enter surface waters and groundwater, which would remain contaminated for the period required for the spent nuclear fuel and high-level radioactive waste materials to be depleted and contaminants to migrate out. Environmental concentrations of chemically toxic materials would be extremely low and would not result in adverse impacts. Released radioactive materials could produce chronic radiation exposures to the public, which could result in adverse health impacts. Intruders could incur severe radiation exposures, including fatal exposures. The number of people who would be affected by the migration of radioactive materials would be much greater in Scenario 2 than in Scenario 1.

IMPACTS FROM NO-ACTION SCENARIO 2

Industrial hazards

- 2 worker fatalities in the first 100 years and none in the next 9,900 years (workers not present at the site)
- 7 fatalities in the public and worker population from worker commuting and transportation of maintenance materials over 100 years

Radiological

- 3,300 latent cancer fatalities in exposed public population over 10,000 years (compared to 900 million expected from other causes along the 20 major waterways that would be contaminated)
- No latent cancer fatalities in involved worker population after 100 years
- No latent cancer fatalities in noninvolved worker population after 100 years
- Depending on the population at the site, between 3 and 13 latent cancer fatalities would be expected in the event of a severe accident (a postulated aircraft crash) at a degraded concrete storage module

S.6.2.3 Sabotage

Above-ground storage of spent nuclear fuel and high-level radioactive waste for 10,000 years would entail a continued risk of intruder access at each of the 77 sites. Sabotage could result in a release of radionuclides to the environment around the facility. Under Scenario 1, the analysis assumed that safeguards and security measures currently in place would remain in effect during the 10,000-year analysis period, thereby reducing the risk of sabotage.

As Nuclear Regulatory Commission licensees, the individual sites would be required to comply with Commission regulations and maintain the highest level of security as determined by the Commission, and any results from the reexamination of existing physical security and safeguard systems following the terrorist attack of September 11, 2001.

Because it is not possible to predict whether sabotage events would occur and, if they did, the nature of such events, DOE examined various accidents in this Final EIS, which provide an approximation of the consequences that could occur.

For Scenario 2, the storage of spent nuclear fuel and high-level radioactive waste for 10,000 years without institutional control would entail a greater risk of intruder access at the 77 sites than exists under current conditions. Due to the lack of institutional control and degraded facilities, sabotage could result in a release of radionuclides to the environment around the facility. The analysis assumed that safeguards and security measures would not be maintained after approximately the first 100 years. For the remaining 9,900 years of the analysis period, the cumulative risk of intruder attempts would increase. As the storage containers degraded, they would become more vulnerable to failure. Any amount of material released from its storage container could contaminate areas with radioactivity. Therefore, the risks of sabotage would increase substantially under this scenario in comparison to Scenario 1.

S.7 Cumulative Impacts of the Proposed Action

DOE evaluated cumulative short-term impacts from the construction, operation and monitoring, and closure of a geologic repository at Yucca Mountain, and cumulative long-term impacts after repository closure. It also evaluated cumulative impacts from the transportation of spent nuclear fuel and high-level radioactive waste to the repository, including those from the construction and operation of a branch rail line or of an intermodal transfer station and highway upgrades for heavy-haul trucks.

> **CUMULATIVE IMPACTS**
>
> A cumulative impact is "the impact on the environment which results from the incremental impact of the 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" (Council on Environmental Quality Regulations, 40 CFR 1508.7). Cumulative impacts can result from individually minor but collectively potentially significant actions that occur over time.

An assessment of the environment around the Yucca Mountain site included the cumulative impacts of past and present actions in the area the Proposed Action would affect. Reasonably foreseeable future actions include the disposal of inventories of spent nuclear fuel and high-level radioactive waste that exceed the Proposed Action inventory of 70,000 MTHM, along with other Federal and non-Federal actions at the Nellis Air Force Range and the Nevada Test Site, DOE waste management activities, a private space launch facility, and a private intermodal transfer station, and private mineral and energy projects.

DOE could not reasonably predict future actions for the indefinite future. For that reason, DOE did not attempt to estimate cumulative impacts beyond about 100 years with the exception of impacts of radioactive materials reaching the groundwater and resulting in potential impacts to the public.

S.7.1 INVENTORY MODULES 1 AND 2

Section 114(d) of the Nuclear Waste Policy Act provides that the maximum amount allowed to be disposed of in a first repository until a second repository is in operation is 70,000 MTHM of spent nuclear fuel and high-level radioactive waste. Comments that DOE received from the public during the scoping process for this EIS expressed the concern that more spent nuclear fuel and high-level radioactive waste would be generated than the 70,000 MTHM accounted for in the Proposed Action. In response to these comments, DOE evaluated the emplacement of the total projected inventory of commercial spent nuclear fuel and DOE spent nuclear fuel and high-level radioactive waste (Inventory Module 1) and emplacement of that total inventory plus the inventories of commercial Greater-Than-Class-C waste and DOE Special-Performance-Assessment-Required waste (Inventory Module 2).

The emplacement of Inventory Module 1 or 2 at Yucca Mountain would require legislative action by Congress unless a second repository were in operation. In addition, the emplacement of commercial Greater-Than-Class-C and DOE Special-Performance-Assessment-Required wastes could require either legislative action or a determination by the Nuclear Regulatory Commission to classify these materials as high-level radioactive waste.

The emplacement of Inventory Module 1 or 2 would increase the size of the subsurface repository facilities and, thus, the amount of land disturbed. In addition, because more time would be required to emplace more materials (an additional 14 years for emplacement and perhaps another 6 years for closure under the lower-temperature repository operating mode) emplacement of Inventory Module 1 or 2 would

INVENTORIES

Proposed Action
- 63,000 MTHM of commercial spent nuclear fuel
- 2,333 MTHM of DOE spent nuclear fuel
- 8,315 canisters of DOE high-level radioactive waste (equivalent of 4,667 MTHM)

Inventory Module 1
- 105,000 MTHM of commercial spent nuclear fuel
- 2,500 MTHM of DOE spent nuclear fuel
- 22,280 canisters of DOE high-level radioactive waste (equivalent of about 11,500 MTHM)

Inventory Module 2
- 105,000 MTHM of commercial spent nuclear fuel
- 2,500 MTHM of DOE spent nuclear fuel
- 22,280 canisters of DOE high-level radioactive waste (equivalent of about 11,500 MTHM)
- 2,000 cubic meters (72,500 cubic feet) of Greater-Than-Class-C waste
- 4,000 cubic meters (142,000 cubic feet) of Special-Performance-Assessment-Required waste

produce greater human health impacts to workers and to the public, increase energy use, create larger amounts of waste, and increase transportation impacts. Although such impacts would increase by as much as 70 percent with the emplacement of larger waste volumes, most of the impacts themselves would be small. The following paragraphs focus on occupational and public health and safety impacts related to the disposal of the additional inventories.

Occupational and Public Health and Safety

Impacts to Workers from Industrial Hazards. Up to 4 fatalities under Module 1 or 2 could occur compared to about 2 to 3 during the Proposed Action prior to closure. Most of the impacts would occur during the operations phase. Industrial safety impacts for injuries, illnesses, and lost workday cases for Module 1 or 2 would be about 30 to 40 percent greater than those for the Proposed Action.

Radiological Impacts to Workers. Most of the total worker radiation dose would result from activities during the operations and monitoring phase. As many as approximately 5 to 8 fatalities under Module 1 or 2 could occur in the worker population, compared to approximately 4 to 7 under the Proposed Action.

Radiological Impacts to the Public. Radiological health impacts to the public from construction, operation and monitoring, and closure of the repository would be small. The calculated likelihood that the maximally exposed individual would experience a latent cancer fatality is about 2.6×10^{-5} under Module 1 or 2, compared to 1.6×10^{-5} for the higher-temperature repository operating mode. Impacts for the lower-temperature operating mode would range from about the same as the higher-temperature operating mode to about twice the impacts of the higher-temperature mode. However, the estimated number of latent cancer fatalities for all operating modes for the Proposed Action or the Inventory Modules would be much less than 1.

Long-Term Radiological Impacts. Long-term cumulative impacts (impacts after closure at the repository) to public health would occur from radionuclides ultimately from Yucca Mountain, past weapons testing on the Nevada Test Site, and past, present, and future disposal of radioactive waste on the Nevada Test Site and near Beatty, Nevada. Cumulative impacts over 10,000 years from radionuclides released to groundwater would result in about 0.0003 latent cancer fatality over 10,000 years.

S.7.2 OTHER FEDERAL AND NON-FEDERAL ACTIONS

This EIS evaluates the potential cumulative impacts of other Federal and non-Federal actions. The evaluation includes activities by local governments, private citizens, the Nellis Air Force Range, the Bureau of Land Management, the National Park Service, and the Nevada Test Site. It shows that earlier underground nuclear testing potentially results in long-term cumulative impacts due to potential groundwater contamination. Using conservative assumptions, the evaluation calculated the maximum potential dose from the radionuclides from underground testing to be 0.007 millirem per year. Therefore, the maximum cumulative impact of the Proposed Action in 10,000 years [using the mean impact at 18 kilometers (11 miles) from the repository] would be 0.00002 millirem per year (potential Yucca Mountain Repository impact) plus 0.007 millirem per year (potential underground testing impact), or 0.007 millirem per year.

S.7.3 TRANSPORTATION

The EIS analysis assumed the shipment of Inventory Module 1 or 2 to the repository would use the transportation routes described for the Proposed Action but would require almost twice as many shipments and an additional 14 years. This would result in increased industrial hazards, traffic fatalities, and latent cancer fatalities. For example, under the mostly legal-weight truck scenario, radiological and vehicle emission impacts from incident-free national transportation could increase from 12 to 24 occupational latent cancer fatalities, and estimated latent cancer fatalities in the general population could increase from 3 to 7 for the 38-year transportation of Inventory Module 1 or 2. Traffic-related fatalities from shipments of the modules would also be greater, increasing from 5 for the Proposed Action to 9 for Module 1 or 2. The incident-free impacts of the mostly rail scenario could be smaller because there would be fewer shipments.

National transportation of radiological materials from 1943 to 2047, not associated with the proposed repository would result in a total dose to affected transportation workers as high as 350,000 person-rem, which could result in about 140 latent cancer fatalities. These same activities would result in a total dose to the public of 340,000 person-rem, which could result in about 170 latent cancer fatalities. In addition, an estimated 97 traffic fatalities would result from the 104 years of transportation of radiological materials not associated with the Proposed Action.

The cumulative impacts to workers from transportation activities could be up to 160 or 180 latent cancer fatalities for Inventory Module 1 or 2, respectively. As many as 110 cumulative traffic fatalities would result from transporting radiological materials, including the inventory modules.

S.8 Cumulative Impacts of the No-Action Alternative

DOE analyzed the cumulative impacts of the No-Action Alternative with respect to Inventory Module 1. The Department did not analyze the cumulative impacts of the No-Action Alternative with respect to Inventory Module 2 because it did not have sufficient and readily available information about the Greater-Than-Class-C and Special-Performance-Assessment-Required wastes in that module to perform a meaningful analysis. Furthermore, this information could not be obtained without an exorbitant commitment of resources. However, information was sufficient to make the determination that there would be a small incremental increase in impacts over those of Module 1.

DOE estimated that about 6,400 concrete storage modules at the 72 commercial sites and three below-grade vaults at the DOE sites would be required to store 70,000 MTHM of spent nuclear fuel and high-level radioactive waste. In comparison, an additional 4,600 concrete storage modules (11,000 total) at the commercial sites and an additional five below-grade vaults (eight total) at the DOE sites would be required to store the entire inventory of Module 1.

Impacts to Workers from Industrial Hazards. As many as 3 fatalities could occur at the storage and generator sites during the first 100 years under the No-Action Alternative with Inventory Module 1. This compares to 2 worker fatalities during the first 100 years with the 70,000-MTHM inventory. Over the next 9,900 years, approximately 490 fatalities could occur under No-Action Scenario 1 with Inventory Module 1, in comparison to 320 with the 70,000-MTHM inventory. No industrial hazard fatalities are projected for either the 70,000-MTHM inventory or Inventory Module 1 under No-Action Scenario 2 after the first 100 years because that scenario assumes there would be no workers at the sites.

Radiological Impacts to Workers. Approximately 43 latent cancer fatalities could occur at the storage and generator sites as a result of No-Action Scenario 1 with Inventory Module 1 over 10,000 years. This compares to 28 latent cancer fatalities in the worker population with the 70,000-MTHM inventory.

ESTIMATED NATIONAL TRANSPORTATION IMPACTS INVENTORY MODULE 1 OR 2 (for 38 years of operation)[a]

Impact	Mostly legal-weight truck scenario	Mostly rail scenario
Incident-free latent cancer fatalities		
Involved worker	24	7
Public[b]	5	<2
Latent cancer fatalities from accidents		
Public	0.0004	0.0008
Traffic fatalities[c]	9	6
Latent cancer fatalities from maximum reasonably foreseeable accident	0.55	5
Frequency of occurrence per year	2.3×10^{-7}	2.8×10^{-7}

a. Modules 1 and 2 involve approximately the same number of shipments.
b. Potential latent cancer fatalities result from very small doses to a very large population.
c. Does not include 13 to 20 fatalities that could occur from repository workers commuting and transporting construction materials to the repository.

As with the 70,000-MTHM inventory, no latent cancer fatalities are projected in the worker population for Inventory Module 1 under No-Action Scenario 2 after 100 years because there would be no workers at the sites.

Radiological Impacts to the Public. About 5 latent cancer fatalities could occur in the exposed population over 10,000 years as a result of No-Action Scenario 1 with Inventory Module 1. This compares to about 4 latent cancer fatalities with the 70,000-MTHM inventory.

Under No-Action Scenario 2, the number of latent cancer fatalities could increase from about 3,300 in the exposed population with the 70,000-MTHM inventory over 10,000 years to about 3,700 in the same period with Inventory Module 1.

S.9 Management Actions to Mitigate Potential Adverse Environmental Impacts

DOE has identified the types of mitigation measures it could take to reduce or avoid potential adverse impacts from construction, operation and monitoring, and closure of the proposed repository. The type of actions identified to date include:

- Commitments included as part of the Proposed Action that would reduce impacts. These commitments are based on DOE's studies of Yucca Mountain that have been ongoing for more than 10 years.

- Actions that are under consideration in the event the U.S. Nuclear Regulatory Commission grants a license for the site. DOE would continue to evaluate these potential additional commitments. The analyses in the EIS do not take credit for these mitigations that may be decided on in the future.

In addition, DOE continues to evaluate additional measures to improve the long-term performance of the repository and to reduce uncertainties in estimates of performance. These measures include barriers to limit releases and transport of radionuclides, measures to control heat and moisture in the underground, and various designs to support operational considerations.

S.10 Unavoidable Adverse Impacts; Short-Term Uses and Long-Term Productivity; and Irreversible or Irretrievable Commitments of Resources

The construction, operation and monitoring, and eventual closure of the proposed Yucca Mountain Repository and the associated transportation of spent nuclear fuel and high-level radioactive waste would have the potential to produce some environmental impacts that DOE could not completely mitigate. Similarly, some aspects of the Proposed Action could affect the long-term productivity of the environment or would require the permanent use of some resources. For example:

- The permanent withdrawal of approximately 600 square kilometers (230 square miles) of land for the repository would be likely to prevent human use of the withdrawn lands for other purposes.

- Death or displacement of individual members of some animal species, including the desert tortoise, as a result of site clearing and vehicle traffic would be unavoidable.

- Injuries to workers or worker fatalities could result from facility construction, including accidents.

- Transportation of spent nuclear fuel and high-level radioactive waste would have the potential to affect workers and the public through exposure to radiation and vehicle emissions, and through traffic accidents.

Further, in the view of the Native American tribes in the Yucca Mountain region, the implementation of the proposed repository and its facilities would further degrade the environmental setting. Even after closure and reclamation, the presence of the repository would, from the perspective of Native Americans, result in an irreversible impact to traditional lands.

In addition, the Proposed Action would involve the following commitments of resources:

- Electric power, fossil fuels, and construction materials would be irreversibly committed to the project.

- DOE would use fossil fuel from the nationwide supply system to transport spent nuclear fuel and high-level radioactive waste to the repository.

S.11 Statutory and Other Applicable Requirements

Several statutes and regulations would apply to the licensing, development, operation, and closure of a geologic repository. These include the NWPA; the National Environmental Policy Act; the Atomic Energy Act; the Federal Land Policy and Management Act of 1976; site-specific public health and environmental radiation protection standards established by the Environmental Protection Agency; site-specific technical licensing regulations established by the Nuclear Regulatory Commission; and site suitability guidelines established by DOE. DOE is also subject to environmental protection and transportation requirements such as those set by the Clean Air Act; Clean Water Act; Hazardous Material Transportation Act; Emergency Planning and Community Right-to-Know Act of 1986; Comprehensive Environmental Response, Compensation, and Liability Act; Resource Conservation and Recovery Act; National Historic Preservation Act; Archaeological Resources Protection Act; Endangered Species Act; Nuclear Regulatory Commission regulations applicable to the transportation of radioactive materials; U.S. Department of Transportation regulations governing the transportation of hazardous materials; and applicable Nevada State statutes and regulations. In accordance with several statutes, DOE would need several new permits, licenses, and approvals from both Federal and State agencies to construct, operate and monitor, and eventually close the proposed Yucca Mountain Repository.

Under the authority of the Atomic Energy Act, DOE is responsible for establishing a comprehensive health, safety, and environmental program for its activities and facilities. The Department has established a framework for managing its facilities through the promulgation of regulations and the issuance of DOE Orders. In general, DOE Orders set forth policies, programs, and procedures for implementing policies. Many DOE Orders contain specific requirements in the areas of radiation protection, nuclear safety and safeguards, and security of nuclear material. Because the Nuclear Regulatory Commission is authorized to license the proposed Yucca Mountain repository, DOE issued Order 250.1 exempting such a repository from compliance with provisions of DOE Orders that overlap or duplicate Nuclear Regulatory Commission licensing requirements.

DOE has interacted with agencies authorized to issue permits, licenses, and other regulatory approvals, as well as those responsible for protecting such significant resources as endangered species, wetlands, or historic properties. DOE also has coordinated with the affected units of local government, U.S. Nuclear Regulatory Commission, U.S. Air Force, U.S. Navy, U.S. Department of Agriculture, U.S. Department of Transportation, U.S. Environmental Protection Agency, Department of the Interior including its Bureaus (U.S. Fish and Wildlife Service, National Park Service, and Bureau of Land Management), the Council on Environmental Quality, Nevada Department of Transportation, and Native American tribes. In addition, DOE provided a copy of the Draft EIS and Supplement to the Draft EIS to these agencies and entities.

S.12 Conclusions

S.12.1 MAJOR CONCLUSIONS OF THE EIS

In general, the Proposed Action would cause small, short-term public health impacts due primarily to the transportation of spent nuclear fuel and high-level radioactive waste from the existing commercial and DOE sites to the proposed repository. The specific impacts at the repository site would be very small as indicated in Table S-1. The transportation impacts would be associated mainly with nonradiological traffic fatalities and very low radiological doses to members of the public from the routine transportation of radioactive materials.

The EIS analysis demonstrated that the long-term performance of the proposed repository over 10,000 years would result in a mean peak annual dose of 0.00002 millirem to a reasonably maximally exposed individual hypothetically located 18 kilometers (11 miles) from the repository. The analysis of a human intrusion event occurring at 30,000 years indicated a mean peak annual dose of 0.002 millirem to the reasonably maximally exposed individual at the same location.

As a result of this evaluation, DOE does not expect the repository to result in impacts to public health beyond those that could result from the prescribed radiation exposure and activity concentration limits in 40 CFR Part 197 and 10 CFR Part 63 during the 10,000-year period after closure.

IMPACTS FROM THE PROPOSED ACTION

Nonradiological hazards

- 2 to 3 worker fatalities from repository construction, operation and monitoring, and closure
- 2 to 4 worker fatalities from traffic accidents while commuting to and from the repository
- 6 to 14 traffic fatalities associated with the transportation of construction materials and public involved in accidents with commuters
- 3 to 5 traffic fatalities associated with the shipment of spent nuclear fuel and high-level radioactive waste
- 2 to 3 fatalities in the general population due to latent effects of vehicle emissions (transportation of spent nuclear fuel and high-level radioactive waste, construction materials, and commuters)

Radiological

- 4 to 7 latent cancer fatalities to workers at the repository
- 3 to 12 latent cancer fatalities to workers during the loading and transport of spent nuclear fuel and high-level radioactive waste
- 0.5 to 2 latent cancer fatalities in the general population from releases of naturally occurring radon from the repository
- 0.6 to 2.5 latent cancer fatalities in the general population from loading and transport of spent nuclear fuel and high-level radioactive waste
- Essentially zero long-term latent cancer fatalities within 10,000 years associated with the repository performance

These values represent the range of impacts for all operating modes, transportation scenarios, and implementing alternatives.

Under the No-Action Alternative, latent cancer fatalities would be unlikely in the short term in either the worker or public populations. These short-term impacts would be very similar to those associated with the Proposed Action. In addition, under the No-Action Alternative there would be no impacts associated with the transportation of spent nuclear fuel and high-level radioactive waste to the proposed repository. However, the obligation to store these materials continually in a safe configuration would become the responsibility of future generations.

There could be large public health and environmental consequences under the No-Action Alternative if there were no effective institutional control, causing storage facilities and containers to deteriorate and radioactive contaminants from the spent nuclear fuel and high-level radioactive waste to enter the environment. In such circumstances, there would be widespread contamination at the 72 commercial and 5 DOE sites across the United States, with resulting human health impacts.

Table S-1 compares the potential impacts associated with the Proposed Action to those associated with the No-Action Alternative.

S.12.2 DISTINCTIONS BETWEEN IMPACTS OF THE PROPOSED ACTION AND NO-ACTION ALTERNATIVE

The analysis of the potential short-term environmental impacts associated with the Proposed Action and with the two No-Action scenarios revealed that the impacts would be small and related to health and safety and to socioeconomics.

Table S-1. Impacts associated with the Proposed Action and No-Action Alternative.[a] (page 1 of 4).

	Flexible design potential operating modes–range of impacts			No-Action Alternative		
	Short-term (through closure)		Long-term (after closure, to 10,000 years)	Short-term	Long-term (100 to 10,000 years)	
Resource area	Repository	Transportation		(100 years)	Scenario 1	Scenario 2
Land use and ownership	Small; the flexible design range of disturbed land is from 4.3 km^2[(b)] to about 6.0 km^2 of the 600 km^2 that comprise the analyzed withdrawal area	Small to moderate; 0 to about 20 km^2 of land disturbed for new transportation routes; Air Force identified Nellis Air Force Range conflicts for some routes; some routes pass close to or through Wilderness Study Areas; some corridors could directly impact Native Americans and Indian reservations; and one corridor could conflict with the Ivanpah Airport construction and operation	Small; potential for limited access into the area; the only surface features remaining would be markers	Small; storage would continue at existing sites	Small; storage would continue at existing sites	Large; potential contamination of 0.04 to 0.4 km^2 surrounding each of the 72 commercial and 5 DOE sites
Air quality	Small; releases and exposures well below regulatory limits (less than 6 percent of limits)	Small; releases and exposures below regulatory limits; pollutants from vehicle traffic and trains would be small in comparison to other national vehicle and train traffic; Clean Air Act General Conformity Requirements might apply in Clark County Nevada	Very small, 5.3×10^{-10} latent cancer fatalities peak effect	Small; releases and exposures well below regulatory limits	Small; releases and exposures well below regulatory limits	Small; degraded facilities would preclude large atmospheric releases
Hydrology (groundwater and surface water)	Groundwater–small; water demand (230 to 290 acre-feet[c] per year) well below lowest estimate of the groundwater basin's perennial yield (580 acre-feet)	Small; withdrawal of up to 710 acre-feet from multiple wells and hydrographic areas over about 4 years	Small amounts of contamination of groundwater in Amargosa Valley during the first 10,000 years. Contamination is several hundred thousand times less than the groundwater protection standard in 40 CFR 197	Small; usage would be small in comparison to other site use	Small; usage would be small in comparison to other site use	Large; potential for radiological contamination of groundwater around 72 commercial and 5 DOE sites
	Surface water–small; new land disturbance of 2.8 to 4.5 square kilometers would result in minor changes to runoff and infiltration rates; floodplain assessment concluded impacts would be small	Small; minor changes to runoff and infiltration rates; all rail corridors pass through areas of identified 100-year flood zones, additional floodplain assessments would be performed in the future as necessary	Small; minor changes to runoff and infiltration rates	Small; minor changes to runoff and infiltration rates	Small; minor changes to runoff and infiltration rates	Large; potential for radiological releases and contamination of drainage basins downstream of 72 commercial and 5 DOE sites (concentrations potentially exceeding current regulatory limits)

Table S-1. Impacts associated with the Proposed Action and No-Action Alternative.[a] (page 2 of 4).

	Flexible design potential operating modes–range of impacts			No-Action Alternative		
	Short-term (through closure)		Long-term (after closure, to 10,000 years)	Short-term	Long-term (100 to 10,000 years)	
Resource area	Repository	Transportation		(100 years)	Scenario 1	Scenario 2
Biological resources and soils	Small to moderate; loss of about 4.3 km^2 to 6.0 km^2 of desert soil, habitat, and vegetation; adverse impacts to individual threatened desert tortoises (not the species as a whole); reasonable and prudent measures to minimize impacts; impacts to other plants and animals and habitat small; wetlands assessment concluded impacts would be small	Small to moderate; loss of 0 to 20 km^2 of desert soil, habitat, and vegetation for heavy-haul routes and rail corridors; adverse impacts to individual threatened desert tortoises (not the species as a whole); reasonable and prudent measures to minimize impacts; impacts to other plants and animals and habitat small; additional wetlands assessments would be performed in the future as necessary prior to any construction	Small; slight increase in temperature of surface soil directly over the repository for 10,000 years resulting in a potential temporary shift in plant and animal communities in this small area (about 8 km^2)	Small; storage would continue at existing sites	Small; storage would continue at existing sites	Large; potential adverse impacts at each of the 77 sites from subsurface contamination of 0.04 to 0.4 km^2
Cultural resources	Small to moderate; repository development would disturb up to about 4.5 km^2 of previously undisturbed land; mitigation measures would avoid or minimize damage to and illicit collecting at archaeological sites; programs in place to minimize impacts; opposing Native American viewpoint	Small to moderate; loss of 0 to 20 km^2 of land disturbed for new transportation routes; mitigation measures would avoid or minimize damage to and illicit collecting at archaeological sites; programs in place to minimize impacts; opposing Native American viewpoint	Small; potential for limited access into the area; opposing Native American viewpoint	Small; storage would continue at existing sites; limited potential of disturbing sites	Small; storage would continue at existing sites; limited potential of disturbing sites	Small; no construction or operation activities; no impacts
Socioeconomics	Small; estimated peak total employment of 3,400 occurring in 2006 would result in less than a 1 percent increase in composite regional employment; therefore, impacts would be small. Estimated peak direct employment for the repository during construction would be approximately 1,900 in 2006.	Small; employment increases would range from less than 1 percent to 4.9 percent (use of intermodal transfer station in Lincoln County) of employment in affected counties	Small; no workers, no impact	Small; population and employment changes would be small compared to totals in the regions	Small; population and employment changes would be small compared to totals in the regions	Small; no workers; no impacts
Occupational and public health and safety						
Public						
Radiological[d]						
MEI (probability of an LCF)	1.6×10^{-5} to 3.1×10^{-5}	1.4×10^{-4} to 1.2×10^{-3}	4×10^{-10} to 4×10^{-9} at the boundary of the controlled area (approximately 18 km south of the repository)	4.3×10^{-6}	1.3×10^{-6}	(e)
Population (LCFs)	0.46 to 2.0	0.61 to 2.5	2×10^{-6} to 3×10^{-4}	0.41	3	3,300[f]
Nonradiological (fatalities due to emissions)	Small; exposures well below regulatory limits	1.6 to 2.8[g]	Small; exposures well below regulatory limits or guidelines	Small; exposures well below regulatory limits or guidelines	Small; exposures well below regulatory limits or guidelines	Moderate to large; substantial increases in releases of hazardous substances in the spent nuclear fuel and high-level radioactive waste and exposures to the public

Table S-1. Impacts associated with the Proposed Action and No-Action Alternative.[a] (page 3 of 4).

Resource area	Flexible design potential operating modes–range of impacts: Short-term (through closure): Repository	Flexible design potential operating modes–range of impacts: Short-term (through closure): Transportation	Flexible design potential operating modes–range of impacts: Long-term (after closure, to 10,000 years)	No-Action Alternative: Short-term (100 years)	No-Action Alternative: Long-term (100 to 10,000 years): Scenario 1	No-Action Alternative: Long-term (100 to 10,000 years): Scenario 2
Occupational and public health and safety (continued)						
Workers (involved and noninvolved)						
Radiological (LCFs)	4.0 to 6.8	3.2 to 11.7	No workers, no impacts	16	10	No workers, no impacts
Nonradiological fatalities (includes commuting traffic fatalities)	2.0 to 3.3	12 to 23[h]	No workers, no impacts	9	1,080	No workers, no impacts
Accidents						
Public						
Radiological						
MEI (probability of an LCF)	2.9×10^{-13} to 1.9×10^{-5}	0.0015 to 0.015	Not applicable	No impacts	No impacts	Not applicable
Population (LCFs)	1.4×10^{-11} to 1.1×10^{-2}	0.55 to 5	Not applicable	No impacts	No impacts	3 to 13
Workers	Large; for some unlikely accident scenarios workers would likely be severely injured or killed	Large; for some unlikely accident scenarios workers would likely be severely injured or killed	No workers, no impacts	Large; for some unlikely accident scenarios workers would likely be severely injured or killed	Large; for some unlikely accident scenarios workers would likely be severely injured or killed	Small; no workers; no impacts
Noise/Ground Vibration	Small; impacts to public would be low due to large distances to residences; workers exposed to elevated noise levels–controls and protection used as necessary	Small to moderate; transient and not excessive, less noise than 90 dBA[i]; ground vibration infrequent and less than 88 dBV at 25 m	Small; no activities, therefore, no noise or ground vibration	Small; transient and not excessive, less than 90 dBA	Small; transient and not excessive, less than 90 dBA	Small; no activities, therefore, no noise
Aesthetics	Small; low adverse impacts to aesthetic or visual resources in the area. There may be increase in lighting impacts due to lighting associated with the ventilation system	Small; possible temporary and transient; conflict with visual resource management goals for Wilson Pass Option of the Jean rail corridor; and discernible impacts from the Caliente Intermodal transfer facility near Kershaw-Ryan State Park.	Small; only surface features remaining would be markers	Small; storage would continue at existing sites; expansion as needed	Small; storage would continue at existing sites; expansion as needed	Small; aesthetic value decreases as facilities degrade
Utilities, energy, materials, and site services	Small; use of materials would be very small in comparison to amounts used in the region; electric power delivery system to the Yucca Mountain site would have to be enhanced	Small; use of materials and energy would be small in comparison to amounts used nationally	Small; no use of materials or energy	Small; materials and energy use would be small compared to total site use	Small; materials and energy use would be small compared to total site use	Small; no use of materials or energy
Management of site-generated waste and hazardous materials	Small; radioactive and hazardous waste generated would be a few percent of existing offsite capacity; other wastes would be managed onsite	Small; waste generated would be a fraction of existing offsite capacity	Small; no waste generated or hazardous materials used	Small; waste generated and materials used would be small compared to total site generation and use	Small; waste generated and materials used would be small compared to total site generation and use	Small; no waste generated or hazardous materials used

Table S-1. Impacts associated with the Proposed Action and No-Action Alternative.[a] (page 4 of 4).

	Flexible design potential operating modes – range of impacts			No-Action Alternative		
	Short-term (through closure)		Long-term (after closure, to 10,000 years)	Short-term (100 years)	Long-term (100 to 10,000 years)	
Resource area	Repository	Transportation			Scenario 1	Scenario 2
Environmental justice	Small; no disproportionately high and adverse impacts to minority or low-income populations; opposing Native American viewpoint	Small; no disproportionately high and adverse impacts to minority or low-income populations; opposing Native American viewpoint	Small; no disproportionately high and adverse impacts to minority or low-income populations; opposing Native American viewpoint	Small; no disproportionately high and adverse impacts to minority or low-income populations	Small; no disproportionately high and adverse impacts to minority or low-income populations	Large; potential for disproportionately high and adverse impacts to minority or low-income populations

a. Ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because these values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.

b. km^2 = square kilometers; to convert to acres, multiply by 247.1.

c. To convert acre-feet to cubic meters, multiply by 1233.49.

d. LCF = latent cancer fatality; MEI = maximally exposed individual.

e. With no effective institutional controls, the maximally exposed individual could receive a fatal dose of radiation within a few weeks to months. Death would be caused by acute direct radiation exposure.

f. Downstream exposed population of approximately 3.9 billion over 10,000 years.

g. Nonradiological fatalities due to exhaust emissions health effects from spent nuclear fuel and high-level radioactive waste transportation, including loadout; exhaust emissions health effects from commuter and materials transportation for repository construction, operation, and closure; and rail line or heavy-haul truck/intermodal transfer station construction, maintenance, and operation.

h. Nonradiological traffic fatalities from spent nuclear fuel and high-level radioactive waste transportation and commuter traffic fatalities. As many as 10 to 17 of these fatalities could be members of the public.

i. dBA = *A-weighted decibels*, a common sound measurement. A-weighting accounts for the fact that the human ear responds more effectively to some pitches than to others. Higher pitches receive less weighting than lower ones.

For the Proposed Action, using DOE's preferred transportation mode (mostly rail), about 24 to 38 latent cancer fatalities and nonradiological fatalities would be associated with the transportation of spent nuclear fuel and high-level radioactive waste and the construction, operation and monitoring, and closure of the repository at Yucca Mountain. Depending on the transportation mode, transportation impacts of the Proposed Action would result in about 4 latent cancer fatalities and 14 to 23 nonradiological fatalities. Construction and operation of the repository would result in 4 to 8 latent cancer fatalities and 2 to 3 nonradiological fatalities, depending on the repository operating mode.

In comparison, there would be about 25 latent cancer fatalities and nonradiological fatalities from the No-Action Alternative (both scenarios) during the first 100 years. For both scenarios, there would be about 7 nonradiological fatalities from commuting and shipping construction materials and about 16 latent cancer fatalities and 2 nonradiological fatalities from construction and operations.

Short-term socioeconomic impacts would occur in the Yucca Mountain region and at the existing storage locations under the Proposed Action; impacts under the No-Action Alternative would occur only in the Yucca Mountain region. Under the Proposed Action, there would be nearly 2,700 new jobs in the three-county area around Yucca Mountain (Clark, Lincoln, and Nye Counties). In addition, under the Proposed Action there would be lost jobs at each of the sites across the United States as spent nuclear fuel and high-level radioactive waste was removed. Under the No-Action Alternative, there would be a loss of about 4,700 direct and indirect jobs in the three-county area around Yucca Mountain once reclamation was completed. There would be no short-term socioeconomic impacts at the storage sites under the No-Action Alternative.

The potential long-term (postclosure to 10,000 years) environmental impacts of the Proposed Action and No-Action Scenario 1 (continued institutional control) would also be small. Under the Proposed Action, there would be virtually no latent cancer fatalities (much less than 1) over 10,000 years. In addition, there would be a potential for very small impacts to vegetation and animals over the repository area as soil surface temperatures increased. Under the No-Action Scenario 1, there would be about 13 latent cancer fatalities and about 1,100 nonradiological fatalities associated with the construction and replacement of storage facilities, monitoring of facilities, worker commuting, and transportation of construction materials. Small impacts to other resources (for example, socioeconomics, biological resources, utilities and services) would occur.

There would be differences in the potential long-term environmental impacts under No-Action Scenario 2 (no institutional control after 100 years) compared to No-Action Scenario 1. Under No-Action Scenario 2, there would be about 3,300 latent cancer fatalities over 10,000 years as storage facilities across the United States degraded and radionuclides from spent nuclear fuel and high-level radioactive waste reached and contaminated the environment. There would be no fatalities associated with transportation, construction, or operation because those activities would not occur after the presumed loss of institutional control.

S.12.3 AREAS OF CONTROVERSY

The Department acknowledges that areas of controversy exist regarding the Proposed Action and the analyses in this EIS. Areas of controversy were identified during the public interaction processes. Many of these are not resolvable because they reflect either differing points of view or irreducible uncertainties in predicting the future. However, the Department has considered these areas in the development of this Final EIS. Other issues raised by the public are summarized in Section S.4.2.4.

Native American Viewpoint

Disagreement exists about the nature of the repository as it might impact elements of the natural and cultural environment that are of concern to Native American tribes.

Perceived Risk and Stigma

Disagreement exists concerning whether the perception of risk and stigma cause behavioral changes, the ability of researchers to predict future human behavior based on perception of risk and stigma, and the capability to reliably predict economic effects of any such stigma.

High-Level Radioactive Waste—Equivalency of Metric Tons of Heavy Metal

Disagreement exists about the method for calculating the amount of MTHM in a canister of high-level radioactive waste. This would affect the number of canisters that could be disposed of under the Proposed Action.

Engineered Barriers

Disagreement exists about how much reliance should be placed on engineered barriers versus natural barriers to achieve waste isolation in a geologic repository.

Transportation

Disagreement exists regarding factors relevant to the analyses of the potential environmental impacts from the transportation of spent nuclear fuel and high-level radioactive waste including for example, the need for community- and highway-specific information, and assumptions and input information used in the analyses.

Evaluation of Long-Term Performance

Disagreement exists regarding the ability to predict long-term performance for 10,000 years or more. Uncertainties associated with complex natural systems and engineered barrier behaviors and the use of computer models that are unable to rely on the results of long-term testing raise questions about the ability of the Department to predict repository performance.

S.12.4 ISSUES TO BE RESOLVED

There are no issues that remain to be resolved for this Final EIS to accompany any site recommendation.

However, prior to initiation of the Proposed Action to construct, operate and monitor, and eventually close a repository at Yucca Mountain, three primary issues would require resolution:

1. The Yucca Mountain site must be designated under the NWPA for development of a geologic repository.

2. If the site was designated, the Department would have to complete selection of the design features required to support a Licence Application to the Nuclear Regulatory Commission.

3. If the site was designated, the Department would have to make transportation-related decisions required to support implementation of the Proposed Action. Such decisions would include the choice of a national mode of transportation outside of Nevada (mostly legal-weight truck or mostly rail), the choice among alternative transportation modes in Nevada (mostly rail, mostly legal-weight truck, or heavy-haul truck with use of an associated intermodal transfer station), and the choice among alternative rail corridors or heavy-haul truck routes with use of an intermodal transfer station in Nevada.

S.13 Detailed Nevada Transportation Maps

Figures S-23 through S-35 are maps that show the candidate rail corridors and heavy-haul truck routes in Nevada. Figures S-23 and S-30 are index maps for rail and heavy-haul routes, respectively. That is, they identify the relationships of the more detailed maps that follow them. Figure S-23 shows the relationship of six detailed maps (Figures S-24 through S-29), each of which shows potential corridors (or portions of corridors) for the five candidate rail corridors, including variations. Similarly, Figure S-30 shows the relationship of four detailed maps (Figures S-31 through S-34), each of which shows candidate heavy-haul truck routes (or portions of routes). Finally, Figure S-35 is a legend for all of the detailed maps.

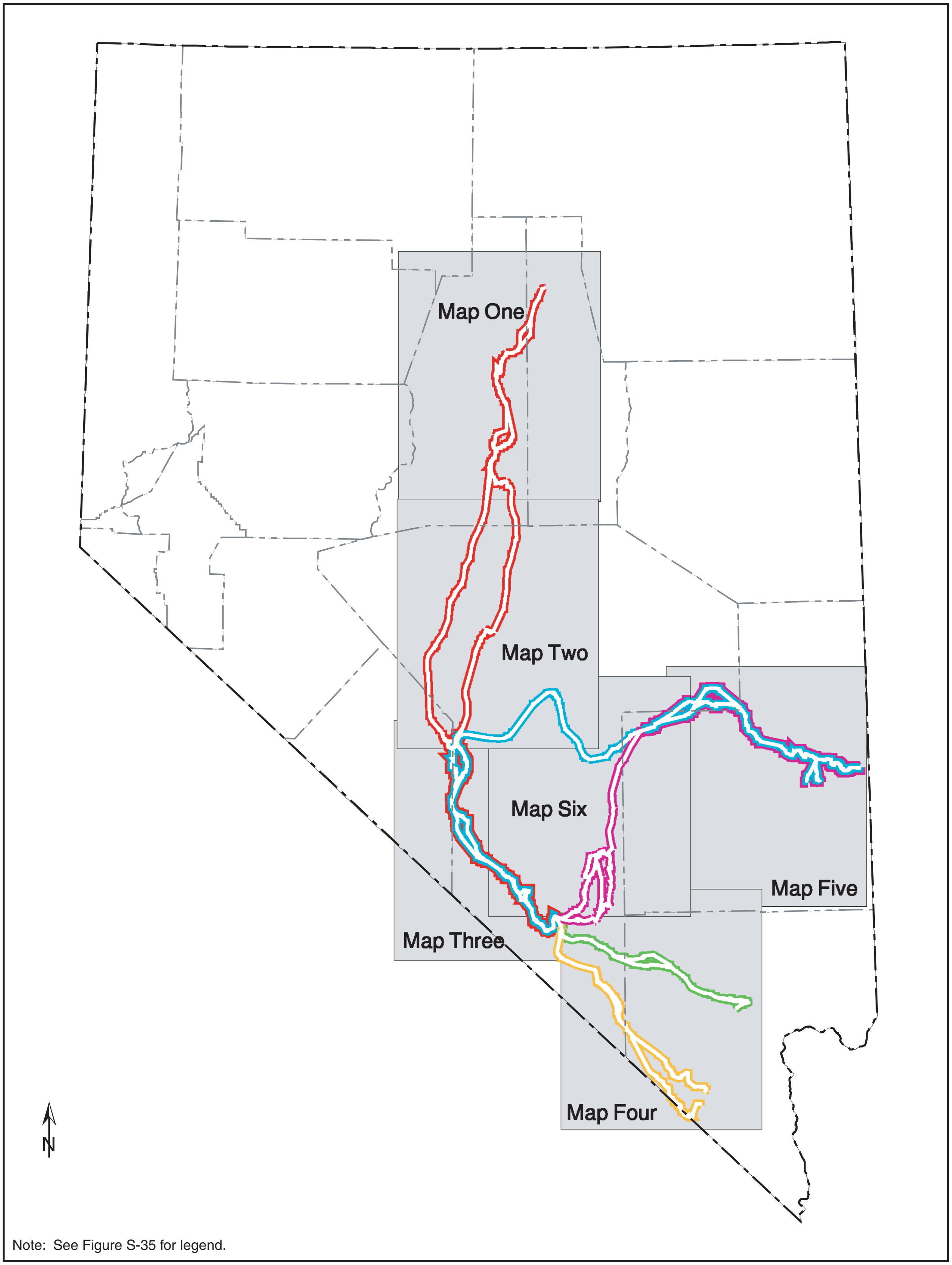
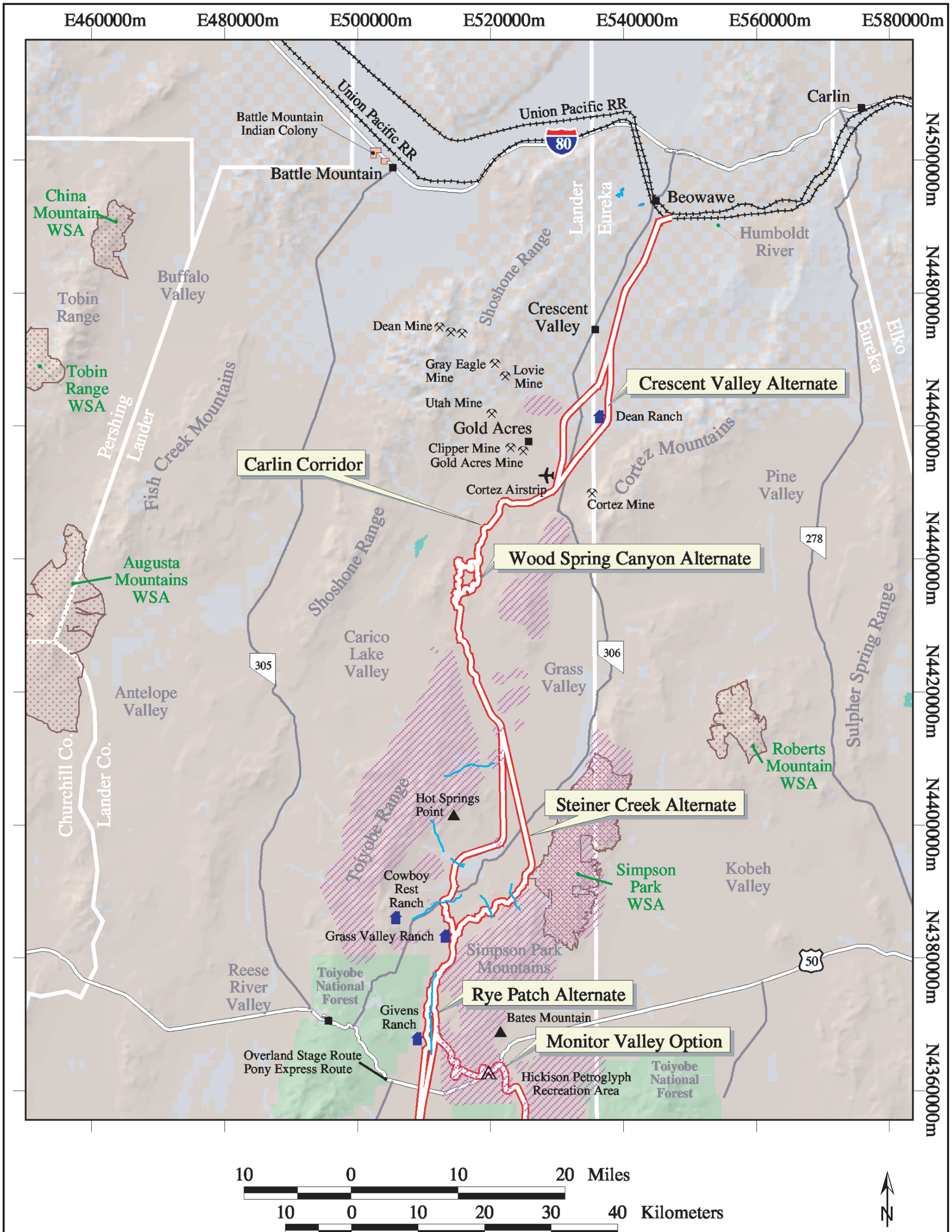


Figure S-23. Candidate rail corridors (Index).



Note: See Figure S-35 for legend.

Figure S-24. Candidate rail corridors (Map One).

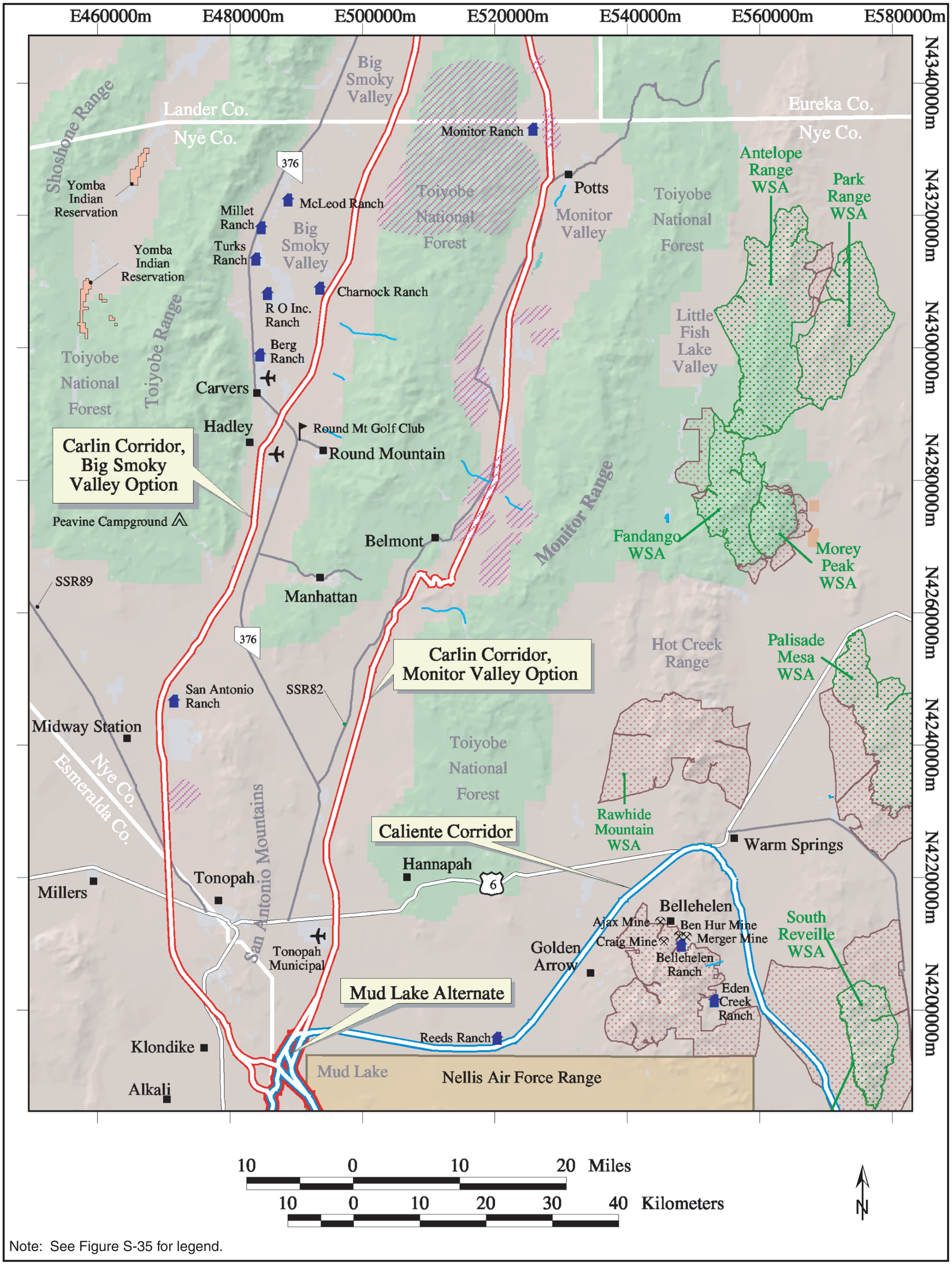


Figure S-25. Candidate rail corridors (Map Two).

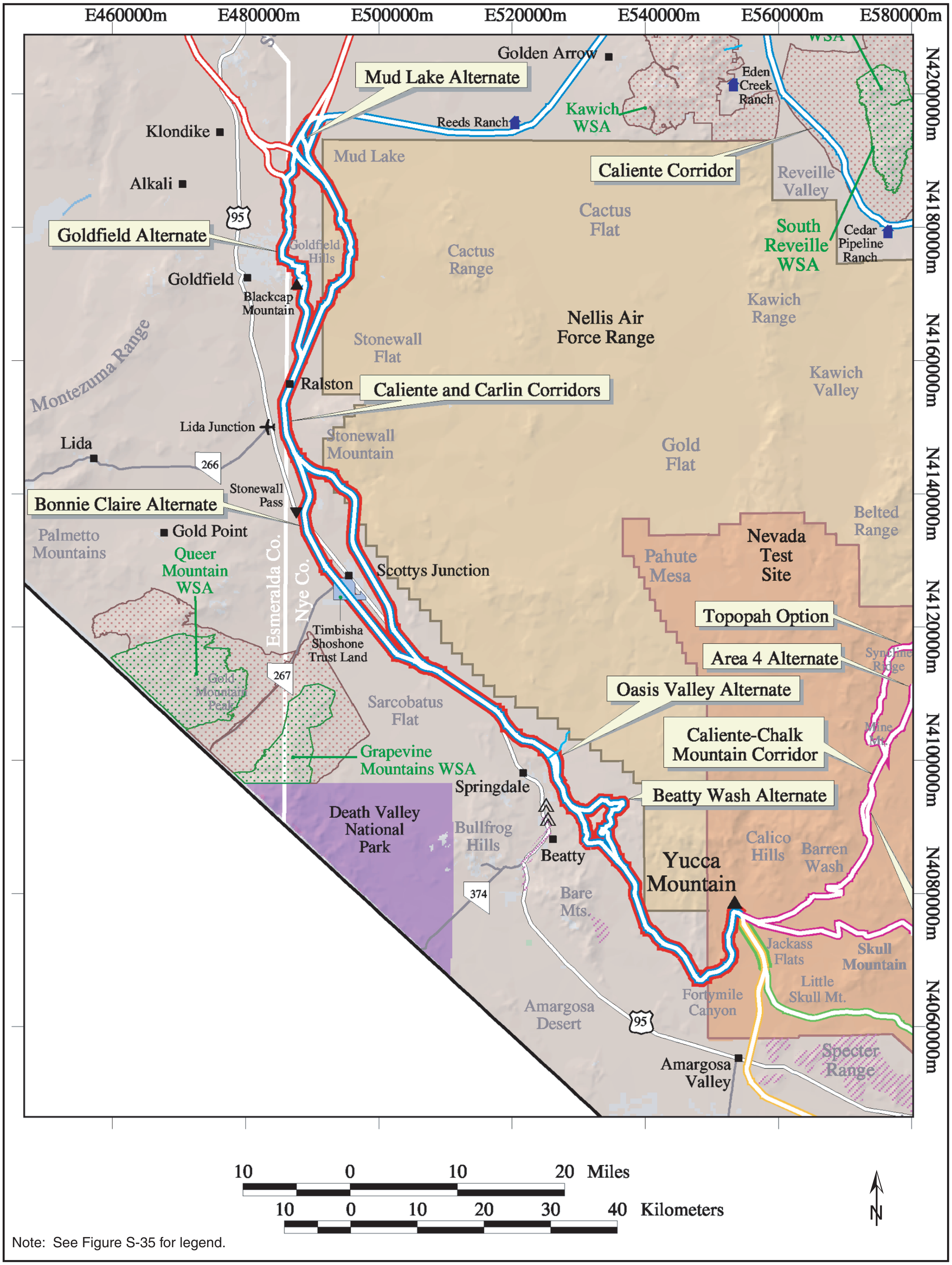


Figure S-26. Candidate rail corridors (Map Three).

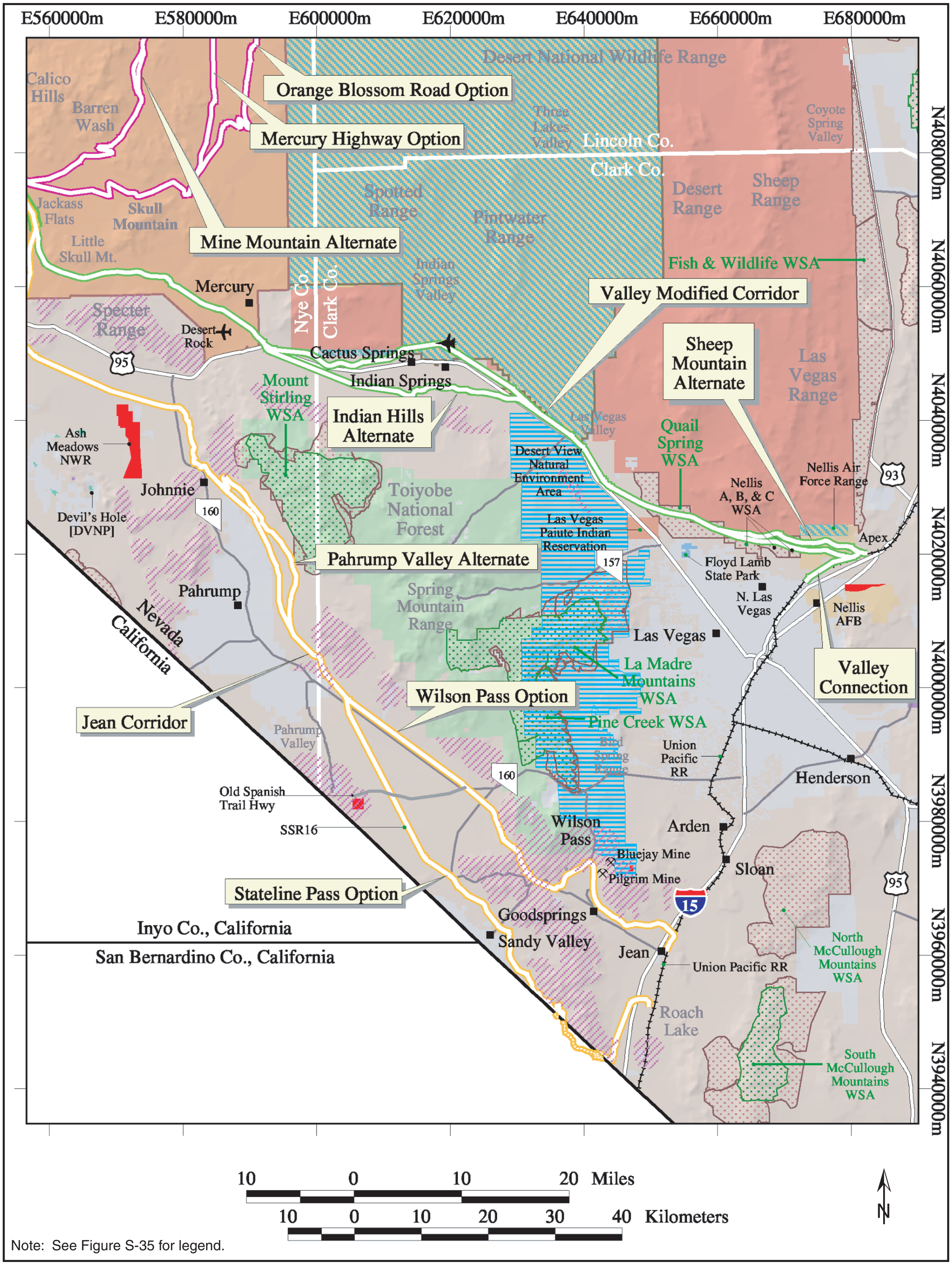


Figure S-27. Candidate rail corridors (Map Four).

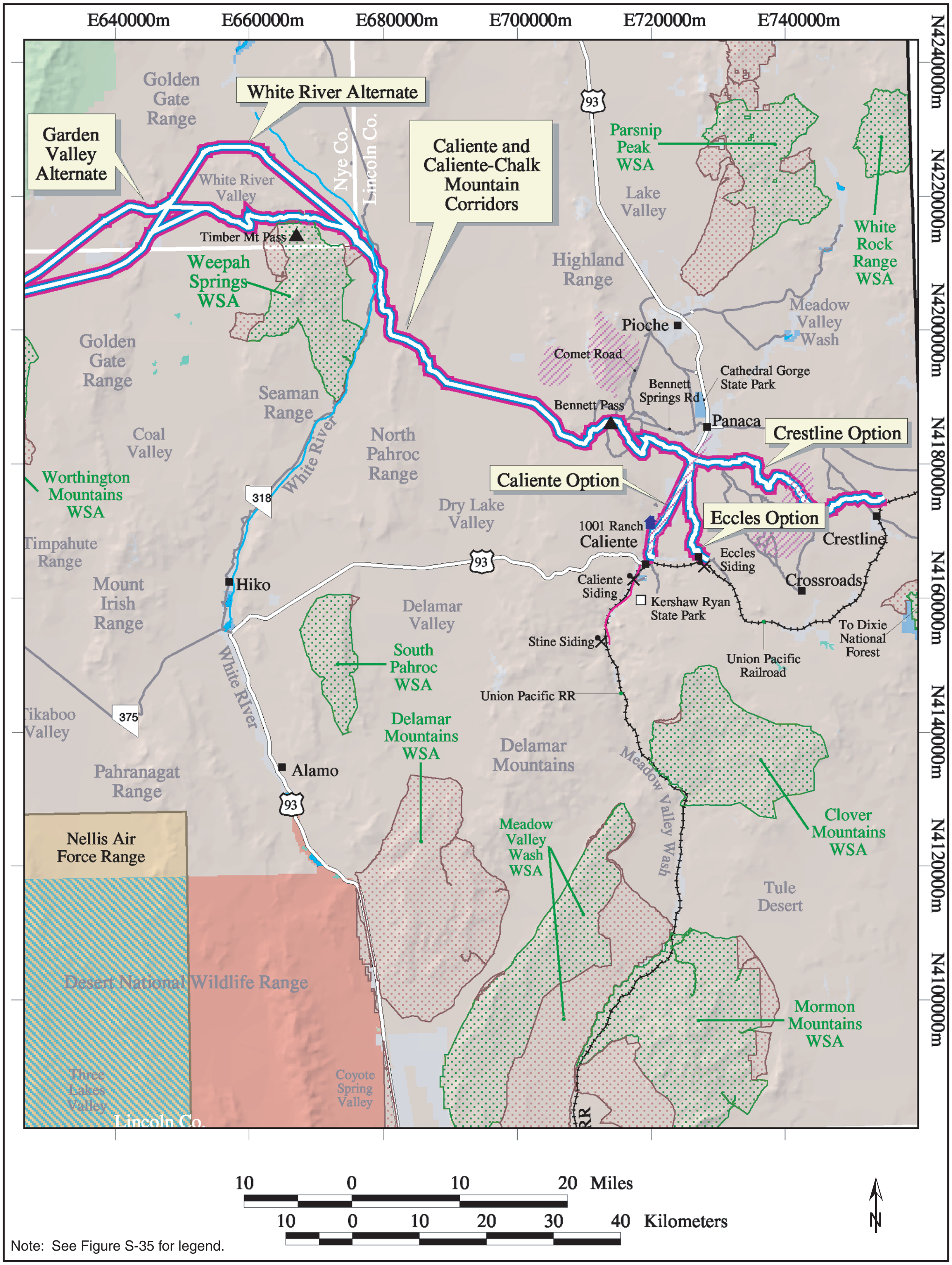


Figure S-28. Candidate rail corridors (Map Five).

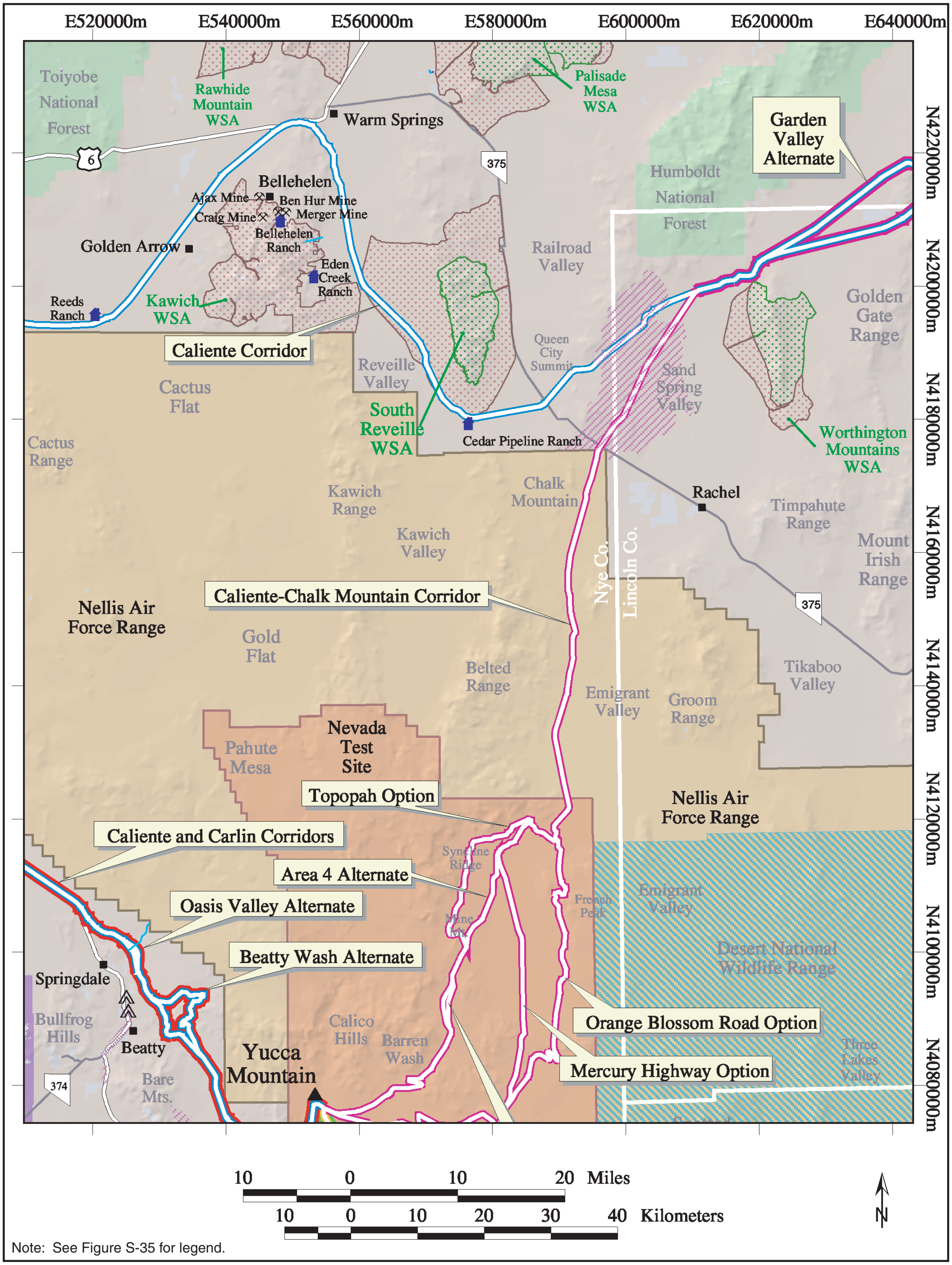


Figure S-29. Candidate rail corridors (Map Six).

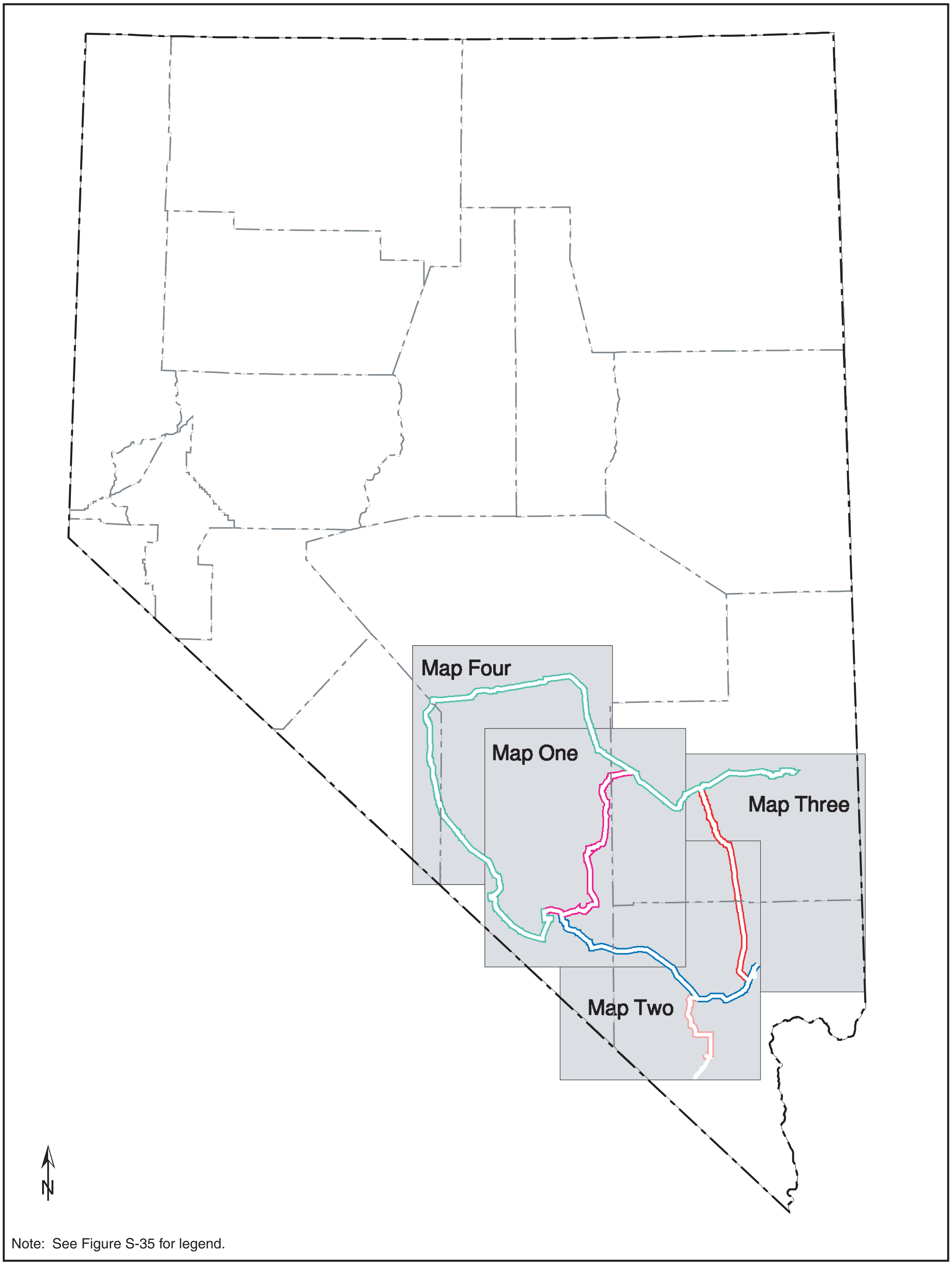


Figure S-30. Candidate heavy-haul truck routes (Index).

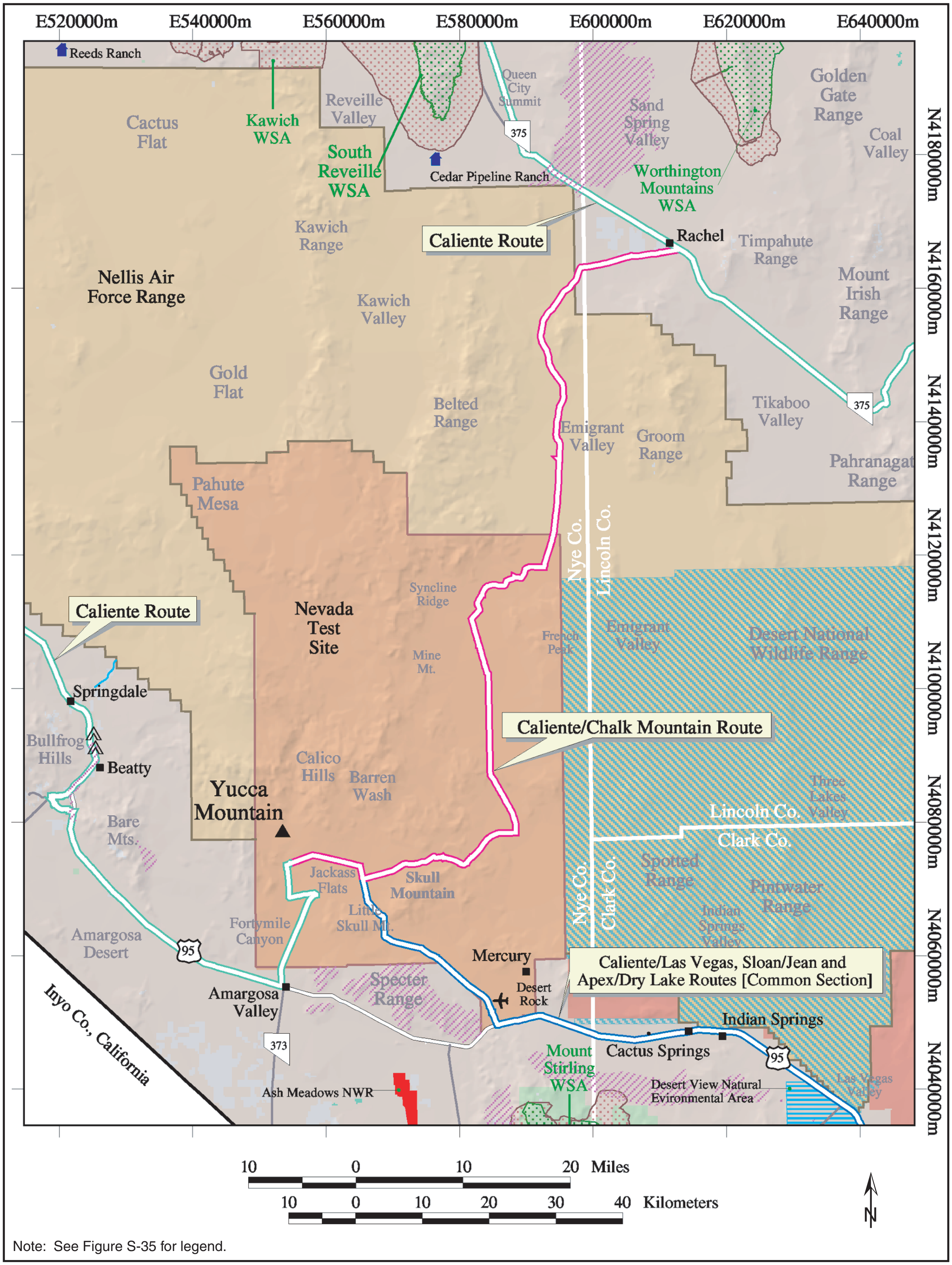
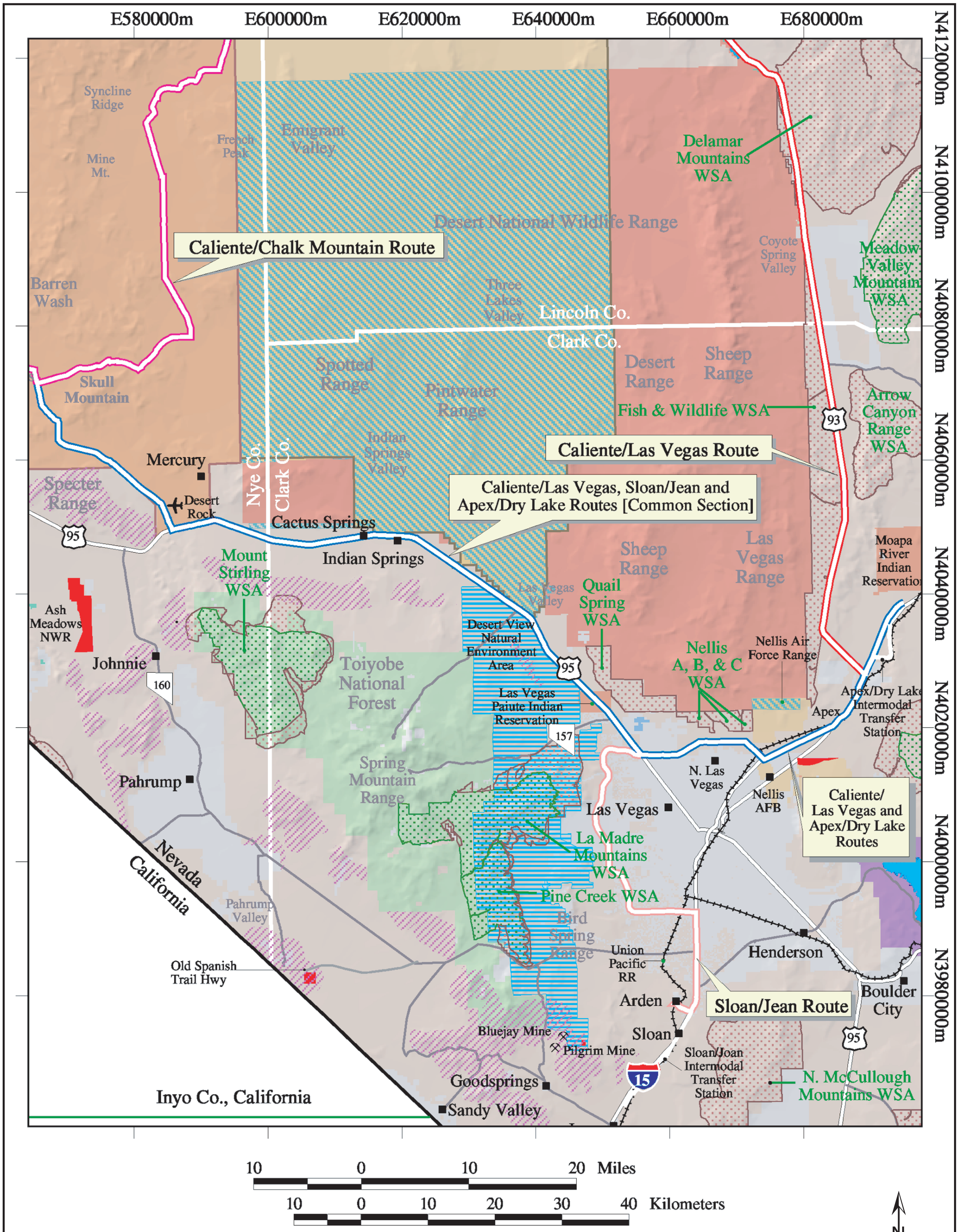
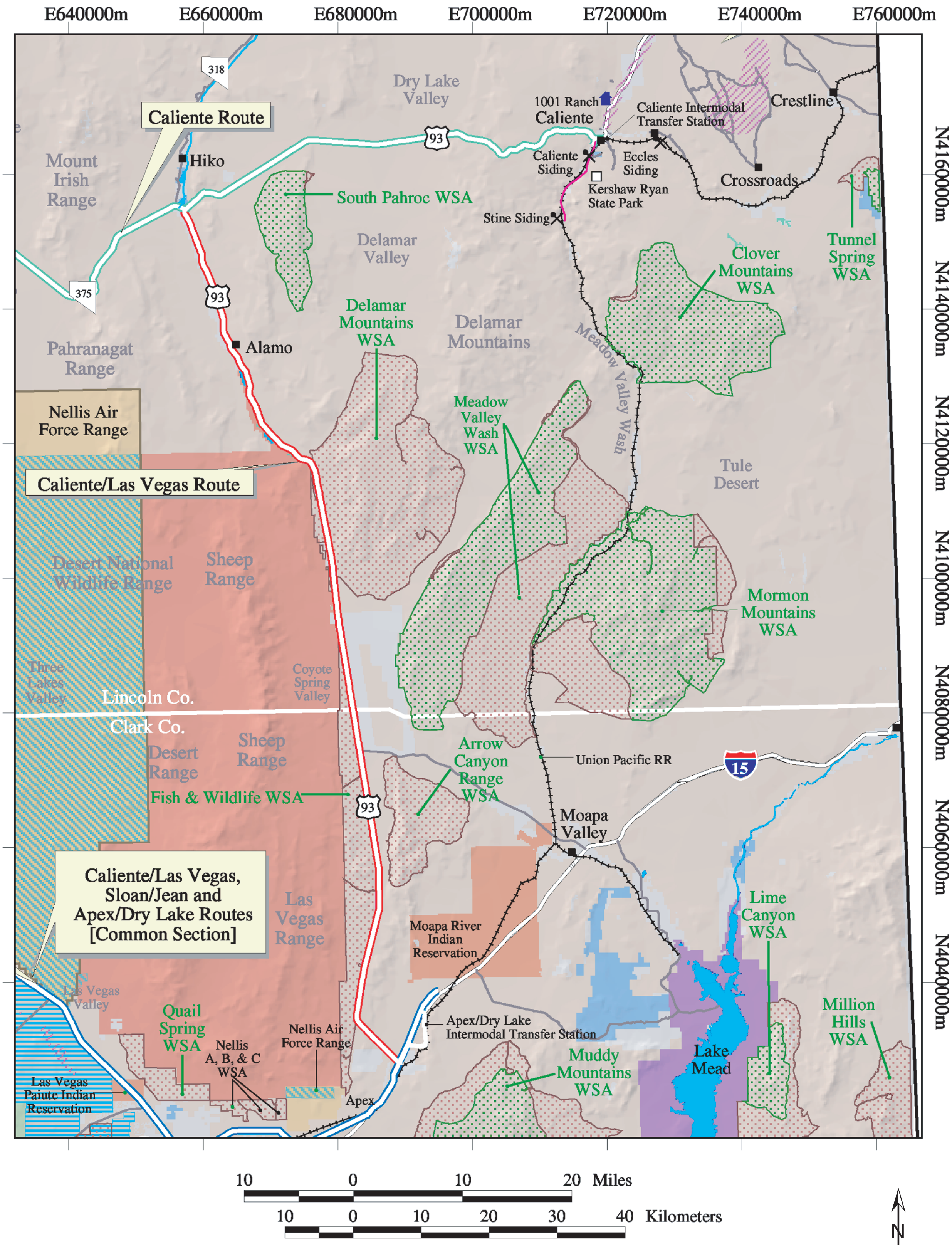


Figure S-31. Candidate heavy-haul truck routes (Map One).



Note: See Figure S-35 for legend.

Figure S-32. Candidate heavy-haul truck routes (Map Two).



Note: See Figure S-35 for legend.

Figure S-33. Candidate heavy-haul truck routes (Map Three).

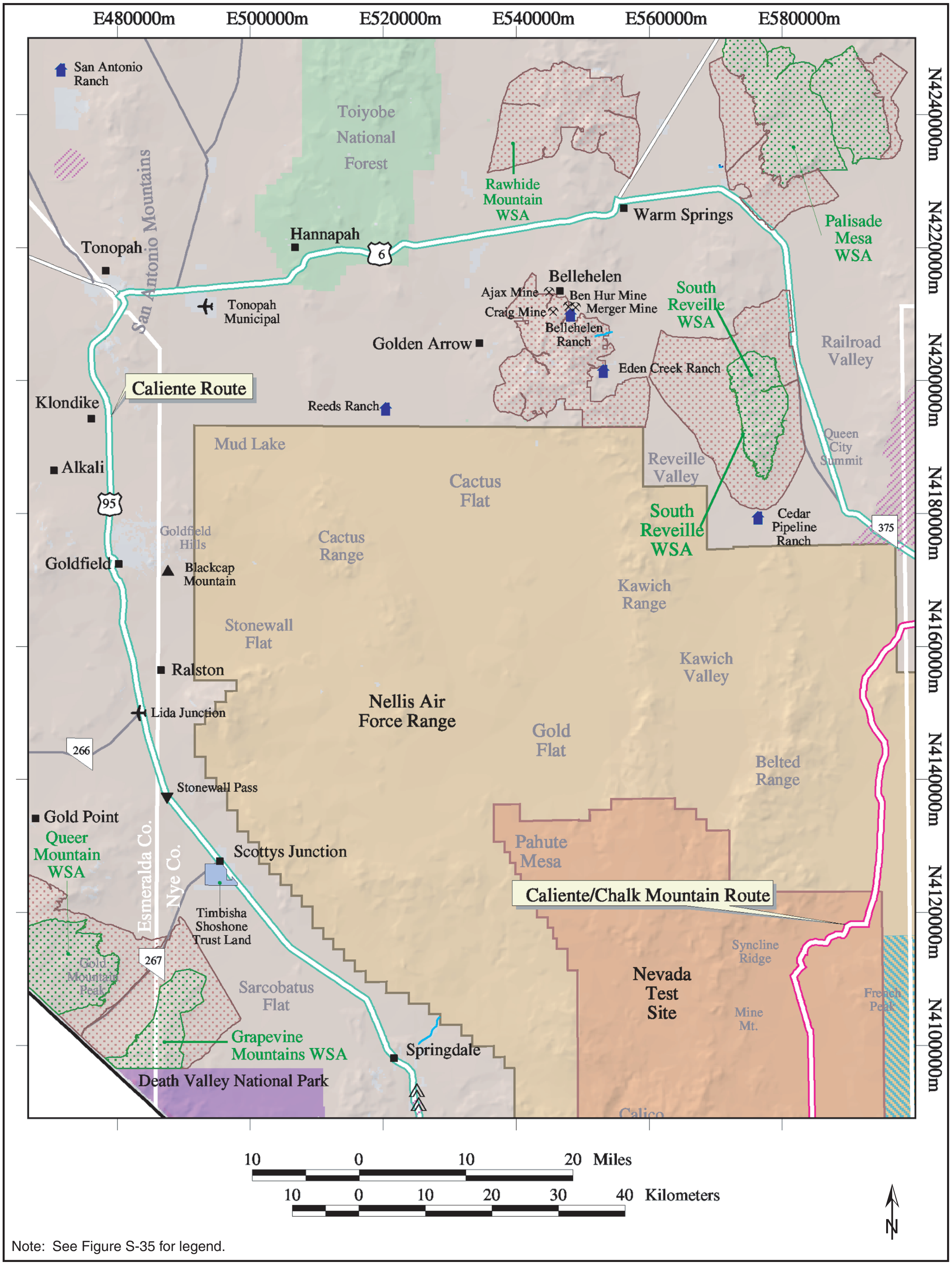


Figure S-34. Candidate heavy-haul truck routes (Map Four).

Figure S-35. Legend for candidate rail corridors and heavy-haul truck routes.

CONVERSIONS

METRIC TO ENGLISH			ENGLISH TO METRIC		
Multiply	**by**	**To get**	**Multiply**	**by**	**To get**
Area					
Square meters	10.764	Square feet	Square feet	0.092903	Square meters
Square kilometers	247.1	Acres	Acres	0.0040469	Square kilometers
Square kilometers	0.3861	Square miles	Square miles	2.59	Square kilometers
Concentration					
Kilograms/sq. meter	0.16667	Tons/acre	Tons/acre	0.5999	Kilograms/sq. meter
Milligrams/liter	1[a]	Parts/million	Parts/million	1[a]	Milligrams/liter
Micrograms/liter	1[a]	Parts/billion	Parts/billion	1[a]	Micrograms/liter
Micrograms/cu. meter	1[a]	Parts/trillion	Parts/trillion	1[a]	Micrograms/cu. meter
Density					
Grams/cu. cm	62.428	Pounds/cu. ft.	Pounds/cu. ft.	0.016018	Grams/cu. cm
Grams/cu. meter	0.0000624	Pounds/cu. ft.	Pounds/cu. ft.	16,025.6	Grams/cu. meter
Length					
Centimeters	0.3937	Inches	Inches	2.54	Centimeters
Meters	3.2808	Feet	Feet	0.3048	Meters
Kilometers	0.62137	Miles	Miles	1.6093	Kilometers
Temperature					
Absolute					
Degrees C + 17.78	1.8	Degrees F	Degrees F – 32	0.55556	Degrees C
Relative					
Degrees C	1.8	Degrees F	Degrees F	0.55556	Degrees C
Velocity/Rate					
Cu. meters/second	2118.9	Cu. feet/minute	Cu. feet/minute	0.00047195	Cu. meters/second
Grams/second	7.9366	Pounds/hour	Pounds/hour	0.126	Grams/second
Meters/second	2.237	Miles/hour	Miles/hour	0.44704	Meters/second
Volume					
Liters	0.26418	Gallons	Gallons	3.78533	Liters
Liters	0.035316	Cubic feet	Cubic feet	28.316	Liters
Liters	0.001308	Cubic yards	Cubic yards	764.54	Liters
Cubic meters	264.17	Gallons	Gallons	0.0037854	Cubic meters
Cubic meters	35.314	Cubic feet	Cubic feet	0.028317	Cubic meters
Cubic meters	1.3079	Cubic yards	Cubic yards	0.76456	Cubic meters
Cubic meters	0.0008107	Acre-feet	Acre-feet	1233.49	Cubic meters
Weight/Mass					
Grams	0.035274	Ounces	Ounces	28.35	Grams
Kilograms	2.2046	Pounds	Pounds	0.45359	Kilograms
Kilograms	0.0011023	Tons (short)	Tons (short)	907.18	Kilograms
Metric tons	1.1023	Tons (short)	Tons (short)	0.90718	Metric tons
ENGLISH TO ENGLISH					
Acre-feet	325,850.7	Gallons	Gallons	0.000003046	Acre-feet
Acres	43,560	Square feet	Square feet	0.000022957	Acres
Square miles	640	Acres	Acres	0.0015625	Square miles

a. This conversion is only valid for concentrations of contaminants (or other materials) in water.

METRIC PREFIXES

Prefix	Symbol	Multiplication factor		
exa-	E	1,000,000,000,000,000,000	=	10^{18}
peta-	P	1,000,000,000,000,000	=	10^{15}
tera-	T	1,000,000,000,000	=	10^{12}
giga-	G	1,000,000,000	=	10^{9}
mega-	M	1,000,000	=	10^{6}
kilo-	k	1,000	=	10^{3}
deca-	D	10	=	10^{1}
deci-	d	0.1	=	10^{-1}
centi-	c	0.01	=	10^{-2}
milli-	m	0.001	=	10^{-3}
micro-	µ	0.000 001	=	10^{-6}
nano-	n	0.000 000 001	=	10^{-9}
pico-	p	0.000 000 000 001	=	10^{-12}