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

Volume I - Impact Analyses
Chapters 1 through 15

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

DOE/EIS-0250D

July 1999

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.

BWR	boiling-water reactor
CFR	Code of Federal Regulations
DOE	U.S. Department of Energy (also called *the Department*)
EIS	environmental impact statement
EPF	energy partition factor
FR	*Federal Register*
LCF	latent cancer fatality
MTHM	metric tons of heavy metal
NWPA	Nuclear Waste Policy Act, as amended
OCRWM	Office of Civilian Radioactive Waste Management
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
PWR	pressurized-water reactor
UFSAR	Updated Final Safety Analysis Report
USC	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

$10^1 = \times 1 = 10$

$10^2 = 10 \times 10 = 100$

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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COVER SHEET

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

TITLE: 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

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

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ABSTRACT: The Proposed Action addressed in this 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 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.

PUBLIC COMMENTS: A 180-day comment period on this Draft EIS begins with the publication of the Environmental Protection Agency Notice of Availability in the *Federal Register*. DOE will consider comments received after the end of the 180-day period to the extent practicable. DOE will hold public meetings to receive comments on the Draft EIS at the times and locations to be announced in local media and a DOE Notice of Availability in the *Federal Register*. Written comments can also be submitted by U.S. mail to Wendy R. Dixon at the above address, or via the Internet at *http://www.ymp.gov*.

FOREWORD

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. The potential repository would be located in Nye County, Nevada. The EIS also provides information on the 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 amended in 1987, 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.
- Prepare an EIS.
- Decide whether to recommend approval of the development of a geologic repository at Yucca Mountain to the President.

The Nuclear Waste Policy Act, as amended (the EIS refers to the amended Act as the NWPA), also requires the U.S. Department of Energy (DOE) to hold hearings to provide the public in the vicinity of Yucca Mountain with opportunities to comment on the Secretary's possible recommendation of the Yucca Mountain site to the President. The hearings would be separate from the public hearings on the Draft EIS required under the National Environmental Policy Act. If, after completing the hearings and site characterization activities, the Secretary decides to recommend that the President approve the site, the Secretary will 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.

If the Secretary recommends the Yucca Mountain site to the President, a comprehensive statement of the basis for the recommendation, including the Final EIS, will accompany the recommendation. This Draft EIS has been prepared now so that DOE can consider the Final EIS, including the public input on the Draft EIS, in making a decision on whether to recommend the site to the President.

Presidential Recommendation and Congressional Action

If, after a recommendation by the Secretary, the President considers the site qualified for application to the U.S. Nuclear Regulatory Commission for a construction authorization, the President will submit a recommendation of the site to Congress. The Governor or legislature of Nevada may object to 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 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 did submit 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

Once a site designation became effective, the Secretary of Energy would submit to the Nuclear Regulatory Commission a License Application, based on a particular facility design, for a construction authorization within 90 days. The NWPA requires the Commission to adopt the Final EIS to the extent practicable as part of the 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 baseline for comparison with the Proposed Action. DOE has developed the information about the potential environmental impacts that could result from either the Proposed Action or the No-Action Alternative to inform the Secretary of Energy's determination whether to recommend Yucca Mountain as the site of this Nation's first monitored geologic repository for spent nuclear fuel and high-level radioactive waste. In making that determination, the Secretary would consider not only the potential environmental impacts identified in this EIS, but also other factors as provided in the NWPA.

As part of the Proposed Action, 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, alternative intermodal (rail to truck) transfer station locations, associated heavy-haul truck routes, and alternative rail transport corridors in Nevada. Although it is uncertain at this time when DOE would make any transportation-related decisions, DOE believes that the EIS provides the information necessary to make decisions regarding the basic approaches (for example, mostly rail or mostly truck shipments), as well as the choice among alternative transportation corridors. However, follow-on implementing decisions, such as 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 routes, would require additional field surveys, state and local government consultations, environmental and engineering analyses, and National Environmental Policy Act reviews.

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Purpose and Need for Agency Action

1. PURPOSE AND NEED FOR AGENCY ACTION

Spent nuclear fuel and high-level radioactive waste are long-lived, highly radioactive materials that result from nuclear activities. For more than 50 years these materials have accumulated and continue to accumulate at sites across the United States. Figure 1-1 shows the 72 commercial nuclear power sites and the 5 U.S. Department of Energy (DOE) sites in 35 states that currently store these radioactive materials. Because of their nature, spent nuclear fuel and high-level radioactive waste must be isolated, confined, and monitored for long periods. The United States has focused a national effort on siting and developing a geologic repository for disposal of these materials and on developing systems for transporting the materials from their present storage locations to a repository.

Congress has determined through the passage of the Nuclear Waste Policy Act, as amended (NWPA) (42 USC 10101 *et seq.*), that:

- The Federal Government has the responsibility to dispose of these materials permanently to protect the public health and safety and the environment.
- The Federal Government needs to take precautions to ensure these materials do not adversely affect the public health and safety and the environment for this or future generations.
- The Yucca Mountain site in southern Nevada should be evaluated as a potential location for a monitored geologic repository.

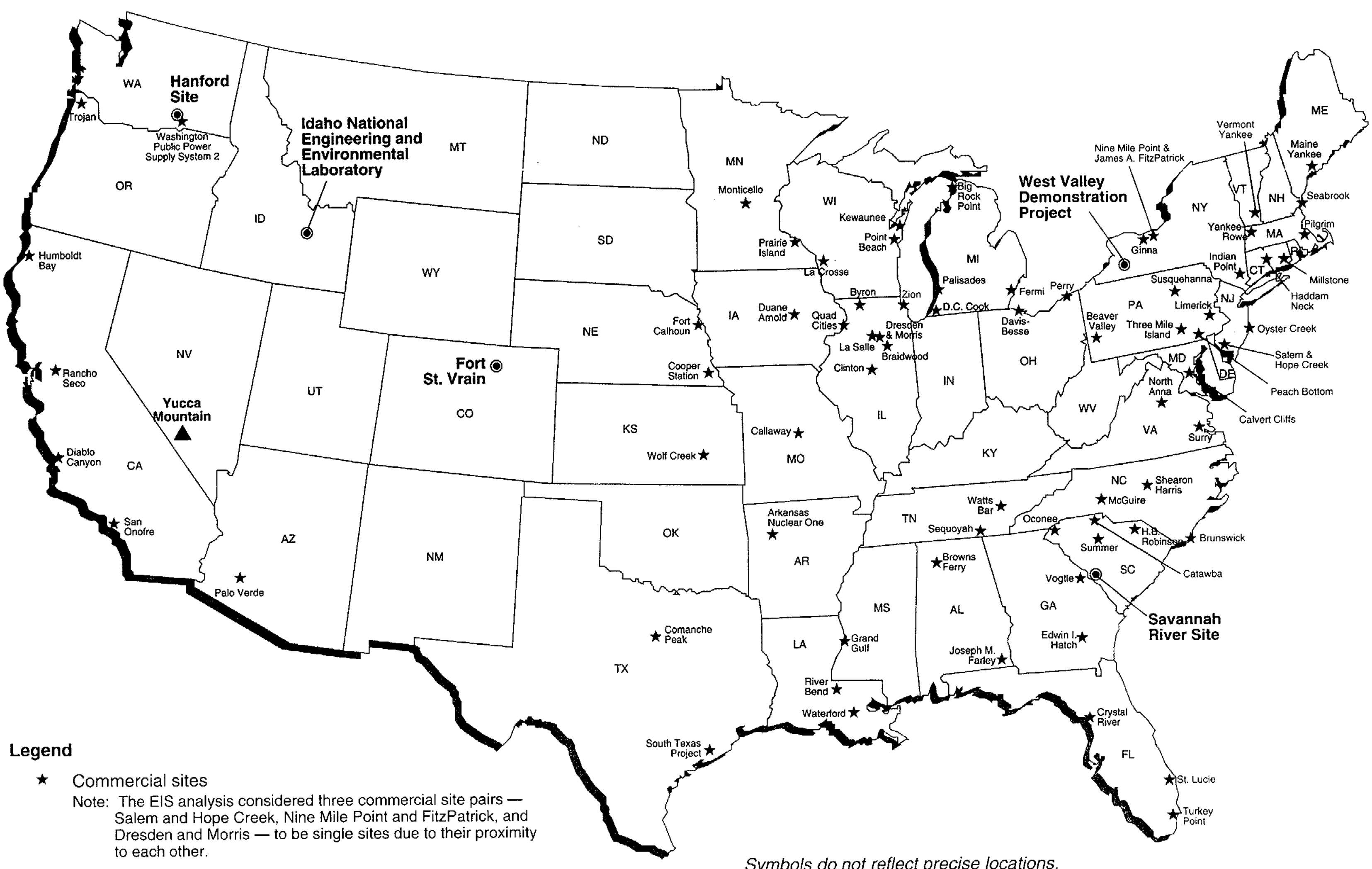
A geologic repository for spent nuclear fuel and high-level radioactive waste is a system for permanently isolating radioactive materials in a deep subsurface location to ensure minimal risk to the health and safety of the public. This environmental impact statement (EIS) addresses actions that DOE proposes to take to develop a repository at Yucca Mountain, and also considers systems for the transportation of spent nuclear fuel and high-level radioactive waste from the 77 sites to the Yucca Mountain site.

ENVIRONMENTAL IMPACT STATEMENT

An *environmental impact statement* or *EIS* is a detailed analysis that addresses a major Federal action that may significantly affect the quality of the human and natural environment. An EIS describes the potential beneficial and adverse environmental effects of the proposed action and alternatives. It is a tool to assist in decisionmaking and provides public disclosure of information.

In addition, DOE has ultimate management responsibility for other highly radioactive materials. Examples of such materials include Greater-Than-Class-C and Special-Performance-Assessment-Required wastes. The Department might need to dispose of these materials in a monitored geologic repository to protect public health and safety. However, disposal of Greater-Than-Class-C and Special-Performance-Assessment-Required wastes at the proposed Yucca Mountain Repository could require additional legislative action or a determination by the U.S. Nuclear Regulatory Commission to classify them as high-level radioactive waste.

Section 1.1 describes potential actions and decisions concerning the proposed repository. Section 1.2 provides an overview of spent nuclear fuel and high-level radioactive waste. Section 1.3 describes the major steps in the process Congress has established for evaluations and decisions concerning the Yucca Mountain site. Section 1.4 provides an overview of the site, potential transportation systems for moving spent fuel and radioactive waste to the site, and studies of the site. Section 1.5 presents information on the EIS process as it applies to the proposal for a monitored geologic repository at Yucca Mountain.



Legend

★ Commercial sites

Note: The EIS analysis considered three commercial site pairs — Salem and Hope Creek, Nine Mile Point and FitzPatrick, and Dresden and Morris — to be single sites due to their proximity to each other.

◉ DOE sites

Note: The EIS analysis included the high-level radioactive waste and spent nuclear fuel at West Valley. The State of New Yorkowns the high-level radioactive waste and the site. Under the West Valley Demonstration Project Act, DOE is responsible for solidifying and transporting the high-level radioactive waste off the West Valley site. DOE owns and is responsible for the spent nuclear fuel at the site.

Source: Modified from DOE (1998a, Overview, page 5).

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

1.1 Potential Actions and Decisions Regarding the Proposed Repository

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 baseline for comparison with the Proposed Action. DOE has developed the information about the potential environmental impacts that could result from either the Proposed Action or the No-Action Alternative to inform the Secretary of Energy's determination whether to recommend Yucca Mountain as the site of this Nation's first monitored geologic repository for spent nuclear fuel and high-level radioactive waste. In making that determination, the Secretary would consider not only the potential environmental impacts identified in this EIS, but also other factors as provided in the NWPA.

PROPOSED REPOSITORY

DOE has used the term *proposed repository* as a term of convenience to indicate the relationship of the Yucca Mountain Repository to the Proposed Action of this EIS. DOE could not pursue the use of Yucca Mountain as a repository until the Secretary of Energy decided whether to recommend approval of the site to the President and a Presidential site designation has become effective. At that time DOE would submit a License Application to the Nuclear Regulatory Commission seeking authorization to construct a repository at Yucca Mountain.

As part of the Proposed Action, 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, alternative intermodal (rail to truck) transfer station locations, associated heavy-haul truck routes, and alternative rail transport corridors in Nevada. Although it is uncertain at this time when DOE would make any transportation-related decisions, DOE believes that the EIS provides the information necessary to make decisions regarding the basic approaches (for example, mostly rail or mostly truck shipments), as well as the choice among alternative transportation corridors. However, follow-on implementing decisions, such as 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 routes, would require additional field surveys, state and local government consultations, environmental and engineering analyses, and National Environmental Policy Act reviews.

1.2 Radioactive Materials Considered for Disposal in a Monitored Geologic Repository

Commercial nuclear powerplants, which supply approximately 20 percent of the Nation's electricity, produce spent nuclear fuel. In addition, DOE manages a complex of large government-owned facilities that formerly produced nuclear weapons materials, and in doing so produced spent nuclear fuel and high-level radioactive waste. DOE also operates research reactors that produce spent nuclear fuel and processing facilities that produce high-level radioactive waste.

The following discussion describes spent nuclear fuel and high-level radioactive waste, including mixed-oxide fuel (a mixture of uranium oxide and plutonium oxide that could be used to power commercial nuclear reactors) and immobilized plutonium forms. The discussion also identifies other waste forms, particularly Greater-Than-Class-C wastes and Special-Performance-Assessment-Required wastes, that are currently classified as low-level radioactive wastes but that could require disposal in a monitored geologic repository.

1.2.1 GENERATION OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE

The material used to power commercial nuclear reactors typically consists of cylindrical fuel pellets made of uranium oxide. Fuel pellets are placed in tubes that are ordinarily about 3.7 meters (12 feet) long and 0.64 centimeter (0.25 inch) in diameter. Sealed tubes with fuel pellets inside them are called fuel rods (Appendix A). Fuel rods are arranged in bundles called fuel assemblies (see Figure 1-2), which are placed in a reactor.

In the reactor, neutrons from the fuel strike other uranium atoms, causing them to split into parts, and producing heat, radioactive fission products, and more free neutrons. This splitting of atoms is a form of nuclear reaction called *fission*. The neutrons produced by the fission process sustain the nuclear reaction by striking other uranium atoms in the fuel pellets, causing additional atoms to split. Control of the configuration and machinery associated with the fuel assemblies provides control of the rate at which fission occurs and, consequently, the amount of heat produced.

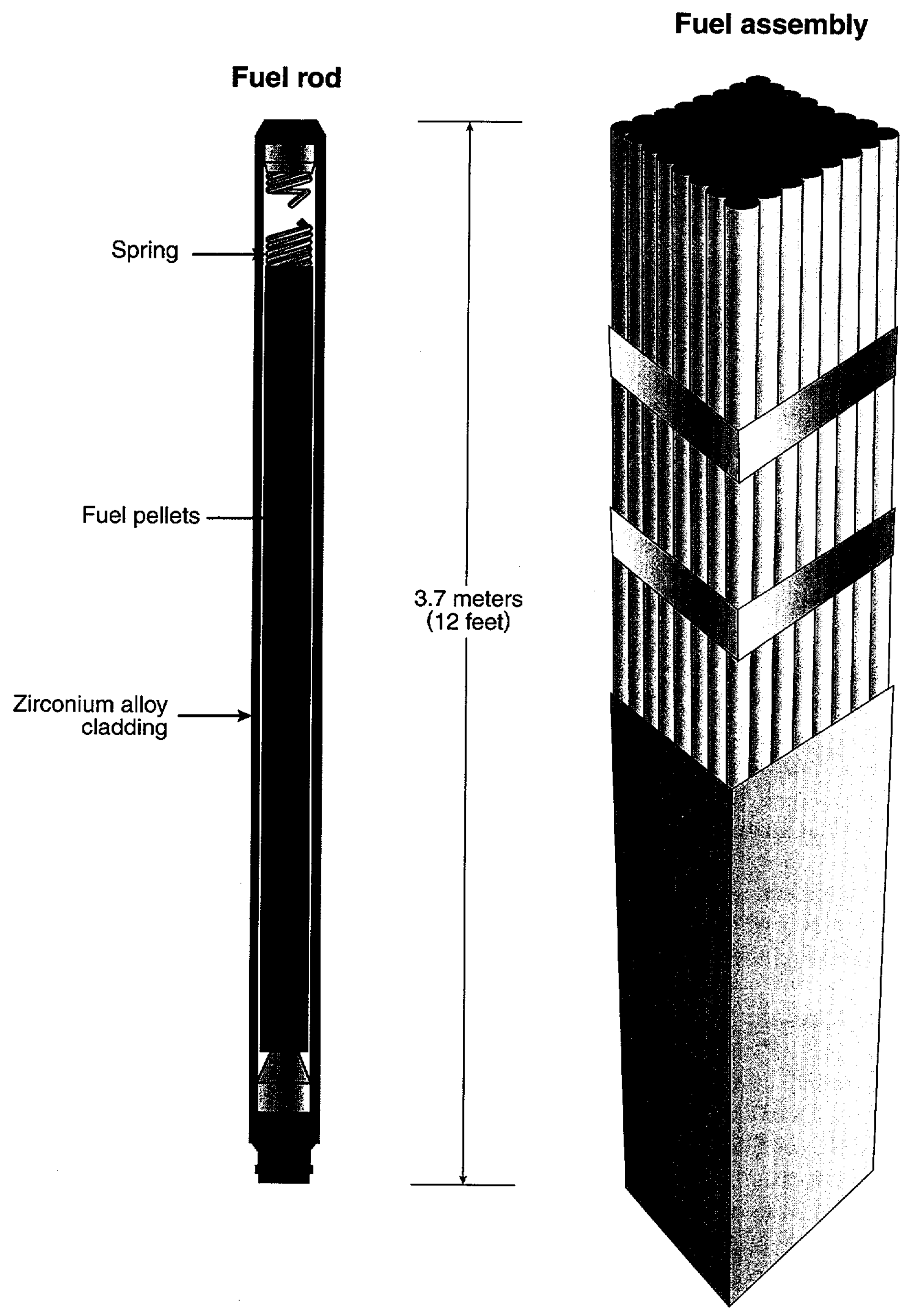
In a commercial power reactor, the heat that fission produces is used to convert water to steam. The steam turns turbine generators to produce electric energy. The reactors that power many naval vessels use the steam primarily to turn turbines to provide ship propulsion. Some research reactors also use the steam produced to generate electricity.

After a period in operation, enough of the fissile uranium atoms have undergone fission that the fuel is said to be "spent"; some of these spent nuclear fuel assemblies must be replaced with fresh fuel for operation to continue. During replacement, fresh fuel is placed in the reactor and spent fuel is placed in a pool of water. In commercial reactors, typical fuel cycles run 18 to 24 months, after which 25 to 50 percent of the spent nuclear fuel is replaced.

Nuclear reactor operators initially store spent nuclear fuel under water in spent fuel pools because of high levels of radioactivity and heat from decay of radionuclides. When the fuel has cooled and decayed sufficiently, operators can use two storage options: (1) continued in-pool storage or (2) above-ground dry storage in an independent installation. Twenty-six sites have existing or planned independent above-ground dry storage facilities. Dry storage includes the storage of spent nuclear fuel at reactor sites in approved storage casks.

Beginning in 1944, the United States operated reactors to produce materials such as plutonium for nuclear weapons. All of these reactors have been shut down for several years. When defense plutonium production reactors were operating, they used a controlled fission process to irradiate nuclear fuel and generate plutonium. DOE used chemical processes (called *reprocessing*) to extract plutonium and other materials from spent nuclear fuel for defense purposes. One of the chemical byproducts remaining after reprocessing is high-level radioactive waste. The reprocessing of limited quantities of naval reactor fuels and some commercial reactor fuels, DOE test reactor fuels, and university research reactor fuels has also produced high-level radioactive waste.

Concerns about safety and environmental hazards contributed to DOE decisions to shut down parts of the weapons production complex in the 1980s. The shutdown, which became permanent due primarily to the reduced need for weapons materials at the end of the Cold War, included both production reactors and



Source: Modified from DOE (1995a, page 1-3).

Figure 1-2. Typical nuclear fuel assembly and rod.

spent fuel reprocessing facilities. As a result, not all DOE spent nuclear fuel was reprocessed. Some of this fuel is now stored at DOE sites.

1.2.2 SPENT NUCLEAR FUEL

Spent nuclear fuel consists of nuclear fuel that has been withdrawn from a nuclear reactor following irradiation, provided that the constituent elements of the fuel have not been separated by reprocessing. Commercial spent nuclear fuel comes from nuclear reactors operated to produce electric power for domestic use. DOE manages spent nuclear fuel from DOE defense production reactors, U.S. naval reactors, and DOE test and experimental reactors, as well as fuel from university research reactors, commercial reactor fuel acquired by DOE for research and development, and fuel from foreign research reactors. Most nuclear fuel is encased in highly corrosion-resistant cladding before being placed in a reactor. The fuel remains in the cladding after it is irradiated and withdrawn as spent nuclear fuel. The purpose of the cladding is to protect its contents in operating conditions associated with a reactor, which can reach temperatures of around 370°C (700°F) and pressures of 1.4 million kilograms per square meter (2,000 pounds per square inch) (Appendix A). Cladding, if it is not damaged or corroded, has the capability to isolate the spent nuclear fuel and delay the release of radionuclides to the environment for long periods.

Spent nuclear fuel is intensely radioactive in comparison to nonirradiated fuel and would be the primary source of radioactivity and heat generation in the proposed repository.

1.2.2.1 Commercial Spent Nuclear Fuel

Commercial spent nuclear fuel typically consists of uranium oxide fuel (which also contains actinides, fission products, and other materials), the cladding that contains the fuel, and the assembly hardware. The cladding for nuclear fuel assemblies is normally made of a zirconium alloy. However, about 1 percent of the spent nuclear fuel included in the Proposed Action is clad in stainless steel (Appendix A).

The sources of commercial spent nuclear fuel are the commercial nuclear powerplants throughout the United States. Figure 1-1 shows the locations of these sites. Appendix A, Section A.2.1, provides details on spent nuclear fuel and discusses the amount currently stored and projected to be stored at each site. Mixed-oxide fuel would be part of the commercial spent nuclear fuel inventory for the proposed repository. Section 1.2.4 includes a discussion of mixed-oxide fuel.

1.2.2.2 DOE Spent Nuclear Fuel

DOE spent nuclear fuel, like commercial spent nuclear fuel, has been withdrawn from a reactor following irradiation. Much of the DOE spent nuclear fuel is associated with past operations of reactors at the Hanford and Savannah River Sites that previously produced material for DOE's defense programs and research and development programs. These reactors are no longer operating. Smaller quantities of spent nuclear fuel have resulted from experimental reactor operations and from research conducted by approximately 55 university- and government-owned test reactors. DOE spent nuclear fuel also includes spent fuel from reactors on nuclear-powered naval vessels and naval reactor prototypes.

DOE stores most of its spent nuclear fuel in pools or dry storage facilities at three primary locations: the Hanford Site in Washington State, the Idaho National Engineering and Environmental Laboratory in Idaho, and the Savannah River Site in South Carolina. Some DOE spent nuclear fuel is currently stored at the Fort St. Vrain dry storage facility in Colorado and the West Valley site in New York, a site presently owned by the New York State Energy Research and Development Authority (see Figure 1-1). Additional small quantities remain at other locations. With the exception of Fort St. Vrain, which will retain its spent nuclear fuel in dry storage until disposition, DOE plans to ship all of the spent nuclear fuel for which it is responsible from other sites to one of the three primary locations mentioned above for storage and preparation for ultimate disposition [discussed in DOE (1995b, all)]. This EIS does not analyze consolidation of spent nuclear fuel at DOE sites (see DOE 1995a, all). Appendix A, Section A.2.2, provides details on DOE spent nuclear fuel and discusses the amount currently stored and projected to be stored at each site.

1.2.3 HIGH-LEVEL RADIOACTIVE WASTE

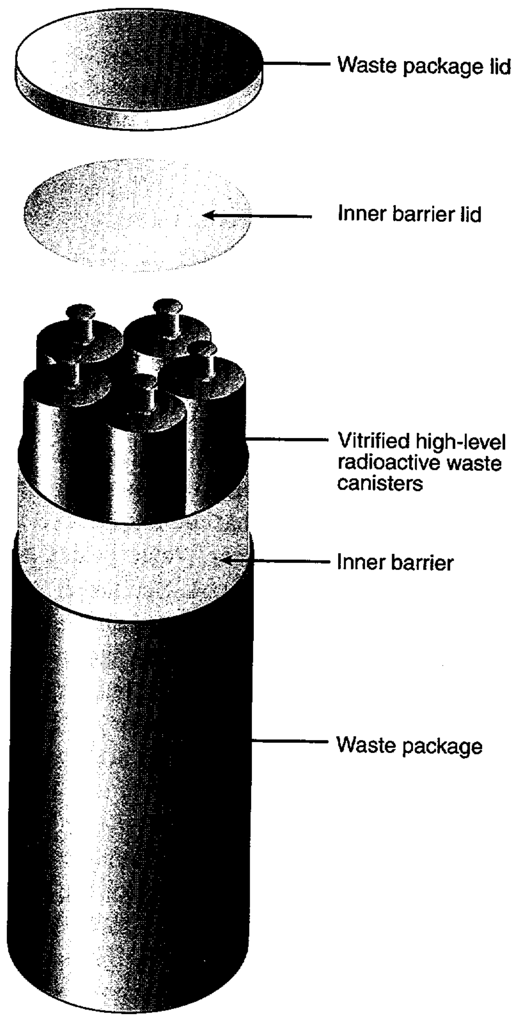
DOE stores high-level radioactive waste in below-grade tanks at the Hanford Site, the Savannah River Site, the Idaho National Engineering and Environmental Laboratory, and West Valley (see Figure 1-1 for locations). High-level radioactive waste can be in a liquid, sludge, or saltcake form, and a solid immobilized glass form (see below). Liquid waste consists of water and organic compounds that contain dissolved salts. Sludge is a mixture of insoluble (that is, materials that will not dissolve in tank liquid) metallic salt compounds that precipitated and settled out of the solution after the waste became alkaline. Saltcake is primarily sodium and aluminum salt that crystallized from the solution following evaporation. High-level radioactive waste can also include other highly radioactive material that the Nuclear Regulatory Commission determines by rule to require permanent isolation (Nuclear Waste Policy Act definitions, Section 12), as well as immobilized plutonium waste forms. Appendix A, Section A.2.3, provides details on high-level radioactive waste and discusses the amount currently stored and projected to be stored at each site. Included in this total is immobilized high-level radioactive waste that would result from the proposed electrometallurgic treatment of DOE sodium-bonded nuclear fuel at Argonne National Laboratory-West on the Idaho National Engineering and Environmental Laboratory site. DOE is preparing an EIS (64 *FR* 8553, February 22, 1999) to help it decide the disposition of this sodium-bonded fuel.

The DOE process for preparing high-level radioactive waste for disposal starts with the transfer of the waste from storage tanks to a treatment facility. Treatment ordinarily includes separation of the waste into high-activity and low-activity fractions, followed by vitrification of the high-activity fraction. Vitrification involves adding materials to the waste and heating the mixture until it melts. The melted mixture is poured into canisters, where it cools into a solid glass or ceramic form that is very resistant to the leaching of radionuclides. The solidified, immobilized glass forms have been developed to keep the waste stable, confined, and isolated from the environment when inserted into disposal containers and disposed of in a monitored geologic repository. DOE will store the solidified high-level radioactive waste on the sites in canisters (see Figure 1-3) before eventual shipment to a repository.

DOE has begun to solidify and immobilize waste at the Savannah River Site and West Valley and plans to begin solidification and immobilization at Hanford. DOE is preparing an EIS (62 *FR* 49209, September 19, 1997) to help it determine the method it will use to solidify and immobilize high-level radioactive waste at the Idaho National Engineering and Environmental Laboratory.

1.2.4 SURPLUS WEAPONS-USABLE PLUTONIUM

DOE has declared 50 metric tons (55 tons) of weapons-usable plutonium to be surplus to national security needs. This material includes purified plutonium, nuclear weapons components, and materials and residues that could be processed to produce purified plutonium (Appendix A). DOE currently stores these plutonium-containing materials at the Pantex Plant, the Rocky Flats Environmental Technology Site, the Savannah River Site, the Hanford Site, the Idaho National Engineering and Environmental Laboratory, and the Oak Ridge, Los Alamos, and Lawrence Livermore National Laboratories.



Source: Modified from (DOE 1998a, Volume 3 Figure 2-3, page 2-12).

Figure 1-3. Vitrified high-level radioactive waste canisters in waste package.

DOE could emplace surplus weapons-usable plutonium in the repository in two forms. One form would be an immobilized plutonium ceramic that DOE would dispose of as high-level radioactive waste. The second form would be mixed uranium and plutonium oxide fuel (called mixed-oxide fuel) assemblies that would be used for power production in commercial nuclear reactors and disposed of in the same manner as other commercial spent nuclear fuel. The analysis in this EIS assumed that approximately 18 metric tons (20 tons) of surplus plutonium would be immobilized plutonium and approximately 32 metric tons (35 tons) would be mixed-oxide spent nuclear fuel (Appendix A). The final waste forms would be immobilized plutonium and spent mixed-oxide fuel. The actual split could include the immobilization of between 18 and 50 metric tons (20 and 55 tons). Appendix A, Section A.2.4, contains details on sources, generation and storage status, and material characteristics of this surplus plutonium, and other high-level radioactive waste forms (for example, electrometallurgically treated sodium-bonded fuel).

1.2.5 OTHER WASTE TYPES WITH HIGH RADIONUCLIDE CONTENT

The Nuclear Regulatory Commission classifies most low-level radioactive waste into Classes A, B, and C (10 CFR Part 61), which reflect increasing levels of radioactivity. *Greater-Than-Class-C* is the term for radioactive waste generated by commercial activities that exceeds Nuclear Regulatory Commission concentration limits for Class C waste, as specified in 10 CFR Part 61. The Nuclear Regulatory Commission has determined that shallow land burial of Greater-Than-Class-C low-level radioactive waste generally is not acceptable. *Special-Performance-Assessment-Required* waste is DOE-generated low-level radioactive waste with radioactive content higher than Class C shallow land disposal limits.

1.3 National Effort To Manage Spent Nuclear Fuel and High-Level Radioactive Waste

This section provides background information on the management of spent nuclear fuel and high-level radioactive waste, and describes the Nuclear Waste Policy Act and its amendments.

1.3.1 BACKGROUND

In the late 1950s, active investigation began on the concept of mined geologic repositories for the disposal of spent nuclear fuel and high-level radioactive waste. In the 1970s, the United States reprocessed a small amount of commercial spent nuclear fuel to extract plutonium and studied the feasibility of expanded reprocessing. The plutonium would have been combined with uranium and used again as reactor fuel, substantially reducing the total amount of new enriched uranium required (NRC 1976, all). President Carter cancelled consideration of this approach, leaving disposal as a primary option for spent nuclear fuel.

In a February 12, 1980, message to Congress, President Carter stated that the safe disposal of radioactive materials generated by both defense and civilian nuclear activities is a national responsibility. In fulfillment of that responsibility, he announced a comprehensive program for the management of radioactive materials and adopted an interim planning strategy focusing on "the use of mined geologic repositories capable of accepting both waste from reprocessing and unreprocessed commercial spent fuel" (DOE 1980, page 2.7). President Carter stated that he would reexamine this interim strategy and decide if changes were required after the completion of the environmental reviews required by the National Environmental Policy Act. As part of this reexamination, DOE issued the *Final Environmental Impact Statement, Management of Commercially Generated Radioactive Waste* (DOE 1980, all). That EIS analyzed the environmental impacts that could occur if DOE developed and implemented various technologies for the management and disposal of spent nuclear fuel and high-level radioactive waste. It examined several alternatives, including mined geologic disposal, very deep hole disposal, disposal in a mined cavity that resulted from rock melting, island-based geologic disposal, subseabed disposal, ice sheet disposal, well injection disposal, transmutation, space disposal, and no action. The 1981 Record of Decision for that EIS announced the DOE decision to pursue the mined geologic disposal alternative for the disposition of spent nuclear fuel and high-level radioactive waste (46 *FR* 26677, May 14, 1981).

1.3.2 NUCLEAR WASTE POLICY ACT

In 1982, Congress enacted the Nuclear Waste Policy Act (Public Law 97-425; 96 Stat 2201), which acknowledged the Federal Government's responsibility to provide permanent disposal of the nation's spent nuclear fuel and high-level radioactive waste, and established the Office of Civilian Radioactive Waste Management, which has the responsibility to carry out the evaluative, regulatory, developmental, and operational activities the Act assigns to the Secretary of Energy. The Nuclear Waste Policy Act began a process for selecting sites for technical study as potential geologic repository locations. In accordance with this process (shown in Figure 1-4), 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 in May 1986. DOE recommended three of the five sites (Deaf Smith County, the Hanford Site, and Yucca Mountain) for possible study as repository site candidates, and President Reagan approved the three as candidates. In addition, the Nuclear Waste Policy Act recognized a need to ensure that spent nuclear fuel and high-level radioactive waste now accumulating at commercial and DOE sites do not adversely affect public health and safety and the environment [NWPA, Section 111(a)(7)].

In 1987, Congress significantly amended the Nuclear Waste Policy Act. This Act, as amended (42 USC 10101 *et seq.*), which this EIS refers to as the NWPA, identified one of the three Presidentially approved candidate sites, Yucca Mountain, as the only site to be studied as a potential location for a geologic repository. Congress directed the Secretary of Energy to study the Yucca Mountain site and recommend whether the President should approve the site for development as a repository. Congress also required that a Final EIS accompany a Secretarial recommendation to approve the Yucca Mountain site to the President [NWPA, Section 114(a)(1)]. DOE is preparing this EIS to fulfill that requirement.

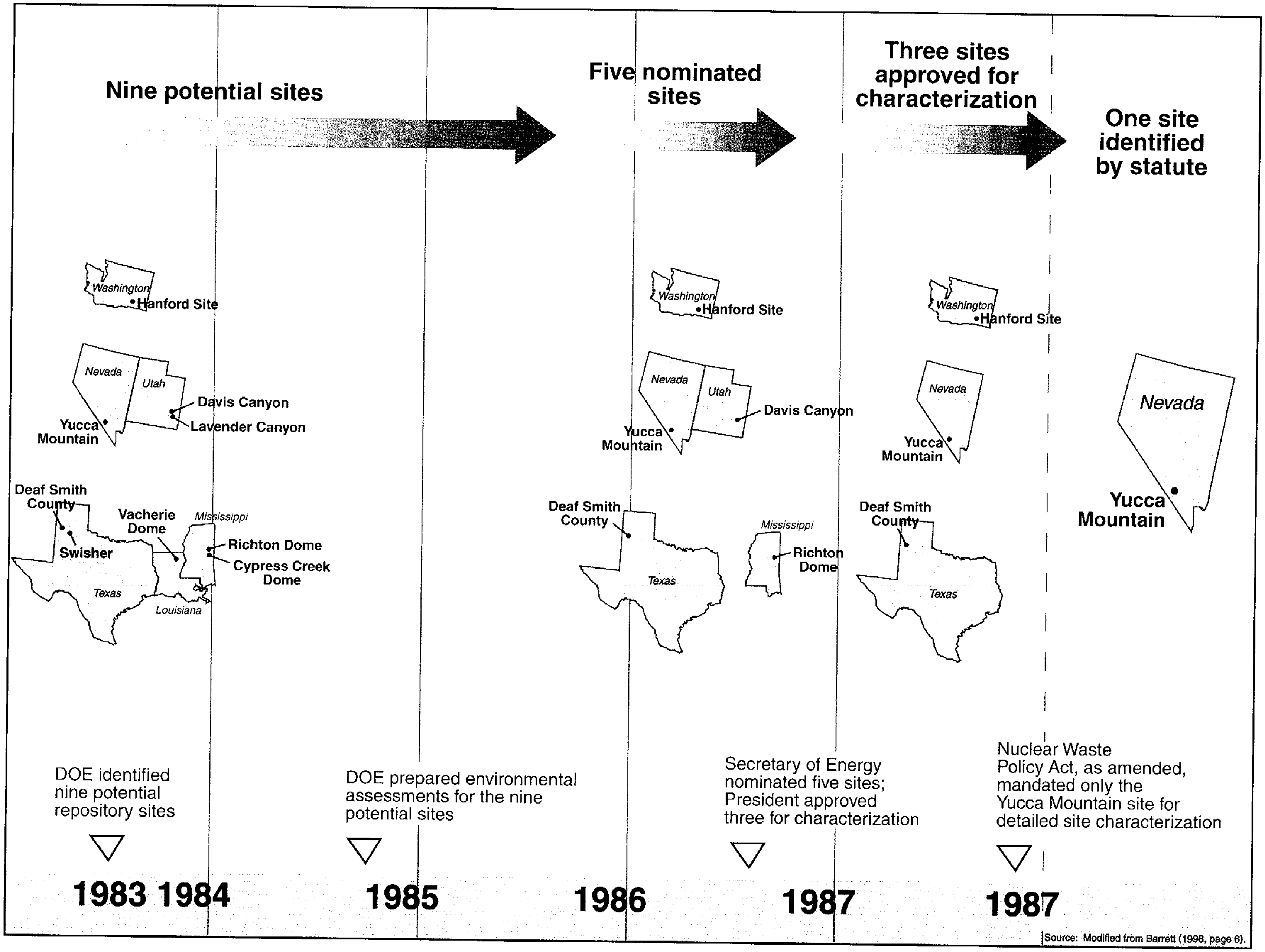


Figure 1-4. Events leading to selection of Yucca Mountain for study.

1.3.2.1 Requirement To Study and Evaluate the Site

In addition to the general responsibilities it establishes, the NWPA requires the Secretary of Energy specifically to characterize and evaluate the Yucca Mountain site for a geologic repository. The Act directs the Secretary of Energy to characterize only the Yucca Mountain site as a potential repository location and establishes a decisionmaking process to determine whether to designate Yucca Mountain as qualified for an application for repository construction authorization (NWPA, Sections 113, 114, 115, and 160).

Congress created the Nuclear Waste Technical Review Board as an independent organization to evaluate the technical and scientific validity of site characterization activities for the proposed repository and activities related to the packaging and transportation of spent nuclear fuel and high-level radioactive waste (NWPA, Section 503). The Nuclear Waste Technical Review Board must report findings, conclusions, and recommendations based on its evaluations to Congress and to the Secretary of Energy at least twice each year (NWPA, Section 508).

1.3.2.2 Elements of Site Evaluation

Sections 113, 114, and 115 of the NWPA contain specific and mostly sequential steps in the evaluation and decisionmaking process Congress has established for the Yucca Mountain site. The rest of this section and Section 1.3.2.3 describe that process.

The first steps in the evaluation and decisionmaking process for the Yucca Mountain site require the Secretary of Energy and, by extension, DOE, to gather data about Yucca Mountain and evaluate whether to recommend Yucca Mountain for approval as the site for a license application to the Nuclear Regulatory Commission for repository development. The Secretary's specific duties include:

- Undertake physical characterization of the Yucca Mountain site.
- Hold public hearings in the Yucca Mountain site vicinity.
- Prepare a description of the site, of spent nuclear fuel and high-level radioactive waste forms and packaging to be used, and of site safety.
- Make a recommendation to the President on whether to approve the site for development as a repository.

Section 1.4.3.3 describes the elements that the Secretary of Energy must develop and consider in making a site recommendation to the President and in providing a statement of the basis for that recommendation.

The NWPA directs the Secretary of Energy to evaluate a scenario under which DOE would place an inventory of material in the proposed Yucca Mountain Repository. This EIS considers a repository inventory of 70,000 metric tons of heavy metal (MTHM) comprised of 63,000 MTHM of commercial spent nuclear fuel and 7,000 MTHM of DOE spent nuclear fuel and high-level radioactive waste. This overall inventory includes approximately 50 metric tons (55 tons) of surplus weapons-usable plutonium as spent mixed-oxide fuel and immobilized plutonium. Appendix A provides additional details of the inventory of materials.

To determine the number of canisters of high-level radioactive waste included in the Proposed Action waste inventory, DOE used 0.5 MTHM per canister of defense high-level radioactive waste. DOE has used the 0.5-MTHM-per-canister approach since 1985. Using a different approach would change the number of canisters of high-level radioactive waste in the Proposed Action. Regardless of the number of canisters, the impacts of the analysis would not significantly change because long-term repository performance results would be dominated by the spent nuclear fuel inventory. In addition, the EIS analyzes the impacts from the entire inventory of high-level radioactive waste in the cumulative impacts analysis.

Operating nuclear powerplants could generate approximately 105,000 MTHM through 2046. The total projected DOE inventory of materials includes 2,500 MTHM of spent nuclear fuel and approximately 22,280 canisters of high-level radioactive waste. Chapter 8 evaluates potential consequences of using a repository at Yucca Mountain to dispose of all spent nuclear fuel and high-level radioactive waste that could be produced through 2046 for which DOE retains ultimate responsibility.

1.3.2.3 Site Qualification and Authorization Process

The Nuclear Waste Policy Act, enacted by Congress in 1982 and amended in 1987, 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.
- Prepare an EIS.
- Decide whether to recommend approval of the development of a geologic repository at Yucca Mountain to the President.

The Nuclear Waste Policy Act, as amended (the EIS refers to the amended Act as the NWPA), also requires DOE to hold hearings to provide the public in the vicinity of Yucca Mountain with opportunities to comment on the Secretary's possible recommendation of the Yucca Mountain site to the President. These hearings would be separate from the public hearings on the Draft EIS required under the National Environmental Policy Act. If, after completing the hearings and site characterization activities, the Secretary decides to recommend that the President approve the site, the Secretary will 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.

If the Secretary recommends the Yucca Mountain site to the President, a comprehensive statement of the basis for the recommendation, including the Final EIS, will accompany the recommendation. This Draft EIS has been prepared now so that DOE can consider the Final EIS, including the public input on the Draft EIS, in making a decision on whether to recommend the site to the President.

If, after the recommendation by the Secretary, the President considers the site qualified for an application to the Nuclear Regulatory Commission for a construction authorization, the President will submit a recommendation of the site to Congress. The Governor or legislature of Nevada may object to 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 a notice within the 60-day period, the site designation would become effective without further action by the President or Congress. However, if the Governor or the legislature did submit 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.

If the site designation became effective, the Secretary of Energy would submit to the Nuclear Regulatory Commission a License Application, based on a particular facility design, for a construction authorization no later than 90 days after the designation. The NWPA requires the Commission to adopt the Final EIS to the extent practicable as part of the Commission's decisionmaking on the License Application.

1.3.2.4 Environmental Protection and Approval Standards for the Yucca Mountain Site

Section 121 of the Nuclear Waste Policy Act of 1982 directed the U.S. Environmental Protection Agency to establish generally applicable standards to protect the general environment from offsite releases from radioactive materials in repositories and directed the Nuclear Regulatory Commission to issue technical requirements and criteria for such repositories. In 1992, Congress modified the rulemaking authorities of the Environmental Protection Agency and the Nuclear Regulatory Commission in relation to a possible repository at Yucca Mountain. Section 801(a) of the Energy Policy Act of 1992 directed the Environmental Protection Agency to retain the National Academy of Sciences to conduct a study and issue findings and recommendations on setting reasonable standards for protecting public health and safety in relation to a repository at Yucca Mountain. Section 801(a) also directs the Environmental Protection Agency to establish Yucca Mountain-specific standards based on and consistent with the Academy's findings and recommendations. The standards will set health-based limits for any radioactive releases from a repository at Yucca Mountain. The National Academy of Sciences issued its findings and recommendations in a 1995 report (National Research Council 1995, all). The Environmental Protection Agency is in the process of establishing standards and is expected to place them in the Code of Federal Regulations (probably at 40 CFR Part 197). Chapter 11 contains a more detailed discussion of applicable regulations and other requirements.

Section 801(b) of the Energy Policy Act directs the Nuclear Regulatory Commission to revise its general technical requirements and criteria for geologic repositories (10 CFR Part 60) to be consistent with the Environmental Protection Agency site-specific Yucca Mountain standards. The Nuclear Regulatory Commission has issued draft site-specific technical requirements and criteria (proposed 10 CFR Part 63). The Commission would use these requirements and criteria, when final, to evaluate an application to construct a repository at Yucca Mountain, to receive and possess spent nuclear fuel and high-level radioactive waste at such a repository, and to close and decommission such a repository.

The Nuclear Waste Policy Act of 1982 required the Secretary of Energy to issue general guidelines for use in recommending potential repository sites for detailed site characterization. DOE issued these guidelines in 1984 (10 CFR Part 960). DOE is issuing this EIS before the Environmental Protection Agency and the Nuclear Regulatory Commission have completed their rulemaking processes and before DOE has determined whether to modify 10 CFR Part 960. The EIS provides current information on the proposed repository and presents an evaluation of the repository site, potential repository development, and anticipated repository performance measured against human health and other relevant technical criteria. DOE intends the results of the EIS evaluation to be useful for decisionmakers and to enhance the understanding and knowledge of members of the public.

1.4 Yucca Mountain Site and Proposed Repository

Spent nuclear fuel and high-level radioactive waste generate large amounts of radiation from the gradual decay of radioactive isotopes. These isotopes have the potential to cause severe human health impacts. In addition, the materials can generate heat from radioactive decay for periods lasting thousands of years. The Nuclear Waste Policy Act directs DOE to analyze and consider the disposal of spent nuclear fuel and high-level radioactive waste in a geologic repository.

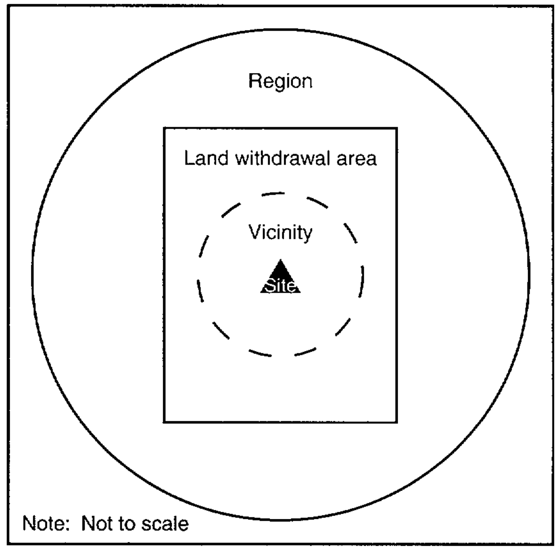
SITE-RELATED TERMS

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.



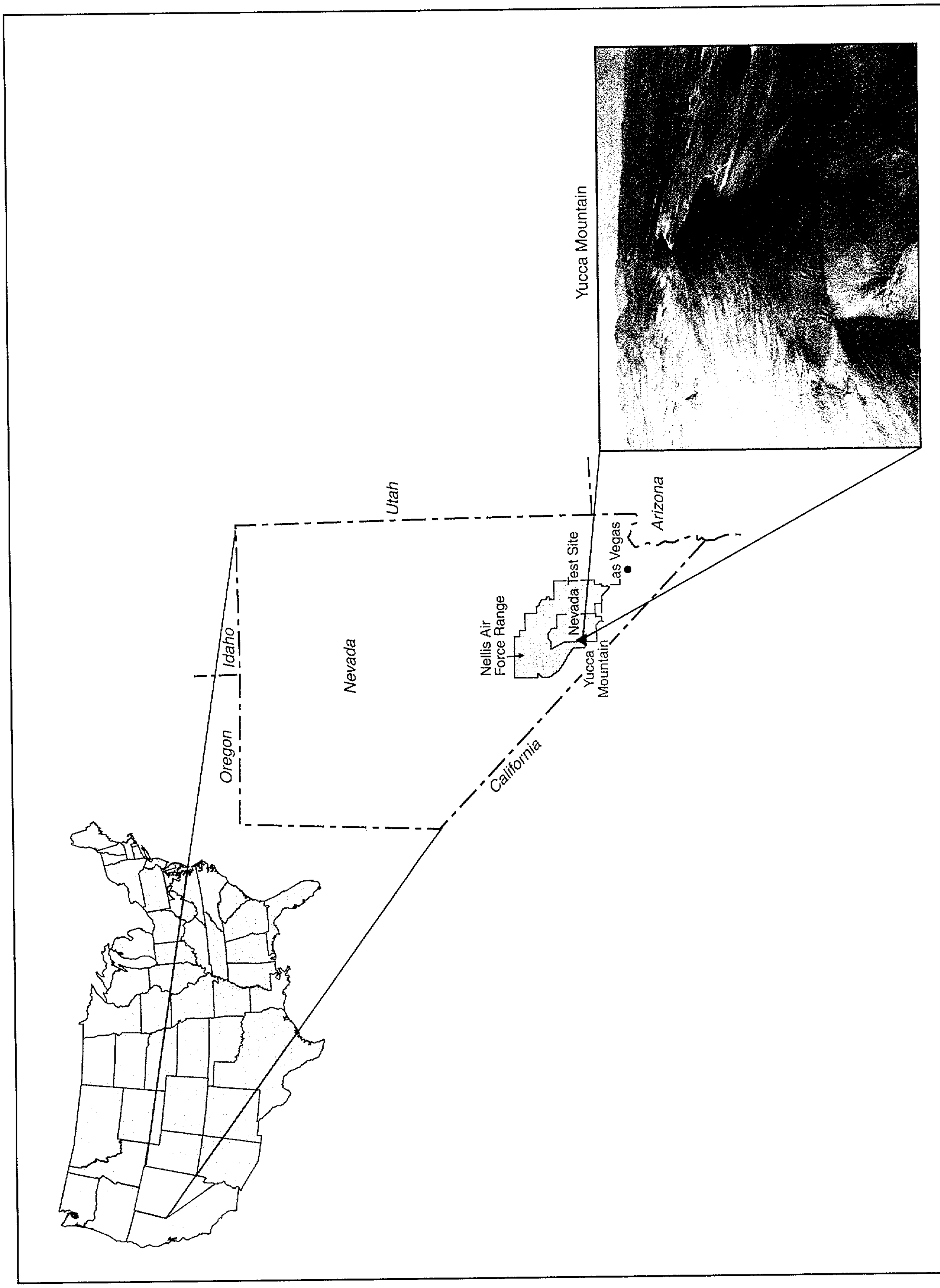
1.4.1 YUCCA MOUNTAIN SITE

The site of the proposed Yucca Mountain Repository (see Figure 1-5) is on lands administered by the Federal Government in a remote area of the Mojave Desert in Nye County in southern Nevada, approximately 160 kilometers (100 miles) northwest of Las Vegas, Nevada. The area surrounding the site is sparsely populated and receives an average of about 170 millimeters (7 inches) of precipitation per year. Chapter 3, Section 3.1, provides detailed information on the environment at the site.

The land withdrawal area analyzed in the EIS includes about 600 square kilometers (230 square miles or 150,000 acres) of land currently under the control of DOE, the U.S. Department of Defense, and the U.S. Department of the Interior (see Figure 1-6). Approximately 3.5 square kilometers (1.4 square miles or 870 acres) comprising the repository site would be needed for development of surface repository facilities, with the remainder serving as a large buffer zone. If Yucca Mountain is recommended for development as a repository, all or a portion of the land withdrawal area would have to be withdrawn permanently from public access to satisfy Nuclear Regulatory Commission licensing requirements currently at 10 CFR 60.121. If the land to be withdrawn included land that this EIS does not consider for withdrawal, DOE would perform additional analysis as required by the National Environmental Policy Act.

1.4.2 PROPOSED DISPOSAL APPROACH

The proposed monitored geologic repository at Yucca Mountain would be a large underground excavation with a network of *drifts* (tunnels) serving as the emplacement area for spent nuclear fuel and high-level radioactive waste. Rail, legal-weight trucks, or heavy-haul trucks would provide most of the transportation of spent nuclear fuel and high-level radioactive waste from the present storage sites to the repository. Barges could move spent nuclear fuel from some sites to rail and truck transfer points. Shippers would transport the materials in Nuclear Regulatory Commission-approved shipping containers designed to transport radioactive materials with minimal risk to the public health and safety and to the



Source: Modified from DOE (1998a, Overview, pages 10 and 11).

Figure 1-5. Yucca Mountain location.

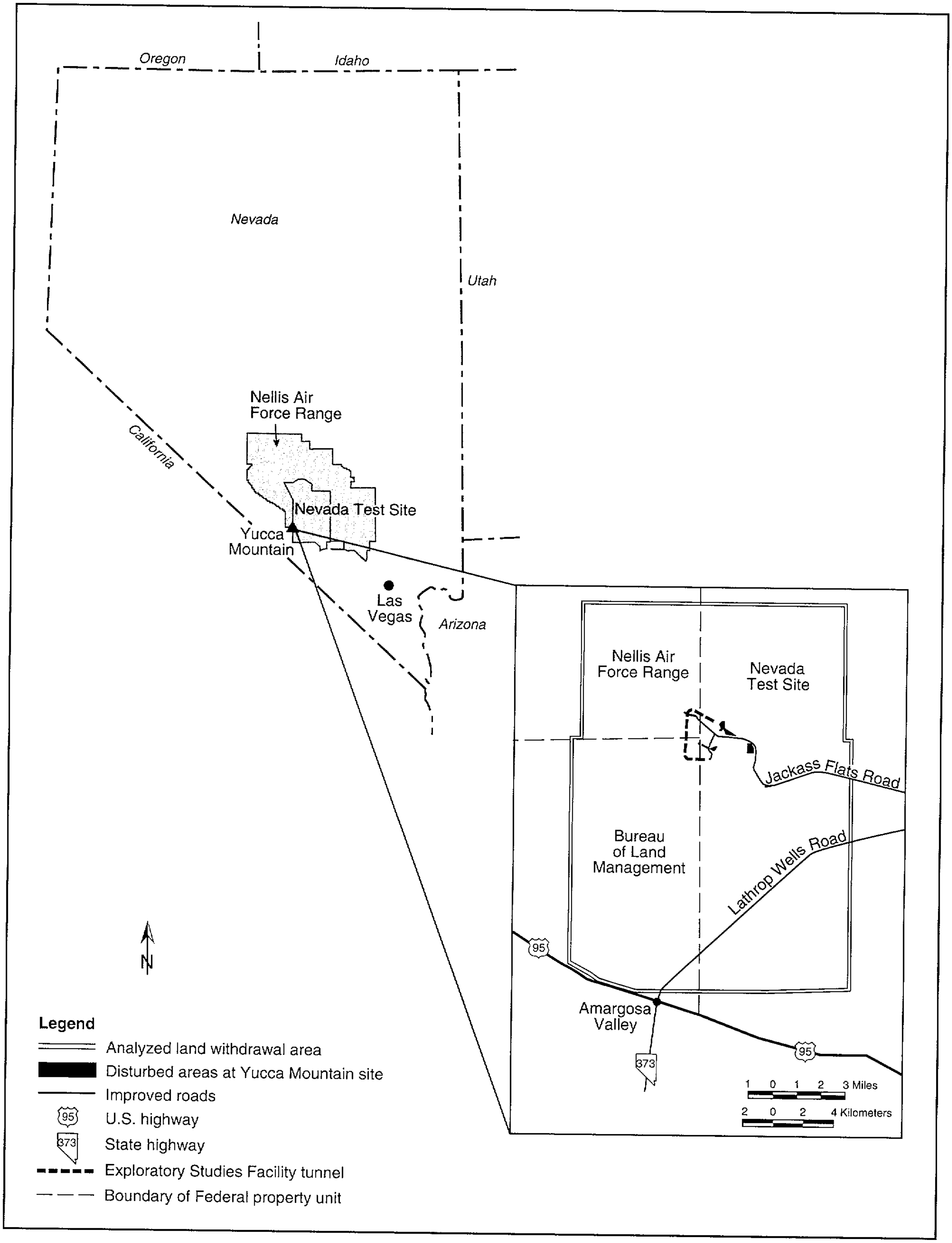


Figure 1-6. Land withdrawal area used for analytical purposes.

environment. (Chapter 6 discusses potential transportation systems.) Figure 1-7 shows the concept of temporary storage of spent nuclear fuel and high-level radioactive waste at storage sites, transporting these materials to the proposed repository, and disposing of the materials in an emplacement area.

At the repository, the material would be loaded in disposal containers. The filled disposal containers would be sealed, thereby becoming waste packages. The waste packages would be moved underground by rail. Remote-controlled handling vehicles would place the waste packages in emplacement drifts. The waste packages, which would be designed to remain intact for thousands of years (at a minimum), would be part of an engineered barrier system inside the mountain that would isolate spent nuclear fuel and high-level radioactive waste from the environment. The engineered barrier system, together with the geologic and hydrologic properties of the Yucca Mountain site, would ensure that a potential release of radioactive material after repository closure would meet applicable performance standards to contain and isolate the waste for 10,000 years or more. Chapter 5 provides detailed discussions of the natural system and of waste packages. Chapter 2 describes the Proposed Action at Yucca Mountain in additional detail, including the transportation activities required to move the spent nuclear fuel and high-level radioactive waste to the site.

Under the NWPA, the proposed repository, if authorized, would be a facility for the permanent disposal of 70,000 MTHM of spent nuclear fuel and high-level radioactive waste. The Nuclear Waste Policy Act requires the Nuclear Regulatory Commission to include in the authorization a prohibition against the emplacement of more than 70,000 MTHM in the first repository until a second repository is in operation [Nuclear Waste Policy Act, Section 114(d)]. DOE has allocated 63,000 MTHM of commercial spent nuclear fuel and 7,000 MTHM equivalent of DOE spent nuclear fuel and high-level radioactive waste to the proposed repository at Yucca Mountain. The Proposed Action that this EIS evaluates, therefore, includes the transportation of spent nuclear fuel and high-level radioactive waste from the present storage sites to Yucca Mountain and the emplacement of as much as 70,000 MTHM of spent nuclear fuel and high-level radioactive waste in the proposed repository. Chapter 8 of this EIS analyzes cumulative impacts from the disposal at Yucca Mountain of all spent nuclear fuel and high-level radioactive waste projected to be produced through 2046 for which DOE will retain ultimate responsibility. Chapter 8 also considers the disposal of Greater-Than-Class-C waste and Special-Performance-Assessment-Required waste at Yucca Mountain.

1.4.3 DOE ACTIONS TO EVALUATE THE YUCCA MOUNTAIN SITE

The primary evaluation activities related to the Yucca Mountain site that DOE has performed or will perform are site characterization studies, a Viability Assessment, and a potential Site Recommendation. The following sections address these activities.

1.4.3.1 Site Characterization Activities

In accordance with the NWPA [Section 113(b)], the DOE Office of Civilian Radioactive Waste Management prepared a Site Characterization Plan for the Yucca Mountain site (DOE 1988a, all). DOE has had an ongoing program of investigations and evaluations to assess the suitability of the Yucca Mountain site as a potential geologic repository and to provide information for this EIS. The program consists of scientific, engineering, and technical studies and activities.

Examples of activities, investigations, and evaluations associated with site characterization include the following:

- Construction of an Exploratory Studies Facility, including the North and South Portal Ramps (openings into the mountain)

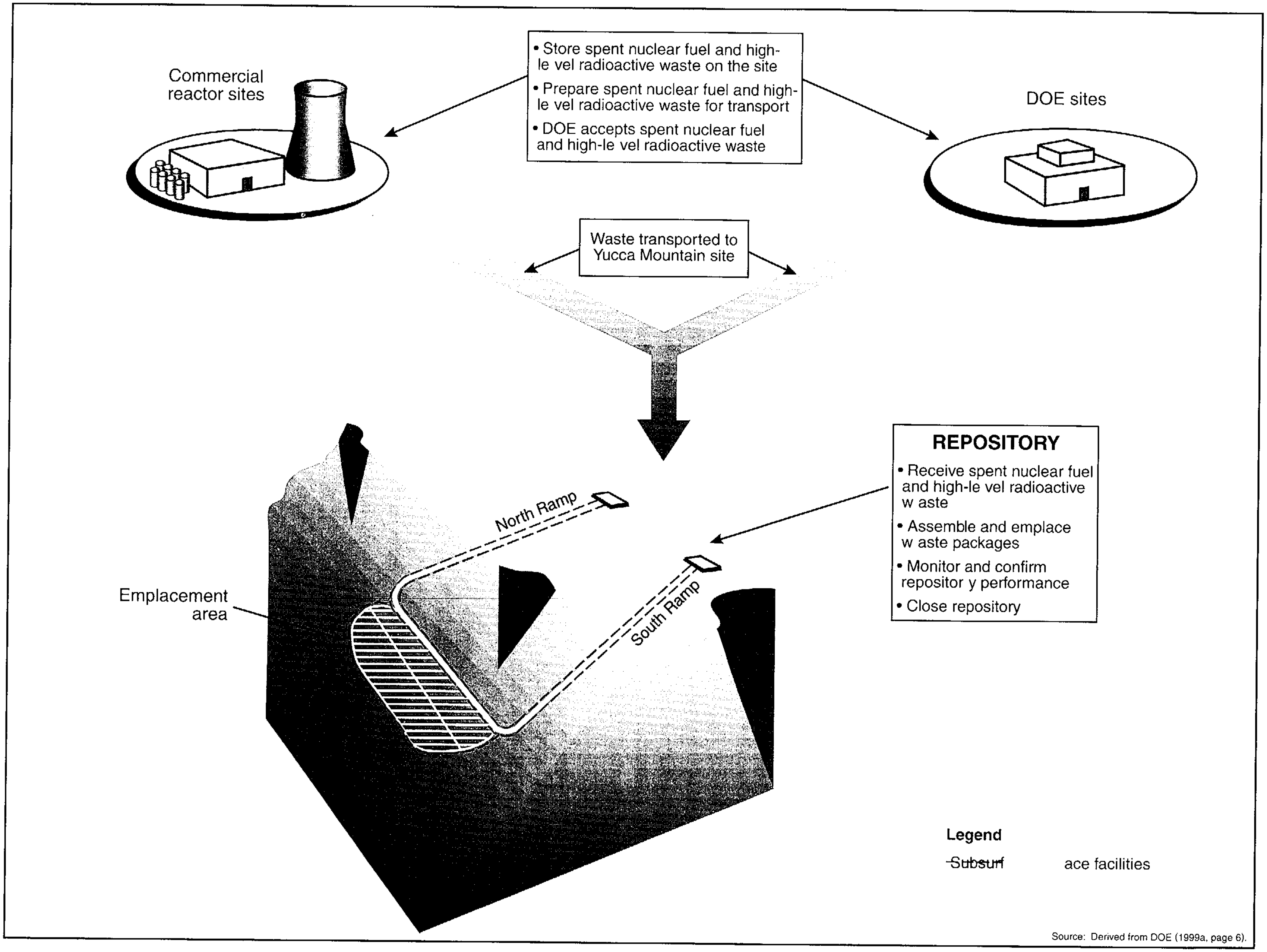


Figure 1-7. Spent nuclear fuel and high-level radioactive waste temporary storage, transportation, and disposal.

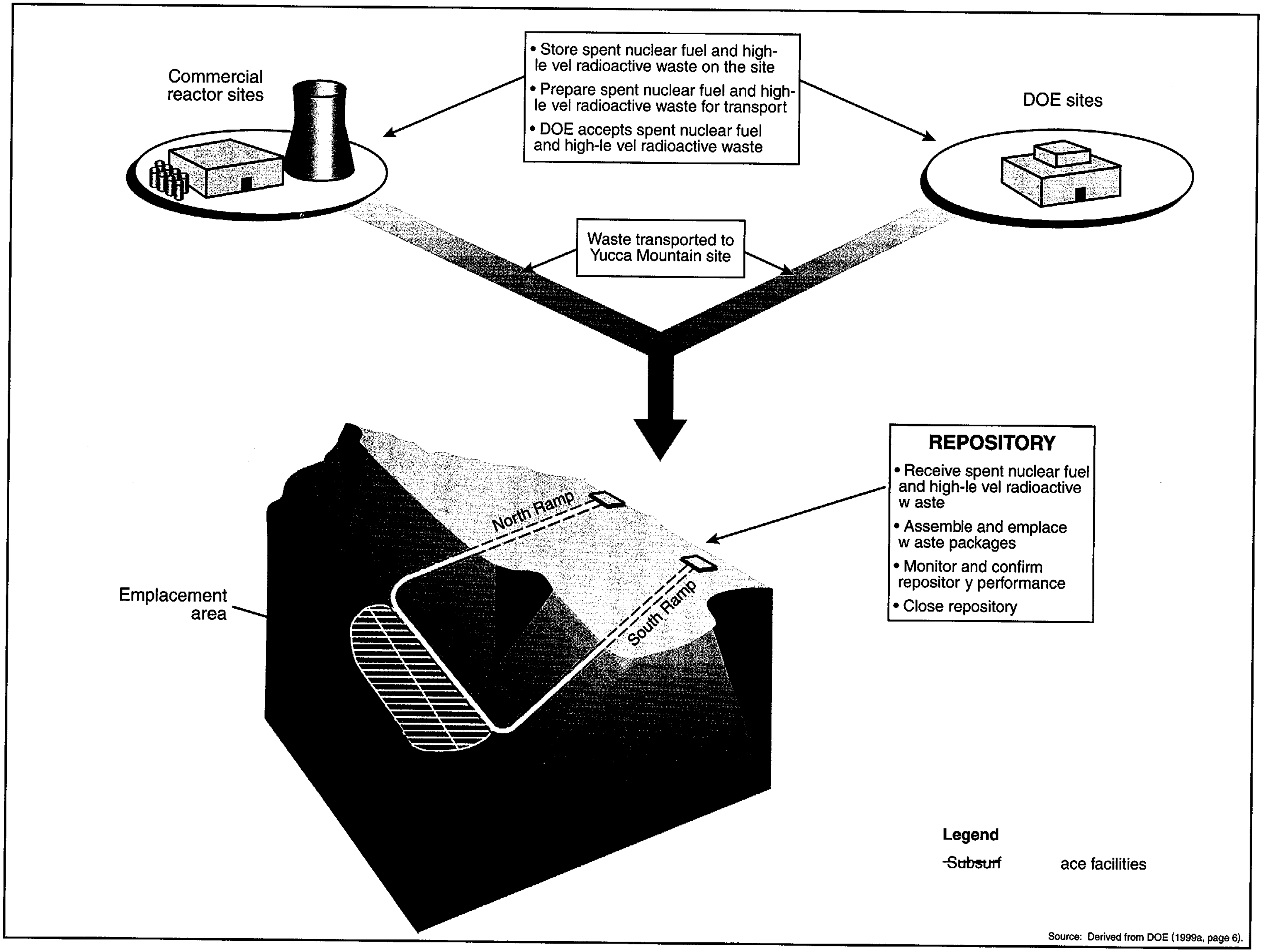


Figure 1-7. Spent nuclear fuel and high-level radioactive waste temporary storage, transportation, and disposal.

- Excavation of underground tunnels and rooms in the Exploratory Studies Facility for scientific and engineering studies, testing, and experiments
- Investigations of such topics as hydrology, including groundwater characteristics; general site geology; and specific geologic issues such as erosion, seismicity, and volcanic activity
- Field monitoring, including air quality, meteorological, radiological, and water resources monitoring
- Cultural resources studies, including Native American interests
- Terrestrial ecosystem studies

1.4.3.2 Viability Assessment

Pursuant to the Energy and Water Development Appropriations Act for Fiscal Year 1997 (Public Law 104-206), DOE issued the *Viability Assessment of a Repository at Yucca Mountain* in December 1998 (DOE 1998a, all). The Viability Assessment provides information on the progress of the Yucca Mountain Site Characterization Project to Congress, the President, regulatory agencies, stakeholder organizations, and the general public. In addition, the Viability Assessment identifies issues to be addressed before the Secretary of Energy can make a recommendation to the President on whether to approve the site for development as a repository. Further, the Viability Assessment provides an understanding of Yucca Mountain's capability to contain and isolate spent nuclear fuel and high-level radioactive waste in the repository system and limit releases to the accessible environment. The Viability Assessment includes the following:

- The preliminary design concept for the critical elements of the repository and waste package
- A total system performance assessment, based on the design concept and the scientific data and analyses available by 1998, that describes the probable behavior of the repository in the Yucca Mountain geologic setting
- A plan and cost estimate for the remaining work required to complete and submit a License Application to the Nuclear Regulatory Commission
- An estimate of the costs to construct and operate the repository in accordance with the design concept

This EIS summarizes results from the Viability Assessment, where applicable (see Chapter 5), and data analyses that continued after the completion of the Viability Assessment.

TOTAL SYSTEM PERFORMANCE ASSESSMENT

The *total system performance assessment* is an analysis tool to evaluate one particular environmental impact—possible future radioactivity doses to people living near the proposed repository. If it occurred, this impact would take place thousands of years in the future. Therefore, calculations must be used, based on the best available knowledge today of future phenomena. The analysis brings together computer simulations of the processes in the natural and engineered components of the repository, transport of radioactive substances to the affected people via available pathways, and effects of these materials on people and the environment. Because we cannot know definitively what will happen, the analysis considers a range of possible inputs. Therefore, the results are statistical ranges of outcomes.

1.4.3.3 Site Recommendation

Section 114(a) of the Nuclear Waste Policy Act requires that the recommendation be based on the record of information developed during site characterization and be submitted to the President together with a comprehensive statement of the basis of that recommendation. The recommendation is to be supported by:

- A description of the proposed repository, including preliminary engineering specifications for the facility
- A description of the material forms or packaging proposed for use at the repository, and an explanation of the relationship between the forms or packaging and the geologic medium of the site
- A discussion of data obtained in site characterization activities that relate to the safety of the site
- A Final EIS prepared for the Yucca Mountain site accompanied by comments from the Secretary of the Interior, the Council on Environmental Quality, the Environmental Protection Agency, and the Nuclear Regulatory Commission
- The preliminary comments of the Nuclear Regulatory Commission on the extent to which the material form proposal and the at-depth site characterization analysis are sufficient for inclusion in a License Application
- The views and comments of the governor and legislature of any state and of the governing bodies of affected Native American tribes
- Any impact report submitted under Section 116(c)(2)(B) of the Nuclear Waste Policy Act, as amended, by the State of Nevada
- Other information the Secretary considers appropriate

1.4.3.4 No-Action Alternative

Under the No-Action Alternative, DOE would end site characterization activities at Yucca Mountain and begin site decommissioning and reclamation. The commercial utilities and DOE 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, in a condition ready for shipment to a repository. The potential environmental impacts from two No-Action scenarios, described below, serve as a baseline to compare the potential environmental impacts of the Proposed Action.

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.

- Scenario 1 assumes that spent nuclear fuel and high-level radioactive waste would remain at the commercial and 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 commercial and DOE 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.

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 baseline for comparison to the Proposed Action. There are a number of possibilities that DOE 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 alternatives to deep geologic disposal. However, these potential actions are speculative.

1.5 Environmental Impact Analysis Process

The National Environmental Policy Act of 1969, as amended, and regulations promulgated by the Council on Environmental Quality established the procedures for Federal agencies to use when considering potential beneficial and adverse environmental consequences of proposed major Federal actions. This process requires Federal agencies to analyze potential impacts of proposed major Federal actions on the human and natural environments to assist the agencies in making informed decisions on those actions. A major emphasis of the EIS process is to promote public awareness of the proposed actions and provide opportunities for public involvement.

An agency prepares an EIS in a series of steps: (1) soliciting comments from Federal and state agencies, stakeholders, Tribal Nation representatives, and the general public to assist in defining the proposed action, alternatives, and issues requiring analysis (a process known as *scoping*); (2) preparing a Draft EIS for public distribution and comment; (3) receiving and responding to public comments on the Draft EIS; and (4) preparing a Final EIS that incorporates or summarizes (if the public comments are exceptionally voluminous) and responds to public comments on the Draft EIS. DOE conducted the scoping process for this EIS from August to December 1995 (see Section 1.5.1). After a public comment period on this Draft EIS, and after considering comments received, DOE will prepare a Final EIS. The Final EIS is scheduled for publication in August 2000.

The NWPA includes four specific provisions relevant to this EIS. Under the NWPA, the Secretary is not required to consider in this EIS (1) the need for a geologic repository, (2) the time at which a repository could become available, and (3) alternatives to isolating spent nuclear fuel and high-level radioactive waste in a repository. The fourth provision addresses the issue of potential alternative sites by providing that the EIS does not need to consider any site other than Yucca Mountain for repository development [NWPA, Section 114(f)(2) and (3)]. However, DOE has focused the EIS analysis on two alternatives: (1) the Proposed Action of constructing, operating and monitoring, and eventually closing a repository at Yucca Mountain, and (2) the No-Action Alternative, which assumes that site characterization activities at Yucca Mountain would end, resulting in spent nuclear fuel remaining at commercial sites and spent nuclear fuel and high-level radioactive waste remaining at DOE facilities.

1.5.1 NOTICE OF INTENT AND SCOPING MEETINGS

The EIS scoping process is intended to determine the scope and the significant issues to be analyzed in depth in the EIS. The scoping process must begin early and must be open, and must include public notice of public meetings and of the availability of environmental documents to inform those persons and agencies who might be interested in or affected by a proposed action.

On August 7, 1995, DOE published a Notice of Intent announcing that it would prepare an EIS for a proposed repository at Yucca Mountain, Nevada (60 *FR* 40164, August 7, 1995). To encourage broad participation by the public, before publishing the Notice of Intent DOE notified stakeholders, the media, Congressional representatives with jurisdiction over nuclear issues, the Nevada Congressional delegation, the Office of the Governor of Nevada, affected units of local government in the Yucca Mountain site vicinity, Native American tribes, the Nuclear Regulatory Commission, and the Nuclear Waste Technical

Review Board. The notification discussed the Proposed Action and No-Action Alternative, the proposed schedule of scoping meetings, and the means by which DOE intended to solicit public comments.

DOE representatives met with 13 Native American tribes and organizations to describe the EIS scoping process and to request tribal involvement in the process. In addition, DOE invited public interest groups, transportation interests, industry and utility organizations, regulators, and members of the general public to participate in the process. The Department mailed a series of information releases to Yucca Mountain stakeholders and members of the public notifying them of the opportunity to comment; submitted press releases and public service announcements to newspapers and television and radio stations; and made information about Yucca Mountain, the EIS, and the scoping process available to the public on the Internet (at *http://www.ymp.gov*) and in designated public reading rooms around the country. 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. The scoping period officially closed on December 5, 1995 (DOE 1997a, page 7).

PUBLIC SCOPING MEETING LOCATIONS

Sacramento, California
Denver, Colorado
College Park, Georgia (near Atlanta)
Boise, Idaho
Chicago, Illinois
Linthicum, Maryland (near Baltimore)
Kansas City, Missouri
Caliente, Nevada
Las Vegas, Nevada
Pahrump, Nevada
Reno, Nevada
Tonopah, Nevada
Troy, New York (near Albany)
Dallas, Texas
Salt Lake City, Utah

A total of 568 people submitted more than 1,000 comment documents during the public scoping period. DOE responded to these comments in the *Summary of Public Scoping Comments Related to the 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 1997a, all).

DOE considered all comments received during the scoping process. Several of these comments led to changes in the analytical approach to the EIS. The two most notable changes were the consideration of additional inventories and the addition of new Nevada transportation route alternatives. 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 (including an analysis of the potential for receipt of spent nuclear fuel and high-level radioactive waste prior to the start of emplacement); describe the potential decisions that the EIS would support; and examine activities other than construction, operation and monitoring, and eventual closure of a repository at Yucca Mountain.

Other concerns raised by the public during scoping emphasized that DOE needed to ensure that the EIS thoroughly addresses the impacts of constructing and operating a geologic repository and related facilities (including the use of a rail line, heavy-haul truck routes, and intermodal transfer stations) on:

- Land uses in the Yucca Mountain vicinity (including consistency with existing land-use plans)
- Regional air quality and meteorology
- Geology (including the effects of earthquakes and volcanism and the potential for transport of radioactive and hazardous materials from the repository)
- Regional hydrology (including groundwater quality in Amargosa Valley, Ash Meadows, and Death Valley National Park)

- Biological resources (including postclosure effects on wildlife from potential increased surface temperatures)
- Health and safety (including past radiation exposures from activities at the Nevada Test Site for both pre- and postclosure periods)
- Long-term performance assessment for the repository (including an evaluation of the ability of the overall system to meet potential performance objectives, waste package performance and degradation given different thermal loads, infiltration rates, corrosion models, and other relevant factors)
- Sabotage and safeguards and security measures during waste transport and disposal
- Cultural and historic resources and environmental justice
- Socioeconomics
- Mitigation (including the mitigation of impacts from both routine operations and accident conditions)

DOE included discussions and analyses in the EIS that respond to these public issues and concerns. In addition, DOE received many requests for more formal involvement in the EIS preparation process by representatives of the affected units of local government and Native American tribes. In response, DOE tasked (and funded) the American Indian Writers Subgroup to prepare a document setting forth Native American perspectives and views regarding the repository and Yucca Mountain; that document is quoted and referenced in the EIS. A similar opportunity was extended to the State of Nevada and the affected units of local government to prepare their own documents setting forth perspectives and views on a variety of issues of local and regional concern, which DOE agreed to incorporate by reference in the EIS. At Draft EIS publication, Nye County (Buqo 1999, all) had prepared such a document. In addition, other documents related to the Yucca Mountain region have been prepared in the past by several local government units including Clark, Lincoln, and White Pine Counties.

Many other public scoping comments presented views and concerns not related to the scope or content of the Proposed Action. Examples of such comments include statements in general support of or opposition to Yucca Mountain, repositories, and nuclear power; lack of public confidence in the Yucca Mountain program; inequities and political aspects of the siting process by which Yucca Mountain was selected for further study by Congress; the constitutional basis for waste disposal in Nevada; psychological costs or effects; risk perception and stigmatization; legal issues involving Native American land claims and treaty rights; and unrelated DOE activities. DOE considered and recorded these concerns in the comment summary document on the scoping process (DOE 1997a, all), but has not included analyses of these issues in the EIS.

1.5.1.1 Additional Inventory Studies

The Proposed Action is to construct, operate and monitor, and eventually close a geologic repository for the disposal of 70,000 MTHM of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. During the scoping period, DOE received many comments that noted the potential existence of more than 70,000 MTHM of these materials and encouraged DOE to evaluate the total projected inventory. For example, presently operating nuclear powerplants could generate approximately 105,000 MTHM of spent nuclear fuel eligible for disposal by 2046 if all commercial licenses were extended. In addition, some commenters requested that the EIS evaluate the disposal of radioactive waste types that might require permanent isolation, such as Greater-Than-Class-C waste and Special-Performance-Assessment-Required waste. For these reasons, DOE has included in the EIS cumulative impact analysis an evaluation of the cumulative environmental impacts that could occur as a result of the disposal of all projected spent nuclear fuel and high-level radioactive waste and the disposal of quantities of Greater-Than-Class-C and Special-Performance-Assessment-Required waste in the Yucca Mountain Repository (see Chapter 8).

1.5.1.2 Additional Nevada Transportation Analyses

In response to public comments, DOE decided to analyze a fifth branch rail line and a fifth route for heavy-haul trucks in Nevada. The Department added analyses of the Caliente-Chalk Mountain branch rail line and the Caliente-Chalk Mountain route for heavy-haul trucks to the analyses of four rail corridors and four heavy-haul routes it had previously identified for potential transportation impacts in Nevada. Chapter 6 and Appendix J describe the transportation analyses. The U.S. Air Force opposes the use of the Caliente-Chalk Mountain rail corridor and heavy-haul truck route because of national security concerns; at this time DOE regards these routes as nonpreferred alternatives.

APPROXIMATE WASTE INVENTORIES
(Measurement methods differ among waste types)

Commercial spent nuclear fuel
- Projected total: 105,000 MTHM in 2046
- Current disposal plan: 63,000 MTHM (includes as much as 32 metric tons of plutonium disposed of as mixed oxide spent nuclear fuel)

DOE spent nuclear fuel
- Projected total: 2,500 MTHM
- Current disposal plan: 2,333 MTHM (one-third of the 7,000-MTHM total of DOE material proposed for disposal, which includes high-level radioactive waste)

High-level radioactive waste
- Projected total: 22,280 canisters (would include as much as 50 metric tons of immobilized plutonium)
- Current disposal plan: 8,315 canisters (includes 18 metric tons of immobilized plutonium)

Greater-Than-Class-C waste
- Projected total: 2,100 cubic meters
- Disposal evaluated in Chapter 8

Special-Performance-Assessment-Required waste
- Projected total: 4,000 cubic meters
- Disposal evaluated in Chapter 8

1.5.2 CONFORMANCE WITH DOCUMENTATION REQUIREMENTS

DOE has performed formal documented reviews of data to identify gaps, inconsistencies, omissions, or other conditions that would cause data to be suspect or unusable.

DOE planned analyses to ensure consistency and thoroughness in the environmental studies conducted for this EIS. DOE has also used configuration control methods to ensure that EIS inputs are current, correct, and appropriate, and that outputs reflect the use of appropriate inputs.

All work products for this EIS have undergone documented technical, editorial, and managerial reviews for adequacy, accuracy, and conformance to project and DOE requirements. Work products related to impact analyses (for example, calculations, data packages, and data files) have also undergone formal technical and managerial reviews. Calculations (manual or computer-driven) generated to support impact analyses have been verified independently and completely in accordance with project management procedures.

1.5.3 RELATIONSHIP TO OTHER ENVIRONMENTAL DOCUMENTS

A number of completed, in-preparation, or proposed DOE National Environmental Policy Act documents relate to this EIS. In addition, other Federal agencies have prepared related EISs. As directed by the Council on Environmental Quality regulations that implement the National Environmental Policy Act, DOE has used information from these documents in its analysis and has incorporated this material by reference as appropriate throughout this EIS. Table 1-1 lists the documents that formed a basis for decisions associated with a geologic disposal program and investigation of Yucca Mountain as a potential repository site; these include the EIS for Management of Commercially Generated Radioactive Waste (DOE 1980, all), the Surplus Plutonium Disposition Draft EIS (DOE 1998b, all), and the Yucca Mountain Site Environmental Assessment (DOE 1986a, all).

Table 1-1. Related environmental documents[a] (page 1 of 3).

Document	Material type	Relationship to Yucca Mountain Repository EIS
Nuclear materials activities		
Final EIS, Management of Commercially Generated Radioactive Waste (DOE 1980, all)	Commercial SNF; DOE SNF and HLW	Examines different disposal alternatives. ROD documented DOE decision to pursue geologic disposal for SNF and HLW.
EA, Yucca Mountain Site, Nevada Research and Development Area (DOE 1986a, all)	Commercial SNF; DOE SNF and HLW	Examines impacts of site characterization activities and possible geologic repository at Yucca Mountain.
Final Supplemental EIS, Defense Waste Processing Facility, Savannah River Site, Aiken, South Carolina (DOE 1994a, all)	HLW	Examines impacts of constructing and operating DWPF, which processes HLW at SRS. SRS HLW could be eligible for repository disposal.
Final EIS, Waste Management, Savannah River Site (DOE 1995c, all)	HLW	Examines impacts of managing five types of waste (including liquid HLW) at SRS over 10 years. SRS HLW could be eligible for repository disposal.
Final EIS, Interim Management of Nuclear Materials at the Savannah River Site (DOE 1995d, all)	HLW	Examines impacts of stabilization and interim storage of plutonium, uranium, and other nuclear materials. SRS SNF and HLW could be eligible for repository disposal.
Final EIS, Management of Spent Nuclear Fuel from the K-Basins at the Hanford Site, Richland, Washington (DOE 1996a, all)	DOE SNF	Examines impacts of managing SNF in K-Basins at Hanford. Hanford SNF could be eligible for repository disposal.
Draft EIS, Completion of the West Valley Demonstration Project and Closure or Long-Term Management of Facilities at the Western New York Nuclear Service Center (DOE 1996b, all)	HLW	Examines impacts of solidifying liquid HLW obtained from reprocessing commercial SNF. WVDP HLW could be eligible for repository disposal.
Final EIS, Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel (DOE 1996c, all)	DOE SNF	Examines impacts of managing SNF from foreign research reactors in accordance with U.S. policy to reduce nuclear weapons proliferation. SNF from foreign research reactors stored at SRS and INEEL could be eligible for repository disposal.
Final EIS, Hanford Site Tank Waste Remediation System (DOE 1996d, all)	HLW	Examines impacts of long-term management and disposal of Hanford tank waste, including HLW. Hanford HLW could be eligible for repository disposal.
Draft EIS, Surplus Plutonium Disposition (DOE 1998b, all)	Plutonium	Examines the alternatives for and impacts of disposition of 50 metric tons (55 tons) of surplus plutonium. Ultimate disposition of the plutonium could involve repository disposal.

Table 1-1. Related environmental documents[a] (page 2 of 3).

Document	Material type	Relationship to Yucca Mountain Repository EIS
Nuclear materials activities (continued)		
Supplement to the Surplus Plutonium Disposition Draft Environmental Impact Statement (DOE 1999b, all)	Plutonium	Examines potential environmental impacts of using mixed oxide fuel in six reactors as well as program changes made since the publication of the Draft EIS.
Draft EIS, Idaho High-Level Waste and Facilities Disposition (in preparation)	HLW	Examines impacts of treatment, storage, and disposal of INEEL HLW and facilities disposition. INEEL HLW could be eligible for repository disposal.
Draft EIS, Savannah River Site Spent Nuclear Fuel Management (DOE 1998c, all)	DOE SNF	Examines impact of several technologies for management of SNF at SRS, including placing these materials in forms suitable for ultimate disposition. Information from this EIS aids the study of packaging, transportation, and disposition of SNF.
Record of Decision (USN 1997a, all) and the Second Record of Decision (USN 1997b, all) for a Container System for the Management of Naval Spent Nuclear Fuel Final EIS (USN 1996a, all)	DOE SNF	Evaluates potential impacts of using alternative container systems for management of naval SNF following examination at INEEL. Naval SNF processed and stored at INEEL could be eligible for repository disposal. DOE used information from this EIS to estimate impacts from manufacture of disposal containers and shipping casks.
Supplement Analysis for a Container System for the Management of DOE Spent Nuclear Fuel Located at INEEL (DOE 1999e, all)	DOE SNF	Determines the use of a multipurpose canister or comparable system for the management of DOE SNF at INEEL that might be suitable for shipment using existing transportation casks.
Record of Decision for a Multi-Purpose Canister or Comparable System for Idaho National Engineering and Environmental Laboratory Spent Nuclear Fuel (DOE 1999f, all)	DOE SNF	Evaluates the impacts of using dual-purpose canisters to prepare DOE SNF located at INEEL for interim storage and transport outside the State of Idaho.
Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Main Report, Final Report NUREG-1437 (NRC 1996, all) and the Draft Supplement for the Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Addendum 1 (NRC 1999, all)	Commercial SNF	Addresses the cumulative impacts of transportation of commercial spent nuclear fuel in the vicinity of the proposed repository at Yucca Mountain, Nevada, and the impacts of transporting higher-burnup fuel.
Programmatic examination of waste management		
Record of Decision (DOE 1995b, all) for the Final Programmatic EIS, Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs (DOE 1995a, all)	DOE SNF	Examines programmatic impacts of storage of DOE SNF that could be eligible for repository disposal. In the associated ROD, DOE decided where DOE SNF would be managed.
Final Programmatic EIS, Storage and Disposition of Weapons-Usable Fissile Materials (DOE 1996e, all)	DOE SNF and HLW	Examines impacts of long-term storage of plutonium and highly enriched uranium at several DOE sites. Spent mixed-oxide fuel and immobilized plutonium could be eligible for repository disposal.
Final Programmatic EIS, Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste (DOE 1997b, all)	HLW	Examines impacts of managing five types of waste at DOE sites. Examines storage of HLW canisters and transportation of HLW canisters between DOE sites and Yucca Mountain.

Table 1-1. Related environmental documents[a] (page 3 of 3).

Document	Material type	Relationship to Yucca Mountain Repository EIS
Programmatic examination of waste management (continued)		
Final EIS, Nevada Test Site and Off-Site Locations in the State of Nevada (DOE 1996f, all)		Examines potential impacts of future mission activities at NTS. DOE used information from NTS EIS for Yucca Mountain site description and environmental impacts of NTS waste management activities. Cumulative impact analysis included activities analyzed in NTS EIS.
Regional description and cumulative impact information		
Final EIS, Withdrawal of Public Lands for Range Safety and Training Purposes at Naval Air Station Fallon, Nevada (USN 1998, all)		Examines impacts of land withdrawal around Naval Air Station Fallon. Repository EIS analysis of cumulative impacts considered proposed actions at Naval Air Station Fallon.
Legislative EIS for Nellis Air Force Range Renewal (USAF 1999, all)		Examines impacts of renewal of land withdrawal for Nellis Air Force Range. Yucca Mountain site is partly on range, and Repository EIS considers proposed actions at Nellis in its cumulative impacts analysis.
Proposed Caliente Management Framework Plan Amendment and FEIS for the Management of Desert Tortoise Habitat (BLM 1999a, all)		Examines the implementation of BLM management goals and actions for the administration of the desert tortoise habitat in Lincoln County, Nevada.
Final EIS for the Cortez Pipeline Gold Deposit (BLM 1996, all)		Examines potential for impacts from mining-related activities at a location in western Nevada.
EA, Pipeline Infiltration Project (BLM 1999b, all)		Examines potential for impacts from mining-related activities at a location in western Nevada.
Environmental Impact Analysis process for a Draft Secretarial Report to Congress regarding a proposal to establish permanent Timbisha Shoshone Tribal land use in and around Death Valley National Park (64 *FR* 19193 to 19194, April 19, 1999)		Examines the potential for impacts from creating a Timbisha Shoshone Tribal reservation in and around Death Valley National Park.

a. Abbreviations: BLM = Bureau of Land Management; DOE = U.S. Department of Energy; DWPF = Defense Waste Processing Facility; EA = environmental assessment; EIS = environmental impact statement; HLW = high-level radioactive waste; INEEL = Idaho National Engineering and Environmental Laboratory; NTS = Nevada Test Site; ROD = Record of Decision; SNF = spent nuclear fuel; SRS = Savannah River Site; WVDP = West Valley Demonstration Project.

2

Proposed Action and No-Action Alternative

2. PROPOSED ACTION AND NO-ACTION ALTERNATIVE

Under the Proposed Action, the U.S. Department of Energy (DOE) would 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 (see Section 2.1). The Proposed Action includes transportation of spent nuclear fuel and high-level radioactive waste from commercial and DOE sites to the Yucca Mountain site (see Figure 2-1).

Under the No-Action Alternative (see Section 2.2), DOE would end site characterization activities at Yucca Mountain, and the commercial and DOE sites would continue to manage their spent nuclear fuel and high-level radioactive waste (see Figure 2-1). The No-Action Alternative assumes that spent nuclear fuel and high-level radioactive waste would be treated and packaged as necessary for its safe onsite management. DOE does not intend to represent the No-Action Alternative as a viable long-term solution but rather to use it as a baseline against which the Proposed Action can be evaluated.

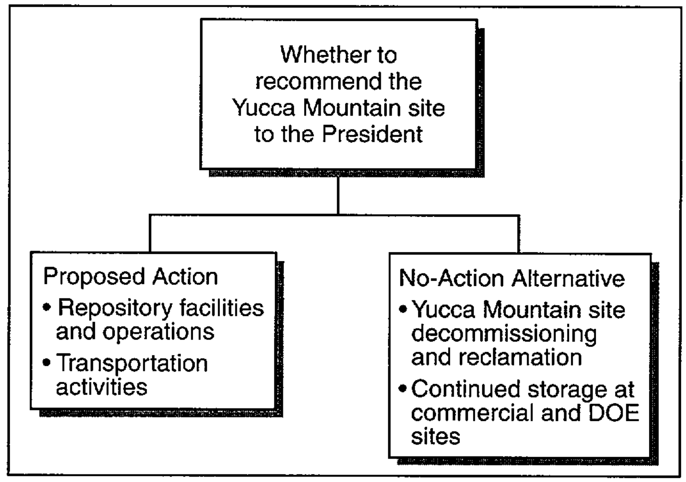


Figure 2-1. General activity areas evaluated under the Proposed Action and No-Action Alternative.

Section 2.3 discusses the alternatives that DOE considered but eliminated from detailed study in this environmental impact statement (EIS). Section 2.4 summarizes findings from the EIS and compares the potential environmental impacts of the Proposed Action and the No-Action Alternative. Section 2.5 addresses the collection of information and analyses performed for the EIS. Section 2.6 identifies the preferred alternative.

DOE has developed the information about the potential environmental impacts that could result from either the Proposed Action or the No-Action Alternative to inform the Secretary of Energy's determination whether to recommend Yucca Mountain as the site of this Nation's first monitored geologic repository for spent nuclear fuel and high-level radioactive waste.

As part of the Proposed Action, the EIS analyzes the 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, alternative intermodal (rail to truck) transfer station locations, associated heavy-haul truck routes, and alternative rail transport corridors in Nevada. Although it is uncertain at this time when DOE would make any transportation-related decisions, DOE believes that the EIS provides the information necessary to make decisions regarding the basic approaches (for example, mostly rail or mostly truck shipments), as well as the choice among alternative transportation corridors. However, follow-on implementing decisions, such as 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 routes, would require additional field surveys, state and local government consultations, environmental and engineering analyses, and National Environmental Policy Act reviews.

2.1 Proposed Action

DOE proposes to construct, operate and monitor, and eventually close a geologic repository at Yucca Mountain for the disposal of spent nuclear fuel and high-level radioactive waste. About 600 square kilometers (230 square miles or 150,000 acres) of land in Nye County, Nevada, could be permanently withdrawn from public access for DOE use for the repository (see Figure 2-2 for location of area). DOE would dispose of spent nuclear fuel and high-level radioactive waste in the repository using the inherent, natural geologic features of the mountain and engineered (manmade) barriers to ensure the long-term isolation of the waste from the human environment. DOE would build the repository inside Yucca Mountain between 200 and 425 meters (660 and 1,400 feet) below the surface and between 175 and 365 meters (570 and 1,200 feet) above the water table.

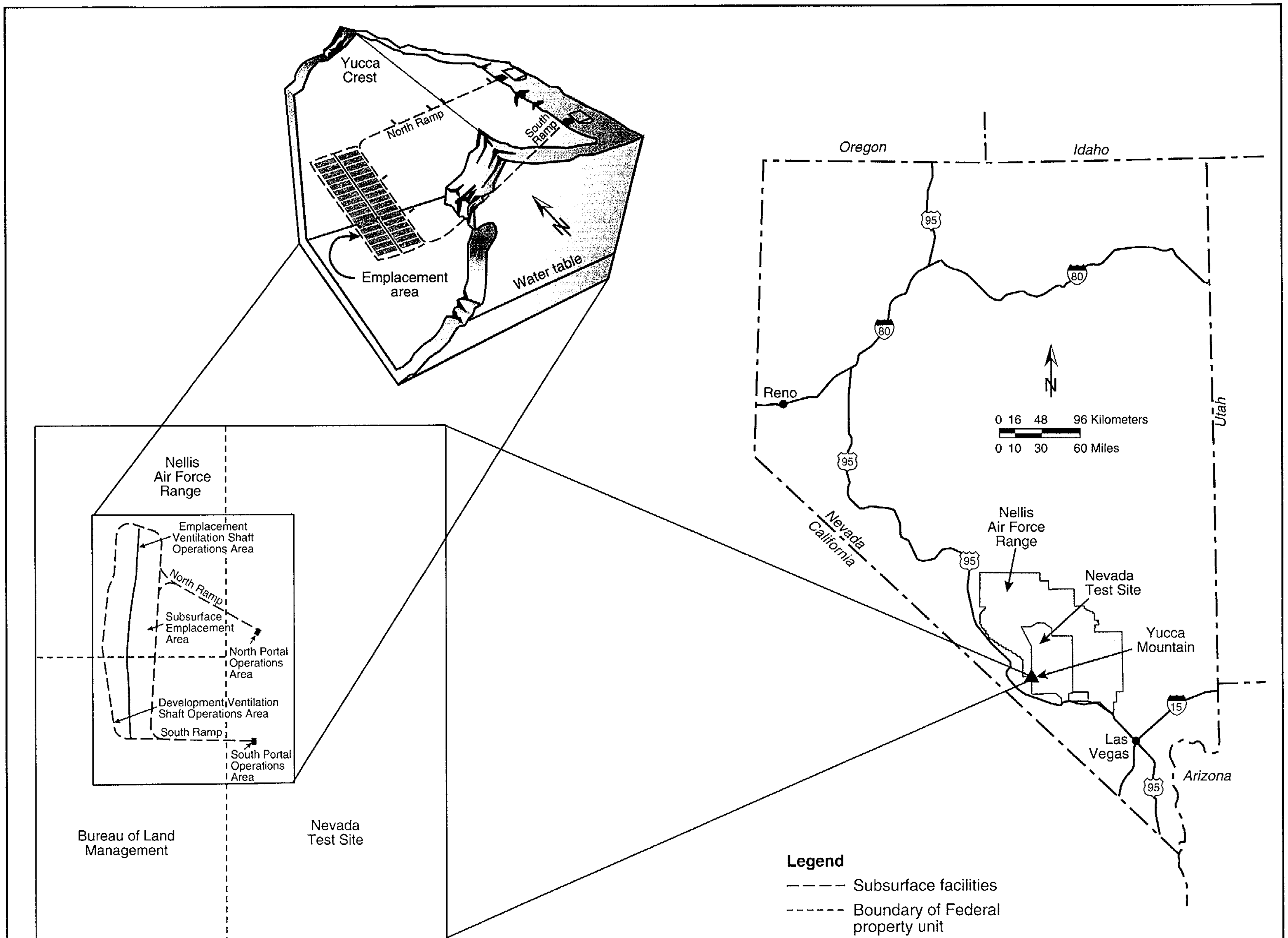
Under the Proposed Action, DOE would permanently place approximately 10,000 to 11,000 waste packages containing no more than 70,000 metric tons of heavy metal (MTHM) of spent nuclear fuel and high-level radioactive waste in the repository. Of the 70,000 MTHM to be emplaced in the repository, 63,000 MTHM would be spent nuclear fuel assemblies from boiling-water and pressurized-water reactors (Figure 2-3) that DOE would ship from commercial nuclear sites to the repository. The remaining 7,000 MTHM would consist of about 2,333 MTHM of DOE spent nuclear fuel and 8,315 canisters (4,667 MTHM) containing solidified high-level radioactive waste (see Figure 2-3) that the Department would ship to the repository from its facilities. The 70,000 MTHM inventory would include 50 metric tons (55 tons) of surplus weapons-usable plutonium as spent mixed-oxide fuel or immobilized plutonium. Appendix A contains additional information on the inventory and characteristics of spent nuclear fuel, high-level radioactive waste, and other materials that DOE could emplace in the proposed repository. For this EIS, a connected action includes the offsite manufacturing of the containers that DOE would use for the transport and disposal of spent nuclear fuel and high-level radioactive waste.

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.

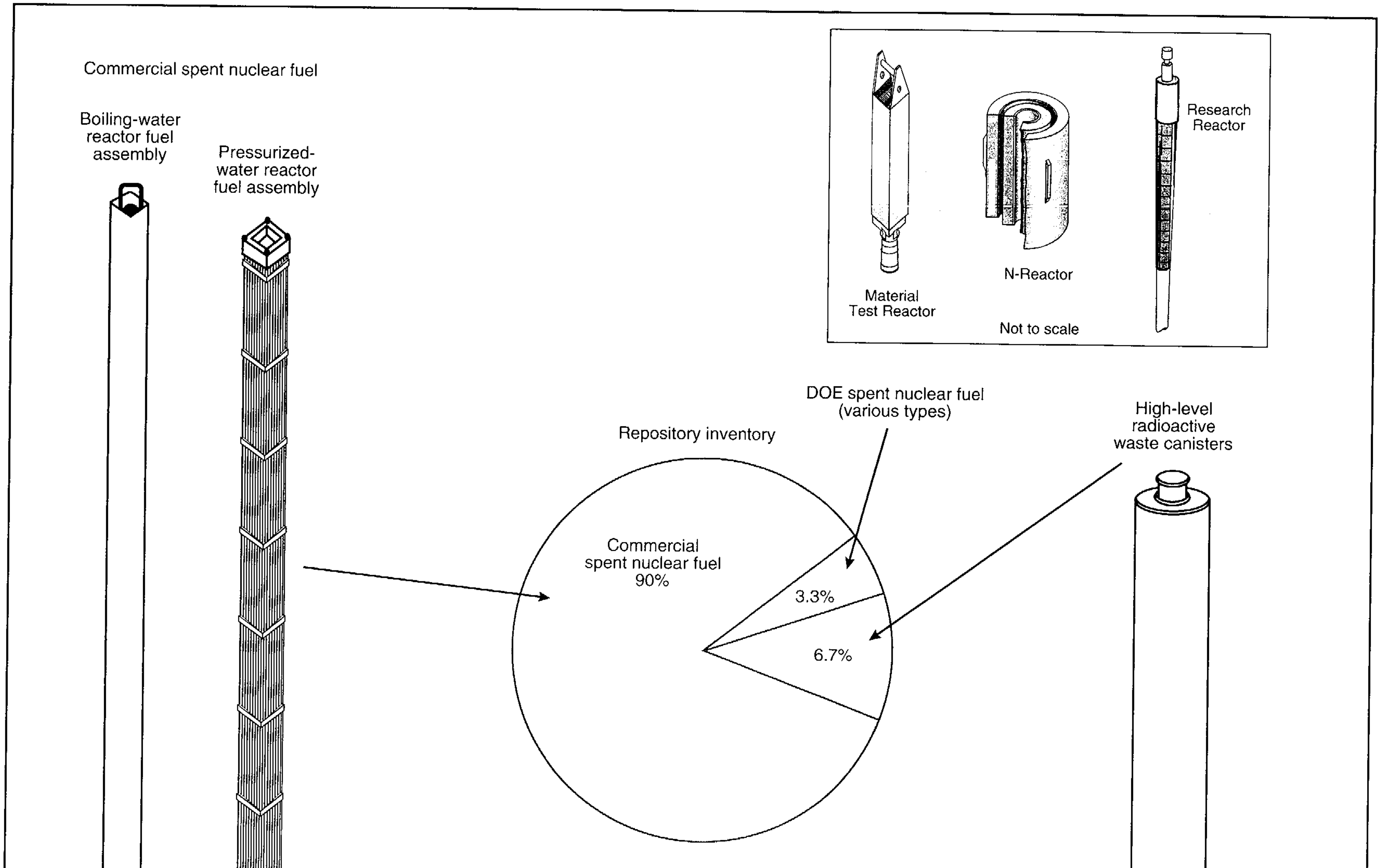
Figure 2-4 is an overview of components or activities associated with the Proposed Action. The implementing alternatives and scenarios analyzed in this EIS, as described in Section 2.1.1, represent the potential range of variables associated with implementing the Proposed Action that could affect environmental impacts. The Proposed Action would require surface and subsurface facilities and operations for the receipt, packaging, and emplacement of spent nuclear fuel and high-level radioactive waste (see Section 2.1.2) and transportation of these materials to the repository (see Section 2.1.3). Section 2.1.4 summarizes the estimated cost of the Proposed Action. Chapters 4, 5, and 6 evaluate potential environmental impacts from the Proposed Action. As part of the process to develop implementing concepts, mitigation techniques have been designed into the Proposed Action through the use of best engineering and management practices, as applicable.

The Proposed Action would use two types of institutional controls—active and passive. Active institutional controls (monitored and enforced limitations on site access; inspection and maintenance of waste packages, facilities, equipment, etc.) would be used through closure. Passive institutional controls (markers, engineered barriers, etc., that are not monitored or maintained) would be put in place during closure and used to minimize inadvertent exposures to members of the public in the future.



Sources: Modified from TRW (1999a, Attachment IV, Figure 1).

Figure 2-2. Diagram and location of the proposed repository at Yucca Mountain.



Notes: 1. Fifty metric tons (55 tons) of surplus weapons-usable plutonium would be included in the inventory of commercial spent nuclear fuel as spent mixed-oxide fuel or in the inventory of high-level radioactive waste as immobilized plutonium.

2. Typical boiling-water reactor fuel assemblies are 4.5 meters (15 feet) long with a cross section of 14 x 14 centimeters (5.5 x 5.5 inches). Typical pressurized-water reactor fuel assemblies are 4.1 meters (13 feet) long with a cross section of 21 x 21 centimeters (8.3 x 8.3 inches). High-level radioactive waste canisters are 0.61 meters (2 feet) in diameter and range from 3.0 to 4.5 meters (10 to 15 feet) long.

Fig[illegible]-3. Sources of spent nuclear fuel and high-level radioactive [illegible] proposed for disposal at the Yucca Mountain Repository.

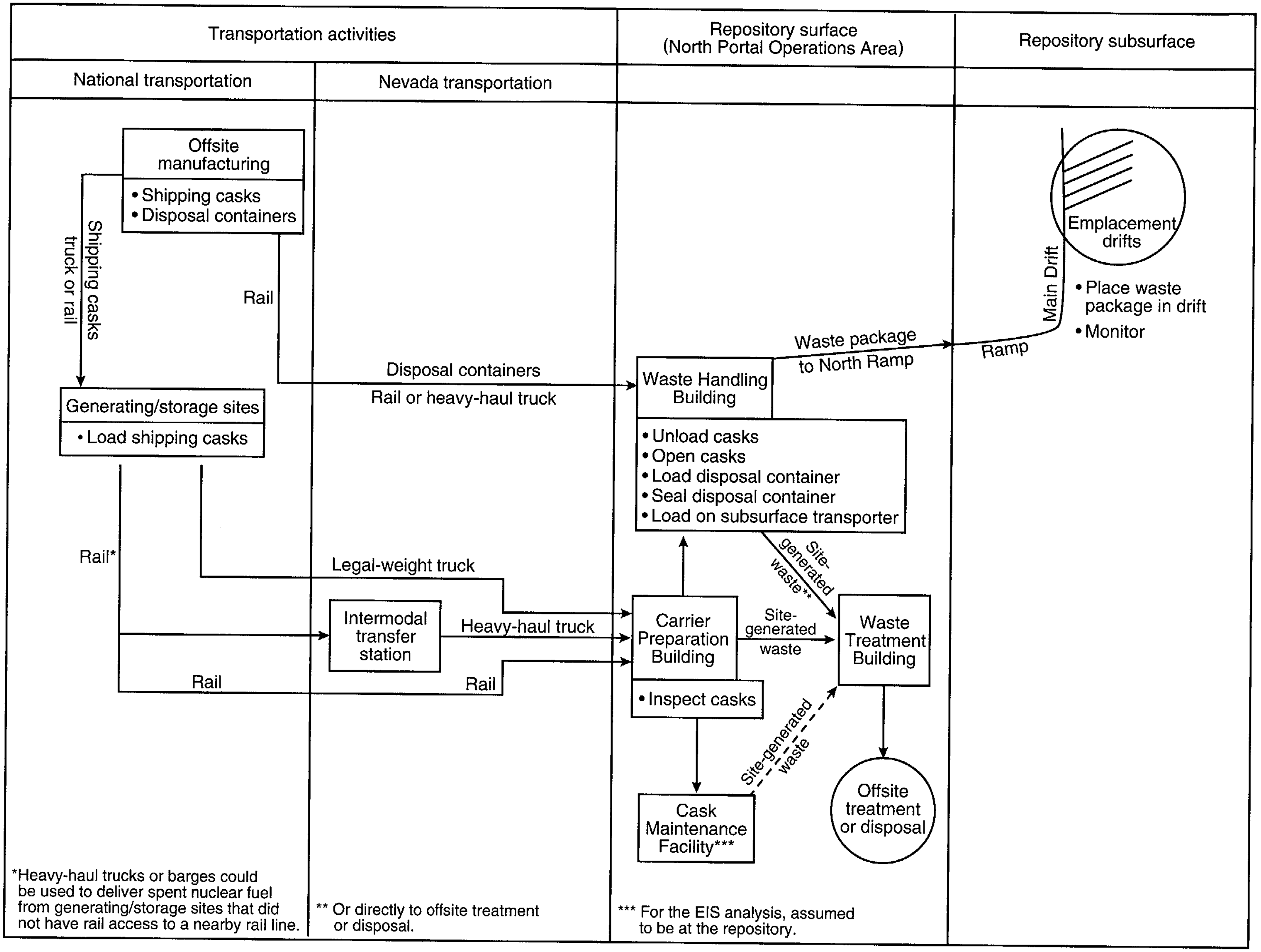


Figure 2-4. Overview flowchart of the Proposed Action.

2.1.1 OVERVIEW OF IMPLEMENTING ALTERNATIVES AND SCENARIOS

This EIS describes and evaluates the current preliminary design concept for repository surface facilities, subsurface facilities, and disposal containers (waste packages), and the current plans for the construction, operation and monitoring, and closure of the repository. DOE recognizes that plans for the repository would continue to evolve during the development of the final repository design and as a result of the U.S. Nuclear Regulatory Commission licensing review of the repository. In addition, decisions on how spent nuclear fuel and high-level radioactive waste would be shipped to the repository (for example, truck or rail) and how spent nuclear fuel would be packaged (uncanistered or in disposable or dual-purpose canisters) would be part of future transportation planning efforts.

For these reasons, DOE developed implementing alternatives and analytical scenarios to bound the environmental impacts likely to result from the Proposed Action (see Figure 2-5). The Department selected the implementing alternatives and scenarios to accommodate and maintain flexibility for potential future revisions to the design and plans for the repository. Because of uncertainties, DOE selected implementing alternatives and scenarios that incorporate conservative assumptions that tend to overstate the risks to address those uncertainties.

The following paragraphs describe the packaging scenarios, thermal load scenarios, national transportation scenarios, Nevada transportation scenarios, and implementing rail and intermodal alternatives evaluated in the EIS. In addition, these paragraphs discuss the continuing investigation of options DOE is considering for the repository design at the next major program milestones (that is, Site Recommendation and License Application).

DOE will evaluate future repository design revisions in accordance with its regulations for implementing the National Environmental Policy Act (10 CFR 1021.314) to determine if there are substantial changes in the proposal or significant new circumstances or information relevant to environmental concerns. Based on these regulations, DOE will determine whether it will conduct further National Environmental Policy Act reviews.

2.1.1.1 Packaging Scenarios

DOE operations at repository surface facilities would differ depending on how the spent nuclear fuel in shipping casks was packaged. Commercial spent nuclear fuel could be received either uncanistered or in disposable or dual-purpose canisters.

The EIS assumes that DOE spent nuclear fuel and high-level radioactive waste would be shipped to the repository in disposable canisters. In addition, it evaluates the following packaging scenarios for commercial spent nuclear fuel to cover the potential range of environmental impacts from repository surface facility construction and operation:

- A mostly uncanistered fuel scenario
- A mostly canistered fuel scenario that includes:
  - Disposable canisters
  - Dual-purpose canisters

Table 2-1 summarizes these scenarios.

DISPOSAL CONTAINERS AND WASTE PACKAGES

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

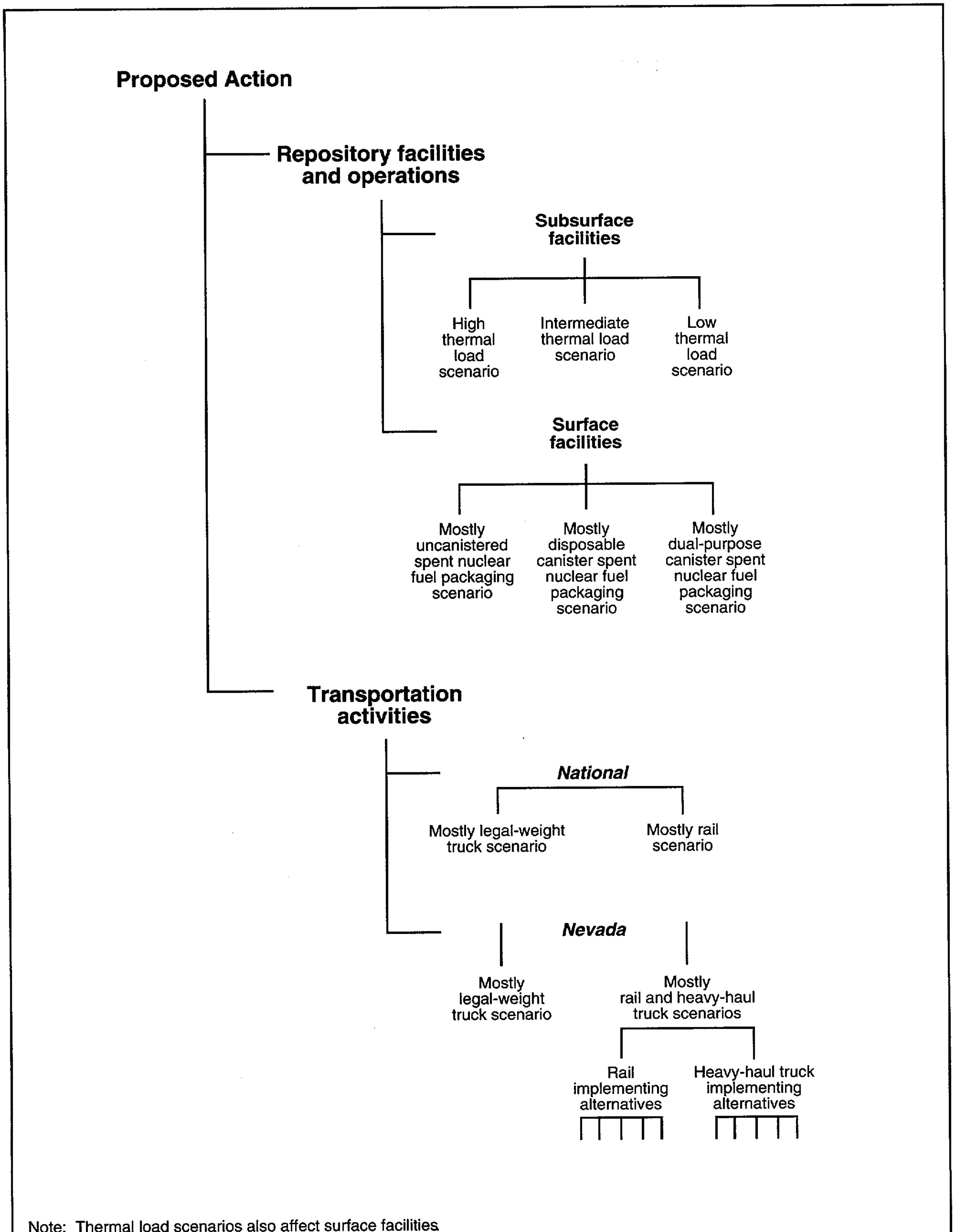


Figure 2-5. Analytical scenarios and implementing alternatives associated with the Proposed Action.

Table 2-1. Packaging scenarios (percentage based on number of shipments).

Material[a]	Mostly uncanistered fuel	Mostly canistered fuel	
		Disposable canister	Dual-purpose canister
Commercial SNF	100% uncanistered fuel	About 80% disposable canisters; about 20% uncanistered fuel	About 80% dual-purpose canisters; about 20% uncanistered fuel
HLW	100% disposable canisters	100% disposable canisters	100% disposable canisters
DOE SNF	100% disposable canisters	100% disposable canisters	100% disposable canisters

a. SNF = spent nuclear fuel; HLW = high-level radioactive waste.

DEFINITIONS OF PACKAGING TERMS

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

Canister: A thin-walled metal vessel used to hold spent nuclear fuel assemblies or solidified high-level radioactive waste.

Dual-purpose canister: A canister suitable for storing (in a storage facility) and shipping (in a shipping cask) 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. The opened canister would be recycled or disposed of offsite as low-level radioactive waste.

Disposable canister: A canister for 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.

Uncanistered spent nuclear fuel: Fuel placed directly into storage canisters or shipping casks without first being placed in a canister. At the repository, spent nuclear fuel assemblies would be removed from the shipping cask and placed in a disposal container.

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.

2.1.1.2 Thermal Load Scenarios

The heat generated by spent nuclear fuel and high-level radioactive waste (the thermal load) could affect the long-term performance of the repository (that is, the ability of the engineered and natural barrier systems to isolate the emplaced waste from the human environment). Different thermal loads would have a direct effect on internal and external waste package temperatures, thereby potentially affecting the corrosion rate and integrity of the waste package. The heat generated by the waste packages would also affect the geochemistry, hydrology, and mechanical stability of the emplacement drifts, which in turn would influence the flow of groundwater and the transport of radionuclides from the engineered and natural barrier systems to the environment. The thermal load would depend on factors related to the design of the repository including, but not limited to, the age of the spent nuclear fuel at the time of emplacement, the spacing of the emplacement drifts and the waste packages in them, the repository ventilation, and the decision on whether to backfill the emplacement drifts.

DOE evaluated three thermal load scenarios. These scenarios include a relatively high emplacement density of spent nuclear fuel and high-level radioactive waste (high thermal load – 85 MTHM per acre), a relatively low emplacement density (low thermal load – 25 MTHM per acre), and an emplacement density between the high and low thermal loads (intermediate thermal load – 60 MTHM per acre). The additional spacing required for the lower thermal loads would increase the subsurface area and the amount of excavation. In addition, the different thermal loads would affect the area requirements for the excavated rock pile on the surface.

2.1.1.3 National Transportation Scenarios

The national transportation scenarios evaluated in this EIS encompass the transportation options or modes (legal-weight truck and rail) that are practical for DOE to use to ship spent nuclear fuel and high-level radioactive waste from the commercial and DOE sites to the Yucca Mountain site. DOE would use both legal-weight truck and rail transportation, and would determine the number of shipments by either mode as part of future transportation planning efforts. Therefore, the EIS evaluates two national transportation scenarios (mostly legal-weight truck and mostly rail) that cover the possible range of transportation impacts to human health and the environment.

TERMS ASSOCIATED WITH TRANSPORTATION

Legal-weight trucks have 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. In addition, the dimensions, axle spacing, and, if applicable, axle loads of these vehicles must be in compliance with Federal and state regulations.

An **intermodal transfer station** is a facility for transferring freight from one transportation mode to another (for example, from railcar to truck). In this EIS, intermodal transfer station refers to a facility DOE would use to transfer rail shipping casks containing spent nuclear fuel or high-level radioactive waste from railcars to heavy-haul trucks, and to transfer empty rail shipping casks from heavy-haul trucks to railcars.

Heavy-haul trucks are overweight, overdimension vehicles that must have permits from state highway authorities to use public highways. In this EIS, heavy-haul trucks refers to vehicles DOE would use on public highways to move spent nuclear fuel or high-level radioactive waste shipping casks designed for a railcar.

2.1.1.4 Nevada Transportation Scenarios and Rail and Intermodal Implementing Alternatives

The transportation of spent nuclear fuel and high-level radioactive waste to the proposed repository would affect all the states through which the shipments would travel, including Nevada. However, to highlight the impacts that could occur in Nevada, DOE has chosen to discuss them separately. DOE is looking at three transportation scenarios for Nevada. These scenarios include legal-weight truck and rail, which are the same as the national scenarios but highlight the Nevada portion of the transportation, and heavy-haul truck. The heavy-haul truck scenario includes the construction of an intermodal transfer station with associated highway improvements for heavy-haul trucks in the State. DOE has identified five potential rail corridors leading to Yucca Mountain and three potential intermodal transfer station locations with five associated potential highway routes for heavy-haul trucks. Section 2.1.3.3 describes these implementing alternatives.

2.1.1.5 Continuing Investigation of Design Options

As noted, this EIS describes and evaluates the current preliminary design concept for the repository and current plans for repository construction, operation and monitoring, and closure (see Section 2.1.2). DOE continues to investigate design options for possible incorporation in the final repository design; Appendix E identifies design features and alternative design concepts that DOE is considering for the final design (for example, smaller waste packages, a waste package design using two corrosion-resistant materials, and a long-term ventilated repository). The criteria for selecting these design options are related to improving or reducing uncertainties in repository performance (the potential to provide containment and isolation of radionuclides) and operation (for example, worker and operational safety, ease of operation).

DOE has assessed each of the design options still being considered for the expected change it would have on short- and long-term environmental impacts and has compared these impacts to the potential impacts determined for the packaging, thermal load, and transportation scenarios evaluated in the EIS. This assessment, which is described in Appendix E, found that the changes in environmental impacts for the design options would be relatively minor in relation to the potential impacts evaluated in this EIS. Therefore, DOE has concluded that the analytical scenarios and implementing alternatives evaluated in this EIS provide a representative range of potential environmental impacts the Proposed Action could cause. Chapter 9 discusses mitigation from design options that could be beneficial in reducing impacts associated with repository performance or operation.

2.1.2 REPOSITORY FACILITIES AND OPERATIONS

This section describes proposed repository surface and subsurface facilities and operations (Sections 2.1.2.1 and 2.1.2.2), repository closure (Section 2.1.2.3), and the performance confirmation program (Section 2.1.2.4). The description is based on TRW (1999a, all), TRW (1999b, all), and TRW (1999c, all), unless otherwise noted. The following paragraphs contain an overview of the repository facilities and operations and the sequence of planned repository construction, operation and monitoring, and closure. DOE would design the repository based on the extensive information collected during the Yucca Mountain site characterization activities. These activities are summarized in semiannual site characterization reports. [See the semiannual Site Characterization Progress Reports that the Department prepares in accordance with Section 113(b)(3) of the NWPA (for example, DOE 1991a, all).] The facilities used for site characterization activities at Yucca Mountain would be incorporated in the repository design to the extent practicable. (See Chapter 3, Section 3.1, for additional information on existing facilities at Yucca Mountain developed during site characterization activities.)

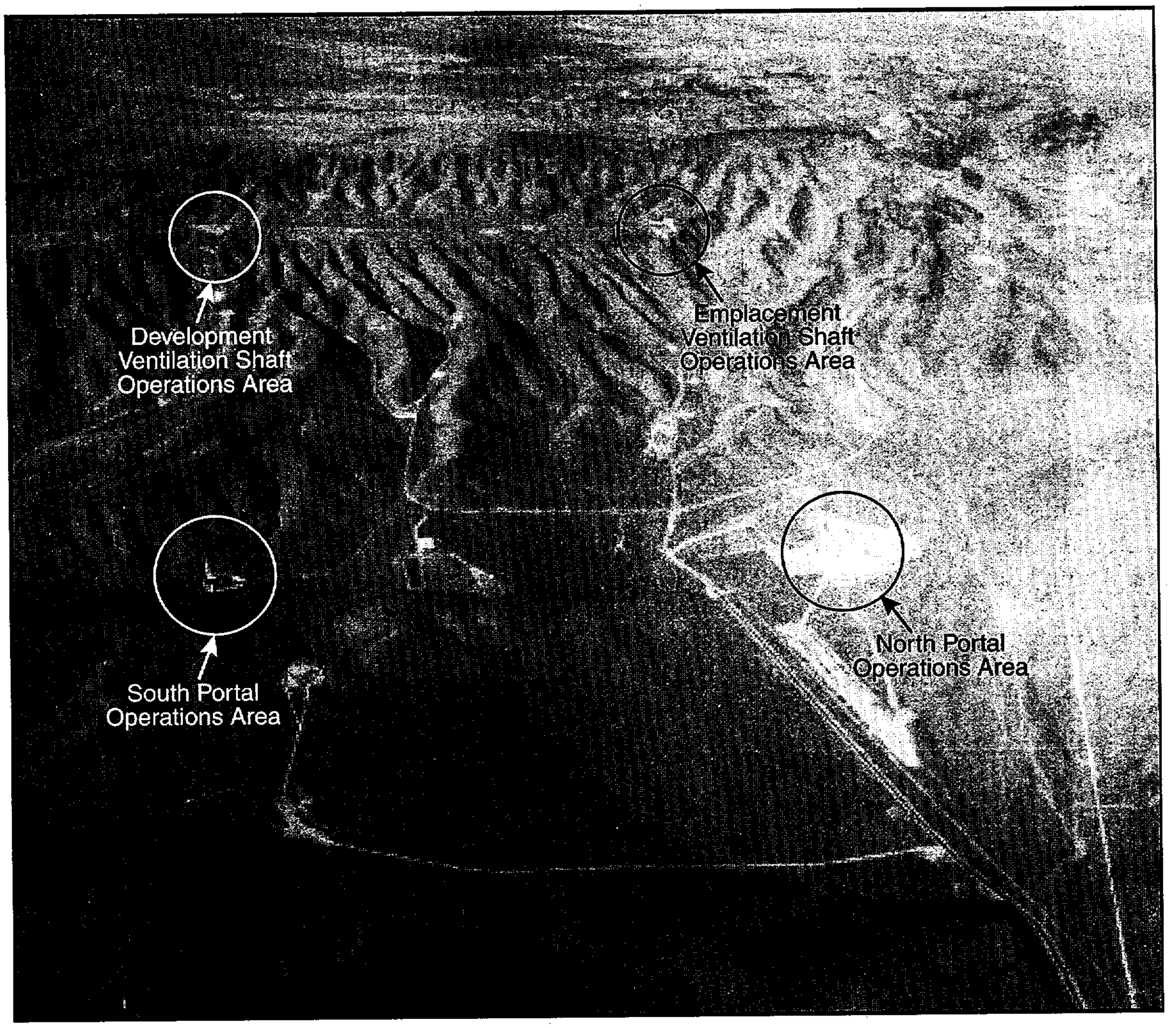
DOE would construct surface facilities at the repository site to receive, prepare, and package spent nuclear fuel and high-level radioactive waste for underground emplacement. In addition, surface facilities would support the construction of subsurface facilities. These facilities include the following primary surface operations areas:

- North Portal Operations Area – Receive, prepare, and package spent nuclear fuel and high-level radioactive waste for underground emplacement

- South Portal Operations Area – Support the construction of subsurface facilities

- Emplacement Ventilation Shaft Operations Area – Exhaust air from the subsurface facilities where waste packages would be emplaced (emplacement side)
- Development Ventilation Shaft Operations Area – Supply air to subsurface facilities where construction activities would occur (development side)

Figure 2-6 is an aerial photograph of the Yucca Mountain site showing the locations of these surface facilities. Figure 2-7 is an illustration of the repository surface facilities at the North Portal Operations Area. The spent nuclear fuel and high-level radioactive waste would be handled remotely with workers shielded from exposure to radiation using design and operations practices in use at licensed nuclear facilities to the maximum extent practicable. The repository operations areas and supporting areas, utilities, roads, etc., would require the active use of about 3.5 square kilometers (870 acres) of land. Of this total area, about 1.5 square kilometers (370 acres) have been disturbed by previous activities.

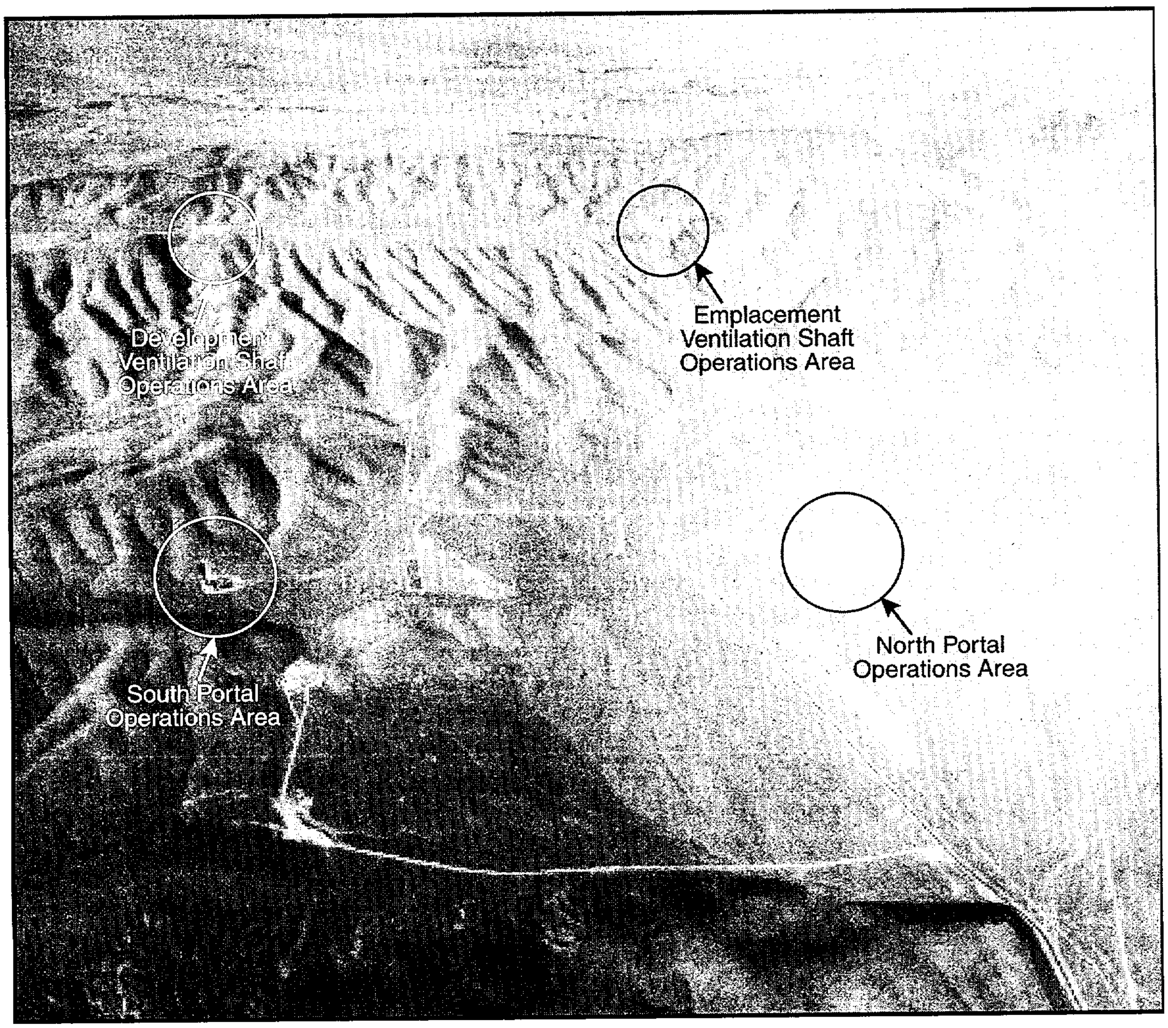


Note: The North and South Portal Operations Areas are approximately 2.7 kilometers (1.7 miles) apart.

Figure 2-6. Surface facilities at the proposed Yucca Mountain Repository.

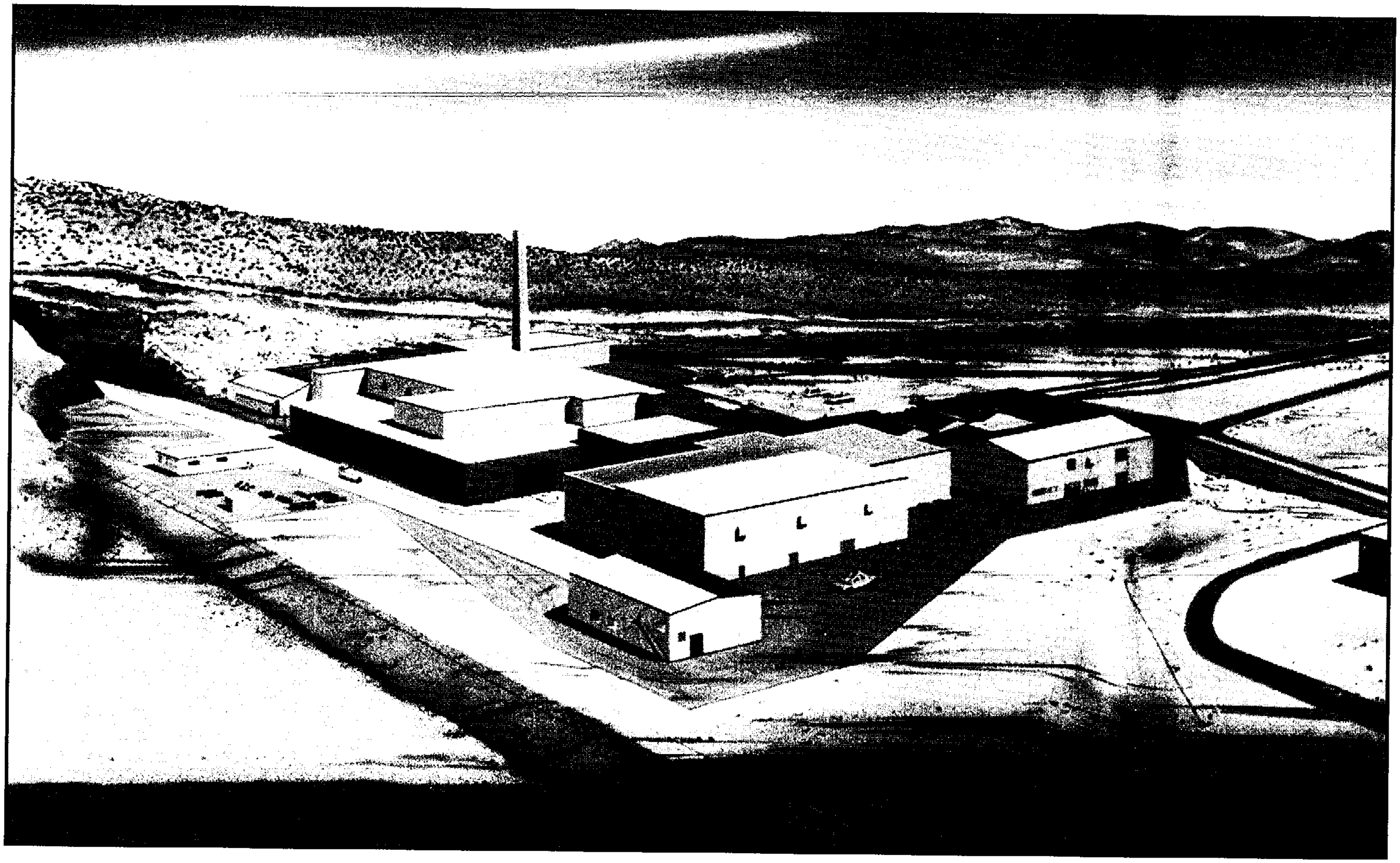
- Emplacement Ventilation Shaft Operations Area – Exhaust air from the subsurface facilities where waste packages would be emplaced (emplacement side)
- Development Ventilation Shaft Operations Area – Supply air to subsurface facilities where construction activities would occur (development side)

Figure 2-6 is an aerial photograph of the Yucca Mountain site showing the locations of these surface facilities. Figure 2-7 is an illustration of the repository surface facilities at the North Portal Operations Area. The spent nuclear fuel and high-level radioactive waste would be handled remotely with workers shielded from exposure to radiation using design and operations practices in use at licensed nuclear facilities to the maximum extent practicable. The repository operations areas and supporting areas, utilities, roads, etc., would require the active use of about 3.5 square kilometers (870 acres) of land. Of this total area, about 1.5 square kilometers (370 acres) have been disturbed by previous activities.



Note: The North and South Portal Operations Areas are approximately 2.7 kilometers (1.7 miles) apart.

Figure 2-6. Surface facilities at the proposed Yucca Mountain Repository.



Source: DOE (1998a, Overview, page 13).

Figure 2-7. Artist's conception of proposed repository surface facilities at the North Portal Operations Area.

Figure 2-8 shows the subsurface layout of the repository, which would consist of tunnels (called *drifts*) and vertical ventilation shafts that DOE would excavate in the mountain. Along with the main drifts, gently sloping ramps from the surface to the subsurface facilities would move workers, equipment, and waste packages. Waste packages of spent nuclear fuel and high-level radioactive waste would be placed in the emplacement drifts. The ventilation systems would move air for workers and would cool the repository.

Figure 2-9 shows the expected timing for construction, operation and monitoring, and closure of the proposed repository at Yucca Mountain. If a recommendation was made to proceed with the development of the repository, DOE would continue performance confirmation activities to support a License Application to the Nuclear Regulatory Commission. Preconstruction performance confirmation activities at and in the vicinity of the Yucca Mountain site would be similar to those performed during site characterization. These activities could require surface excavations, subsurface excavations and borings, and in-place testing of rock characteristics.

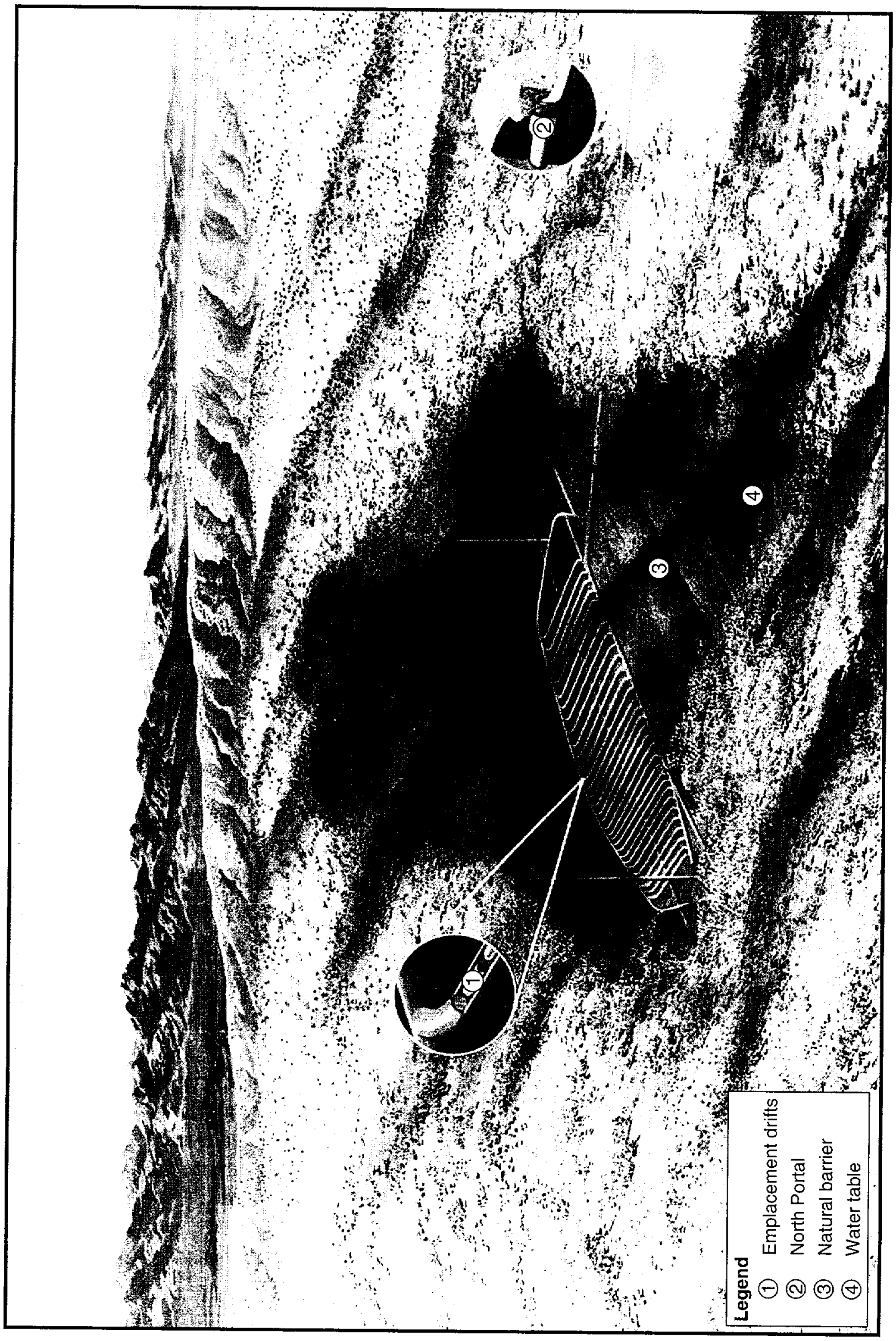
The construction of repository facilities for the handling of spent nuclear fuel and high-level radioactive waste could begin only after the receipt of construction authorization from the Nuclear Regulatory Commission. For this EIS, DOE assumed that construction would begin in 2005. The repository surface facilities, the main drifts, ventilation system, and initial emplacement drifts would be built in approximately 5 years, from 2005 to 2010.

Repository operations would begin after DOE received a license from the Nuclear Regulatory Commission to receive and possess spent nuclear fuel and high-level radioactive waste. For this EIS, DOE assumed that the receipt and emplacement of these materials would begin in 2010 and that emplacement would occur over a 24-year period ending in 2033, based on the emplacement of 70,000 MTHM at approximately 3,000 MTHM per year.

The construction of emplacement drifts would continue during emplacement and would end in about 2032. The repository design would enable simultaneous construction and emplacement operations, but it would physically separate activities on the construction or development side from activities on the emplacement side.

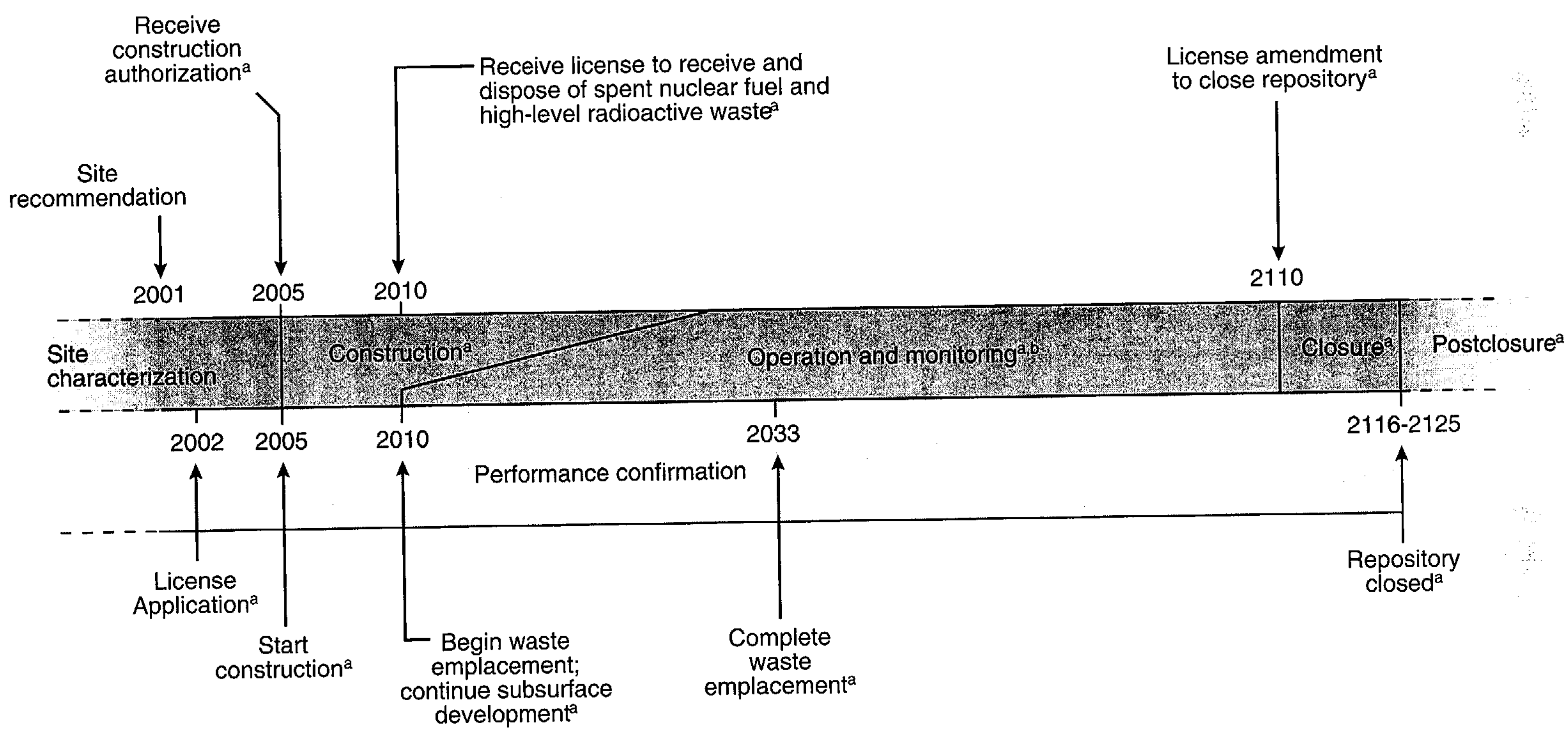
Monitoring and maintenance activities would start with the first emplacement of waste packages and would continue through repository closure. After the completion of emplacement, DOE would maintain those repository facilities, including the ventilation system and utilities (air, water, electric power) that would enable continued monitoring and inspection of the emplaced waste packages, continued investigations in support of predictions of long-term repository performance, and the retrieval of waste packages if necessary. Immediately after the completion of emplacement, DOE would decontaminate and close the facilities that handled nuclear materials on the surface to eliminate a potential radioactive material hazard. However, DOE would maintain an area of the Waste Handling Building for the possible recovery and testing of waste packages as a quality assurance contingency in the performance confirmation program (see Section 2.1.2.4). Future generations would decide whether to continue to maintain the repository in an open monitored condition or to close it. To ensure flexibility to future decisionmakers, DOE is designing the repository with the capability for closure as early as 50 years or as late as 300 years after the start of emplacement. This EIS assumes that closure would begin 100 years after the start (76 years after the completion) of emplacement, but assesses impacts (in Chapter 4) for closure beginning 50 and 300 years after the start of emplacement.

Repository closure would occur after DOE received a license amendment from the Nuclear Regulatory Commission. The period to accomplish closure would range from about 6 years for the high thermal load scenario to about 15 years for the low thermal load scenario. The closure of the repository facilities



Source: Modified from DOE (1998a, Overview, page 9).

Figure 2-8. Artist's conception of proposed repository subsurface layout.



a. If Yucca Mountain is approved.
b. The EIS analysis assumed that waste emplacement would occur over a 24-year period ending in 2033.

Source: Modified from TRW (1999b, Figure 1.5-1, page 1-3).

Figure 2-9. Expected monitored geologic repository milestones.

would include closing the subsurface facilities, decontamination and decommissioning the surface facilities, reclaiming the site, and establishing long-term institutional barriers, including land records and warning systems to limit or prevent intentional or unintentional activity in and around the closed repository (see Section 2.1.2.3).

The performance confirmation program would continue some site characterization activities through repository closure, including various types of tests, experiments, and analytical procedures. DOE would conduct performance confirmation activities to evaluate the accuracy and adequacy of the information it used to determine with reasonable assurance that the repository would meet the performance objectives for the period after permanent closure (see Section 2.1.2.4).

2.1.2.1 Repository Surface Facilities and Operations

Surface facilities at the repository site would be used to receive, prepare, and package spent nuclear fuel and high-level radioactive waste for subsurface emplacement. Surface facilities would also support the construction of the subsurface facilities. DOE would upgrade some facilities built for site characterization, but most surface facilities would be new. Most facilities would be in four areas—the North Portal Operations Area, the South Portal Operations Area, the Emplacement Ventilation Shaft Operations Area(s), and the Development Ventilation Shaft Operations Area(s)—as shown on Figure 2-10. Facilities to support waste emplacement would be concentrated near the North Portal, and facilities to support subsurface facility development would be concentrated near the South Portal.

2.1.2.1.1 *North Portal Operations Area*

This area, shown in Figure 2-11, would be the largest of the primary operations areas, covering about 0.6 square kilometer (150 acres) at the North Portal. It would include two areas: a Restricted Area for receipt of spent nuclear fuel and high-level radioactive waste handling and packaging for emplacement, and a Balance of Plant Area for support services (administration, training, emergency, and general maintenance). The Restricted Area (called the *Radiologically Controlled Area* in other DOE documents) would be enclosed by a fence and monitored to ensure adequate safeguards and security for radioactive materials. The two principal facilities in the Restricted Area would be the Carrier Preparation Building and the Waste Handling Building. Other support facilities planned for the North Portal Operations Area include basic facilities for personnel support, warehousing, security, and transportation (motor pool).

When a legal-weight truck or railcar hauling a cask containing spent nuclear fuel or high-level radioactive waste arrived at the repository site, it would move through the security check into the Restricted Area parking area or to the Carrier Preparation Building. Rail casks arriving on heavy-haul trucks might be transferred to a railcar outside the Restricted Area before entering it. Operations in the Carrier Preparation Building would include performing inspections of the vehicle and cask, removing barriers from the vehicle that protected personnel during shipment, and removing impact limiters from the cask. The vehicle would then move to the Waste Handling Building for unloading or to a storage yard until space became available for unloading. In the Waste Handling Building shipping casks would be removed from the vehicle and placed on carts (see Figure 2-12). The carts would move through the Waste Handling Building airlock to cask preparation areas, where the casks would be checked for contamination and the interior gases sampled. The casks would then be vented and cooled, and the cask lids would be unbolted.

After cask preparation operations, receipt and packaging operations would begin; the nature of these operations would depend on how the spent nuclear fuel in the shipping cask was packaged. The following paragraphs describe the different receipt and packaging operations for different types of packages.

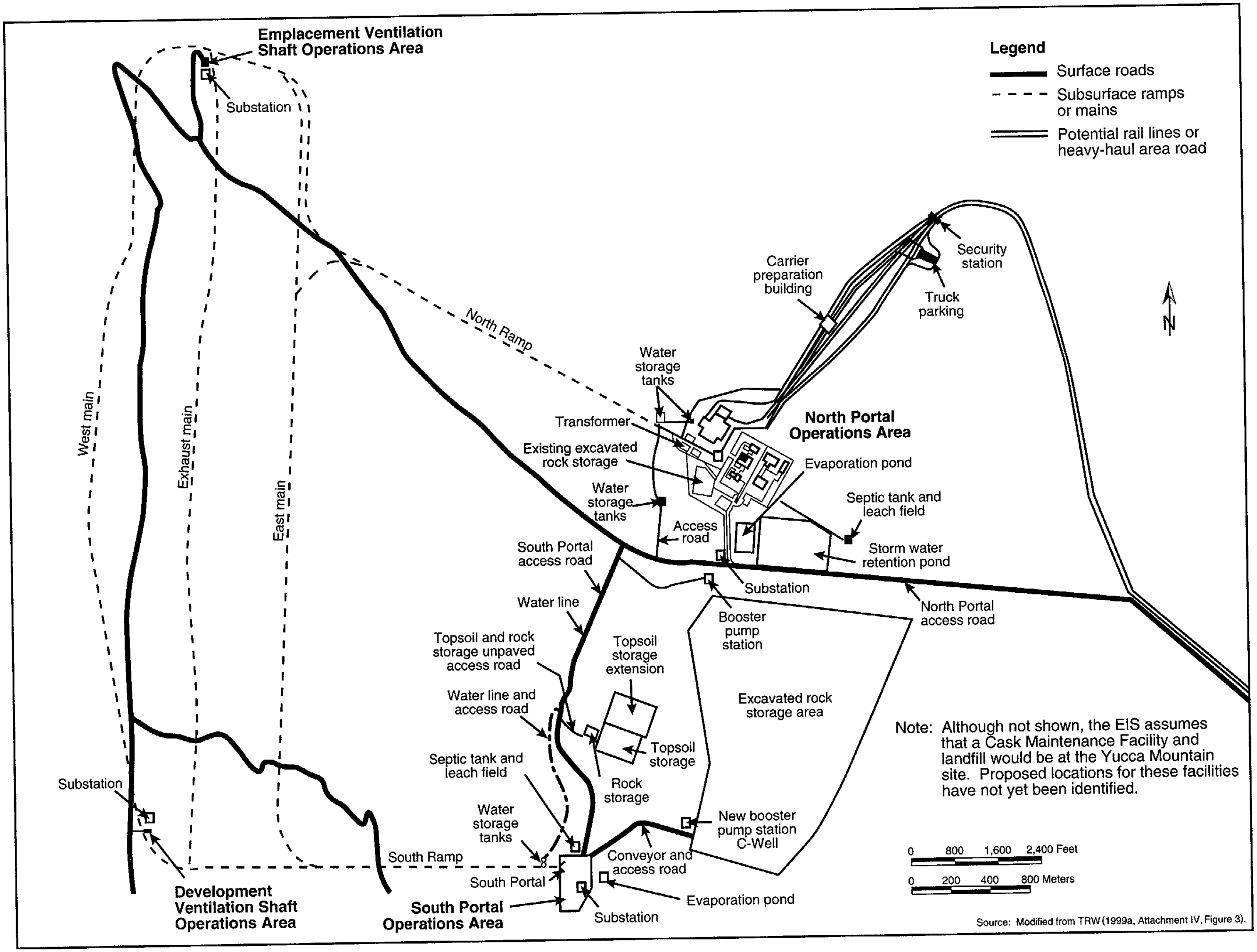
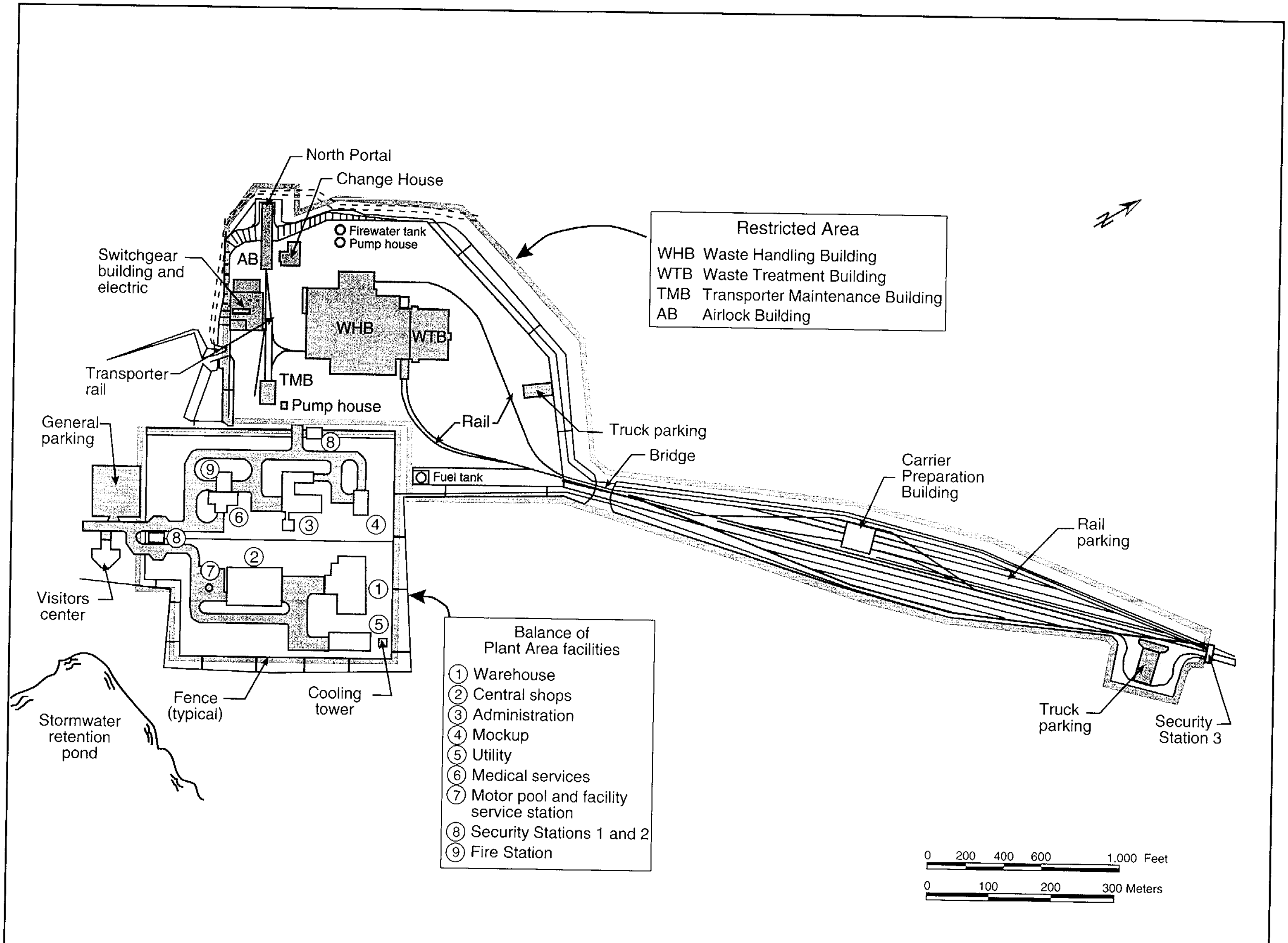


Figure 2-10. Repository surface facilities site plan.



Source: Modified from TRW (1999a, Attachment IV, Figure 4).

Figure 2-11. North Portal Operations Area site plan.

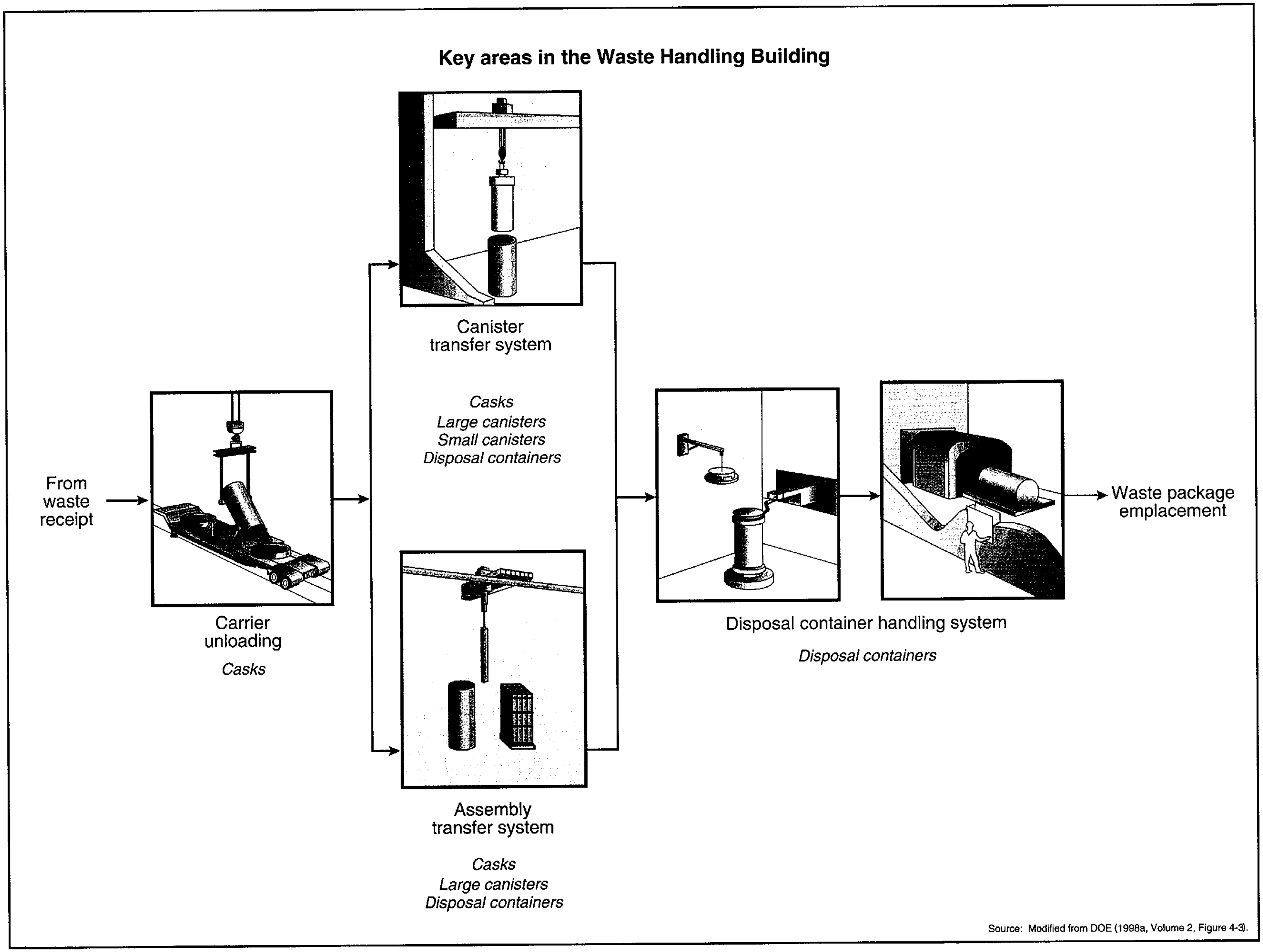


Figure 2-12. Key components of the waste handling operations.

Uncanistered spent nuclear fuel in a cask would be placed in a water transfer pool in the Waste Handling Building. The cask lid would be removed and each fuel assembly would be removed and placed in a transfer basket. When the transfer basket was loaded, it would be *staged* or moved from the pool to an assembly transfer cell and dried. The dried assemblies would be loaded in a disposal container, which would be decontaminated, and either transferred directly to a welding area or stored temporarily until a welding area was available. Welding operations would include installing and welding the inner and outer lids of the disposal container. The disposal container would be filled with an inert gas such as helium after the inner lid was welded. Each welding operation would be followed by nondestructive weld examination and certification. After weld certification, the loaded disposal container is called a *waste package* (see Section 2.1.2.2). Each waste package would be decontaminated and loaded in a shielded waste package transporter for transfer to the repository or held in the Waste Handling Building until a transporter became available.

Shipping casks containing spent nuclear fuel or high-level radioactive waste in disposable canisters would be moved directly to a dry canister transfer handling area. The shipping cask lid would be removed and the disposable canisters would be staged, or transferred directly into a disposal container. The disposal container sealing and welding process would be similar to that described for uncanistered spent nuclear fuel.

Shipping casks containing spent nuclear fuel assemblies in dual-purpose canisters would be placed in a water transfer pool. The shipping cask lid would be removed, the canister inside would be removed and opened, and the assemblies would be unloaded to a transfer basket. Once the assemblies were in the basket, the process would be the same as that described for uncanistered fuel.

DOE would decontaminate empty canisters, shipping casks, and related components as required in the Waste Handling Building. After decontamination, the empty canisters and shipping casks would be loaded on truck or rail carriers, sent to the Carrier Preparation Building for processing, and shipped off the site.

Waste generated at the repository from the decontamination of canisters and shipping casks and from other repository housekeeping activities would be collected, processed, packaged, and staged in the Waste Treatment Building before being shipped off the site for disposal at permitted facilities. Waste minimization and pollution prevention measures would reduce the amount of site-generated waste requiring such management. For example, decontamination water could be treated and recycled to the extent practicable. Site-generated wastes would include low-level radioactive waste, hazardous waste, and industrial solid waste. Operations would not be likely, but that could occur, could produce small amounts of mixed wastes (wastes containing both radioactive and hazardous materials). The repository design would include provisions for collecting and storing mixed waste for offsite disposal.

The ventilation systems for the Waste Handling Building and the Waste Treatment Building would provide confinement of radioactive contamination by using pressure differentials to ensure that the air would flow from areas free of contamination to areas potentially contaminated to areas that are normally contaminated. The monitored exhaust air from both buildings would pass through high-efficiency particulate air filters before being released through a single exhaust stack.

2.1.2.1.2 *South Portal Operations Area*

The South Portal Operations Area would cover about 0.15 square kilometer (37 acres) immediately adjacent to the South Portal of the subsurface facility. The structures and equipment in this area, which would support the development of subsurface facilities, would include a concrete plant for fabricating and curing precast components and supplying concrete for in-place casting, and basic facilities for personnel support, maintenance, warehousing, material staging, security, and transportation. From this area, overland conveyors would transport excavated rock from the repository to the excavated rock pile.

2.1.2.1.3 *Emplacement Ventilation Shaft Operations Areas*

DOE would develop these areas where ventilation shafts from the emplacement side of the subsurface reached the surface. The number of shafts required to ventilate the subsurface would depend on the thermal load scenario for the repository. A repository design with a high or intermediate thermal load would require a single ventilation shaft with a corresponding surface operations area for the emplacement side. A design with a low thermal load would require three emplacement ventilation shafts with corresponding surface operations areas because of the increased area to be ventilated. Two of these operations areas would contain fans to pull air from the emplacement area; the other would not contain fans but would supply air to the emplacement area.

An Emplacement Ventilation Shaft Operations Area would cover about 12,000 square meters (3 acres) and would normally be unstaffed. An emplacement side ventilation system would contain two fans, each driven by a 2,000-horsepower electric motor with a capacity of about 17,000 cubic meters (600,000 cubic feet) per minute. One fan would be in continuous operation and the other would be on standby. Section 2.1.2.2 contains a description of the subsurface ventilation design.

2.1.2.1.4 *Development Ventilation Shaft Operations Areas*

Development ventilation shafts would supply air to the development side of the repository. A repository design with a high or intermediate thermal load would require a single development ventilation shaft with a corresponding surface operations area. A design with a low thermal load would require two development ventilation shafts with corresponding surface operations areas because of the increased area to be ventilated. Each Development Ventilation Shaft Operations Area would be similar in size to the Emplacement Ventilation Shaft Operations Areas, and would contain two fans, each with a capacity of about 17,000 cubic meters (600,000 cubic feet) per minute and driven by a 2,000-horsepower electric motor. One fan would be in continuous operation, forcing air into the repository, and the other fan would be on standby. Section 2.1.2.2 contains a description of the subsurface ventilation design.

2.1.2.1.5 *Support Equipment and Utilities*

Repository support equipment and utilities would be on the surface in the general vicinity of the North and South Portal Operations Areas (see Figure 2-10). The storage area for excavated rock would be the largest support area. For the high or intermediate thermal load scenario, the excavated rock storage area would be between the North and South Portals, as shown in Figure 2-10, and would require about 1.0 and 1.2 square kilometers (250 and 300 acres), respectively. For the low thermal load scenario, the excavated rock storage area would be about 5 kilometers (3 miles) east of the South Portal Operations Area, as shown on Figure 2-13. Because the excavated rock pile would be higher at this location, the area required would be about 1.1 square kilometers (270 acres).

The repository site would have two evaporation ponds for industrial wastewater, one at the North Portal and one at the South Portal. Sources of industrial wastewater would include water used for dust suppression during construction, water used for cooling tower operations at the North Portal, and water used for concrete mixing and for form cleanup at the South Portal. Heavy plastic sheets would line both ponds to prevent water migration into the soil. The North Portal pond would cover about 24,000 square meters (6 acres). The evaporation pond at the South Portal would be about 2,300 square meters (0.6 acre). The North Portal area would also include an approximately 130,000-square-meter (32-acre) stormwater retention pond to control stormwater runoff from the North Portal Operations Area.

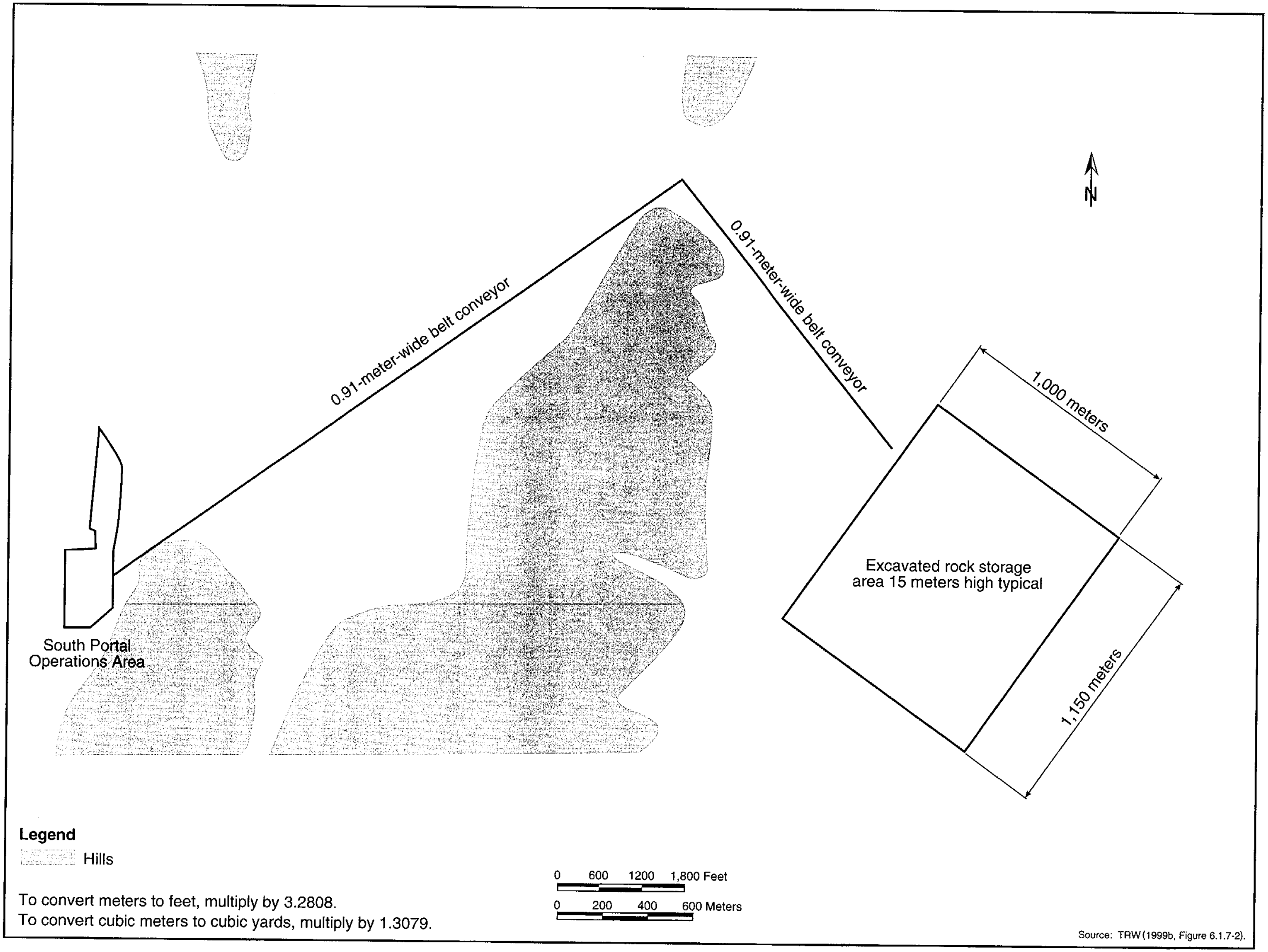


Figure 2-13. Location of excavated rock storage area for low thermal load scenario.

DOE would develop an appropriately sized landfill [approximately 0.036 square kilometer (9 acres)] at the repository site for nonhazardous and nonradiological construction and sanitary solid waste and for similar waste generated during the operation and monitoring and closure phases. The South Portal Operations Area would have a septic tank and leach field for the disposal of sanitary sewage. The North Portal Operations Area has an existing septic system that would be adequate for use during repository operations.

At present, electric power is obtained from the Nevada Test Site power distribution system. For the repository, electric power would be distributed throughout the surface and subsurface areas and to remote areas such as the Ventilation Shaft Operations Areas, construction areas, environmental monitoring stations, transportation lighting and safety systems, and water wells. To accommodate the expected demand for the repository, DOE would upgrade existing electrical transmission and distribution systems. Backup equipment and uninterruptable electric power would be provided to ensure personnel safety and operations requiring electric power continuity. Diesel generators and associated switchgear would provide the backup power capability.

DOE would use existing wells about 5.6 kilometers (3.5 miles) southeast of the North Portal Operations Area to supply water for repository activities. These wells have supplied water for site characterization activities at Yucca Mountain. Water would be pumped to a booster pump station and then to potable and nonpotable water systems that would distribute the water to the Restricted and Balance of Plant Areas and to the subsurface.

Fuel supply systems would include fuel oil for a central heating (hot water) plant, which would consist of a 950,000-liter (250,000-gallon) main tank and a 57,000-liter (15,000-gallon) day tank. In addition, there would be fuel supply systems for generating steam to cure precast concrete, for fire water system tank heaters, for diesel-powered standby generators and air compressors, and for backup fire pumps. Diesel fuel and gasoline would also be provided to fuel vehicles during the construction, operation and monitoring, and closure of the repository.

2.1.2.2 Repository Subsurface Facilities and Operations (Including Waste Packages)

DOE would construct the subsurface facilities of the repository and emplace the waste packages above the water table in a mass of volcanic rock known as the Topopah Spring Formation (welded tuff) (see Chapter 3, Section 3.1.3.1). The specific area in this formation where DOE would build the repository would satisfy several criteria. The primary criteria would be to (1) be within select portions of the Topopah Spring formation that have desirable properties, (2) avoid major faults for reasons related to both hydrology and seismic hazard (see Section 3.1.3.2), (3) be at least 200 meters (660 feet) below the surface, and (4) be at least 100 meters (330 feet) above the water table (TRW 1993, pages 5-99 to 5-101).

Figures 2-14, 2-15, and 2-16 show the repository footprint for the emplacement of spent nuclear fuel and high-level radioactive waste for the high, intermediate, and low thermal load scenarios, respectively. DOE would develop a high thermal load repository in the upper emplacement block, using 3 square kilometers (740 acres), with two ventilation shafts to the surface, one on the emplacement side and one on the development side (Figure 2-14). An intermediate thermal load repository would also be in the upper emplacement block, would have an area of 4.25 square kilometers (1,050 acres), and would require two ventilation shafts to the surface (Figure 2-15). A low thermal load repository would be in the upper and lower emplacement blocks and in Area 5, would use an area of approximately 10 square kilometers (2,500 acres), and would require three emplacement and two development ventilation shafts (Figure 2-16).

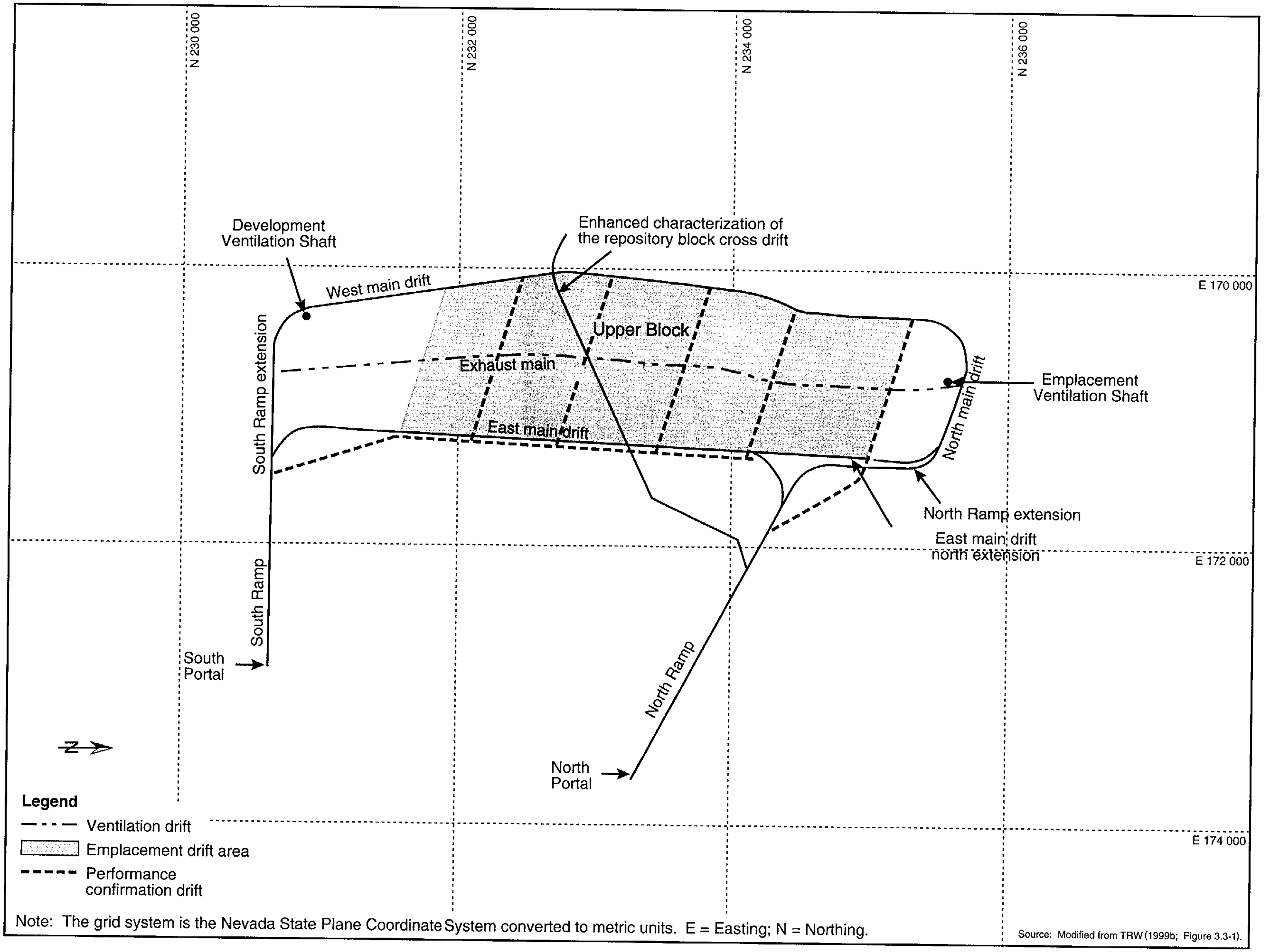


Figure 2-14. High thermal load repository layout.

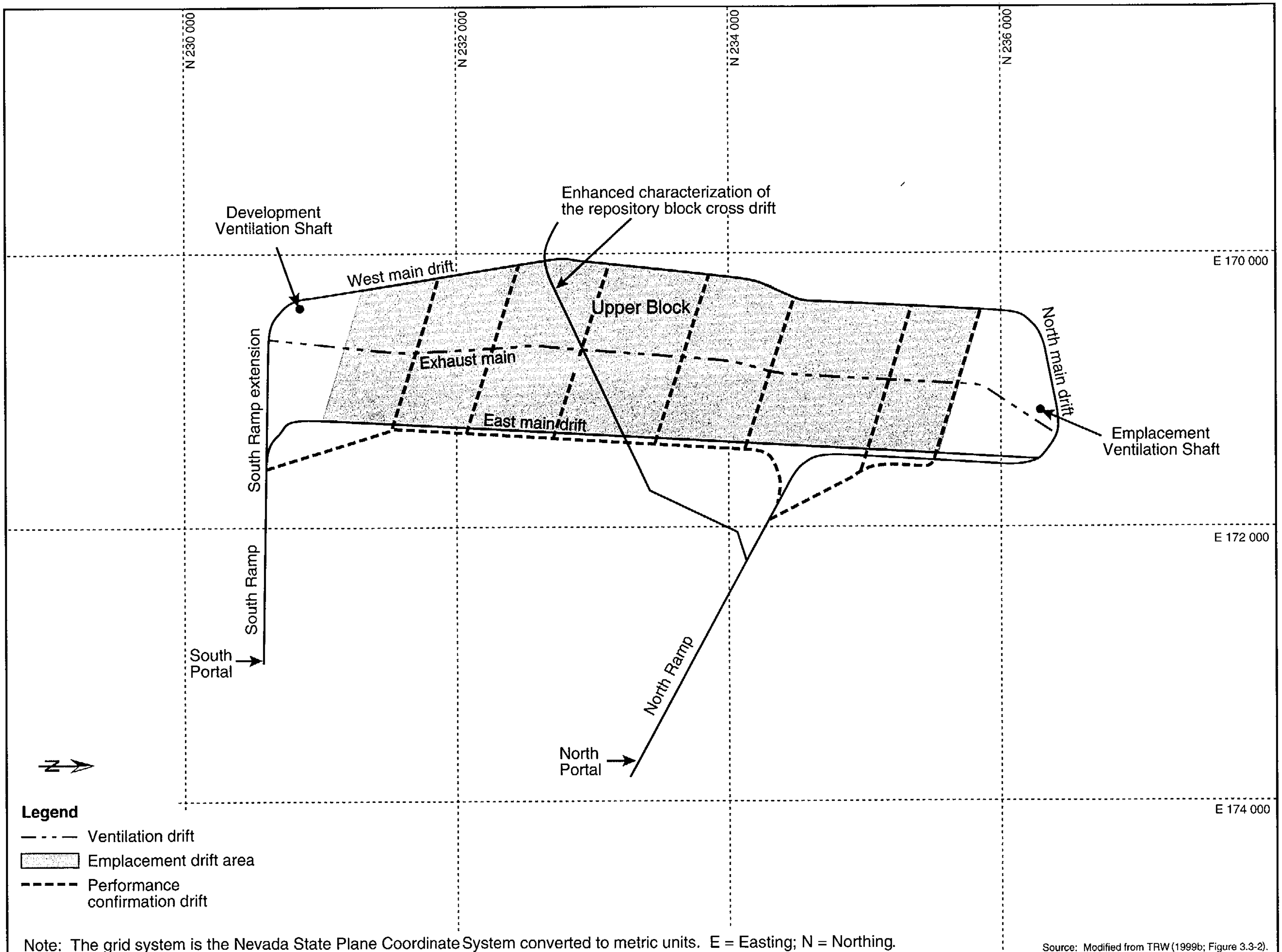


Figure 2-15. Intermediate thermal load repository layout.

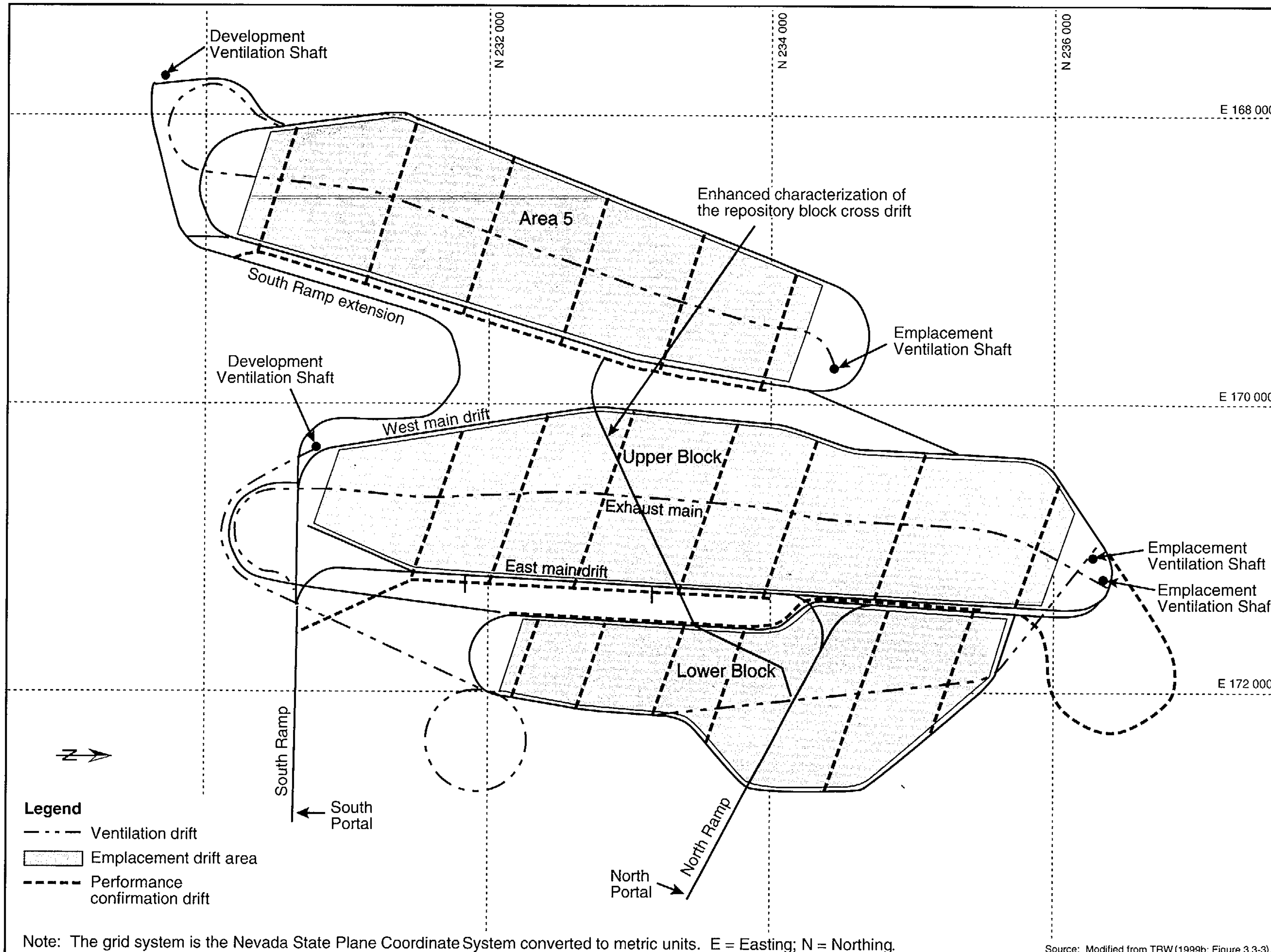


Figure 2-16. Low thermal load repository layout.

The following paragraphs describe the subsurface facility design and construction (including the ventilation system), the design of the waste packages, and waste package emplacement operations.

2.1.2.2.1 *Subsurface Facility Design and Construction*

The subsurface design would incorporate most of the drifts developed during the site characterization activities. Other areas would be excavated during the repository construction phase. Excavated openings would include gently sloping access ramps to enable rail-based movement of construction and waste package handling vehicles between the surface and subsurface, subsurface main drifts to enable the movement of construction and waste package handling 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. There would also be performance confirmation drifts for the placement of instrumentation to monitor emplaced waste packages (see Figures 2-14, 2-15, and 2-16).

Access ramps connecting the surface and subsurface would be concrete-lined, 7.6-meter (25-foot)-diameter tunnels excavated by electric-powered tunnel boring machines (see Figure 2-17). Rail lines and an overhead trolley system would enable the movement of electric-powered construction and waste package handling vehicles. The North and South Ramps were developed during site characterization and would become part of the proposed repository. The North Ramp begins at the North Portal Operations Area on the surface (see Section 2.1.2.1) and extends through the subsurface to the edge of the repository area. It would support waste package emplacement operations. The South Ramp originates at the South Portal Operations Area on the surface (see Section 2.1.2.1) and extends through the subsurface to the edge of the repository area. It would support subsurface construction activities.

The main drifts for a high thermal load, shown in Figure 2-14, would include the East Main, the West Main, and the North Main. These drifts would be extended for the intermediate or low thermal load scenario. Additional main drifts would be excavated for the low thermal load scenario to provide access to other emplacement areas. Main drifts would be concrete-lined, 7.6-meter (25-foot)-diameter tunnels excavated by tunnel boring machines. Rail lines and an overhead trolley system in the main drifts would enable the movement of electric-powered construction and waste package handling vehicles. The East Main drift was excavated as part of site characterization activities but was not lined with concrete. During the operation and monitoring phase, the main drifts would support both subsurface construction and waste package emplacement, which would occur simultaneously. Ventilation barriers creating airlocks would 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 any air leakage would be from the development side to the emplacement side.

Emplacement drifts would be 5.5-meter (18-foot)-diameter tunnels connecting the main drifts; they could have steel ribbing or be lined with concrete. These drifts would be excavated by an electrically powered tunnel boring machine. An emplacement drift would be large enough to permit the movement of waste packages over emplaced packages in the drift. Steel isolation doors at the emplacement drift entrances would prevent unauthorized human access and reduce radiation exposure to personnel. In addition, radiation shields would be placed at the ends of emplacement drifts that contained waste packages. The isolation doors would be opened and closed remotely. Figure 2-18 shows an emplacement drift branching off the East Main drift.

Exhaust main drifts would ventilate the emplacement side of the repository; they would be roughly perpendicular to and at a level below the emplacement drifts (see Figure 2-19). The exhaust main drift would connect with the emplacement drifts through a ventilation raise and would connect with an emplacement ventilation shaft. For a high thermal load configuration, a 6.7-meter (22-foot) exhaust main

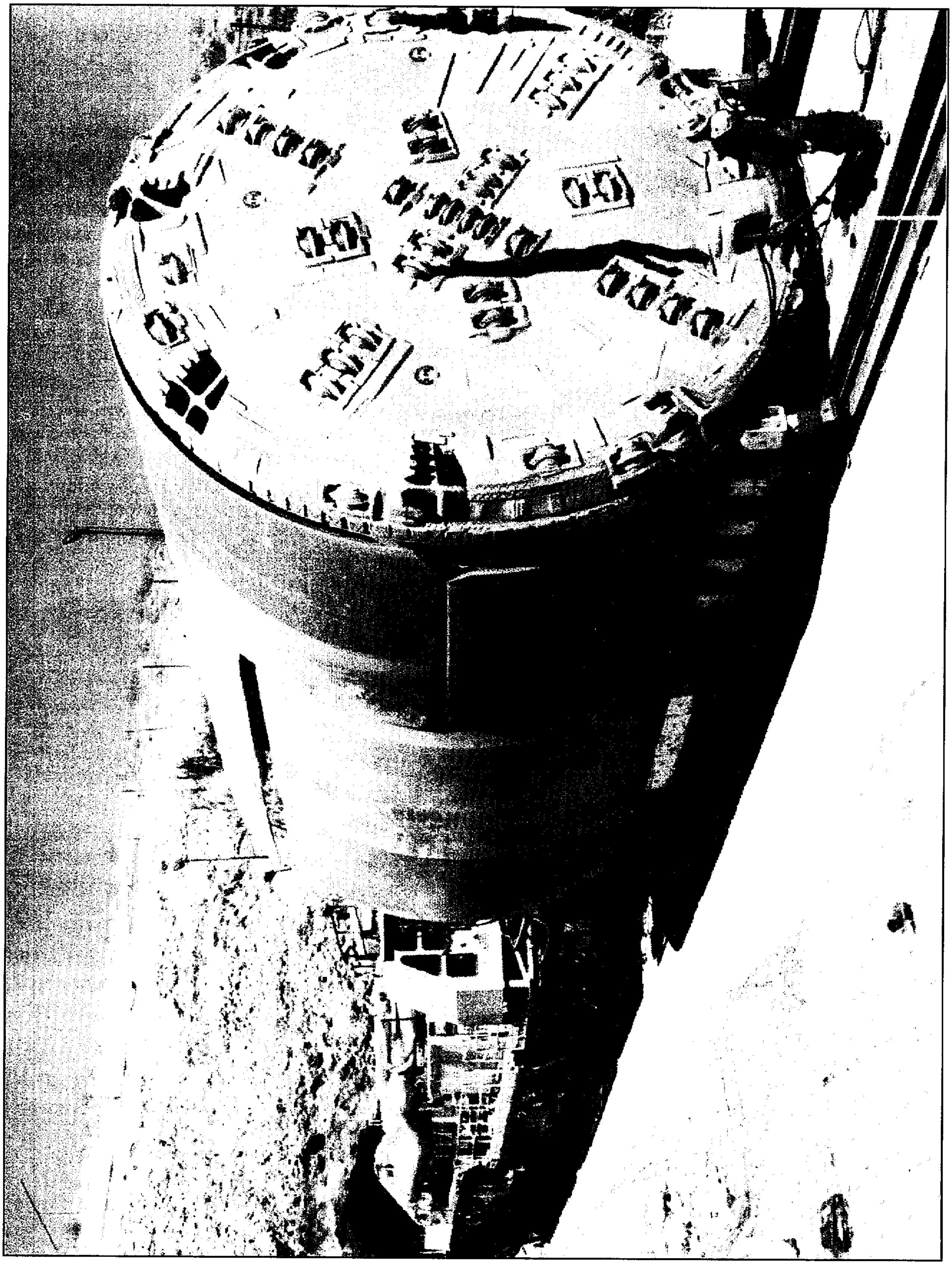
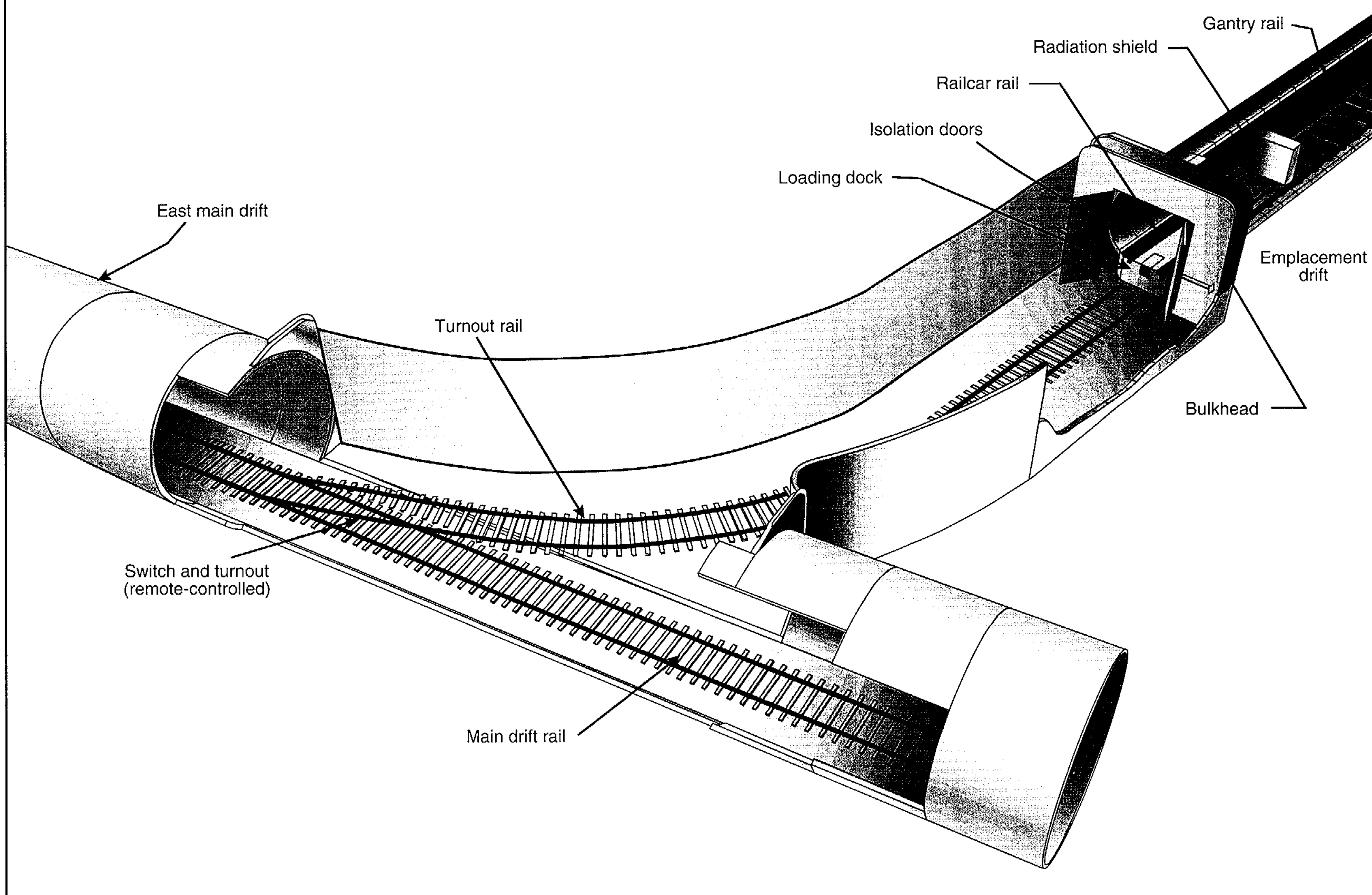
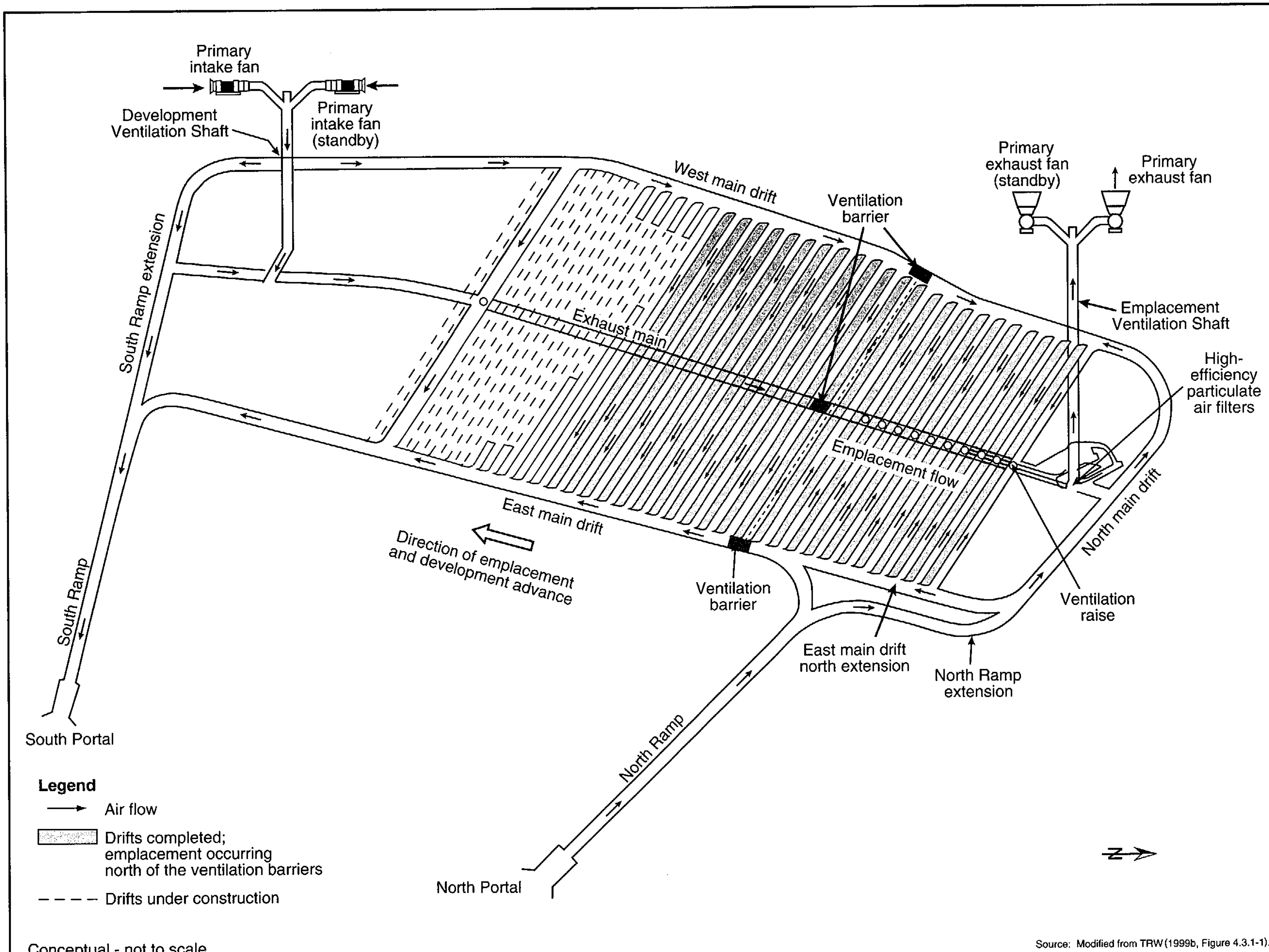


Figure 2-17. Tunnel boring machine.



Source: Modified from TRW (1999b, Figure 4.3.2.8-1).

Figure 2-18. Artist's conception of emplacement drift branching from main drift.



Fig[illegible]-19. Subsurface conceptual design for ventilation air flow d[illegible] construction and operations.

drift would be excavated approximately 10 meters (33 feet) below the emplacement drift. This drift would be extended for the intermediate and low thermal load scenarios. For the low thermal load scenario, other exhaust main drifts would be excavated to ventilate the additional emplacement areas. For a high thermal load configuration, DOE would excavate two 6.7-meter (22-foot)-diameter shafts for repository ventilation, an emplacement ventilation shaft at the north end and a development ventilation shaft at the south end of the upper emplacement block. An intermediate thermal load configuration would also require two shafts. These vertical shafts would extend from approximately 10 meters (33 feet) below the repository to the surface of the mountain. The emplacement ventilation shaft shown in Figure 2-19 would connect to the north end of the exhaust main drift and provide the only route for emplacement side air to leave the repository. It would be the primary ventilation exhaust airway for emplacement and monitoring activities before closure; as such, it would contain continuous radiation detection and monitoring equipment. During emplacement and monitoring operations, fans on the surface would pull air up the emplacement ventilation shaft. If the monitors detected a radioactive material leak from an emplacement drift, the exhaust air would be diverted automatically through the high-efficiency particulate air filters installed at the bottom of the emplacement ventilation shaft. Fresh air would be pulled into the repository through the North Ramp.

The development ventilation shaft, shown in Figure 2-19, would supply fresh air to the construction side of the repository. It would be the primary ventilation intake airway for subsurface development activities. Fans at the development ventilation shaft operations area would force air down to the development side of the repository. The South Ramp would be the exhaust path for air in the development side.

For a low thermal load configuration, DOE would excavate five ventilation shafts—three on the emplacement side of the repository and two on the development side. Two of the shafts on the emplacement side would contain fans to pull the air from the subsurface; the third would be an intake air shaft with no fans. Air would be pulled into the subsurface from this shaft and the North Ramp. An additional ventilation shaft would force air into the development side.

As noted above, electrically powered tunnel boring machines would excavate the emplacement drifts and most main drifts. DOE would use other mechanical excavators in areas where tunnel boring machines were impractical (for example, excavating turnouts and small alcoves) or industry-standard drill and blast techniques in limited applications where mechanical excavators were impractical. No drill and blast operations are currently envisioned, but if they were needed, care would be taken to ensure that the waste isolation properties of the mountain were not compromised. Ventilation shafts would be bored from the surface to the repository. Specialized equipment would move excavated rock in the subsurface to the conveyor system, which would move the rock from the subsurface to the excavated rock storage area on the surface. During drift excavation, water supplied to the subsurface in pipelines would be used for dust control at the excavation location and along the conveyor carrying excavated rock. Some of the water would be removed from the subsurface with the excavated rock, some would evaporate and be removed in the ventilation air, and the remainder would be collected in sumps near the point of use and pumped to the evaporation pond at the South Portal. DOE could recycle the water discharged to the evaporation pond for surface dust suppression activities. Controls would be established, as necessary, to ensure that water application for subsurface (and surface) dust control would not affect repository performance.

2.1.2.2.2 *Waste Package Design*

The function of the waste package changes over the repository lifetime. During the operation and monitoring phase, the disposal containers or waste packages would function as the vessels for safely handling, emplacing, and retrieving (if necessary) their contents. After closure, the waste packages would be the primary engineered barrier to inhibit the release of radioactive material to the environment.

DOE is developing specific waste package designs for uncanistered spent nuclear fuel assemblies, canistered spent nuclear fuel assemblies, and high-level radioactive waste canisters (Figure 2-20). The waste packages would be cylindrical containers and, in the preliminary conceptual design, range from 3.7 meters (12 feet) to 6.2 meters (20 feet) long and 1.25 to 2.0 meters (4.1 to 6.6 feet) in diameter. The waste packages of commercial spent nuclear fuel would hold as many as 21 pressurized-water reactor fuel assemblies or 44 boiling-water reactor fuel assemblies. There would be two general waste package designs for other types of spent nuclear fuel. These two designs would hold either a canister containing assemblies of naval spent nuclear fuel, or several canisters containing DOE spent nuclear fuel assemblies. There would be two general co-disposal waste package loading options, which would hold either five high-level radioactive waste canisters with an additional canister containing DOE spent nuclear fuel assemblies, or five canisters containing both high-level radioactive waste and immobilized plutonium waste forms. In addition, there would be waste packages that would contain only high-level radioactive waste.

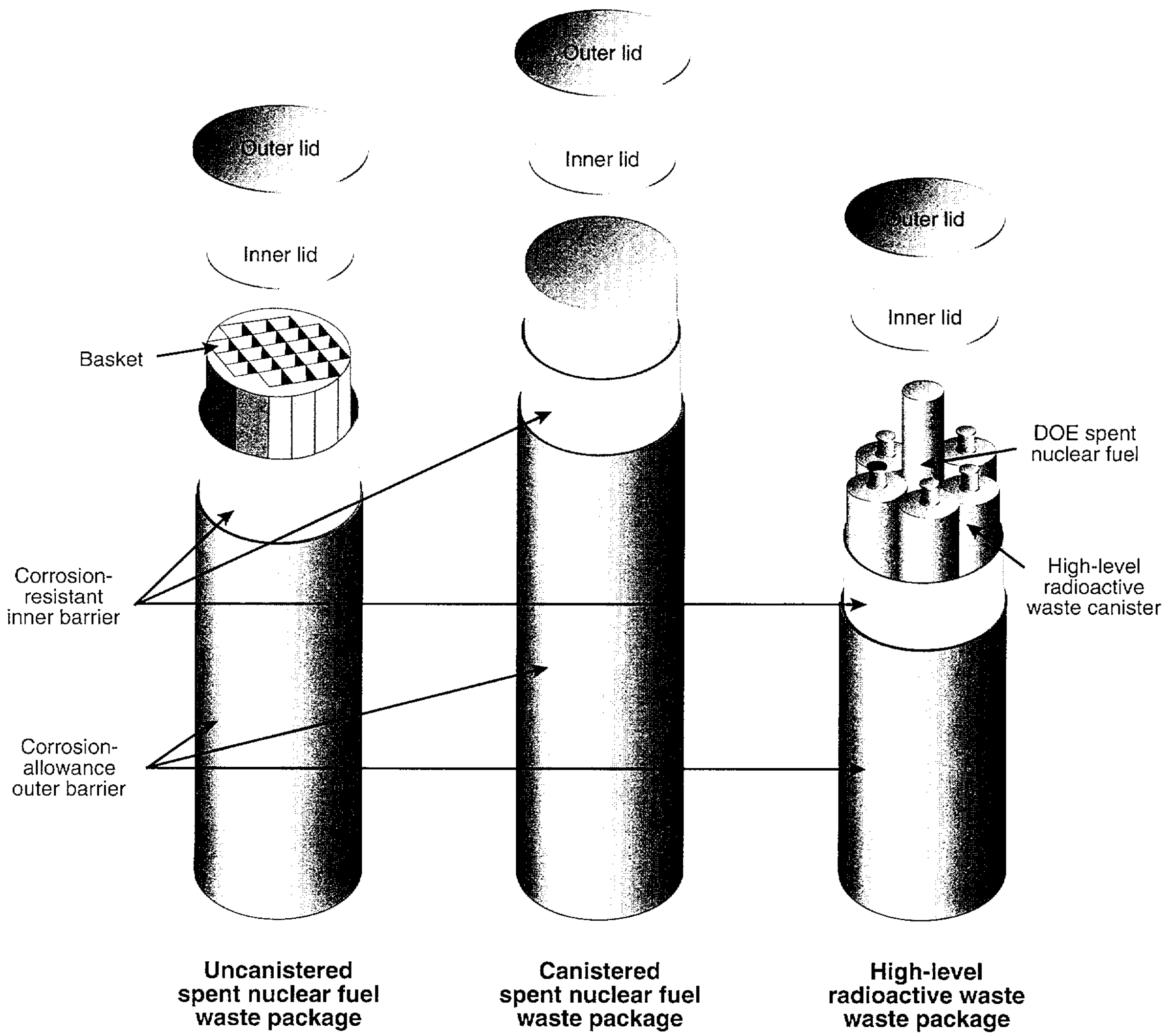
The preliminary conceptual design of the waste packages would have two layers: a structurally strong outer layer of carbon steel about 10 centimeters (4 inches) thick, and a corrosion-resistant inner layer of high-nickel alloy (Alloy 22) about 2 centimeters (0.79 inch) thick. These two layers would work together to preserve the integrity of the waste package for thousands of years.

Commercial spent nuclear fuel, DOE spent nuclear fuel, and immobilized plutonium contain *fissile material,* which is material capable, in principle, of sustaining a fission chain reaction. For a self-sustaining chain reaction to take place, a critical mass of fissile material—uranium-233 or -235 or one of several plutonium isotopes—must be arranged in a critical configuration. Waste packages are loaded with fissile material and neutron absorbers, if needed, so criticality cannot occur even in the unlikely event that the waste package somehow became full of water.

The waste packages would be placed horizontally on supports in the emplacement drifts (Figure 2-21). The supports would be steel and concrete structures that would hold the waste packages above the drift floor. DOE would place approximately 10,000 to 11,000 waste packages, which would include both spent nuclear fuel and high-level radioactive waste, in the repository. For the high thermal load scenario, the emplacement drifts would be spaced approximately 28 meters (92 feet) apart; for the intermediate thermal load scenario, they would be spaced approximately 28 to 40 meters (92 to 130 feet) apart; and for the low thermal load scenario, they would be spaced approximately 38 meters (125 feet) apart. In the emplacement drifts, DOE would then use the optimum spacing of waste packages based on their actual heat load; therefore, spacing would be greatest for the low thermal load scenario.

2.1.2.2.3 *Waste Package Emplacement Operations*

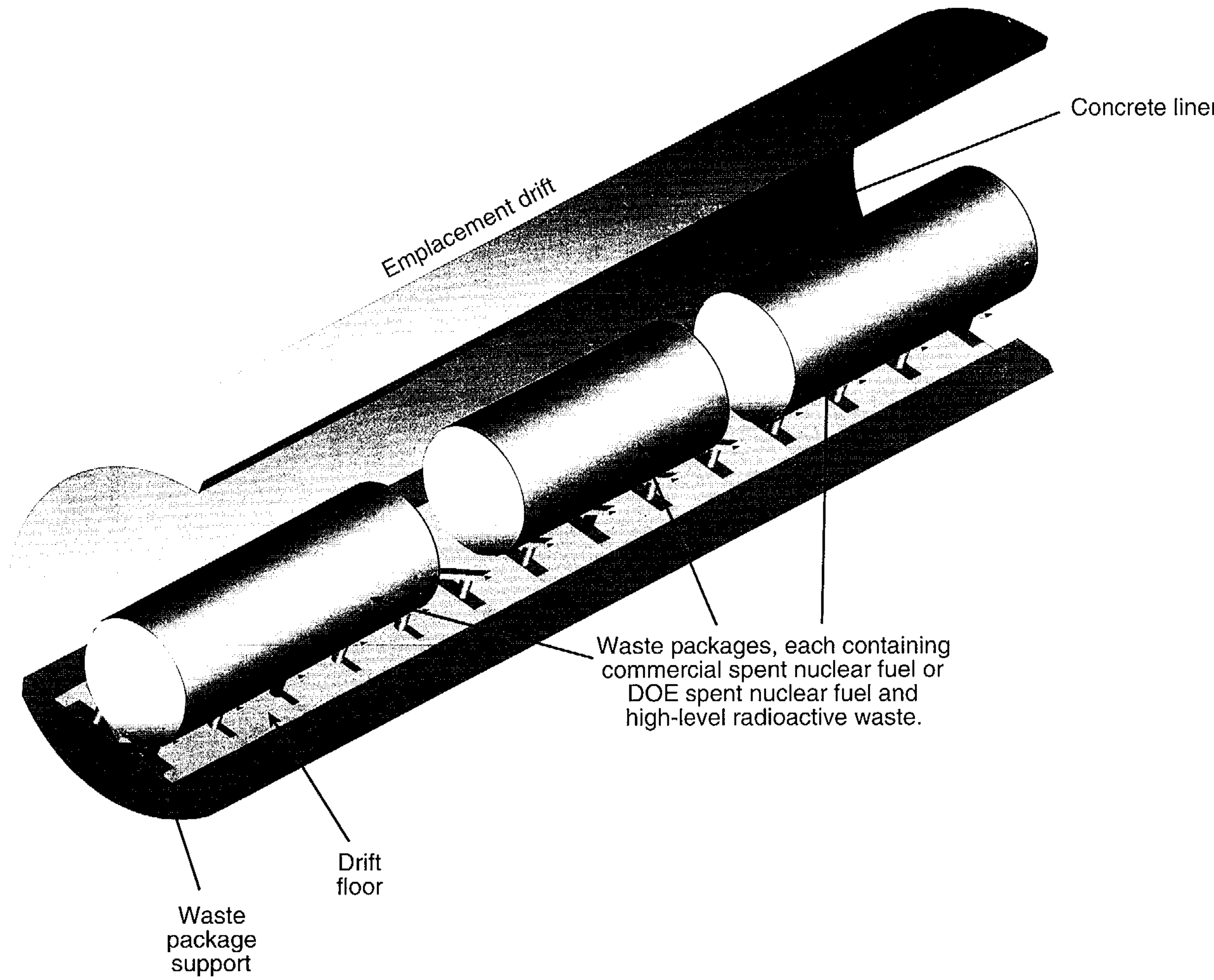
The transport of each waste package to the subsurface would start after the loading of a waste package on a reusable railcar and the loading of that railcar in a shielded waste package transporter in the Waste Handling Building (Figure 2-22). The transporter would be coupled at its closed end to a primary electric powered locomotive (trolley). A secondary electric powered locomotive would be coupled to the door end of the waste package transporter outside the Waste Handling Building. All waste packages would be transported underground through the North Ramp to the emplacement area main drift (Figure 2-23). On arrival at the emplacement drift, the secondary locomotive would be uncoupled from the transporter, and the transporter would be pushed into the emplacement drift turnout by the primary locomotive and stopped short of the isolation doors and loading dock. The doors would be opened remotely, as would the transporter doors. The transporter would be moved to align with the loading dock. The waste package would be moved on the railcar to the emplacement drift loading dock. The gantry would lift the waste package from the railcar and carry it to its emplacement location. The empty railcar would be returned to



Note: Waste packages would range in size from 3.7 to 6.2 meters (12 to 20 feet) long and 1.25 to 2.0 meters (4.1 to 6.6 feet) in diameter. They would range in weight from 35,000 kilograms (77,000 pounds) to 83,000 kilograms (183,000 pounds).

Source: Modified from DOE (1998a, Volume 3, Figure 2-3).

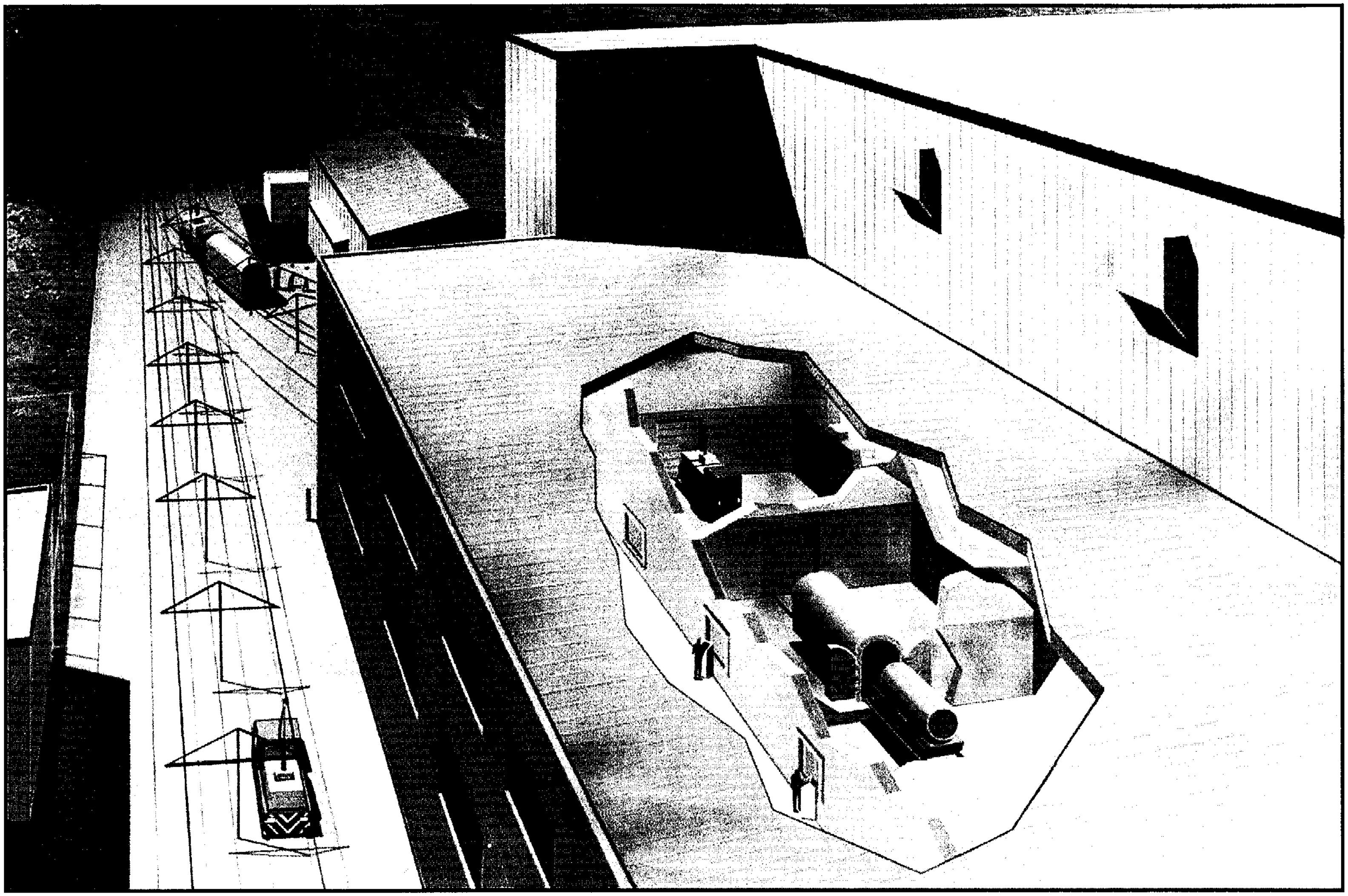
Figure 2-20. Potential waste package designs for spent nuclear fuel and high-level radioactive waste.



Note: Spacing between packages is for illustration only. The actual spacing would be determined as a function of the final repository thermal load design.

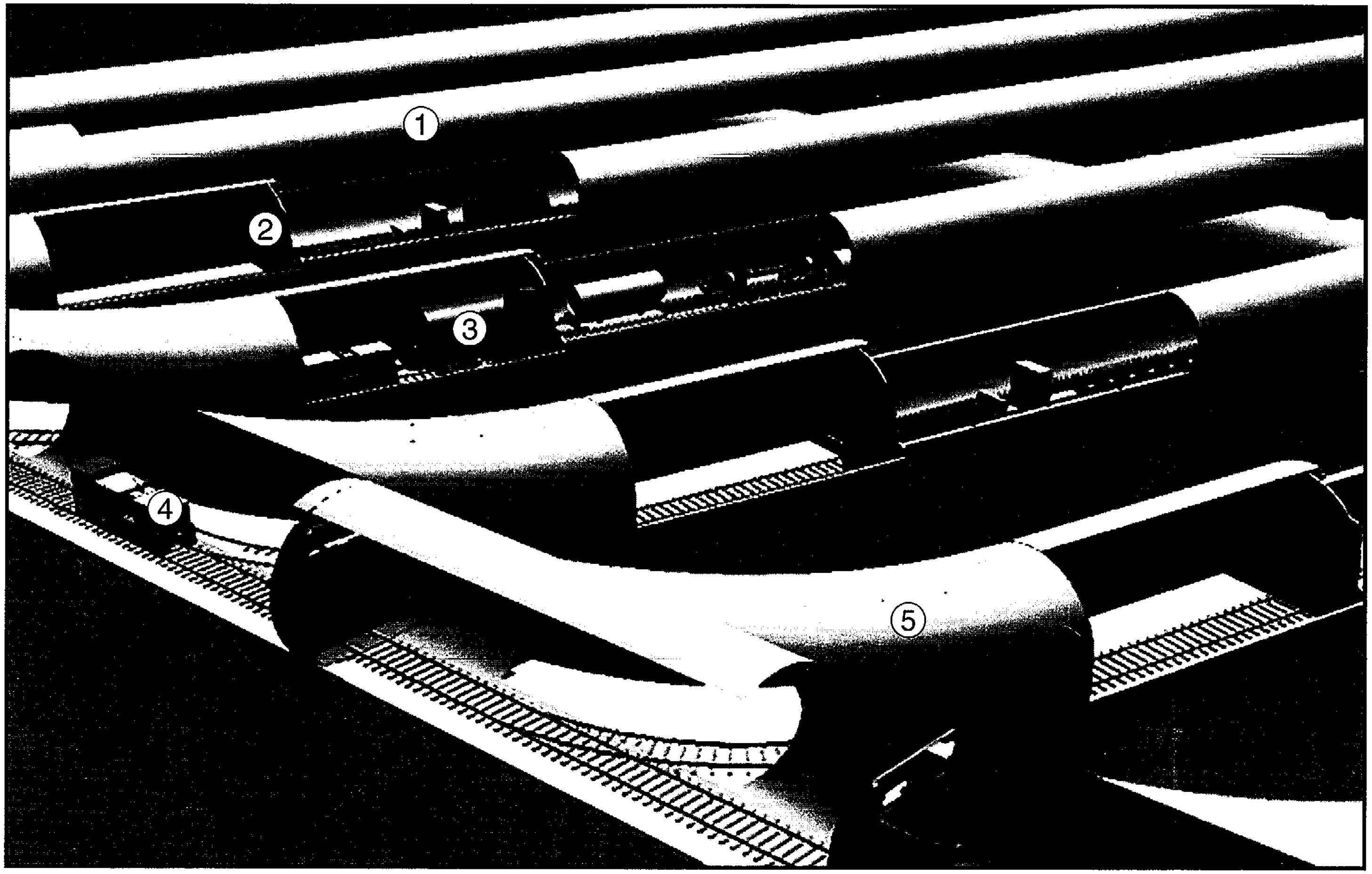
Sources: Modified from DOE (1998a, Volume 2, Figure 5-1).

Fig ?-21. Conceptual design of waste packages in emplacement



Source: DOE (1998a, Overview, page 28).

Figure 2-22. Artist's conception of operations to move waste underground (view of Waste Handling Building and North Portal).



(1) Emplacement drift
(2) Emplacement drift isolation door
(3) Waste package transporter (waste package waiting for gantry)
(4) Electric-powered locomotive (trolley)
(5) Turnout

Sources: Modified from DOE (1998a, Overview, page 14).

Fi -23. Artist's conception of repository underground facilities operation.

the transporter, the isolation doors would be closed remotely, and the empty transporter with locomotives coupled front and rear would be returned to the surface for reuse.

2.1.2.3 Repository Closure

Permanent closure of the proposed repository would include closing the subsurface facilities, decontaminating and decommissioning the surface facilities, reclaiming the site, and establishing institutional barriers. This EIS assumes that repository closure would begin 100 years after the start of emplacement (76 years after the completion of emplacement). The time to complete repository closure would vary from about 6 years for the high and intermediate thermal load scenarios to about 15 years for the low thermal load scenario.

The closure of the subsurface repository facilities would include the removal and salvage of equipment and materials; filling of the main drifts, access ramps, and ventilation shafts; and sealing of openings, including ventilation shafts, access ramps, and boreholes. Filling operations would require surface operations to obtain fill material from the excavated rock pile or other source, and processing (screening, crushing, and possibly washing) the material to obtain the required particle size. Fill material would be transported on the surface in trucks and underground in open gondola railcars. A fill placement system would place the material in the underground main drifts and ramps. Seals for shafts, ramps, and boreholes would be strategically located to reduce radionuclide migration over extended periods, and so that they could not become pathways that could compromise the repository's postclosure performance. Seal materials and placement methods would be selected to reduce, to the extent practicable, the creation of preferential pathways for groundwater to contact the waste packages and the migration of radionuclides through existing pathways.

Decommissioning surface facilities would include decontamination activities, if required, and facility dismantlement and removal. Equipment and materials would be salvaged, recycled, or reused, if possible. Site reclamation would include restoring the site to as near its preconstruction condition as practicable. Reclamation could require the recontouring of disturbed surface areas, surface backfill, soil buildup and reconditioning, site revegetation, site water course configuration, and erosion control.

DOE would use institutional controls, including land records and warning systems, to limit or prevent intentional and unintentional activities in and around the closed repository. The repository area would be identified by monuments that would be designed, fabricated, and placed to be as permanent as practicable. Provisions could be added for postclosure monitoring.

2.1.2.4 Performance Confirmation Program

Performance confirmation refers to the program of tests, experiments, and analyses that DOE would conduct to evaluate the accuracy and adequacy of the information used to determine with reasonable assurance that long-term performance objectives have been met. The performance confirmation program, which would continue through the closure phase, would include elements of site testing, repository testing, repository subsurface support facilities construction, and waste package testing. Some of these activities would be a continuation of activities that began during site characterization. The data collection focus of the performance confirmation program initially would be to collect additional information to support enhanced confidence in the data used in the License Application. After the granting of licenses, the activities primarily would focus on monitoring and data collection for parameters important to terms and conditions of the license. The types of data important in the performance confirmation programs could include:

- Thermal response of the rock mass
- Air temperature and relative humidity in the emplacement drifts

- Possible emanation of radioactive gases from the emplacement drifts
- Condition of the waste packages and emplacement drifts
- Placement and recovery of test amounts of sample materials in the emplacement drifts
- Saturated zone monitoring
- Possible groundwater flow into the emplacement drifts and evidence of standing water accumulating in the emplacement drifts
- Air permeability, stress, and deformation and displacement of the rocks around the emplacement drifts
- Soil and rock temperature around the repository
- Moisture content, vapor content and humidity, fluid temperature, and air pressure in the rock adjacent to the emplacement drifts that would be most strongly affected by the presence of the emplaced waste

Performance confirmation drifts would be built about 15 meters (50 feet) above the emplacement drifts (see Figures 2-14, 2-15, and 2-16). DOE would drill boreholes from the performance confirmation drifts that would approach the rock mass near the emplacement drifts; instruments in these boreholes would gather data on the thermal, mechanical, hydrological, and chemical characteristics of the rock after waste emplacement. DOE would acquire performance confirmation data by sampling and mapping, from instruments in performance confirmation drifts or along the perimeter mains, ventilation exhaust monitoring, remote inspection systems in emplacement drifts, and possible recovery of waste packages for testing.

The performance confirmation program data would be used to evaluate total system performance and to confirm predicted system response. If the data determined that actual conditions differed from those predicted, the results could support further evaluation of the impacts of actual conditions on the long-term performance of the repository system.

2.1.3 TRANSPORTATION ACTIVITIES

Under the Proposed Action, DOE would transport spent nuclear fuel and high-level radioactive waste from commercial and DOE sites to the repository. The Naval Nuclear Propulsion Program would transport naval spent nuclear fuel from the Idaho National Engineering and Environmental Laboratory to the repository. Transportation activities would include the loading of these materials for shipment at generator sites (Section 2.1.3.1), transportation of the materials to the Yucca Mountain site by truck, rail, or possibly barge [see Sections 2.1.3.2 (National) and 2.1.3.3 (Nevada)], and shipping cask manufacturing, maintenance, and disposal (Section 2.1.3.4).

2.1.3.1 Loading Activities at Commercial and DOE Sites

This EIS evaluates the loading of spent nuclear fuel and high-level radioactive waste at commercial and DOE sites for transportation to the proposed repository at Yucca Mountain. Activities would include removing the spent nuclear fuel or high-level radioactive waste from storage, loading it in a shipping cask, and placing the cask on a vehicle (see Figures 2-24 and 2-25) for shipment to the repository. This EIS assumes that at the time of shipment the spent nuclear fuel and high-level radioactive waste would be in a form that met approved acceptance and disposal criteria for the repository.

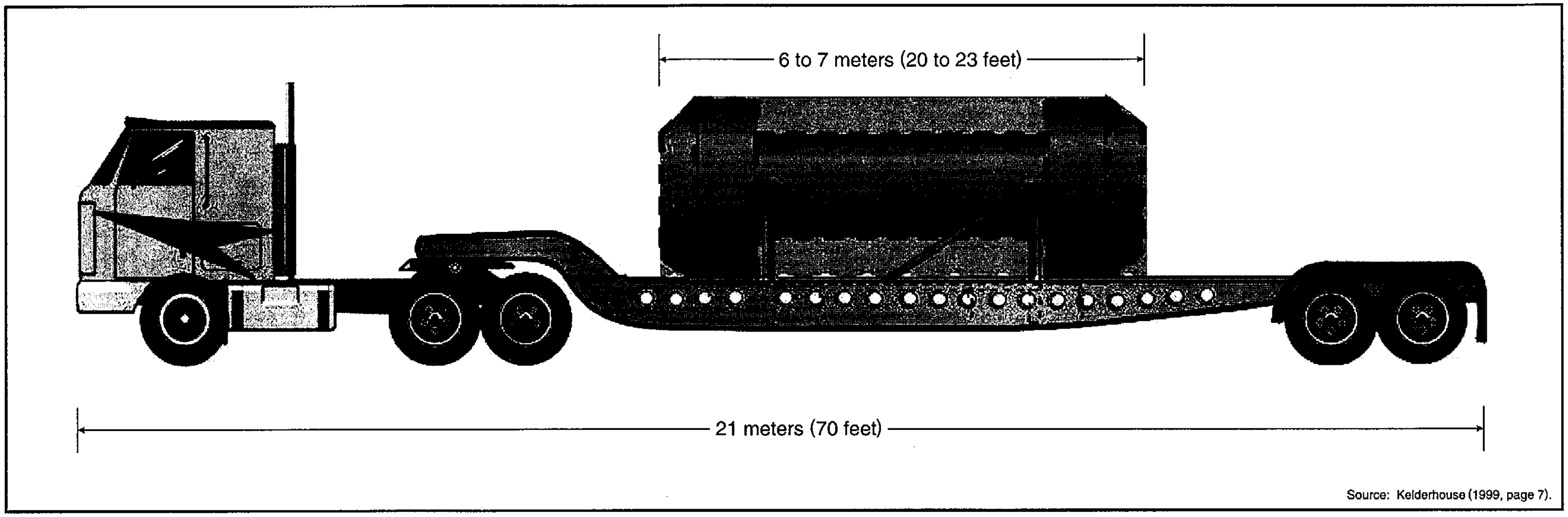


Figure 2-24. Artist's conception of a truck cask on a legal-weight tractor-trailer truck.

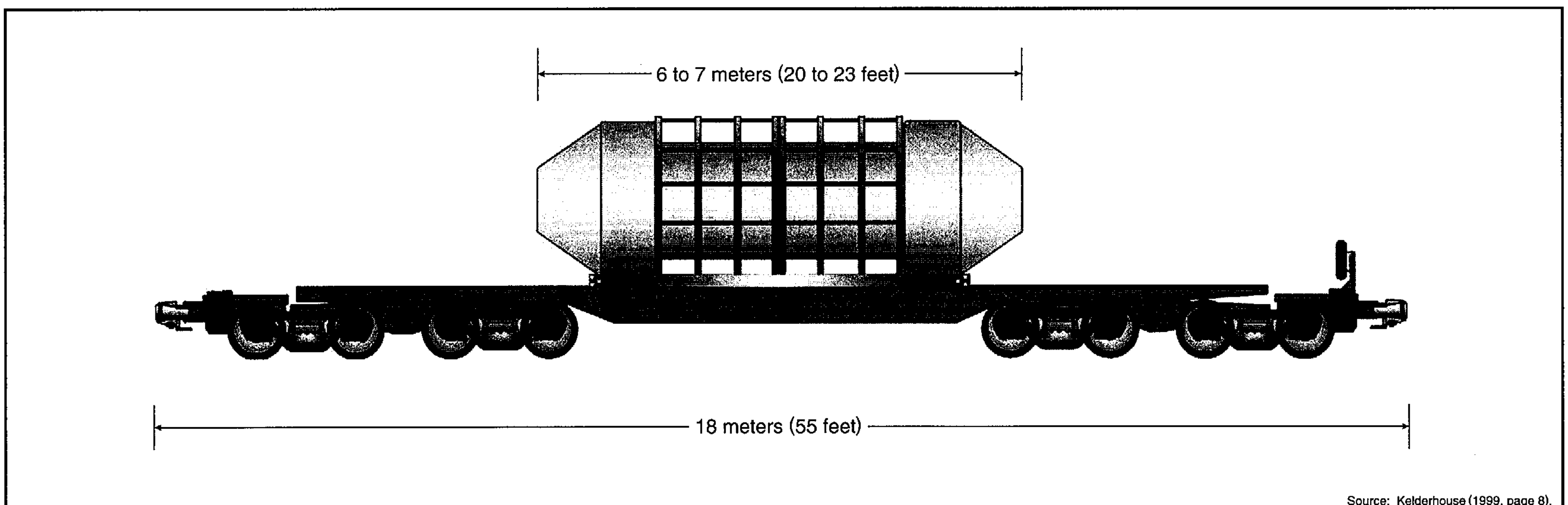


Figure 2-25. Artist's conception of a large rail cask on a railcar.

2.1.3.2 National Transportation

National transportation includes the transport of spent nuclear fuel and high-level radioactive waste from the commercial and DOE sites to the Yucca Mountain site using existing highways (see Figure 2-26) and railroads (see Figure 2-27). Heavy-haul trucks could be used to transport spent nuclear fuel from commercial sites that did not have rail access to a nearby rail access point. Such sites on navigable waterways could use barges to deliver spent nuclear fuel to a nearby rail access point. The transportation of spent nuclear fuel and high-level radioactive waste to the repository would comply with applicable regulations of the U.S. Department of Transportation and the Nuclear Regulatory Commission, as well as applicable state and local regulations.

DOE has developed TRANSCOM, a satellite-based transportation tracking and communications system, to track current truck and rail shipments. Using the TRANSCOM system, DOE would monitor shipments of spent nuclear fuel and high-level radioactive waste to the repository at frequent intervals. This or a similar system could provide users (for example, DOE, the Nuclear Regulatory Commission, and state and tribal governments) with information about shipments to the repository and would enable communication between the vehicle operators and a central communication station. In heavily populated areas, armed escorts would be required for highway and rail shipments (10 CFR 73.37).

Section 180(c) of the Nuclear Waste Policy Act requires DOE to provide technical and financial assistance to states and tribes for training public safety officials in jurisdictions through which it plans to transport spent nuclear fuel and high-level radioactive waste. The training is to include procedures for the safe routine transportation of these materials and for emergency response situations. DOE is developing the policy and procedures for implementing this assistance and has started discussions with the appropriate organizations. The Department would institute these plans before beginning shipments to the repository. In the event of an incident involving a shipment of spent nuclear fuel or high-level radioactive waste, the transportation vehicle crew would notify local authorities and the central communications station monitoring the shipment. DOE would make resources available to local authorities as appropriate to mitigate such an incident.

2.1.3.2.1 *National Transportation Shipping Scenarios*

DOE would ship spent nuclear fuel and high-level radioactive waste from commercial and DOE sites in some combination of legal-weight truck, rail, heavy-haul truck, and possibly barge. This EIS considers two national transportation scenarios, which for simplicity are referred to as the mostly legal-weight truck scenario and the mostly rail scenario. These scenarios illustrate the broadest range of operating conditions relevant to potential impacts to human health and the environment. Table 2-2 summarizes these scenarios, and Appendix J provides additional details.

Table 2-2. National transportation scenarios (percentage based on number of shipments).[a]

Material	Mostly legal-weight truck	Mostly rail
Commercial SNF	100% by legal-weight truck	About 80% by rail; about 20% by legal-weight truck
HLW	100% by legal-weight truck	100% by rail
DOE SNF	Mostly legal-weight truck; includes about 300 naval SNF shipments from INEEL to Nevada by rail	100% by rail

a. SNF = spent nuclear fuel; HLW = high-level radioactive waste; INEEL = Idaho National Engineering and Environmental Laboratory.

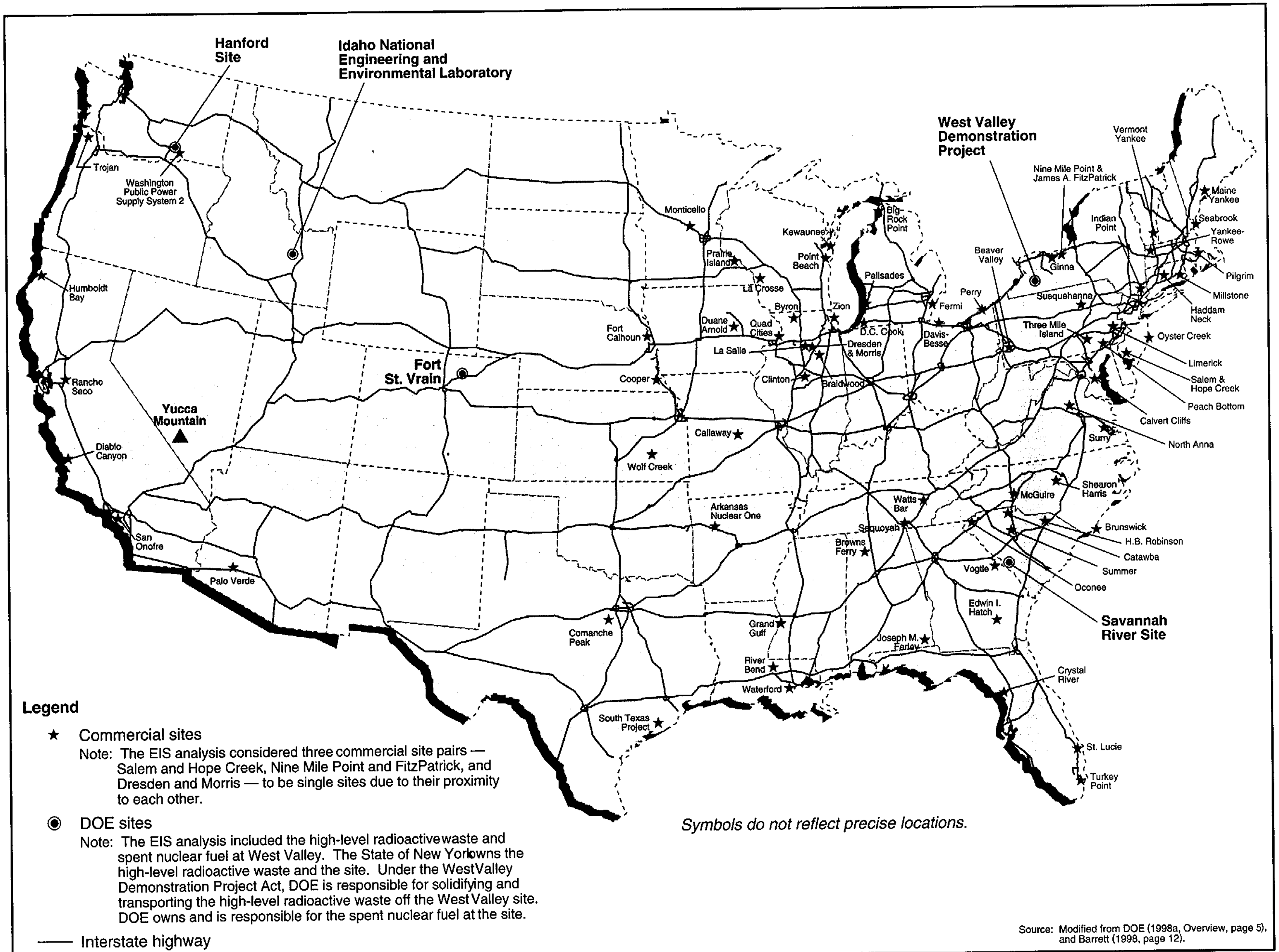


Figure 2-26. Commercial and DOE sites and Yucca Mountain in relation to the U.S. Interstate Highway System.

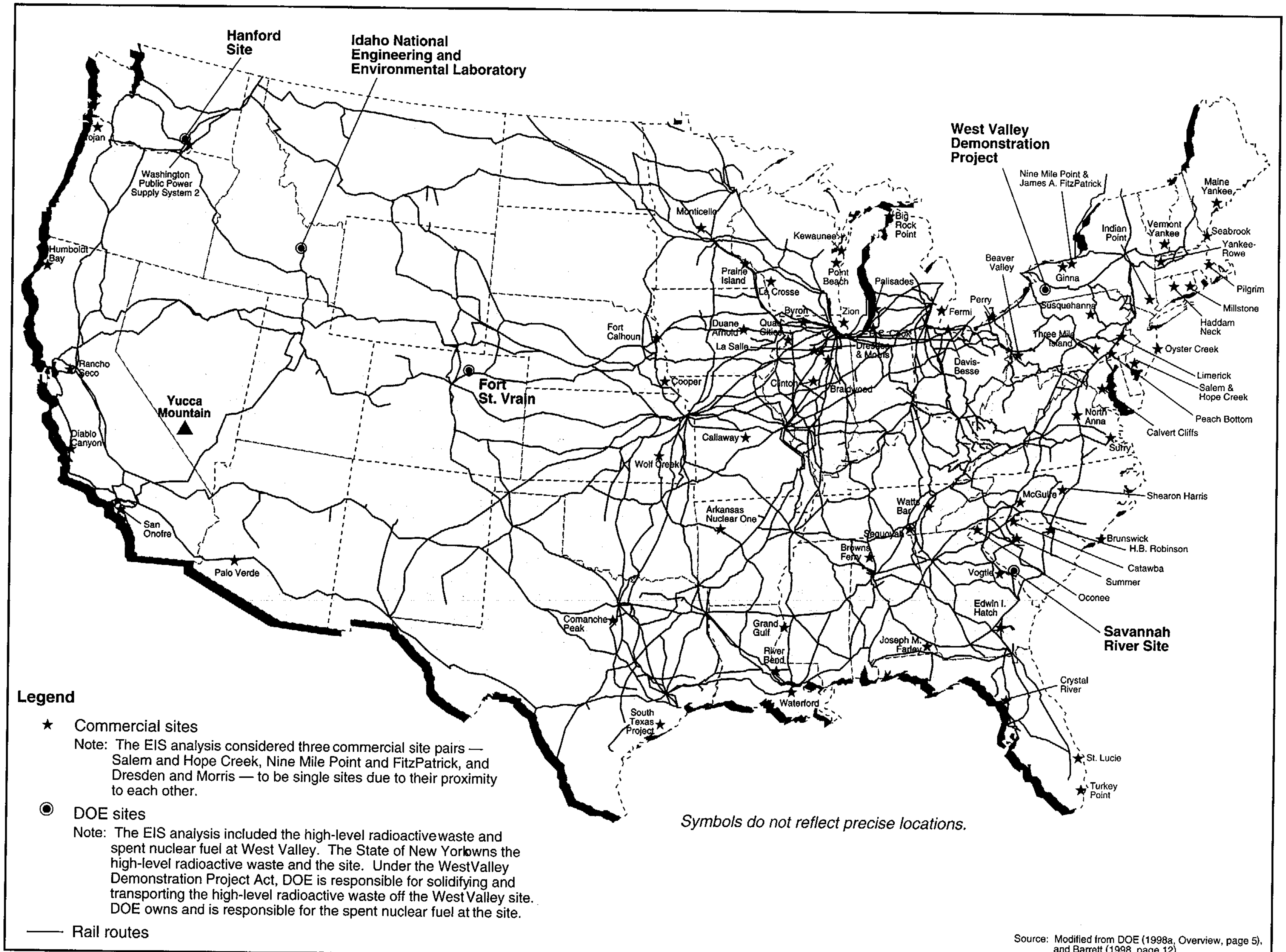


Figure 2-27. Commercial and DOE sites and Yucca Mountain in relation to the U.S. railroad system.

2.1.3.2.2 *Mostly Legal-Weight Truck Shipping Scenario*

Under this scenario, DOE would ship all high-level radioactive waste and most spent nuclear fuel from commercial and DOE sites to the Yucca Mountain site by legal-weight truck. About 50,000 shipments of these materials would travel on the Nation's Interstate Highway System during a 24-year period. There would be about 38,000 commercial spent nuclear fuel shipments and about 12,000 shipments of DOE spent nuclear fuel and high-level radioactive waste. The exception would be about 300 shipments of naval spent nuclear fuel that would travel from the Idaho National Engineering and Environmental Laboratory to Nevada by rail. [The Navy prepared an EIS (USN 1996a, all) and issued two Records of Decision (62 *FR* 1095, January 8, 1997; 62 *FR* 23770, May 1, 1997) on its spent nuclear fuel.]

Truck shipments would use Nuclear Regulatory Commission-certified, reusable shipping casks secured on legal-weight trucks (Figure 2-24). With proper labels and vehicle placards (hazard identification) and vehicle and cask inspections, a truck carrying a shipping cask of spent nuclear fuel or high-level radioactive waste would travel to the repository on highway routes selected in accordance with U.S. Department of Transportation regulations (49 CFR 397.101), which require the use of preferred routes. These routes include the Interstate Highway System, including beltways and bypasses. Alternative routes could be designated by states and tribes following Department of Transportation regulations (49 CFR 397.103) that require consideration of the overall risk to the public and prior consultation with affected local jurisdictions and with any other affected states.

Shipments of naval spent nuclear fuel would travel by rail in reusable shipping casks certified by the Nuclear Regulatory Commission. These shipments would use applicable and appropriate placards and inspection procedures.

2.1.3.2.3 *Mostly Rail Shipping Scenario*

Under this scenario, DOE would ship most spent nuclear fuel and high-level radioactive waste to Nevada by rail, with the exception of material from commercial nuclear sites that do not have the capability to load large-capacity rail shipping casks. Those sites would ship spent nuclear fuel to the repository by legal-weight truck. Commercial sites that have the capability to load large-capacity rail shipping casks but not rail access could use heavy-haul trucks or barges to transport their spent nuclear fuel to a nearby rail line. Under this scenario, about 11,000 railcars of spent nuclear fuel and high-level radioactive waste would travel on the nationwide rail network over a period of 24 years. Rail shipments would consist of Nuclear Regulatory Commission-certified, reusable shipping casks secured on railcars (see Figure 2-25). In addition, there would be about 2,600 legal-weight truck shipments. All shipments would be marked with the appropriate labels and placards and would be inspected in accordance with applicable regulations.

Some of the logistics of rail transportation to the repository would depend on whether DOE used general or dedicated freight service. General freight shipments of spent nuclear fuel and high-level radioactive waste would be part of larger trains carrying other commodities. A number of transfers between trains could occur as a railcar traveled to the repository. The basic infrastructure and activities would be similar between general freight and dedicated trains. However, dedicated train service would contain only railcars destined for the repository. In addition to railcars carrying spent nuclear fuel or high-level radioactive waste, there would be buffer and escort cars, in accordance with Federal regulations. DOE would use a satellite-based system to monitor all spent nuclear fuel shipments (see Section 2.1.3.2).

TERMS RELATED TO RAIL SHIPPING

General freight rail service: A train that handles a number of commodities. Railcars carrying spent nuclear fuel or high-level radioactive waste could switch in railyards or on sidings to a number of trains as they traveled from commercial and DOE sites to Nevada.

Dedicated freight rail service: A train that handles only one commodity (in this case, spent nuclear fuel or high-level radioactive waste). Use of a separate train with its own crew carrying spent nuclear fuel or high-level radioactive waste would avoid switching railcars between trains.

Buffer cars: Railcars placed in front and in back of those carrying spent nuclear fuel or high-level radioactive waste to provide additional distance from possibly occupied railcars. Federal regulations (49 CFR 174.85) require the separation of a railcar carrying spent nuclear fuel or high-level radioactive waste from a locomotive, occupied caboose, or carload of undeveloped film by at least one buffer car. These could be DOE railcars or, in the case of general freight service, commercial railcars.

Escort cars: Railcars in which escort personnel (for example, security personnel) would reside on trains carrying spent nuclear fuel or high-level radioactive waste.

2.1.3.3 Nevada Transportation

Nevada transportation is part of national transportation, but the EIS also discusses it separately. Depending on how a shipment was transported, DOE could use one of three options or modes of transportation in Nevada: legal-weight trucks, rail, or heavy-haul trucks. Legal-weight truck shipments arriving in Nevada would travel directly to the Yucca Mountain site. Two Interstate highways cross Nevada—I-80 in the north and I-15 in the south. I-15, the closest Interstate highway to the proposed repository, travels through Salt Lake City, Utah, to southern California, passing through Las Vegas. Figure 2-28 shows the existing highway infrastructure in southern Nevada. The EIS analysis assumed that the proposed Interstate bypass around the urban core of Las Vegas (the Las Vegas Beltway) would be operational before 2010.

Shipments arriving in Nevada by rail would travel to the repository site by rail or heavy-haul truck (legal-weight trucks could not be used due to the size and weight of the rail shipping casks). Existing rail lines in the State include two northern routes and one southern route; the Southern Pacific Railroad owns one of the northern routes and the Union Pacific Railroad owns the other northern route and the southern route. The northern routes pass through or near the cities of Elko, Carlin, Battle Mountain, and Reno. The southern route runs through Salt Lake City, Utah, to Barstow, California, passing through Caliente, Las Vegas, and Jean, Nevada. Figure 2-29 shows the Nevada rail infrastructure. Rail access is not currently available to the Yucca Mountain site, so DOE would have to build a branch rail line from an existing mainline railroad to the site or transfer the rail cask to a heavy-haul truck at an intermodal transfer station for transport to the repository.

To indicate distinctions between available transportation options or modes in Nevada and to define the range of potential impacts associated with transportation in the State, this EIS analyzes three transportation scenarios: the first, associated with the national legal-weight truck scenario, is a Nevada legal-weight truck scenario; the second and third, both associated with the national rail scenario, are rail transport directly to the Yucca Mountain site, and an intermodal transfer from railcar to heavy-haul truck for travel to the site. Table 2-3 summarizes the Nevada transportation scenarios.

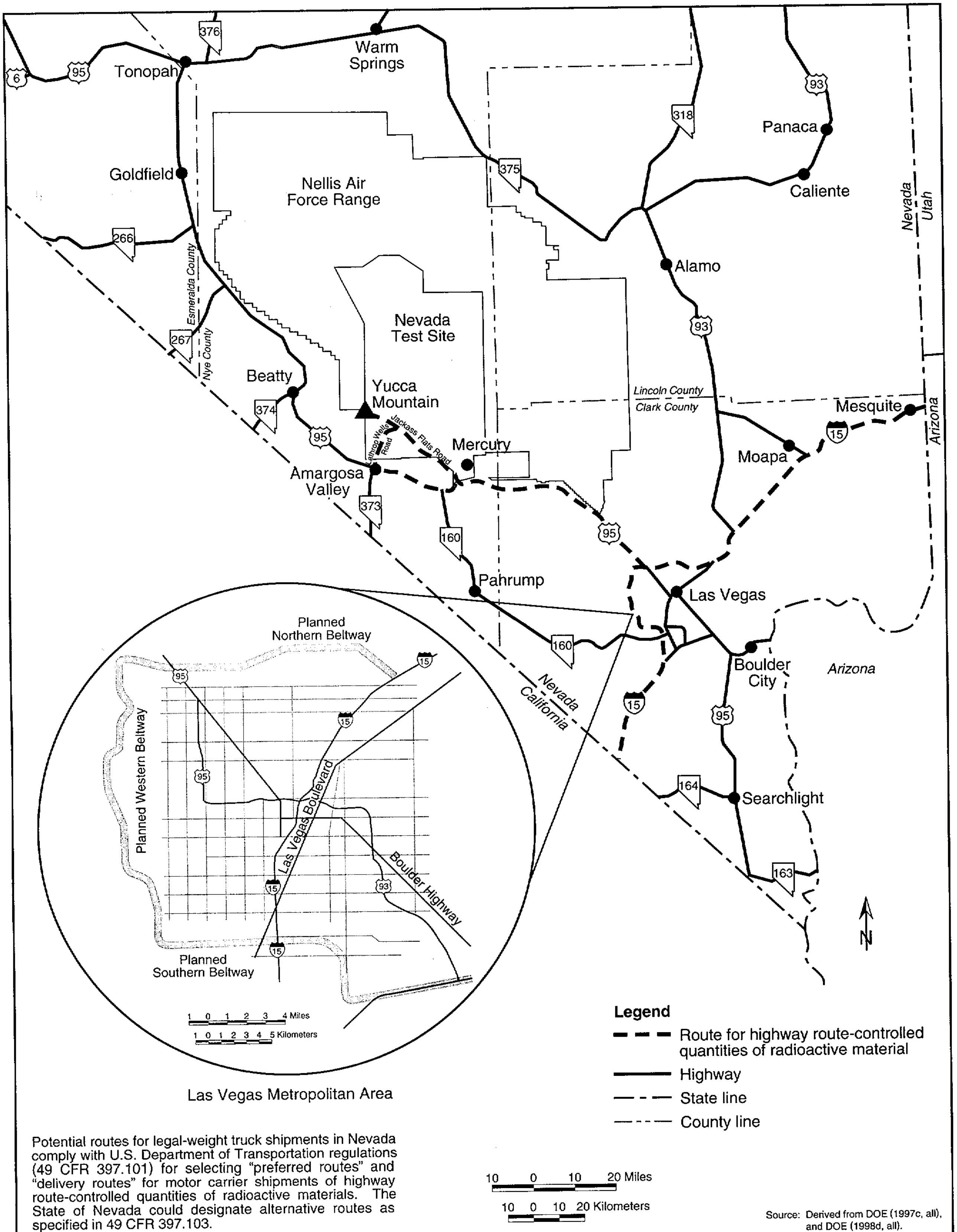


Figure 2-28. Southern Nevada highways.

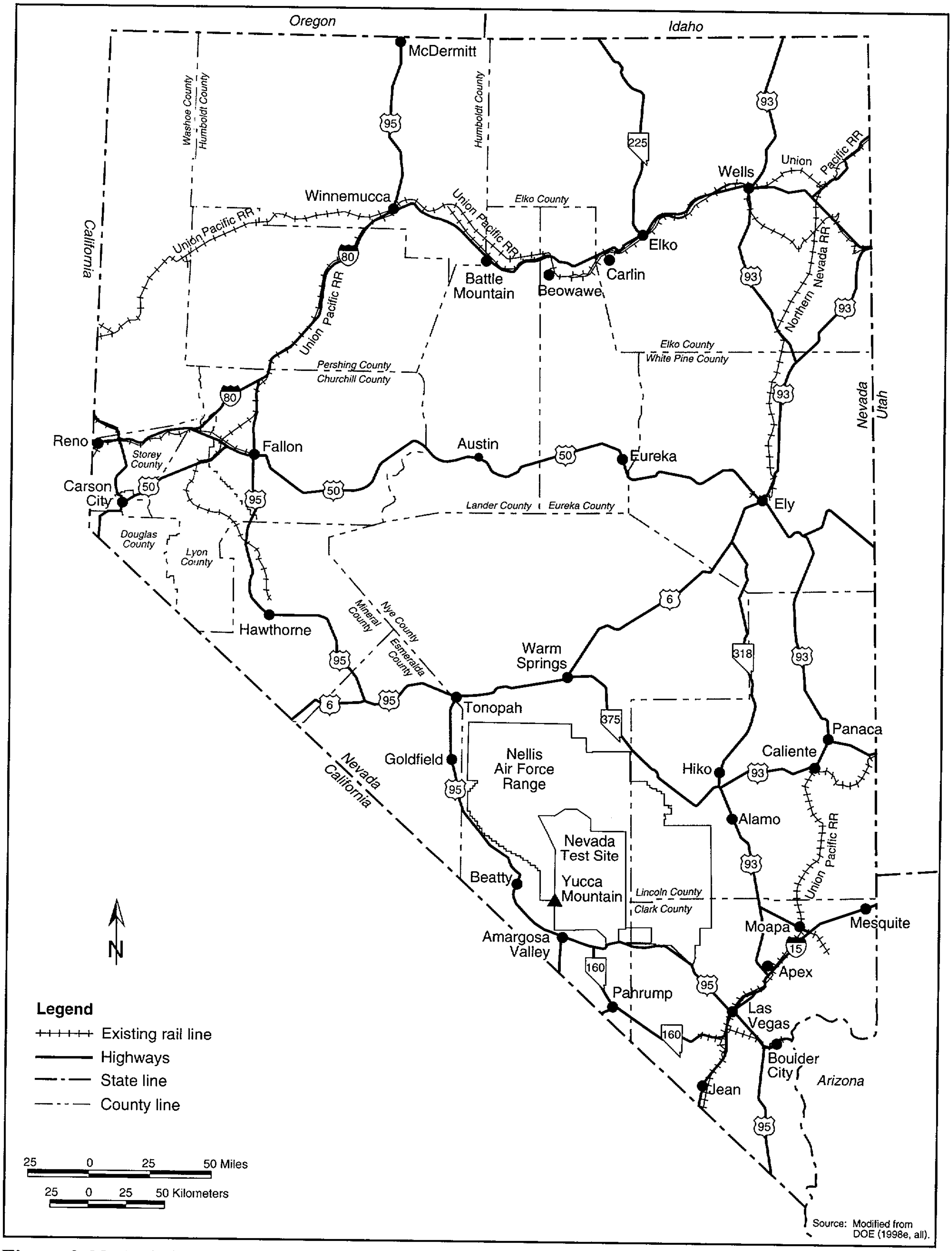


Figure 2-29. Existing Nevada rail lines.

Table 2-3. Nevada transportation shipping scenarios (percentage based on number of shipments).[a]

Material	Mostly legal-weight truck	Mostly rail	Mostly heavy-haul truck[b]
Commercial SNF	100% by legal-weight truck	About 80% by rail; about 20% by legal-weight truck	About 80% by heavy-haul truck; about 20% by legal-weight truck
HLW	100% by legal-weight truck	100% by rail	100% by heavy-haul truck
DOE SNF	Mostly by legal-weight truck; includes about 300 naval SNF shipments by rail and heavy-haul truck	100% by rail	100% by heavy-haul truck

a. SNF = spent nuclear fuel; HLW = high-level radioactive waste.
b. Rail shipment to intermodal transfer station, and heavy-haul truck shipment from intermodal transfer station to the repository.

The following sections describe the Nevada transportation scenarios and the implementing alternatives DOE is considering for a new branch rail line or a new intermodal transfer station and associated highway route for heavy-haul trucks. Detailed engineering descriptions are based on TRW (1999d, all), unless otherwise noted.

2.1.3.3.1 *Nevada Legal-Weight Truck Scenario*

Under this scenario, DOE would use legal-weight trucks in Nevada to transport spent nuclear fuel and high-level radioactive waste to the repository. Naval spent nuclear fuel would be transported to Nevada by rail. In Nevada, DOE would use heavy-haul trucks to transport these 300 shipments. DOE would establish an intermodal transfer capability and an associated heavy-haul shipment capability (see Section 2.1.3.3.3).

Legal-weight truck shipments would use existing routes that satisfy regulations of the U.S. Department of Transportation for the shipment of highway route-controlled quantities of radioactive materials (49 CFR 397.101). Legal-weight trucks would enter Nevada on I-15 from the north or south, bypass the Las Vegas area on the proposed beltway, and travel north on U.S. 95 to the Nevada Test Site and then to the Yucca Mountain site (Figure 2-28).

2.1.3.3.2 *Nevada Rail Scenario*

Under this scenario, DOE would construct and operate a branch rail line in Nevada. Based on previous studies (described in Section 2.3), DOE has narrowed its consideration for a new branch rail line to five potential rail corridors—Caliente, Carlin, Caliente-Chalk Mountain, Jean, and Valley Modified. These rail corridors are shown on Figure 2-30 and are described in the following paragraphs. DOE would need to obtain a 0.4-kilometer (0.25-mile)-wide right-of-way to construct a rail line and an associated access road. As shown in Figure 2-30, there are possible alignment variations, which are described further in Appendix J.

- *Caliente Rail Corridor Implementing Alternative.* The Caliente corridor originates at an existing siding to the Union Pacific mainline railroad near Caliente, Nevada (Figure 2-30). The corridor is 513 kilometers (319 miles) long from the Union Pacific line connection to the Yucca Mountain site.
- *Carlin Rail Corridor Implementing Alternative.* The Carlin corridor originates at the Union Pacific main line railroad near Beowawe in north-central Nevada (Figure 2-30). The Carlin and Caliente corridors converge near the northwest boundary of the Nellis Air Force Range (also known as the Nevada Test and Training Range). Past this point, they are identical. The corridor is 520 kilometers (323 miles) long from the tie-in point with the Union Pacific line to the Yucca Mountain site.

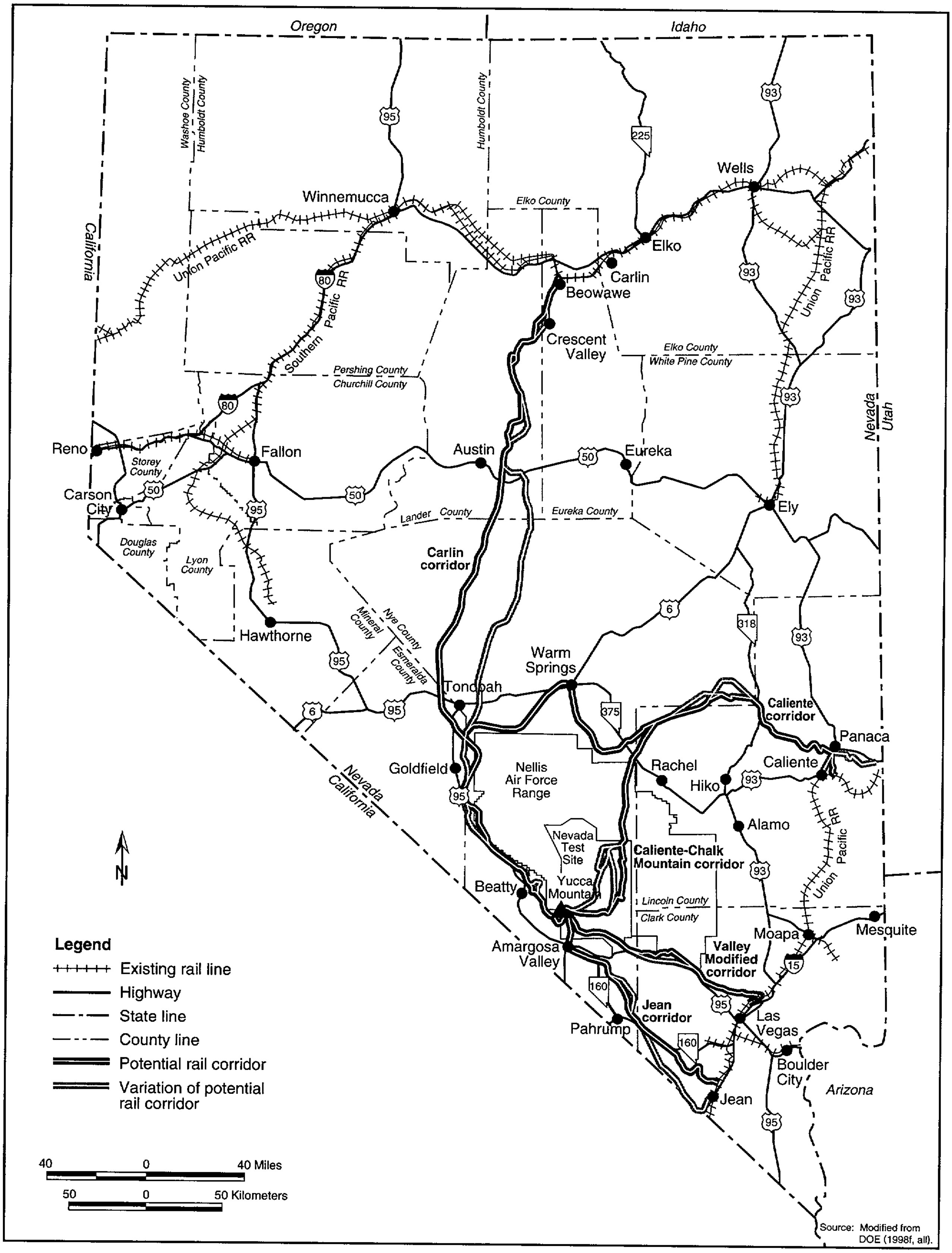


Figure 2-30. Potential Nevada rail routes to Yucca Mountatin.

- *Caliente-Chalk Mountain Rail Corridor Implementing Alternative.* The Caliente-Chalk Mountain corridor is identical to the Caliente corridor until it approaches the northern boundary of the Nellis Air Force Range. At that point the Caliente-Chalk Mountain corridor turns south through the Nellis Air Force Range and the Nevada Test Site to the Yucca Mountain site (Figure 2-30). The corridor is 345 kilometers (214 miles) long from the tie-in point at the Union Pacific line to the Yucca Mountain Site.

- *Jean Rail Corridor Implementing Alternative.* The Jean corridor originates at the existing Union Pacific mainline railroad near Jean, Nevada (Figure 2-30). The corridor is 181 kilometers (112 miles) long from the tie-in point at the Union Pacific line to the Yucca Mountain site.

- *Valley Modified Rail Corridor Implementing Alternative.* The Valley Modified corridor originates at an existing rail siding off the Union Pacific mainline railroad northeast of Las Vegas. The corridor is about 159 kilometers (98 miles) long from the tie-in point with the Union Pacific line to the Yucca Mountain site.

2.1.3.3.2.1 Rail Line Construction. The selected rail line would be designed and built in compliance with Federal Railroad Administration safety standards. In addition, a service road along the rail line would be built and maintained. Rail line construction along any of the corridors would take an estimated 2.5 years. Construction would start after the selection of a route, completion of engineering studies, completion of the rail line design, and land acquisition.

Construction activities would include the development of construction support areas; construction of access roads to the rail line construction initiation points and to major structures to be built, such as bridges; and movement of equipment to the construction initiation points. The number and location of construction initiation points would be based on such variables as the route selected, the length of the line, the construction schedule, the number of contractors used for construction, the number of structures to be built, and the locations of existing access roads adjacent to the rail line.

RAILROAD CONSTRUCTION TERMS

Borrow areas: Areas outside the rail corridor where construction personnel could obtain materials to be used in the establishment of a stable platform (subgrade) for the rail track. Aggregate crushing operations could occur in these areas.

Spoils areas: Areas outside the rail corridor for the deposition of excavated materials from rail line development.

Construction support areas: Areas along the rail route that could be used as temporary residences for construction crews, material and equipment storage areas, and concrete production areas. Such camps probably would be for the construction of routes far from population centers.

The construction of a rail line would require the clearing and excavation of previously undisturbed lands in the corridor and the establishment of borrow and spoils areas outside the corridor. To establish a stable platform for the rail track, construction crews would excavate some areas and fill (add more soil to) others, as determined by terrain features. To the extent possible, material excavated from one area would be used in areas that required fill material. However, if the distance to an area requiring fill material was excessive, the excavated material would be disposed of in adjacent low areas, and a borrow area would be established adjacent to the area requiring fill material. Access roads to spoils and borrow areas would be built during the track platform construction work.

Typical heavy-duty construction equipment (front-end loaders, power shovels, and other diesel-powered support equipment) would be used for clearing and excavation work. Trucks would spray water along graded areas for dust control and soil compaction. The fill material used along the rail line to establish a stable platform for the track would be compacted to meet design requirements. Water could be shipped from other locations or obtained from wells drilled along the route.

Railroad track construction would consist of the placement of railbed material, ties, rail, and ballast (support and stabilizing materials for the rail ties) over the completed railbed platform. Other activities would include the following:

- Installation of at-grade crossings (which would require rerouting existing utility lines in some areas)
- Installation of fences along the rail line, if requested by other agencies (for example, the Bureau of Land Management or the Fish and Wildlife Service)
- Installation of the train control system (monitoring equipment, signals, communications equipment)
- Final grading of slopes, installation of rock-fall protection devices, replacement of topsoil, revegetation and installation of other permanent erosion control systems, and completion of the adjacent maintenance road

2.1.3.3.2.2 Rail Line Operations. Branch rail line operations from the junction with the main line to the proposed repository at Yucca Mountain would meet Federal Railroad Administration standards for maintenance, operations, and safety. Current plans for the branch rail line anticipate a train with two 3,000-horsepower, diesel-electric locomotives; from one to five railcars containing spent nuclear fuel and high-level radioactive waste; buffer cars; and escort cars.

The operational interface between the Union Pacific and the branch rail line would be determined by whether the waste was shipped to Nevada by dedicated rail service or by general freight rail service. With dedicated rail service to Nevada, the railcars would be transferred to the branch rail line and shipped immediately to the repository. With general freight service, the railcars carrying spent nuclear fuel or high-level radioactive waste could be parked on a side track (off the main rail line) at the connection point until a train could be assembled to travel to the repository site. A small secure railyard off the main rail line would be established for switching operations. Railcars with spent nuclear fuel or high-level radioactive waste would have to be moved within 48 hours in accordance with U.S. Department of Transportation regulations (49 CFR 174.14).

This EIS assumes there would be about four trains per week for shipments of spent nuclear fuel and high-level radioactive waste to the repository. In addition, the rail line would enable the transport of other material to the repository, including empty disposal containers, bulk concrete materials, steel, large equipment, and general building materials. The EIS assumes one train per week for this other material for a total of about five trains per week to the repository from about 2010 to 2033.

2.1.3.3.3 *Nevada Heavy-Haul Truck Scenario*

Under this scenario, rail shipments to Nevada would go to an intermodal transfer station where the shipping cask would transfer from the railcar to a heavy-haul truck. The heavy-haul truck would travel on existing roads to the repository. The following sections describe the implementing alternatives (the intermodal transfer station locations and associated highway routes for heavy-haul trucks) that the EIS analyzes.

2.1.3.3.3.1 Intermodal Transfer Stations. To enable intermodal transfers and heavy-haul shipments to the repository, an intermodal transfer station would be built and operated in Nevada. DOE is considering three potential locations for intermodal transfer operations: near Caliente, northeast of Las Vegas (Apex/Dry Lake), and southwest of Las Vegas (Sloan/Jean) (Figure 2-31). DOE has identified general areas at these three locations where it could build and operate an intermodal transfer station:

- *Caliente Intermodal Transfer Station Implementing Alternative.* The Caliente siting areas are south of Caliente in the Meadow Valley Wash. DOE has identified two possible areas along the west side of the wash.

- *Apex/Dry Lake Intermodal Transfer Station Implementing Alternative.* The potential areas northeast of Las Vegas are between the Union Pacific rail sidings at Dry Lake and Apex. Two large contiguous areas are available for intermodal transfer station siting near the Apex/Dry Lake sidings. The first area is directly adjacent to the Dry Lake siding along the west side of the Union Pacific line. The second area is on the east side of I-15 adjacent to the Union Pacific line and south of where the main Union Pacific line crosses I-15. Because this area is between the Dry Lake and Apex sidings, the construction of an additional rail siding would be necessary.

- *Sloan/Jean Intermodal Transfer Station Implementing Alternative.* The potential areas for an intermodal transfer station southwest of Las Vegas are between the existing Union Pacific rail sidings at Sloan and Jean. One area is on the west side of I-15, north of the Union Pacific rail underpass at I-15. The second is south of the Sloan rail siding along the east side of the rail line. A third area is south of the second, directly north of the Jean interchange on I-15.

The intermodal transfer station would be a fenced area of about 250 meters (820 feet) by 250 meters and a rail siding that would be about 2 kilometers (1.2 miles) long (see Figure 2-32). The estimated total area occupied by the facility and support areas would be about 0.2 square kilometer (50 acres). It would include rail tracks, two shipping cask transfer cranes (one on a gantry rail, and one on a backup rubber-tired vehicle), an office building, and a maintenance and security building. It would also have connection tracks to the existing Union Pacific line and storage and transfer tracks inside the station boundary. The maintenance building would provide space for routine service and minor repairs to the heavy-haul trailers and tractors. The station would have power, water, and other services. Diesel generators would provide a backup electric power source. Construction of an intermodal transfer station would take an estimated 1.5 years.

Intermodal transfer station operations would depend on whether the railcars that carried spent nuclear fuel and high-level radioactive waste arrived on dedicated or general freight trains. A dedicated train would enter the intermodal transfer station, passing the opened security gate and parking on a track for cask inspection. After inspection, the train would proceed to a loading and unloading track or a designated storage track (if the loading and unloading tracks were occupied).

General freight trains would switch from the main Union Pacific track to an existing or newly constructed passing track. The railcars carrying casks of spent nuclear fuel or high-level radioactive waste would be uncoupled from the freight train and switched to the intermodal transfer station track. The freight train would return to the main Union Pacific line and continue its trip. A railyard locomotive would move the cars containing the casks to the station.

The loading and unloading process would begin with the return of a heavy-haul truck from the repository. The empty cask returning from the repository would be lifted from the truck, loaded on an empty railcar, and secured. The gantry or mobile crane would then remove a loaded cask from another railcar and transfer it to the same truck, where it would be secured and inspected before shipment to the repository.

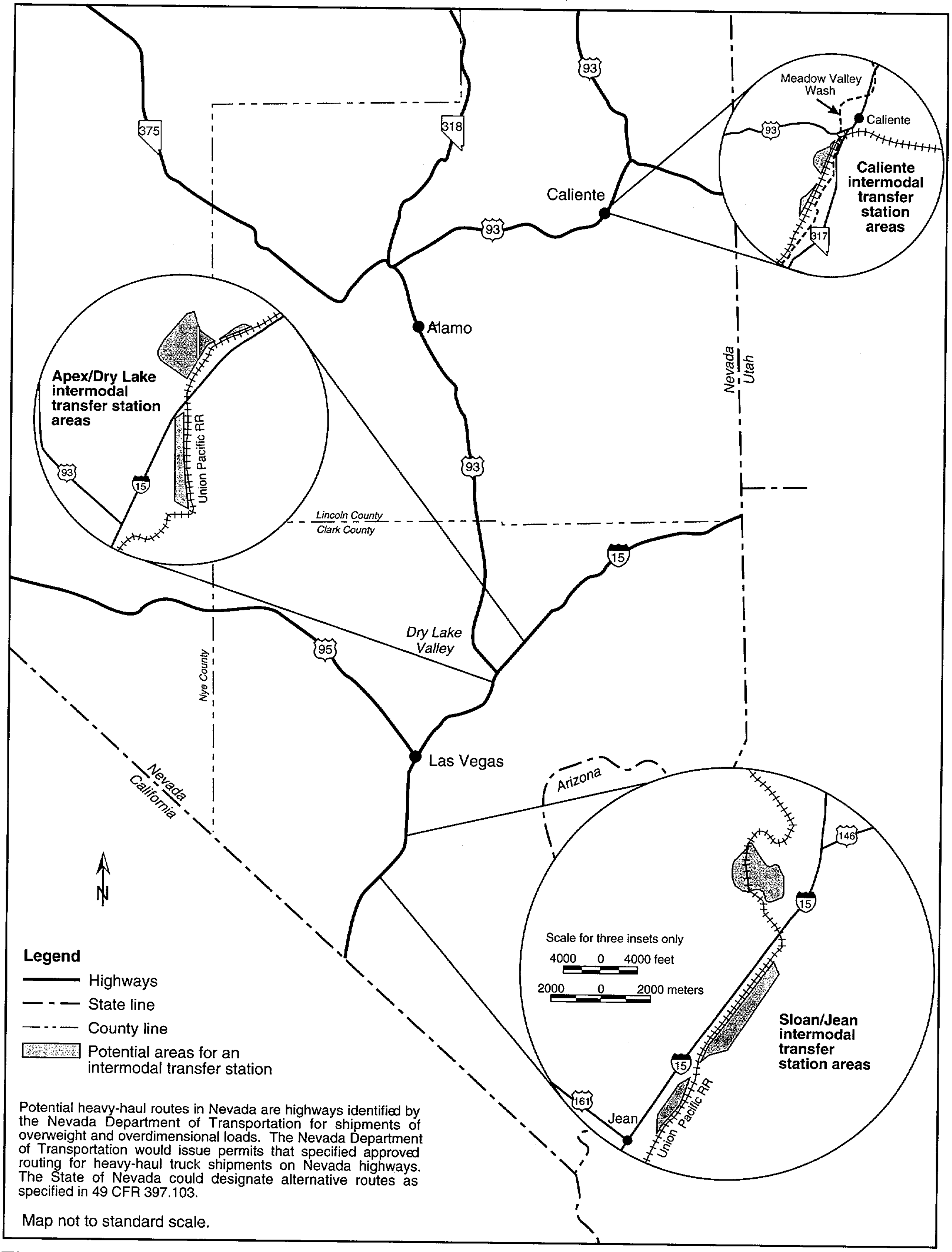


Figure 2-31. Potential intermodal transfer station locations.

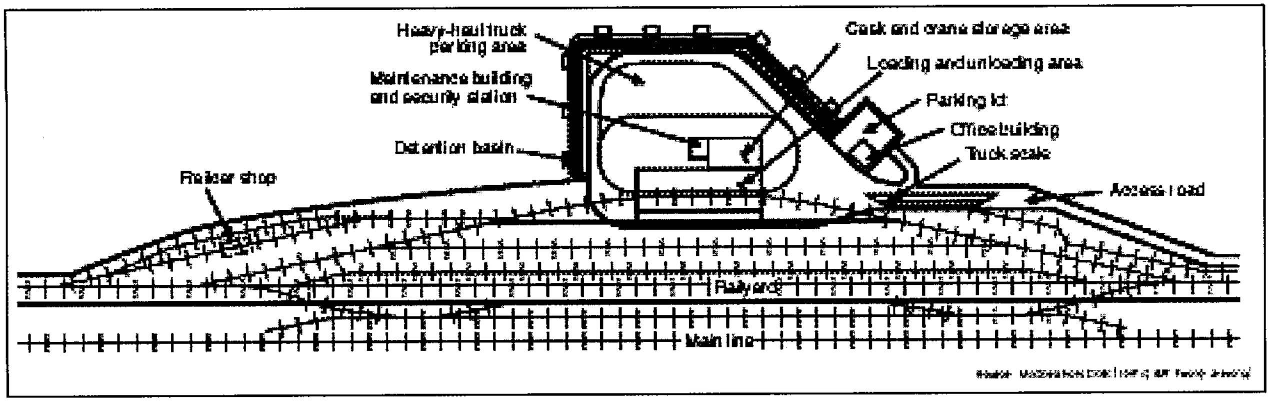


Figure 2-32. Conceptual diagram of intermodal transfer station layout.

The station would accept railcars as they arrived (24 hours a day, 7 days a week), but it would normally dispatch heavy-haul trucks during early morning daylight hours on weekdays, consistent with current Nevada heavy-haul shipment regulations.

At the completion of the 24 years of shipping, the intermodal transfer station would be decommissioned and, if possible, reused.

2.1.3.3.3.2 Highway Routes for Heavy-Haul Shipments. Figure 2-33 is an illustration of a heavy-haul truck that DOE could use to transport spent nuclear fuel and high-level radioactive waste to the repository. The heavy-haul truck would weigh about 91,000 kilograms (200,000 pounds) unloaded and would be up to 67 meters (220 feet) long. It would be custom-built for repository shipments. Average trip speeds would be 32 to 48 kilometers (20 to 30 miles) per hour.

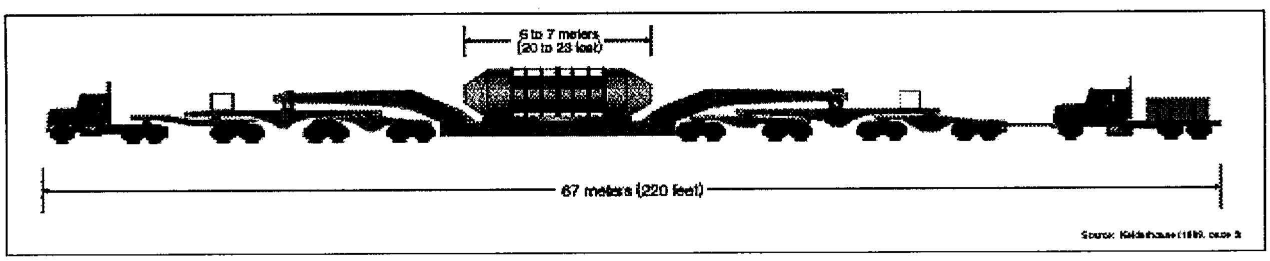


Figure 2-33. Artist's conception of a heavy-haul truck carrying a rail shipping cask.

Heavy-haul truck shipments from an intermodal transfer station to the repository would comply with U.S. Department of Transportation requirements for shipments of highway route-controlled quantities of radioactive materials (49 CFR Part 177) and with State of Nevada permit requirements for heavy-haul shipments. Nevada permits heavy-haul shipments on Monday through Friday (excluding holidays) but only in daylight hours.

Road upgrades for candidate routes, if necessary, would involve four kinds of construction activities: (1) widening the shoulders and constructing turnouts and truck lanes, (2) upgrading intersections that are inadequate for heavy-haul truck traffic, (3) increasing the asphalt thickness (overlay) of some sections, and (4) upgrading engineered structures such as culverts and bridges. The overlay work would include upgrades needed to remove frost restrictions from some road sections.

Shoulder widening and the construction of turnouts and truck lanes would occur as needed along the side of the existing pavement. Shoulders would be widened from 0.33 or 0.66 meter (1 or 2 feet) to 1.2 meters (4 feet). Widening would build the existing shoulder up to pavement height. Truck lanes would be built on roadways with grades exceeding 4 percent. Turnout lanes would be built approximately every 8 to 32 kilometers (5 to 20 miles) depending on projected traffic. The truck lanes and turnouts would require land clearing and soil excavation or fill to establish the roadway. Culverts under the roadway would be lengthened. Most borrow material for construction could come from existing Nevada Department of Transportation borrow areas, if the State agreed. Asphalt could be produced at a portable plant in the borrow areas. Appendix J contains descriptions of the specific highway improvements for the five routes.

The following paragraphs describe the potential highway routes for heavy-haul trucks DOE is considering for the intermodal transfer station location and unique operational considerations for each route.

- *Caliente Intermodal Transfer Station Highway Routes.* Heavy-haul trucks leaving the Caliente intermodal transfer station could travel on one of three potential routes: (1) Caliente, (2) Caliente-Chalk Mountain, and (3) Caliente-Las Vegas (see Figure 2-34).

  The Caliente route would be approximately 533 kilometers (331 miles) long. Heavy-haul trucks leaving an intermodal transfer station in the Caliente area would travel directly from the station to U.S. Highway 93. The trucks would travel west on U.S. 93 to State Route 375, then on State Route 375 to the intersection with U.S. Highway 6. The trucks would continue on U.S. 6 to the intersection with U.S. 95 in Tonopah, then into Beatty on U.S. 95, where an alternate truck route would be built because the existing intersection is too constricted to allow a turn. Heavy-haul trucks would then travel south on U.S. 95 to the Lathrop Wells Road exit, which accesses the Yucca Mountain site. Because of the estimated travel time associated with the Caliente route and the restriction on nighttime travel for heavy-haul vehicles, DOE would construct a parking area along the route to enable these vehicles to park overnight. This parking area would be near the U.S. 6 and U.S. 95 interchange at Tonopah.

  The Caliente-Chalk Mountain route would be approximately 282 kilometers (175 miles) long. Heavy-haul trucks leaving an intermodal transfer station in the Caliente area would travel directly from the station to U.S. 93. The trucks would travel on U.S. 93 to State Route 375, on State Route 375 to Rachel, and head south through the Nellis Air Force Range to the Nevada Test Site.

  The Caliente-Las Vegas route would be approximately 377 kilometers (234 miles) long. Heavy-haul trucks leaving an intermodal transfer station in the Caliente area would travel directly from the station to U.S. 93. The trucks would travel south on U.S. 93 to the intersection with I-15, northeast of Las Vegas. The trucks would travel south on I-15 to the exit for the proposed northern Las Vegas Beltway, then would travel west on the beltway. They would leave the beltway at U.S. 95, and head north on U.S. 95 to the Nevada Test Site. The trucks would travel on Jackass Flats Road on the Nevada Test Site to the Yucca Mountain site.

- *Apex/Dry Lake Intermodal Transfer Station Highway Route.* Heavy-haul trucks would leave the intermodal transfer station at the Apex/Dry Lake location and enter I-15 at the Apex interchange. The trucks would travel south on I-15 to the exit to the proposed northern Las Vegas Beltway, and would travel west on the beltway. The trucks would leave the beltway at U.S. 95, and travel north on U.S. 95 to the Nevada Test Site. They would then travel on Jackass Flats Road on the Nevada Test Site to the Yucca Mountain site. This route is about 183 kilometers (114 miles) long (see Figure 2-34).

- *Sloan/Jean Intermodal Transfer Station Highway Route.* Heavy-haul trucks leaving a Sloan/Jean intermodal transfer station would enter I-15 at the Sloan interchange. The trucks would travel on I-15 to the exit to the southern portion of the proposed Las Vegas Beltway, and then travel northwest on the beltway. They would leave the beltway at U.S. 95, and travel to the Nevada Test Site. They would then travel on Jackass Flats Road to the Yucca Mountain site. This route would be approximately 188 kilometers (117 miles) long (see Figure 2-34).

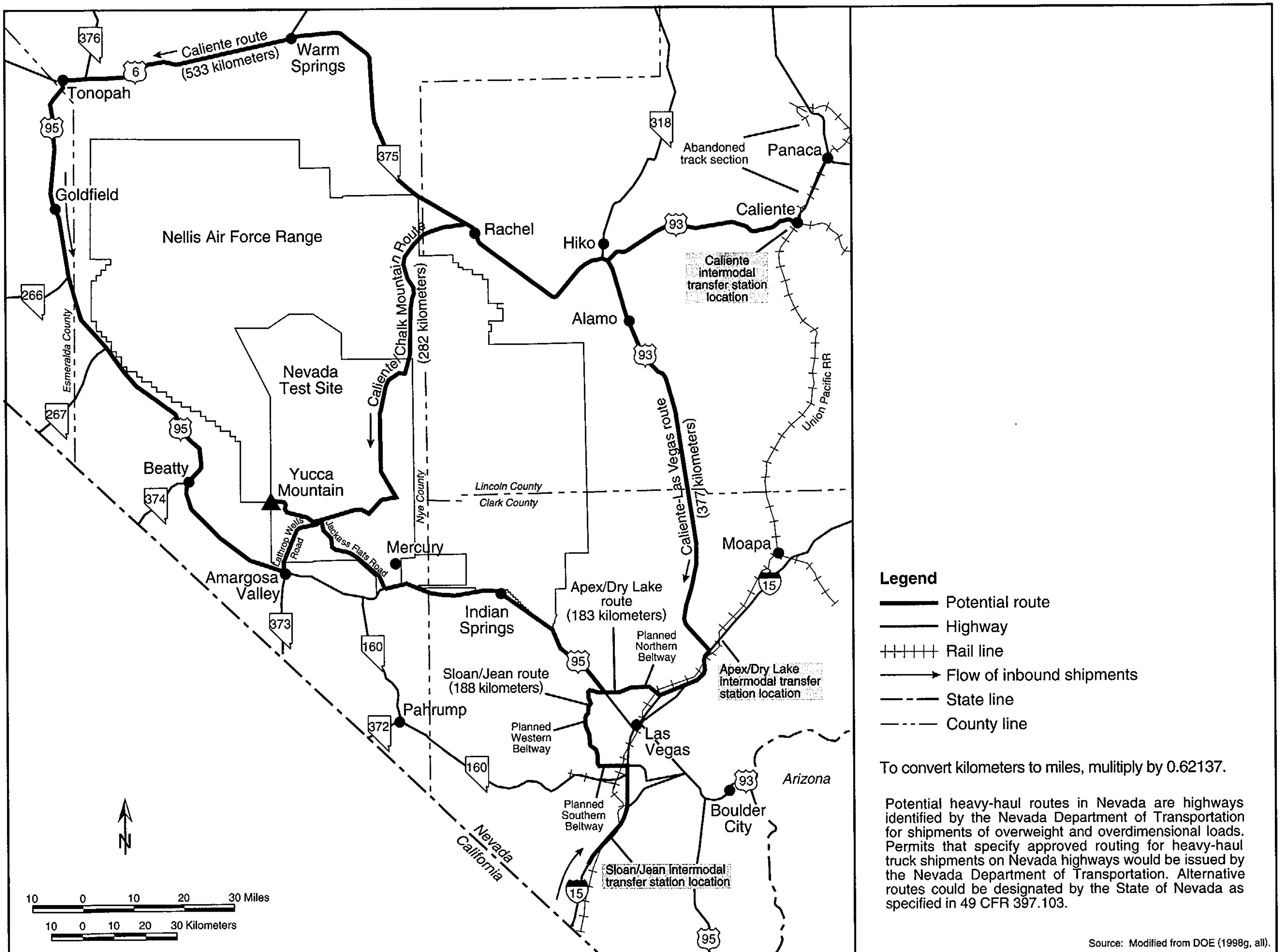


Figure 2-34. Potential routes in Nevada for heavy-haul trucks.

2.1.3.4 Shipping Cask Manufacturing, Maintenance, and Disposal

To transport spent nuclear fuel and high-level radioactive waste to the repository, DOE would use existing or new shipping casks that met Nuclear Regulatory Commission regulations (10 CFR Part 71). One or more qualified companies that provide specialized metal structures, tanks, and other heavy equipment would manufacture new shipping casks. The number and type of shipping casks required would depend on the predominant mode of transportation.

DOE would remove casks from service periodically for maintenance and inspection. These activities would occur at a cask maintenance facility(s) where cask functions and components would be checked and inspected in compliance with Nuclear Regulatory Commission requirements and preventive maintenance procedures. The major operations involved in cask maintenance would include decontamination, replacement of limited-life components such as O-rings, and verification of radiation shielding integrity, structural integrity, and heat transfer efficiency.

The large number of repository shipments would require new facilities for cask maintenance. DOE has not decided where in the United States it would locate a cask maintenance facility(s), but this EIS assumes that such a facility would be at the repository inside the Restricted Area at the North Portal on approximately 0.01 square kilometer (2.5 acres). Minor cask maintenance activities could occur at commercial or DOE sites.

2.1.4 ALTERNATIVE DESIGN CONCEPTS AND DESIGN FEATURES

The EIS analyzed thermal load and packaging scenarios to identify the range of potential short- and long-term impacts of a repository at Yucca Mountain. This analysis used conceptual designs, which is typical for an EIS. However, the level of design is insufficient to meet information needs for a License Application to the Nuclear Regulatory Commission. Therefore, the repository design will continue to evolve through the submittal of the License Application.

As part of this evolving design process, DOE is evaluating various design features and alternatives. The purpose of the evaluation is to determine if these features and alternatives would reduce uncertainties in the long-term performance of the repository, reduce costs, or improve operations. Other construction materials could be evaluated in the future. The License Application Design Selection project is considering a variety of design alternatives and features, as described in Appendix E. In addition, DOE has made preliminary identification of five combinations of design features and alternatives, called Enhanced Design Alternatives, as part of this process (Table 2-4). The EIS analysis categorized the design features and alternatives into three groups, based on their primary function, which are intended to:

- Limit the release and transport of radionuclides
- Control the thermal/moisture environment in the repository
- Support operational and cost considerations

The following sections summarize the design approaches for the three groups DOE is considering within the scope of the design features and alternatives.

2.1.4.1 Design Features and Alternatives To Limit Release and Transport of Radionuclides

The features related to improving the barriers that limit the release and transport of radioactive material focus on two areas of the design. Some of the features focus on improvements in the long-term integrity

Table 2-4. Design features and alternatives used to form Enhanced Design Alternatives.

Category	Enhanced Design Alternative				
	I	II	III	IV	V
Barriers to limit release and transport of radionuclides					
Drip shields	X[a]	X	X	X	X
Backfill to protect waste package and drip shield from rockfall		X		X	
Waste package corrosion-resistant barrier	X	X	X		X
Additives and fillers				X	
Ground support options			X		
Repository design to control thermal/moisture environment					
Low thermal alternative evaluation	X	X			
Aging and blending of waste	X	X			X
Continuous postclosure ventilation	X	X	X	X	X
Drift diameter	X				
Waste package spacing and drift spacing	X	X	X	X	X
Higher thermal load					X
Repository designs to support operational and cost considerations					
Enhanced access design	X	X	X	X	X
Timing of repository closure	X	X	X	X	X
Maintenance of underground design features and ground support			X		

a. X specifies what is used in each Enhanced Design Alternative.

of the waste packages; others focus on limiting the transport of radioactive material released from a waste package to the environment. Examples of designs include the following:

- Designs to improve the long-term integrity of waste packages, including coating the package with a ceramic or using multiple types of corrosion-resistant materials, which should directly reduce waste package failure due to corrosion.

- Designs to reduce the potential of structural damage to waste packages from rockfall, such as backfilling the drifts or providing mechanical support to the drift wall (concrete or steel liner).

- Designs to limit the transport of radionuclides, including additives and fillers to the waste packages or getters under the waste packages; these substances would capture radionuclides chemically to limit transport.

Some features provide the potential to limit both the release and transport of radionuclides, and to modify the temperature environment. For instance, backfill could protect against the release and transport of contaminants by capturing corrosive salts in the water and retarding flow and by increasing the emplacement drift temperature to decrease the relative humidity. For convenience of presentation, each feature is listed in only one category.

2.1.4.2 Design Features and Alternatives To Control the Thermal/Moisture Environment in the Repository

Potentially the most effective repository design would provide an environment in the emplacement drifts that would accommodate the heat discharge from the waste packages, maintain the materials and contents of the packages at low temperatures, and maintain low ambient moisture. Several alternatives and features focus on these goals. An example of a design to control the repository drift environment would be continuous postclosure ventilation of the drifts to provide both heat and moisture removal.

Many designs use an integrated approach to control the drift environment. The high thermal load designs, for example, provide ambient temperatures above 100°C (212°F) through portions of the repository so moisture would vaporize and disperse. Designs involving the diameter and spacing of drifts and the loading of waste packages consider similar integrated effects to control the heat load. Some designs focus only on moisture control, such as those that involve surface modifications directly above the repository to retard or eliminate any infiltration of moisture.

2.1.4.3 Design Features and Alternatives To Support Operational and Cost Considerations

In general, these design features and alternatives focus on repository operation and cost, so they would not usually affect long-term (postclosure) performance but could have short-term (preclosure) impacts. Designs to enhance access to the drifts and to facilitate performance monitoring incorporate approaches that would reduce occupational exposure. Modular design and phased construction would result in slightly increased short-term impacts but would accommodate incremental funding of repository construction.

The final design of the repository is likely to evolve from the current design (as described in Section 2.1 and analyzed in this EIS), combinations of the design features and alternatives, and other design concepts that evolve from the DOE License Application Design Selection process (that is, Enhanced Design Alternatives). The identification and evolution of the features and alternatives was underway as DOE was preparing the Draft EIS. The evolution of the repository design is likely to incorporate some of the features and alternatives discussed in this section and Appendix E. After incorporating modifications in the design, DOE will evaluate the environmental impacts associated with the updated design in the Final EIS.

The design features and alternatives are functionally equivalent to potential mitigation measures because they have the potential to improve long-term (postclosure) performance (that is, they would reduce risk), reduce operational impacts, or reduce costs. Chapter 9 summarizes the mitigation aspects of these design features and alternatives and Appendix E describes them more fully. However, there are tradeoffs associated with many of these features and alternatives that could have negative short-term (preclosure) or long-term impacts that could be greater than the impacts associated with the basic design under the thermal load and packaging scenarios evaluated as part of the Proposed Action. Appendix E contains qualitative descriptions of the features and alternatives, including the reasons for their consideration (potential benefits) and potential negative environmental considerations.

2.1.5 ESTIMATED COSTS ASSOCIATED WITH THE PROPOSED ACTION

DOE has estimated the total cost of the Proposed Action to construct, operate and monitor, and close a geologic repository at Yucca Mountain, including the transportation of spent nuclear fuel and high-level radioactive waste to the repository (TRW 1999e, all). The estimate is based on acceptance and disposal of about 63,000 MTHM of commercial spent nuclear fuel, 2,333 MTHM of DOE spent nuclear fuel, and 8,315 canisters of solidified high-level radioactive waste (4,667 MTHM). Table 2-5 lists the estimated costs. The costs would total about $29 billion. This is representative and would vary

Table 2-5. Proposed Action costs.[a,b]

Description	Costs
Monitored geologic repository	$18.7
Waste acceptance, storage, and transportation	4.5
Nevada transportation	0.8
Program integration	2.1
Institutional	2.7
Total	**$28.8**

a. Source: TRW (1999e, all).

b. Adjusted to constant 1998 dollars, in billions.

somewhat, depending on the thermal load, packaging, and transportation scenarios and on the Nevada transportation implementing alternative selected.

2.2 No-Action Alternative

This section describes the No-Action Alternative, which provides a baseline for comparison with the Proposed Action. Under the No-Action Alternative and consistent with the Nuclear Waste Policy Act, as amended [Section 113(c)(3) (the EIS refers to the amended Act as the NWPA)], DOE would end site characterization activities at Yucca Mountain and undertake site reclamation to mitigate adverse environmental impacts from characterization activities. Commercial nuclear power utilities and DOE would continue to manage spent nuclear fuel and high-level radioactive waste at 77 sites in the United States (see Figure 2-35).

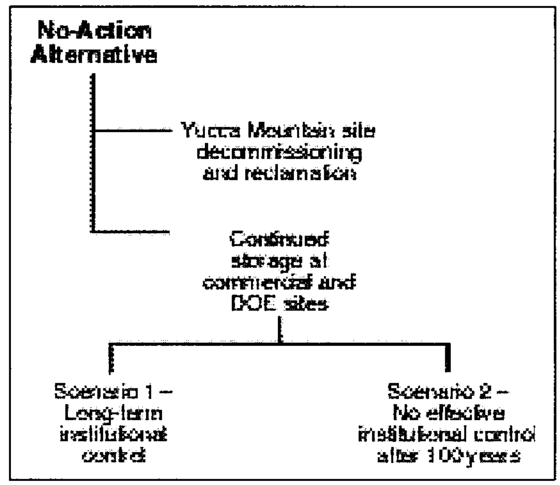


Figure 2-35. No-Action Alternative activities and analytical scenarios.

Under the NWPA, if DOE decided not to proceed with the development of a repository at Yucca Mountain, it would prepare a report to Congress with its 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. Furthermore, DOE intends to comply with the terms of existing consent orders and compliance agreements regarding the management of spent nuclear fuel and high-level radioactive waste. However, the future course that Congress, DOE, and the commercial nuclear power utilities would take if Yucca Mountain were not recommended as a repository remains uncertain. A number of possibilities could be pursued, 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 (Chapter 1 discusses alternative sites previously selected by DOE for technical study); development of new technologies (for example, transmutation); or reconsideration of other disposal alternatives to deep geologic disposal (Section 2.3.1 discusses other disposal options previously evaluated by DOE). The environmental considerations related to continued storage at current locations or at one or more centralized location(s) have been analyzed in other contexts for both commercial and DOE spent nuclear fuel and high-level radioactive waste in several documents (see Chapter 7, Table 7-1 for a description of representative studies). Under any future course that would include continued storage, both commercial and DOE sites would have an obligation to continue managing spent nuclear fuel and high-level radioactive waste in a manner that protected public health and safety and the environment.

In light of the uncertainties described above, DOE decided to illustrate one set of possibilities by focusing its analysis of the No-Action Alternative on the potential impacts of two scenarios:

- Long-term storage of spent nuclear fuel and high-level radioactive waste at the current storage sites with effective institutional control for at least 10,000 years (Scenario 1)

- Long-term storage at the current storage sites with no effective institutional control after approximately 100 years (Scenario 2)

DOE recognizes that neither of these scenarios is likely to occur in the event there is a decision not to develop a repository at Yucca Mountain. However, these two scenarios were chosen for analysis because they provide a baseline for comparison to the impacts from the Proposed Action and they reflect a range of the impacts that could occur. Scenario 1, which includes an analysis of impacts under effective institutional controls for at least 10,000 years, is consistent with the portion of the analysis of the Proposed Action that includes an analysis of effective institutional controls for the first 100 years after closure. Scenario 2, in which the analyses do not consider institutional controls after approximately 100 years, is consistent with the portion of the analysis of the Proposed Action in which long-term performance after 100 years also does not include institutional controls.

The following sections describe expected Yucca Mountain site decommissioning and reclamation activities (Section 2.2.1), and further describe the scenarios for continued spent nuclear fuel and high-level radioactive waste management at the commercial and DOE sites (Section 2.2.2). Chapter 7 describes the potential environmental impacts of the No-Action Alternative.

2.2.1 YUCCA MOUNTAIN SITE DECOMMISSIONING AND RECLAMATION

Under the No-Action Alternative, site characterization activities would end at Yucca Mountain and decommissioning and reclamation would begin as soon as practicable and could take several years to complete. Decommissioning and reclamation would include removing or shutting down surface and subsurface facilities, and restoring lands disturbed during site characterization.

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.

Portable and prefabricated buildings would be emptied of their contents, dismantled, and removed from the site. Other facilities could be shut down without being removed from the site. DOE would remove and salvage such equipment as electric generators and tunneling, ventilation, meteorological, and communications equipment. Foundations and similar materials would remain in place.

DOE would remove equipment and materials from the underground drifts and test rooms. Horizontal and vertical drill holes extending from the subsurface would be sealed. Subsurface drifts and rooms would not be backfilled, but would be left with the concrete inverts in place. The North and South Portals would be gated to prohibit entry to the subsurface.

Excavated rock piles would be stabilized. Topsoil previously removed from the excavated rock pile area and stored in a stockpile would be returned and the areas would be revegetated. Areas disturbed by surface studies (drilling, trenching, fault mapping) or used during site characterization (borrow areas, laydown pads, etc.) would be restored. Fluid impoundments (mud pits, evaporation ponds) would be backfilled or capped as appropriate and reclaimed. Access roads throughout the site (paved or graveled) and parking areas would be left in place and would not be restored.

2.2.2 CONTINUED STORAGE OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE AT COMMERCIAL AND DOE SITES

Under the No-Action Alternative, spent nuclear fuel and high-level radioactive waste would be managed at the 72 commercial and 5 DOE sites (the Hanford Site, the Idaho National Engineering and Environmental Laboratory, the Savannah River Site, Fort St. Vrain, and the West Valley Demonstration Project) (see Figure 1-1). The No-Action Alternative assumes that the spent nuclear fuel and high-level radioactive waste would be treated, packaged, and stored. The amount of spent nuclear fuel and high-level radioactive waste considered in this analysis is the same as that in the Proposed Action—70,000 MTHM, including 63,000 MTHM of commercial spent nuclear fuel, 2,333 MTHM of DOE spent nuclear fuel, and 8,315 canisters of solidified high-level radioactive waste (4,667 MTHM). This EIS assumes that the No-Action Alternative would start in 2002.

2.2.2.1 Storage Packages and Facilities at Commercial and DOE Sites

A number of designs for storage packages and facilities at the commercial and DOE sites would provide adequate protection to the environment from spent nuclear fuel and high-level radioactive waste. Because specific designs have not been identified for most locations, DOE selected a representative range of commercial and DOE designs for analysis as described in the following paragraphs.

Spent Nuclear Fuel Storage Facilities

Most commercial nuclear utilities currently store their spent nuclear fuel in water-filled basins (fuel pools) at the reactor site. Some utilities have built *independent spent fuel storage installations* in which they store spent nuclear fuel dry, above ground, in metal casks or in weld-sealed canisters inside reinforced concrete storage modules. Some utilities are planning to build independent spent fuel storage installations so they can proceed with decommissioning their nuclear plants and terminating their operating licenses (for example, the Rancho Seco and Trojan plants). Because utilities could elect to continue operations until their fuel pools are full and then cease operations, the EIS analysis originally considered ongoing wet storage in existing fuel pools to be a potentially viable option for spent nuclear fuel storage. However, dry storage is the preferred option for long-term spent nuclear fuel storage at commercial sites for the following reasons (NRC 1996, pages 6-76 and 6-85):

- Dry storage is a safe economical method of storage.
- Fuel rods in dry storage are likely to be environmentally secure for long periods.
- Dry storage generates minimal, if any, amounts of low-level radioactive waste.
- Dry storage units are simpler and easier to maintain.

Accordingly, this EIS assumes that all commercial spent nuclear fuel would be in dry storage at independent spent fuel storage installations at existing locations. This includes spent nuclear fuel at sites that no longer have operating nuclear reactors. Figure 2-36 shows a photograph of the independent spent fuel storage installation at the Calvert Cliffs commercial nuclear site. Although most utilities and DOE have not constructed independent spent fuel storage installations or designed dry storage containers, this analysis evaluated the impacts of storing all commercial and most DOE spent nuclear fuel in horizontal concrete storage modules (see Figure 2-37) on a concrete pad at the ground surface. Concrete storage modules have openings that allow outside air to circulate and remove the heat of radioactive decay. The analysis assumed that both pressurized-water reactor and boiling-water reactor spent nuclear fuel would have been loaded into a dry storage canister that would be placed inside the concrete storage module. Figure 2-38 shows a typical dry storage canister, which would consist of a stainless-steel outer shell, welded end plugs, pressurized helium internal environment, and criticality-safe geometry for 24 pressurized-water or 52 boiling-water reactor fuel assemblies.

The combination of the dry storage canister and the concrete storage module would provide safe storage of spent nuclear fuel as long as the fuel and storage facilities were properly maintained. The reinforced concrete storage module would provide shielding against the radiation emitted by the spent nuclear fuel. The concrete storage module would also provide protection from damage from such occurrences as aircraft crashes, earthquakes, and tornadoes.

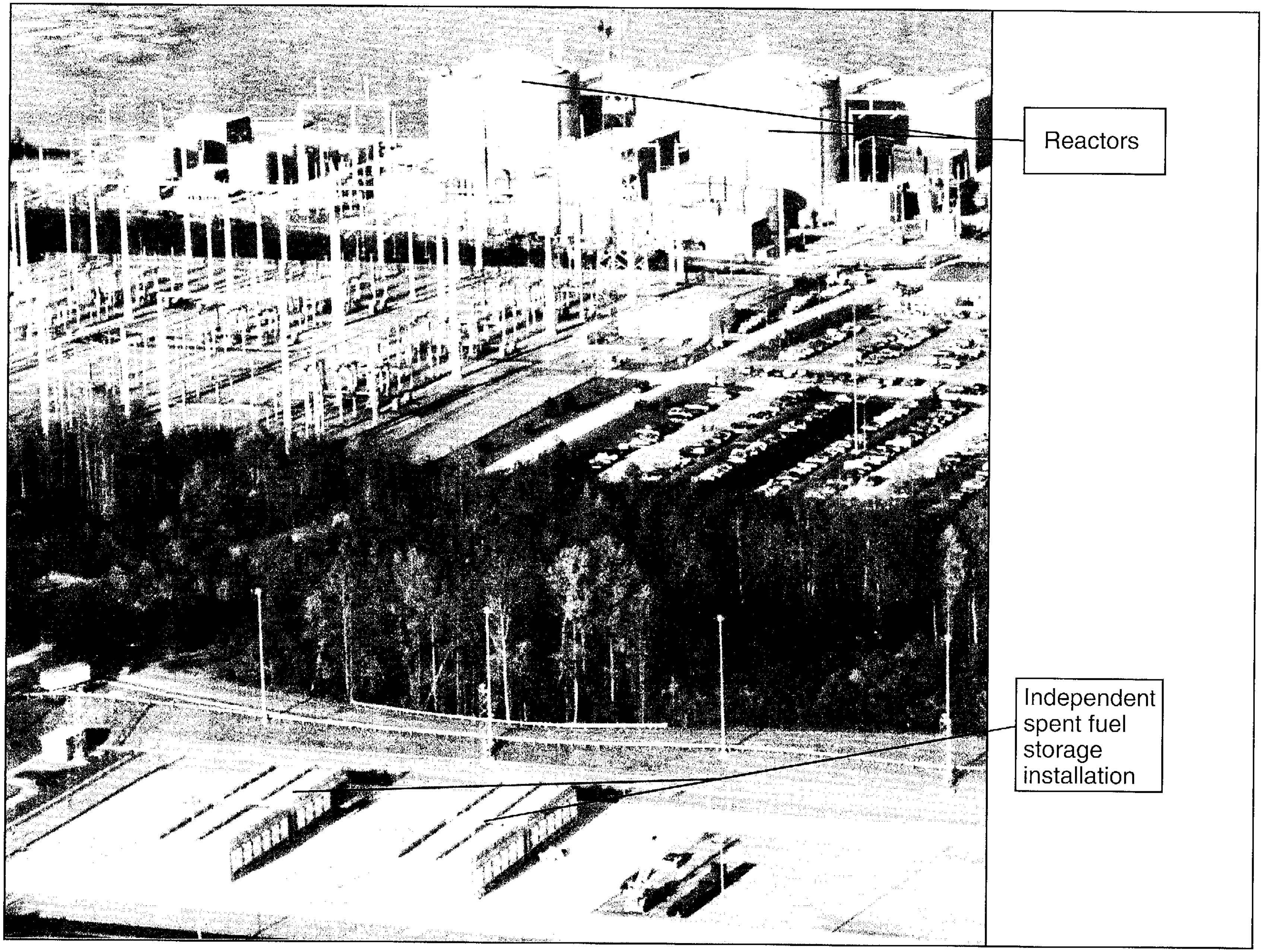
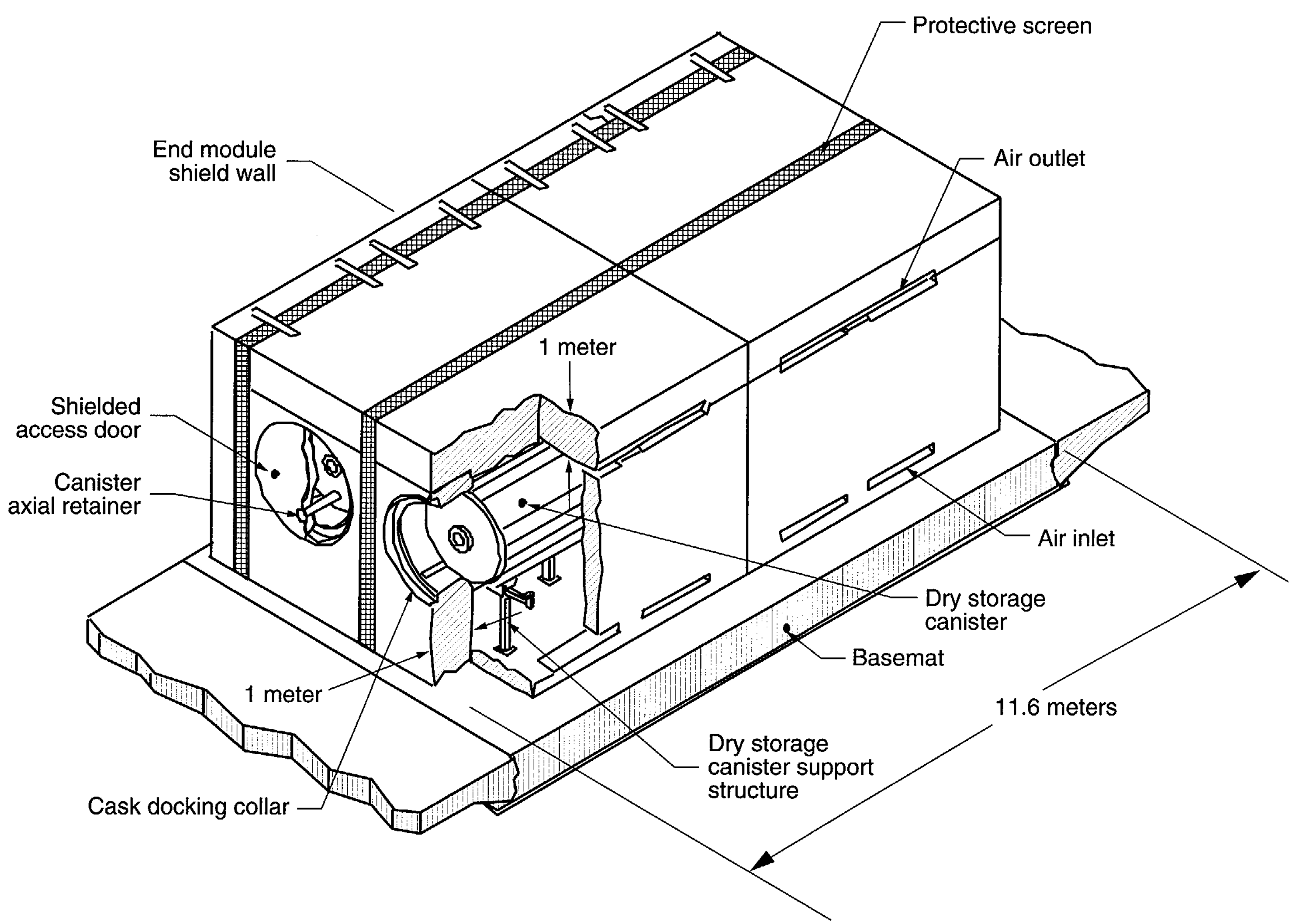


Fig -36. Calvert Cliffs independent spent fuel storage installatio reactors.

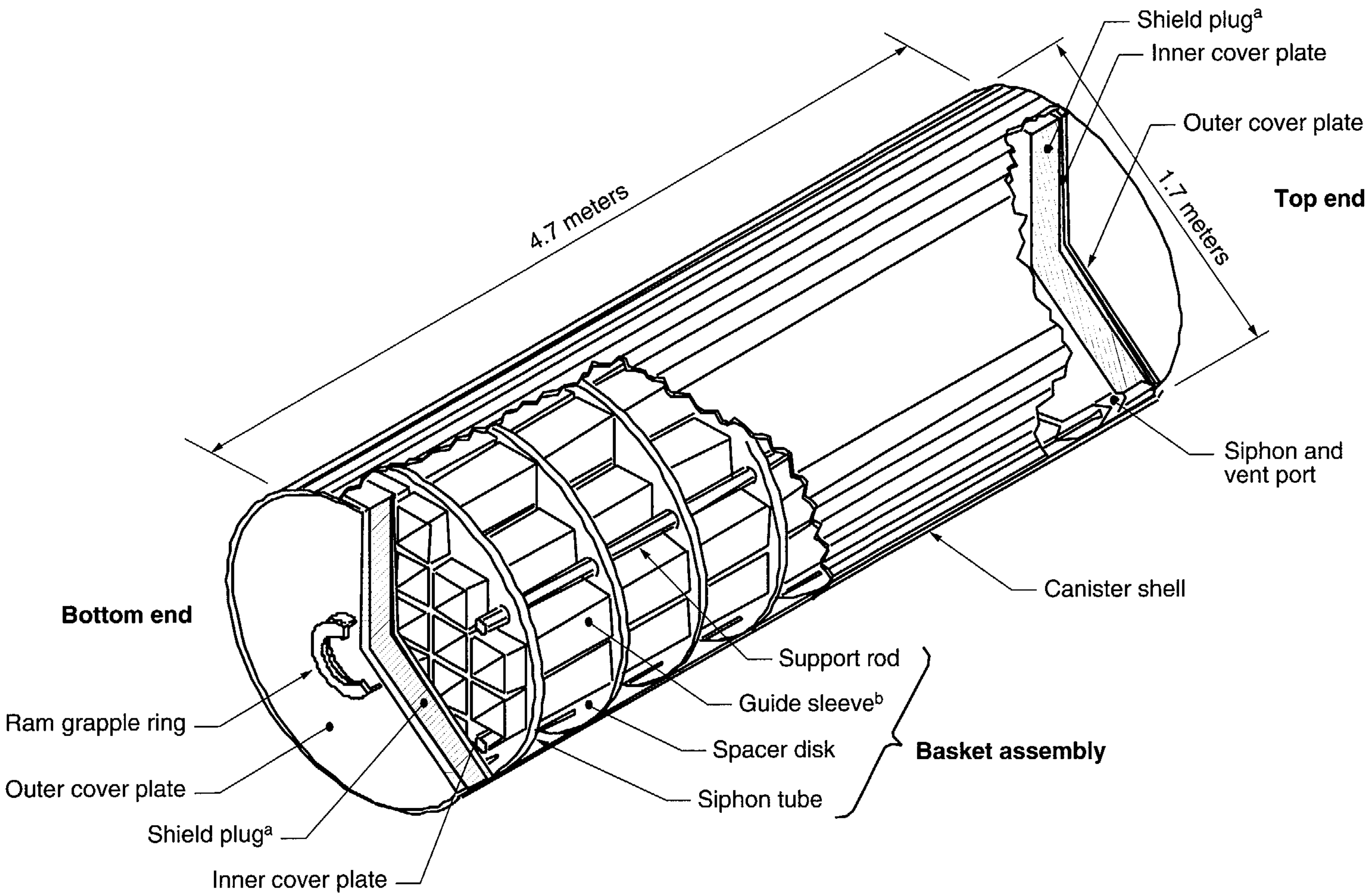


To convert meters to feet, multiply by 3.2808.

Note: Arrangement shown is a row of two storage modules with two canisters in each module.

Source: Modified from Poe (1998a, page 1-2).

Figure 2-37. Spent nuclear fuel concrete storage module.



All materials 304 stainless steel except as noted.

a. Shield plug would be lead.

b. Borated neutron absorber plate
for boiling-water reactor spent nuclear fuel assemblies.

To convert meters to feet, multiply by 3.2808.

Source: Modified from Poe (1998a, page 1-5).

Fi[illegible]-38. Spent nuclear fuel dry storage canister.

This analysis assumed that DOE spent nuclear fuel at the Savannah River Site, Idaho National Engineering and Environmental Laboratory, and Fort St. Vrain would be stored dry, above ground in stainless-steel canisters inside concrete casks. In addition, it assumed that the design of DOE above-ground spent nuclear fuel storage facilities would be similar to the independent spent fuel storage installations at commercial nuclear sites.

The analysis assumed that DOE spent nuclear fuel at Hanford would be stored dry in below-grade storage facilities. The Hanford N-Reactor fuel would be stored in the Canister Storage Building, which would consist of three below-grade concrete vaults with air plenums for natural convective cooling. Storage tubes of carbon steel would be installed vertically in the vaults. Each storage tube, which would be able to accommodate two spent nuclear fuel canisters, would be closed and sealed with a shield plug. The vaults would be covered by a structural steel shelter.

High-Level Radioactive Waste Storage Facilities

With one exception, this analysis assumed that high-level radioactive waste would be stored in a below-grade solidified high-level radioactive waste storage facility (Figure 2-39). At the West Valley Demonstration Project, it was assumed that DOE would use a dry storage system similar to a commercial spent nuclear fuel storage installation for high-level radioactive waste storage.

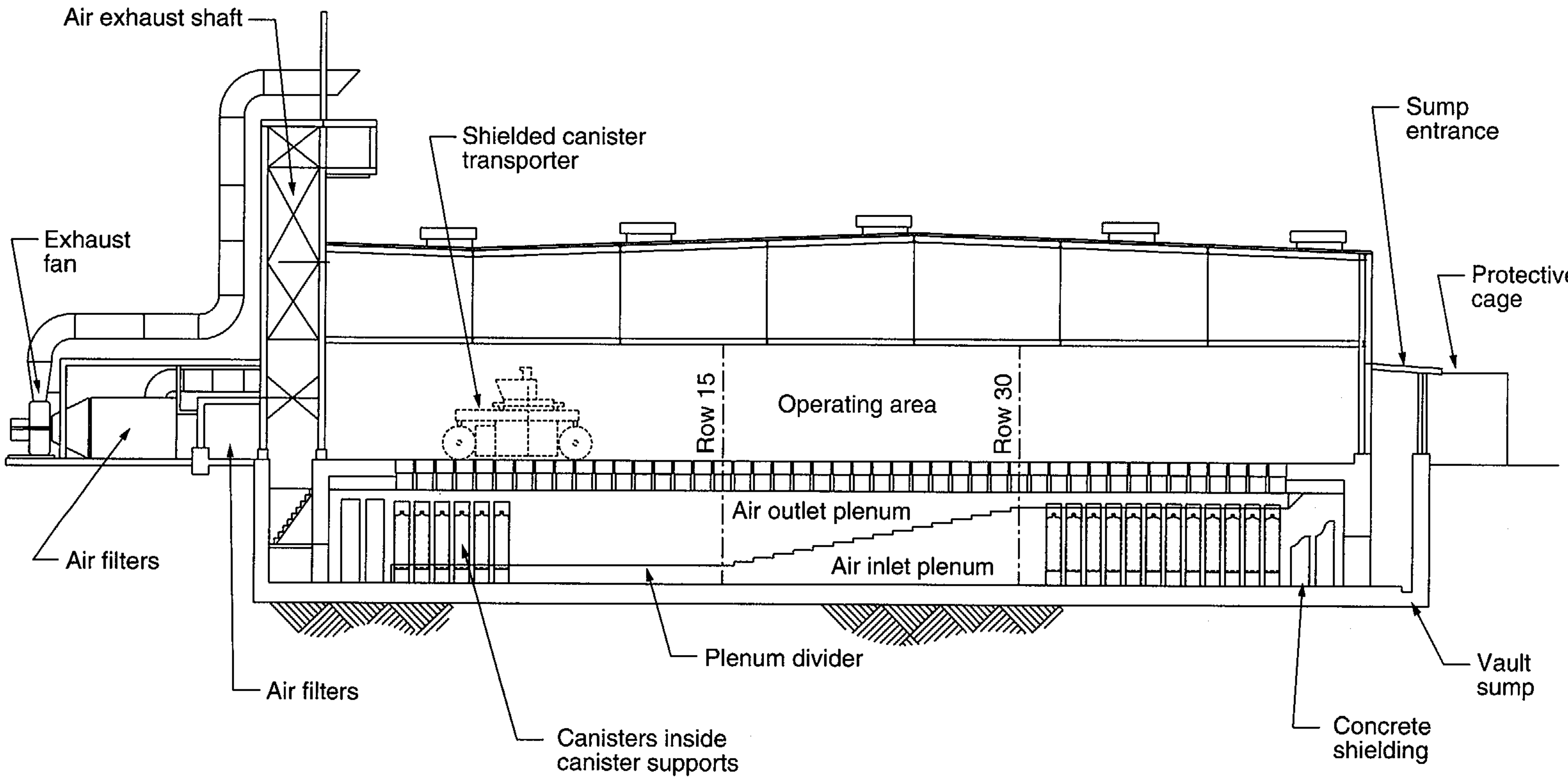
The high-level radioactive waste storage facility has four areas: below-grade storage vaults, an operating area above the vaults, air inlet shafts, and air exhaust shafts. The canister cavities are galvanized-steel large-diameter pipe sections arranged in a grid. Canister casings are supported by a concrete base mat. Space between the pipes is filled with overlapping horizontally stepped steel plates that direct most of the ventilation air through the storage cavities.

The below-grade storage vault would be below the operating floor, which would be slightly above grade. The storage vault would be designed to withstand earthquakes and tornadoes. In addition, the operating area would be enclosed by a metal building, which would provide weather protection and prevent the infiltration of precipitation. The storage vault would be designed to store the canisters and protect the operating personnel, the public, and the environment as long as the facilities were maintained. Radiation shielding would be provided by the surrounding earth, concrete walls, and a concrete deck that would form the floor of the operating area. Canister cavities would have individual precast concrete plugs.

Each vault would have an air inlet, air exhaust, and air passage cells. The heat of radioactive decay would be removed from around the canisters by the facility's forced air exhaust system. The exhaust air could be filtered with high-efficiency particulate air filters before it was discharged to the atmosphere through a stack, or natural convection cooling could be used with no filter. The oversize diameter of the pipe storage cavities would allow air passage around each cavity.

2.2.2.2 No-Action Scenario 1

In No-Action Scenario 1, DOE would continue to manage its spent nuclear fuel and high-level radioactive waste in above- or below-grade dry storage facilities at five sites around the country. Commercial utilities would continue to manage their spent nuclear fuel at 72 sites. The commercial and DOE sites would remain under effective institutional control for at least 10,000 years. Under institutional control, these facilities would be maintained to ensure that workers and the public were protected adequately in accordance with current Federal regulations (10 CFR Parts 20 and 835) and the requirements in DOE Order 5400.5, *Radiation Protection of the Public and the Environment.* DOE based the 10,000-year analysis period on the generally applicable Environmental Protection Agency regulation for the disposal of spent nuclear fuel and high-level radioactive waste (40 CFR Part 191), even though the regulation would not apply to disposal at Yucca Mountain.



Source: Derived from Poe (1998a, pages 4-7, 4-8, and 4-11).

Fig ·39. Conceptual design for solidified high-level radioactive storage facility.

Under Scenario 1, the storage facilities would be completely replaced every 100 years. They would undergo one major repair during the first 100 years, because this scenario assumes that the design of the first storage facilities at a site would include a facility life of less than 100 years. The 100-year lifespan of future storage facilities is based on analysis of concrete degradation and failure in regions throughout the United States (Poe 1998a, all). The facility replacement period of 100 years represents the assumed useful lifetime of the structures. Replacement facilities would be built on land adjacent to the existing facilities. After the spent nuclear fuel and high-level radioactive waste had been transferred to the replacement facility, the older facility would be demolished and the land prepared for the next replacement facility, thereby minimizing land-use impacts. The top portion of Figure 2-40 shows the conceptual timeline for activities at the storage facilities for Scenario 1. Only the relative periods shown on this figure, not the exact dates, are important to the analysis.

2.2.2.3 No-Action Scenario 2

In No-Action Scenario 2, spent nuclear fuel and high-level radioactive waste would remain in dry storage at commercial and DOE sites and would be under effective institutional control for approximately 100 years (the same as Scenario 1). Beyond that time, the scenario assumes no effective institutional control. Therefore, after about 100 years and up to 10,000 years, the analysis assumed that the spent nuclear fuel and high-level radioactive waste storage facilities at 72 commercial and 5 DOE sites would begin to deteriorate and that the radioactive materials in them could eventually be released to the environment. DOE based the choice of 100 years on a review of generally applicable Environmental Protection Agency regulations for the disposal of spent nuclear fuel and high-level radioactive waste (40 CFR Part 191, Subpart B), Nuclear Regulatory Commission regulations for the disposal of low-level radioactive material (10 CFR Part 61), and a National Research Council report on standards for the proposed Yucca Mountain Repository that generally discounts the consideration of institutional control for longer periods in performance assessments for geologic repositories (National Research Council 1995, Chapter 4). The lower portion of Figure 2-40 shows the conceptual timeline for activities at the storage facilities for Scenario 2.

2.2.3 NO-ACTION ALTERNATIVE COSTS

The total estimated cost of the No-Action Alternative includes costs for the decommissioning and reclamation of the Yucca Mountain site, and for the storage of spent nuclear fuel at 72 commercial sites (63,000 MTHM), storage of DOE spent nuclear fuel (2,333 MTHM) at 4 sites (there would be no spent nuclear fuel at the West Valley Demonstration Project), and storage of solidified high-level radioactive waste (8,315 canisters) at 4 sites (there is no high-level radioactive waste at Fort St. Vrain). As listed in Table 2-6, the estimated cost of both Scenarios 1 and 2 for the first 100 years ranges from $51.5 billion to $56.7 billion, depending on whether the dry storage canisters have to be replaced every 100 years. The estimated cost for the remaining 9,900 years of Scenario 1 ranges from $480 million to $529 million per year. There are no costs for Scenario 2 after the first 100 years because the scenario assumes no effective institutional control.

2.3 Alternatives Considered but Eliminated from Detailed Study

This section addresses alternatives that DOE considered but eliminated from detailed study in this EIS. These include alternatives that the NWPA states this EIS need not consider (Section 2.3.1); design alternatives that DOE considered but eliminated during the evolution of the repository design analyzed in this EIS (Section 2.3.2); and alternative rail corridors and highway routes for heavy-haul trucks and associated intermodal transfer station locations that DOE considered but eliminated during the transportation studies that identified the 10 Nevada implementing rail and intermodal alternatives analyzed in this EIS (Section 2.3.3).

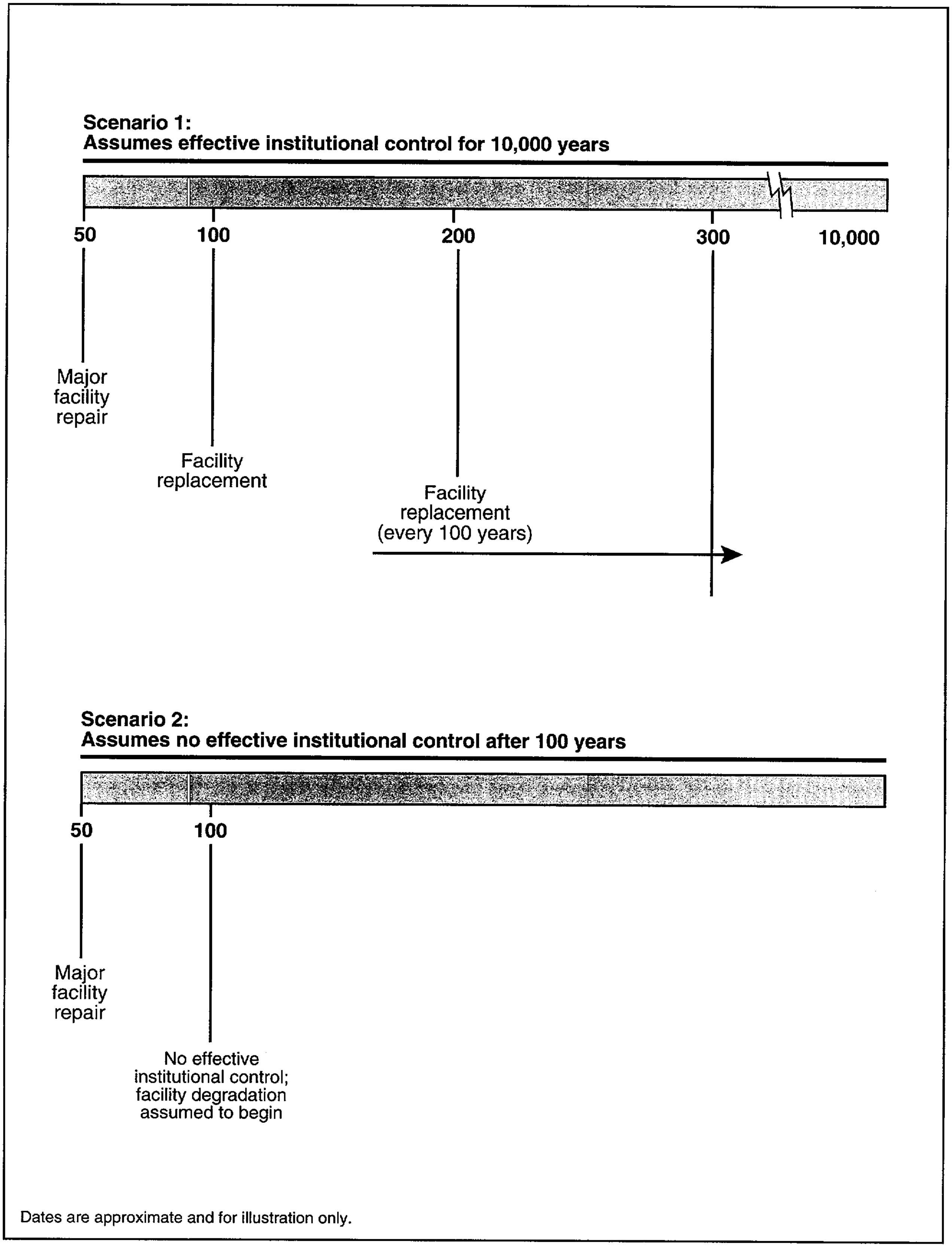


Figure 2-40. Facility timeline assumptions for No-Action Scenarios 1 and 2.

Table 2-6. No-Action Alternative life-cycle costs (in billions of 1998 dollars).[a]

Factor	First 100 years	Remaining 9,900 years (per year)	
	Scenarios 1 and 2[b]	Scenario 1[b,c]	Scenario 2[d]
72 commercial sites (63,000 MTHM)	$40.3 - 45.5	$0.376 - 0.425	$0
DOE spent nuclear fuel storage sites (2,333 MTHM)	7.4	0.069	0
High-level radioactive waste storage sites (8,315 canisters)	3.8	0.035	0
Decommissioning and reclamation of the Yucca Mountain site	(e)	NA[f]	0
Totals	**$51.5 - 56.7**	**$0.480 - 0.529**	**$0**

a. Source: TRW (1999e, all).
b. The range of costs for commercial sites is based on the assumption that the spent nuclear fuel would either be placed in dry storage canisters that would not need to be replaced over the 10,000-year period (low cost) or would have to be placed in new dry storage canisters every 100 years (high cost).
c. Stewardship costs are expressed in average annual disbursement costs (constant year 1998 dollars) only.
d. Costs are not applicable.
e. The costs for decommissioning and reclamation of the Yucca Mountain site would contribute less than 0.1 percent to the total life-cycle cost of continued storage.
f. NA = not applicable.

2.3.1 ALTERNATIVES ADDRESSED UNDER THE NUCLEAR WASTE POLICY ACT

The NWPA states that, with respect to the requirements imposed by the National Environmental Policy Act, compliance with the procedures and requirements of the NWPA shall be deemed adequate consideration of the need for a repository, the time of the initial availability of a repository, and all alternatives to the isolation of spent nuclear fuel and high-level radioactive waste in a repository [Section 114(f)(2)]. The geologic disposal of radioactive waste has been the focus of scientific research for more than 40 years. Starting in the 1950s, the Atomic Energy Commission and the Energy Research and Development Administration (both predecessor agencies to DOE) investigated different geologic formations as potential hosts for repositories and considered different disposal concepts, including deep-seabed disposal, disposal in the polar ice sheets, and rocketing waste into the sun. After extensive discussion of the options in an EIS (DOE 1980, all), DOE decided in 1981 to pursue disposal in an underground mined geologic repository (46 *FR* 26677, May 14, 1981). A panel of the National Academy of Sciences noted in 1990 that there is a worldwide scientific consensus that deep geologic disposal, the approach being followed by the United States, is the best option for disposing of high-level radioactive waste (National Research Council 1990, all).

Chapter 1 of this EIS summarizes the process that led to the 1987 amendments to the Nuclear Waste Policy Act of 1982, in which Congress directed DOE to study only Yucca Mountain to determine if it is suitable for a repository. Consistent with this approach, the NWPA states that, for purposes of complying with the requirements of the National Environmental Policy Act, DOE need not consider alternative sites to Yucca Mountain for the repository [Section 114(f)(3)].

Under the Proposed Action, this EIS does not consider alternatives for the emplacement of more than 70,000 MTHM of spent nuclear fuel and high-level radioactive waste in a repository at Yucca Mountain because the NWPA prohibits the Nuclear Regulatory Commission from approving the emplacement in the first repository of a quantity of spent nuclear fuel containing more than 70,000 MTHM or a quantity of solidified high-level radioactive waste resulting from the reprocessing of such a quantity of spent nuclear fuel until a second repository is in operation [Section 114(d)]. However, Chapter 8 of this EIS analyzes the cumulative impacts from the disposal of all projected spent nuclear fuel and high-level radioactive waste, as well as Greater-Than-Class-C waste and Special-Performance-Assessment-Required waste in the proposed Yucca Mountain Repository.

2.3.2 REPOSITORY DESIGN ALTERNATIVES ELIMINATED FROM DETAILED STUDY

The preliminary design concept for the proposed Yucca Mountain Repository analyzed in this EIS is the result of a design process that began with early site characterization activities. The design process identified design alternatives (options) that DOE considered. Some of the design options were eliminated from further detailed study during the design evolution. Examples include placement of the emplacement drifts in the saturated zone (rather than the unsaturated zone); vertical shafts (rather than the gently sloping North and South Ramps); use of drilling and blasting methods for emplacement drift construction (rather than mechanical excavation methods such as tunnel-boring machines); and use of diesel-powered vehicles for waste package emplacement (rather than electrically powered, rail-based vehicles).

DOE recently undertook a comprehensive review and examination of possible design options to provide information for use in support of the suitability recommendation and License Application. Appendix E discusses the design options that DOE considered in this review, and Section 2.1.1 discusses their consideration in this EIS.

2.3.3 NEVADA TRANSPORTATION ALTERNATIVES ELIMINATED FROM DETAILED STUDY

Because rail access is not currently available to the Yucca Mountain site, DOE would have to build a branch rail line from an existing mainline railroad to the repository or transfer rail shipping casks to heavy-haul trucks at an intermodal transfer station to make effective use of rail transportation for shipping spent nuclear fuel and high-level radioactive waste to the repository. Section 2.1.3 describes the 10 implementing rail and intermodal alternatives for Nevada transportation that this EIS evaluates. DOE selected these implementing alternatives based on transportation studies that identified, evaluated, and eliminated other potential Nevada transportation rail and intermodal alternatives (Tappen and Andrews 1990, all; TRW 1995a, all; TRW 1996, all). This section identifies the potential rail and highway routes for heavy-haul trucks and associated intermodal transfer station locations that DOE considered but eliminated from further detailed study.

2.3.3.1 Potential Rail Routes Considered but Eliminated from Further Detailed Study

In the *Preliminary Rail Access Study* (Tappen and Andrews 1990, all), DOE identified 10 potential branch rail line routes to the Yucca Mountain site (Valley, Arden, Jean, Crucero, Ludlow, Mina, Caliente, Carlin, Cherry Creek, and Dike). Figure 2-41 shows these potential rail routes, each named for the area where it would connect to the mainline railroad. Alternatives within each route were developed wherever possible. The routes were chosen to maximize the use of Federal lands, provide access to regional rail carriers, avoid obvious land-use conflicts, and meet current railroad engineering practices. After the development of these rail routes, Lincoln County and the City of Caliente identified three additional routes (identified as Lincoln County Routes A, B, and C).

DOE evaluated these 13 potential rail routes in Tappen and Andrews (1990, all) and reevaluated them in the *Nevada Potential Repository Preliminary Transportation Strategy, Study 1* (TRW 1995a, all). One new route, Valley Modified, was added in the 1995 study based on updated information from the Bureau of Land Management on the status of two Wilderness Study Areas that represent possible land-use conflicts for the Valley route in the original evaluation. Three additional alignments—Caliente-Chalk Mountain, Elgin/Rox, and Hancock Summit—were evaluated in the Nevada Potential Repository Preliminary Assessment of the Caliente-Chalk Mountain Rail Corridor. The evaluations reviewed each potential rail corridor to identify land-use compatibility issues (the presence or absence of land-use conflicts, and the potential for mitigation of a conflict if one exists) and for access to regional rail carriers. The evaluations also compared other factors of the routes, including favorable topography (gently sloping rather than rugged terrain) and avoidance of lands withdrawn from public use by Federal action. Based

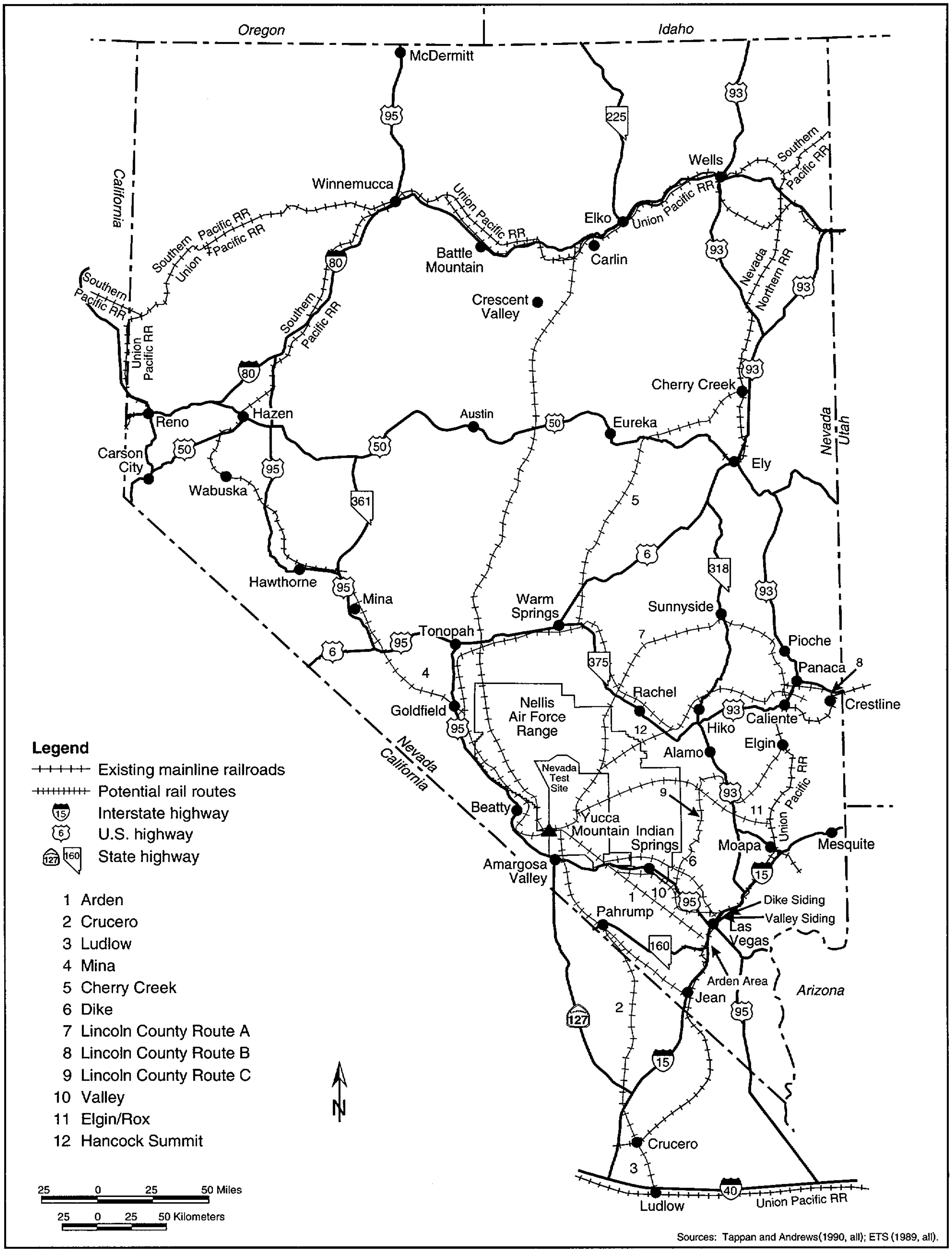


Figure 2-41. Potential rail routes to Yucca Mountain, Nevada, considered but eliminated from detailed study.

on these evaluations, DOE eliminated the Valley, Arden, Crucero, Ludlow, Mina, Cherry Creek, Dike, Elgin/Rox, Hancock Summit, and Lincoln County A, B, and C rail routes from further study.

2.3.3.2 Potential Highway Routes for Heavy-Haul Trucks and Associated Intermodal Transfer Station Locations Considered but Eliminated from Further Detailed Study

DOE identified and evaluated potential highway routes for heavy-haul trucks from existing mainline railroads to the Yucca Mountain site (TRW 1995a, all; TRW 1996, all; TRW 1999d, all). The Department identified highway routes for heavy-haul trucks and associated intermodal transfer station locations to provide reasonable access to existing mainline railroads, to minimize transport length from an existing mainline rail interchange point, and to maximize the use of roads identified by the Nevada Department of Transportation for the highest allowable axle load limits. In addition to the five implementing intermodal alternatives selected for analysis in this EIS (see Section 2.1.3), Figure 2-42 shows highway routes for heavy-haul trucks and associated intermodal transfer station locations that DOE considered but eliminated from further detailed study. The eliminated alternatives include four routes named for the location of the intermodal transfer station—Apex, Arden, Baker, and Apex/Dry Lake (Las Vegas Bypass)—and three that are representative of routes from the northern Union Pacific mainline railroad (Northern Routes 1, 2, and 3).

DOE considered the development of new roads for dedicated heavy-haul truck shipments. The analysis assumed those routes would be within the corridors identified for potential rail routes, because the selection criteria for heavy-haul routes and rail routes (land-use compatibility issues, access to regional rail carriers, etc.) would be similar (TRW 1996, page 6-3). DOE also considered routes for heavy-haul trucks in the potential rail corridors that could use portions of the existing road system for part of the route length. DOE eliminated the development of a new road for heavy-haul trucks from further detailed evaluation, because the construction of a new branch rail line would be only slightly more expensive and transportation by rail would be safer (no intermodal transfers) and more efficient (TRW 1996, page 6-7).

2.4 Summary of Findings and Comparison of the Proposed Action and the No-Action Alternative

This section summarizes and compares the potential environmental impacts of the Proposed Action and the No-Action Alternative (Section 2.2). Detailed descriptions of the impact analyses are contained in the following chapters:

- Chapter 4 describes the short-term environmental impacts associated with construction, operation and monitoring, and closure of the repository and includes the manufacture of waste disposal containers and shipping casks.
- Chapter 5 describes long-term (postclosure) environmental impacts from the disposal of spent nuclear fuel and high-level radioactive waste in the repository.
- Chapter 6 describes the impacts associated with the transportation of spent nuclear fuel, high-level radioactive waste, other materials, and personnel to and from the repository.
- Chapter 7 describes the short-term and long-term impacts associated with the No-Action Alternative.

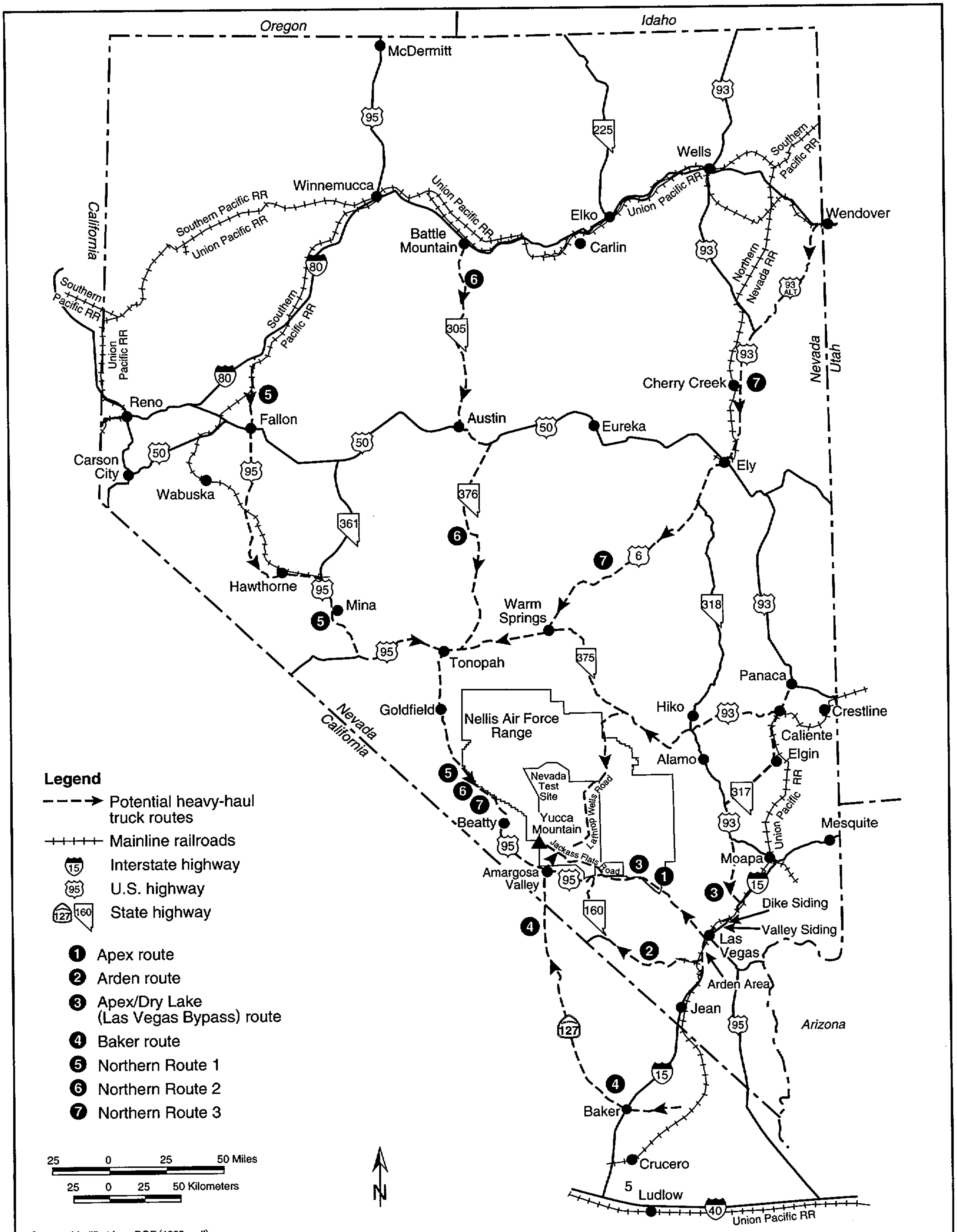


Figure 2-42. Potential highway routes for heavy-haul trucks to Yucca Mountain, Nevada, considered but eliminated from detailed study.

This EIS defines *short-term impacts* as those that would occur until and during the closure of the repository (approximately 100 years following the start of emplacement) and *long-term impacts* as those that would occur after repository closure (after 100 years) and for as long as 10,000 years.

This section summarizes the findings of the EIS analyses and contains a general comparison of the Proposed Action and No-Action Alternative (Section 2.4.1), potential short-term impacts (Section 2.4.2), long-term impacts (Section 2.4.3), and transportation impacts (Section 2.4.4).

2.4.1 PROPOSED ACTION AND NO-ACTION ALTERNATIVE

In general, the EIS analyses showed that the environmental impacts associated with the Proposed Action would be small, as described in Chapters 4, 5, 6, and 8. For some of the resource areas specifically analyzed in this study, there would be no impacts. Table 2-7 provides an overview approach to comparing the Proposed Action and the No-Action Alternative.

Although generally small, environmental impacts would occur under the Proposed Action. DOE would reduce or eliminate many such impacts with mitigation measures or implementation of standard Best Management Practices. Under the No-Action Alternative, the short-term impacts would be the same under Scenarios 1 or 2. Under Scenario 1, DOE would continue to manage spent nuclear fuel and high-level radioactive waste facilities at 5 DOE sites, and commercial utilities would continue to manage their spent nuclear fuel at 72 sites on a long-term basis and to isolate the material from human access with institutional control. Under Scenario 2, with the assumption of no effective institutional control after 100 years, the spent nuclear fuel and high-level radioactive waste storage facilities would begin to deteriorate and radioactive materials could escape to the environment, contaminating the local atmosphere, soils, surface water, and groundwater, thereby representing a considerable human health risk.

2.4.2 SHORT-TERM IMPACTS OF REPOSITORY CONSTRUCTION, OPERATION AND MONITORING, AND CLOSURE

DOE analyzed short-term impacts (about 100 years) for the Proposed Action and No-Action Alternative in various resource areas. The information presented in Table 2-7 shows that the short-term environmental impacts for the Proposed Action and the No-Action Alternative would generally be small and do not differentiate dramatically between the two alternatives. The analyses also included cost estimates for the two alternatives. Estimated short-term (to 100 years) costs for the Proposed Action would be about $29 billion, and those for the No-Action Alternative would be as much as $57 billion for the same period.

2.4.3 LONG-TERM IMPACTS OF THE PROPOSED ACTION AND THE NO-ACTION ALTERNATIVE

In addition to the short-term impacts described above, DOE assessed the impacts from radiological and nonradiological hazardous materials released over a much longer period (100 years to as long as 10,000 years) after the closure of the repository. Because these projections are based essentially on best available scientific techniques, DOE focused the assessment of long-term impacts on human health, biological resources, surface-water and groundwater resources, and other resource areas for which the analysis determined the information was particularly important and could establish estimates of impacts.

The EIS also examined possible biological impacts from the long-term production of heat by the radioactive materials disposed of in Yucca Mountain. Because there would be no repository activity after approximately 100 years, there would be no changes in land use, employment of workers, and use of water or utilities. The analysis determined that there would be no impacts to land use, noise, socioeconomic resources, cultural resources, surface-water resources, aesthetics, utilities, or site services

Table 2-7. Impacts associated with the Proposed Action and No-Action Alternative (page 1 of 4).

	Proposed Action			No-Action Alternative		
	Short-term (through closure, about 100 years)		Long-term (after closure, about 100 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	Withdraw about 600 km^2[a] of land now under Federal control; active use of about 3.5 km^2	0 to about 20 km^2 of land disturbed for new transportation routes; Air Force identified conflicts for some routes; Valley Modified rail corridor would pass near the Las Vegas Paiute Indian Reservation; some rail corridors could overlap with potential Las Vegas growth; heavy-haul trucks could slow traffic flow; some heavy-haul routes would pass near or through the Moapa and Las Vegas Paiute Indian Reservations	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	Potential contamination of 0.04 to 0.4 km^2 surrounding each of the 72 commercial and 5 DOE sites
Air quality	Releases and exposures well below regulatory limits (less than 5 percent of limits)	Releases and exposures below regulatory limits; pollutants from vehicle traffic and trains would be small in comparison to other national vehicle and train traffic	No air releases	Releases and exposures well below regulatory limits	Releases and exposures well below regulatory limits	Increases in airborne radiological releases and exposures (potentially exceeding current regulatory limits)
Hydrology (groundwater and surface water)	Water demand well below Nevada State Engineer's ruling on perennial yield (250 to 480 acre-feet[b] per year)	Withdrawal of up to 710 acre-feet[b] from multiple wells and hydrographic areas over 2.5 years	Low-level contamination of groundwater in Amargosa Valley after a few thousand years (estimated concentration would be below drinking water standards)	Small; usage would be small in comparison to other site use	Small; usage would be small in comparison to other site use	Potential for radiological contamination of groundwater around 72 commercial and 5 DOE sites
	Small; minor changes to runoff and infiltration rates; floodplain assessment concluded impacts would be small	Small; minor changes to runoff and infiltration rates; 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	Potential for radiological releases and contamination of drainage basins downstream of 72 commercial and 5 DOE sites (concentrations potentially exceeding current regulatory limits)

Table 2-7. Impacts associated with the Proposed Action and No-Action Alternative (page 2 of 4).

	Proposed Action			No-Action Alternative		
	Short-term (through closure, about 100 years)		Long-term (after closure, about 100 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	Loss of about 3.5 km^2 of desert soil, habitat, and vegetation; adverse impacts to threatened desert tortoise (individuals, 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	Loss of 0 to about 20 km^2 of desert soil, habitat, and vegetation for heavy-haul routes and rail corridors; adverse impacts to threatened desert tortoise (individuals, 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	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	Potential adverse impacts at each of the 77 sites from subsurface contamination of 0.04 to 0.4 km^2
Cultural resources	Repository development would disturb about 3.5 km^2; damage to and illicit collecting at archaeological sites; programs in place to minimize impacts; opposing Native American viewpoint	Loss of 0 to about 20 km^2 of land disturbed for new transportation routes; damage to and illicit collecting at archaeological sites; programs in place to minimize impacts; opposing Native American viewpoint	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	No construction or operation activities; no impacts
Socioeconomics	Estimated peak employment of 1,800 occurring in 2006 would result in less than a 1 percent increase in direct and indirect regional employment; therefore, impacts would be low	Employment increases would range from less than 1 percent to 5.7 percent (use of intermodal transfer station or rail line in Lincoln County, Nevada) of total employment by county; therefore, impacts would be low	No workers, no impacts	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	No workers; no impacts
Occupational and public health and safety						
Public						
Radiological (LCFs[c])						
MEI[c]	1.9×10^{5} to 5.1×10^{-5}	1.6×10^{4} to 1.2×10^{3}	1.9×10^{8} to 4.4×10^{5}	4.3×10^{-6}	1.3×10^{-6}	(d)
Population	0.14 to 0.41	3 to 18	5.5×10^{5} to 5.3×10^{4}	0.41	3	3,300[e]
Nonradiological	Exposures well below regulatory limits	Exposures below regulatory limits; pollutants from vehicle traffic and trains	Exposures well below regulatory limits or guidelines	Exposures well below regulatory limits or guidelines	Exposures well below regulatory limits or guidelines	Increases in releases of hazardous substances in the spent nuclear fuel and high-level radioactive waste and exposures to the public

Table 2-7. Impacts associated with the Proposed Action and No-Action Alternative (page 3 of 4).

Resource area	Proposed Action: Short-term (through closure, about 100 years): Repository	Proposed Action: Short-term (through closure, about 100 years): Transportation	Proposed Action: Long-term (after closure, about 100 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)	3 to 4	3 to 11	No workers, no impacts	16	12	No workers, no impacts
Nonradiological fatalities (includes commuting traffic fatalities)	1 to 2	11 to 16[f]	No workers, no impacts	9	1,080	No workers, no impacts
Accidents						
Probability (frequency per year)	8.6×10^{-7} to 1.1×10^{-2}	1.4×10^{-7} to 1.9×10^{-7}	No credible accidents	3.2×10^{-6}	3.2×10^{-6}	3.2×10^{-6}
Public						
Radiological (LCFs)						
MEI	2.9×10^{-13} to 2.1×10^{-6}	0.002 to 0.013	Not applicable	No impacts	No impacts	Not applicable
Population	1.0×10^{-11} to 7.8×10^{-5}	0.02 to 0.07	Not applicable	No impacts	No impacts	3 to 13
Workers	For some accident scenarios workers would likely be severely injured or killed	For some accident scenarios workers would likely be severely injured or killed	No workers; no impacts	For some accident scenarios workers would likely be severely injured or killed	For some accident scenarios workers would likely be severely injured or killed	No workers; no impacts
Noise	Impacts to public would be low due to large distances to residences; workers exposed to elevated noise levels – controls and protection used as necessary	Transient and not excessive, less than 90 dBA[g]	No activities, therefore, no noise	Transient and not excessive, less than 90 dBA	Transient and not excessive, less than 90 dBA	No activities, therefore, no noise
Aesthetics	Low adverse impacts to aesthetic or visual resources in the region	Low, temporary, and transient; possible conflict with visual resource management goals for Jean rail corridor	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	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.	Use of materials and energy would be small in comparison to amounts used nationally	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	No use of materials or energy

Table 2-7. Impacts associated with the Proposed Action and No-Action Alternative (page 4 of 4).

	Proposed Action			No-Action Alternative		
	Short-term (through closure, about 100 years)		Long-term (after closure, about 100 to 10,000 years)	Short-term	Long-term (100 to 10,000 years)	
Resource area	Repository	Transportation		(100 years)	Scenario 1	Scenario 2
Management of site-generated waste and hazardous materials	Radioactive and hazardous waste generated would be a few percent of existing offsite capacity; other wastes would be managed offsite and some waste potentially at an onsite landfill	Radioactive and hazardous waste generated would be a few percent of existing offsite capacity; other wastes would be managed offsite and some waste potentially at an onsite landfill	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	No waste generated or hazardous materials used
Environmental justice	No disproportionately high and adverse impacts to minority or low-income populations; opposing Native American viewpoint	No disproportionately high and adverse impacts to minority or low-income populations; opposing Native American viewpoint	No disproportionately high and adverse impacts to minority or low-income populations; opposing Native American viewpoint	No disproportionately high and adverse impacts to minority or low-income populations	No disproportionately high and adverse impacts to minority or low-income populations	Potential for disproportionately high and adverse impacts to minority or low-income populations

a. km^2 = square kilometers; to covert to acres, multiply by 247.1.
b. To convert acre-feet to cubic meters, multiply by 1233.49.
c. LCF = latent cancer fatality; MEI = maximally exposed individual.
d. 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.
e. Downstream exposed population of approximately 3.9 billion over 10,000 years.
f. As many as 8 of these fatalities could be members of the public; fatalities include commuting traffic fatalities.
g. 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.

from the Proposed Action and limited impacts from the No-Action Alternative, depending on the scenario. The analysis led to the following conclusions:

- From 0.04 to 0.4 square kilometer (10 to 100 acres) of land could be contaminated to the extent it would not be usable for long periods near each of the 77 sites for No-Action Scenario 2. There could be accompanying impacts on biological resources, socioeconomic conditions, cultural resources, and aesthetic resources for long periods. Such impacts for the Proposed Action and No-Action Scenario 1 would be very small.

- For No-Action Scenario 2, there could be low levels of contamination in the surface watershed and high concentrations of contaminants in the groundwater downstream of the 77 sites for long periods. There would be no such impacts for No-Action Scenario 1. For the Proposed Action, there could be low levels of contamination in the groundwater in the Amargosa Desert for a long period.

- Projected radiological impacts to the public for the first 10,000 years for the Proposed Action would be low (0.000055 to 0.00053 latent cancer fatality per year) compared to No-Action Scenario 2 (3,300 latent cancer fatalities).

- Radionuclides would be released for a long period of time under the Proposed Action and peak doses would occur hundreds of thousand years after closure of the repository.

- Projected long-term fatalities associated with No-Action Scenario 1 would be about 1,000, primarily to the workforce at the storage sites.

- Risks associated with sabotage and materials diversion in relation to the fissionable material stored at the 77 sites would be much greater than they would be if the fissionable material were in a monitored deep geologic repository.

The projected cost associated with No-Action Scenario 1 would be approximately $600 million a year (1998 dollars) for 9,900 years. Projected long-term costs for the Proposed Action would be very low while there would be none for No-Action Scenario 2 due to the lack of institutional control.

2.4.4 IMPACTS OF TRANSPORTATION SCENARIOS

2.4.4.1 National Transportation

This section summarizes and compares transportation-related environmental impacts for the movement of spent nuclear fuel and high-level radioactive waste from the 77 sites to the Yucca Mountain site. Table 2-8 compares the environmental impacts for the two national transportation scenarios analyzed, mostly rail and mostly legal-weight truck (see Section 2.1.3.2). Because DOE does not know the actual mix for these potential national transportation modes, the analyses used these two scenarios to bound the impacts from transportation activities that would move spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site. In addition, Table 2-8 lists estimates of the environmental impacts associated with transportation activities in Nevada.

The values listed in Table 2-8 are limited to radiological impacts. As discussed in more detail in Chapter 6, shipments of spent nuclear fuel and high-level radioactive waste to Yucca Mountain would be a small fraction of the overall railroad and highway shipping activity in the United States. Thus, the incremental impacts from shipments to Yucca Mountain for the resource areas would be small in comparison to background impacts from all shipping activities, with the exception of potential radiological impacts.

Table 2-8. National transportation impacts for the transportation of spent nuclear fuel and high-level radioactive waste for the mostly rail and mostly legal-weight truck scenarios.

Group	Impact	Mostly legal-weight truck scenario	Mostly rail scenario
Worker	*Incident-free health impacts, radiological*		
	Maximally exposed individual (rem)	48	48
	Individual latent cancer fatality probability	0.02	0.02
	Collective dose (person-rem)	11,000	1,900 - 2,300[a]
	Latent cancer fatality incidence	4.5	0.8 - 0.9[a]
Public	*Incident-free health impacts, radiological*		
	Maximally exposed individual (rem)	2.4	0.31
	Individual latent cancer fatality probability	0.001	0.00016
	Collective dose (person-rem)	35,000	3,300 - 5,000[a]
	Latent cancer fatality incidence	18	1.6 - 2.5[a]
	Incident-free vehicle emissions impacts		
	Fatalities	0.6	0.3
Public	*Radiological impacts from maximum reasonably foreseeable accident scenario*		
	Probability (per year)	1.9 in 10,000,000	1.4 in 10,000,000
	Maximally exposed individual (rem)	3.9	26
	Individual latent cancer fatality probability	0.002	0.013
	Collective dose (person-rem)	9,400	61,000
	Latent cancer fatality incidence	4.7	31
Public and transportation workers	*Fatalities from vehicular accidents*	3.9	3.6

a. Range for the 10 rail and heavy-haul truck implementing alternatives in Nevada.

The following conclusions can be drawn from the analysis results summarized in Table 2-8:

- Radiological impacts from maximum foreseeable accident scenarios during the transportation of spent nuclear fuel and high-level radioactive waste would be lower for the mostly legal-weight truck case.
- Impacts from the transportation of spent nuclear fuel and high-level radioactive waste from the commercial and DOE sites to the Yucca Mountain site would be low for either national shipping mode.
- Radiological impacts to the public and to workers for normal transportation activities would be lower for the mostly rail scenario.

Most of the occupational and public health and safety impacts to the public and to workers would occur during the repository operating and monitoring phase.

Incremental differences in short-term impacts for the thermal load scenarios would be small, generally by less than a factor of about 2. Short-term impacts would generally be largest for the low thermal load and lowest for the high thermal load.

2.4.4.2 Nevada Transportation

For shipments coming into the State of Nevada by rail, there is no rail line to connect the national rail routes with the Yucca Mountain site (see Section 2.1.3.3). As a consequence, DOE evaluated the impacts in Nevada of moving spent nuclear fuel and high-level radioactive waste to the site using 10 implementing alternatives. These included five potential corridors for a new branch rail line (see Section 2.1.3.3.2) and five potential combinations of intermodal transfer stations and highway routes for heavy-haul trucks (see Section 2.1.3.3.3).

Tables 2-9 and 2-10 compare the impacts from transportation activities in potential Nevada rail corridors and heavy-haul truck corridors, respectively. In addition, they list impacts associated with engineering attributes for each implementing alternative. These engineering factors include cost, institutional acceptability of the route, construction and schedule risk, and operational compatibility. Additional attributes could affect a decision on the choice of a transportation mode or route in Nevada.

The following conclusions can be drawn from the information in Tables 2-9 and 2-10:

- Environmental impacts for each of the 10 implementing alternatives would be small.
- With the exception of collective dose, the environmental impacts for shipment by legal-weight truck in Nevada would be smaller than those from the 10 implementing alternatives associated with incoming shipments by rail. However, even for shipment by rail or heavy-haul truck in Nevada, the projected collective dose impacts would be small (approximately 2 latent cancer fatalities to both the public and transportation workers).
- With the exception of land use, differences in environmental impacts for the 10 implementing alternatives related to incoming shipments by rail would be small, so environmental impacts do not appear to be a major factor in the selection of transportation mode, route, or corridor in Nevada for incoming rail shipments.
- For land use, the Caliente-Chalk Mountain routes for a rail corridor and for a highway route for heavy-haul trucks would have conflicts with ongoing national defense activities at the Nellis Air Force Range.
- Impacts to cultural resources for any of the potential implementing alternative routes or corridors cannot be fully assessed until more detailed archaeological and ethnographic studies are conducted, but they are likely to be similar to one another. Impacts to Native American values could occur from the use of any of the routes including the use of highways in Nevada by legal-weight trucks that would pass through the Moapa and Las Vegas Paiute Indian reservations.

2.5 Collection of Information and Analyses

DOE conducted a broad range of studies to obtain or evaluate the information needed for the assessment of Yucca Mountain as a monitored geologic repository for spent nuclear fuel and high-level radioactive waste. The Department used the information from these studies in the analyses described in this EIS. Because some of these studies are ongoing, some of the information is incomplete.

The complexity and variability of the natural system at Yucca Mountain, the long periods evaluated, and factors such as the use of incomplete information or the unavailability of information have resulted in a certain degree of uncertainty associated with the analyses and findings in this EIS. DOE believes that it is important that the EIS identify the use of incomplete and unavailable information and uncertainty to enable an understanding of its findings. It is also important to understand that research can produce results or conclusions that might disagree with other research. The interpretation of results and conclusions has resulted in the development of views that differ from those that DOE presents in this EIS. DOE has received input from a number of organizations interested in the Proposed Action or No-Action Alternative or from potential recipients of impacts from those actions. These organizations include among others the State of Nevada, local governments, and Native American groups. Their input includes documents that present research or information that in some cases disagrees with the views that DOE presents in this EIS. The Department reviewed these documents and evaluated their findings for inclusion as part of the EIS analyses. If the information represents a substantive view, DOE has made every effort to incorporate that view in the EIS and to identify its source.

Table 2-9. Comparison of impacts for Nevada rail implementing alternatives and for legal-weight truck shipments (page 1 of 2).

Impact	Caliente	Carlin	Caliente-Chalk Mountain	Jean	Valley Modified	Mostly legal-weight truck
Land use and ownership						
Disturbed land (square kilometers)[a]	18	19	12	9	5	None
Private land (square kilometers)	0.9	7	0.8	3.6	0	None
Nellis Air Force Base land (square kilometers)	20	19	22	0	10	None
Air quality						
PM_{10} (construction)	Areas in attainment of air quality standards - branch rail line construction not a significant source of pollution	Areas in attainment of air quality standards - branch rail line construction not a significant source of pollution	Areas in attainment of air quality standards - branch rail line construction not a significant source of pollution	Except in Clark County, areas in attainment of air quality standards - branch rail line construction would not be a significant source of pollution	Clark County is in nonattainment of air quality standards for PM_{10} - branch rail line construction would not be a significant source of pollution	No construction
CO (operations)	93% of General Conformity Rule threshold	93% of General Conformity Rule threshold	93% of General Conformity Rule threshold	93% of General Conformity Rule threshold	93% of General Conformity Rule threshold	93% of General Conformity Rule threshold
Hydrology						
Surface water	Low	Low	Low	Low	Low	None
Groundwater						
Water use (acre-feet)[b]	710	660	480	410	320	None
Water use (number of wells)	64	67	43	23	20	None
Biological resources and soils	Low	Low	Low	Low	Low	None
Cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological or historical resources. Route passes close to the Las Vegas Paiute Indian Reservation	Since shipments would use existing highways, none to archaeological or historical resources. Shipments from the northeast would pass through the Moapa Indian Reservation. All shipments would pass through the Las Vegas Paiute Indian Reservation
Noise	Moderate	Low	Moderate	Moderate	Moderate	Low
Utilities and resources						
Diesel (million liters)[c]	42	39	33	26	13	Low
Steel (thousand metric tons)[d]	71	72	48	26	22	None

Table 2-9. Comparison of impacts for Nevada rail implementing alternatives and for legal-weight truck shipments (page 2 of 2).

Impact	Caliente	Carlin	Caliente-Chalk Mountain	Jean	Valley Modified	Mostly legal-weight truck
Concrete (thousand metric tons)[e]	420	400	280	150	130	None
Aesthetics	Very low	Very low	Very low	Potential small area of conflict	Very low	None
Socioeconomics						
New jobs (percent of workforce in affected counties	1,200 (< 1% to 4%)	1,100 (< 1%)	910 (< 1% to 5.7%)	720 (< 1%)	350 (< 1%)	Low
Peak real disposable income (million dollars)	27	25	19	16	7	Low
Peak incremental Gross Regional Product (million dollars)	49	44	35	29	14	NA[f]
Waste management	Limited quantity	Limited quantity	Limited quantity	Limited quantity	Limited quantity	None
Environmental justice (disproportionately high and adverse impacts)	None	None	None	None	None	None
Incident-free health and safety						
Industrial hazards						
Total recordable incidents	250	240	220	170	130	NA
Lost workday cases	130	120	110	90	70	NA
Fatalities	1.3	1.2	1	0.9	0.5	NA
Collective dose (person-rem [LCFs])						
Workers	430 [0.17]	470 [0.19]	390 [0.16]	400 [0.16]	380 [0.15]	1,600 [0.63]
Public	390 [0.20]	420 [0.21]	380 [0.19]	430 [0.21]	380 [0.19]	2,800 [1.4]
Fatalities from vehicle emissions	0.0019	0.0025	0.0017	0.014	0.0018	0.005
Traffic accident fatalities						
Construction and operations workforce	1.9	1.8	1.5	1.2	0.9	NA[f]
SNF[g] and HLW[h] shipping	0.13	0.15	0.11	0.11	0.1	0.5
Radiological impacts, accident scenarios						
Maximum exposed individual (rem)	26	26	26	26	26	3.9
Individual latent cancer fatality probability	0.02	0.02	0.02	0.02	0.02	0.002
Collective dose	0.09	0.1	0.09	0.15	0.09	0.5
Latent cancer fatalities	0.00005	0.00005	0.00004	0.00008	0.00004	0.0002

a. To convert square kilometers to acres, multiply by 247.1.
b. To convert acre-feet to gallons, multiply by 325,850.1.
c. To convert liters to gallons, multiply by 0.26418.
d. To convert metric tons to tons, multiply by 1.1023.
e. To convert cubic feet to cubic meters, multiply by 0.028317.
f. NA = not applicable.
g. SNF = spent nuclear fuel.
h. HLW = high-level radioactive waste.

Table 2-10. Comparison of impacts for Nevada heavy-haul truck implementing alternatives and for legal-weight truck shipments (page 1 of 2).

Impact	Caliente	Caliente-Chalk Mountain	Caliente-Las Vegas	Sloan/Jean	Apex/Dry Lake	Mostly legal-weight truck
Land use and ownership						
Disturbed land (square kilometers)[a]	0.28	0.24	0.24	0.2	0.2	None
Private land (square kilometers)	0	0	0	0	0	None
Nellis Air Force Base land (square kilometers)	0	0	0	0	0	None
Air quality						
PM_{10} (construction)	Areas in attainment of air quality standards - highway upgrades not a significant source of pollution	Areas in attainment of air quality standards - highway upgrades not a significant source of pollution	Except Clark County, areas in attainment of air quality standards - highway upgrades not a significant source of pollution	48% of GCR Threshold for IMT construction	48% of GCR Threshold for IMT construction	No construction
CO (operations)	93% of General Conformity Rule threshold	93% of General Conformity Rule threshold	93% of General Conformity Rule threshold	93% of General Conformity Rule threshold	93% of General Conformity Rule threshold	
Hydrology						
Surface water	Low	Low	Low	Low	Low	None
Groundwater						
Water use (acre-feet)[b]	100	60	44	8	8	None
Water use (number of wells)	16	5	7	Truck water	Truck water	None
Biological resources and soils	Low	Low	Low	Low	Low	None
Cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological, historical, or cultural resources; route near Moapa Indian Reservation and passes across 1.6-kilometer (1-mile) corner of the Las Vegas Paiute Indian Reservation	None identified to archaeological, historical, or cultural resources; route passes across 1.6-kilometer (1-mile) corner of the Las Vegas Paiute Indian Reservation	None identified to archaeological, historical, or cultural resources; IMT[c] and route near the Moapa Indian Reservation and passes across 1.6-kilometer (1-mile) corner of the Las Vegas Paiute Indian Reservation	Since shipments would use existing highways, none to archaeological or historical resources. Shipments from the northeast would pass through the Moapa Indian Reservation. All shipments would pass through the Las Vegas Paiute Indian Reservation
Noise	Low	Low	Low	Low	Low	Low
Utilities and resources						
Diesel (million liters)[d]	13	4.7	5.5	1.7	1.6	Low
Steel (metric tons)[f]	49	14	21	2.3	2.3	None
Concrete (thousand metric tons)[f]	1.8	0.5	0.8	0.1	0.1	None
Aesthetics	Some potential near Caliente	Some potential near Caliente	Some potential near Caliente	Very low	Very low	None

Table 2-10. Comparison of impacts for Nevada heavy-haul truck implementing alternatives and for legal-weight truck shipments (page 2 of 2).

Impact	Caliente	Caliente-Chalk Mountain	Caliente-Las Vegas	Sloan/Jean	Apex/Dry Lake	Mostly legal-weight truck
Socioeconomics						
New jobs (percent of workforce in affected counties)	1,000 (< 1% to 2.3%)	830 (< 1% to 2.6%)	810 (< 1% to 2%)	720 (< 1%)	540 (< 1%)	Low
Peak real disposable personal income (million dollars)	25	20	20	20	15	Low
Peak incremental Gross Regional Product (million dollars)	42	35	35	34	26	Low
Waste management	Limited quantity	Limited quantity	Limited quantity	Limited quantity	Limited quantity	None
Environmental justice (disproportionately high and adverse impacts)	None	None	None	None	None	None
Incident-free health and safety						
Industrial hazards						
Total recordable incidents	340	330	300	180	180	NA[g]
Lost workday cases	190	180	160	100	100	NA
Fatalities	0.7	0.6	0.6	0.4	0.4	NA
Incident-free health and safety (continued)						
Collective dose (person-rem [LCFs])						
Workers	780 [0.31]	710 [0.29]	740 [0.30]	710 [0.29]	690 [0.28]	1,600 [0.63]
Public	2,100 [1.0]	1,200 [0.62]	1,600 [0.77]	1,000 [0.51]	940 [0.47]	2,800 [1.4]
Fatalities from vehicle emissions	0.0016	0.0012	0.0013	0.012	0.0012	0.005
Traffic accident fatalities						
Construction and operations workforce	5.6	2.9	3.4	2.0	2.0	NA[g]
SNF[h] and HLW[i] shipping	0.73	0.42	0.54	0.33	0.31	0.5
Radiological impacts, accident scenarios						
Maximum exposed individual (rem)	26	26	26	26	26	3.9
Individual latent cancer fatality probability	0.02	0.02	0.02	0.02	0.02	0.002
Collective dose	0.29	0.26	0.72	4.1	0.67	0.5
Latent cancer fatalities	0.0001	0.0001	0.0004	0.002	0.0003	0.0002

a. To convert square kilometers to acres, multiply by 247.1.
b. To convert acre-feet to gallons, multiply by 325,850.1.
c. IMT = intermodal transfer.
d. To convert liters to gallons, multiply by 0.26418.
e. To convert metric tons to tons, multiply by 1.1023.
f. To convert cubic feet to cubic meters, multiply by 0.028317.
g. NA = not applicable.
h. SNF = spent nuclear fuel.
i. HLW = high-level radioactive waste.

2.5.1 INCOMPLETE OR UNAVAILABLE INFORMATION

Some of the analyses in this EIS had to use incomplete information. To ensure an understanding of the status of its information, DOE has identified the use of incomplete information or the unavailability of information in the EIS in accordance with the Council on Environmental Quality regulations pertaining to incomplete and unavailable information (40 CFR 1502.22). Such cases describe the basis for the analyses, including assumptions, the use of preliminary information, or conclusions from draft or incomplete studies. DOE continues to study issues relevant to understanding what could happen in the future at Yucca Mountain and the potential impacts associated with its use as a repository. As a result, the Final EIS will include information that was not available for the Draft EIS. In addition, DOE might not complete some of the studies and design development for the repository until after it has issued the Final EIS. DOE believes, however, that sufficient information is currently available to assess the range of impacts that could result from either the Proposed Action or the No-Action Alternative.

2.5.2 UNCERTAINTY

The results and conclusions of analyses often have some associated uncertainty. The uncertainty could be the result of the assumptions used, the complexity and variability of the process being analyzed, the use of incomplete information, or the unavailability of information. To enable an understanding of the status of its findings, this EIS contains descriptions of the uncertainties, if any, associated with the results and conclusions presented.

2.5.3 OPPOSING VIEWS

In this EIS, opposing views are defined as differing views or opinions currently held by organizations or individuals outside DOE. These views are considered to be opposing if they include or rely on data or methods that DOE is not currently using in its own impact analysis. In addition, these views are reasonably based on scientific, regulatory, or other information supported by credible data or methods that relate to the impacts analyzed in the EIS.

DOE has attempted to identify and address the range of opposing views in this EIS. The Department identified potential opposing views by reviewing published or other information in the public domain. Sources of information included reports from universities, other Federal agencies, the State of Nevada, counties, municipalities, other local governments, and Native American groups. DOE reviewed the potential opposing views to determine if they:

- Address issues analyzed in the EIS
- Differ from the DOE position
- Are based on scientific, regulatory, or other information supported by credible data or methods that relate to the impacts analyzed in the EIS
- Have significant basic differences in the data or methods used in the analysis or to the impacts described in the EIS

DOE has included potential opposing views that met the above criteria in the EIS where it discusses the particular subject. For example, opposing views on the groundwater system are discussed in the sections on groundwater.

2.6 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. The analyses in this EIS did not identify any potential environmental impacts that would be a basis for not proceeding with the Proposed Action. DOE has not chosen any transportation mode, corridor, or route as preferred at this time.

DOE recognizes that implementation of the preferred alternative would require the completion of a number of actions. As part of this process, the Secretary of Energy is to:

- Undertake (and complete) site characterization activities at Yucca Mountain to provide information and data required to evaluate the site.
- Prepare an EIS.
- Decide whether to recommend approval of the development of a geologic repository at Yucca Mountain to the President.

The NWPA also requires DOE to hold hearings to provide the public in the vicinity of Yucca Mountain 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, the Secretary decides to recommend that the President approve the site, the Secretary will 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.

If the Secretary recommends the Yucca Mountain site to the President, a comprehensive statement of the basis for the recommendation, including the Final EIS, will accompany the recommendation. This Draft EIS has been prepared now so that DOE can consider the Final EIS, including the public input on the Draft EIS, in making a decision on whether to recommend the site to the President.

If, after a recommendation by the Secretary, the President considers the site qualified for application to the Nuclear Regulatory Commission for a construction authorization, the President will submit a recommendation of the site to Congress. The Governor or legislature of Nevada may object to 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 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 did submit 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.

In determining whether to recommend the Yucca Mountain site to the President, DOE would consider not only the potential environmental impacts identified in this EIS, but also other factors. Those factors could include those identified through public input, as well as other available information. Examples of such other possible factors include the following:

- Ability to obtain necessary approvals, license and permits
- Ability to fulfill stakeholder agreements
- Consistency with DOE mission
- Assurance of safety
- Facility construction and operation flexibility

- Cost of implementation
- Ability to mitigate adverse impacts

As part of the Proposed Action, the EIS analyzes the impacts of transporting spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site from 77 sites across the United States. As part of this analysis, the EIS includes information, such as the comparative impacts of truck and rail transportation, alternative intermodal (rail to truck) transfer station locations, associated heavy-haul truck routes, and alternative rail transport corridors in Nevada, that might not lead to near-term decisions. It is uncertain at this time when DOE would make these transportation-related decisions. If and when it is appropriate to make such decisions, DOE believes that the EIS provides the information necessary to make these decisions. However, measures to implement those decisions, such as 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 routes, would require additional field surveys, state and local government consultations, environmental and engineering analyses, and National Environmental Policy Act reviews.

3

Affected Environment

3. AFFECTED ENVIRONMENT

To analyze potential environmental impacts that could result from the implementation of the Proposed Action, the U.S. Department of Energy (DOE) has compiled extensive information about the environments that could be affected. The Department used this information to establish the baseline against which it measured potential impacts (see Chapter 4). Chapter 3 describes (1) environmental conditions that will exist at and in the region of the proposed repository site at Yucca Mountain after the conclusion of site characterization activities (Section 3.1); (2) environmental conditions along the proposed transportation corridors in Nevada that DOE could use to ship spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site (Section 3.2); and (3) environmental conditions at the 72 commercial and 5 DOE sites in the United States that manage spent nuclear fuel and high-level radioactive waste (Section 3.3).

DOE obtained baseline environmental information from many sources. These sources included reports and studies sponsored by DOE, other Federal agencies (for example, the U.S. Geological Survey), and the State of Nevada and affected units of local government. (Affected units of local government include county governments near the potential repository site and along potential transportation routes within Nevada.)

DOE received reports from the State of Nevada and affected units of local government during the EIS scoping process, informally from local government personnel, and formally during ongoing interactions between DOE and State and local governments. The subjects of these reports include socioeconomics, cultural resources, hydrology, transportation planning and emergency response, and resource supply. DOE evaluated these reports and, where appropriate, they are discussed in individual resource area sections of the EIS.

3.1 Affected Environment at the Yucca Mountain Repository Site at the Conclusion of Site Characterization Activities

To define the existing environment at and in the region of the proposed repository, DOE has compiled environmental baseline information for 13 subject areas. This environment includes the manmade structures and physical disturbances from DOE-sponsored site selection studies (1977 to 1988) and site characterization studies (1989 to 2001) to determine the suitability of the site for a repository. This chapter and supporting documents, called *environmental baseline files,* contain baseline information for:

- *Land use and ownership:* Land-use practices and land ownership information in the Yucca Mountain region (Section 3.1.1)
- *Air quality and climate:* The quality of the air in the Yucca Mountain region and the area's climatic conditions (temperature, precipitation, etc.) (Section 3.1.2)
- *Geology:* The geologic characteristics of the Yucca Mountain region both at and below the ground surface, the frequency and severity of seismic activity, volcanism, and mineral and energy resources (Section 3.1.3)
- *Hydrology:* Surface-water and groundwater features in the Yucca Mountain region and the quality of the water (Section 3.1.4)

- *Biological resources and soils:* Plants and animals that live in the Yucca Mountain region, the occurrence of special status species and wetlands, and the kinds and quality of soils in the region (Section 3.1.5)

- *Cultural resources:* Historic and archaeological resources in the Yucca Mountain region, the importance those resources hold, and for whom (Section 3.1.6)

- *Socioeconomic environment:* The labor market, population, housing, community services, and transportation services in the Yucca Mountain region (Section 3.1.7)

- *Occupational and public health and safety:* The levels of radiation that occur naturally in the Yucca Mountain air, soil, animals, and water; radiation dose estimates for Yucca Mountain workers from background radiation; radiation exposure, dispersion, and accumulation in air and water for the Nevada Test Site area from past nuclear testing and current operations; and public radiation dose estimates from background radiation (Section 3.1.8)

- *Noise:* Noise sources and levels of noise that commonly occur in the Yucca Mountain region during the day and at night, and the applicability of Nevada standards for noise in the region (Section 3.1.9)

- *Aesthetics:* The visual resources of the Yucca Mountain region in terms of land formations, vegetation, and color, and the occurrence of unique natural views in the region (Section 3.1.10)

- *Utilities, energy, and materials:* The amount of water available for the Yucca Mountain region, water-use practices, water sources, the demand for water at different times of the year, the amounts of power supplied to the region, the means by which power is supplied, and the availability of natural gas and propane (Section 3.1.11)

- *Waste and hazardous materials:* Ongoing solid and hazardous waste and wastewater management practices at Yucca Mountain, the kinds of waste generated by current activities at the site, the means by which DOE disposes of its waste, and DOE recycling practices (Section 3.1.12)

- *Environmental justice:* The locations of low-income and minority populations in the Yucca Mountain region and the income levels among low-income populations (Section 3.1.13)

DOE evaluated the existing environments in regions of influence for each of the 13 subject areas. Table 3-1 defines these regions, which are specific to the subject areas in which DOE could reasonably expect to predict potentially large impacts related to the proposed repository. Human health risks from exposure to airborne contaminant emissions were assessed for an area within approximately 80 kilometers (50 miles), and economic effects, such as job and income growth, were evaluated in a three-county socioeconomic region.

In the past, the vicinity around Yucca Mountain has been the subject of a number of studies in support of mineral and energy resource exploration, nuclear weapons testing, and other DOE activities at the Nevada Test Site. From 1977 to 1988, the Yucca Mountain Project performed studies to assist in the site selection process for a repository. These studies, which involved the development of roads, drill holes, trenches, and seismic stations, along with non-Yucca Mountain activities, disturbed about 2.5 square kilometers (620 acres) of land in the vicinity of Yucca Mountain (DOE 1998h, page 1). Yucca Mountain site characterization activities began in 1989 and will continue until 2001. These activities include surface excavations, excavations of exploration shafts, subsurface excavations and borings, and testing to evaluate the suitability of Yucca Mountain as the site for a repository. By 2001, these activities

Table 3-1. Regions of influence for the proposed Yucca Mountain Repository.

Subject area	Region of influence
Land use and ownership	Land around site of proposed repository that DOE would disturb and over which DOE would need to obtain control; analyzed land withdrawal area is 600 square kilometers[a] (Section 3.1.1).
Air and climate	An approximate 80-kilometer[b] radius around Yucca Mountain, and at boundaries of controlled lands surrounding Yucca Mountain (Section 3.1.2).
Geology	The regional geologic setting and the specific geology of Yucca Mountain (Section 3.1.3).
Hydrology	*Surface water:* construction areas that would be susceptible to erosion, areas affected by permanent changes in flow, and areas downstream of the repository that would be affected by eroded soil or potential spills of contaminants. *Groundwater:* aquifers that would underlie areas of construction and operation, aquifers that could be sources of water for construction, and aquifers downstream of the repository that repository use or long-term releases from the repository could affect (Section 3.1.4).
Biological resources and soils	Area that contains all potential surface disturbances resulting from the Proposed Action (described in Chapter 2) plus some additional area to evaluate local animal populations; roughly equivalent to the analyzed land withdrawal area of about 600 square kilometers (Section 3.1.5).
Cultural resources	Land areas that repository activities would disturb (described in Chapter 2) and areas in the analyzed land withdrawal area where impacts could occur (Section 3.1.6).
Socioeconomic environment	Three Nevada counties (Clark, Lincoln, and Nye) in which repository activities could influence local economies and populations (Section 3.1.7).
Occupational and public health and safety	An approximate 80-kilometer radius around Yucca Mountain and at the approximate boundary of analyzed land withdrawal area (Section 3.1.8).
Noise	Existing residences in the Yucca Mountain region and at the approximate edge of the analyzed land withdrawal area (Section 3.1.9).
Aesthetics	Approximate boundary of analyzed land withdrawal area (Section 3.1.10).
Utilities, energy, and materials	Public and private resources on which DOE would draw to support the Proposed Action (for example, private utilities, cement suppliers) (Section 3.1.11).
Waste and hazardous materials	On- and offsite areas, including landfills and hazardous and radioactive waste processing and disposal sites, in which DOE would dispose of site-generated repository waste (Section 3.1.12).
Environmental justice	Varies with the different subject areas. The environmental justice regions of influence will correspond to those of the specific subject areas, as defined in this table (Section 3.1.13).

a. 600 square kilometers = about 150,000 acres or 230 square miles.
b. 80 kilometers = about 50 miles.

will have disturbed about an additional 1.5 square kilometers (370 acres) in the vicinity of Yucca Mountain (TRW 1999a, Table 6-2). Reclamation activities have started and will continue to occur as sites are released from further study.

The existing environment at Yucca Mountain includes the Exploratory Studies Facility, which includes the tunnel (drift), the North and South Portal pads and supporting structures, an excavated rock storage area, a topsoil storage area, borrow pits, boreholes, trenches, roads, and supporting facilities and disturbances for site characterization activities. Table 3-2 lists existing facilities, structures, equipment, and disturbances at Yucca Mountain and at the central support site in Area 25 of the Nevada Test Site. Area 25 was used in the early 1960s by the Atomic Energy Commission (a DOE predecessor agency) and the National Aeronautics and Space Administration as part of a program to develop nuclear reactors for use in the Nation's space program. The former Nuclear Rocket Development Station administrative areas complex in Area 25 has become the Yucca Mountain Site Characterization Central Support Site.

Table 3-2. Existing facilities, structures, and disturbances at Yucca Mountain.[a]

Yucca Mountain	Area 25 Central Support Site
Exploratory Studies Facility (North Portal pad and supporting structures)	Field Operations Center
	Hydrologic research facility
Exploratory Studies Facility (South Portal pad)	Sample management facility and warehouse
Cross drift[b]	Radiological studies facility
Concrete batch plant and precast yard	Meteorology/air quality studies facility
Fill borrow pits (3) and screening plants	Project accumulation area for hazardous waste
Subdock equipment storage facility	Gas station
Equipment/supplies laydown yard	Maintenance facility
Hydrocarbon management facility	U.S. Geological Survey technical warehouse
Boxcar equipment and supplies yard	Tunnel rescue facility
Water wells J-12 and J-13	Sewage lagoon operated by the Nevada Test Site
Excavated rock storage pile	
Topsoil storage pile	
Explosives storage magazines (2)	
Water booster pump and distribution system	
Boreholes (about 300)	
Trenches and test pits (about 200)	
Busted Butte geologic test drift	
Fran Ridge heated-block test facility	
Water infiltration test sites	
Meteorological monitoring towers	
Air quality monitoring sites	
Radiological monitoring sites	
Ecological study plots	
Reclamation study plots	
Septic system	
Roads	

a. Source: Modified from DOE (1998i, all).
b. Drift is a mining term for a horizontal tunnel.

3.1.1 LAND USE AND OWNERSHIP

The region of influence for land use and ownership includes the lands that surround the site of the proposed repository over which DOE would have to obtain permanent control to operate the repository. The Department has compiled land-use and ownership information for this region. Most of the land in the region is managed by agencies of the Federal Government. Sections 3.1.1.1 and 3.1.1.2 discuss land use and ownership for the region of influence and for a larger area around Yucca Mountain. Section 3.1.1.3

describes the analyzed land withdrawal area for the repository. Section 3.1.1.4 discusses Native American views about the ownership of the land around Yucca Mountain. TRW (1999f, all) is the basis of the information in this section unless otherwise noted.

3.1.1.1 Regional Land Use and Ownership

The Federal Government manages more than 85 percent of the land in Nevada (about 240,000 square kilometers or 93,000 square miles). Most of this land is under the control of the Bureau of Land Management (which is part of the U.S. Department of the Interior), the U.S. Department of Defense, and DOE. The remainder of the Federally managed land is primarily under the jurisdiction of the Forest Service, which is part of the U.S. Department of Agriculture, with smaller areas under the control of the National Park Service and the Bureau of Reclamation, both of which are parts of the Department of the Interior. About 42,000 square kilometers (16,000 square miles) are under State, local, or private ownership, and about 5,000 square kilometers (2,000 square miles) are Native American lands. Table 3-3 summarizes Nevada land holdings and the controlling authority. Figure 3-1 shows ownership and use of lands around the site of the proposed repository.

Table 3-3. Nevada land areas and controlling authorities (square kilometers).[a,b]

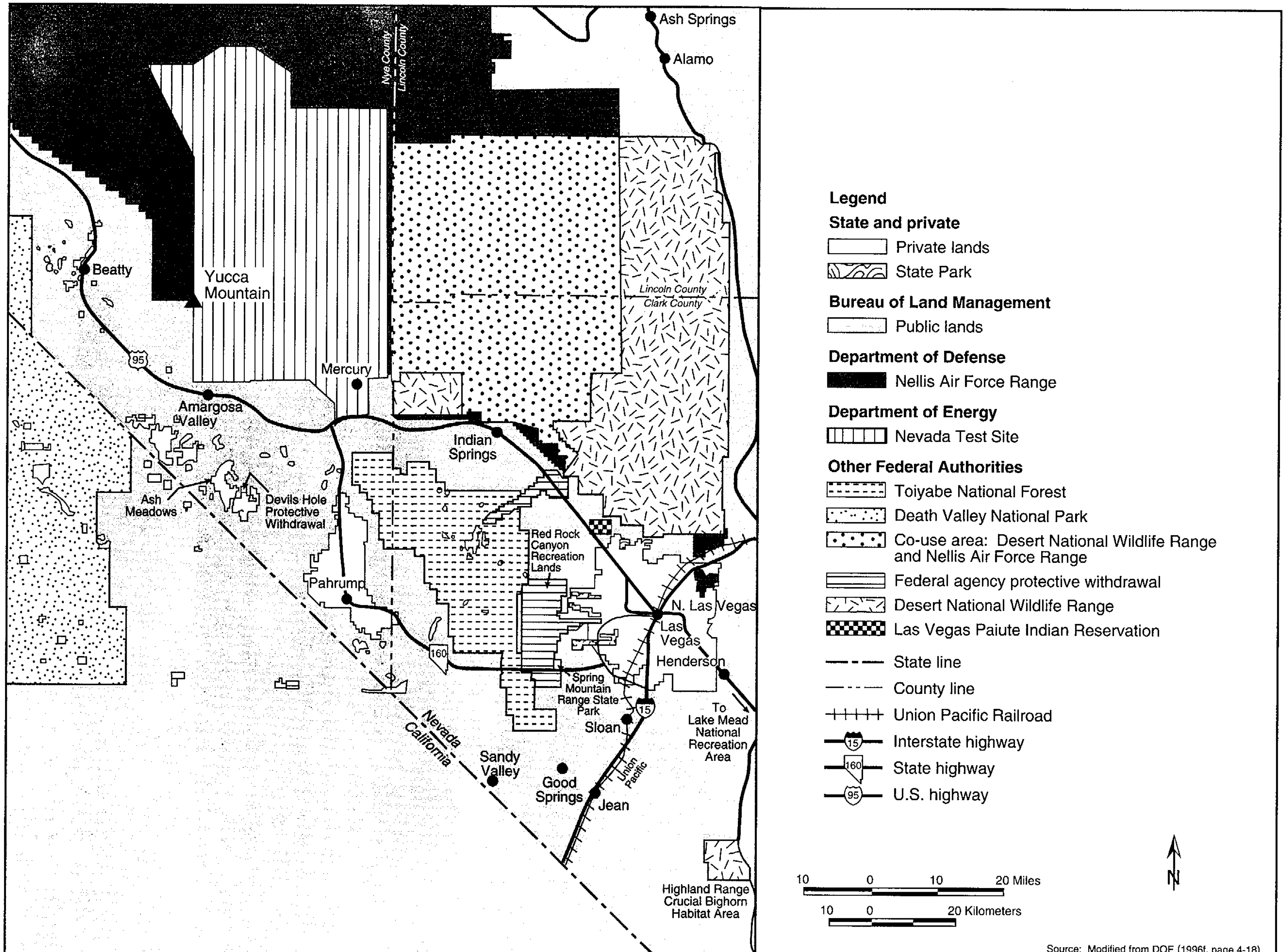
Authority	Area
State, local, county, or private	42,000
Bureau of Land Management	190,000
Department of Defense	13,000
Department of Energy	3,500
Other Federal authorities	31,000
Native American tribes	5,000

a. Source: TRW (1999f, page 1).
b. To convert square kilometers to square miles, multiply by 0.3861.

The Nevada Test Site, which is a DOE facility, covers about 3,500 square kilometers (1,400 square miles). The Atomic Energy Commission, a DOE predecessor agency, established the Nevada Test Site in the 1950s to test nuclear devices. More information on current and future uses of the Nevada Test Site is available in the *Final Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada* (DOE 1996f, all). The U.S. Air Force operates the Nellis Air Force Range, which covers about 13,000 square kilometers (5,000 square miles) and is one of the largest and most active military training ranges in the United States. More information on current and future uses of the Nellis Air Force Range is available in the *Renewal of the Nellis Air Force Range Land Withdrawal Legislative Environmental Impact Statement* (USAF 1999, all).

The region has special-use areas, which generally are excluded from development that would require terrain alterations unless such 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 Refuge and the Ash Meadows National Wildlife Range, which are about 50 kilometers (30 miles) east and 39 kilometers (24 miles) south of Yucca Mountain, respectively (Figure 3-1). 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 is in California approximately 35 kilometers (22 miles) southwest of Yucca Mountain. The small enclave of Devils Hole Protective Withdrawal in Nevada south of Ash Meadows is also administered by the National Park Service (Figure 3-1).

There is virtually no State-owned land immediately adjacent to the repository site. There are scattered tracts of private land in and near the Towns of Beatty, Amargosa Valley, and Indian Springs in Nevada. There are also larger private tracts in the agricultural areas of the Las Vegas Valley, near Pahrump, and in the Amargosa Desert south of the Town of Amargosa Valley. The closest year-round housing is at Lathrop Wells in the Amargosa Valley, about 22 kilometers (14 miles) south of the site. There is



Fig[illegible]**·1.** Land use and ownership in the Yucca Mountain region.

farming—primarily grasses and legumes—for hay and dairy operations about 30 kilometers (19 miles) south of the proposed repository in the Town of Amargosa Valley (Figure 3-1).

3.1.1.2 Current Land Use and Ownership at Yucca Mountain

DOE has established land-use agreements to support its site characterization activities at Yucca Mountain. The Yucca Mountain Site Characterization Zone (Figure 3-2) includes DOE, Bureau of Land Management, and Air Force lands.

The Bureau of Land Management granted DOE a right-of-way reservation (N-47748) for Yucca Mountain site characterization activities (BLM 1988, all). This reservation comprises 210 square kilometers (81 square miles). The land in this reservation is open to public use, with the exception of about 20 square kilometers (8 square miles) near the site of the proposed repository that were withdrawn in 1990 from the mining and mineral leasing laws to protect the physical integrity of the repository rock (P.L. Order 6802, "Withdrawal of Public Land to Maintain the Physical Integrity of the Repository Rock"). The lands in this reservation not withdrawn from the mining and mineral leasing laws contain a number of unpatented mining claims (lode and placer). In addition, there is one patented mining claim in the reservation. Patented Mining Claim No. 27-83-0002 covers 0.8 square kilometer (0.3 square mile) to mine volcanic cinders used as a raw material in the manufacture of cinderblocks.

The Bureau of Land Management manages surface resources on the Nellis Air Force Range. In 1994, the Bureau granted DOE a right-of-way reservation (N-48602) to use about 75 square kilometers (29 square miles) of Nellis land for Yucca Mountain site characterization activities (BLM 1994a, all). This land, which is closed to public access and use, has been studied extensively. Many of the exploratory facilities are on Nellis land.

The Yucca Mountain Site Characterization Office and the DOE Nevada Operations Office have a management agreement that allows the use of about 230 square kilometers (90 square miles) of Nevada Test Site land for site characterization activities.

3.1.1.3 Potential Repository Land Withdrawal

Nuclear Regulatory Commission licensing conditions for a monitored geologic repository (10 CFR Part 60) include a requirement that DOE have either ownership or permanent control of the lands for which it is seeking a repository license. As noted, portions of the lands being used for site characterization that would be required for the repository are controlled by the Bureau of Land Management, the Air Force, and the DOE Nevada Operations Office. Because all of these lands are not under permanent DOE control, a land withdrawal would be required.

The procedure for land withdrawal is the method by which the Federal Government places exclusive control over land it owns with a particular agency for a particular purpose. Only Congress has the power to withdraw Federal lands permanently for the exclusive purposes of specific agencies. Congress can authorize and direct a permanent withdrawal of lands such as those required for the proposed repository at Yucca Mountain. The extent and conditions of the withdrawal would be determined by Congress. The extent of a land withdrawal area is important to the analysis and understanding of the impacts of the Proposed Action. For example, the magnitude of impacts to a member of the public from an accident at an operating repository would be determined in part by the proximity of the land withdrawal boundary to the repository operations areas. As a consequence, DOE used a land withdrawal area as the basis for analysis in this EIS.

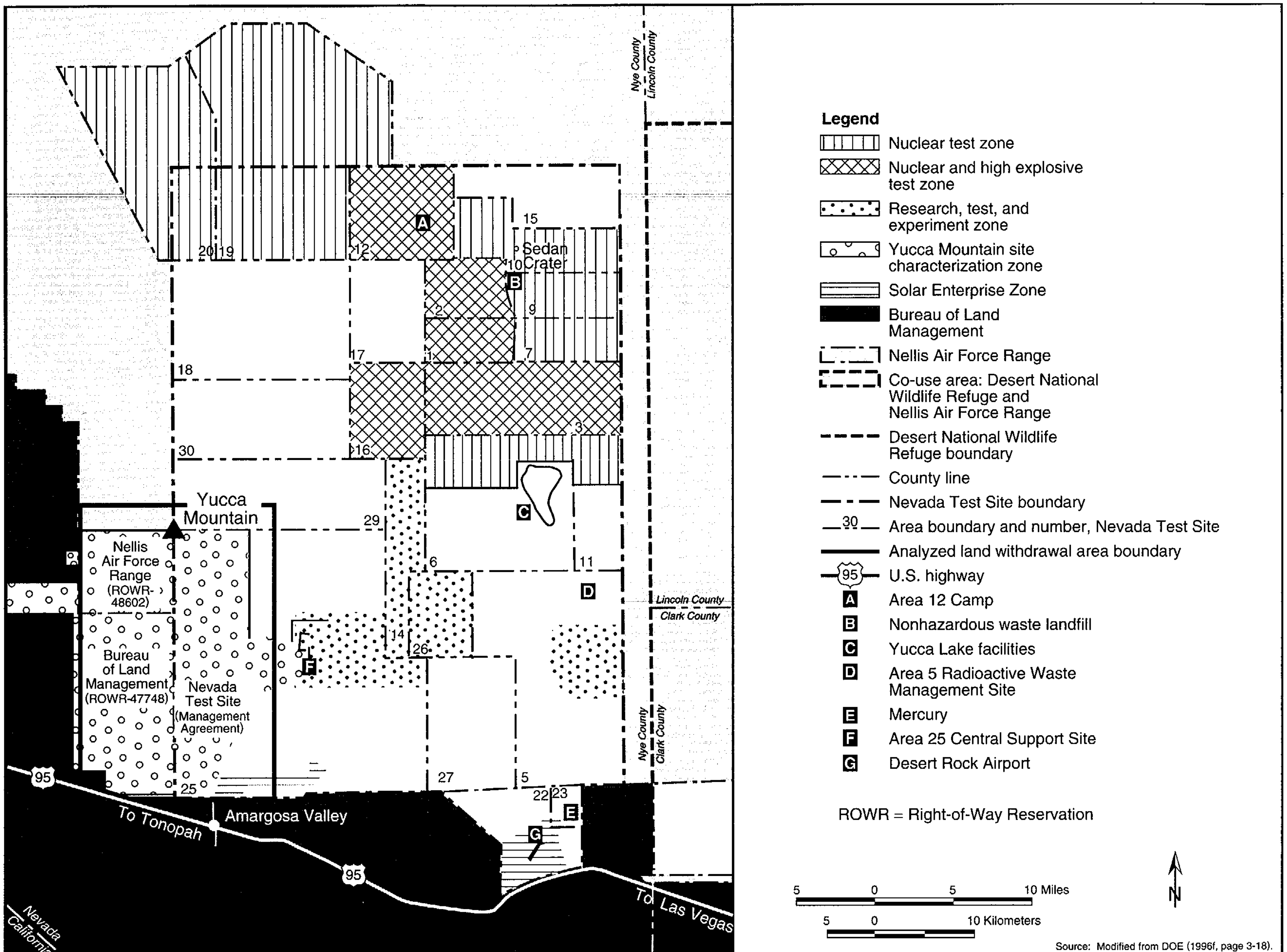


Figure 3-2. Land use and ownership in the analyzed land withdrawal area and vicinity.

Figure 3-2 shows the land withdrawal area analyzed in this EIS that encompasses the current right-of-way reservations for site characterization. This area includes about 600 square kilometers (150,000 acres) of land. The land in this area is currently under the control of the Air Force, DOE, and the Bureau of Land Management (Table 3-4).

Table 3-4. Current land ownership and public accessibility to the analyzed land withdrawal area.[a,b]

Agency	Area (square kilometers)[c]	Current accessibility
DOE (Nevada Test Site)	300	No public access
U.S. Air Force (Nellis Air Force Range)	97	No public access
Bureau of Land Management (public land)	200	Public access
Private land (one patented mining claim)	1	No public access

a. Source: DOE (1998j, all).
b. A description of the area by township, range, and section is available from DOE, Las Vegas, Nevada.
c. To convert square kilometers to square miles, multiply by 0.3861.

Most of the land controlled by the Bureau of Land Management in the analyzed land withdrawal area is associated with the current right-of-way reservation (N-47748) for Yucca Mountain site characterization activities. This land is open to public use, with the exception of about 20 square kilometers (8 square miles) near the site of the proposed repository that are withdrawn from the mining and mineral leasing laws except for an existing patented mining claim. That claim (No. 27-83-0002) covers 0.8 square kilometer (0.3 square mile) to mine volcanic cinders (a raw material used in the manufacture of cinderblocks). The lands open to public use also contain a number of unpatented mining claims (lode and placer). Off-road vehicle use is permitted in these lands. There is a designated utility corridor in the southern portion of these lands.

More detailed descriptions of the land under the control of the Bureau of Land Management in the region of Yucca Mountain are available in the *Proposed Las Vegas Resource Management Plan and Final Environmental Impact Statement* (BLM 1998, all).

3.1.1.4 Native American Treaty Issue

One Native American ethnic group with cultural and historic ties to the Yucca Mountain region is the Western Shoshone. A special concern of the Western Shoshone people is the Ruby Valley Treaty of 1863. The Western Shoshone people maintain that the treaty gives them rights to 97,000 square kilometers (24 million acres) in Nevada, including the Yucca Mountain region (Western Shoshone v. United States 1997, all). The legal battle over the land began in 1946 when the Indian Claims Commission Act gave tribes the right to sue the Federal Government for unkept treaty promises. If a tribe were to win a claim against the Government, the Act specifies that the tribe could receive only a monetary award and not land or other remunerations.

The Western Shoshone people filed a claim in the early 1950s alleging that the Government had taken their land. The Indian Claims Commission found that Western Shoshone title to the Nevada lands had gradually extinguished and set a monetary award as payment for the land. In 1977, the Commission granted a final award to the Western Shoshone people, who dispute the Commission findings and have not accepted the monetary award for the lands in question. They maintain that no payment has been made (the U.S. Treasury is holding these monies in an interest-bearing account) and that Yucca Mountain is on Western Shoshone land. A 1985 U.S. Supreme Court decision (United States v. Dann 1985, all) ruled that even though the money has not been distributed, the United States has met its obligations with the Commission's final award and, as a consequence, the aboriginal title of the land had been extinguished.

3.1.2 AIR QUALITY AND CLIMATE

The region of influence for air quality is an area within a radius of about 80 kilometers (50 miles) around the site of the proposed repository and at the boundaries of controlled lands around Yucca Mountain. This region encompasses portions of Clark and Nye Counties in Nevada and a portion of Inyo County, California. To determine the air quality and climate for the Yucca Mountain region, DOE site characterization activities have included the monitoring of air quality and meteorological conditions. The Department has monitored the air for gaseous criteria pollutants (carbon monoxide, nitrogen dioxide, ozone, and sulfur dioxide) and for particulate matter. This section describes the existing air quality and climate at the proposed repository site and in the surrounding region. Sections 3.1.2.1 and 3.1.2.2 describe the air quality and climate, respectively. Unless otherwise noted, the *Environmental Baseline File for Meteorology and Air Quality* (TRW 1999g, all) is the basis for the information provided in this section.

3.1.2.1 Air Quality

Air quality is determined by measuring concentrations of certain pollutants in the atmosphere. The U.S. Environmental Protection Agency designates an area as being *in attainment* for a particular pollutant if ambient concentrations of that pollutant are below National Ambient Air Quality Standards (Table 3-5).

Table 3-5. National and Nevada ambient air quality standards.[a]

	Primary and Secondary NAAQS,[b] except as noted		Highest measured Yucca Mountain concentration[c]	Nevada standards[d]
Pollutant	Period	Concentration		
Sulfur dioxide	Annual[e]	0.03 part per million	0.002	Same
	24-hour[f]	0.14 part per million	0.002	
Sulfur dioxide (secondary)	3-hour[f]	0.5 part per million	0.002	
PM_{10}[g]	Annual[h]	50 micrograms per cubic meter	12	Same
	24-hour[i]	150 micrograms per cubic meter	67	
$PM_{2.5}$[j]	Annual[h]	15 micrograms per cubic meter	N/A[k]	None
	24-hour[l]	65 micrograms per cubic meter	N/A	
Carbon monoxide	8-hour[f]	9 parts per million	0.2	Same[m]
	1-hour[f]	35 parts per million	0.2	Same
Nitrogen dioxide	Annual[e]	0.053 part per million	0.002	Same
Ozone	1-hour[n]	0.12 part per million	0.1	Same
	8-hour[o]	0.08 part per million	N/A	None

a. Sources: 40 CFR 50.4 through 50.11; Nevada Administrative Code 445B.391.
b. NAAQS = National Ambient Air Quality Standard.
c. Units correspond to the units listed in the concentration column.
d. Nevada Administrative Code 445B.391.
e. Average not to be exceeded in the period shown.
f. Average not to be exceeded more than once in a calendar year.
g. PM_{10} = particulate matter with a diameter less than 10 micrometers (0.0004 inch). If and until the revised State Implementation Plan is approved 40 CFR 50.6 applies; then 40 CFR 50.7 would apply.
h. Expected annual arithmetic mean should be less than value shown.
i. Number of days per calendar year exceeding this value should be less than 1. Under 40 CFR 50.7, 99th-percentile value should be less than value shown.
j. $PM_{2.5}$ = particulate matter with a diameter less than 2.5 micrometers (0.0001 inch). Standard has not been implemented.
k. N/A = not available; no monitoring data has been collected since the new standard was implemented.
l. 98th-percentile value should be less than value shown.
m. The Nevada ambient air quality standard for carbon monoxide is 9 parts per million at less than 1,500 meters (4,900 feet) above mean sea level and 6 parts per million at or above 1,500 meters; Nevada Administrative Code 445B.31.
n. This standard was replaced in 1998 by 40 CFR 50.10 for all air quality regions of interest.
o. Standard implemented in 1998. Three-year average of the fourth-highest monitored daily maximum 8-hour average concentration.

(Ambient air is that part of the atmosphere outside buildings to which the general public has access.) The Environmental Protection Agency established the national standards, as directed by the Clean Air Act, to define levels of air quality that are necessary, with an adequate margin of safety, to protect the public health (primary standards) and the public welfare (secondary standards). The standards specify the maximum pollutant concentrations and frequencies of occurrence for specific averaging periods.

Areas in violation of one or more of these standards are called *nonattainment areas*. If there are not enough air quality data to determine the status of attainment of a remote or sparsely populated area, the area is listed as *unclassified*. For regulatory purposes, unclassified areas are considered to be in attainment.

The quality of the air at the site of the proposed repository and the surrounding parts of the Nevada Test Site, Nellis Air Force Range, and southern Nye County is unclassified because there are limited air quality data (40 CFR 81.329). Data collected at the site indicate the air quality is within applicable standards. Portions of Clark County in the air quality region of influence are in attainment with the National Ambient Air Quality Standards. Inyo County, California, is in attainment with national and California ambient air quality standards for carbon monoxide, nitrogen dioxide, and sulfur dioxide. It is in attainment with the national PM_{10} standard, but in nonattainment with the more restrictive California standard (CEPA 1998, pages H6 to H35).

Air quality in attainment areas is controlled under the Prevention of Significant Deterioration program of the Clean Air Act, with the goal of preventing significant deterioration of existing air quality. Under the Prevention of Significant Deterioration provisions, Congress established a land classification scheme for areas of the country with air quality better than the National Ambient Air Quality Standards. Class I allows very little deterioration of air quality; Class II allows moderate deterioration; and Class III allows more deterioration; but in all cases the pollution concentrations shall not violate any of the National Ambient Air Quality Standards. Congress designated certain areas as mandatory Class I, which precludes redesignation to a less restrictive class, to acknowledge the value of maintaining these areas in relatively pristine condition. Congress also protected other nationally important lands by originally designating them as Class II and restricting redesignation to Class I only.

All other areas were initially classified as Class II, and can be redesignated as either Class I or Class III. In the region of influence, all areas are designated as Class II. There are no Class I areas, although one area, the Death Valley National Park, is a national monument and a protected Class II area that could be redesignated as Class I (EPA 1999a, all; EPA 1999b, all). It is about 35 kilometers (22 miles) southwest of Yucca Mountain.

The construction and operation of a facility in an attainment area could be subject to the requirements of the Prevention of Significant Deterioration program if the facility received a classification as a major source of air pollutants. At present, the proposed repository site and the Nevada Test Site have no sources subject to those requirements (DOE 1996f, page 4-146).

As part of Yucca Mountain site characterization, DOE obtained an air quality operating permit from the State of Nevada (NDCNR 1996, all). The permit places specific operating conditions on various systems that DOE uses during site characterization activities. These conditions include limiting the emission of criteria pollutants, defining the number of hours a day and a year a system is allowed to operate, and determining the testing, monitoring, and recordkeeping required for the system.

In 1989, DOE began monitoring particulate matter at the site of the proposed repository as part of site characterization activities and later as part of the Nevada Air Quality operating permit requirements. Concentration levels of inhalable particles smaller than 10 micrometers in diameter have been well below applicable National Ambient Air Quality Standards, with annual average concentrations 20 to 25 percent of the standard (see Table 3-5).

In 1997, the Environmental Protection Agency issued National Ambient Air Quality Standards for ozone and particulate matter. The new standard for particulate matter (40 CFR 50.7) includes fine particles in the respirable range with diameters smaller than 2.5 micrometers (see Table 3-5). The implementation of this new standard applies to all areas, but initial monitoring will focus on urban areas because (1) this pollutant comes primarily from combustion (auto exhaust, etc.) rather than fugitive dust sources (windblown dust, etc.) and (2) the first priority for monitoring programs is the assessment of densely populated areas.

From October 1991 through September 1995, DOE monitored the site of the proposed repository for gaseous criteria pollutants (carbon monoxide, nitrogen dioxide, ozone, and sulfur dioxide) as part of site characterization. The concentration levels of each pollutant were well below the applicable National Ambient Air Quality Standards (see Table 3-5). In fact, concentrations of carbon monoxide and sulfur dioxide were not detectable during the entire monitoring period. Nitrogen dioxide was detected occasionally at concentrations of a few parts per billion (around 0.002 part per million) by volume, probably from nearby vehicle exhausts, about 4 percent of the applicable annual average standard (see Table 3-5). Ozone was the only criteria pollutant routinely detected, although these concentrations were barely detectable (0.081 to 0.096 part per million) and ranged from 67 to 80 percent of the 1-hour regulatory standard. The source of the ozone has not been determined, but could be urban areas in southern California. In 1998, the Environmental Protection Agency revoked the 1-hour ozone standard for all counties in the United States with no current measured violations, including all of Nevada and the region around Yucca Mountain, and replaced it with a new 8-hour ozone standard. Nonattainment areas for the new ozone standard will be designated in 2000.

3.1.2.2 Climate

The Yucca Mountain region has a relatively arid climate, with annual precipitation totals ranging between approximately 10 and 25 centimeters (4 and 10 inches) per year (DOE 1998a, Volume 1, page 2-29). Precipitation at a given location depends on nearby topographic features. The winter season is mild, with some periods of below freezing temperatures. Occasional periods of persistent rain have produced more than 5 centimeters (2 inches) of rainfall in daily periods. The summer season is typically hot and dry, with occasional periods of monsoon thunderstorms producing locally large amounts of rain. Storms can produce more than 2.5 centimeters (1 inch) of rain in a matter of hours.

Mean nighttime and daytime air temperatures typically range from 22°C to 34°C (72°F to 93°F) in the summer and from 2°C to 10.5°C (34°F to 51°F) in the winter (TRW 1997a, pages A-1 to A-16). Temperature extremes range from -15°C to 45°C (5°F to 113°F). On average, the daily range in temperature change is about 10°C (18°F). Higher elevations are cooler, though the coldest areas can be in canyons and washes to which heavy cold air flows at night. Relative humidity levels range from about 10 percent on summer afternoons to about 50 percent on winter mornings and to near 100 percent during precipitation events.

In the valleys, airflow is channeled by local topography, particularly at night during stable conditions (TRW 1997a, pages 4-13 to 4-16). With the exception of the nearby confining terrain, which includes washes and small canyons on the east side of Yucca Mountain, local wind patterns have a strong daily cycle of daytime winds from the south and nighttime winds from the north. Confined areas also have daily cycles, but the wind directions are along terrain axes, typically upslope in the daytime and downslope at night. Wind direction can also vary with height. As shown in Figure 3-3, the winds at a height of 60 meters (200 feet) show a strong north-south flow up and down the valley. The winds at

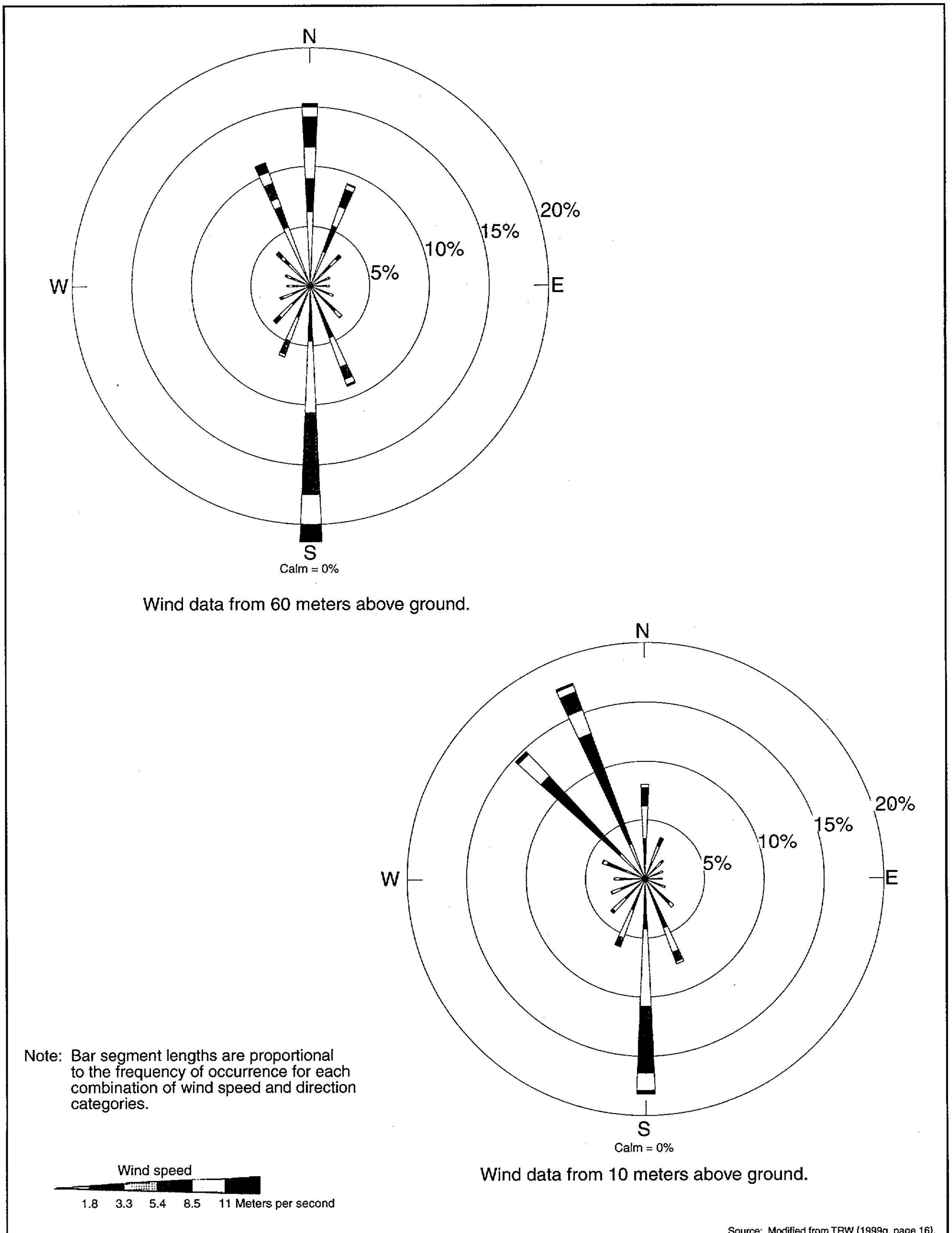


Figure 3-3. Wind rose plots for 10 and 60 meters (33 and 200 feet) above ground in the proposed repository facilities vicinity.

10 meters (33 feet) show a strong southerly flow, but at night the wind pattern reflects more of the drainage flow downslope from Yucca Mountain. Hourly average wind speeds are usually greater than 1.8 meters a second (4 miles an hour), indicating few calm periods. Over the entire monitoring network, the average wind speed ranges from 2.5 to 4.4 meters a second (5.6 to 9.8 miles an hour); the fastest 1-minute wind speeds range from 19 to 33 meters a second (42 to 74 miles an hour); and the peak gusts range from 26 to 38 meters a second (59 to 86 miles an hour). The highest wind speeds typically occur on exposed ridges.

Severe weather can occur in the region, usually in the form of summer thunderstorms. These storms can generate an abundant amount of lightning, strong winds, and heavy and rapid precipitation. Tornadoes can occur, though they are not a substantial threat in the region; four have been recorded within 240 kilometers (150 miles) of the site of the proposed repository during the past 53 years, and one occurred in 1987 in Amargosa Valley about 50 kilometers (30 miles) south of the site (TRW 1997a, page 4-26).

3.1.3 GEOLOGY

DOE has studied the existing physiographic setting (characteristic landforms), stratigraphy (rock strata), and geologic structure (structural features resulting from rock deformations) at Yucca Mountain and in the surrounding region. These studies have yielded detailed information about the surface and subsurface features in the region. This section describes the baseline conditions of the region's geology. DOE investigated seismicity (earthquake activity) in the Yucca Mountain region; the investigations focused on understanding the Quaternary history of movement on faults in the region and the historic record of earthquake activity. The Department also investigated volcanoes in the Yucca Mountain region to assess the potential for volcanism to result in adverse effects to a repository. In addition, DOE considered the possibility that there might be minerals and energy resources at or near the site of the proposed repository. Unless otherwise referenced, the information in this section is from the *Geology/Hydrology Environmental Baseline File* (TRW 1999h, all), the *Yucca Mountain Site Description* (TRW 1998a, all), or the *Viability Assessment of a Repository at Yucca Mountain* (DOE 1998a, all).

3.1.3.1 Physiography (Characteristic Landforms)

Yucca Mountain is in the southern part of the Great Basin subprovince of the Basin and Range Physiographic Province (Figure 3-4), a region characterized by generally north-trending, linear mountain ranges separated by intervening valleys (basins). The Great Basin encompasses nearly all of Nevada plus parts of Utah, Idaho, Oregon, and California. Mountain ranges of the Great Basin, including Yucca Mountain, are mostly tilted, fault-bounded crustal blocks that are as much as 80 kilometers (50 miles) long and 8 to 24 kilometers (5 to 15 miles) wide. Ranges typically rise from 300 to 1,500 meters (1,000 to 4,900 feet) above the adjacent valley floors and occupy 40 to 50 percent of the total land area.

Valleys between the mountain ranges are filled with alluvial sediments (deposits of sand, mud, and other such materials formed by flowing water) from the adjacent ranges. Most valleys are called *closed basins* because they lack a drainage outlet. Water and sediment from adjacent ranges become trapped and move to the lowest part of such valleys to form a *playa*, a flat area that is largely vegetation-free owing to high salinity, which results from evaporation of the water. Valleys with drainage outlets have intermittent stream channels that carry eroded sediment to lower drainage areas.

The present landscape, distinguished by the broad series of elongated mountain ranges alternating with parallel valleys, is the result of past episodes of faulting that elevated the ranges above the adjacent valleys. Section 3.1.3.2 addresses such faulting. Yucca Mountain is an irregularly shaped volcanic upland, 6 to 10 kilometers (4 to 6 miles) wide and 40 kilometers (25 miles) long. This mountain is part of

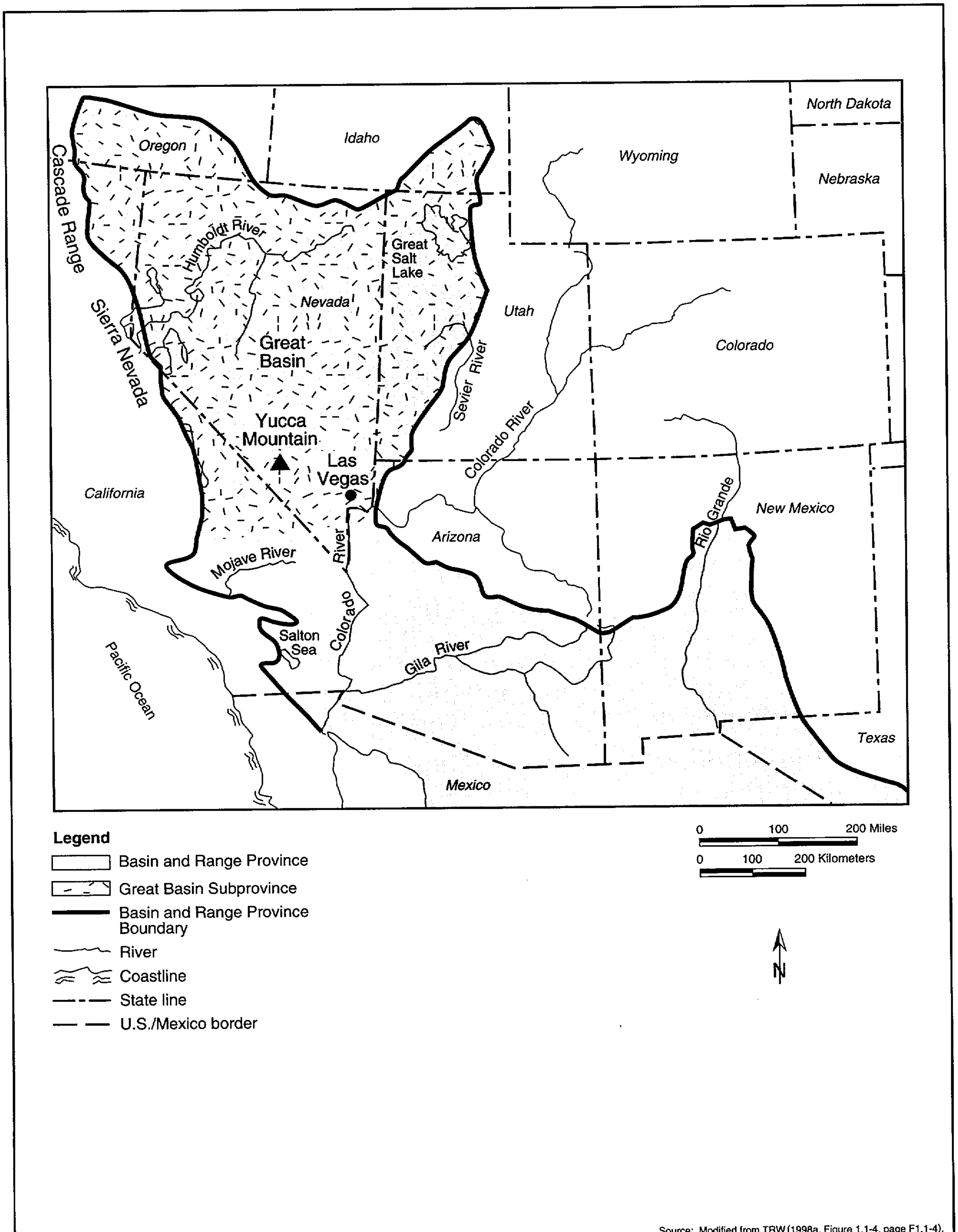


Figure 3-4. Basin and Range Physiographic Province and Great Basin Subprovince.

a volcanic plateau formed between about 14 million and 11.5 million years ago (Sawyer et al. 1994, page 1304) known as the Southwestern Nevada volcanic field. Although Yucca Mountain is a product of both volcanic activity and faulting, the region exhibits evidence of a complex history of deformation associated with past interactions of crustal segments (plates) (TRW 1998a, page 3.2-1). Geologic relations indicate that many of the current features and the landscape in the Yucca Mountain region formed between 12.7 million and 11.7 million years ago (TRW 1998a, page 3.4-2). Remnants of the Timber Mountain caldera (one of the centers of the southwestern Nevada volcanic field from which most of the volcanic rocks on the surface of Yucca Mountain were erupted) and other calderas are north of Yucca Mountain (see Figure 3-5).

CALDERA

A volcanic crater that has a diameter many times that of the vent. It is formed by collapse of the central part of a volcano or by explosions of extraordinary violence. The erupted materials are commonly spread over great distances beyond the caldera. Volcanic debris that erupted from the Timber Mountain and other calderas north of Yucca Mountain formed the southwestern Nevada volcanic field of which the volcanic rocks at Yucca Mountain are a part.

Almost without exception, west-facing slopes at Yucca Mountain are steep and east-facing slopes are gentle, which expresses the underlying geologic structure (see Section 3.1.3.2). Small valleys eroded in the mountain are narrow, V-shaped drainages that flatten and broaden near the mountain base. The crest of Yucca Mountain is between 1,400 meters (4,600 feet) and 1,500 meters (4,900 feet) above sea level. The bottoms of the adjacent valleys are approximately 600 meters (2,000 feet) lower.

Yucca Mountain is bordered on the north by Pinnacles Ridge and Beatty Wash, on the west by Crater Flat, on the south by the Amargosa Valley, and on the east by the Calico Hills and by Jackass Flats, which contains Fortymile Wash (Figure 3-6). Beatty Wash is one of the largest tributaries of the Amargosa River (see Section 3.1.4.1) and drains the region north and west of Pinnacles Ridge, including the northern end of Yucca Mountain.

Crater Flat (Figure 3-6) is an oval-shaped valley between Yucca Mountain and Bare Mountain. It contains four prominent volcanic cinder cones and related lava flows that rise above the valley floor. Crater Flat drains to the Amargosa River through a gap in the southern end of the basin.

Jackass Flats is an oval-shaped valley east of Yucca Mountain bordered by Yucca, Shoshone, Skull, and Little Skull Mountains (Figure 3-6). It drains southward to the Amargosa River. Fortymile Wash is the most prominent drainage through Jackass Flats to the Amargosa River.

Site Stratigraphy and Lithology

The exposed stratigraphic section at Yucca Mountain is dominated by mid-Tertiary volcanic ash-flow and ash-fall deposits with minor lava flows and reworked materials. These deposits originated in the calderas shown in Figure 3-5. Regionally, the thick series of volcanic rocks that form Yucca Mountain overlies Paleozoic sedimentary rocks that are largely of marine origin. The volcanic rocks, in turn, are covered in many areas by a variety of late Tertiary and Quaternary surficial deposits. The stratigraphic section is summarized in Table 3-6, which depicts rock assemblages according to the geologic age during which they were deposited. The stratigraphic sequence of the Yucca Mountain area consists, from oldest to youngest, of Pre-Cenozoic sedimentary and metasedimentary (sedimentary rocks that have been altered by metamorphism), mid-Tertiary siliceous (rich in silica) volcanic rocks, Tertiary to Quaternary basalts, and late Tertiary to late Quaternary surficial deposits.

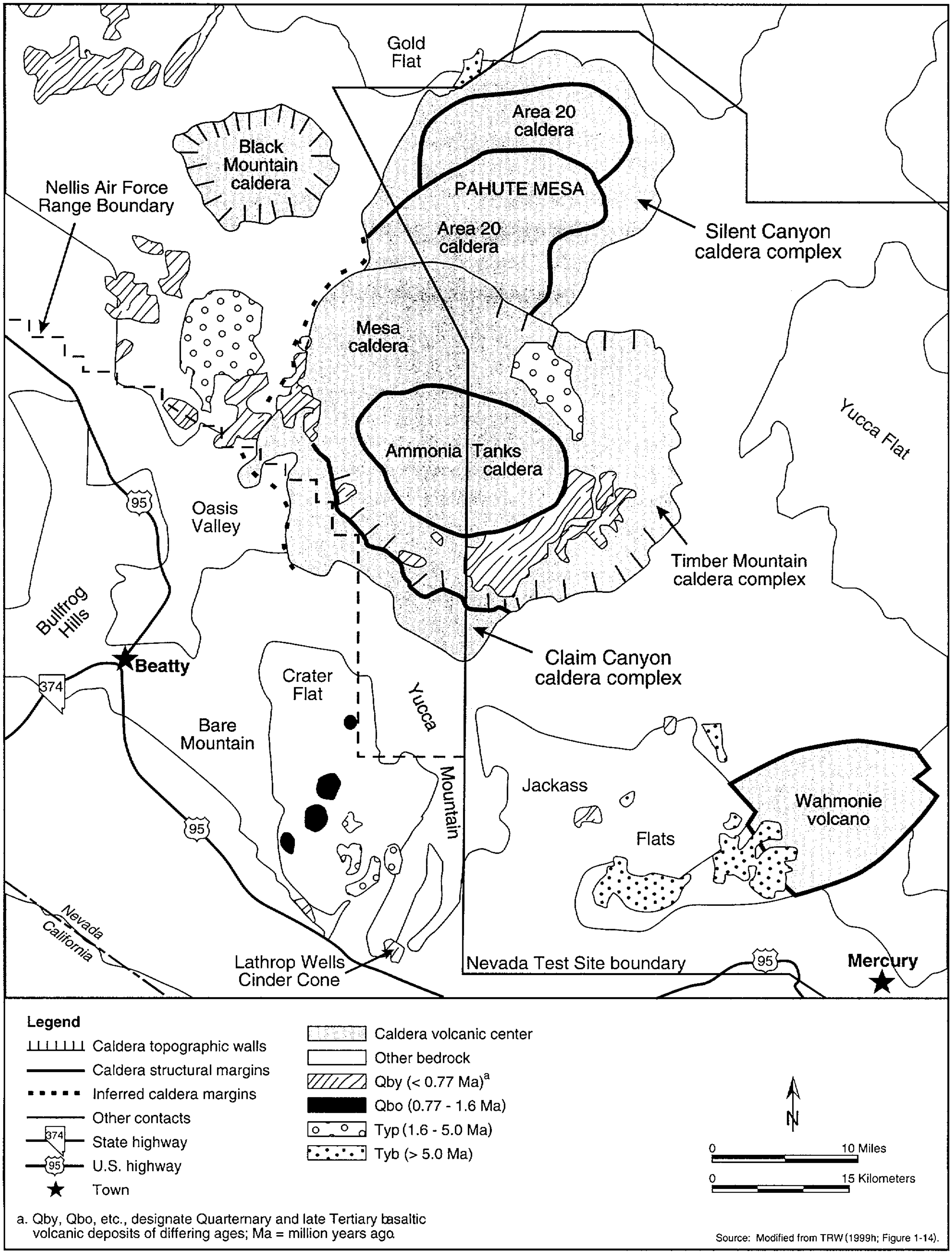


Figure 3-5. Calderas of the southwest Nevada volcanic field in the Yucca Mountain vicinity.

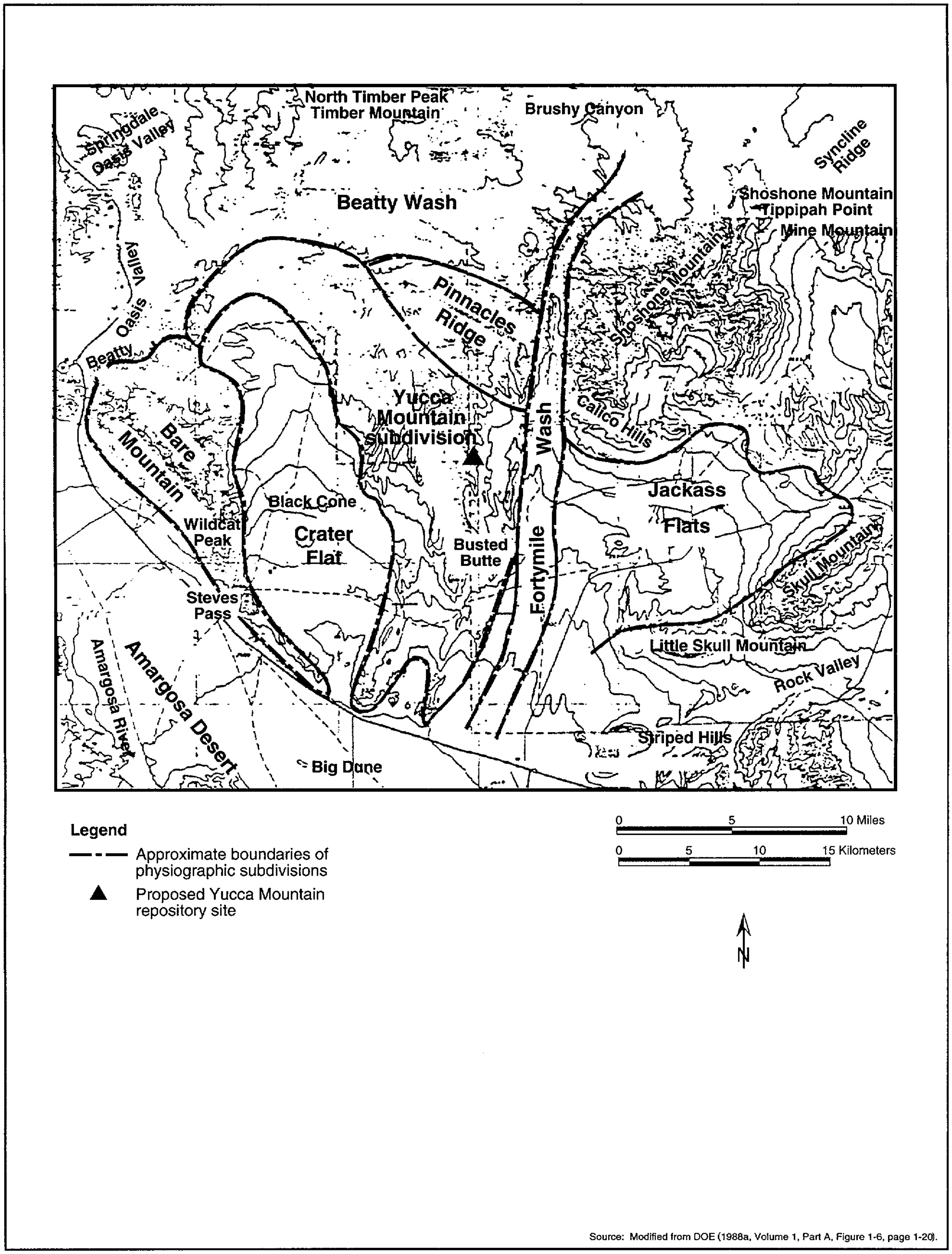


Figure 3-6. Physiographic subdivisions in the Yucca Mountain vicinity.

Table 3-6. Highly generalized stratigraphy summary for the Yucca Mountain region.[a]

Geologic age designation	Major rock types (lithologies)
Cenozoic Era	
Quaternary Period (< 1.6 Ma)[b]	Alluvium; basalt
Tertiary Period (< 65 - 1.6 Ma)	Silicic ash-flow tuffs; minor basalts. Predominantly volcanic rocks of the southwestern Nevada volcanic field (includes Topopah Spring Tuff, host rock for the potential repository). Table 3-7 lists major volcanic formations at Yucca Mountain.
Mesozoic Era (240 - 65 Ma)	No rocks of this age found in Yucca Mountain region.
Paleozoic Era (570 - 240 Ma)	Three major lithologic groups (lithosomes) predominate: a lower (older) carbonate (limestone, dolomite) lithosome deposited during the Cambrian through Devonian Periods (see Figure 3-15), a middle fine-grained clastic lithosome (shale, sandstone) formed during the Mississippian Period, and an upper (younger) carbonate lithosome formed during the Pennsylvanian and Permian Periods.
Precambrian Era (> 570 Ma)	Quartzite, conglomerates, shale, limestone, and dolomite that overlie older igneous and metamorphic rocks that form the crystalline "basement."

a. Source: Adapted from TRW (1999h, Section 1.2, pages 1-8 to 1-15).
b. Ma = approximate years ago in millions.

Only Tertiary and younger rocks are exposed at Yucca Mountain. Parts of the older (Pre-Cenozoic) rock assemblages described in Table 3-6 are exposed at Bare Mountain (Figure 3-6) about 15 kilometers (9 miles) west of Yucca Mountain and at other localities scattered around the region. Many of these older rocks are widespread in the Great Basin where their cumulative thickness is thousands of feet. Detailed information about their characteristics is lacking at Yucca Mountain because only one borehole, about 2 kilometers (1.2 miles) east of Yucca Mountain, has penetrated these rocks. Paleozoic carbonate rocks were penetrated in this borehole at a depth of about 1,250 meters (4,100 feet) (Carr et al. 1986, page 5-5). Paleozoic carbonate rocks form important aquifers in southern Nevada (Winograd and Thordarson 1975, all).

Table 3-7 lists the principal mid-Tertiary volcanic stratigraphic units mapped at the surface, encountered in boreholes, and examined in the Exploratory Studies Facility that have been a major focus of site characterization investigations. The proposed repository and access to it would be entirely in the Paintbrush Group, so investigations have focused particularly on the formations in that stratigraphic unit. Detailed descriptions of the volcanic stratigraphic units are in the Yucca Mountain Project Stratigraphic Compendium (DOE 1996g, all). The following paragraphs provide a general summary based on the *Yucca Mountain Site Description* (TRW 1998a, pages 3.5-1 to 3.5-28).

The bulk of the volcanic sequence consists of tuffs. Volcanic rocks known as ash-flow tuff (or pyroclastic flow deposits) form when a hot mixture of volcanic gas and ash violently erupts and flows. As the ash settles, it is subjected to various degrees of compaction and fusion depending on temperature and pressure conditions. If the temperature is high enough, glass and pumice fragments are compressed and fused to produce welded tuff (a hard, brick-like rock with very little open pore space in the rock matrix). Nonwelded tuffs, compacted and consolidated at lower temperatures, are less dense and brittle and generally have greater porosity. Ash-fall tuffs are formed from ash that cooled before settling on the ground surface, and bedded tuffs are composed of ash that has been reworked by stream action. All of these are found in the volcanic assemblage at Yucca Mountain.

In general, characterization of the various volcanic units is based on changes in depositional features, the development of zones of welding and devitrification (crystallization of glassy material), and the

Table 3-7. Tertiary volcanic rock sequence at Yucca Mountain.[a]

Name	Age millions of years)	Thickness (meters)[b]	Characteristics
Timber Mountain Group			
• Ammonia Tanks Tuff	11.5	215	Welded to nonweld rhyolite tuff; exposed in southern Crater Flat.
• Rainier Mesa Tuff	11.6	< 30 - 40	Nonwelded to moderately welded vitric to devitrified tuff exposed locally along downthrown sides of large normal faults.
Post-Tiva Canyon, pre-Rainier Mesa Tuffs	12.5	0 - 61	Pyroclastic flows and fallout tephra deposits in subsurface along east flank of Yucca Mountain.
Paintbrush Group			Four formations (below) interlayered locally with lava flows and reworked volcanic deposits.
• Tiva Canyon Tuff	12.7	< 50 - 175	Crystal-rich to crystal-poor densely welded rhyolite tuff that forms most rock at surface of Yucca Mountain.
• Yucca Mountain Tuff	--[c]	0 - 45	Mostly nonwelded tuff but is partially to densely welded where it thickens to north and west.
• Pah Canyon Tuff	--	0 - 70	Northward-thickening nonwelded to moderately welded tuff with pumice fragments.
• Topopah Spring Tuff	12.8	Maximum: 380	Rhyolite tuff divided into upper crystal-rich member and lower crystal-poor member. Each member contains variations in lithophysal content, zones of crystallization, and fracture density. Glassy unit (vitrophyre) present at the base. Proposed host for repository.
Calico Hills Formation	12.9	15 - 460	Northward-thickening series of pyroclastic flows, fallout deposits, lavas, and basal sandstone; abundant zeolites except where entire formation is vitric in southwest part of central block of Yucca Mountain.
Crater Flat Group			Pyroclastic flows and interbedded tuffs of rhyolitic composition distinguished by abundance of quartz and biotite.
• Prow Pass Tuff	13.1	60 - 228	Sequence of variably welded pyroclastic deposits.
• Bullfrog Tuff	13.3	76 - 275	Partially welded, zeolytic upper and lower parts separated by a central densely welded tuff.
• Tram Tuff	13.5	60 - 396	Lower lithic-rich unit overlain by upper lithic-poor unit.
• Lithic Ridge Tuff	14.0	185 - 304	Southward thickening wedge of welded and nonwelded pyroclastic flows and interbedded tuff extensively altered to clays and zeolites.
Pre-Lithic Ridge	+14.0	180 - 345+	Mostly altered pyroclastic flows, lavas, and bedded tuff of rhyolitic composition.

a. Modified from TRW (1999h, pages 1-16 to 1-28).
b. To convert meters to feet, multiply by 3.208.
c. -- = no absolute dates.

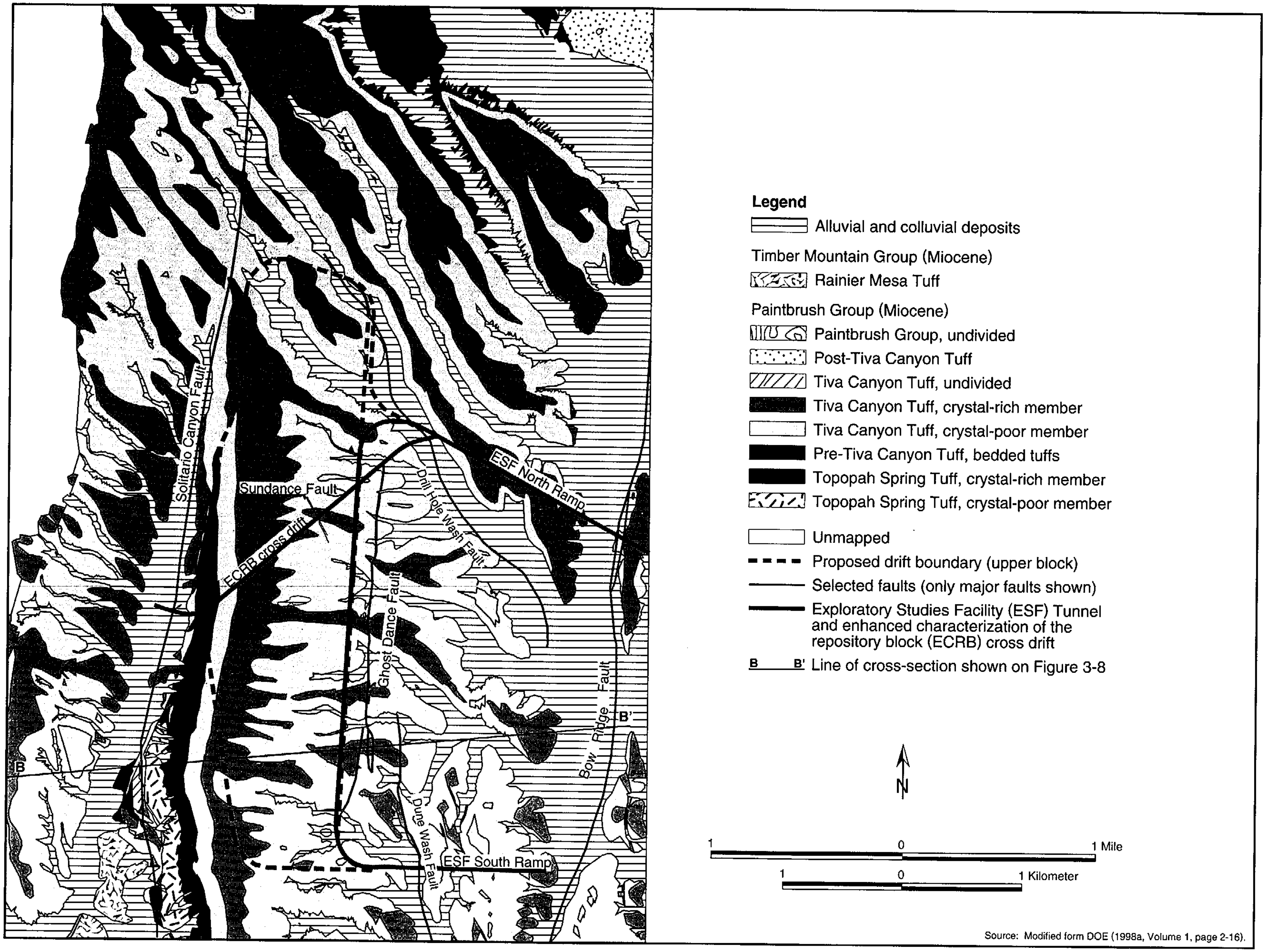
development of alteration products in some rocks. Mineral and chemical composition and properties such as density and porosity also have been used in distinguishing some units. Most of the formations listed in Table 3-7 contain phenocrysts (mineral grains distinctly larger than the surrounding rock matrix) and lithic clasts (rock fragments), have some part that is at least partially welded, and typically have some part that has devitrified during cooling of the deposit. In addition, the vitric (glassy) parts of many formations have been partly altered to clay and zeolite minerals, and all the rocks have developed various amounts of fractures, some of which contain secondary mineral fillings.

Lithophysal cavities are prominent features in some units, notably in the Tiva Canyon and Topopah Spring Tuffs, where they range from 1 to 50 centimeters (0.4 to 20 inches) in diameter and are a basis for the further subdivision of these formations. Lithophysal cavities are voids resulting from vapors trapped in densely welded parts of the formations. Lithophysal zones contain fewer fractures compared to nonlithophysal zones.

Although welded tuffs dominate the volcanic sequence, bedded tuffs are present in the Paintbrush Group and in some older parts of the sequence. Joints and fractures are common in the welded tuffs, producing much greater bulk permeabilities than those of the nonwelded and bedded tuffs. This is an important distinction with regard to investigation of hydrologic conditions.

Some parts of the volcanic formations contain secondary mineral products created by alteration of the original materials after their original deposition and consolidation. Some alteration has resulted from reactions with groundwater, and the types of new mineral substances found can differ based on occurrence below or above the water table. Alteration products such as clay minerals and zeolites occur in several parts of the volcanic sequence; in some places, in-filling with zeolites has reduced the porosity and thus affected hydrologic properties. In most of the formations, contacts between vitric and devitrified layers are commonly marked by an interval containing clay or zeolite alteration minerals. A notable example is the interval, as much as several meters thick, where glassy rock at the base of the Topopah Spring Tuff (the basal vitrophyre) is in contact with the overlying nonlithophysal zone; this interval of alteration occurs in most boreholes in the vicinity of the proposed site. Subtle differences in geochemical conditions are believed to have given rise locally over short distances to some unusual zeolites. One in particular is the fibrous zeolite erionite, which is a potential human health hazard (see Section 3.1.8). Data from rock samples show that in the potential repository horizon erionite, if it occurs, is either in the altered zone immediately above the Topopah Spring lower vitrophyre or in the moderately welded zone underlying this vitrophyre. It has also been identified in the lower Tiva Canyon Tuff (DOE 1998a, Volume 1, page 2-25).

Figure 3-7 is a geologic map that shows the surficial distribution of Tertiary volcanic units and younger surficial deposits in the vicinity of the proposed site. Figure 3-8 is a vertical cross-section through the southern part of this area that shows the subsurface expression of the mapped units, including structural aspects (east-dipping rock units and predominantly west-dipping normal faults). Volcanic rocks younger than the Tertiary units occur locally at and in the Yucca Mountain vicinity but are of limited extent (Figure 3-5). They represent such relatively quiet, nonexplosive eruptions of basaltic materials as lava flows and cinder cones. Examples include the lava flows that cap Skull and Little Skull Mountains at the south and southeast margins of Jackass Flats, a basalt ridge that forms the southern boundary of Crater Flat, and a basaltic dike dated at 10 million years that intrudes in the northern part of the Solitario Canyon fault, which bounds the west flank of Yucca Mountain. A north-trending series of cinder cones and lava flows on the southeast side of Crater Flat has been dated at 3.7 million years, and in the center of Crater Flat a series of four northeast-trending cinder cones (Qbo in Figure 3-5) has been dated at about 1 million years. The youngest basaltic center is the Lathrop Wells center, which is a single cone estimated to be 75,000 years old.



Figr 3-7. General bedrock geology of the proposed repository Cer lock Area.

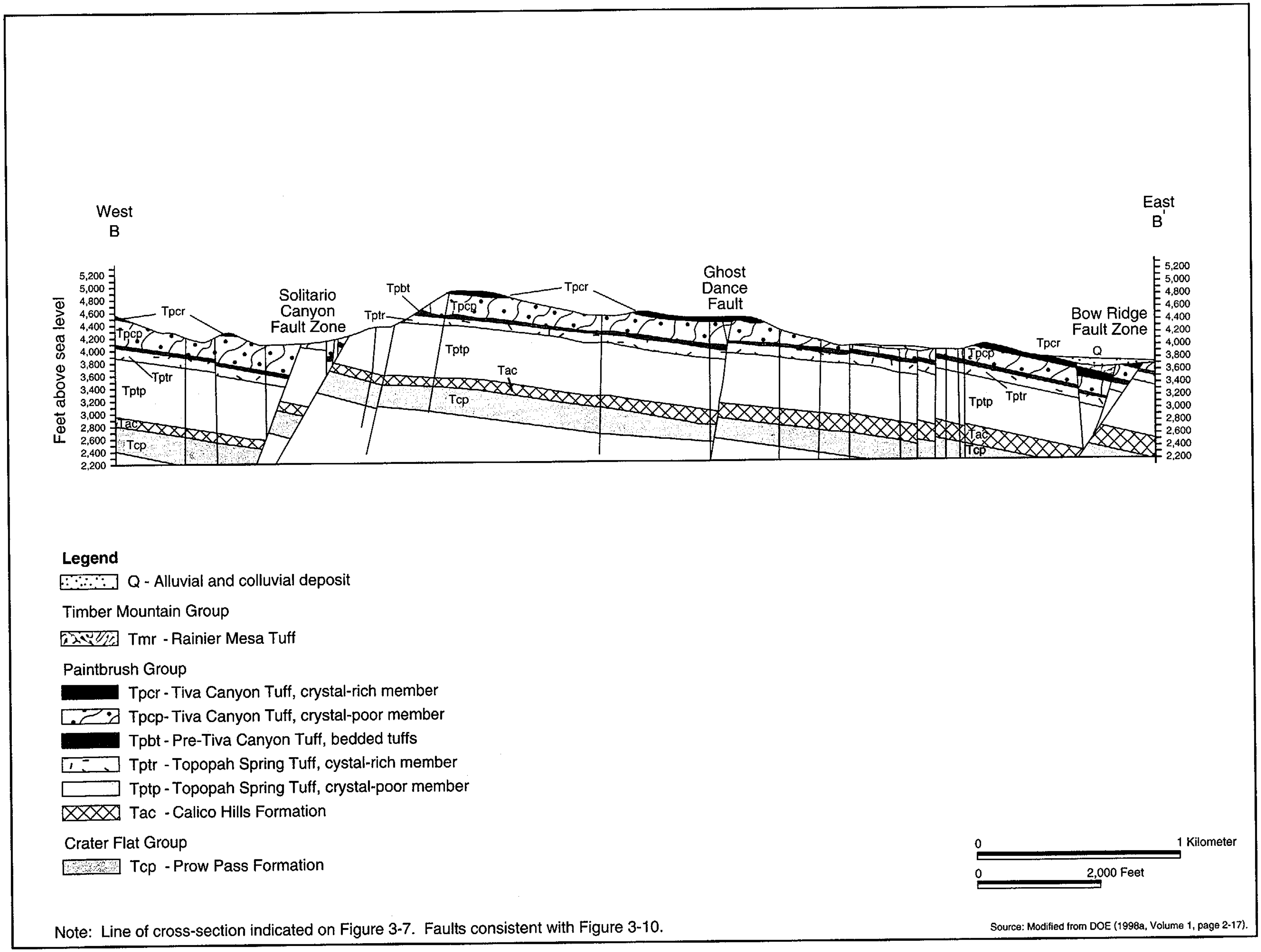


Figure 3-8. Simplified geologic cross-section of Yucca Mountain, west to east.

The youngest stratigraphic units at Yucca Mountain are the predominantly unconsolidated surficial deposits of late Tertiary and Quaternary age. They are shown in Figure 3-7 as alluvium (material such as sand, silt, or clay deposited on land by water) and colluvium (loose earth material that has accumulated at the base of a hill through the action of gravity) but have been classified in more detail as stream (alluvial) deposits, hillslope (colluvial) deposits, spring deposits, and windblown (eolian) deposits (TRW 1998a, pages 3.4-1 to 3.4-33). Most Quaternary units exposed at the surface were deposited during the last 100,000 years (DOE 1998a, Volume 1, page 2-26). The bulk of these consist of alluvium deposited by intermittent streams that transported rock debris from hillslopes to adjacent washes and valleys.

Selection of Repository Host Rock

Selection of the Topopah Spring tuff as the repository host rock was based on several considerations, which include (1) depth below the ground surface sufficient to protect nuclear waste from exposure to the environment, (2) extent and characteristics of the host rock, (3) location of faults that could adversely affect the stability of underground openings or act as pathways for water flow that could eventually lead to radionuclide release, and (4) location of groundwater in relation to the proposed repository (TRW 1993, pages 5-99 to 5-101).

DOE selected the middle to lower portion of the Topopah Spring tuff as the potential repository horizon. The rock is strongly welded with variable fracture density and void space; experience gained from the excavation of the Exploratory Studies Facility shows the capability to construct stable openings in this rock. Thermal and mechanical properties of this section of rock should enable it to accommodate the range of temperatures anticipated (thermal properties will not be affected greatly by construction and operation, as compared to postemplacement), and the identified repository volume is between major faults. Finally, the selected repository horizon is well above the present groundwater table. Based on geologic evidence the water table under Yucca Mountain has not been more than about 100 meters (330 feet) higher than its present level in the past several hundred thousand years; at such levels the water table would still be about 100 to 200 meters (330 to 660 feet) below the selected repository horizon (DOE 1998a, Volume 1, page 2-24). Section 3.1.4 discusses the water table level further.

Potential for Volcanism at the Yucca Mountain Site

DOE has performed extensive investigations to determine the ages and nature of the volcanic episodes that produced the rocks described above (see Chapter 5). The rocks that form the southwestern Nevada volcanic field, characterized by large-volume silicic ash flows (including the host rock for the proposed repository), were erupted during a period of intense tectonic activity associated with active geologic faulting (Sawyer et al. 1994, all). The volcanism that produced these ash flows is complete and, based on the geology of similar volcanic systems in the Great Basin, no additional large-volume silicic activity is likely.

Basaltic volcanism in the Yucca Mountain region began about 11 million years ago as silicic eruptions waned and continued as recently as about 75,000 years ago (TRW 1998a, pages 3.2-18 and 3.2-19). Basaltic volcanic events were much smaller in magnitude and less explosive than the events that produced the ash flows mentioned above. Typical products are the small volcanoes or cinder cones and associated lava flows in Crater Flat (about 1 million years old) and the Lathrop Wells volcano (possibly as young as 75,000 years).

Differing views on the likelihood of volcanism near Yucca Mountain result from uncertainties in the hazard assessment. To address these uncertainties, DOE has performed analyses, conducted extensive volcanic hazard assessments, considered alternative interpretations of the geologic data, and consulted with recognized experts, representing other Federal agencies (for example, the U.S. Geological Survey), national laboratories, and universities (for example, the University of Nevada and Stanford University). A panel of 10 scientists with expertise in volcanism reviewed the extensive information on volcanic activity in the Yucca Mountain vicinity and assessed the likelihood that future volcanic activity could occur at or in the vicinity of the repository.

The probability of basaltic lava intruding into the repository is expressed as the annual probability that a volcanic event would disrupt (intersect) a repository, given that a volcanic event would occur during the period of concern. In 1995 and 1996, DOE convened the panel of recognized experts representing other Federal agencies (for example, the U.S. Geological Survey, 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 potential Yucca Mountain Repository by a volcanic intrusion (dike) (Geomatrix and TRW 1996, all). The panel estimated the probability of a dike disrupting the repository during the first 10,000 years after closure to be 1 chance in 7,000.

3.1.3.2 Geologic Structure

Geologic structures (folds, faults, etc.) are features that result from deformation to rocks after their original formation. The present-day geologic structure of the Great Basin, including the Yucca Mountain region, is the cumulative product of multiple episodes of deformation caused by both compression and extension (stretching) of the Earth's crust.

Major crustal compression occurred in the Great Basin between about 350 million and 50 million years ago, which resulted in older rocks being thrust over younger rocks for great distances (for example, thrust faults) to produce mountains. During the last 15 million years, crustal extension has resulted in the pattern of elongated mountain ranges and intervening basins. Crustal extension has resulted in vertical, lateral, and oblique movements (Figure 3-9). By about 11.5 million years ago the present mountains and valleys were well developed (Scott and Bonk 1984, all; Day et al. 1996, all).

Figure 3-7 shows the bedrock geology at the Yucca Mountain site and Figure 3-8 shows geologic structure. Figure 3-10 shows the surface traces of faults and their characteristic northerly alignment.

The crustal extension during the last 15 million years fractured the crust along the generally north-trending normal faults. Some of the crustal blocks were downdropped and tilted by movement along their bounding faults (called block-bounding faults). The estimated total displacement along the major north-trending block-bounding faults during the last 12 million years ranges from less than 100 meters (330 feet) to as much as 600 meters (2,000 feet).

The total estimated displacement along the most active north-trending block-bounding faults in the Yucca Mountain region during the past 1.6 million years is less than 50 meters (165 feet) (Simonds et al. 1995, all). During the last 730,000 years the total displacement of north-trending block bounding faults has been as much as 6 meters (20 feet). However, during the past 128,000 years the typical total displacement has been about 1 to 2.5 meters (about 3.3 to 8 feet).

Table 3-8 lists the characteristics of the faults that are important to an understanding of seismic hazards to the potential repository. The Solitario Canyon fault along the west side of Yucca Mountain is the major block-bounding fault. The proposed repository has been configured so that there would be no block-bounding faults in the emplacement zone.

Between the major north-trending, block-bounding faults are many subsidiary northwest-trending faults with smaller displacements (Scott and Bonk 1984, all). There is no clear evidence that displacements have occurred along these subsidiary faults during the last 1.6 million years (Simonds et al. 1995, all). One short northwest-trending subsidiary fault, called the Sundance fault, transects the potential repository area (Figure 3-10). In addition, there is one intrablock fault, called the Ghost Dance fault, in the area of

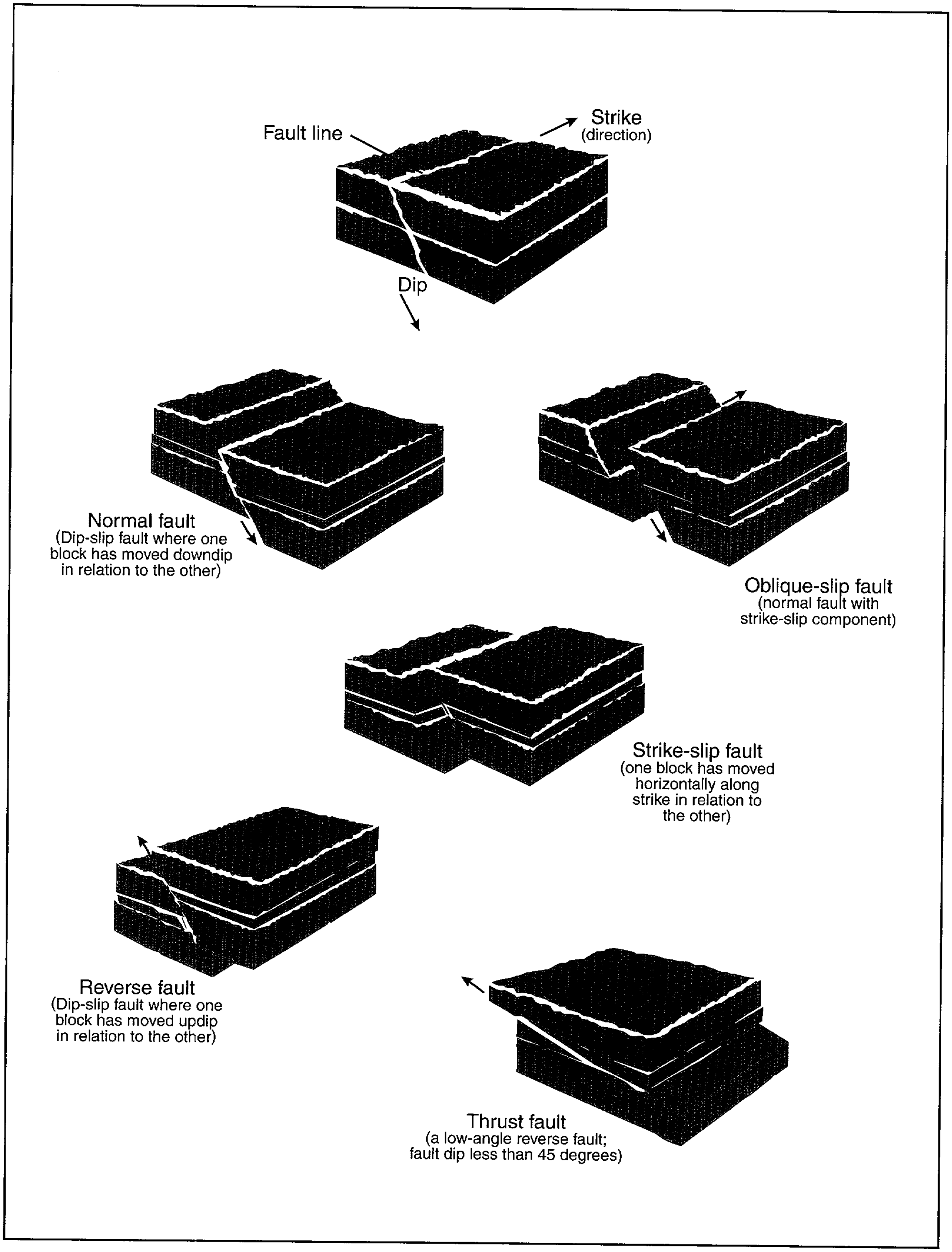


Figure 3-9. Types of geologic faults.

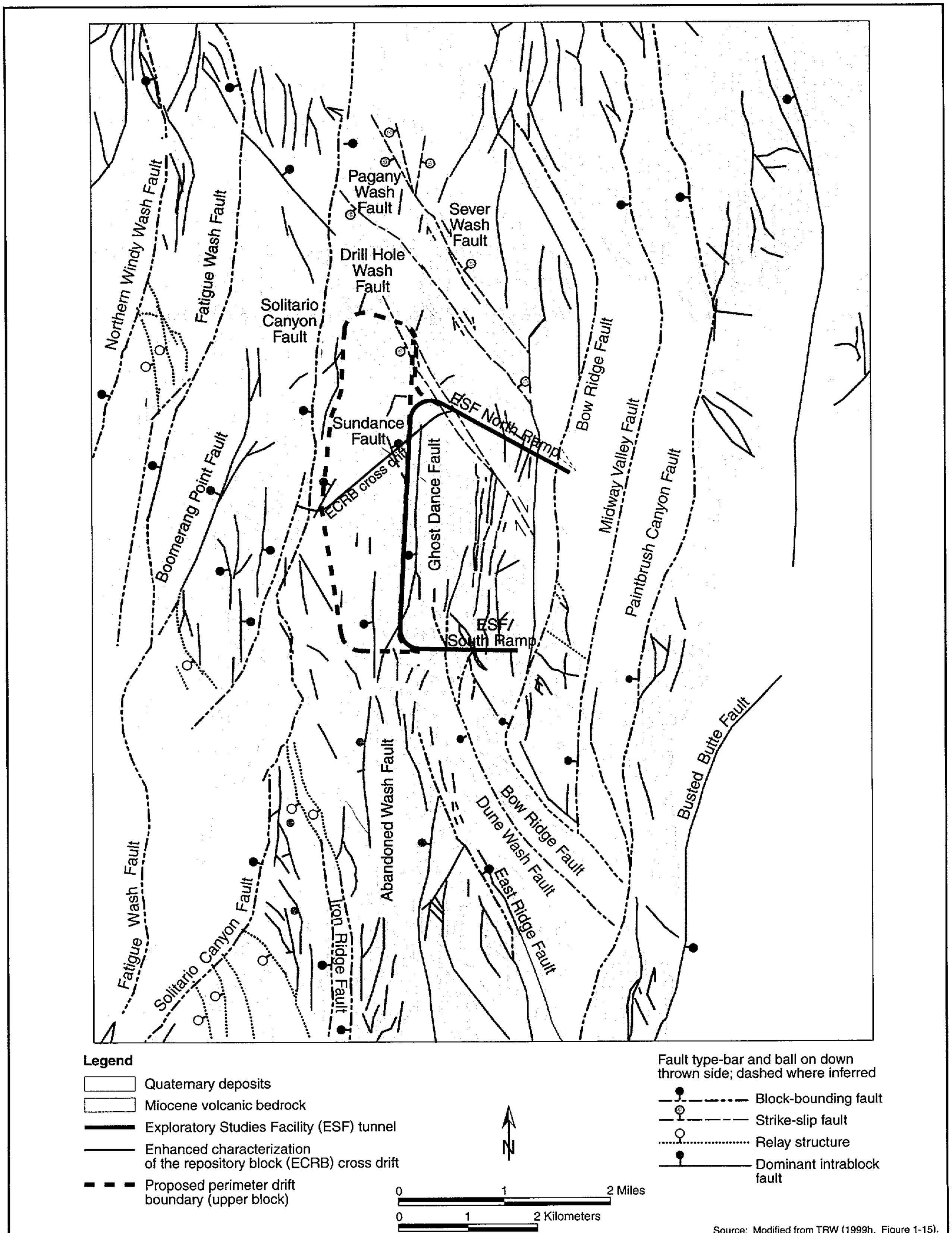


Figure 3-10. Mapped faults at Yucca Mountain and in the Yucca Mountain vicinity.

Table 3-8. Characteristics of major faults at Yucca Mountain.[a]

Fault	Surface features	Evidence of late Quaternary displacement	Quaternary displacement (past 1.6 million years)	Total displacement; type of movement	Fault length (kilometers)[b] and dip
Windy Wash fault[c]	East-facing fault-line scarps in alluvium; bedrock-alluvium fault contacts; merges with Fatigue Wash fault.	Two trenches show multiple ruptures; basalt ash in fault plane; fractures and scarps in alluvium.	1 meter[d] in late Quaternary; < 0.1 meter during past 10,000 years.	Increases southward to 500 meters; dip-slip, west side down.	3 - 25; 61° west.
Fatigue Wash fault[c]	Bedrock and alluvial scarps; fault-line scarps, lineaments in alluvium; merges with Fatigue Wash fault.	One trench shows multiple ruptures; basalt ash in fault plane; fractures and scarps in alluvium.	2.2 meters in late Quaternary.	72 meters; oblique left-lateral, west side down.	9.5 - 17; 71° west.
Solitario Canyon fault[c]	Prominent fault-line scarp; discontinuous fault traces; subtle scarps in alluvium; merges with Stagecoach Road fault.	Nine trenches show multiple ruptures; basalt ash in fault plane; fractures and scarps in alluvium.	1.7 - 2.5 meters in late Quaternary.	Increases southward from 61 meters to > 500 meters; oblique left-lateral, down on east at north end, down on west at south end.	12.5 - > 21; 68° to 71° west.
Ghost Dance fault zone[e]	Bedrock fault in zone of subparallel minor faults and breccia zones.	None	None	Increases southward from 0 - 30 meters; dip-slip, west side down.	3 - 9; ~vertical.
Bow Ridge fault[c]	Fault-line scarp along bedrock/alluvium contact; subtle lineaments; may merge with Paintbrush Canyon fault.	Five trenches show multiple ruptures; basalt ash in fault plane; fractures and scarps in alluvium.	0.5 - 1.3 meters in late Quaternary.	125 meters; oblique left-lateral, west side down.	0.8 - 107; 75° west.
Midway Valley fault[c]	None, fault located on basis of geophysical evidence.	None	None	40 - 60 meters; dip-slip, west side down.	1 - 8 ; west[f]
Paintbrush Canyon fault[c]	Bedrock and alluvial faults, scarps, and lineaments; possibly merges with Stagecoach Road fault.	Four trenches and exposures at Busted Butte show multiple ruptures; basalt ash in fault plane; fractures in alluvium.	1.7 - 2.7 meters (4.6 - 6.3 meters at Busted Butte in last 730,000 years).	250 - 300 meters; dip-slip and oblique left-lateral, west side down.	10 - > 26; 75° west.
Northwest-trending faults[g]	Bedrock faults with local scarps; most located by drilling and geophysical surveys.	None, with the exception of one trench across Pagany Wash fault showing possible Quaternary displacement.	None (see column to left).	40 meters right-lateral, 5 - 10 meters vertical.	2 - 8 per fault; > 70° south.

a. Source: Modified from TRW (1999h, Table 1-2, pages 1-40 and 1-41).
b. To convert kilometers to miles, multiply by 0.62137.
c. Block-bounding fault.
d. To convert meters to feet, multiply by 3.2808.
e. Intrablock fault.
f. The dip and direction of this fault are uncertain.
g. Subsidiary faults (to be verified).

the proposed repository. The Ghost Dance fault has a near-vertical dip from the surface to the depth of the repository (TRW 1998a, page 3.6-24). This fault crosses the Exploratory Studies Facility tunnel. There is no evidence of Quaternary movement along the Ghost Dance fault (Table 3-8).

DOE identified and described alternative tectonic models to explain the current geologic structure resulting from past tectonic processes and deformation events that have affected the Yucca Mountain site. These models are described in the *Yucca Mountain Site Description* (TRW 1998a, Section 3.3), and were considered by the experts in the Probabilistic Seismic Hazard Analysis (USGS 1998, all) discussed below. Computer models provide a means of integrating data on volcanism, deposition, and fault movement, and include a representation of the existing geologic structures and the processes that operate at depth. Tectonic models provide a basis for evaluating the processes and events that could occur in the future and potentially affect the performance of a repository. The DOE hazard assessments used models that are supported by data.

3.1.3.3 Modern Seismic Activity

DOE has monitored seismic activity at the Nevada Test Site since 1978. The epicenters of many earthquakes that the Southern Great Basin Seismic Network has located within 20 kilometers (12 miles) of Yucca Mountain do not correlate with mapped surface traces of Quaternary faults. This lack of correlation is a common feature of earthquakes, particularly those of smaller magnitude, in the Great Basin and elsewhere. Earthquakes in the Yucca Mountain region have focal depths (the point of origin of an earthquake below the ground surface) ranging from near-surface to about 15 kilometers (9 miles). The earthquake focal mechanisms are strike-slip to normal oblique-slip along moderately to steeply dipping fault surfaces. These focal mechanisms indicate the nature of the fault planes on which the earthquakes occur, as shown in Figure 3-9.

The largest recorded historic earthquake within 50 kilometers (30 miles) of Yucca Mountain was the Little Skull Mountain earthquake in 1992, which had a Richter magnitude of 5.6. This seismic event occurred about 20 kilometers (12 miles) southeast of Yucca Mountain, about a day after the magnitude 7.3 earthquake at Landers, California, 300 kilometers (190 miles) south-southeast of Yucca Mountain. The Little Skull Mountain event caused no damage at Yucca Mountain, although some damage occurred at the Field Office Center in Jackass Flats about 5 kilometers (3 miles) north of the epicenter.

Seismic Hazard

DOE based the design ground motion and fault displacement that could be associated with future earthquakes at Yucca Mountain on the record of historic earthquakes in the Great Basin, evaluation of prehistoric earthquakes based on investigations (trenching and detailed mapping) of the faults at Yucca Mountain, and observation of ground motions associated with modern earthquakes using the Southern Great Basin Seismic Network.

Experts have evaluated site data and other relevant information (including differing models) to assess where and how often future earthquakes will occur, how large they will be, how much offset will occur at the Earth's surface, and how ground motion will diminish as a function of distance. Two panels of scientific experts conducted the Probabilistic Seismic Hazard Analysis (USGS 1998, all); one panel characterized sources of future earthquakes and their potential for surface fault displacement and the second addressed ground motion for the Yucca Mountain region. The results of this analysis are hazard curves that show the ground motions and potential fault displacements plotted with annual frequency of being exceeded. These are used to determine the design-basis ground motions and to assess the postclosure performance of the site.

The expert assessments indicate that geologic fault displacement hazard is generally low. For locations not on a major block-bounding fault, displacements greater than 0.1 centimeter (0.04 inch) will be exceeded an average of less than once in 100,000 years, whereas the mean displacements that are likely to be exceeded on the block-bounding Bow Ridge and Solitario Canyon faults are 7.8 and 32 centimeters (3.1 and 13 inches), respectively. Mitigating potential fault displacement effects would involve avoiding faults in laying out repository facilities.

Ground motion studies have investigated the level of shaking produced at Yucca Mountain by both local and regional earthquakes, and have estimated expected ground motion from hypothetical earthquakes. These predictions of probable ground motion amplitudes and frequencies support preliminary design requirements (the Exploratory Studies Facility), and future studies will provide additional site-specific information on soil and rock properties that will enable refinement of preliminary results and facilitate design analyses to mitigate seismic risk to a potential repository (DOE 1998a, Volume 1, pages 2-86 and 2-87).

The seismic design basis for the repository specifies that structures, systems, and components important to safety should be able to withstand the horizontal motion from an earthquake with a return frequency of once in 10,000 years (annual probability of occurrence of 0.0001) (Kappes 1998, page VII-3). A recent comprehensive evaluation of the seismic hazards associated with the site of the proposed repository (USGS 1998, Figure 7-4) concluded that a 0.0001-per-year earthquake would produce peak horizontal accelerations at a reference rock site at Yucca Mountain of about 0.53*g* (mean value). DOE needs to complete additional investigations of ground motion site effects before it can produce the final seismic design basis for the surface facilities.

A recent study published in *Science* magazine (Wernicke et al. 1998, all) claims that the crustal strain rates in the Yucca Mountain area are at least an order of magnitude higher than would be predicted from the Quaternary volcanic and tectonic history of the area. If higher strain rates are present, the potential volcanic and seismic hazards would be underestimated on the basis of the long-term geologic record.

As part of the Yucca Mountain site characterization activities, DOE established a 13-station, 50-kilometer (30-mile), geodetic array, centered on Yucca Mountain, and conducted surveys in 1983, 1984, and 1993. As interpreted by Savage et al. (1994, all), the surveys indicated no large strain accumulation and thus do not support the claims in Wernicke et al. (1998, all). The Yucca Mountain array was resurveyed in 1998 (Savage, Svarc, and Prescott 1998, all). After correction for deformation associated with the Little Skull Mountain earthquake, the data continue to indicate a strain rate about an order of magnitude lower than that reported by Wernicke et al. (1998, all).

DOE is continuing to monitor crustal strain in the Yucca Mountain region to determine if it can confirm the results of Wernicke et al. (1998, all). Through the University of Nevada, DOE is supporting continued monitoring by Dr. Wernicke. If the higher crustal strain rates are confirmed, DOE will reassess the volcanic and seismic hazard at Yucca Mountain.

3.1.3.4 Mineral and Energy Resources

The southern Great Basin contains valuable or potentially valuable mineral and energy resources, including deposits with past or current production of gold, silver, mercury, base metals, and uranium. The proximity of known deposits and the identification of similar geologic features at Yucca Mountain have led some investigators to propose that the analyzed Yucca Mountain land withdrawal area (see Figure 3-2) could have the potential for mineral resources (Weiss, Noble, and Larson 1996, page 5-26).

DOE site investigations included evaluation of the potential for mineral and energy resources in the analyzed withdrawal area because the presence of such resources could lead to exploration and inadvertent human intrusion (see Chapter 5). The *Yucca Mountain Site Description* (TRW 1998a, Section 3.11) describes results of investigations that address relevant natural resources. Site characterization investigators identified no economic deposits of base or precious metals, industrial rocks or minerals, and energy resources, based on present use, extraction technology, and economic value of the resources. DOE believes the potential for economically useful mineral or energy resources in the analyzed Yucca Mountain withdrawal area is low.

3.1.4 HYDROLOGY

This section describes the current hydrologic conditions in the Yucca Mountain region in terms of surface-water and groundwater system characteristics. Unless otherwise specified, the primary references for this section are the *Environmental Baseline File for Water Resources* (TRW 1999i, all) and the *Geology/Hydrology Environmental Baseline File* (TRW 1999h, all). Section 3.1.4.1 describes surface-water conditions, and Section 3.1.4.2 describes groundwater conditions.

The hydrologic system in the Yucca Mountain region is characterized and influenced by a very dry climate, limited surface water [annual average precipitation of about 10 to 25 centimeters (4 to 10 inches) (Section 3.1.2.2), potential evaporation of almost 170 centimeters (66 inches) per year (DOE 1998a, Volume 1, page 2-29)], and deep aquifers. Important characteristics of the hydrologic system include drainages and streambeds, streams, springs, and playa lakes. In addition, water quantity and quality are important characteristics. Yucca Mountain is in the Alkali Flat-Furnace Creek Ranch sub-basin of the larger Death Valley Regional Groundwater Flow System. Death Valley is a terminal hydrologic basin; surface water and groundwater cannot leave except by evapotranspiration (Luckey et al. 1996, page 30). Important characteristics of the groundwater system include recharge zones (areas where water infiltrates from the surface and reaches the saturated zone), discharge points (locations where groundwater reaches the surface), unsaturated zones (the portion of the groundwater system above the water table), saturated zones (the portion of the groundwater system below the water table), and aquifers (water-bearing layers of rock that provide water in usable quantities). In combination, these characteristics define the quantity and quality of the available groundwater. This section also describes groundwater use as part of the system.

EVAPOTRANSPIRATION

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

3.1.4.1 Surface Water

3.1.4.1.1 *Regional Surface Drainage*

Yucca Mountain is in the southern Great Basin, which generally lacks permanent streams and other surface-water bodies. The Amargosa River system drains Yucca Mountain and the surrounding areas (Figure 3-11). 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. Exceptions include short stretches where groundwater discharges to the channel near Beatty, Nevada, south of Tecopa, California, and in southern Death Valley, California (TRW 1998a, page 5.1-4). The river drains an area of about 8,000 square kilometers (3,100 square miles) by the time it reaches Tecopa (Bostic et al. 1997, pages 103 and 112), and its course extends roughly 90 kilometers (56 miles) farther before it ends in the Badwater Basin in Death Valley, which is more than 80 meters (260 feet) below sea level. The nearest surface-water impoundments are Peterson Reservoir, Crystal Reservoir, Lower Crystal Marsh, and Horseshoe

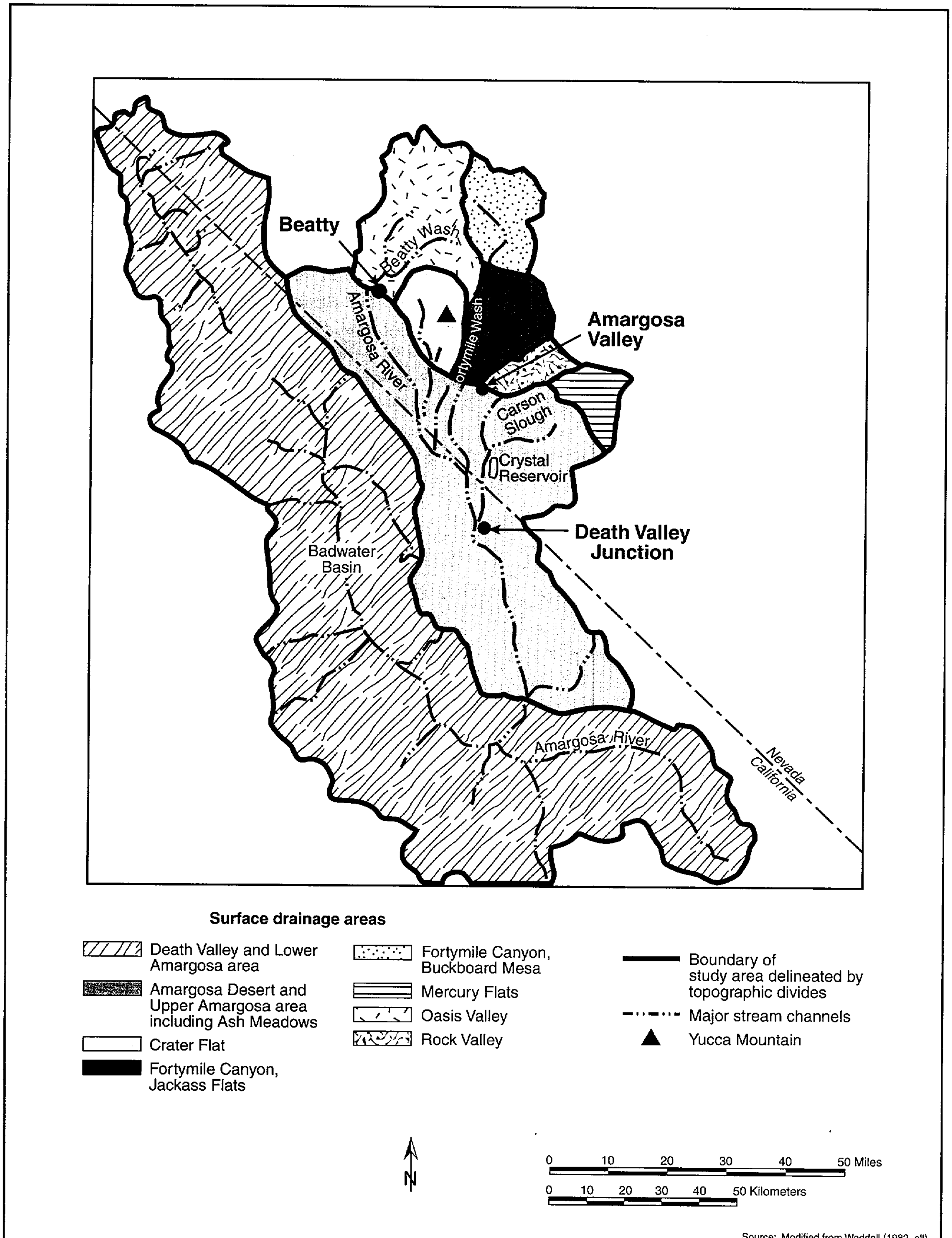


Figure 3-11. Surface areas drained by the Amargosa River and its tributaries.

Reservoir. The largest of these is Crystal Reservoir, a manmade impoundment at Ash Meadows, which captures the discharge from several springs in the area and has a capacity of 1.8 million cubic meters (1,500 acre-feet). Crystal Reservoir and other smaller pools in Ash Meadows drain to the Amargosa River through Carson Slough (TRW 1998a, page 5.1-4).

3.1.4.1.2 *Yucca Mountain Surface Drainage*

Occurrence. No perennial streams, natural bodies of water, or naturally occurring wetlands occur at Yucca Mountain or in the analyzed land withdrawal area. Fortymile Wash, a major wash that flows to the Amargosa River, drains the eastern side of Yucca Mountain (Figure 3-12). The primary washes draining to Fortymile Wash at Yucca Mountain include Yucca Wash to the north; Drill Hole Wash, which, together with its tributary, Midway Valley Wash, drains most of the repository site; and Busted Butte (Dune) Wash to the south. The western side of Yucca Mountain is drained through Solitario Canyon Wash and Crater Flat, both of which eventually drain to the Amargosa River. In this area, most of the water from summer storms is lost relatively quickly to evapotranspiration unless a storm is intense enough to produce runoff or subsequent storms occur before the water is lost. Thunderstorms in the area can be local and intense, creating runoff in one wash while an adjacent wash receives little or no rain. Evapotranspiration is lower during the winter, when water from precipitation or melting snow has a better chance to result in stream flow.

Flood Potential. Although flow in most washes is rare, the area is subject to flash flooding from intense summer thunderstorms or sustained winter precipitation. When it occurs, intense flooding can include mud and debris flows in addition to water runoff (Blanton 1992, page 2). Table 3-9 lists peak discharges for estimated floods along the main washes at Yucca Mountain, including an estimate for a regional maximum flood. In addition to the flood estimates listed in the table, DOE used another estimating method, the *probable maximum flood* methodology [based on American National Standards Institute and American Nuclear Society Standards for Nuclear Facilities (ANS 1992, all)] to generate another maximum flood value for washes adjacent to the existing facilities and operations at the North and South Portals (Blanton 1992, all; Bullard 1992, all). The flood value this method generates, which includes a bulking factor to account for mud and debris, is the most severe reasonably possible for the location under evaluation and is larger than the regional maximum flood listed in Table 3-9. DOE used the probable maximum flood values to predict the areal extent of flooding and to determine if facilities and operations are at risk of flood damage.

PREDICTED FLOODS

100-year flood: The magnitude of peak discharge at any point on a river or drainage channel that can be expected to occur or be exceeded, on average, once in 100 years.

500-year flood: The magnitude of peak discharge at any point on a river or drainage channel that can be expected to occur or be exceeded, on average, once in 500 years.

Regional maximum flood: The magnitude of a peak discharge based on data from extreme floods, in this case, occurring elsewhere in Nevada and in nearby states.

Probable maximum flood: The hypothetical peak discharge considered to be the most severe reasonably possible based on a probable maximum precipitation and other factors favorable for runoff.

Figure 3-12 shows the extent of estimated floods calculated for the proposed repository before the construction of the Exploratory Studies Facility. It shows the area that the estimated 100- and 500-year floods would inundate as well as the inundation area for the most conservative (highest) of the estimated maximum floods. As indicated on the figure, the partial or discontinuous inundation areas in Midway

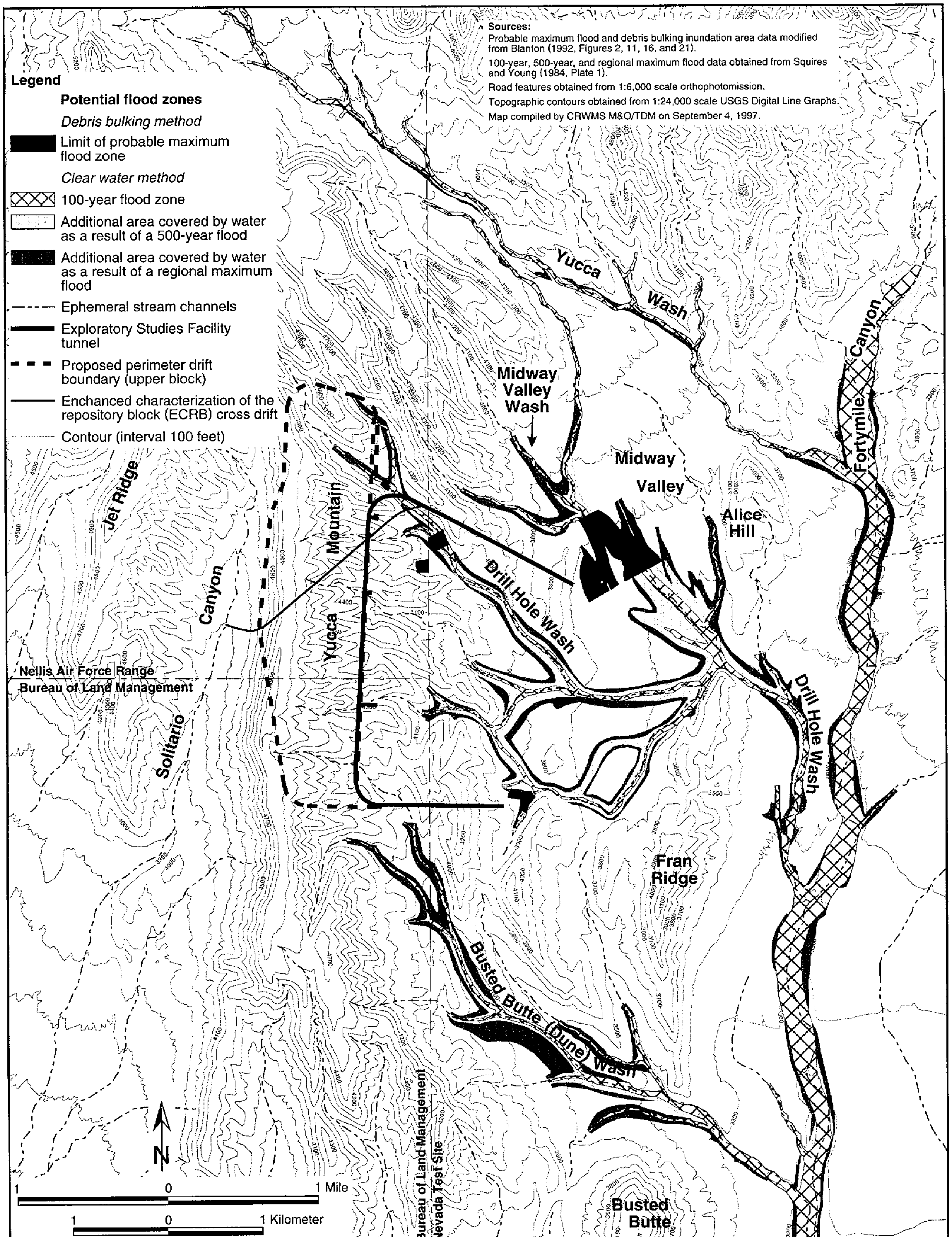


Figure 3-12. Site topography and potential flood areas.

Table 3-9. Estimated peak discharges along washes at Yucca Mountain.[a]

Name	Drainage area (square kilometers)[b]	Peak discharge 100-year flood (cubic meters per second)[c]	Peak discharge 500-year flood (cubic meters per second)	Regional maximum flood (cubic meters per second)
Fortymile Wash	810	340	1,600	15,000
Busted Butte (Dune) Wash	17	40	180	1,200
Drill Hole Wash[d]	40	65	280	2,400
Yucca Wash	43	68	310	2,600

a. Source: TRW (1999h, page 2-4).
b. To convert square kilometers to square miles, multiply by 0.3861.
c. To convert cubic meters to cubic feet, multiply by 35.314.
d. Includes Midway Valley and Coyote Washes as tributaries—North and South Portal Areas.

Valley Wash and the upper reaches of Drill Hole Wash are based on the probable maximum flood values derived in accordance with guidelines of the American National Standards Institute and American Nuclear Society; for other areas, the most extensive flood zones are based on the regional maximum flood levels listed in Table 3-9. The figure also shows that all floods along Fortymile Wash and Yucca Wash would remain within existing stream channels.

Along Busted Butte (Dune) and Drill Hole Washes, the 500-year flood would exceed stream channels at several places, and the probable maximum flood would inundate broad areas in Midway Valley Wash near the North Portal. In no case, however, would flood levels reach either the North or South Portal opening to the subsurface facilities, which would be at either end of the Exploratory Studies Facility tunnel shown in the figure.

The U.S. Geological Survey (Thomas, Hjalmarson, and Waltemeyer 1997, all) recently published a revised methodology for calculating peak flood discharges in the southwestern United States. A preliminary evaluation indicates that the methodology, if appropriate for use, could result in estimates for 100-year floods that are larger than those listed in Table 3-8 and shown in Figure 3-12. However, the new methodology affects only the 100-year flood estimate, so discharge numbers and expanded inundation lines resulting from its use would be within the bounds set by the 500-year flood.

DOE has prepared a floodplain assessment for the Proposed Action in accordance with the requirements of 10 CFR Part 1022. Appendix L contains the floodplain assessment.

Surface-Water Quality. Samples of stream waters in the Yucca Mountain region have been collected and analyzed for their general chemical characteristics. Because surface-water flows are rare and in immediate response to storms, data from sampling events are sparse. Results of the surface-water sample analyses (Table 3-10) bear some resemblance to those from groundwater samples, as discussed in Section 3.1.4.2.2, because both contain bicarbonate as a principal

Table 3-10. Chemistry of surface water in the Yucca Mountain region.[a]

Chemical[b]	Range of chemical composition
pH	6.2 - 8.7
Total dissolved solids (milligrams per liter)	45.0 - 122
Calcium (milligrams per liter)	5.3 - 28.0
Magnesium (milligrams per liter)	0.2 - 4.0
Potassium (milligrams per liter)	3.0 - 11.0
Sodium (milligrams per liter)	2.4 - 46.0
Bicarbonate (milligrams per liter)	32.0 - 340.0
Chloride (milligrams per liter)	1.3 - 13.0
Sulfate (milligrams per liter)	2.8 - 26.0
Silica (milligrams per liter)	4.5 - 48.0

a. Source: TRW (1998a, Table 6.2-5a); TRW (1999h, page 2-8).
b. Based on samples from 15 different surface-water locations (12 involve a single sampling event, 2 involve two sampling events, and 1 involves three sampling events) collected from 1984 to 1995. One milligram per liter is equivalent to one part per million.

component. However, in general, the groundwaters have a higher mineral content, suggesting more interaction between rock and water.

3.1.4.2 Groundwater

This section discusses groundwater, first on a regional basis and then in the Yucca Mountain vicinity. Many studies have been conducted on the groundwater system under and surrounding Yucca Mountain. These studies provide a firm basis of understanding of the hydrology of the region. However, because groundwater systems are complex and difficult to study, there are differences of opinion among experts related to interpreting available data and describing certain aspects of the Yucca Mountain groundwater system. Therefore, this section also discusses the various views on the groundwater system under Yucca Mountain, where viewpoints differ.

3.1.4.2.1 *Regional Groundwater*

The groundwater flow system of the Death Valley region is very complex, involving many aquifers and confining units. Over distance, these layers 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 impermeable to support artesian conditions (where water in a lower aquifer is under pressure in relation to an overlying confining unit; when intersected by a well, the water will rise up the borehole).

In general, the principal water-bearing units of the Death Valley groundwater basin are grouped in three types of saturated hydrogeologic units: basin-fill alluvium (or alluvial aquifer), volcanic aquifers, and carbonate aquifers (TRW 1998a, pages 5.2-4 to 5.2-9). An alluvial aquifer is in a permeable body of sand, silt, gravel, or other detrital material deposited primarily by running water. Volcanic and carbonate aquifers are in permeable units of igneous (of volcanic origin) and carbonate (limestone or dolomite) rock, respectively. The mountainous area that makes up the north portion of the Death Valley hydrologic basin that includes the Yucca Mountain region is often underlain by volcanic rocks and associated volcanic aquifers. The basin areas to the south and southeast of Yucca Mountain contain alluvial aquifers, including those beneath the Amargosa Desert. Carbonate aquifers are regionally extensive and generally occur at large depths below volcanic aquifers or alluvial aquifers (TRW 1998a, page 5.2-8). The discussion of groundwater at Yucca Mountain describes the position of the various aquifers and confining units in relation to each other and to stratigraphic units.

HYDROGEOLOGIC TERMS

Permeability: Describes the ease or difficulty with which water passes through a given material. Permeable materials allow fluids to pass through readily, while less permeable materials inhibit the flow of fluids.

Aquifer: A permeable water-bearing unit of rock or sediment that yields water in a usable quantity to a well or spring.

Confining unit (or aquitard): A rock or sediment unit of relatively low permeability that retards the movement of water in or out of adjacent aquifers.

Inflow: Sources of water flow into a groundwater system such as surface infiltration (recharge) or contributions from other aquifers.

The alluvial aquifers below the Amargosa Desert receive underflow (groundwater movement from one area to another) from sub-basins to the north as well as from sub-basin areas to the east and, therefore, contain a mixture of water from several different aquifers. For example, the volcanic aquifers beneath Yucca Mountain are believed to provide inflow to the alluvial aquifers beneath the Amargosa Desert. In addition, the springs in the Ash Meadows area are fed in part by the carbonate aquifers (Winograd and Thordarson 1975, page C53) and what is not discharged through the springs flows into groundwater moving through the alluvial aquifers at the southeast end of the Amargosa Desert and then discharges at Alkali Flat (Franklin Lake Playa) or continues as groundwater into Death Valley. There is also evidence that indicates a carbonate aquifer might be present below the volcanic sequence, extending from eastern Yucca Mountain south into the Amargosa Desert (Luckey et al. 1996, pages 32 and 40).

Basins. The Death Valley regional groundwater flow system, or basin, covers about 41,000 square kilometers (16,000 square miles) (Harrill, Gates, and Thomas 1988, sheet 1 of 2). Straddling the Nevada-California border, this flow system includes several prominent valleys (Amargosa Desert, Pahrump Valley, and Death Valley) and their separating mountain ranges and extends north to the Kawich Valley, encompassing all of the Nevada Test Site. The major recharge areas are mountains in the east and north portions of the basin. The discharge points are primarily to the south and include the southernmost discharge points in Death Valley and intermediate points such as Ash Meadows in the Amargosa Desert and Alkali Flat. Therefore, flow is primarily to the west or south.

Hydrologic investigations of the Death Valley region date back to the early 1900s, with early work performed primarily by the U.S. Geological Survey (D'Agnese et al. 1997, page 4). More recently, studies by both the U.S. Geological Survey and the State of Nevada have included efforts to collect and compile water-level data from regional wells (TRW 1998a, pages 5.2-17 to 5.2-21). DOE has collected groundwater-level data from wells at Yucca Mountain and in neighboring areas on a routine basis since 1983, and has used the levels to which water rises in these wells—called the *potentiometric surface*—to map the slope of the groundwater surface and to determine the direction of flow. Based on these and other data, groundwater in aquifers below Yucca Mountain and in the surrounding region flows generally south toward discharge areas in the Amargosa Desert and Death Valley (Figure 3-13). The area around Yucca Mountain is in the central portion of the regional groundwater basin, and this portion has three sub-basins: (1) Ash Meadows, (2) Alkali Flat-Furnace Creek Ranch, and (3) Pahute Mesa-Oasis Valley (Rush 1970, pages 10 and 11; Waddell 1982, pages 13 to 20; Luckey et al. 1996, pages 28-30; and D'Agnese et al. 1997, page 65). The aquifers below Yucca Mountain have been included in the Alkali Flat-Furnace Creek Ranch sub-basin because of evidence that the groundwater discharges mainly at Alkali Flat (Franklin Lake Playa) and potentially to the Furnace Creek Wash area of Death Valley.

The Ash Meadows sub-basin is the easternmost of the three sub-basins that make up the Central Death Valley subregion. It underlies eastern portions of the Nevada Test Site (Yucca Flat, Frenchman Flat, Mercury Valley, Rock Valley), parts of Shoshone Mountain, Rainier Mesa to the north, and the Ash Meadows area of the Amargosa Desert in the south. Inflow is principally from the Spring Mountains, Pahranagat Range, Sheep Range, and Pahranagat Valley in the eastern portion of the sub-basin (D'Agnese et al. 1997, pages 67 and 68). Outflow is basically in the form of discharge to the surface and underflow to the lower portion of the Alkali Flat-Furnace Creek Ranch sub-basin. The primary discharge point for this sub-basin is Ash Meadows, where springs occur in a line along a major fault. Estimates of discharge at Ash Meadows range from 21 million to 37 million cubic meters (17,000 to 30,000 acre-feet) per year (Walker and Eakin 1963, page 24; D'Agnese et al. 1997, page 46).

The Pahute Mesa-Oasis Valley sub-basin includes the western portion of Pahute Mesa, Gold Flat, and Oasis Valley. Recharge comes primarily from the north at Black Mountain, Quartz Mountain, and Pahute Mesa, and along the Amargosa River and its tributaries. Subsurface outflow is into the Amargosa Desert

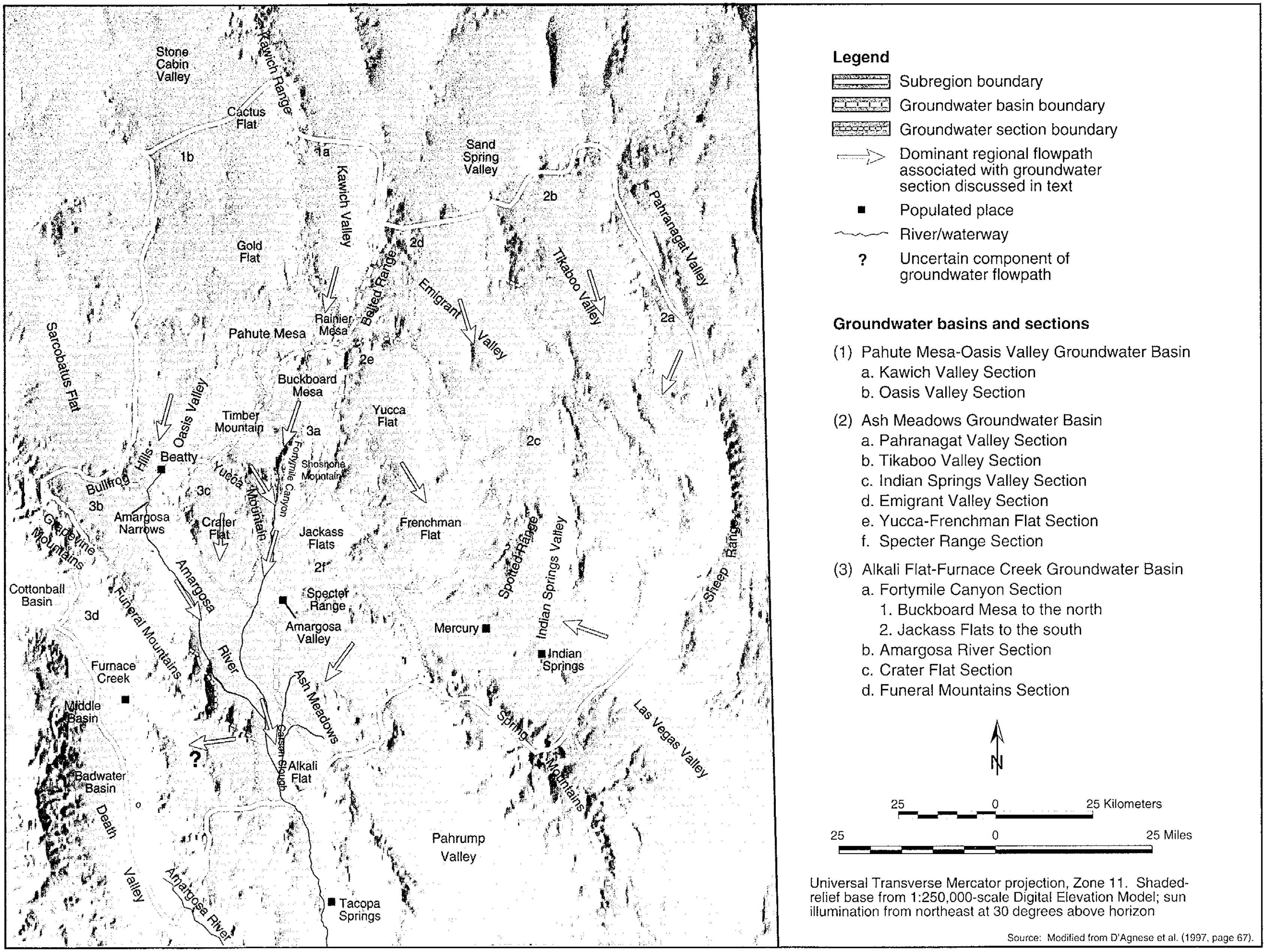


Figure 3-13. Groundwater basins and sections of the Central Death Valley subregion.

of the Alkali Flat-Furnace Creek Ranch sub-basin, and has been estimated at about 0.49 million cubic meters (400 acre-feet) per year (Malmberg and Eakin 1962, page 26).

The Alkali Flat-Furnace Creek Ranch sub-basin is bordered on the northwest by the Pahute Mesa-Oasis Valley sub-basin and on the east by the Ash Meadows sub-basin. This sub-basin includes portions of the Nevada Test Site (parts of Rainier Mesa, Pahute Mesa, and Buckboard Mesa to the north, Shoshone Mountain, Yucca Mountain, and Jackass Flats in the southern half), Crater Flat in the west, and part of Death Valley and the central part of the Amargosa Desert in the south (D'Agnese et al. 1997, pages 67 to 69).

In the immediate vicinity of Yucca Mountain, sources of recharge to the groundwater include Fortymile Wash and precipitation that infiltrates the surface. However, these local sources are not among the primary sources of recharge in the region that makes up the Alkali Flat-Furnace Creek Ranch sub-basin. The primary sources of surface recharge in this region are infiltration on Pahute Mesa, Timber Mountain, and Shoshone Mountain to the north, and the Grapevine and Funeral Mountains to the south (D'Agnese et al. 1997, page 68). One numerical model of infiltration for Yucca Mountain used energy- and water-balance calculations to obtain an average infiltration rate of 6.5 millimeters (0.3 inch) a year over the potential repository area for the current climate. This represents about 4 percent of an average annual precipitation rate of about 170 millimeters (7 inches) at Yucca Mountain. In comparison, areas such as Pahute Mesa, Timber Mountain, and Shoshone Mountain receive more precipitation (DOE 1997e, Plate 1) and have higher estimated percentages of precipitation infiltrating deep into the ground and eventually becoming recharge to the aquifer.

Water infiltrating at Yucca Mountain and becoming recharge to the groundwater would join with water in the Jackass Flats hydrographic area. From there the general direction of groundwater flow is to the Amargosa Desert basin and then Death Valley. There have been many estimates of the amount of groundwater moving along this path. One study (NDCNR 1971, page 50) that is still used extensively by the State of Nevada in its groundwater planning efforts estimated annual groundwater movement of 10 million cubic meters (8,100 acre-feet) from the Jackass Flats basin to the Amargosa Desert basin and 23.4 million cubic meters (19,000 acre-feet) from the Amargosa Desert basin to Death Valley. DOE studies indicate that the quantity of water that might move through a repository area of 10 square kilometers (2,500 acres) under the low thermal load, assuming 6.5 millimeters (0.3 inch) of infiltration per year, would be about 0.3 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.

As water in the Alkali Flat-Furnace Creek Ranch sub-basin moves south through the Amargosa Desert, eastern portions of the flow are joined by underflow from the Ash Meadows sub-basin (DOE 1998a, Volume 1, pages 2-56 to 2-58). The line of springs formed by discharge from the Ash Meadows sub-basin provides much of the boundary between the two sub-basins. In this area there is a marked decline [about 37 meters (120 feet)] in water table elevation between Ash Meadows and the Amargosa Desert area to the west and south (Dudley and Larson 1976, page 23). This elevation decline indicates that the potential groundwater flow is from Ash Meadows toward the Alkali Flat-Furnace Creek Ranch sub-basin, rather than the opposite. The primary groundwater discharge point for this sub-basin is Alkali Flat (Franklin Lake Playa) as indicated by the potentiometric surface (or slope) of the groundwater and hydrochemical data. A small portion could move toward discharge points in the Furnace Creek area of Death Valley.

Different researchers have speculated that the general flow boundaries of the three sub-basins in the Central Death Valley groundwater basin are in slightly different locations (D'Agnese et al. 1997, page 59). Some studies [for example, Waddell (1982, page 15)] have placed the Kawich Valley area in the Alkali Flat-Furnace Creek Ranch sub-basin rather than in the Pahute Mesa-Oasis Valley sub-basin as shown in Figure 3-13. This uncertainty in general flow boundaries is a reflection of the complex groundwater flow systems in the Death Valley region. The differing interpretations of the sub-basin boundaries do not, however, disagree on the relative location of the aquifers below Yucca Mountain, which are consistently placed in the central Alkali Flat-Furnace Creek Ranch sub-basin.

Use. Table 3-11 summarizes groundwater use in the Yucca Mountain region. The hydrographic areas listed in the table are basically a finer division of the basins and sub-basins discussed above; their locations are consistent with the hydrographic areas shown in Figure 3-13. DOE has been using small amounts of Jackass Flats hydrographic area groundwater for Nevada Test Site operations, and Yucca Mountain activities have contributed to water use from this source. Most water use in the Alkali Flat-Furnace Creek sub-basin, however, occurs south of Yucca Mountain, from the Amargosa Desert alluvial aquifer. Between 1985 and 1992, water use in the Amargosa Desert from this aquifer averaged 8.1 million cubic meters (6,600 acre-feet) a year for agriculture, mining, livestock, and domestic purposes. As Table 3-11 indicates, water use averaged about 17.5 million cubic meters (14,000 acre-feet) a year from 1995 through 1997. As listed in Table 3-11, groundwater in the Amargosa Desert is heavily appropriated—at much higher levels than is actually withdrawn. The Ash Meadows area of the Amargosa Desert has restrictions on groundwater withdrawal as a result of a U.S. Supreme Court decision (Cappaert v. United States 1976, all) to protect the water level in Devils Hole.

Table 3-11. Perennial yield and water use in the Yucca Mountain region.

Hydrographic area[a]	Perennial yield[b,c] (acre-feet per year)[d]	Current appropriations[e,c] (acre-feet per year)	Average annual withdrawals 1995-1997 (acre-feet)	Chief uses
Jackass Flats (Area 227a)	880[f] - 4,000	500[g]	340[h]	Nevada Test Site programs and site characterization of Yucca Mountain. Minor amounts of water are also discharged for tests at Yucca Mountain.
Crater Flat (Area 229)	220 - 1,000	1,200[i]	140[j]	Mining, site characterization of Yucca Mountain
Amargosa Desert (Area 230)	24,000 - 34,000	27,000	14,000[j]	Agriculture, mining, livestock, municipal, wildlife habitat
Oasis Valley (Area 228)	1,000 - 2,000	1,700	N/A[k]	Agriculture, municipal

a. A specific area in which the State of Nevada allocates and manages the groundwater resources. See Figure 3-17.
b. An estimate of the quantity of groundwater that can be withdrawn annually from a basin without depleting the reservoir.
c. Sources: Thiel (1997, pages 5-12); perennial yield values only, DOE (1996f, pages 4-117 and 4-118).
d. An acre-foot is a commonly used hydrologic measurement of water volume equal to the amount of water that would cover an acre of ground to a depth of 1 foot. To convert acre-feet to cubic meters, multiply by 1,233.49; to convert to gallons, multiply acre-feet by 325,851.
e. The amount of water that the State of Nevada authorizes for use; the amount used might be much less. These appropriations do not cover Federal Reserve Water Rights held by the Nevada Test Site or Air Force.
f. The low estimate for perennial yield from Jackass Flats breaks the quantity down further into 300 acre-feet for the eastern third of the area and 580 acre-feet for the western two-thirds.
g. Area 227a appropriations include about 370 acre-feet for Yucca Mountain characterization activities.
h. Source of Area 227a withdrawals: Bauer et al. (1996, page 702) and Bostic et al. (1997, page 592) for withdrawals from wells J-12 and J-13 at the Nevada Test Site.
i. Area 229 appropriations include temporary mining rights and 61 acre-feet for Yucca Mountain characterization activities.
j. Sources of Area 229 and 230 withdrawals: La Camera, Westenburg, and Locke (1996, page 74) and La Camera and Locke (1997, page 77).
k. N/A = not available.

Table 3-11 lists water volumes (perennial yield, appropriations, and withdrawals) in acre-feet. This unit of volume is common in hydrology and water resource planning. This EIS describes water volumes in both metric (cubic meters) and English (acre-feet) units.

Groundwater Quality. The U.S. Geological Survey has accumulated and evaluated almost 90 years of groundwater data for the Yucca Mountain region and, in more recent years, has periodically collected and analyzed groundwater quality samples. A recent sampling effort (Covay 1997, all) looked for a wide range of inorganic and organic constituents, as well as general water quality properties. This effort collected samples from five groundwater sources in the Amargosa Desert region and three from the immediate vicinity of Yucca Mountain (as discussed in Section 3.1.4.2.2). The regional sampling locations included two wells in the central Amargosa Desert, one well in the Ash Meadows area, and two springs along the border between the Alkali Flat-Furnace Creek Ranch sub-basin and the Ash Meadows sub-basin.

> **ENVIRONMENTAL PROTECTION AGENCY DRINKING WATER QUALITY STANDARDS**
>
> **Primary standards** are health-based and enforceable for all public drinking water supply systems (including the existing system at the site of the proposed repository).
>
> **Secondary standards** control substances that primarily affect aesthetic qualities (such as taste, odor, and color). They are not Federally enforceable and, if exceeded, would generally not cause health problems.

The U.S. Geological Survey effort compared the regional groundwater quality measurements to the primary and secondary drinking water standards established by the Environmental Protection Agency [EPA 1993, all; see also the Safe Drinking Water Act, as amended, 42 USC 300(f) *et seq.*]. Though drinking water standards are for public water supply systems, it is common to compare results from groundwater sampling and analysis to these standards for an indication of groundwater quality. The findings indicated that the five groundwater sources met primary drinking water standards, but that a few sources exceeded secondary and proposed standards. Specifically, four of the wells exceeded a proposed standard for radon (Section 3.1.8.2 discusses the natural occurrence of radon in the Yucca Mountain region) and one of those four exceeded secondary standards for sulfate and total dissolved solids and a proposed standard for uranium. Overall, however, regional groundwater quality is generally good and consistent with the State of Nevada description that most groundwater aquifers in the State are suitable, or marginally suitable, for most uses (NDWP 1999a, all). Additional water quality data for wells on the Nevada Test Site are available in the *Final Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada* (DOE 1996f, pages 4-124 to 4-126). Section 3.1.4.2.2 discusses radiological parameters, including results from regional sample locations.

3.1.4.2.2 *Groundwater at Yucca Mountain*

Groundwater at Yucca Mountain occurs in an unsaturated zone and a saturated zone. This section describes these zones and the characteristics of the groundwater in them.

Unsaturated Zone

Water Occurrence. The unsaturated zone at Yucca Mountain extends down from the crest of the mountain 500 to 750 meters (about 1,600 to 2,500 feet) to the water table (the upper surface of the saturated zone). The primary emplacement area (the upper block) of the proposed repository would be in the unsaturated zone, between about 175 and 365 meters (570 and 1,200 feet) above the present water table. The excavation of the Exploratory Studies Facility encountered very limited quantities of water, and no dripping water or water in sufficient quantities to collect. Some moist areas were observed during excavations through the Paintbrush nonwelded tuff (Figure 3-14) (Peters 1999, all). Boreholes in the

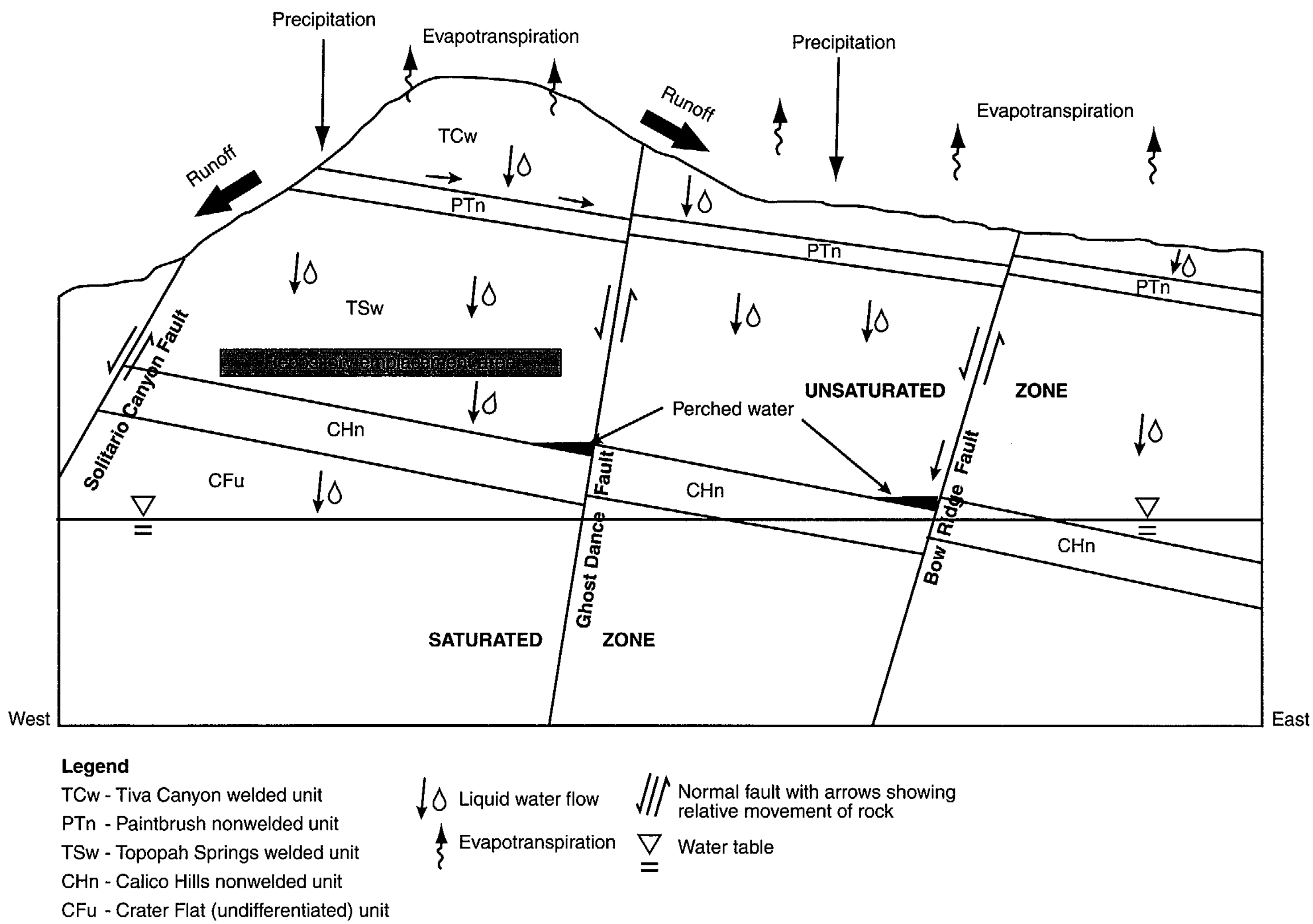
> **SUBSURFACE FORMATIONS CONTAINING WATER**
>
> **Unsaturated zone:** The zone of soil or rock between the land surface and the *water table.*
>
> **Saturated zone:** The region below the *water table* where rock pores and *fractures* are completely saturated with *groundwater.*
>
> **Perched water bodies:** Saturated lenses (thin layers of water) surrounded by unsaturated conditions.

unsaturated zone identified water in the rock matrix, along faults and other fractures, and in isolated saturated zones of perched water (Figure 3-14). The water found in the pores of the rock matrix is chemically different from water found in fractures, perched water, or water in the saturated zone. Perched water in Yucca Mountain occurs where fractured rock overlies rock of low permeability such as unfractured rock, and upslope from faults where permeable or fractured rock lies against less permeable rock and fault fill material. Perched water bodies occur approximately 100 to 200 meters (330 to 660 feet) below the proposed repository horizon (TRW 1998a, page 5.3-236) near the base of the Topopah Spring welded tuff unit (Figure 3-14). Water flow along fractures probably is responsible for recharging the perched water bodies. The apparent age of the perched water based on carbon-14 dating indicates this recharge occurred during the past 6,000 years. Although there are limitations in the use of carbon-14 dating on water (such as knowing the initial activity of carbon-14, estimating sources of losses or gains, and adjusting for postnuclear age contributions), the general conclusion is that the perched water is much too recent to indicate large contributions from pore water in the rock matrix. To learn how recently recharge might have occurred, these dating efforts also looked for the presence of tritium, which would indicate contributions from water affected by atmospheric nuclear weapons tests (after 1952). The results indicate that if tritium has reached the perched water bodies, it is in quantities too small for reliable detection.

Hydrologic Properties of Rock. The unsaturated zone at Yucca Mountain consists of small areas of alluvium (clay, mud, sand, silt, gravel, and other detrital matter deposited by running water) and colluvium (unconsolidated slope deposits) at the surface underlain by volcanic rocks, mainly fragmented materials called tuffs that have varying degrees of welding. The hydrologic properties of tuffs vary widely. Some layers of tuff are welded and have low matrix porosities, but many contain fractures that allow water to flow more quickly than through the rock. Other layers, such as nonwelded and bedded tuff, have high matrix porosities but few fractures. Some layers have many small hollow bubble-like structures (called lithophysae) that tend to reduce water flow in the unsaturated zone.

> **TYPES OF TUFF**
>
> **Welded tuff** results when the volcanic ash is hot enough to melt together and is further compressed by the weight of overlying materials.
>
> **Non-welded tuff** results when volcanic ash cools in the air sufficiently that it does not melt together, yet later becomes rock through compression.

Rock units defined by a set of hydrologic properties do not necessarily correspond to rock units defined by geologic properties and characteristics. For geologic studies, rocks are generally divided on the basis of characteristics that reflect the rock origin and manner of deposition. Hydrogeologic units, on the other hand, reflect the manner in which water moves through the rock. A stratigraphic unit and a hydrogeologic unit commonly do not represent the same layer of rock. For example, a single stratigraphic unit (such as tuff flow) might have been generated by an igneous or volcanic flow. Because of different cooling rates at different depths, a single volcanic flow unit might have layers with different degrees of welding that cause water to move at different rates. The result of this example is a single stratigraphic.



Source: Modified from TRW (1999h, Figure 2-4, page 2-15).

Figure 3-14. Conceptual model of water flow at Yucca Mountain.

unit that includes more than one hydrogeologic unit. Further, because the physical processes of water movement are very different under unsaturated conditions than under saturated conditions, the hydrogeologic units defined in the unsaturated zone can differ from those defined when the same rock sequence is saturated. Figure 3-15 shows the relationship between the stratigraphic units discussed in Section 3.1.3 and the hydrogeologic units discussed in this section, including the aquifers and confining units that make up the area's groundwater system. Table 3-12 lists the hydrogeologic units in the unsaturated zone at Yucca Mountain.

Table 3-12. Hydrogeologic units in the unsaturated zone at Yucca Mountain.[a]

Unit and characteristics[b]	Thickness (meters)[c]
Quaternary alluvium/colluvium Unconsolidated stream deposits beneath valleys and loose slump deposits beneath slopes; porosity and permeability medium to high.	0 - 30
Tiva Canyon welded unit (TCw) Mainly pyroclastic flow tuffs; porosity typically 10 to 30 percent; saturation commonly 50 to 80 percent.	0 - 150
Paintbrush nonwelded unit (PTn) Includes the Yucca Mountain and Pah Canyon Tuffs and uppermost part of the welded Topopah Spring Tuff; porosity generally high, 30 to 60 percent; matrix saturation, 30 to 60 percent.	20 - 100
Topopah Spring welded unit (TSw) Mainly devitrified ash flow tuff; porosity generally low, less than 20 percent, but up to 40 percent in glassy zones; matrix saturation generally greater than 40 percent, commonly greater than 80 percent.	290 - 360
Calico Hills nonwelded unit (CHn) Made up of four subunits, the lower three of which contain zeolites; the unit also includes Prow Pass Tuff (pyroclastic flow) of the Crater Flat Group; porosity variable, 10 to 40 percent; matrix saturation 20 to 90 percent, commonly near 100 percent in zeolitic zones.	100 - 400
Crater Flat undifferentiated unit (CFu) Consists of welded Bullfrog Tuff (stratigraphically above) and nonwelded Tram Tuff (stratigraphically below); is below water table in much of the area, but is unsaturated beneath western part of Yucca Mountain; Bullfrog Tuff has low porosity, less than 20 percent, and high matrix saturation, close to 100 percent; Tram Tuff has porosity 20 to 40 percent; and high matrix saturation.	0 - 200

a. Source: TRW (1999h, pages 2-12 and 2-13).
b. Letters in parentheses are used in Figures 3-14 and 3-15.
c. To convert meters to feet, multiply by 3.2808.

Water Source and Movement. When precipitation falls on Yucca Mountain, part leaves as runoff, part evaporates, and part infiltrates the ground. Some of the water that infiltrates the ground eventually evaporates in the arid climate or passes to plants; the remainder percolates into the ground as infiltration. Some of the infiltration remains at shallow levels, some eventually rises to the surface as vapor, and some (called *net infiltration*) moves deeper into the unsaturated zone. The estimated net infiltration for the current climate is 4.5 millimeters (0.2 inch) per year in a study area of about 230 square kilometers (89 square miles) that includes Yucca Mountain and 6.5 millimeters (0.3 inch) per year in the potential repository area (Flint, Hevesi, and Flint 1996, page 91). These are estimates of average net infiltration for fairly large surface areas. Because of the arid climate, the sporadic nature of storms, and the variation in topography, the actual amount of annual infiltration varies widely from year to year and across the area. Net infiltration varies over segments of the larger areas based, in part, on the amount of unconsolidated material present. The estimated net infiltration ranges from zero where alluvium is more than 6 meters (20 feet) thick to 8 centimeters (3 inches) and more where thin alluvium overlies highly permeable bedrock. On a year-to-year basis, the average net infiltration can range from 0 to 2 centimeters (0.8 inch).

Era	Geologic Age	Stratigraphic unit	Approximate range of thickness (meters)	Hydrogelogic units: Unsaturated	Hydrogelogic units: Saturated	Comments
Cenozoic Era	Quaternary and Tertiary Periods	Alluvium, colluvium, eolian deposits, spring deposits, basalt lavas, lacustrine deposits, playa deposits	0-30	QAL, alluvium	QTa, Valley-fill aquifer; QTc, valley-fill confining unit	QAL restricted to stream channels on Yucca Mountain; QTa occurs mainly in Amargosa Desert; major water-supply source
	Tertiary Period	Timber Mountain Group Rainier Mesa Tuff				Minor erosional remnants at Yucca Mountain
		Paintbrush Group Tiva Canyon Tuff	0-150	TCw Tiva canyon welded unit		Mainly densely welded; caprock on Yucca Mountain; not known in saturated zone at or near Yucca Mountain
		(bedded tuff) Yucca Mountain Tuff Pah Canyon Tuff	20-100	PTn Paintbrush nonwelded unit		Includes bedded and nonwelded tuffs between basal part of Tiva Canyon Tuff and upper part of Topopah Spring Tuff.
		Topopah Spring Tuff (vitrophyre and non-welded tuffs at base)	290-360	TSw Topopah Spring welded unit	uva, Upper volcanic	About 300 meters of densely welded tuff in unsaturated zone; host rock for repository; in saturated zone where downfaulted to east, south, and west of site
		Calico Hills Formation	100-400	CHn Calico Hills nonwelded unit	uvc, Upper volcanic confining unit	Mainly nonwelded tuff, with thin rhyolite lavas in northern site area; varies from vitric in southwest site area to zeolitic where near or below water table
		Crater Flat Group Prow Pass Tuff Bullfrog Tuff Tram Tuff	0-200	CFu Crater Flat undifferentiated unit	mva Middle volcanic aquifer units	Small occurrence in unsaturated zone; widespread in saturated zone; variably welded ash-flow tuffs and rhyolite lavas; commonly zeolitized; most permeable zones are fracture-controlled
		Unnamed flow breccia Lithic Ridge Tuff	1,000-2,000		mvc, Middle volcanic confining unit	Nonwelded tuff, pervasively zeolitized
		Volcanics of Big Dome			lva, Lower volcanic aquifer	Lava flows and welded tuff; not known at Yucca Mountain
	(Lower Tertiary?)	Older volcanics			lvc, Lower volcanic confining unit	Nonwelded tuff, pervasively zeolitized; tuffaceous sediments in lower part
Paleozoic Era	Permian/ Pennsylvanian Periods	Bird Spring Formation Tippipah Limestone	1,000 ±		uca, Upper carbonate aquifer	Limited distribution in saturated zone north and east of Yucca Mountain
	Mississipian/ Devonian Periods	Eleana Formation (Chainman Shale)	2,500 ±		ecu, Eleana confining unit	Argillite (mudstone) and siltstone; occurrence inferred beneath volcanics of northern Yucca Mountain
	Devonian Silurian Ordovician Cambrian Periods	Devils Gate Limestone, Nevada Formation, Ely Springs Dolomite, Eureka Quartzite, Pogonip Group, Nopah Formation, Dunderberg Shale, Bonanza King Formation, Upper Carrara Formation	7,500 ±		lca, Lower carbonate aquifer	Mainly limestone and dolomite with relatively thin shales and quartzites; major regional aquifer, more than 5 kilometers (3.1 miles) thick
		Lower Carrara Formation			zcu, Precambrian confining unit	Dolomite, shale
Proterozoic (Upper Precambrian)		Proterozoic rocks				Quartzite, slate, marble; fractures commonly healed by mineralization

Source: Modified from TRW (1999h, Figure 2-3, pages 2-10 and 2-11).

Figure 3-15. Correlation of generalized stratigraphy with unsaturated and saturated hydrogeologic units in the Yucca Mountain vicinity.

Groundwater movement in the unsaturated zone at Yucca Mountain occurs in the pore space (matrix) of rock units and along faults and fractures of rock units. Water movement through the pore space of rock units is a relatively slow (or stagnant) process compared with flow through faults and fractures. Water movement through faults and fractures is believed to be episodic in nature (occurring at discrete times related to periods of high surface infiltration), is capable of traveling rapidly through rock units, and is the likely source of perched water in the unsaturated zone.

The characteristics of groundwater movement through specific rock units differ based on their hydrogeologic properties. Water that infiltrates into the Tiva Canyon welded unit can often be transported as deep as the underlying Paintbrush nonwelded unit. Due to its high porosity and low fracture density, the Paintbrush unit tends to slow the downward velocity of water flow dramatically in relation to highly fractured units such as the Tiva Canyon unit. However, isotopic (chlorine-36) analysis has identified isolated pathways that provide relatively rapid water movement through the Paintbrush nonwelded unit to the top of the underlying Topopah Springs welded unit where, due to increased fracturing, it has the potential to travel quickly through the unit.

CHLORINE-36 STUDIES

These studies use the fact that a very small portion of chlorine in the atmosphere consists of the radioactive isotope chlorine-36. The production of chlorine-36 (caused in part by interactions between argon molecules and high-energy protons and neutrons in the atmosphere) is sufficiently balanced with the rate of its removal as atmospheric fallout that the ratio of chlorine-36 to stable chlorine (chlorine-35) at any given location remains fairly constant in atmospheric salts deposited on land, such as that dissolved in rainwater. Once chlorine is isolated from the surface environment (as when dissolved in water percolating down through the soil and subsurface rocks), subsequent changes in the chlorine-36-to-total-chlorine ratio can be attributed to decay of the chlorine-36 (Levy et al. 1997, page 2) (that is, if the residence times are long enough in relation to the 301,000-year half-life of this radionuclide). Measuring the chlorine-36-to-total-chlorine ratio in underground water or in residues it leaves behind, and knowing what the ratio was at the time of recharge provides a means of estimating the age of the water. In reality, slight variations over time in the atmospheric ratio and the potential for some minor production of chlorine-36 in the subsurface has made the use of this technique for water dating difficult, and its use is still under investigation. However, the atmospheric ratio of chlorine-36 to total chlorine has increased by orders of magnitude as a result of above-ground nuclear testing during the past 50 years. As a consequence, the technique has been very successful in tracing underground water or water residues that originated at the surface within the past 50 years, with the so-called *bomb-pulse signal* indicating very young water.

DOE has used the ratio of chlorine-36 (a naturally occurring isotope) to total chlorine to determine where and when moisture has moved in the unsaturated zone at Yucca Mountain. High enough chlorine-36 ratios indicate waters exposed to very small amounts of fallout associated with above-ground nuclear weapons testing (called bomb-pulse water). The methodology used in these studies is complicated and is still under investigation; however, findings thus far have been valuable in reaching certain conclusions.

Chlorine-36 analyses at Yucca Mountain have identified locations where water has moved fairly rapidly (in several decades) from the surface to the depth of the proposed repository and also where it has moved very slowly (thousands to tens of thousands of years). The chlorine-36 studies included one study that collected 247 rock samples along the 8-kilometer (5-mile) Exploratory Studies Facility tunnel. About 70 percent of the samples were from areas thought to be more likely to show evidence of rapid water movement [that is, areas of broken rock such as faults, fractures, or breccia zones (areas where rock composed of fragments of older rocks melded together)].

Most of the samples (87 percent) had ratios that were ambiguous in that they fell within the range over which the chlorine-36-to-total-chlorine ratio has varied over the last 50,000 years or more. Results of these samples indicate that the groundwater travel times from the surface to the repository depth in most areas probably are thousands to tens of thousands of years. This is because there is little evidence for measurable radioactive decay of the chlorine-36 signal in the subsurface. However, a few samples indicated ratios low enough to suggest the possible presence of zones of relatively old or stagnant water (TRW 1998a, page 5.3-176). Further, the data indicate that, away from fault zones, travel times to the repository horizon correlate with the thickness of the overlying nonwelded Paintbrush unit. The shortest travel times (less than 10,000 years) occur in the southern part of the Exploratory Studies Facility where the unit is thinnest.

About 13 percent of the samples (31 samples) had high enough chlorine-36-to-total-chlorine ratios to indicate the water originated from precipitation occurring in the past 50 years (that is, nuclear age precipitation) (TRW 1998a, page 5.3-176). Locations where bomb-pulse water occurred were correlated with the physical conditions in the mountain and on the surface that could lead to, or otherwise affect, the findings. The conclusion to date of these ongoing studies is that relatively fast transport of water through the mountain is controlled by the following factors (Fabryka-Martin et al. 1998, page 3-2):

- The presence of a continuous fracture path from the surface: The limiting factor is a fracture or fault cutting the Paintbrush nonwelded bedded tuffs (PTn) hydrogeologic unit (this prominent unit is above the repository horizon; see Figure 3-14 and Table 3-12). Fracture pathways are normally available in the welded portions of the overlying Tiva Canyon and underlying Topopah Spring units. This is consistent with hydrologic modeling of percolation through this nonwelded bedded tuff, which indicates that there must be fracture pathways due to faulting or other disturbances for water to travel through this unit in 50 years or less. Section 3.1.3 discusses fault locations inside Yucca Mountain.

- The magnitude of surface infiltration: There must be enough infiltration to sustain a small component of flow along the connected fracture pathway.

- The residence time of water in the soil cover: This time must be less than 50 years; to achieve this, the depth of the soil overlying the fracture pathway must be less than an estimated 3 meters (10 feet).

Water percolating to the depth of the repository and beyond is affected not only by fractures but also by the nature of the hydrogeologic units it encounters. Pressure testing in boreholes indicates that fractures in the Topopah Spring tuff (the rock unit in which DOE would build the repository) are very permeable and extensively interconnected. Below the repository level, low-permeability zeolite zones impede the vertical flow of water near the Topopah Spring welded unit and its contact with the underlying Calico Hills nonwelded unit, forming perched water bodies. The primary source of the perched water is water traveling down along faults and fractures. In the dipping or sloped strata beneath Yucca Mountain, perched water bodies require vertical impediments such as fault zones where less permeable rock and fault-gouge material block the lateral flow of water (Figure 3-14). If these conditions do not exist at the fault zone, the fault can provide a downward pathway. Even in cases where fault zones are barriers to lateral water flow, they can be very permeable to gas and moisture flow along the fault plane and permit the rapid vertical flow of water from the land surface to great depth. Studies of heat flux above and below the perched water zone appear to indicate more water percolation above the perched water than below. This is consistent with the concept that some of the water moves laterally on top of the zeolite zone before it resumes its downward course to the saturated zone.

Unsaturated Zone Groundwater Quality. DOE has analyzed water from the unsaturated zone, both pore water from the rock matrix and perched water, to obtain information on the mechanisms of recharge and the amount of connection between the two. The preceding sections discuss some of the relevant findings.

Table 3-13 summarizes the chemical composition of perched and pore water samples from the vicinity of Yucca Mountain.

Table 3-13. Water chemistry of perched and pore water samples in the vicinity of Yucca Mountain.[a]

Constituent	Ranges of chemical composition	
	Perched	Pore
pH	7.6 - 8.7	7.7 - 8.4
Total dissolved solids (milligrams per liter)	140 - 330	320 - 360
Calcium (milligrams per liter)	2.9 - 45	1.1 - 62
Magnesium (milligrams per liter)	0 - 4.1	0 - 4.5
Potassium (milligrams per liter)	1.7 - 10	N/A[b]
Sodium (milligrams per liter)	34 - 98	49 - 140
Bicarbonate (milligrams per liter)	110 - 220	170 - 230
Chloride (milligrams per liter)	4.1 - 16	26 - 90
Bromide (milligrams per liter)	0 - 0.41	0
Nitrate (milligrams per liter)	0 - 34	11 - 17
Sulfate (milligrams per liter)	4 - 220	14 - 45

a. Source: Striffler et al. (1996, Table 2).
b. N/A = not available.

The smaller concentrations of dissolved minerals, particularly chloride, in perched water in comparison to those in pore water is a primary indicator of differences between the two. This difference in dissolved mineral concentrations indicates that the two types of water do not interact to a large extent and that the perched water reached its current depth with little interaction with rock. This, in turn, provides strong evidence that flow through faults and fractures is the primary source of the perched water.

Saturated Zone

Water Occurrence. The saturated zone at Yucca Mountain has three aquifers and two confining units. The aquifers are commonly referred to as the upper volcanic aquifer, the lower volcanic aquifer, and the lower carbonate aquifer. The interlayered aquitards (low permeability units that retard water movement) that separate the aquifers are called the upper volcanic confining unit and the lower volcanic confining unit (see Figure 3-15). The upper volcanic aquifer is composed of the Topopah Spring welded tuff, which occurs in the unsaturated zone near the repository but is present beneath the water table to the east and south of the proposed repository. The upper volcanic confining unit includes the Calico Hills nonwelded unit and the uppermost unstructured end of the Prow Pass tuff where they are saturated. The lower volcanic aquifer includes most of the Crater Flat Group, and the lower volcanic confining unit includes the lowermost Crater Flat Group and deeper tuff, lavas, and flow breccias. An upper carbonate aquifer, though regionally important, is not known to occur beneath Yucca Mountain. (The lower volcanic aquifer discussed here corresponds to the middle volcanic aquifer shown in Figure 3-15. The lower volcanic aquifer in Figure 3-15 has not been identified in the area of the proposed repository.)

South of the proposed repository site, downstream in the groundwater flow path from Yucca Mountain, the Tertiary volcanic rocks (and the volcanic aquifers) pinch out and groundwater moves into the valley-fill sediments of the Amargosa Desert (TRW 1998a, page 5.3-7). In the Amargosa Desert south of Yucca Mountain, the most important source of water is an aquifer formed by valley-fill deposits.

The lower carbonate aquifer is more than 1,250 meters (4,100 feet) below the proposed repository horizon. This aquifer, which consists of lower Paleozoic carbonate rocks (limestone and dolomite) that have been extensively fractured during many periods of mountain building (see Section 3.1.3), forms a regionally extensive aquifer system through which large amounts of groundwater flow. Evidence indicates that water in the lower carbonate aquifer is at least as old as most of the water in the volcanic aquifers (with apparent ages in the range of 10,000 to 20,000 years) and, similarly, was recharged during a wetter and cooler climate. Some of the limited carbonate aquifer sample results indicate older water ages (30,000 years and greater), but use of carbon-14 dating on this water has an additional limitation due to the probable contribution of "dead carbon" (nonradioactive) dissolved from the carbonate rock. Limited data show that the level to which water rises in a well that penetrates the lower carbonate aquifer is about 20 meters (66 feet) higher than the water levels in the overlying volcanic aquifers. This indicates that, in the vicinity of Yucca Mountain, water from the lower carbonate aquifer is pushing up against a confining layer with more force than the water in the upper aquifers is pushing down. This suggests that water in the volcanic aquifers does not flow down into the lower carbonate aquifer at Yucca Mountain because it would be moving against a higher upward pressure and that, if mixing occurs, it would be from carbonate to volcanic and not the reverse.

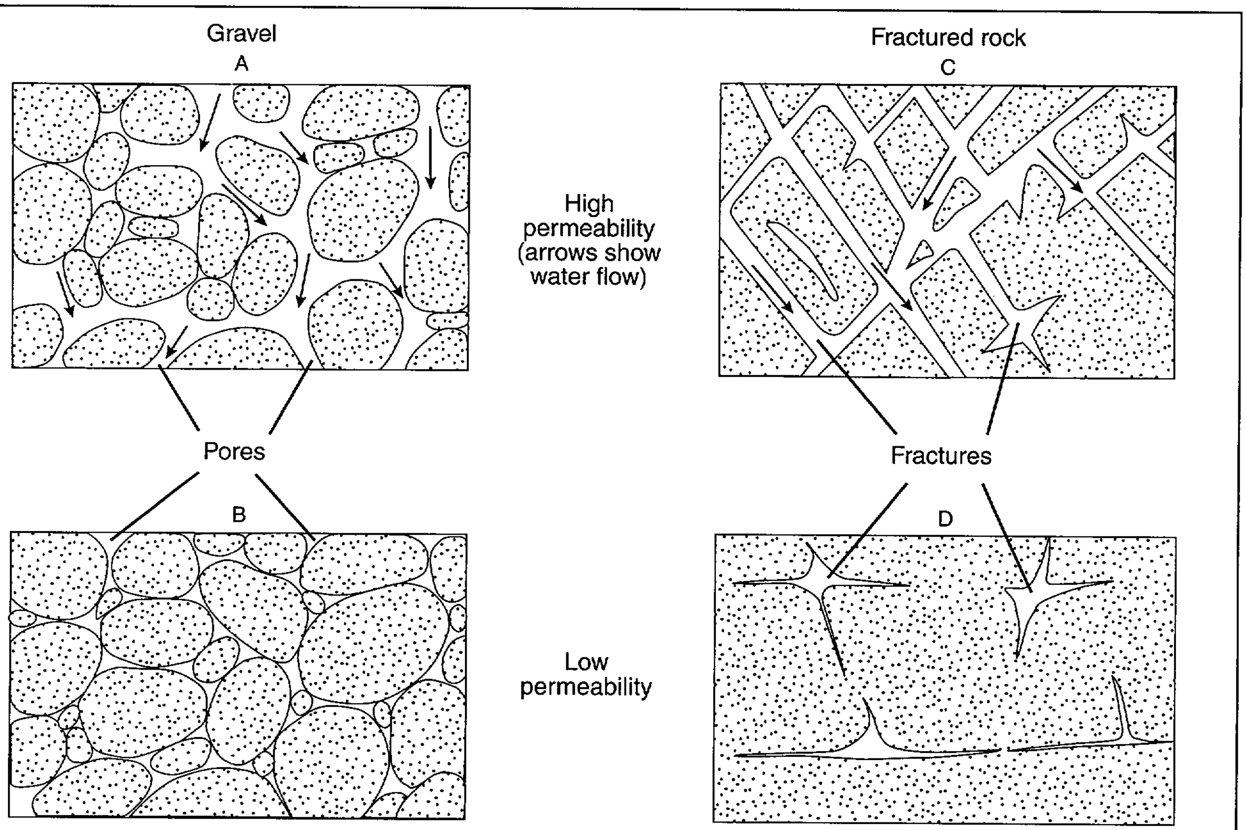
Paleoclimatic (referring to the climate during a former period of geologic time) studies have identified six wetter and cooler periods in the southern Great Basin during late Pleistocene time. These periods occurred 10,000 to 50,000 years ago; 60,000 to 70,000 years ago; 120,000 to 170,000 years ago; 220,000 to 260,000 years ago; 330,000 to 400,000 years ago; and 430,000 to 470,000 years ago. They represent the sequencing of glacial (cooler and wetter) to interglacial (warmer and drier) and back to glacial climates (TRW 1998a, page 4.2-24). During the wetter periods, the elevation of the saturated zone was as much as about 100 meters (330 feet) higher than it is today. The repository would be above this historic maximum elevation (see Section 2.1). Calcite veins and opal were deposited along fractures during the wetter periods. The calcite and opal coatings have been dated by the uranium series method; the calcites have also been dated by the carbon-14 method. The youngest vein deposits are 16,000 years old. The *Yucca Mountain Site Description* (TRW 1998a, pages 4.2-1 to 4.2-41) provides additional information, including supporting evidence, on the timing, magnitude, and character of past climate changes in the Yucca Mountain region.

Several investigators have suggested that the water table in the vicinity of Yucca Mountain has risen dramatically higher than 100 meters (330 feet) above the current level, even reaching the land surface in the past (Szymanski 1989, all). If such an event occurred, it would affect the performance of the proposed repository. These concerns originated in the early- to mid-1980s when surface excavations performed as part of site investigations exposed vein-like deposits of calcium carbonate and opaline silica (TRW 1998a, page 3.4-20). Szymanski (1989, all) hypothesized that the carbonate and silica were deposited by hydrothermal fluids, driven to the surface by pressurization of groundwater by earthquakes (a mechanism called *seismic pumping*) or by thermal processes that occurred in the Yucca Mountain vicinity. A number of investigators and groups, including a National Academy of Science panel specifically designated to look at the issue (National Research Council 1992, all), have examined the model on which this position is based and have rejected its important aspects (Luckey et al. 1996, pages 76-77). The National Research Council panel concluded that the evidence cited as proof of groundwater upwelling in Yucca Mountain and in its vicinity could not reasonably be attributed to that process. In addition, the panel stated its position that the proposed mechanism for upwelling water was inadequate to raise the water table more than a few tens of meters (DOE 1998a, Volume 1, page 2-26). Finally, the panel concluded that the carbonate-rich depositions in fractures were formed from surface water from precipitation and surface processes (TRW 1998a, page 3.4-29).

Another alternative interpretation of past groundwater levels at Yucca Mountain occurs in Dublyansky (1998, all). This study involved the examination of tiny pockets of water (known as *fluid inclusions*) trapped in the carbonate-opal veinlets deposited in rock fractures at Yucca Mountain. According to the report, an analysis of samples collected from the Exploratory Studies Facility includes evidence of trace quantities of hydrocarbons and evidence that the fluid inclusions were formed at elevated temperatures. These findings, and others, are used to support the report's conclusion that the carbonate-opal veinlets were caused by warm upwelling water and not by the percolation of surface water. DOE, given the opportunity to review a preliminary version of the report, arranged for review by a group of independent experts, including U.S. Geological Survey personnel and a university expert. This review group did not concur with the conclusion in the report by Dublyansky (1998, all), which now contains an appendix with the DOE-arranged review comments and the author's responses. Although DOE has disagreed with some of the central scientific conclusions presented in this report, both parties have agreed that additional research is needed to resolve the issues. DOE and the State of Nevada are continuing to evaluate these and other alternative conceptual models and data interpretations.

Hydrologic Properties of Rock. This section discusses the hydrologic properties of rock in the saturated zone, and specifically the aquifers and confining units at Yucca Mountain. As discussed above, these properties depend in part on whether the rocks are saturated. In general, the amount and speed at which water flows through an aquifer depend chiefly on the transmissivity and effective porosity of the rock. *Transmissivity* is a measure of how much water an aquifer can transfer and is equal to the average hydraulic conductivity of the aquifer multiplied by the thickness of the aquifer that is saturated. *Porosity* is the ratio of the rock's void (open) space to its total volume; *effective porosity* is the ratio of interconnected void space to total volume.

Figure 3-16 shows the types of conditions that might exist in gravel and rock aquifers that would make them more or less permeable to water movement. The empty spaces between gravel fragments or in the rock fractures represent the porosity. Although not necessarily representative of conditions at Yucca Mountain, the figure shows that the manner in which void spaces are interconnected, more than their size



A. Gravel with interconnected pore space having relatively high permeability.
B. Gravel with limited interconnected pore space having relatively low permeability.
C. Rock with interconnected fractures having relatively high permeability.
D. Rock with few interconnected fractures having relatively low permeability.

Source: Modified from USGS (1993, page 2).

Figure 3-16. Aquifer porosity and effects on permeability.

or quantity, determines how water can move through the material. At Yucca Mountain, conditions are often such that the rock with the highest porosity is also the rock with the fewest fractures. Because the void spaces are not interconnected very well, such a high-porosity rock has low transmissivity. Because a large portion of the groundwater flow at Yucca Mountain is probably along fractures, representative transmissivity values are difficult to measure. Measurements can vary greatly depending on the nature of the fractures that happen to be intercepted by the borehole and the location in the borehole at which measurements are made. This is reflected in the wide range of transmissivity values listed in Table 3-14, which also lists the characteristics, thicknesses, apparent hydraulic conductivities, and porosities of the three aquifers and two confining units beneath Yucca Mountain. For the lower carbonate aquifer, the table lists a single transmissivity value because there was only a single test for that unit. Similarly, only one apparent hydraulic conductivity value, which is a measure of the aquifer's capacity to transport water, is provided for the lower carbonate aquifer unit because it is based on tests in a single well at Yucca Mountain. However, the value is an average of measurements taken from that well. This and the other hydraulic conductivity values are called *apparent* because they are all based on single-borehole tests. Such measurements, which are believed to represent conditions at a limited distance around the well, could vary greatly depending on whether there are water-bearing fractures in the well zone being tested. When such fractures are present, hydraulic properties measured in a single-borehole test probably reflect conditions only in isolated locations rather than in the overall rock matrix in the test zone.

Table 3-14. Aquifers and confining units in the saturated zone at Yucca Mountain.

Unit	Typical thickness (meters)[a,b,c]	Transmissivity (square meters per day)[d,e]	Apparent hydraulic conductivity (meters per year)[e]	Porosity[f,g] (ratio)
Upper volcanic aquifer Densely welded and densely fractured part of Topopah Spring Tuff	300	120 - 1,600	47 - 6,900	0.036 - 0.16
Upper volcanic confining unit Basal vitrophyre of Topopah Spring Tuff, Calico Hills Formation Tuff, and uppermost nonwelded part of Prow Pass Tuff	90 - 330	2.0 - 26	7.3 - 95	0.17 - 0.35 (Calico Hills)
Lower volcanic aquifer Most of Prow Pass Tuff and underlying Bullfrog and Tram Tuffs of Crater Flat Group	370 - 700	1.1 - 3,200	< 1.4 - 4,700	0.26 - 0.33 (Prow Pass Tuff) 0.12 - 0.26 (Bullfrog Tuff)
Lower volcanic confining unit Bedded tuffs, lava flows, and flow breccia beneath Tram Tuff	370 - > 750	0.003 - 23	0.002 - 40.2	N/A[h]
Lower carbonate aquifer Cambrian through Devonian limestone and dolomite	N/A	120	69	N/A

a. Source: Luckey et al. (1996, Table 2 and Figure 7).
b. To convert meters to feet, multiply by 3.2808.
c. Typical thickness ranges for the upper volcanic confining unit, the lower volcanic aquifer, and the lower volcanic confining unit are based on measurements from 13 boreholes. With respect to the lower volcanic confining unit, only one penetrated and showed a unit thickness of about 370 meters (1,200 feet); of the others, about 750 meters (2,500 feet) was the deepest penetration without passing through. Water was detected in the rock unit that elsewhere makes up the upper volcanic aquifer unit in only one of the 13 boreholes. (Beneath the center of Yucca Mountain, the upper volcanic aquifer is above the saturated zone.) The typical thickness shown here for this unit is based on Figure 7 from Luckey et al. (1996, Figure 7).
d. To convert square meters to square feet, multiply by 10.764.
e. Source: TRW (1998a, Tables 5.3-35 and 5.3-36).
f. Source: TRW (1999h, Table 2-2, page 2-40).
g. Ranges are for means of several hydrogeological subunits.
h. N/A = not available.

Water Source and Movement. Section 3.1.4.2.1 describes the direction of water movement (Figure 3-13), the nature of the rock through which it moves, and where local recharges to and discharges from the aquifer might occur.

When undisturbed by pumping, groundwater levels at Yucca Mountain have been very stable, with long-term measurements generally varying less than 0.1 meter (0.3 foot) since 1983. These small variations are probably due to changes in barometric pressure and Earth tides. In addition, short-term fluctuations in groundwater elevations also have been attributed to apparent recharge events and earthquakes. Water levels in wells have fluctuated by as much as 2.2 meters (7 feet) in response to earthquake events, but the fluctuations are typically of short duration with water levels returning to the pre-earthquake conditions within minutes to a few hours. An exception to this occurred in response to earthquakes in the summer of 1992, when water levels in specific wells at Yucca Mountain fluctuated over several months. At the northern end of Yucca Mountain, the apparent potentiometric surface slopes steeply southward, dropping almost 300 meters (980 feet) in a horizontal distance of 2.5 kilometers (1.6 miles). Experts reviewing the data have suggested several credible reasons for this steep gradient, including that it results from an undetected geological feature with low permeability, that it is caused by groundwater draining to deep aquifers, or that it is a perched water table being encountered in this area (Geomatrix and TRW 1998, pages 3-5 and 3-6). However, there are no obvious geologic reasons for the steep gradient, and it is still under investigation.

The north-trending Solitario Canyon fault, on the west side of Yucca Mountain, apparently impedes the eastward flow of groundwater in the saturated zone. West of the fault, the water table slopes moderately about 20 meters (66 feet) in 0.4 kilometer (0.25 mile), while east of the fault the water table slopes very gently. West of the Solitario Canyon fault groundwater probably flows southward either along the fault or beneath Crater Flat.

The gentle southeastward groundwater gradient east of the Solitario Canyon fault underlies the proposed repository horizon and extends beneath Fortymile Wash and probably farther east into Jackass Flats. This gentle gradient might indicate that the rocks through which the water flows are highly transmissive, that only small amounts of groundwater flow through this part of the system, or a combination of both. This gentle southeastward gradient is a local condition in the regional southward flow of the groundwater.

In an opposing viewpoint about the stability of groundwater levels at Yucca Mountain, Davies and Archambeau (1997, pages 33 and 34) suggests that a moderate magnitude earthquake at the site could cause a southward displacement of the large hydraulic gradient to the north of the proposed repository, resulting in a water table rise of about 150 meters (490 feet) at the site. In addition, that report proposed that a severe earthquake could cause a rise of about 240 meters (790 feet) in the water table, flooding the repository. As part of its study of groundwater flow in the saturated zone, DOE elicited expert opinions on various issues from a panel of five experts in the fields of groundwater occurrence and flow. Among the issues put to the panel were those raised by Davies and Archambeau (1997, all). The panel reviewed the Davies and Archambeau paper and received briefings by project personnel and outside specialists. The consensus of the panel was that a rise of the groundwater to the level of the proposed repository was essentially improbable and that changes to the water table associated with earthquakes would be neither large nor long-lived (Geomatrix and TRW 1998, page 3-14).

Inflow to Volcanic Aquifers at Yucca Mountain. There are four potential sources of inflow to the volcanic aquifers in the vicinity of Yucca Mountain: (1) lateral flow from volcanic aquifers north of Yucca Mountain, (2) recharge along Fortymile Wash from occasional stream flow, (3) precipitation at Yucca Mountain, and (4) upward flow from the underlying carbonate aquifer. The actual and relative amounts of inflow from each source are not known.

North of Yucca Mountain, the potentiometric surface rises steeply toward probable recharge areas on Pahute Mesa (Figure 3-13) and Rainier Mesa. Chemical data indicate that some recharge to the groundwater has occurred everywhere in the Yucca Mountain vicinity during the past 10,000 years, but that most recharge occurred between 10,000 and 20,000 years ago (based on apparent carbon-14 ages) during a wetter climate. From west to east across Yucca Mountain, the age of water in the saturated zone decreases from about 19,000 years to 9,100 years (Benson and McKinley 1985, page 4).

The estimated annual recharge along the 150-kilometer (93-mile) length of Fortymile Wash averages about 4.22 million cubic meters (3,400 acre-feet). Much of the recharge occurs during and after heavy precipitation when water flows in the wash. On rare occasions, Fortymile Wash carries water to Jackass Flats and into the Amargosa Desert. After several periods of flow in Fortymile Wash during 1992 and 1993, water levels in nearby wells rose substantially. Earlier studies found that shallow water in some wells was younger than water deeper in the wells, indicating that recharge was occurring. Paleoclimatic evidence suggests that a perennial stream might have existed in Fortymile Wash 25,000 to 50,000 years ago, and that substantial recharge might have occurred as recently as 15,000 years ago.

Recharge to the saturated zone below Yucca Mountain from precipitation is probably small in comparison to inflow from volcanic aquifers to the north or recharge along Fortymile Wash (see the unsaturated zone discussion). An average net infiltration of 4.5 millimeters (0.2 inch) over a 220-square-kilometer (85-square-mile) vicinity around Yucca Mountain would produce a quantity of recharge less than one quarter of the estimated annual recharge along Fortymile Wash.

Monitoring well data collected during the site characterization effort have shown that the potentiometric surface of the carbonate aquifer (that is, the level to which water rises in wells tapping this aquifer), at least in the immediate vicinity of Yucca Mountain, is higher than the water level in the overlying volcanic aquifer. Based on this and other considerations, studies suggest that, provided structural pathways exist, the lower carbonate aquifer might provide upward flow to the volcanic aquifer beneath the proposed level of the repository and farther south. The amount of inflow, if it occurs, is not known.

Outflow from Volcanic Aquifers at and Near Yucca Mountain. Pathways by which water might leave the volcanic aquifers in the Yucca Mountain vicinity include (1) downgradient movement into other volcanic aquifers and alluvium in the Amargosa Desert, (2) downward movement into the carbonate aquifer (though evidence indicates that this does not occur), and (3) upward movement into the unsaturated zone. In addition, water is pumped from wells for a variety of uses, as described in Section 3.1.4.2.1. With the exception of well withdrawals, the actual and relative amounts of outflow from each source are not known.

The regional slope of the potentiometric surface indicates that much of the groundwater flowing southward beneath Yucca Mountain discharges about 80 kilometers (50 miles) to the south at Alkali Flat (Franklin Lake Playa) and in Death Valley. Death Valley, more than 80 meters (260 feet) below sea level, is the final sink for surface water and groundwater in the Death Valley groundwater basin (Figure 3-13); as such, water leaves only by evapotranspiration. Therefore, the pathway for groundwater beneath Yucca Mountain, as indicated by the potentiometric surface, is southerly where it traverses portions of the volcanic aquifers before encountering the basin-fill alluvium and carbonate rock that underlie the Amargosa Valley.

Outflow from the volcanic aquifers into the underlying carbonate aquifer might occur, but direct evidence for this does not exist. Studies suggest that the steeply sloping potentiometric surface at the north end of Yucca Mountain could be explained by a large outflow from the volcanic aquifers to the carbonate aquifer. However, in the vicinity of Yucca Mountain, data available on the potentiometric head of the carbonate aquifer indicate that the opposite condition (that is, outflow from the carbonate aquifer up to the volcanic aquifer) is more likely.

The third possible pathway of outflow from the volcanic aquifer (that is, upward movement to the unsaturated zone), if present, has not been quantified. However, consistent with the above discussion of net infiltration, DOE believes that there is a net downward movement of water in the unsaturated zone in the vicinity of Yucca Mountain.

Use. Two wells, J-12 and J-13 (shown in Figure 3-17), are part of the water system for site characterization activities at Yucca Mountain. These are the nearest production wells to Yucca Mountain and they support water needs for Area 25 of the Nevada Test Site and for Exploratory Studies Facility activities. Both of these wells withdraw groundwater from the Jackass Flats hydrographic area, as listed in Table 3-11. Groundwater has also been pumped from the Jackass Flats area from various boreholes for hydraulic testing, and most recently from the C-well complex, which consists of three separate wells grouped in an area just east of the South Portal Operations Area (Luckey et al. 1996, Figure 17). In addition, water has been pumped occasionally from borehole USW VH-1 (also designated CF-2) in support of Yucca Mountain characterization activities. But the volume pumped from this well, which is in the Crater Flat hydrographic area, is small (Luckey et al. 1996, page 70).

The Yucca Mountain Site Characterization Project has received water appropriation permits (Numbers 57373, 57374, 57375, and 57376) from the State of Nevada for wells J-12, J-13, VH-1 (also known as F-2), and the C-Well complex (Numbers 58827, 58828, and 58829), and a Potable Water Supply permit (NY-0867-12NCNT) for the distribution system. The permits allow a maximum pumping rate of about 0.028 cubic meter (1 cubic foot) a second, with a maximum yearly withdrawal of about 530,000 cubic meters (430 acre-feet). The permit limits apply to site characterization water use. Table 3-15 lists historic and projected water use from wells J-12 and J-13 from 1992 to 2005 for the Exploratory Studies Facility and Concrete Batch Plant, and from the C-Wells, which is pumped and then reinjected as part of aquifer testing. It also lists the total amount of water pumped from wells J-12 and J-13 for both Yucca Mountain and the Nevada Test Site. The difference between the quantities pumped from wells J-12 and J-13 for Yucca Mountain activities and the total withdrawals from these wells represents the quantities used for Nevada Test Site activities in the area. The water-use projections in Table 3-15 are through the end of site characterization activities; Section 4.1.3 discusses water demand projections for the proposed repository.

The U.S. Geological Survey, in support of Yucca Mountain characterization efforts and in compliance with the State permits, has kept records of the amount of water pumped from the J-12 and J-13 wells and of measured water elevation levels in those and other wells in their immediate area since 1992 (La Camera and Locke 1997, pages 1 and 2). One of the objectives of keeping these records is to detect and document changes in groundwater resources during the Yucca Mountain investigations. Therefore, the Survey effort included the collection of historic water elevation data to establish a baseline. Results from these efforts have been documented in annual reports. The report for 1997 (La Camera, Locke, and Munson 1999, all) includes a summary of 1996 results and detailed results for 1997. Table 3-16 summarizes the changes observed in median groundwater elevations in seven wells in Jackass Flats. The second column of the table identifies the historic or baseline elevation for each well against which the annual median values are being compared. In addition, the table lists the average deviation of measured water levels during the period from which the baseline was generated.

The elevation changes listed in Table 3-16 are different from the short-term fluctuations described above that are a response to changes in barometric pressure and Earth tides. The differences in comparison of annual median values should indicate water level trends, if there are any. The data show that a decline in

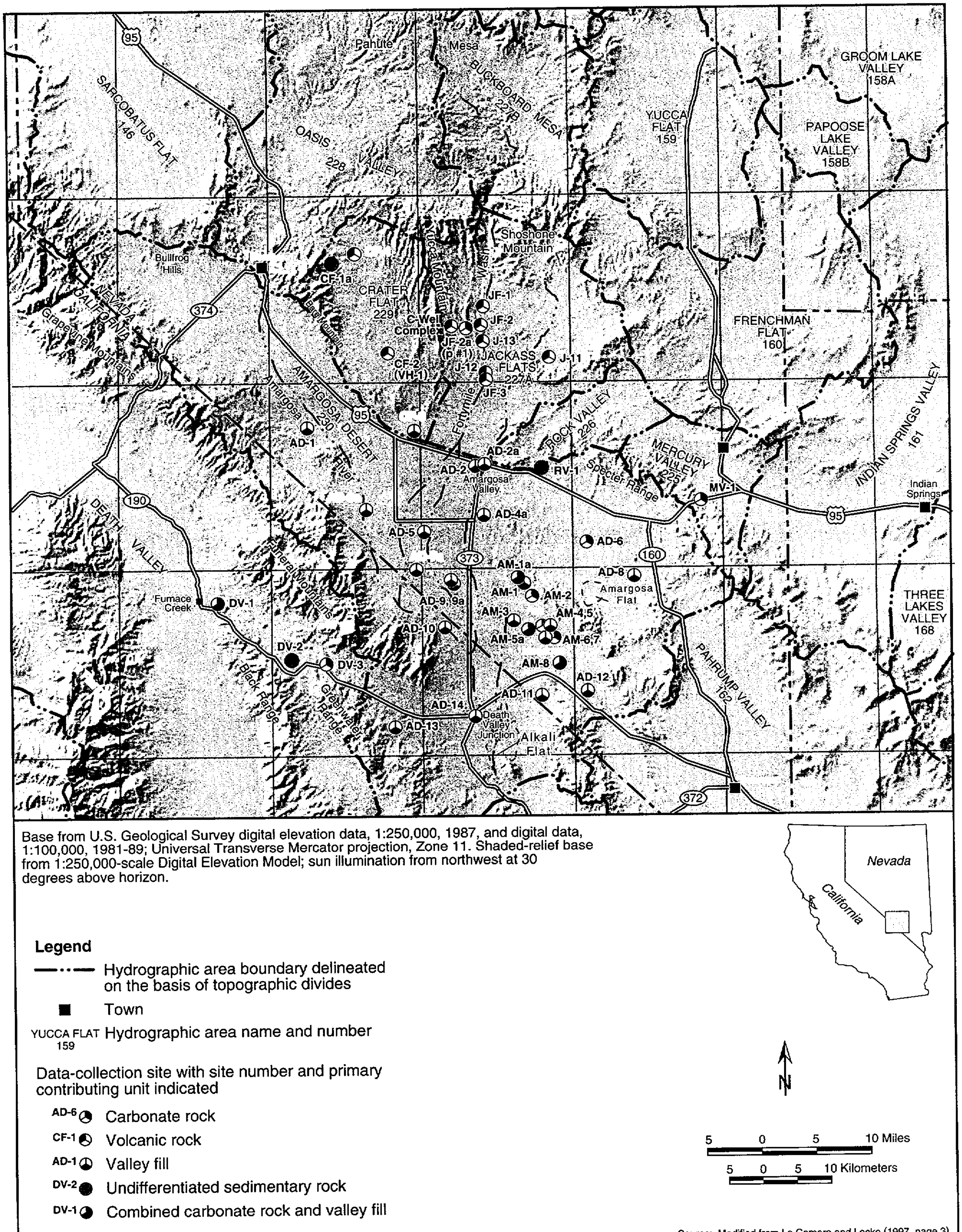


Figure 3-17. Selected groundwater data-collection sites in the Yucca Mountain region.

Table 3-15. Water withdrawals (acre-feet)[a] from wells in the Yucca Mountain vicinity.

Year	J-12 and J-13 Yucca Mountain characterization[b]	J-12 and J-13 total withdrawals[c]	C-wells[b]
1992	18	120	0
1993	80	210	0
1994	75	280	0
1995	94	260	19
1996	66	220	180
1997	63	150	190
1998	63[d]	N/A[e]	190[f]
1999	63	N/A	N/A
2005	63	N/A	N/A

a. To convert acre-feet to cubic meters, multiply by 1233.49.
b. Source: TRW (1999j, page 4).
c. Source: Clary et al. (1995, page 660); Bauer et al. (1996, page 702); Bostic et al. (1997, page 592); Bonner et al. (1998, page 606); La Camera, Locke, and Munson (1999, all); withdrawals for 1992 and 1993 were estimated from figures in La Camera and Locke (1997, page 51).
d. Assumed to remain constant from 1997 through 2005.
e. N/A = not available.
f. Assumed to remain constant from 1997 to 1998.

Table 3-16. Differences between annual median elevations and baseline median elevations.[a]

	Baseline elevations		Difference (in centimeters[b]) baseline					
Well	Median (meters[c] above sea level)	Average deviation about the median (centimeters)	1992	1993	1994	1995	1996	1997
JF-1	729.23	± 6	−3	0	−6	0	−6	−3
JF-2	729.11	± 9	+3	0	+3	+9	0	−3
JF-2a[d]	752.43	± 12	0	+6	+12	+15	+21	+27
J-13	728.47	± 6	−3	−3	−9	−6	−12	−12
J-11	732.19	± 3	0	0	+3	+6	+6	+12
J-12	727.95	± 3	0	0	−3	−3	−9	−9
JF-3	727.95	± 3	N/A[e]	N/A	−6	−6	−9	−9

a. Source: La Camera, Locke, and Munson (1999, Table 10).
b. To convert centimeters to inches, multiply by 0.3937.
c. To convert meters to feet, multiply by 3.2808.
d. Well JF-2a is also known as UE-25 p#1, or P-1.
e. N/A = not available.

groundwater elevation has been seen in some, but not all, of the local wells. Specifically, the data show the following:

- Two wells, JF-1 and JF-2, stayed within the band of elevations characteristic of the baseline data.
- Two wells, JF-2a (also known as UE-25 p#1, or P-1) and J-11, indicated elevation increases of 15 and 9 centimeters (about 5.9 and 3.5 inches), respectively, above the band of elevations characteristic of the baseline data (and even higher above the median of the baseline data as listed in the table).
- Three wells, J-13, J-12, and JF-3, each indicated an elevation decrease of 6 centimeters (about 2.4 inches) below the band of elevations characteristic of the baseline data (and even further below the median of the baseline data as listed in the table).

In its discussion of groundwater levels, the U.S. Geological Survey (La Camera and Locke 1997, page 22) indicated that monitoring of water levels in the seven wells should continue to see if additional decreases occur and if they can be correlated to periods of withdrawal. In regard to overall groundwater levels in the Jackass Flats area, the data do not appear to show any definitive trend in elevation change, either up or down. However, the three wells showing a water decline are either being pumped (J-12 and J-13) or, in the case of JF-3, are close to a production well. Five of these wells (see Figure 3-17) are in or very close to Fortymile Wash and the two wells (JF-2a and J-11) that are farthest from the wash are those wells that have shown a water level increase.

Table 3-17. Water chemistry of volcanic and carbonate aquifers at Yucca Mountain (milligrams per liter).[a]

Chemical constituent	Chemical composition: Volcanic aquifers[b]	Chemical composition: Lower carbonate aquifer[c]
Calcium	1 - 20	100
Magnesium	0.01 - 2	39
Potassium	1 - 5	12
Sodium	38 - 100	150
Bicarbonate	110 - 280	570
Chloride	5 - 10	28
Sulfate	40 - 57	160
Silica	40 - 57	41

a. Source: TRW (1999h, pages 2-43 to 2-44).
b. Based on samples from 12 wells.
c. Based on samples from one well.

Saturated Zone Groundwater Quality. Groundwater quality for the aquifers beneath Yucca Mountain was addressed by the Geological Survey sampling and analysis effort described above for regional groundwater quality. This effort included the collection and analysis of samples from three wells in the Jackass Flats area (including J-12 and J-13); the results indicated that the concentrations of dissolved substances in local groundwater were below the numerical criteria of the primary drinking water standards set by the Environmental Protection Agency for public drinking water systems (Covay 1997, all). However, samples from each of the wells exceeded the secondary standard for fluoride, as was a proposed standard for radon. Both of these constituents occur naturally in the rock through which the groundwater flows. Overall, local groundwater quality is generally good.

Investigations of the chemical and mineral composition of groundwater at Yucca Mountain have provided an indication of the differences between the aquifers beneath the site. The chemical composition of groundwater depends on the chemistry of the recharge water and the chemistry of the rocks through which the water travels. Water in the volcanic aquifers and confining units at Yucca Mountain has a relatively dilute sodium-potassium-bicarbonate composition that probably results from the dissolution of volcanic tuff (Table 3-17). The chemistry of water from the lower carbonate aquifer is very different (a generally more concentrated calcium-magnesium-bicarbonate composition), which would be expected from water traveling through and dissolving carbonate rock (Table 3-17).

As part of the Yucca Mountain project, well and spring monitoring activities performed during 1997 aided the establishment of a baseline for radioactivity in groundwater near the site of the proposed repository (TRW 1998b, all). The quarterly sampling included six wells and two springs that were selected to ensure that at least two were representative of each of the three general aquifers (carbonate, volcanic, and alluvial) in the region. Samples were analyzed for gross alpha, gross beta, total uranium, and concentrations of selected beta and gamma-emitting radionuclides. Table 3-18 lists the results from this monitoring as average values from the quarterly sampling events for each well or spring. The table lists the location of each well or spring, including the data collection site designations shown on Figure 3-17, the contributing aquifer, and a comparison, if applicable, to Maximum Contaminant Levels established by the Environmental Protection Agency for water supplied by public drinking water systems. As indicated in the table, the sites sampled include locations outside the Alkali Flat-Furnace Creek sub-basin in which Yucca Mountain is located. The Cherry Patch location is in the Ash Meadows sub-basin and Crystal Pool and Fairbanks Spring are on the border between the two sub-basins, but are fed by flow

Table 3-18. Results of 1997 groundwater sampling and analysis for radioactivity.[a]

Site name and location description[b]	Contributing aquifer	Average combined radium-226 and -228 (picocuries per liter)	Average gross alpha (picocuries per liter)	Average total uranium[c] (micrograms per liter)	Average gross beta (picocuries per liter)
J-12 Fortymile Wash, SE of Yucca Mtn.	Volcanic	0.18±0.31	BDL[d]	0.52±0.05	6.23±0.86
J-13 Fortymile Wash, SE of Yucca Mtn.	Volcanic	0.45±0.36	BDL	0.51±0.04	5.84±0.85
C-3 (C-well complex) By South Portal, SE of Yucca Mtn.	Volcanic	0.58±0.36	1.34±1.05	1.04±0.09	3.59±0.76
Crystal Pool (Spring) (AM-5a) Ash Meadows	Carbonate/ alluvial[e]	0.93±0.20	BDL	2.64±0.23	14.0±1.28
Fairbanks Spring (AM-1a) Ash Meadows	Carbonate/ alluvial	0.80±0.36	BDL	2.23±0.19	11.1±1.17
Nevada Department of Transportation Well (AD-2a) Amargosa Valley	Alluvial	0.32±0.33	BDL	2.55±0.22	5.95±0.93
Gilgans South Well (AD-9a) Amargosa Desert	Alluvial	0.19±0.31	BDL	0.63 ± 0.05	9.14±0.97
Cherry Patch Well (AD-8) NE of Ash Meadows	Alluvial	0.22±0.33	9.19±4.35	13.1 ± 1.16	18.7±1.65
Drinking water Maximum Contaminant Levels[f]		5	15	NA[g]	NA

a. Source: TRW (1998b, pages 12 to 21).
b. Figure 3-18 shows the locations of the wells.
c. To convert total uranium concentrations in micrograms per liter to picocuries per liter, multiply by 0.68 (TRW 1998b, page 15).
d. BDL = below detection limit.
e. Alluvium is identified as valley fill in TRW (1999h, pages 1-7 and 1-8).
f. Drinking water Maximum Contaminant Levels are set by the Environmental Protection Agency in 40 CFR Part 141.
g. NA = not applicable.

through Ash Meadows. The location variety supports area comparisons as well as comparisons between the different contributing aquifers.

Table 3-18 indicates that Maximum Contaminant Levels for combined radium-226 and radium-228 and for gross alpha were not exceeded by the average values from any of the sampling sites or by the maximum values reported for those parameters (TRW 1998b, pages 12 to 21). The samples were analyzed for other beta- or gamma-emitting radionuclides, specifically tritium, carbon-14, chlorine-36, nickel-59, strontium-89, strontium-90, technetium-99, iodine-129, and cesium-137. The table does not list the results for these parameters because they are below minimum detectable activity (TRW 1998b, page 13). As a conservative measure, however, DOE used the values reported by the laboratory to calculate dose contributions (TRW 1998b, Appendix F). Water from each sampling location was shown to have exposure values well below the 4-millirem-per-year total body (or any internal organ) dose limit set as the Maximum Contaminant Level for beta- or gamma-emitting radionuclides.

There is no indication that DOE activities at the Nevada Test Site have contaminated the groundwater beneath Yucca Mountain. This is consistent with studies performed on the Nevada Test Site. Nimz and Thompson (1992, all) documented about a dozen instances in which radionuclides have migrated into the groundwater from areas of nuclear weapons testing at the Nevada Test Site in 40 years. The maximum distance of tritium migration is believed to be several kilometers; less mobile radioactive constituents, which include a wide variety of isotopes (DOE 1996f, pages 4-126 to 4-129), have migrated no more than about 500 meters (1,600 feet). There has, however, been recent evidence of plutonium migration from one below-groundwater test at Pahute Mesa. Groundwater monitoring results indicate plutonium has migrated at least 1.3 kilometers (0.8 mile) from this site in 28 years and is apparently associated with the movement of very small particles called colloids (Kersting et al. 1999, page 56). None of the nuclear testing occurred in Area 25 where the Yucca Mountain Repository facilities would be. However, the flow of groundwater from areas on Pahute and Buckboard Mesas where DOE conducted 81 and 2 nuclear tests, respectively, could be to the south toward Yucca Mountain. The distance is about 40 kilometers (25 miles) to Pahute Mesa and about 30 kilometers (19 miles) to Buckboard Mesa (Figure 3-17). Because of these distances, there is no reason to believe that radionuclides from nuclear tests could migrate as far as Yucca Mountain during the active life of the repository. Chapter 8 discusses the potential for long-term migrations of radionuclides to result in cumulative radiation from nuclear testing contamination eventually migrating through the groundwater system under the repository.

3.1.5 BIOLOGICAL RESOURCES AND SOILS

DOE used available information and studies on plants and animals at the site of the proposed repository and the surrounding region to identify baseline conditions for biological resources. This information included land cover types, vegetation associations, and the distribution and abundance of plant and animal species in the region of influence (the analyzed land withdrawal area) and in the broader region. The plants and animals in the Yucca Mountain region are typical of species in the Mojave and Great Basin Deserts.

DOE has surveyed the region for naturally occurring wetlands and has studied soil characteristics (thicknesses, water-holding capacity, texture, and erosion hazard) in the region. This section summarizes this information and describes existing soil conditions in relation to potential contaminants. Unless otherwise noted, this information is from the *Environmental Baseline File for Biological Resources* (TRW 1999k, all) or the *Environmental Baseline File for Soils* (TRW 1999l, all).

The State of Nevada (NWPO 1997, all) has expressed the opposing view that there was no systematic, interdisciplinary, environmental program before investigations began in 1982 to characterize the unique and fragile desert environment at Yucca Mountain before potential irreversible alterations (Lemons and Malone 1989, pages 435 to 441). However, after site investigations started and impacts might have occurred, DOE began studies of sensitive species, archaeology, airborne particulates, and groundwater (Lemons and Malone 1989, pages 435 to 441), and established an environmental baseline from these data for use in the preparation of the EIS (Malone 1989, pages 77 to 95). Many of the studies conducted to establish the baseline and evaluate impacts, particularly those on plants and animals (Malone 1995, pages 271 to 284), did not use an integrated ecosystem approach and, therefore, are of little value for evaluating impacts of the repository.

Studies initiated after the start of site investigations are suitable for establishing the baseline needed for this EIS. The purpose of studies of the impacts of site characterization activities on plants and animals was not to evaluate potential impacts from a repository, but rather to focus on the appropriate level of ecological organization for the types of impacts that occurred during characterization activities. DOE used the results of those studies in the EIS analysis to understand and predict possible impacts from similar activities during repository construction and operation (for example, habitat destruction).

3.1.5.1 Biological Resources

3.1.5.1.1 *Vegetation*

Broad categories of land cover types (based primarily on predominant vegetation) have been identified and mapped across the State of Nevada (Utah State University 1996, GAP Data) and at the site of the proposed Yucca Mountain Repository (TRW 1998c, page 9). Land cover types typical of the Mojave and

Great Basin Deserts occur in the analyzed land withdrawal area; they include creosote-bursage (56 percent), blackbrush (14 percent), hopsage (13 percent), Mojave mixed scrub (10 percent), salt desert scrub (4 percent), sagebrush (3 percent), and pinyon-juniper (much less than 1 percent) (Figure 3-18). None of the more than 210 plant species known to occur in the analyzed land withdrawal area is endemic to the area; that is, they all occur in other places.

Plant species typical of the Mojave Desert dominate the vegetation at low elevations in the analyzed land withdrawal area. Low-elevation valleys, alluvial fans, and large washes are dominated by white bursage (*Ambrosia dumosa*), creosotebush (*Larrea tridentata*), Nevada jointfir (*Ephedra nevadensis*), littleleaf ratany (*Krameria erecta*), and pale wolfberry (*Lycium pallidum*). Low-elevation hillsides are dominated by similar species, with the addition of shadscale (*Atriplex confertifolia*), California buckwheat (*Eriogonum fasciculatum*), and spiny hopsage (*Grayia spinosa*).

At higher elevations, generally at the northern end of the analyzed land withdrawal area, species typical of the Great Basin Desert are dominant. Ridge tops and slopes are dominated by blackbrush (*Coleogyne ramosissima*), heathgoldenrod (*Ericameria teretifolius*), Nevada jointfir, broom snakeweed (*Gutierrezia sarothrae*), green ephedra (*Ephedra viridis*), and California buckwheat. On some steep north-facing slopes, big sagebrush (*Artemisia tridentata*) is predominant.

3.1.5.1.2 *Wildlife*

Wildlife at Yucca Mountain is dominated by species associated with the Mojave Desert, with some species from the Great Basin Desert at higher elevations.

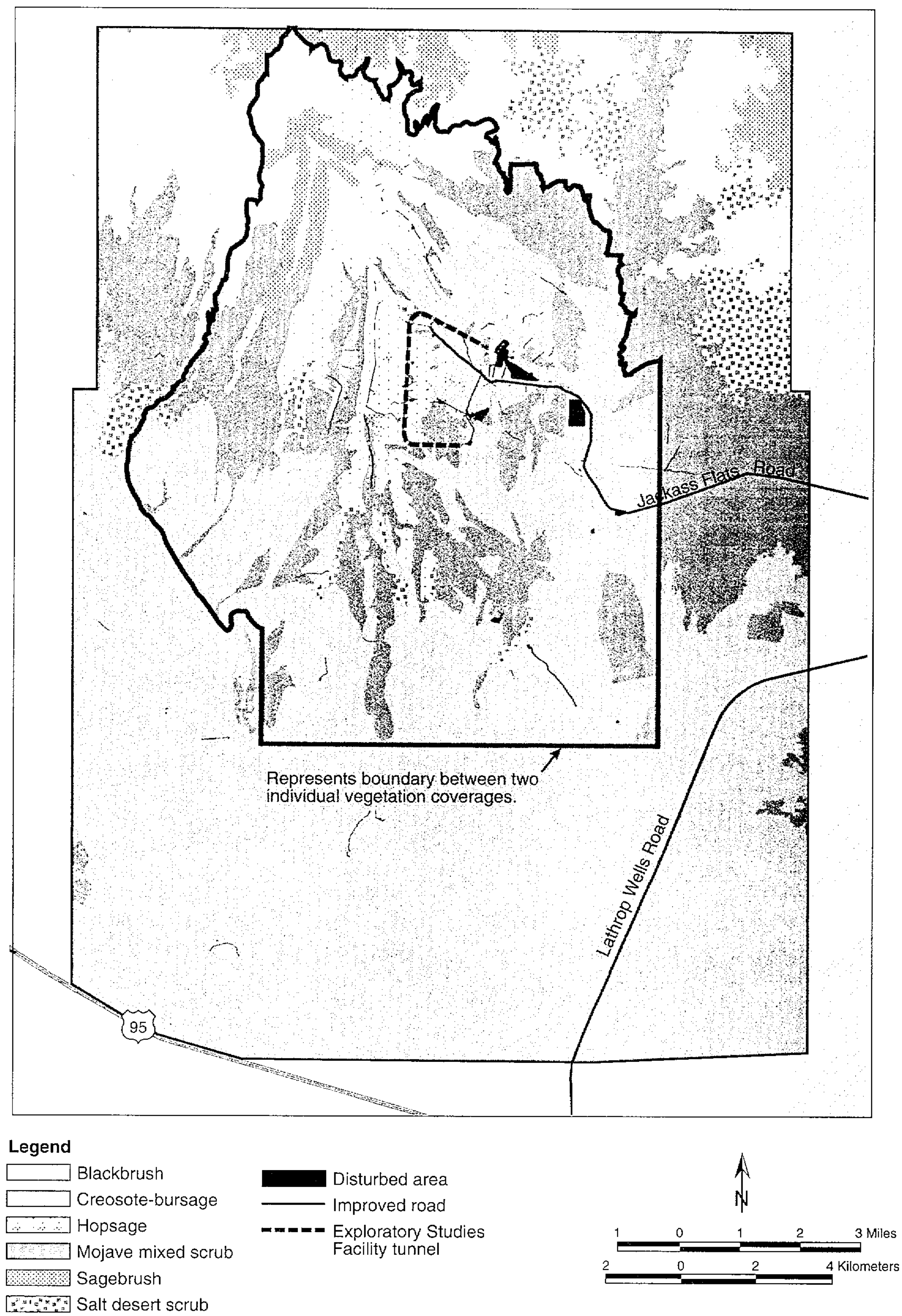
The 36 species of mammals that have been observed in the analyzed Yucca Mountain land withdrawal area include 17 species of rodents, seven species of bats, three species of rabbits and hares, and nine species of large mammals such as coyote *(Canis latrans)*, mule deer *(Odocoileus hemionus)*, and burros (*Equus asinus*). The most abundant species are long-tailed pocket mice *(Chaetodipus formosus*) and Merriam's kangaroo rats (*Dipodomys merriami*).

The 27 species of reptiles include 12 species of lizards, 14 species of snakes, and the desert tortoise (*Gopherus agassizii*). The most abundant lizard is the side-blotched lizard (*Uta stansburiana*), while the western whiptail (*Cnemidophorus tigris*) is common. The most abundant snakes are the coachwhip (*Masticophis flagellum*) and the long-nosed snake (*Rhinocheilus lecontei*). No amphibians have been found at Yucca Mountain.

There have been no formal attempts to quantify the birds present at Yucca Mountain, but at least 120 species have been sighted in or near the analyzed land withdrawal area, including 14 species that nest there. Transient and resident species have been recorded including species typical of the desert, migrating water birds and warblers, and raptors. Black-throated sparrows (*Amphispiza bilineata*) are the most common resident birds and mourning doves (*Zenaida macroura*) are seasonally common.

Researchers have collected invertebrates from 18 orders and 53 families at Yucca Mountain. Members of the insect orders Lepidoptera (butterflies and moths), Hymenoptera (bees, wasps, and ants), and Coleoptera (beetles) were the most numerous of those collected.

Several game species and furbearers (see Nevada Administrative Code 503.125) have been observed in the analyzed land withdrawal area, including (1) three species of game birds—Gambel's quail (*Callipepla gambelii*), chukar (*Alectoris chukar*), and mourning doves, (2) mule deer (*Odocoileus*



Source: Adapted from Utah State University (1996, all) and TRW (1998c all).

Figure 3-18. Vegetation types in the analyzed land withdrawal area.

hemionus), and (3) three species of furbearers—kit foxes (*Vulpes velox*), mountain lions (*Puma concolor*), and bobcats (*Lynx rufus*).

3.1.5.1.3 *Special Status Species*

SPECIAL STATUS SPECIES

An **endangered species** is classified under the Endangered Species Act as being in danger of extinction throughout all or a significant part of its range.

A **threatened species** is classified under the Endangered Species Act as likely to become an endangered species in the foreseeable future.

Candidate species are species for which the Fish and Wildlife Service has enough substantive information on biological status and threats to support proposals to list them as threatened or endangered under the Endangered Species Act. Listing is anticipated but has been precluded temporarily by other listing activities.

The State of Nevada has also designated special status species as endangered, threatened, protected, and sensitive. Species with these classifications are protected under Nevada Administrative Code Chapter 503.

Bureau of Land Management **sensitive species** include species designated by the Bureau's State Director in addition to those listed, proposed, or candidates under the Endangered Species Act or listed by the State of Nevada as endangered or otherwise protected.

No plant species listed as threatened or endangered or that are proposed or candidates for listing under the Endangered Species Act occur in the analyzed land withdrawal area. 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, all of which are protected by the State of Nevada from commercial collection, are scattered throughout the region, including the analyzed land withdrawal area.

One animal species that occurs at Yucca Mountain, 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 (Rautenstrauch, Brown, and Goodwin 1994, page 11), and the abundance of tortoises at Yucca Mountain is low or very low in comparison to other portions of its range. Aspects of the ecology of the desert tortoise population at Yucca Mountain have been studied extensively (TRW 1999k, all).

Individual threatened bald eagles (*Haliaeetus leucocephalus)* or endangered peregrine falcons (*Falco peregrinus)* occasionally migrate through the region; these species have been seen once each at the Nevada Test Site. Both species are rare in the region and have not been seen at Yucca Mountain. The State of Nevada has classified both birds as endangered.

No other Federally listed threatened or endangered species or candidates for listing under the Endangered Species Act occur at Yucca Mountain.

Five species classified as sensitive by the Bureau of Land Management occur at Yucca Mountain. Two species of bats—the long-legged myotis (*Myotis volans*) and the fringed myotis (*M. thysanodes*)—have been observed near the site. Three other species, the western chuckwalla (*Sauromalus obesus*), burrowing owl (*Speotyto cunicularia*), and Giuliani's dune scarab beetle (*Pseudocotalpa giulianii*), occur in the analyzed land withdrawal area. The chuckwalla, one of the largest lizards in Nevada, is locally common and widely distributed in rocky habitats throughout the analyzed land withdrawal area and the surrounding region. The seldom-seen burrowing owl generally occurs in valley bottoms and is known to be a year-round resident at the Nevada Test Site. Giuliani's dune scarab beetle has been found near the cinder cones north of U.S. Highway 95 at the south end of Crater Flat.

Ash Meadows is about 39 kilometers (24 miles) south of Yucca Mountain. Although Ash Meadows is outside the region of influence for biological resources, it contains a number of special status species that an evaluation of regional biological resources should consider. Of the eight endemic plant species at Ash Meadows, one is listed as endangered (Amargosa alkali plant, *Nitrophila mohavensis*) and six are listed as threatened (Spring-loving centaury, *Centaurium namophilum*; Ash Meadows milkvetch, *Astragalus phoenix*; Ash Meadows naked stem sunray, *Enceliopsis nudicaulis* var. *corrugata*; Kings Mousetail, *Ivesia kingii* var. *eremica*; Ash Meadows gumweed, *Grindelia fraximopratensis*; and Ash Meadows blazing star, *Mentzelia leucophylla*) (50 *FR* 20777, May 20, 1985). Four endemic fish species occur in the springs and pools. The Fish and Wildlife Service and the State of Nevada list these species—the Ash Meadows Amargosa speckled dace (*Rhinichthys osculus nevadensis*), Ash Meadows Amargosa pupfish (*Cyprinodon nevadensis mionectes*), Devils Hole pupfish (*C. diabolis*), and Warm Springs Amargosa pupfish (*C. nevadensis pectoralis*)—as endangered. The springs also provide habitat for a number of endemic riffle beetles, springsnails, and other invertebrates, including the threatened Ash Meadows naucorid bug (*Ambrysus amargosus*).

3.1.5.1.4 *Wetlands*

There are no naturally occurring jurisdictional wetlands (wetlands that are regulated under Section 404 of the Clean Water Act) at Yucca Mountain. Four manmade ponds in the Yucca Mountain region have riparian vegetation. Fortymile Wash and some of its tributaries might be classified as waters of the United States as defined by the Clean Water Act. Jurisdictional wetlands associated with Ash Meadows are outside the region of influence for the Proposed Action.

3.1.5.2 Soils

Researchers have conducted a soil survey centered on Midway Valley (the location of the proposed North Portal facilities) and the ridges to the west (Resource Concepts 1989, all), and a more general soil survey of the entire Yucca Mountain region (DOE 1997f, all). The survey that centered on Midway Valley identified 17 soil series and seven map units (Table 3-19) at Yucca Mountain (Resource Concepts 1989, all); none of these series is classified as prime farmland. Based on a wetlands assessment at the Nevada Test Site (Hansen et al. 1997, all), there are no hydric soils at Yucca Mountain. Yucca Mountain soils are derived from underlying volcanic rocks and mixed alluvium dominated by volcanic material, and in general have low water-holding capacities.

SOIL TERMS

Prime farmland: Land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops, and is available for these uses (urban areas are not included). It has the soil quality, growing season, and moisture supply needed for the economic production of sustained high yields of crops when treated and managed (including water management) according to acceptable farming methods (Farmland Protection Policy Act of 1981, 7 CFR 7.658).

Piedmont: Land lying along or near the foot of a mountain. For example, a fan piedmont is a fan-shaped landform between the mountain and the basin floor.

Table 3-19. Soil mapping units at Yucca Mountain.[a]

Map unit	Percent	Geographic setting	Soil characteristics
Upspring-Zalda	11	Mountain tops and ridges. Soils occur on smooth, gently sloping ridge tops and shoulders and on nearly flat mesa tops. Rhyolite and tuffs are parent materials for both soil types.	Typically shallow (10 - 51 cm[b]) to bedrock, or to thin duripan[c] over bedrock. They are well to excessively drained, have low available water-holding capacity, medium to rapid runoff potential, and slight erosion hazard.
Gabbvally-Downeyville-Talus	8	North-facing mountain sideslopes. Talus is stone-sized rock occurring randomly throughout unit in long, narrow, vertically oriented accumulations.	Shallow (10 - 36 cm) to bedrock. Permeability is moderate to moderately rapid. They have moderate to rapid runoff potential, are well drained, and have low available water-holding capacity and moderate erosion hazard.
Upspring-Zalda-Longjim	27	Mountain sideslopes. Soils occur on south-, east-, and west-facing slopes, and on moderately sloping alluvial deposits below sideslopes.	Shallow (10 - 51 cm) to bedrock or to thin duripan over bedrock. They are well to excessively drained and have moderately rapid to rapid permeability and runoff potential, very low available water-holding capacity, and slight erosion hazard.
Skelon-Aymate	22	Alluvial fan remnants. Soils occur on gently to strongly sloping summits and upper sideslopes.	Moderately deep (51 - 102 cm) to indurated[d] duripan or petrocalcic[e] layer with low to very low available water-holding capacity, moderately rapid permeability, slow runoff potential, and slight erosion hazard.
Strozi variant-Yermo-Bullfor	7	Alluvial fan remnants. Soils occur on gently to moderately sloping alluvial fan remnants and stream terraces adjacent to large drainages.	Moderately deep (51 - 102 cm) to deep (102 cm). They are well drained and have rapid permeability, very low available water-holding capacity, slow runoff potential, and slight erosion hazard.
Jonnic variant-Strozi-Arizo	12	Dissected alluvial fan remnants. Soils occur on fan summits, moderately sloping fan sideslopes, and inset fans. They are formed in alluvium from mixed volcanic sources.	Moderately deep (36 - 43 cm) to deep (more than 102 cm), sometimes over strongly cemented duripan. They have slow or rapid permeability, slow or moderate runoff potential, very low available water-holding capacity, and slight erosion hazard.
Yermo-Arizo-Pinez	13	Inset fans and low alluvial sideslopes in mountain canyons; and drainages between fan remnants. Soils occur on moderately to strongly sloping inset fans near drainages, adjacent to lower fan remnants, and below foothills.	Deep (more than 102 cm), sometimes over indurated duripan. They are well drained and have very low available water holding-capacity, moderately slow to rapid permeability, slow to medium runoff potential, and slight erosion hazard.

a. Source: TRW (1999l, pages 3 and 4).
b. To convert centimeters (cm) to inches, multiply by 0.3937.
c. Duripan: A subsurface layer cemented by silica, usually containing other accessory cements.
d. Indurated: Hardened, as in a subsurface layer that has become hardened.
e. Petrocalcic: A subsurface layer in which calcium carbonate or other carbonates have accumulated to the extent that the layer is cemented or indurated.

The shallow soils on ridge tops at Yucca Mountain often consist of a thin *hardpan* (hardened or cemented soil layer) on top of bedrock and range from *well drained* to *excessively drained,* which means that water drains readily to very rapidly. The soil has a topsoil layer typically less than 15 centimeters (6 inches) thick and, in some instances, a subsoil layer 5 to 30 centimeters (2 to 12 inches) thick. Soil textures range from gravelly to cobbly, loamy sands to sandy loams. Soils are calcareous (high in calcium carbonate), with lime coatings on the undersides of rocks in the subsoil layer. The soils are moderately to strongly alkaline, with a pH ranging from 8.0 to 8.6. Rock fragments ranging in size from gravel to cobbles dominate 45 to 65 percent of the ground surface.

Soils on fan piedmonts and in steep, narrow canyons are relatively deep and are *well drained* (water is drained readily, but not rapidly). These soils developed from residues of volcanic parent material, with a component of calcareous eolian sand. Soils formed from the volcanic parent material generally range from *moderately shallow* [50 to 75 centimeters (20 to 30 inches)] to *moderately deep* [75 to 100 centimeters (30 to 40 inches)] over a thin hardpan on top of bedrock. The topsoil layers are generally less than 25 centimeters (10 inches) thick, with a subsoil layer thickness of 25 to 50 centimeters (10 to 20 inches). The mixed soils, containing residues from volcanic parent material and calcareous eolian sand, are often *deep* [100 to 150 centimeters (40 to 60 inches)] or moderately deep, having a well-cemented hardpan. The topsoil layers are less than 15 centimeters (6 inches) thick, with the layer of soil parent material as deep as 150 centimeters (60 inches). Soil textures are gravelly, sandy loams with 35 to 70 percent rock fragments. Soils are generally calcareous and moderately to strongly alkaline.

Soils on alluvial fans and in stream channels are *very deep* [greater than 150 centimeters (60 inches)] and range from well drained to excessively drained. The topsoil layers are generally less than 20 centimeters (8 inches) thick, with the layer of soil parent material as deep as 150 centimeters. Soil textures are very gravelly, with fine sands to sandy loams and abundant rock fragments. The soils are calcareous and moderately alkaline.

The Yucca Mountain site characterization project has sampled and analyzed surface soils for radiological constituents. In addition, records of spills or releases of nonradioactive materials have been maintained to meet regulatory requirements and to provide a baseline for the Proposed Action. A recent summary of existing radiological conditions in soils is based on 98 surface samples collected within 16 kilometers (10 miles) of the Exploratory Studies Facility. The results of that analysis, when compared to other parts of the world, indicate average levels of the naturally occurring radionuclide uranium-238 series decay products and above-average levels of the naturally occurring radionuclides potassium-40 and thorium-232 series decay products. The higher-than-average radionuclide values might be due to the origin of the soil at the site from tuffaceous igneous rocks. The studies also detected concentrations of the manmade radionuclides strontium-90, cesium-137, and plutonium-239 from worldwide nuclear weapons testing.

3.1.6 CULTURAL RESOURCES

Cultural resources include any prehistoric or historic district, site, building, structure, or object resulting from or modified by human activity. Cultural resources could also include potential traditional cultural properties. Under Federal regulation, cultural resources designated as historic properties warrant consideration with regard to potential adverse impacts resulting from proposed Federal actions. A cultural resource is an historic property if its

CULTURAL RESOURCES

Archaeological site: The location of a past event, a prehistoric or historic occupation or activity, or a building or structure, whether standing, ruined, or vanished, where the location itself maintains archaeological value.

Traditional cultural property: A property associated with the cultural practices or beliefs of a living community that are (1) rooted in that community's history, and (2) important in maintaining the cultural identity of the community.

attributes make it eligible for listing or it is formally listed on the *National Register of Historic Places*. For this analysis, DOE has evaluated the importance of historic and archaeological resources according to National Register eligibility criteria.

Cultural resources at Yucca Mountain include archaeological resources that are prehistoric or historic, and other resources important to Native American tribes and organizations, such as potential traditional cultural properties. DOE has collected information on the various types of archaeological sites, detailing their purposes and the kinds of artifacts typically present. DOE also has focused on Native American interests in the region's cultural resources. Section 3.1.6.2 summarizes these issues in discussions of Native American views of the affected environment.

Unless otherwise indicated, the information in this section is derived from either the summary of past archaeological projects at Yucca Mountain (TRW 1999m, all) or from *American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement* (AIWS 1998, all).

3.1.6.1 Archaeological and Historic Resources

Site characterization efforts have led to a number of archaeological investigations at Yucca Mountain over the past two decades, including an archaeological field survey of a 44-square-kilometer (about 11,000-acre) parcel that proposed repository activities probably would affect. The field survey was followed by limited test excavations at 29 sites to determine their scientific importance and to develop management strategies for the protection of archaeological resources. Additional archaeological surveys have been conducted along nearby Midway Valley and Yucca Wash and in lower Fortymile Canyon just east of the Yucca Mountain site.

Concurrent with these investigations, DOE directed archaeological surveys and data-recovery projects before beginning planned ground-disturbing activities specific to the Yucca Mountain Project. Limited data-recovery efforts at 18 archaeological sites support a model for a local cultural sequence that includes a pattern of linear-shaped sites along major drainages dating as far back as 7,000 years, and a shift to a more dispersed pattern of sites about 1,500 years ago. A site monitoring program designed to examine human and natural impacts to cultural resources through time began in 1991 and is continuing at Yucca Mountain.

Decades of cultural resource investigations at Yucca Mountain and at the Nevada Test Site have revealed archaeological features and artifacts. Based on archaeological site file searches at the Desert Research Institute in Las Vegas and Reno and at the Harry Reid Center at the University of Nevada, Las Vegas, approximately 826 archaeological sites have been discovered in the analyzed land withdrawal area. Most of the known archaeological sites are small scatters of lithic (stone) artifacts, usually comprised of fewer than 50 artifacts with few formal tools and no temporally or culturally diagnostic artifacts in the inventory. None of the sites has been listed on the *National Register of Historic Places,* but 150 are potentially eligible for nomination (see Table 3-20). Several reports describe the specific procedures used to study and protect these cultural sites (Buck and Powers 1995, all; DOE 1992a, all). DOE (1988b, all) describes how the Department meets its responsibilities under Section 106 of the National Historic Preservation Act and the American Indian

Table 3-20. Sites in the Yucca Mountain region potentially eligible for the *National Register of Historic Places.*

Type	Number
Temporary camps	43
Extractive localities	14
Processing localities	9
Localities	77
Caches	2
Stations	1
Historic sites	4
Total	**150**

Religious Freedom Act, and interactions with the Advisory Council on Historic Preservation and the Nevada State Historic Preservation Officer.

This EIS separates archaeological sites into two broad groups, prehistoric and historic, separated by the first contact between Native Americans and Euroamericans; in the Great Basin, this contact occurred in the early 1800s. The oldest prehistoric sites in southern Nevada are about 11,000 years old. These sites include one or more of the following features: temporary campsites, rock art, scattered lithic artifacts, quarries, plant-processing remains, hunting blinds, and rock alignments. The sites are categorized as temporary camps, extractive localities, processing localities, localities, caches, and stations. Historic sites include mining sites, ranching sites, transportation and communication sites, and some Cold War facilities. The following paragraphs define eligible types of sites at Yucca Mountain in each group (Table 3-20).

Temporary Camps. When occupied by a group of people, a temporary camp was a hub of activity for raw materials processing, implement manufacturing, and maintenance and general living activities. Camp artifacts typically include debris and discards from the making of stone tools, projectile points, bifacial stone tools, cores, milling stones, pottery, specialized tools, hearths, shelters, structures, and art. The nature and diversity of artifacts and features are the basis for designating a site as a temporary camp.

Extractive Localities. These were sites for specific extractive or resource-procurement tasks. They probably were occupied for short periods and for such limited activities as toolstone quarrying, hunting, and seed gathering. A single locality can contain isolated artifacts or large quantities of artifacts that reflect specific activities. In comparison to temporary camps, extractive localities have a low diversity of artifacts. Extractive locality artifacts include isolated projectile points or bifacial stone tools where hunting occurred, toolstone quarries with thousands of flakes, diffuse scatters of lithic flakes where plant materials were gathered, hunting blinds, and *tinajas* or water-catchment basins.

Processing Localities. Specific resource-processing tasks occurred at processing localities. These localities probably were occupied only for short periods and for limited activities such as butchering, milling, and roasting. A single site can contain an isolated artifact or large quantities of artifacts that reflect specific activities. Like extractive localities, processing localities have a low diversity of artifacts. Examples of processing localities include stone tool manufacturing stations, milling stations for processing food, diffuse scatters containing stone tools for processing meat and hides, hearths, and roasting pits.

Localities. This category includes sites that might have been either extractive or processing localities but for which there is not enough information to determine if such activities occurred.

Caches. Caches are temporary places for storing resources or artifacts. They include sealed rock shelters, rock piles, rock rings without evidence of habitation, rock alignments, brush piles held in place by rocks, and storage pits. A cache can also be an association of similar artifacts such as heat-treated bifacial stone tools, projectile points, and snares, or such resources as toolstone blanks and firewood in or on a natural feature such as at the base of a tree, in a rock shelter, or in a mountain saddle. Caches are distinguished from localities as places for storing resources, rather than as places of procurement or processing.

Stations. Stations are sites where groups gathered to exchange information about such things as game movement, routes of travel, and ritual activities. Examples of stations are rock cairns marking routes of travel, isolated petroglyphs and pictographs, geoglyphs, and observation points and overlooks.

Historic Sites. Historic sites are contemporaneous with or postdate the introduction of European influences in the region. Historic archaeological sites are few in number in the project area, usually represented by a small scatter of artifacts (cans and bottles). These short-term activities were related to mining, ranching, and transportation.

3.1.6.2 Native American Interests

3.1.6.2.1 *Yucca Mountain Project Native American Interaction Program*

In 1987, DOE initiated the Native American Interaction Program to consult and interact with tribes and organizations on the characterization of the Yucca Mountain site and the possible construction and operation of a repository. These tribes and organizations—Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone people from Arizona, California, Nevada, and Utah—have cultural and historic ties to the Yucca Mountain area.

The Native American Interaction Program concentrates on the protection of cultural resources at Yucca Mountain and promotes a government-to-government relationship with the tribes and organizations. Its purpose is to help DOE comply with various Federal laws and regulations, including the American Indian Religious Freedom Act, the Archaeological Resources Protection Act, the National Historic Preservation Act, the Native American Graves Protection and Repatriation Act, DOE Order 1230.2 (*American Indian and Tribal Government Policy*), and Executive Orders 13007 (*Indian Sacred Sites*) and 13084 (*Consultation and Coordination with Indian Tribal Governments*). These regulations mandate the protection of archaeological sites and cultural items and require agencies to include Native Americans and Federally recognized tribes in discussions and interactions on major Federal actions.

Initial studies identified three tribal groups—Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone—whose cultural heritage includes the Yucca Mountain region (Stoffle 1987, page 5-13). Additional ethnographic efforts eventually identified 17 tribes and organizations involved in the Yucca Mountain Project Native American and cultural resource studies. Figure 3-19 shows the traditional boundaries and locations of the 17 tribes and organizations.

Of the 17 tribal groups, 15 are Federally recognized tribes. The Pahrump Paiute Indian Tribe, which consists of a group of Southern Paiutes living in Pahrump, Nevada, has applied for Federal tribal recognition but to date has not received it. In addition, the Las Vegas Indian Center is not a Federally recognized tribe, but DOE included it in the Native American Interaction Program because it represents the urban Native American population of Las Vegas and Clark County, Nevada (Stoffle et al. 1990, page 7).

The 17 tribes and organizations have formed the Consolidated Group of Tribes and Organizations, which consists of officially appointed tribal representatives who are responsible for presenting their respective tribal concerns and perspectives to DOE. The primary focus of this group has been the protection of cultural resources and environmental restoration at Yucca Mountain. Members of the group have participated in many ethnographic interviews and have provided DOE valuable insights into Native American cultural and religious values and beliefs. These interactions have produced several reports that record the regional history of Native American people and the interpretation of Native American cultural resources in the Yucca Mountain region (Stoffle, Evans, and Harshbarger 1989, pages 30 to 74; Stoffle et al. 1990, pages 11 to 25; Stoffle, Olmsted, and Evans 1990, pages 23 to 49). In addition, tribal representatives have identified and discussed traditional and current uses of plants in the area (Stoffle et al. 1989, pages 22 to 139).

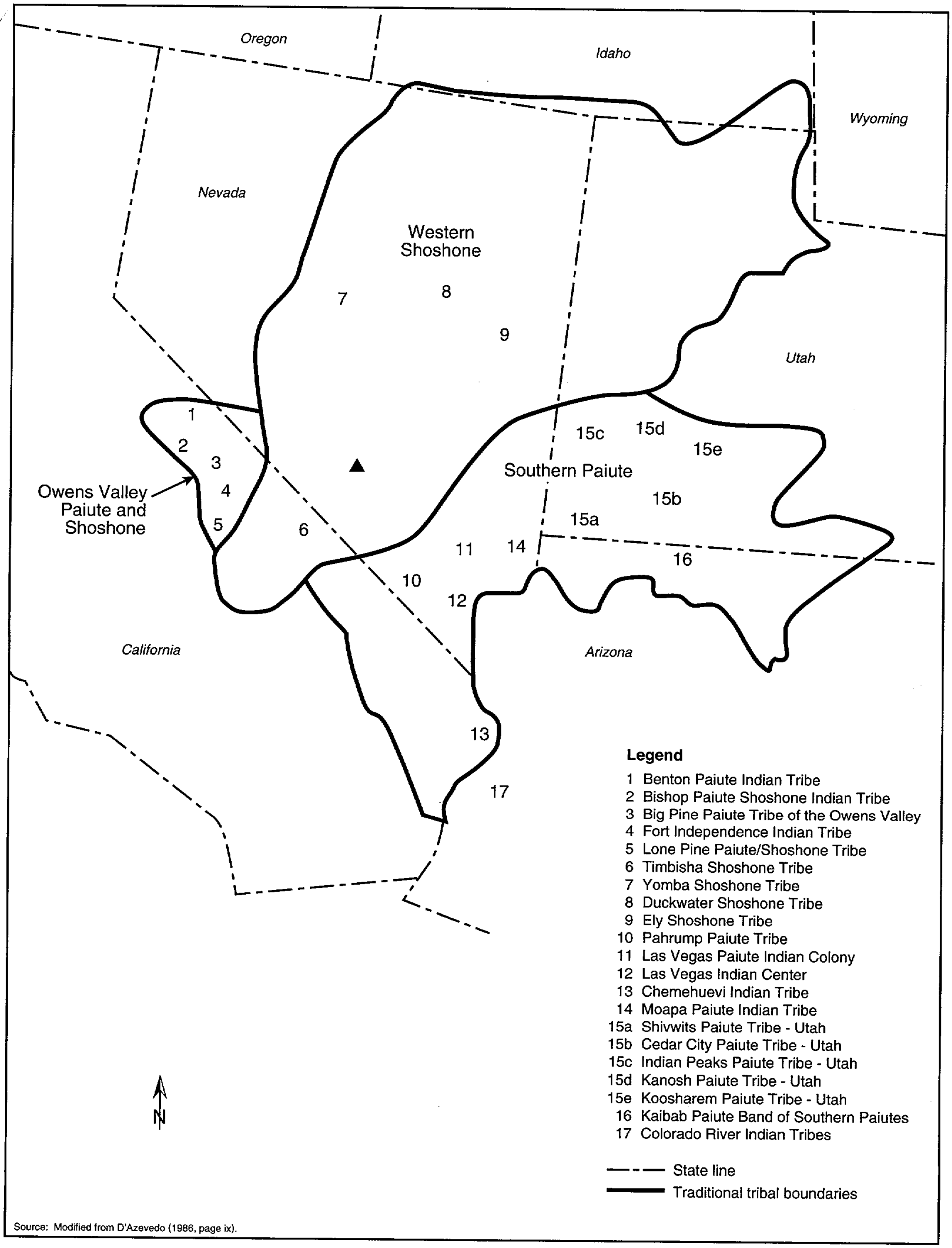


Figure 3-19. Traditional boundaries and locations of tribes in the Yucca Mountain region.

3.1.6.2.2 *Native American Views of Affected Environment*

During the EIS scoping process, DOE visited many tribes to encourage their participation. Members of the Consolidated Group of Tribes and Organizations designated individuals who represented the three tribal groups (Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone) to document their viewpoints on the Yucca Mountain area. This group, the American Indian Writers Subgroup, prepared a resource document that provides Native American perspectives on the repository (AIWS 1998, all). This report also describes the relationship between Native American people and DOE and discusses impacts of the Proposed Action while recommending impact mitigation approaches for reducing potential impacts to Native American resources and other heritage values in the Yucca Mountain region. In addition to the general and specific cultural resources issues, which are summarized in the following paragraphs, the report covers other critical topics, including concerns for occupational and public health and safety, environmental justice and equity issues, and social and economic issues. The report also provides recommendations for the conduct of appropriate consultation procedures for the repository and associated activities, and requests Native American participation in development of project resource management approaches to enable the incorporation of accumulated centuries of ethnic knowledge in long-term cultural resource protection strategies.

Native American people believe that they have inhabited their traditional homelands since the beginning of time. Archaeological surveys have found evidence that Native American people used the immediate vicinity of Yucca Mountain on a temporary or seasonal basis (Stoffle et al. 1990, page 29). Native Americans emphasize that a lack of abundant artifacts and archaeological remains does not mean that their people did not use a site or that the land is not an integral part of their cultural ecosystem. Native Americans assign meanings to places involved with their creation as a people, religious stories, burials, and important secular events. The traditional stories of the Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone peoples identify such places, including the Yucca Mountain area. Native Americans believe that cultural resources are not limited to the remains of native ancestors but include all natural resources and geologic formations in the region, such as plants and animals and natural landforms that mark important locations for keeping their historic memory alive and for teaching their children about their culture. Equally important are the water resources and minerals in the Yucca Mountain region. Native Americans used traditional quarry sites to make tools, stone artifacts, and ceremonial objects; many of these sites are *power places* associated with traditional healing ceremonies. Despite the current physical separation of tribes from Yucca Mountain and neighboring lands, Native Americans continue to value and recognize the meaningful role of these lands in their culture and continued survival. Many areas in the Yucca Mountain region are important to them. Fortymile Canyon was an important crossroad where a number of traditional trails from such distant places as Owens Valley, Death Valley, and the Avawtz Mountain came together. Oasis Valley was an important area for trade and ceremonies. Native Americans believe that Prow Pass was an important ceremonial site and, because of this religious importance, have recommended that DOE conduct no studies in this area. Other areas are important based on the abundance of artifacts, traditional-use plants and animals, rock art, and possible burial sites.

According to Native American people, the Yucca Mountain area is part of the holy lands of the Western Shoshone, Southern Paiute, and Owens Valley Paiute and Shoshone peoples. Native Americans generally do not concur with the conclusions of archaeological investigators that their ancestors were highly mobile groups of aboriginal hunter-gatherers who occupied the Yucca Mountain area before Euroamericans began using the area for prospecting, surveying, and ranching. They believe that these conclusions overlook traditional accounts of farming that occurred before European contact. Yucca Mountain and nearby lands were central in the lives of the Western Shoshone, Southern Paiute, and Owens Valley Paiute and Shoshone peoples, who shared them for religious ceremonies, resource uses, and social events. Native Americans value the cultural resources in these areas, viewing them in a holistic manner. They believe that the water, animals, plants, air, geology, and artifacts are interrelated and dependent on each other for existence.

3.1.7 SOCIOECONOMICS

To define the existing conditions for the socioeconomic environment in the Yucca Mountain region, DOE determined the current economic and demographic status in a well-defined region (called the *region of influence*) near the site of the proposed repository. DOE based its definition of the socioeconomic region of influence on the distribution of the residences of current employees of the Department and its contractors who work on the Yucca Mountain Project or at the Nevada Test Site. The region of influence, therefore, consists of the counties where about 90 percent of the DOE workforce lives. The Department used the residential distribution, which reflects existing commuting patterns, to estimate the future distribution of direct workers associated with the Proposed Action and the No-Action Alternative. Unless otherwise noted, the *Yucca Mountain Site Characterization Project Environmental Baseline File for Socioeconomics* (TRW 1999n, all) is the basis for the information in this section.

DOE received numerous reports from affected units of local government providing socioeconomic baseline environmental information. The reports contain information that characterizes the existing community environment, provides assessments of economic development, or includes basic economic and demographic trends. DOE reviewed these reports and determined that the information provided was consistent with the information used in this EIS.

The socioeconomic region of influence for the Proposed Action consists of Clark, Lincoln, and Nye Counties in southern Nevada (Figure 3-20). Clark County contains the City of Las Vegas and its suburbs. Based on a count of respondents to a 1994 survey, an estimated 79 percent of Yucca Mountain Project and Nevada Test Site onsite employees live in Clark County (Table 3-21). The region of influence includes Lincoln County because of the possibility that DOE could build and operate an intermodal transfer station there.

Table 3-21. Distribution of Yucca Mountain Project and Nevada Test Site onsite employees (survey respondents) by place of residence.[a]

Place of residence	Onsite workers	Percent of total
Clark County	1,268	79
Lincoln County	5	0.3
Nye County	310	19
Total region of influence	**1,583**	**98**
Outside region of influence	31	2
Total respondents	***1,614***	***100.0***

a. Source: TRW (1994a, all).

3.1.7.1 Population

DOE used the Regional Economic Models, Inc. (REMI) model to estimate baseline socioeconomic conditions at the conclusion of site characterization (Treyz, Rickman, and Shao 1992, all).

Southern Nevada has been and continues to be one of the fastest-growing areas in the country. During the 1980s, the population of the region of influence had an average annual growth rate of 4.8 percent, adding more than 29,000 people annually and reaching 780,000 residents in 1990. In comparison to the State of Nevada, which had a average annual growth rate of 4 percent between 1980 and 1990, the United States had a growth rate of less than 1 percent during the same period (Bureau of the Census 1999, all). This trend has increased during the 1990s. From 1990 to 1997, the region of influence had an annual growth rate of 5.5 percent, averaging 51,000 new residents annually. In 1997, the population of the region increased 5.4 percent and added 57,000 new residents, bringing the estimated population to about 1.14 million. Led by Clark County, Nevada is the fastest growing state in the country. From 1990 to 1997, Nevada had an annual growth rate of 4.5 percent compared to the 1-percent annual growth rate of the United States.

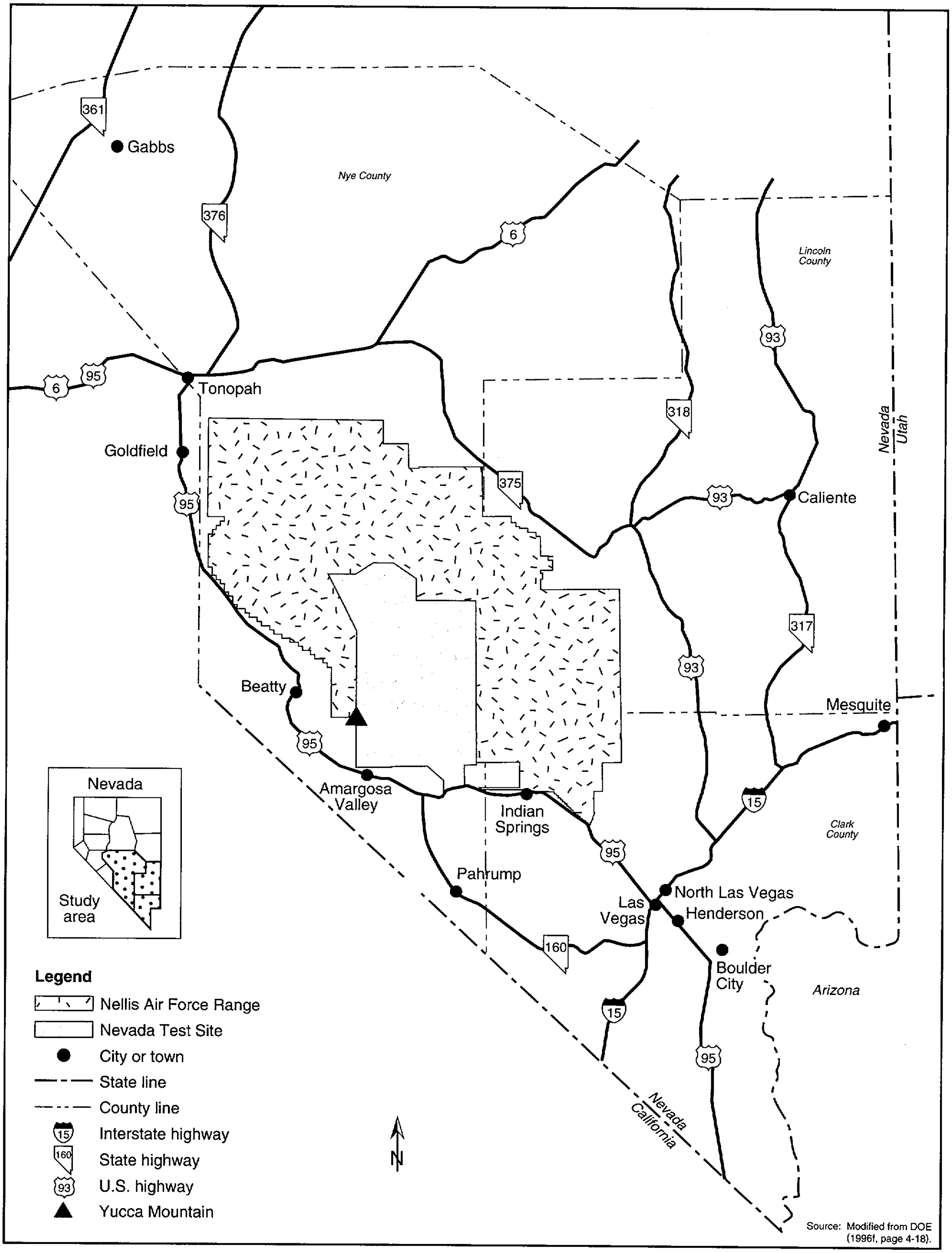


Figure 3-20. Socioeconomic region of influence.

Las Vegas and the immediate surrounding area dominate the Clark County population. The Las Vegas economy is driven by the growth of the hotel and gaming industry. As the popularity of gaming grew in the 1970s and 1980s, Las Vegas evolved as one of the country's major tourism and convention destinations. In 1997, Las Vegas hosted 30.5 million visitors, contributing $25 billion to the local economy (LVCVA 1999, all). The tourism trend is expected to continue well into the next century. The relatively inexpensive land, Sunbelt climate, and favorable business conditions have also contributed to commercial and residential growth.

Another factor influencing strong growth is the number of retirees moving to communities in the region of influence. The pleasant climate, abundance of recreational opportunities, and Nevada's favorable tax structure have attracted retirees from across the United States.

Nye County, which has been the site of booms and busts due to fluctuating mining activity and the recent decline of Nevada Test Site employment, is home to approximately 19 percent of the Yucca Mountain Project workforce (Table 3-21). Pahrump, in southern Nye County, is experiencing growth caused primarily by inmigrating retirees.

In 1997, Nye County had about 26,000 residents, and it has experienced a 3.7-percent annual growth rate in the 1990s. The 1997 population in Lincoln County was about 4,200, up from about 3,800 in 1990. Although the annual growth rate of the region of influence is likely to slow, the population should increase 2 to 4 percent a year in the next decade. Clark County should lead the population growth in the foreseeable future in the region of influence.

The region of influence includes a number of incorporated cities as well as unincorporated towns (Table 3-22). The largest city in Clark County is Las Vegas, followed by Henderson. In 1997, Las Vegas had a population of about 430,000 compared to Henderson, which had about 150,000 residents. Nye County has one incorporated city, but the largest community is unincorporated Pahrump, which had an estimated population of about 19,000 in 1997. Lincoln County also has only one incorporated city, Caliente, which is the largest community. In 1997, Caliente had a population of about 1,100.

Table 3-22. Population of incorporated cities and selected unincorporated towns, 1991 to 1997.[a,b]

Jurisdiction	1991	1995	1997
Clark County			
Boulder City	13,000	14,000	14,000
Henderson	77,000	120,000	150,000
Indian Springs[c]	N/A[d]	N/A	1,200
Las Vegas	290,000	370,000	430,000
Mesquite	2,100	5,100	9,300
North Las Vegas	51,000	78,000	93,000
Nye County			
Amargosa Valley[c]	N/A	N/A	990
Beatty[c]	N/A	N/A	1,600
Gabbs	680	360	400
Pahrump[c]	N/A	N/A	19,000
Tonopah[c]	N/A	N/A	2,800
Lincoln County			
Caliente	1,100	1,200	1,100

a. Source: TRW (1999n, all).
b. Population numbers have been rounded to two significant figures.
c. Selected unincorporated towns.
d. N/A = not available.

3.1.7.2 Employment

Of the three counties that comprise the region of influence, Clark County has by far the largest economy; in 1995, the estimated employment was about 620,000. This constituted 98 percent of the regional employment and about 64 percent of the State employment. During the same year Nye County had an employment of about 11,000, and the Lincoln County employment was about 2,100. Clark County should continue to outpace the growth of the other counties in the region.

Between 1980 and 1990, Clark County added an average of 19,000 jobs a year (Table 3-23). Since 1990 that pace has increased to more than 30,000 new jobs a year with an average annual growth rate of 6.1 percent. Total employment increased 35 percent between 1990 and 1995, adding about 160,000 jobs. By 2000, Clark County is expected to have an employment of about 860,000, continuing to create over 2,000 new jobs a month. The services employment sector is the largest in Clark County, representing 46 percent of the employment in 1995.

Table 3-23. Clark County employment by sector, 1980 to 2000.[a,b]

Sector	1980	1990	1995	2000
Private sector (totals)	*230,000*	*410,000*	*560,000*	*780,000*
Agriculture, forestry, and fisheries	1,300	3,900	6,200	9,000
Mining	590	820	1,200	1,300
Construction	16,000	41,000	53,000	79,000
Manufacturing	7,300	12,000	18,000	20,000
Transportation and public utilities	14,000	21,000	29,000	37,000
Wholesale trade	6,500	14,000	19,000	24,000
Retail trade	44,000	72,000	98,000	130,000
Finance, insurance, and real estate	20,000	32,000	44,000	55,000
Services	120,000	210,000	290,000	420,000
Government (totals)	*38,000*	*51,000*	*62,000*	*79,000*
Federal Government - civilian	4,800	6,900	7,800	7,700
Federal Government - military	11,000	11,000	9,500	10,000
State and local government	22,000	33,000	45,000	11,000
Farm	*420*	*400*	*300*	*310*
Totals	***268,420***	***460,000***	***620,000***	***859,310***

a. Sources: 1980, 1990, and 1995: TRW (1999n, all); 2000: estimated.
b. Employment numbers have been rounded to two significant figures.

Although Nye County's employment increased between 1980 and 1990, it declined to about 11,000 in 1995, a decrease of 15 percent (Table 3-24). The services sector represented the largest in the Nye County economy. In 1995, services comprised 47 percent of the employment. Projections indicate that employment will decline to about 10,000 by 2000. Lincoln County employment also declined between 1990 and 1995 after growth during the 1980s (Table 3-25). In 1995, Lincoln County had a employment of about 2,100, a decline of 13 percent from 1990. As in Clark and Nye Counties, services represented the largest sector of the Lincoln County economy. In 1995, services comprised 39 percent of the employment.

Las Vegas, in Clark County, has one of the fastest growing economies in the country. The rapid growth of the Las Vegas area is driven by the gaming and tourism industry. For each hotel room constructed, an employment multiplier effect creates an estimated 2.5 direct and indirect jobs. About 14,000 hotel rooms were added between 1996 and 1998. Five new major resorts under construction with completion dates between Spring 1998 and Spring 2000 will add about 14,000 hotel rooms (*Las Vegas Sun* 1998, all). Despite an inventory of more than 100,000 rooms, hotels consistently operate at 90 percent occupancy, reaching to 97 percent on weekends.

Table 3-24. Nye County employment by sector, 1980 to 2000.[a,b]

Sector	1980	1990	1995	2000
Private sector (totals)	*6,900*	*12,000*	*9,600*	*11,000*
Agriculture, forestry, and fisheries	50	70	110	120
Mining	1,100	2,000	1,400	1,000
Construction	410	390	560	1,000
Manufacturing	88	160	250	290
Transportation and public utilities	[210]	[280]	280	380
Wholesale trade	25	49	100	150
Retail trade	530	960	1,200	1,800
Finance, insurance, and real estate	[360]	[290]	450	490
Services	4,100	7,700	5,200	5,500
Government (totals)	*770*	*1,200*	*1,500*	1,700
Federal Government - civilian	130	200	200	*200*
Federal Government - military	100	77	53	79
State and local government	540	930	1,200	1,400
Farm	*220*	*260*	*210*	210
Totals	***7,890***	***13,360***	***11,310***	***12,910***

a. Sources: 1980, 1990, and 1995: TRW (1999n, all), except estimates in [brackets] appear wherever data suppression by TRW (1999n) was indicated by zeros; 2000: estimated.
b. Employment numbers have been rounded to two significant figures.

Table 3-25. Lincoln County employment by sector, 1980 to 2000.[a,b]

Sector	1980	1990	1995	2000
Private sector (totals)	*1,300*	*1,712*	*1,380*	*1,558*
Agriculture, forestry, and fisheries	[4]	[30]	22	24
Mining	310	30	18	14
Construction	75	47	44	24
Manufacturing	12	[10]	10	37
Transportation and public utilities	96	88	62	62
Wholesale trade	12	10	[17]	41
Retail trade	310	250	[270]	386
Finance, insurance, and real estate	51	47	68	74
Services	380	[1,200]	[869]	846
Government (totals)	*400*	*537*	*607*	*573*
Federal Government - civilian	25	45	39	34
Federal Government - military	12	12	*8*	9
State and local government	360	480	560	530
Farm	*160*	*180*	*150*	*149*
Totals	***1,860***	***2,429***	***2,137***	***2,280***

a. Sources: 1980, 1990, and 1995: TRW (1999n, all), except estimates in [brackets] appear wherever data suppression by TRW (1999n) was indicated by zeros; 2000: estimated.
b. Individual employment numbers have been rounded to two significant figures.

Because of the thousands of new jobs added to the economy each month, the Las Vegas area has a low unemployment rate. In 1997, Clark and Nye Counties had unemployment rates below the Nevada and national rates at 4.0 percent and 3.9 percent, respectively. The planned closing of the Bullfrog Mine in Nye County will increase unemployment. In 1997, the Bullfrog Mine employed approximately 290 workers; however, it will probably close in 2000 (Meyers 1998, all). Lincoln County had an unemployment rate above the national average at 7.8 percent (Reel 1998, all). The State of Nevada had an unemployment rate of 4.1 percent and the United States had a rate of 4.9 percent (NDETR 1999, all). Onsite employment levels at the Exploratory Studies Facility remained relatively constant between 1995 and 1997, and are not likely to fluctuate substantially through the end of site characterization activities.

In 1997, an average of about 1,600 workers (140 on the site and 1,460 off the site) worked on the Yucca Mountain Project. Most offsite workers are in the Las Vegas area (TRW 1998d, all). The employment projection for 2000 reflects expected changes due to new hotel construction, closure of the Bullfrog Mine, and Yucca Mountain Project employment.

3.1.7.3 Payments Equal to Taxes

Another issue of interest is the DOE Payments-Equal-To-Taxes Program. Section 116(c)(3)(A) of the Nuclear Waste Policy Act of 1982, as amended, requires the Secretary of Energy to "...grant to the State of Nevada and any affected unit of local government an amount each fiscal year equal to the amount such State or affected unit of local government, respectively, would receive if authorized to tax site characterization activities...." The Yucca Mountain Site Characterization Office is responsible for implementing and administering this program for the Yucca Mountain Project. DOE acquired data from the project organizations that purchase or acquire property for use in Nevada, have employees in Nevada, or use property in Nevada. These organizations include Federal agencies, national laboratories, and private firms. Not all of them have a Federal exemption, so they pay the appropriate taxes. The purchases (sales and use tax), employees (business tax), and property (property or possessory use taxes) of the Yucca Mountain Project organizations that exercise a Federal exemption are subject to the Payments-Equal-To-Taxes Program (NLCB 1996, all).

The estimated sales and use taxes, property taxes, and Nevada business taxes Yucca Mountain Project organizations paid from May 1986 through June 1996 have been totaled. These organizations paid sales or use taxes of $2.25 million for purchases consumed in Clark County and $3.8 million in Nye County, paid property or possessory taxes of about $110,000 in Clark County and $37,355 in Nye County, and paid Nevada business taxes of about $460,000 (NLCB 1996, all).

The Payments-Equal-To-Taxes for sales or use taxes from May 1986 through June 1996 was about $1.68 million for purchases consumed in Clark County and $240,000 in Nye County. For property taxes it was about $200,000 in Clark County, $14.8 million in Nye County, $8,000 in Lincoln County, $3,700 in Esmeralda County, and $24,000 in Inyo County. For Nevada business taxes, about $95,000 has been paid.

3.1.7.4 Housing

Spurred by the rapid population growth and soaring employment opportunities, the residential housing market is strong and steady in the Las Vegas area. From 1992 to 1996, annual sales of new homes exceeded 16,000 units. In 1996, a record 19,000 units were sold. More than 400 residential developers sell properties in the Las Vegas area, leading to a highly competitive market. The competition has kept price increases to the rate of inflation. Eighty-five percent of the new homes sold were priced between $100,000 and $190,000. The average home sold for about $131,000 in 1996. Large master-planned communities are common, and average about 30 percent of the total home sales. Steady employment and population growth should continue to spur demand for housing. Sustained growth will depend on further development of large-scale resort and gaming projects.

The housing stock of Clark County in 1990 was about 320,000 units, which consisted of about 150,000 single-family units, 130,000 multifamily units, and 33,000 mobile homes or other accommodations. About 290,000 of these units were occupied, resulting in 2.5 persons per household (Bureau of the Census 1998, all). Assuming that the persons per household and occupancy rate remain the same, the expected number of households in Clark County in 2000 is about 570,000.

The housing stock of Nye County in 1990 was about 8,100 units, which consisted of about 2,300 single-family units, 560 multifamily units, and 5,200 mobile homes or other accommodations. About 6,700 of these units were occupied, resulting in 2.5 persons per household (Bureau of the Census 1998, all). Assuming that the persons per household and occupancy rate remain the same, the expected number of households in Nye County in 2000 is about 12,000.

The housing stock of Lincoln County in 1990 was about 1,800 units, which consisted of about 1,000 single-family units, 160 multifamily units, and 600 mobile homes or other accommodations. About 1,300 of these units were occupied, resulting in 2.6 persons per household (Bureau of the Census 1998, all). Assuming that the persons per household and occupancy rate remain the same, the expected number of households in Lincoln County in 2000 is about 1,800.

Because most population and employment growth in the region of influence will occur in Clark County, most housing growth also will occur there. The only other area in the region likely to see large growth is Pahrump in southern Nye County. Housing changes in Lincoln County probably will be minimal in the foreseeable future.

3.1.7.5 Public Services

Education. In the 1996-1997 school year, the region of influence contained about 180 elementary and middle schools, 34 high schools, 13 alternative schools, and 4 special education schools. The average pupil-teacher ratio was about 21-to-1 for elementary schools and 19-to-1 for secondary schools (Clark County 1997a, all; NDE 1997, page 4). In 1997, the national pupil-teacher ratio was about 19-to-1 for elementary schools and 15-to-1 for secondary schools (USDE 1999, all). Clark County has the tenth-largest school district in the country; during the 1996-1997 school year, Clark County had about 210 schools and nearly 180,000 students (Table 3-26). During the same period, Nye County had 16 schools and fewer than 5,000 students, and Lincoln County had nine schools and about 1,000 students (Clark County 1997a, all; TRW 1999n, all; NDE 1997, page 4).

Because Clark County is experiencing rapid growth, voters have passed three bond issues totaling $1.85 billion dollars since 1988 to renovate existing schools and build new schools. The most recent was a $643 million bond in 1996. Eleven new schools—six elementary, three middle, and two high schools—were scheduled to open during the 1997-1998 school year (Clark County 1998, all). Nye County was scheduled to seek approval in a 1998 bond issue to build a new middle and elementary school over the next few years (Harge 1997, page 18).

Table 3-26. Enrollment by school district and grade level.[a,b]

District	Actual 1996-1997[c]	Projected 2000-2001[d]
Clark County[e]		
Prekindergarten	1,000	1,300
Kindergarten	15,000	19,000
Elementary (grades 1-6)	90,000	110,000
Secondary (grades 7-12)	73,000	91,000
District totals	**179,000**	**221,300**
Nye County[f]		
Prekindergarten	43	44
Kindergarten	310	380
Elementary (grades 1-6)	2,300	2,400
Secondary (grades 7-12)	2,200	2,300
District totals	**4,853**	**5,124**
Lincoln County[g]		
Prekindergarten	22	20
Kindergarten	57	51
Elementary (grades 1-6)	400	360
Secondary (grades 7-12)	630	570
District totals	**1,109**	**1,001**

a. Figures include ungraded students who are enrolled in school for special education and students who cannot be assigned to a grade because of the nature of their condition; Prekindergarten refers to 3- and 4-year-old minors receiving special education.
b. Enrollment numbers have been rounded to two significant figures.
c. Enrollments for the 1996-1997 school year are as of the end of the first school month.
d. Projected enrollment for the 2000-2001 school year is based on the ratio of actual 1996-1997 figures to the 1996 population estimate multiplied by the 2000 population forecast.
e. Source: Clark County (1997a, all).
f. Source: NDE (1997, page 4).
g. Source: TRW (1999n, all).

Health Care. Health care services in the region of influence are concentrated in Clark County, particularly in the Las Vegas area. In 1995, Clark County had seven hospitals and four specialized care facilities. Although Nye County has one hospital in Tonopah, most people in the southern part of the county use local clinics or go to hospitals in Las Vegas. Lincoln County has one hospital in Caliente (Rodefer et al. 1996, all). Table 3-27 lists hospital use in the region of influence.

Table 3-27. Hospital use by county in the region of influence.[a,b]

County	1990	1995	2000
Clark			
Population	750,000	1,000,000	1,310,000
Average number of beds	2,000	2,100	2,900[c]
Beds per 1,000 residents	2.6	2.2	2.2[d]
Patient-days	490,000	530,000	700,000[e]
Nye			
Population	18,000	24,000	26,000
Average number of beds	21	21	22[c]
Beds per 1,000 residents	1.2	0.86	0.86[d]
Patient-days	1,800	1,900	2,000[e]
Lincoln			
Population	3,800	3,900	3,400
Average number of beds	5	4	4[c]
Beds per 1,000 residents	1.3	1.0	1.0[d]
Patient-days	520	360	310[e]

a. Source: Rodefer et al. (1996, pages 214 to 216).
b. All numbers have been rounded to two or three significant figures.
c. Calculated assuming number of beds per 1,000 residents remained constant.
d. Held constant at 1995 levels.
e. 2000 patient-days calculated by multiplying 2000 population by 1995 ratio of patient-days to population.

Medical services are available at the Nevada Test Site for Exploratory Studies Facility personnel; these services include two paramedics and an ambulance in Area 25. Backup services are on call from other Test Site locations. In addition, the Nevada Test Site provides medical services for Yucca Mountain Project workers at a clinic in Mercury, which has no overnight capability. When patients need urgent care, the Yucca Mountain Project relies on the helicopter "Flight for Life" and "Air Life" operations from Las Vegas. In emergencies, Area 25 can call on Nellis Air Force Base or Nye County for help.

Law Enforcement. The Las Vegas Metropolitan Police Department is responsible for law enforcement in Clark County with the exceptions of the Cities of North Las Vegas, Henderson, Boulder City, and Mesquite, which have their own police departments. The Las Vegas police department is the largest law enforcement agency in Nevada; in 1996, it had about 1,200 employees, a ratio of about 1.2 employees per 1,000 residents. In 1996, the Nye County Sheriff Department had 110 employees, a ratio of 4.4 employees per 1,000 residents, and Lincoln County had 14 sheriff department employees, a ratio of 3.7 employees per 1,000 residents. In comparison, the national officer-to-population ratio is 2.4 officers per 1,000 residents, (FBI 1996, pages 1 to 3). Assuming that the number of employees per 1,000 residents remains the same, the expected law enforcement staffing in 2000 will be about 1,600 in Clark County, 120 in Nye County, and 15 in Lincoln County.

Fire Protection and Emergency Management. A combination of fire departments provides protection in the region of influence; these include the Clark County, Las Vegas, and North Las Vegas fire departments and several other city, county, and military departments. In 1992, Clark County had about 1,100 paid, 420 volunteer, and 80 seasonal or inmate firefighters, a ratio of 1.9 firefighters per 1,000 residents. In 1992, Nye County had 150 paid and 330 volunteer firefighters, a ratio of about 25 firefighters per 1,000 residents, and Lincoln County had 73 volunteer firefighters, a ratio of about 19 firefighters per 1,000 residents. The national average is 4.1 firefighters (full and volunteer) per 1,000 residents.

3.1.8 OCCUPATIONAL AND PUBLIC HEALTH AND SAFETY

The public health and safety region of influence consists of the number of persons residing within an 80-kilometer (50-mile) radius of the repository site at the end of site characterization. The estimated population in 2000 is about 28,000. The region of influence encompasses communities in Nye and Clark Counties in Nevada, as well as Inyo County in California (Figure 3-21). Potentially affected workers include those at the repository site and at nearby Nevada Test Site facilities. This section describes the existing radiation environment and the baseline cancer incidence in the region of influence. Unless otherwise noted, the *Environmental Baseline File for Human Health* (TRW 1999o, all) is the basis of the information in this section.

Section 3.1.8.1 describes the various radiation sources that make up the radiation environment. Section 3.1.8.2 describes the existing radiation environment in the Yucca Mountain region. Section 3.1.8.3 describes the health-related mineral issues encountered during site characterization activities. Section 3.1.8.4 describes the worker industrial safety experienced from site characterization activities.

3.1.8.1 Radiation Sources in the Environment

There are ambient levels of radiation at and around the site of the proposed repository just as there are around the world. All people are inevitably exposed to the three sources of ionizing radiation: those of *natural* origin unaffected by human activities, those of natural origin but affected by human activities (called *enhanced natural* sources), and *manmade* sources. Natural sources include cosmic radiation from space, *terrestrial* radiation from natural radioactive sources in the ground (radon, for example), radiation from radionuclides naturally present in the body, and inhaled and ingested radionuclides of natural origin. Enhanced natural sources include those that can increase exposure as a result of human actions, deliberate or otherwise. For example, air travel, especially at very high altitudes, increases exposure to cosmic radiation, and tunneling through rock (as at Yucca Mountain) increases worker exposure to naturally occurring sources. A variety of exposures result from manmade materials and devices such as radiopharmaceuticals and X-rays in medicine, and consumer products such as some smoke detectors. Exposures can also result from episodic events, such as uncontained nuclear weapons tests.

External background radiation comes from two sources of approximately equal magnitude: cosmic radiation from space and terrestrial gamma radiation from radionuclides in the environment, mainly from the Earth itself. In the case of cosmic radiation, charged particles (primarily protons from extraterrestrial sources) have sufficiently high energies to generate secondary particles that have direct and indirect ionizing properties. The three main contributors to the terrestrial gamma radiation field are potassium-40 and the members of the thorium and uranium decay series. Most terrestrial gamma radiation comes from the top 20 centimeters (8 inches) of soil, with a small contribution from airborne radon decay products.

Cosmogenic radionuclides are produced by interactions of cosmic particles with certain atoms in the atmosphere or in the Earth. There are four cosmogenic radionuclides of interest for internal doses: tritium (hydrogen-3), beryllium-7, carbon-14, and sodium-22. With the exception of beryllium-7, all are isotopes of important elements in the human body. The dose rates from natural cosmic, cosmogenic, and terrestrial radiation vary throughout the world depending on such factors as altitude and geology. Natural background radiation is the largest contributor to the average radiation dose to individuals and is the most variable component of background radiation. Table 3-28 lists estimated radiation doses from natural sources to individuals in the region of influence and other locations.

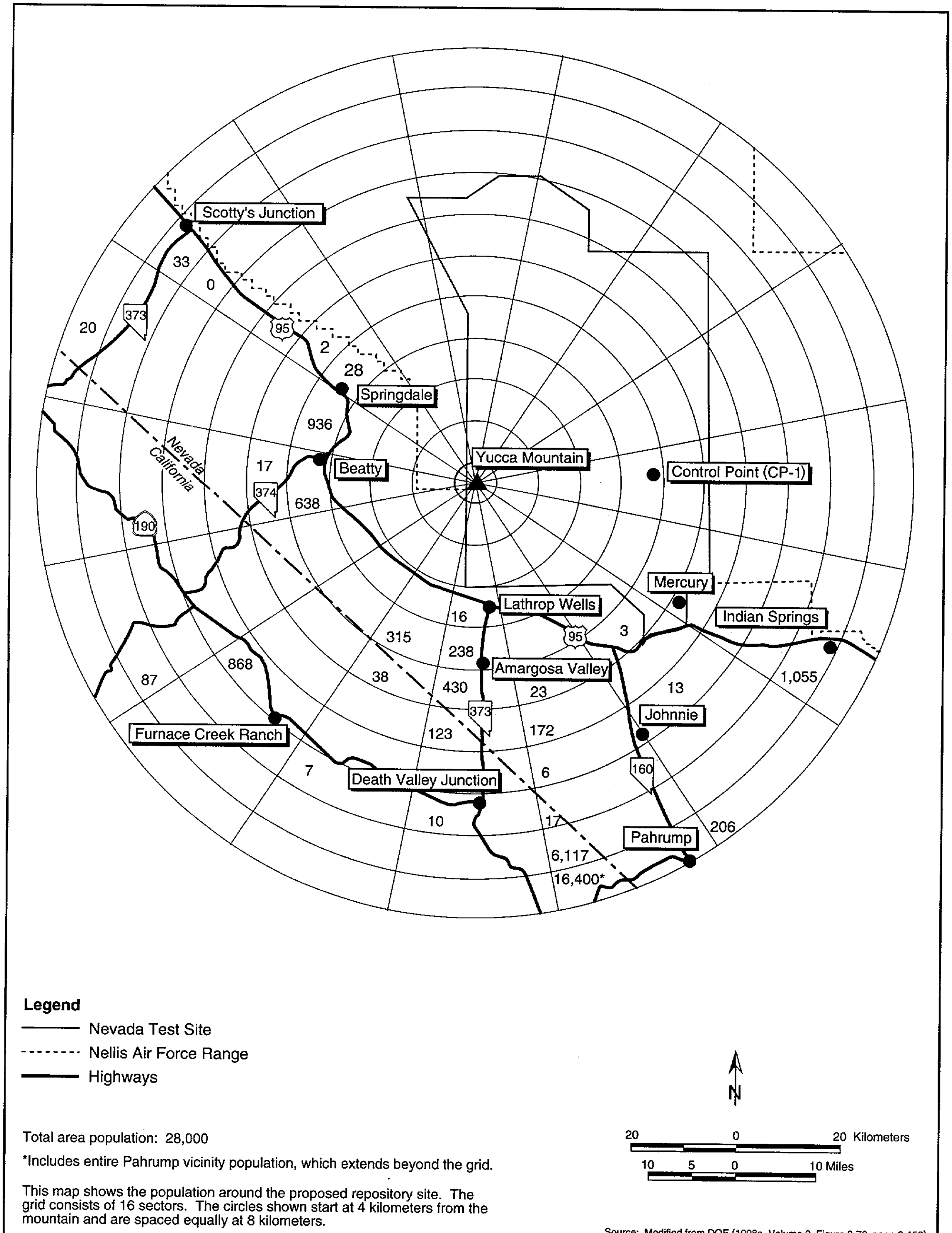


Figure 3-21. Population distribution within 80 kilometers (50 miles) of the proposed repository site, year 2000 estimate.

Table 3-28. Radiation exposure from natural sources (millirem per year).[a]

	Annual dose (effective dose equivalent)					
					Region of influence	
Source	U.S. average	Aiken[b]	Oak Ridge[c]	Las Vegas	Amargosa Valley	Beatty
Cosmic and cosmogenic	28	33	29	(d)	40	(d)
Terrestrial	28	43	38	89	56	150
Radon in homes (inhaled)[e]	200	200	200	200	200	200
In body	40	40	40	40	40	40
Totals[f]	**300**	**320**	**310**	**330**	**340**	**390**

a. Sources: Bechtel (1998, page 4-31); DOE (1995e, pages 4-211 and 4-394); NCRP (1987, Section 2).
b. Aiken, South Carolina, is the location of the DOE Savannah River Site.
c. Oak Ridge, Tennessee, is the location of the DOE Oak Ridge National Laboratory.
d. Included in the terrestrial source.
e. Value for radon is an average for the United States.
f. Totals might differ from sums due to rounding.

The effect of radiation on people depends on the kind of radiation exposure (alpha and beta particles, and X-rays and gamma rays), the total amount of tissue exposed to radiation, and the duration of the exposure. The amount of radiant energy imparted to tissue from exposure to ionizing radiation is referred to as *absorbed dose*. The sum of the absorbed dose to each tissue, when multiplied by certain quality and weighting factors that take into account radiation quality and different sensitivities of the various tissues, is referred to as *effective dose equivalent* and is measured in rem. The Code of Federal Regulations contains further discussion of DOE radiation protection standards and methods of dose assessment (10 CFR Part 835).

An individual can be exposed to radiation from outside or inside the body because radioactive materials can enter the body by ingestion or inhalation. External dose is different from internal dose in that it is delivered only during the actual time of exposure. An internal dose, however, continues to be delivered as long as the radioactive source is in the body (although both radioactive decay and elimination of the radionuclide by ordinary metabolic processes decrease the dose rate with the passage of time).

TERMS USED IN RADIATION DOSE ASSESSMENT

Curie: A unit of radioactivity equal to 37 billion disintegrations per second; also a quantity of any nuclide or mixture of nuclides having 1 curie of radioactivity.

Picocurie per liter: A unit of measure describing the amount of radioactivity in a liter of a given substance (for example, air or water). A picocurie is one one-trillionth of a curie.

Roentgen: A unit of measure of X-ray or gamma-ray radiation exposure described in terms of the amount of energy transferred to a unit mass of air. One roentgen corresponds to the absorption of 87.7 ergs (about 6.5×10^{-6} foot-pound) per gram of air.

Rem: The dose of an ionizing radiation that will cause the same biological effect as 1 roentgen of X-ray or gamma ray exposure (rem means Roentgen Equivalent in Man).

Radiation can cause a variety of adverse health effects in people. A large dose of radiation can cause prompt death. At low doses, the most important adverse health effect for depicting the consequences of environmental and occupational radiation exposures (which are typically low doses) is the potential inducement of cancers that can lead to death in later years. This effect is referred to as *latent cancer* *fatalities* because the cancer can take years to develop and for death to occur, and might never actually be the cause of death.

The collective dose to an exposed population is calculated by summing the estimated doses received by each member of the exposed population. This is referred to as a *population dose*. The total population dose received by the exposed population is measured in person-rem. For example, if 1,000 people each received a dose of 0.001 rem, the population dose would be 1.0 person-rem (1,000 persons multiplied by 0.001 rem equals 1.0 person-rem). The same population dose (1.0 person-rem) would result if 500 people each received a dose of 0.002 rem (500 persons multiplied by 0.002 rem equals 1 person-rem).

The factor used in this EIS to relate a dose to its potential effect is 0.0004 latent cancer fatality per person-rem for workers and 0.0005 latent cancer fatality per person-rem for individuals among the general population (NCRP 1993a, page 3). The latter factor is slightly higher because some individuals in the public, such as infants, might be more sensitive to radiation than workers. These risk factors have been endorsed by the International Commission on Radiological Protection, Environmental Protection Agency, Nuclear Regulatory Commission, and National Council on Radiation Protection and Measurements. The factors apply if the dose to an individual is less than 20 rem and the dose rate is less than 10 rem per hour. At doses greater than 20 rem, the factors used to relate radiation doses to latent cancer fatalities are doubled. At much higher doses, prompt effects, rather than latent cancer fatalities, might be the primary concern.

These concepts can be used to estimate the effects of exposing a population to radiation. For example, if 100,000 people were each exposed only to background radiation (0.3 rem per year), 15 latent cancer fatalities could occur as a result of 1 year of exposure (100,000 persons multiplied by 0.3 rem per year multiplied by 0.0005 latent cancer fatality per person-rem equals 15 latent cancer fatalities per year).

Calculations of the number of latent cancer fatalities associated with radiation exposure do not normally yield whole numbers and, especially in environmental applications, can yield numbers less than 1.0. For example, if 100,000 people were each exposed to a total dose of only 1 millirem (0.001 rem), the population dose would be 100 person-rem, and the corresponding estimated number of latent cancer fatalities would be 0.05 (100,000 persons multiplied by 0.001 rem multiplied by 0.0005 latent cancer fatality per person-rem equals 0.05 latent cancer fatality).

The *average* number of deaths that would result if the same exposure situation were applied to many different groups of 100,000 people is 0.05. In most groups, nobody (zero people) would incur a latent cancer fatality from the 1-millirem 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 the groups would be 0.05 latent fatal cancer (just as the average of 0, 0, 0, and 1 divided by 4 is 0.25). The most likely outcome is no latent cancer fatalities in these different groups.

The same concepts apply to estimating the effects of radiation exposure on a single individual. Consider the effects, for example, of exposure to background radiation over a lifetime. The "number of latent cancer fatalities" corresponding to a single individual's exposure to 0.3 rem a year over a (presumed) 70-year lifetime is:

$$\begin{aligned}\text{Latent cancer fatality} &= 1 \text{ person} \times 0.3 \text{ rem per year} \times 70 \text{ years} \\ &\quad \times 0.0005 \text{ latent cancer fatality per person-rem} \\ &= 0.011 \text{ latent cancer fatality.}\end{aligned}$$

Again, this should be interpreted in a statistical sense; that is, the estimated effect of background radiation exposure on the exposed individual would produce a 1.1-percent chance that the individual would incur a latent fatal cancer. The baseline Nevada cancer fatality rate in a population of 100,000 is about 185 deaths per year (ACS 1998, page 6), resulting in a baseline rate of about 50 cancer deaths per year in the region of influence.

3.1.8.2 Radiation Environment in the Yucca Mountain Region

Ambient radiation levels from cosmic and terrestrial sources at Yucca Mountain are higher than the U.S. average. The higher elevation at Yucca Mountain results in higher levels of cosmic radiation due to less shielding by the atmosphere. The U.S. average for cosmic, cosmogenic, and terrestrial radiation exposures is 56 millirem per year (Table 3-28). The exposures at the Yucca Mountain ridge and Yucca Mountain surface facilities are about 160 and 150 millirem per year, respectively. Moreover, there are higher amounts of naturally occurring radionuclides in the soil and parent rock of this region than in some other regions of the United States, which also results in higher radiation doses.

The Yucca Mountain Project and the DOE Nevada Operations Office (in conjunction with the Environmental Protection Agency) conduct environmental surveillances around the Nevada Test Site. This monitoring has identified no radioactivity attributable to current operations at the Test Site. It did detect trace amounts of manmade radionuclides from worldwide nuclear testing in milk, game, and foods and in soil. Even though the monitoring has not detected ongoing releases to the environment related to the Test Site, DOE has made quantitative estimates of offsite doses from releases from past weapons testing activities at the Nevada Test Site (Bechtel 1998, page 7-5). Sources of ongoing releases at the Nevada Test Site include water containment ponds and contaminated soil resuspension. The estimated maximum annual radiation dose to a hypothetical individual in Springdale, Nevada [approximately 16 kilometers (10 miles) north of Beatty on U.S. 95], from airborne radioactivity is 0.09 millirem. The estimated maximum annual radiation dose for a hypothetical individual at the Nevada Test Site boundary is 0.12 millirem. These doses, which are about 1 percent of the 10-millirem-per-year dose limit that the Environmental Protection Agency established for a member of the public from emissions to the air from manmade sources (40 CFR Part 61), are conservative because data from offsite surveillance do not support doses of this magnitude.

Workers in the Exploratory Studies Facility can inhale naturally occurring radon-222 (a radioactive noble gas that is a decay product of naturally occurring uranium in rock) and its radioactive decay products. Radon concentration measurements during working hours, at a location representative of repository conditions, ranged from about 0.22 to 72 picocuries per liter, with a median concentration of about 6.5 picocuries per liter (TRW 1999o, page 12). The median annual dose to involved workers from inhalation of radon and decay products underground was estimated to be about 60 millirem. Appendix F contains additional information on the estimated underground external dose to involved workers from radon.

Workers in the Exploratory Studies Facility are also exposed to external gamma radiation from radon decay products and other naturally occurring radionuclides. Ambient radiation monitoring in this facility indicated a dose rate from background sources of radionuclides in the drift walls of about 40 millirem per year, which is about the same as the cosmic and cosmogenic components from background radiation on the surface in the Amargosa Valley region (see Table 3-28).

Naturally occurring radon-222 and decay products are released from the Exploratory Studies Facility in the exhaust ventilation air. The estimated annual release of radon and decay products is about 80 curies. The estimated annual dose to an individual 20 kilometers (12 miles) south of the repository is about 0.1 millirem. The estimated annual dose to the population within 80 kilometers (50 miles) is about

0.6 person-rem. These doses are small percentages of the dose from natural sources shown in Table 3-28. Appendix G contains additional information on the estimated releases of radon from the repository.

3.1.8.3 Health-Related Mineral Issues Identified During Site Characterization

Certain minerals known to present a potential risk to worker health are present in the volcanic rocks at Yucca Mountain (DOE 1998a, Volume 1, pages 2-24 and 2-25). The risks are generally related to potential exposures caused by inhalation of airborne particulates (dust). Some of the minerals represent a hazard commonly associated with underground construction, whereas others are rare and less well known.

Crystalline silica (silicon dioxide) comes in several forms—among them quartz, tridymite, and cristobalite. Inhaling silica dust causes a disease called *silicosis* that damages an area of the lungs called the air sac (alveoli) (EPA 1996a, all). The presence of silica dust in the alveoli causes a defensive reaction that results in the formation of scar tissue in the lungs. This scar tissue can reduce overall lung capacity.

DOE typically performs evaluations of exposure to crystalline silica at Yucca Mountain for cristobalite that encompass potential impacts from exposure to other forms of crystalline silica. The repository host rock has a cristobalite content ranging from 18 to 28 percent (TRW 1999b, page 4-81). The American Conference of Governmental Industrial Hygienists has established Threshold Limit Values for various forms of crystalline silica (ACGIH 1999, page 61). These limits are based on an 8-hour day and 40-hour week and, therefore, could be exceeded for a short period—as long as the average time spent by a worker is below the limit. The Threshold Limit Values for respirable cristobalite dust and quartz dust are 0.05 and 0.1 milligram per cubic meter, respectively. In addition, crystalline silica has been listed by the World Health Organization as a carcinogen (IARC 1997, page 41).

Normal underground mechanical excavation produces dust when the rock is broken loose from the face. Dust is also generated when the broken rock is transferred to railcars or conveyors, or a storage pile. Dust can also be generated by wind erosion of excavated rock storage piles. Excavation activities during site characterization have caused exceedances of crystalline silica Threshold Limit Values at specific work locations. Workers at these locations were required to wear respirators. DOE will use the experience gained during Experimental Studies Facility activities to design engineering controls to minimize future exposures.

Erionite is an uncommon zeolite mineral that the International Agency for Research on Cancer recognized as a human carcinogen in 1987; at Yucca Mountain, it occurs primarily in the basal vitrophyre of the Topopah Spring tuff and in isolated zones of the Tiva Canyon tuff (see Section 3.1.3). Even at low doses erionite is believed to be a potent carcinogen capable of causing mesothelioma, a form of lung cancer. As a result of its apparent carcinogenicity, erionite could pose a risk if encountered in quantity during underground construction, even with standard modern construction practices. Because erionite appears to be absent or rare at the proposed repository depth and location, most repository operations should not be affected. However, repository workers would take precautions (for example, dust suppression, air filters, personal protective gear) during construction when penetrating horizons in which erionite could occur, such as in the basal vitrophyre of the Topopah Spring tuff.

A number of other minerals present at Yucca Mountain might have associated health risks if prolonged exposures occur; however, there is no evidence suggesting a link to cancer. Therefore, the International Agency for Research on Cancer has ranked these substances not classifiable (IARC 1997, all). Some of the minerals identified and considered in establishing health and safety practices for potential repository operations include the zeolite group minerals mordenite (which is fibrous and similar in some respects to erionite), clinoptilolite, heulandite, and phillipsite. Because there is no known risk associated with the other zeolite minerals, and because they occur primarily in nonwelded units below the repository horizon, they probably do not represent a large risk. The measures implemented to mitigate risk from silica (for example, dust suppression, air filters, personal protective gear) should also protect workers from exposure to other minerals.

3.1.8.4 Industrial Health and Safety Impacts During Construction of the Exploratory Studies Facility

During Yucca Mountain site characterization activities, health and safety impacts to workers have resulted from common industrial hazards (such as tripping and falling). The categories of worker impacts include total recordable incidents, lost workdays, and fatalities. Recordable incidents or cases are occupational injuries or occupation-related illnesses that result in (1) a fatality, regardless of the time between the injury or the onset of the illness and death, (2) lost workday cases (nonfatal), and (3) incidents that result in the transfer of a worker to another job, termination of employment, medical treatment, loss of consciousness, or restriction of motion during work activities.

Site characterization activities at Yucca Mountain have had no involved worker fatalities. DOE has compiled statistics for the other types of health and safety impacts in accordance with the regulations of the Occupational Safety and Health Administration (29 CFR Part 1904) (see Appendix F, Table F.2-3). These statistics cover the 30-month period from the fourth quarter of 1994 through the first quarter of 1997. DOE selected this period because there was high onsite work activity in which the tunnel-boring machine was in operation in the Exploratory Studies Facility. DOE expects this condition to be characteristic of the types of activities that would occur during the construction of the surface facilities and the development of the emplacement drifts. Table 3-29 lists the industrial health and safety loss statistics for industry, general construction, general mining, and the Yucca Mountain site.

Table 3-29. Comparison of health and safety statistics for mining activities from the Bureau of Labor Statistics to those for Yucca Mountain during excavation of the Exploratory Studies Facility.[a]

Statistic	Total industry[b]	General construction[b]	General mining[b]	Yucca Mountain experience from DOE CAIRS data base, involved workers[c]
Total recordable cases rate	7.1	9.5	5.9	6.8
Lost workday cases rate	3.3	4.4	3.7	4.8
Lost workdays rate	Not available	Not available	Not available	100

a. Statistics based on 100 full-time equivalent work years or 200,000 worker hours.
b. Source: BLS (1998, all).
c. Source: Appendix F, Table F.2-3.

3.1.9 NOISE

Noise comes from either natural or manmade sources. DOE has evaluated existing noise conditions in the Yucca Mountain region and has compiled the detected ranges of noise levels at different locations under differing conditions.

3.1.9.1 Noise Sources and Levels

Yucca Mountain is in a quiet desert environment where natural phenomena such as wind, rain, and wildlife account for most background noise. The acoustic environment is typical of other desert environments where average day-night sound-level values range from 22 decibels on calm days to 38 decibels on windy days (Brattstrom and Bondello 1983, page 170).

NOISE MEASUREMENT

What are *sound* and *noise*?

When an object vibrates it possesses energy, some of which transfers to the air, causing the air molecules to vibrate. The disturbance in the air travels to the eardrum, causing it to vibrate at the same frequency. The ear and brain translate the vibration of the eardrum to what we call *sound*. *Noise* is simply unwanted sound.

How is sound measured?

The human ear responds to sound pressures over an extremely wide range of values. The range of sounds people normally experience extends from low to high pressures by a factor of 1 million. Accordingly, scientists have devised a special scale to measure sound. The term decibel (abbreviated dB), borrowed from electrical engineering, is the unit commonly used.

Another common sound measurement is the A-weighted sound level, denoted as dBA. The A-weighting accounts for the fact that the human ear responds more effectively to some pitches than others. Higher pitches receive less weighting than lower ones. Most of the sound levels provided in this EIS are A-weighted; however, some are in decibels due to lack of information on the frequency spectrum of the sound. The scale to the right provides common references to sound on the A-weighted sound-level scale.

Source: Modified from DOE (1999g, page 3-39).

TYPICAL A-WEIGHTED SOUND LEVELS

	DECIBELS	
50-horsepower siren (33 meters)[a]	140	
Jet takeoff (66 meters)	130	
Riveting machine[b]	120	Diesel motors
Cut-off saw Pneumatic peen hammer[b]	110	
	100	Outdoor public address system loudspeakers
Rock drill (16 meters) Textile weaving plant[b] Subway train (6.6 meters) Dump truck (16 meters) Pneumatic drill (16 meters)	90	Ventilation fans
Freight train (33 meters) Vacuum cleaner (3.3 meters)	80	Inside sports car (24 meters per second)[c]
Speech (0.33 meters) Passenger auto (16 meters)	70	
Large transformer (66 meters)	60	Near freeway (auto traffic) Large store Accounting office
	50	Private business office Light traffic (33 meters) Average residence
Soft whisper (13 centimeters)	40	
	30	Studio (speech)
	20	Quiet
	10	
Threshold of hearing (youths)	0	

a. To convert meters to feet, multiply by 3.2808.
b. Operator's position.
c. 24 meters per second = about 50 miles per hour.
d. 13 centimeters = about 5 inches.

Manmade noise occurs periodically in the area as vehicles travel to and from Yucca Mountain, from site characterization activities at the operations areas, and from occasional low-flying military jets. Sound-level measurements recorded in May 1997 at areas adjacent to and at the Yucca Mountain operations areas were consistent with noise levels associated with industrial operations [sound levels from 44 to 72 decibels (A-weighted)] (Brown-Buntin 1997, pages 4-6). Table 3-30 lists estimated sound-level values for Yucca Mountain, nearby communities and cities, and other environments.

3.1.9.2 Regulatory Standards

With the exception of prohibiting nuisance noise, neither the State of Nevada nor local governments have established numerical noise standards. Nevertheless, many Federal agencies use average day-night sound

Table 3-30. Estimated sound levels in southern Nevada environments.[a]

Environment	Sound level[b] (decibels)
Calm day at Yucca Mountain	22
Windy day at Yucca Mountain	38
Rural communities (Panaca, Hadley, Rachel, Alamo, Jean, Goodsprings, Sandy)	40 - 47
Small towns or rural communities along busy highways (Beatty, Indian Springs, Pahrump, Lathrop Wells, Caliente, Tonopah, Goldfield, Mercury) and at the intersection of proposed transportation routes to Yucca Mountain	45 - 55
Suburban parts of Las Vegas	52 - 60
Urban parts of Las Vegas	56 - 66
Dense urban parts of Las Vegas with heavy traffic	64 - 74
Under flight path at McCarran International Airport (0.8 to 1.6 kilometers[c] from runway)	78 - 88

a. Source: modified from EPA (1974, page 14); Brattstrom and Bondello (1983, page 170).
b. Day-night average sound level.
c. About 0.5 to 1 mile.

levels as guidelines for land-use compatibility and to assess the impacts of noise on people. Many agencies, including the Environmental Protection Agency, recognize an average day-night sound level of 55 decibels (A-weighted) as an outdoor goal for protecting public health and welfare in residential areas (EPA 1974, page 3). This noise level, which has been established by scientific consensus, is not a regulatory criterion in Nevada, and could protect against activity interference and annoyance. As required, DOE monitors noise levels in worker areas, and a hearing protection program has been in place during site characterization. Hearing protection is used as a supplement to engineering controls, which are the primary method of noise suppression.

3.1.10 AESTHETICS

Visual resources include the natural and manmade physical features that give a particular landscape its character and value as an environmental factor. Sections 3.1.3 and 3.1.5 describe the geologic and biological settings, respectively, at Yucca Mountain.

The region surrounding Yucca Mountain consists of unpopulated to sparsely populated desert and rural lands. Because Yucca Mountain is on the Nevada Test Site and Nellis Air Force Range with restricted public access, public visibility is limited to portions of U.S. Highway 95 near Amargosa Valley.

The Bureau of Land Management uses four visual resource classes in the management of public lands (BLM 1986, all). Classes I and II are the most valued, Class III is moderately valued, and Class IV is of least value. Visual resources fall into one of these classes based on a combination of three factors: (1) scenic quality, (2) visual sensitivity, and (3) distance from travel routes or observation points (BLM 1986, all). There are three scenic quality classes in the Visual Resource Management system. Class A includes areas that combine the most outstanding characteristics of each physical feature category. Class B includes areas in which there is a combination of some outstanding and some fairly common characteristics. Class C includes areas in which the characteristics are fairly common to the region. A visual sensitivity rating for an area is based on the number and types of users, public interest in the area, and adjacent land uses.

The Bureau of Land Management has not assigned a Visual Resource Management class to Yucca Mountain because the Nevada Test Site is not under the Bureau's jurisdiction. However, using the Bureau's method of determining scenic quality, DOE has evaluated the visual resources of the Yucca Mountain region from two observation points—one at Lathrop Wells on U.S. 95 and the other on the Nevada Test Site at a location that provides a clear view of the proposed repository site (TRW 1999p, all).

BUREAU OF LAND MANAGEMENT VISUAL RESOURCE MANAGEMENT CLASS OBJECTIVES (used in the management of public lands)

Class I	The objective of this class is to preserve the existing character of the landscape. This class provides for natural ecological changes; however, it does not preclude very limited management activity. The level of change to the characteristic landscape should be very low and must not attract attention.
Class II	The objective of this class is to retain the existing character of the landscape. The level of change to the characteristic landscape should be low. Management activities may be seen, but should not attract the attention of the casual observer. Any changes must repeat the basic elements of form, line, color, and texture found in the predominant natural features of the characteristic landscape.
Class III	The objective of this class is to partially retain the existing character of the landscape. The level of change to the characteristic landscape should be moderate. Management activities may attract attention but should not dominate the view of the casual observer. Changes should repeat the basic elements found in the predominant natural features of the characteristic landscape.
Class IV	The objective of this class is to provide for management activities that require major modification of the existing character of the landscape. The level of change to the characteristic landscape can be high. These management activities may dominate the view and be the major focus of viewer attention. However, every attempt should be made to minimize the impact of these activities through careful location, minimal disturbance, and repeating the basic elements.

The visual assessment at both these locations concluded that the scenic quality classification of Yucca Mountain is C.

3.1.11 UTILITIES, ENERGY, AND SITE SERVICES

DOE research into the current consumer demand for utilities and energy in the Yucca Mountain region has yielded information on water and power sources, use, and supply systems. The research included water treatment capabilities. The region of influence for potential impacts to utility and energy supplies consists of Clark, Lincoln, and Nye Counties in Nevada. Sections 3.1.11.1 and 3.1.11.2 contain information on current water and energy suppliers and consumer use. Unless otherwise noted, the *Yucca Mountain Site Characterization Project Environmental Baseline File for Utilities, Energy, and Site Services* (TRW 1999j, all) is the basis of the information in this section.

3.1.11.1 Utilities

Water and sewer utilities in the region could be affected by the Proposed Action as a result of project-related increases in population and the associated increases in water demand and sewage production. DOE anticipates that the predominant project-related increase in population would occur in Clark County, with a smaller increase in Nye County (see Section 3.1.7).

Water. The Southern Nevada Water Authority supplies water to five communities in Clark County: Boulder City, Henderson, Las Vegas (including parts of unincorporated Clark County), Nellis Air Force Base, and North Las Vegas. Eighty-five percent of the water supplied to the Las Vegas Valley comes from the Colorado River through Lake Mead; the remaining 15 percent comes from groundwater (Las Vegas Valley Hydrographic Area; SNWA 1997, page 2). To meet growing water demands, the Water Authority is upgrading current facilities and installing new facilities, such as a second raw water intake at Lake Mead, a second water treatment facility, and additional pipelines and pumping stations.

In southern Nye County, where the repository would be, groundwater is the only source of water. In August 1996, a water supply and demand evaluation for southern Nye County, including Beatty, Amargosa Desert, and Pahrump, was performed (Buqo 1996, all). In Beatty (Oasis Valley Hydrographic Area), the local water utility will have difficulty meeting future water demands due not to a high growth rate but to falling well yields and poor water quality in some wells. Existing pumping capacity is not adequate to meet projected peak demands between 1997 and 2000, and one or more additional wells will be needed. In Amargosa Desert (Amargosa Desert Hydrographic Area), the current committed amount of groundwater appropriations (permits and certificates) is larger than the lower estimate of perennial yield for the applicable groundwater. However, historic pumping amounts have never been higher than the estimates of yield. In Pahrump (Pahrump Valley Hydrographic Area), the total groundwater pumped from the basin in 1995 was almost 30 million cubic meters (24,000 acre-feet). This is about 25 percent higher than the upper end of estimates of the basin's perennial yield, which range from 15 million cubic meters [12,000 acre-feet (NDWP 1992, page 7)] to 23 million cubic meters [19,000 acre-feet (Buqo 1996, page 17)]. Much of Pahrump's water consumption results from about 7,000 domestic water supply wells. Drilling continues at a rate of about two wells a year (Buqo 1999, page 34). Alternatives to address long-term water supply issues in Pahrump Valley include optimizing the locations of new wells, reducing per capita consumption, developing the carbonate aquifer, and importing water from other groundwater basins. Overall groundwater withdrawals in Nye County totaled about 93 million cubic meters (75,000 acre-feet) in 1995. The predominant use of this water was agriculture, accounting for 80 percent of the total; domestic use was responsible for only 7 percent of the total withdrawal (Horton 1997, Table 1).

Sewer. Wastewater treatment needs in the Las Vegas Valley are supported by three major wastewater treatment facilities: one operated by the City of Las Vegas (which also serves the City of North Las Vegas); one operated by the City of Henderson; and one operated by the Clark County Sanitation District. The County Sanitation District includes all the unincorporated areas in Clark County, and it provides services to several outlying communities including Blue Diamond, Laughlin, Overton, and Searchlight (Clark County 1999, all). However, its primary service area is the portion of the Las Vegas Valley south and east of the City of Las Vegas and extending to Henderson. There might be other small wastewater treatment units serving parts of Clark County outside the populous area of the Las Vegas Valley, but septic tank and drainage field systems provide the primary means of wastewater treatment in these outlying areas, particularly for private residences.

Southern Nye County does not have a metropolitan area or a sanitation district comparable to Clark County, and communities in this area rely primarily on individual dwelling or small communal wastewater treatment systems. For example, Pahrump has no community-wide wastewater treatment system. Several wastewater treatment units serve parts of the town, such as the dairy and the jail, but most households have septic tank and drainage field systems. This is likely to be typical of the small communities in southern Nye County.

3.1.11.2 Energy

Electric Power. Three different power distributors—Nevada Power Company, Valley Electric Association, Inc., and Lincoln County Power District No. 1—supply electric power in the region of influence.

Nevada Power Company supplies electricity to southern Nevada in a corridor from southern Clark County, including Las Vegas, North Las Vegas, Henderson, and Laughlin, to the Nevada Test Site in Nye County. In 1996, the power sources were 50 percent company-generated (38 percent coal, 12 percent natural gas), 4 percent Hoover Dam hydroelectric, and 46 percent purchased power. In 1996, Nevada Power Company sold 13.7 million megawatt-hours to its 490,000 customers, with average annual sales per residential customer of about 13,000 kilowatt-hours. In 1996, the peak load was the highest ever at about 3,300 megawatts with a generating capacity and firm purchases of about 3,900 megawatts. Nevada Power Company has an annual customer growth rate of 7.2 percent. To keep pace with demands for electricity, each year Nevada Power must build more substations and transmission and distribution facilities; in 1996, it invested about $180 million in such equipment (NPC 1997, all).

The Valley Electric Association is a nonprofit cooperative that distributes power to southern Nye County, including Pahrump Valley, Amargosa Valley, Beatty, and the Nevada Test Site. The Western Area Power Administration allocates Valley Electric a portion of the lower cost hydroelectric power from the Colorado River dams. The private power market supplies the supplemental power necessary to meet the needs of the members. Since 1995, the amount of power available in the marketplace has been abundant. The amount of energy that Valley Electric sells annually to its members almost tripled in the 11 years from 1985 through 1995. In 1995, Valley Electric sold about 300 million kilowatt-hours to its 8,600 members (McCauley 1997, pages 54 and 55). To meet the power demands of its members, Valley Electric has built a new 230-kilovolt transmission line from Las Vegas to Pahrump and plans to install three new substations in Pahrump.

At present, two commercial utility companies own transmission lines that supply electricity to the Nevada Test Site (Figure 3-22). The electric power for the Yucca Mountain Project in Area 25 comes through the Nevada Test Site power grid. The Test Site buys power at 138 kilovolts at the Mercury Switch Station and at the Jackass Flats Substation. The 138-kilovolt system at the Test Site has nine substations, one switching center, and one tap station, which are connected by approximately 210 kilometers (130 miles) of transmission line. A 138-kilovolt line owned by Nevada Power Company connects the Mercury Switch Station to the Jackass Flats substation, which reduces the power and transmits it to the Field Operations Center and nearby buildings in Area 25 that support the Yucca Mountain Project. A Valley Electric Association 138-kilovolt line also provides power to the Jackass Flats Substation. From the Jackass Flats substation, a 138-kilovolt line feeds the Canyon Substation in Area 25, which provides power to the Exploratory Studies Facility. The Canyon Substation reduces the voltage from 138 to 69 kilovolts, with a capacity of 10 megawatts, and transmits it to the Yucca Mountain substation at the Exploratory Studies Facility.

The capacity of the Nevada Test Site grid is 72 megawatts. Since 1990, the historic monthly peak use was about 18,000 megawatt-hours in January 1992, with a peak load of about 37 megawatts (Thurman 1997, page 1).

Table 3-31 lists the combined historic and projected electricity use for the Exploratory Studies Facility and the Field Operations Center for 1995 through 2000. The Exploratory Studies Facility consumed about 70 percent of the listed amounts (Thurman 1997, all). Annual power use and peak demand at the Exploratory Studies Facility would probably decline and stabilize at a lower level than the 1997 use rates because site activity would decline until

Table 3-31. Electric power use for the Exploratory Studies Facility and Field Operations Center.[a,b]

	Power use	
Fiscal Year	Consumption (megawatt-hours)	Peak (megawatts)
1995	9,800	3.5
1996	19,000	4.9
1997	23,000	5.3
1998[c]	21,000	4.2
1999[c]	17,000	4.2
2000[c]	8,700	4.2

a. Source: TRW (1998a, Table 2, page 8).
b. Before 1995, Yucca Mountain Project power was not metered separately.
c. Projected.

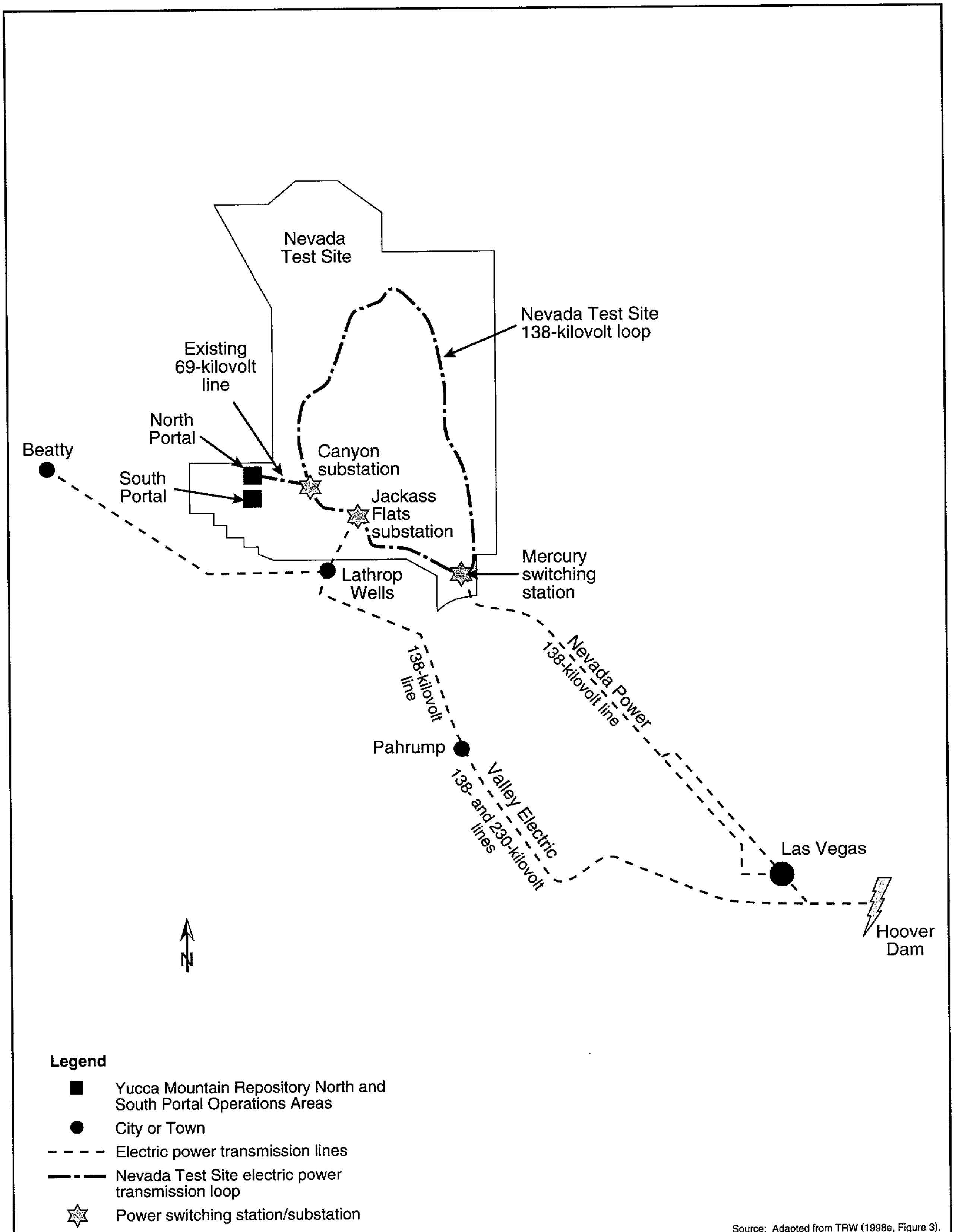


Figure 3-22. Existing Nevada Test Site electric power supply.

repository construction began in 2005. Historically, from 1995 through 1997 Exploratory Studies Facility use has accounted for about 15 percent to 20 percent of the electric power used by all of the Nevada Test Site (TRW 1998a, Table 2, page 8).

Fossil Fuel. The fossil fuels that DOE has used at the Exploratory Studies Facility are heating oil, propane, diesel, gasoline, and kerosene. Natural gas, coal, and jet fuel have not been used. In 1996, site activities consumed about 1.02 million liters (270,000 gallons) of heating oil and diesel fuel and about 65,000 liters (17,000 gallons) of propane; in 1997, they consumed slightly less than 1 million liters (264,000 gallons) of heating oil and diesel fuels. The amounts of gasoline and kerosene used at the Exploratory Studies Facility were very small in those years. Fossil-fuel supplies are delivered to the Nevada Test Site and the Exploratory Studies Facility by truck from readily available supplies in southern Nevada.

3.1.11.3 Site Services

DOE has established an existing support infrastructure to provide emergency services to the Exploratory Studies Facility. The Yucca Mountain Project *Emergency Management Plan* (DOE 1998k, all) describes emergency planning, preparedness, and response. The project cooperates with the Nevada Test Site in such areas as training and emergency drills and exercises to provide full emergency preparedness capability to the site. In addition, the project trains and maintains an underground rescue team. The Nevada Test Site security program is responsible for project security, with enforcement provided by a contractor following direction from DOE. The Nye County Sheriff's Department provides law enforcement and officers for Yucca Mountain site patrol. Nevada Test Site personnel and equipment support fire protection and medical services. Medical services are provided through the Nevada Test Site by two paramedics and an ambulance stationed in Area 25 with backup from other Test Site locations. The Yucca Mountain staff uses a medical clinic with outpatient capability at Mercury. Urgent medical transport is provided by the "Flight for Life" and "Air Life" programs from Las Vegas. Nellis Air Force Base and Nye County also provide emergency support.

3.1.12 WASTE AND HAZARDOUS MATERIALS

The Yucca Mountain Site Characterization Project developed its waste management systems to handle the waste and recyclable material generated by its activities. This material includes nonhazardous solid waste; construction debris; hazardous waste; recyclables such as lead-acid batteries, used oil, metals, paper, and cardboard (Harris 1997, Page 6); sanitary sewage; and wastewater. It does not include low-level radioactive or mixed wastes. DOE uses landfills to dispose of solid waste and construction debris; accumulates and consolidates hazardous waste, then transports it off the site for treatment and disposal; treats and reuses wastewater; and treats and disposes of sanitary waste. In most categories of waste, especially solid waste, some types of material can be recycled or reused. DOE has processes in place to ensure that it collects the material and recycles it as appropriate.

3.1.12.1 Solid Waste

DOE disposes of Yucca Mountain Site Characterization Project solid waste and construction debris in landfills in Areas 23 and 9, respectively, on the Nevada Test Site. The Area 23 landfill has a capacity of 450,000 cubic meters (16 million cubic feet) (DOE 1996f, page 4-37) and a 100-year estimated life (DOE 1995f, page 9). The Area 9 landfill, which is in Crater U-10C, is an open circular pit with steep, almost vertical sides formed as a result of an underground nuclear test. The Area 9 landfill has a disposal capacity of 990,000 cubic meters (35 million cubic feet) (DOE 1996f, page 4-37) and an estimated 70-year operational life (DOE 1995f, page 8). The environmental impact statement for the Nevada Test Site describes these landfills (DOE 1996f, page 4-37). DOE disposes of Yucca Mountain Site

Characterization Project oil-contaminated debris from maintenance activities at the industrial landfill at Apex, Nevada, using an environmental company for transport and disposal. The Apex facility is a multilined landfill with on- and offsite monitoring in compliance with State of Nevada requirements (Harris 1997, page 4).

DOE recycles as many materials as feasible from its site characterization activities. The *Waste Minimization and Pollution Prevention Awareness Plan, Approved* (DOE 1997h, all) governs recycling and other waste minimization activities. At present, a Nevada Test Site contractor collects paper, cardboard, and scrap metal and recycles it. For such recyclables as oils, solvents, coolants, lead-acid batteries, and oil-contaminated soils, the Yucca Mountain Site Characterization Project contracts directly with recycling services (Harris 1997, pages 1 to 3).

3.1.12.2 Hazardous Waste

The Yucca Mountain Site Characterization Project is a small-quantity [less than 1,000 kilograms (2,200 pounds) a month] generator of hazardous waste. DOE accumulates hazardous wastes near their generation sources, consolidates them at a central location at the Yucca Mountain site (Harris 1997, page 5), and ships them off the site for treatment and disposal. The hazardous waste accumulation areas are managed in accordance with Federal and State regulations. The waste is treated and disposed of off the site at a permitted treatment, storage, and disposal facility under contract to the Nevada Test Site (Harris 1997, page 5).

3.1.12.3 Wastewater

DOE uses a septic system to treat and dispose of sanitary sewage at the Yucca Mountain site (TRW 1998f, page 15). The system design can handle a daily flow of about 76,000 liters (20,000 gallons) (TRW 1998g, page 64).

At present, wastewater from tunneling operations and water from secondary containment (following rains) is processed through an oil-water separator, and the treated water is used for dust suppression in accordance with a State of Nevada permit (Harris 1997, page 2). The oil is recycled with the other used oil generated by the project.

3.1.12.4 Existing Low-Level Radioactive Waste Disposal Capacity

The Nevada Test Site accepts low-level radioactive waste for disposal from approved generator sites. It has an estimated disposal capacity of 3.1 million cubic meters (110 million cubic feet). DOE estimates that a total of approximately 670,000 cubic meters (23.7 million cubic feet) of low-level radioactive waste will be disposed of at the Test Site through 2070 (DOE 1998l, page 2-23), not including repository-generated waste.

Commercial spent nuclear fuel generators and contractor-operated transportation facilities such as an intermodal transfer station would dispose of low-level radioactive waste in commercial facilities. Commercial disposal capacity for a broad range of low-level radioactive wastes is available at two licensed facilities, and three more disposal facilities are under license review (NRC 1997a, U.S. Low-Level Radioactive Waste Disposal Section).

3.1.12.5 Materials Management

DOE has programs and procedures in place to procure and manage hazardous and nonhazardous chemicals and materials (DOE 1996h, all). By using these programs, the Department is able to minimize the number and quantities of hazardous chemicals and materials stored at the Yucca Mountain site and maintain appropriate storage facilities.

The chemical and material inventory report (Dixon 1999, pages 4, 4a, and 5) for the Nevada State Fire Marshal's office lists 33 hazardous chemicals and materials. The Yucca Mountain Project holds many of these in small quantities, and it stores sulfuric acid in larger quantities [above the threshold planning quantity of about 450 kilograms (1,000 pounds) that requires emergency planning]. Most of the sulfuric acid is in lead-acid batteries (Dixon 1999, all). In addition, the Yucca Mountain Site Characterization Project stores the following hazardous chemicals in large amounts [exceeding 4,500 kilograms (10,000 pounds)]: propane, gasoline, cement, and lubricating and hydraulic oils. The project does not store highly toxic substances in quantities higher than the State of Nevada reporting thresholds (Dixon 1999, page 1).

3.1.13 ENVIRONMENTAL JUSTICE

ENVIRONMENTAL JUSTICE TERMS

Minority: Hispanic, Black, Asian/Pacific Islander, American Indian/Eskimo, Aleut, and other non-white person.

Low income: Below the poverty level as defined by the Bureau of the Census.

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, directs each Federal agency "to make achieving environmental justice a part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations." In a memorandum that accompanies the Executive Order, President Clinton directs that "...environmental effects, including human health, economic and social effects, of Federal actions, including effects on minority communities and low-income communities, [be analyzed] when such analysis is required by the National Environmental Policy Act."

DOE has identified the minority and low-income communities in the Yucca Mountain region of influence, which consists of Clark, Lincoln, and Nye Counties in southern Nevada. Unless otherwise noted, the *Environmental Baseline File for Environmental Justice* (TRW 1999q, all) is the basis for information in this section.

To identify minority and low-income communities in the region of influence, DOE analyzed Bureau of the Census population designations called *block groups.* DOE pinpointed block groups where the percentage of minority or low-income residents is meaningfully greater than average. For environmental justice purposes, the pinpointed block groups are minority or low-income communities. This EIS considers whether activities at Yucca Mountain could cause disproportionately high and adverse human health or environmental effects to those communities.

3.1.13.1 State of Nevada

Minority persons comprised 21 percent of the population in Nevada in the 1990 census (Bureau of the Census 1992a, Tables P8 and P12). As defined by the Nuclear Regulatory Commission (NRC 1995, all), a minority population is present in a community when the percentage of minority persons in the area exceeds the percentage of minority persons in the state or region affected by a project by 10 percent or more (that is, 31 percent or more minority persons in a community). This analysis identifies communities at the Bureau of the Census block group level. The following discussion uses data from the 1990 census. Figure 3-23 shows block groups in which 31 percent or more of the population consists of minority persons.

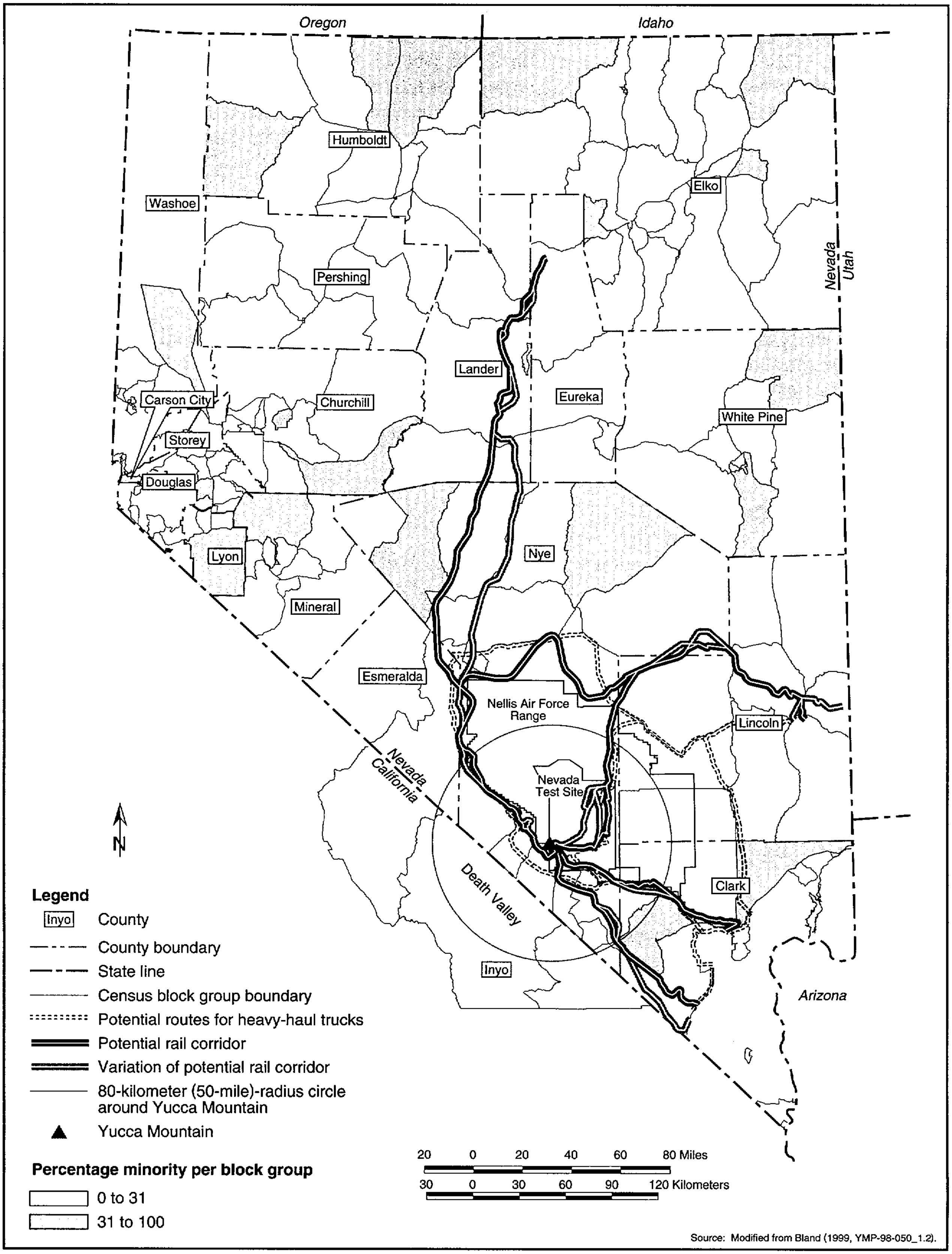


Figure 3-23. Minority communities in Nevada.

The 1990 census characterized about 10 percent of the people in Nevada as living in poverty (Bureau of the Census 1992a, Table P117). The Bureau of the Census characterizes persons in poverty as those whose income is less than a statistical poverty threshold, which is based on family size and the ages of its members. In the 1990 census the threshold for a family of four was a 1989 income of $12,674 (Bureau of the Census 1995, Section 14). In this environmental impact statement, low-income communities are those in which the percentage of persons in poverty equals or exceeds 20 percent as reported by the Bureau of the Census. Figure 3-24 shows low-income communities.

3.1.13.2 Clark County

In 1990, the minority population of Clark County was about 180,000 persons, or 25 percent of the total population (Bureau of the Census 1992b, Tables P8 and P12). A total of 6,800 residents, or 11 percent of the Clark County population, was characterized as living in poverty (Bureau of the Census 1992b, Table P117) Forty-three of Clark County's 325 block groups had both minority populations greater than the 31-percent threshold necessary for identification as minority communities and populations that exceeded the 20-percent low-income community threshold. Thirty-five more block groups had minority populations greater than the 31-percent threshold. An additional 12 block groups had low-income populations greater than the 20-percent threshold. In all, the process identified 90 block groups in Clark County for environmental justice study.

3.1.13.3 Lincoln County

In 1990, the Lincoln County minority population consisted of about 370 persons, or 10 percent of the population (Bureau of the Census 1992c, Tables P8 and P12). Five hundred persons, or 14 percent of the population, were characterized as living in poverty (Bureau of the Census 1992c, Table P117). No block groups exceeded the 31-percent threshold for identification as a minority community. One of the block groups in Lincoln County exceeded the threshold for identification as a low-income community.

3.1.13.4 Nye County

In 1990, the Nye County minority population was about 2,200 persons, or 12 percent of the population (Bureau of the Census 1992d, Tables P8 and P12). There were 2,000 persons, or 11 percent of the population, characterized as living in poverty (Bureau of the Census 1992d, Table P117). Two block groups had populations that exceeded the thresholds for both minority and low-income populations. Three more of the 25 block groups in Nye County exceeded the threshold for identification as low-income communities.

3.1.13.5 Inyo County, California

One block group with a low-income population located in the area of the Stewart Valley in Inyo County, California, lies partly within the 80-kilometer (50-mile) air quality region of influence for the repository (Figure 3-21). DOE performed additional review and concluded that low-income persons living in the block group would be likely to live outside the 80-kilometer region of influence for the repository.

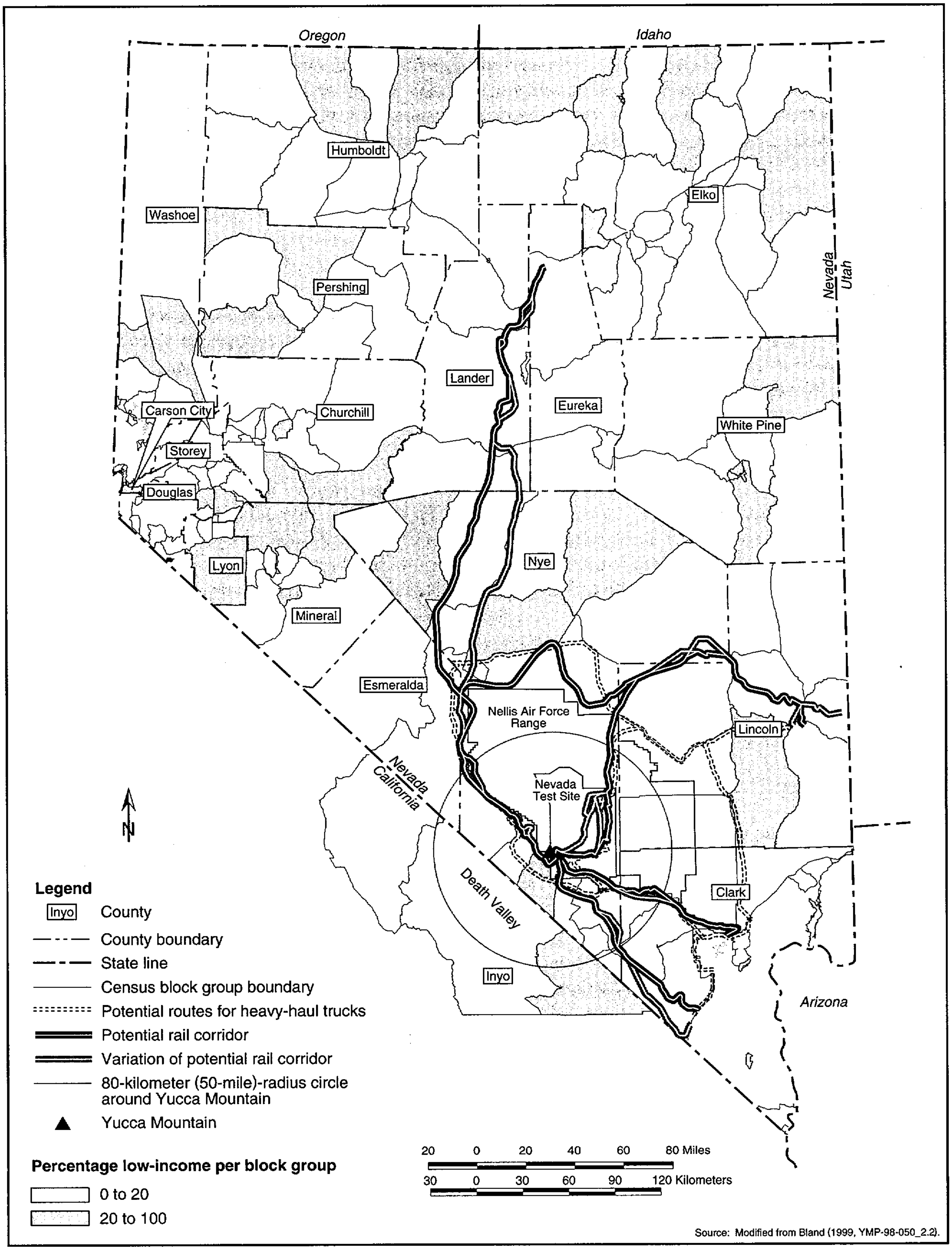


Figure 3-24. Low-income communities in Nevada.

3.2 Affected Environment Related to Transportation

This section describes the existing (or baseline) environmental conditions along the potential transportation corridors to the Yucca Mountain site. Section 3.2.1 discusses the existing national transportation infrastructure that DOE would use to ship spent nuclear fuel and high-level radioactive waste to Nevada.

Section 3.2.2 describes the existing environmental conditions along the proposed transportation corridors and routes in Nevada.

3.2.1 NATIONAL TRANSPORTATION

The loading and shipping of spent nuclear fuel and high-level radioactive waste would occur at 72 commercial and 5 DOE sites in 37 states. The Department's efforts to transport these materials to the Yucca Mountain site could use trains, legal-weight trucks, heavy-haul trucks, and barges; the trains and trucks would travel on the Nation's railroads and highways. Barges and heavy-haul trucks would be used for short-distance transport of spent nuclear fuel from storage sites to nearby railheads. (Heavy-haul trucks could also be used for Nevada transportation, as discussed in Section 3.2.2.2.)

The national transportation of spent nuclear fuel and high-level radioactive waste would use existing highways and railroads and would represent a small fraction of the existing national highway and railroad traffic [0.006 percent of truck miles per year or 0.007 percent of railcar miles per year (BTS 1998, page 5)]. Because no new land acquisition and construction would be required to accommodate these shipments, this EIS focuses on potential impacts to human health and safety and the potential for accidents along the shipment routes.

The region of influence for public health and safety along existing transportation routes is 800 meters (0.5 mile) from the centerline of the transportation rights-of-way and from the boundary of railyards for incident-free (nonaccident) conditions. The region of influence extends to 80 kilometers (50 miles) to address potential human health and safety impacts from accident scenarios.

3.2.1.1 Highway Transportation

Highway (legal-weight truck) transportation of spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site would use local highways near the commercial and DOE sites and near Yucca Mountain, Interstate Highways, Interstate bypasses around metropolitan areas, and preferred routes designated by state routing agencies where applicable. DOE used the HIGHWAY computer program (Johnson et al. 1993a, all) to derive highway routes for shipping spent nuclear fuel and high-level radioactive waste. This model considered population densities along the routes, and selected existing highway routes between the commercial and DOE sites and the proposed repository in accordance with U.S. Department of Transportation routing constraints. Population density distributions were calculated along the routes to support human health risk consequences.

Appendix J describes the routes used for analysis in this EIS. Final transportation mode and routing decisions will be made on a site-specific basis during the transportation planning process, following a decision to build a repository at Yucca Mountain.

3.2.1.2 Rail Transportation

In most cases, rail transportation of spent nuclear fuel and high-level radioactive waste would originate on track operated by shortline rail carriers that provide service to the commercial and DOE sites. At railyards near the sites, shipments in general freight service would switch from trains and tracks operated by the shortline rail carriers to trains and tracks operated by national mainline railroads. Figure 2-29 in Chapter 2 is a map of mainline track for the major U.S. railroads that DOE could use for shipments to Nevada. This interlocking network has about 290,000 kilometers (180,000 miles) of track that link the major population centers and industrial, agricultural, and energy and mineral resources of the Nation (AAR 1996, all). With the exception of shortline regional railroads that serve the commercial and DOE sites, DOE anticipates that cross-country shipments would move on mainline railroads.

Rail transportation routing of spent nuclear fuel and high-level radioactive waste shipments is not regulated by the U.S. Department of Transportation. The routes used in this EIS were derived from the INTERLINE computer program (Johnson et al. 1993b, all). The selection of these routes was based on current routing activities using existing routes. Appendix J describes the rail routes used in this EIS analysis.

3.2.1.3 Barge and Heavy-Haul Truck Transportation

Commercial sites that do not have direct rail service could ship spent nuclear fuel on heavy-haul trucks or barges to nearby railheads. Heavy-haul trucks would use local highways to carry the spent nuclear fuel to a nearby railhead for transfer to railcars for transport to Nevada. Barge shipments would use navigable waterways accessible from the nuclear plant site. These shipments would travel on the waterways to nearby railheads for transfer to railcars for transport to Nevada. Appendix J describes the heavy-haul truck and barge routes used in this EIS analysis.

3.2.2 NEVADA TRANSPORTATION

Shipments of spent nuclear fuel and high-level radioactive waste arriving in Nevada would be transported to the Yucca Mountain site by legal-weight truck, rail, or heavy-haul truck. The discussion of national transportation modes and routes in Section 3.2.1 addresses the affected environment for legal-weight truck transport from commercial and DOE facilities to the Yucca Mountain site, including travel in Nevada. This section addresses the affected environment in Nevada for candidate rail corridors, heavy-haul truck routes, and potential locations for an intermodal transfer station that DOE could use for transporting spent nuclear fuel and high-level radioactive waste and that would require new construction.

Legal-weight truck shipments in Nevada would use existing highways and would be a very small fraction of the total traffic [less than 0.5 percent of commercial vehicle traffic on U.S. Highway 95 in southern Nevada (NDOT 1997, page 9; Cerocke 1998, page 1). Because no new land acquisition and construction would be required to accommodate legal-weight trucks, this EIS focuses on potential impacts to human health and safety and the potential for accidents along the shipment routes from legal-weight truck shipments. Appendix J contains baseline environmental information related to human health and safety and the impacts from accident scenarios.

To allow large-capacity rail cask shipments to the repository, DOE is considering the construction of a new branch rail line or the establishment of heavy-haul truck shipment capability. Sections 3.2.2.1 and 3.2.2.2 describe the existing (or baseline) environment for each of the candidate rail corridors and heavy-haul truck routes and for potential locations for an intermodal transfer station.

3.2.2.1 Environmental Baseline for Potential Nevada Rail Corridors

This section discusses the environmental characteristics of land areas that could be affected by the construction and operation of a rail line to transport spent nuclear fuel and high-level radioactive waste to the proposed repository. It describes the environmental conditions in five alternative rail corridors—Caliente, Carlin, Caliente-Chalk Mountain, Jean, and Valley Modified. Chapter 2, Section 2.1.3.2, describes these corridors in more detail. Figures 6-10 through 6-15 in Chapter 6 show detailed maps for these corridors.

To define the existing (or baseline) environment along the five proposed rail corridors; DOE has compiled environmental information for each of the following subject areas:

- *Land use and ownership:* The condition of the land, current land-use practices, and land ownership information (Section 3.2.2.1.1)
- *Air quality and climate:* The quality of the air and the climate (Section 3.2.2.1.2)
- *Hydrology:* The characteristics of surface water and groundwater (Section 3.2.2.1.3)
- *Biological resources:* Important biological resources (Section 3.2.2.1.4)
- *Cultural resources:* Important cultural resources (Section 3.2.2.1.5)
- *Socioeconomic environments:* The existing socioeconomic environments (Section 3.2.2.1.6)
- *Noise:* The existing noise environments (Section 3.2.2.1.7)
- *Aesthetics:* The existing visual environments (Section 3.2.2.1.8)
- *Utilities, energy, and materials:* Existing supplies of utilities, energy, and materials (Section 3.2.2.1.9)
- *Environmental justice:* The locations of low-income and minority populations (Section 3.2.2.1.10)

The INTERLINE computer program (Johnson et al. 1993b, all) provided population distributions for differing population zones (urban, rural, suburban) along the alternative rail corridors. This approach is consistent with the national transportation analysis (see Chapter 6 for more detail).

DOE expects waste quantities generated by rail line construction and operation to be minor in comparison to those from repository construction and operation. As such, no discussion of existing waste disposal infrastructure along the routes is provided.

DOE evaluated the potential impacts of the implementing alternatives in regions of influence for each of the subject areas listed above. Table 3-32 defines these regions, which are specific to the subject areas, in which DOE could reasonably expect to predict potentially large impacts related to rail line construction and operation. The following sections describe the various environmental baselines for the rail implementing alternatives.

3.2.2.1.1 *Land Use and Ownership*

Table 3-33 summarizes the estimated land commitment and current ownership or control of the land in each rail corridor. Public lands in and near the corridors are used for a variety of activities including grazing, mining, and recreation. All public land in the Caliente, Carlin, Jean, and Valley Modified corridors is open to mining and mineral leasing laws and offroad vehicle use, with restrictions in some areas (BLM 1979, all; BLM 1994b, all; BLM 1999a, all).

Caliente. Most of the lands associated with the Caliente corridor (88 percent) are public lands managed by the Ely, Battle Mountain, and Las Vegas offices of the Bureau of Land Management. Detailed

Table 3-32. Regions of influence for rail implementing alternatives.

Subject area	Region of influence
Land use and ownership	Land areas that would be disturbed or whose ownership or use would change as a result of construction and use of branch rail line
Air quality and climate	The Las Vegas Valley for implementing alternatives where constructing and operating a branch rail line could contribute to the level of carbon monoxide and PM_{10} already in nonattainment of standards, and the atmosphere in the vicinity of sources of criteria pollutants that would be emitted during branch rail line construction and operations
Hydrology	*Surface water:* areas near where construction would take place that would be susceptible to erosion, areas affected by permanent changes in flow, and areas downstream of construction that could be affected by eroded soil or potential spills of construction contaminants
	Groundwater: aquifers that would underlie areas of construction and operations and aquifers that might be used to obtain water for construction
Biological resources	Habitat, including jurisdictional wetlands and riparian areas inside the 400-meter-wide[a] corridors; habitat, including jurisdictional wetlands outside the corridor that could be disturbed by rail line construction and operations; habitat, including jurisdictional wetlands, and riparian areas that could be affected by permanent changes in surface-water flows; migratory ranges of big game animals that could be affected by the presence of a branch rail line
Cultural resources	Lands inside the 400-meter-wide rail corridors
Socioeconomic environments	Clark, Lincoln, Nye and other counties that a potential branch rail line would traverse
Public health and safety	800 meters[b] on each side of the rail line for incident-free transportation, 80-kilometer[c] radius for potential impacts from accident scenarios
Noise	Inhabited commercial and residential areas where noise from rail line construction and operations could be a concern
Aesthetics	The landscapes along the potential rail corridors with aesthetic qualities that could be affected by construction and operations
Utilities, energy, and materials	Local, regional, and national supply infrastructure that would be required to support rail line construction and operations
Environmental justice	Varies with the individual resource area

a. 400 meters = 0.25 mile.
b. 800 meters = 0.5 mile.
c. To convert kilometers to miles, multiply by 0.62137.

Table 3-33. Land ownership for the candidate rail corridors.[a]

	Land in corridor					
		Ownership or control (percent)[d]				
Corridor	Totals (km^2)[b,c]	BLM	USAF	DOE	Private	Other
Caliente	200	88	9	2	< 1	0
Carlin	210	85	9	2	3	0
Caliente-Chalk Mountain	140	57	16	27	< 1	0
Jean	72	83	0	12	5	0
Valley Modified	64	50	14	33	0	3

a. Source: (TRW 1999d, all).
b. To convert square kilometers (km^2) to acres, multiply by 247.1.
c. Totals might differ from sums due to rounding.
d. Bureau of Land Management (BLM) property is public land administered by the Bureau; U.S. Air Force property is the Nellis Air Force Range; DOE property is the Nevada Test Site; and the single Other designation is the Desert National Wildlife Refuge managed by the Fish and Wildlife Service.

information on land use is available in the *Proposed Tonopah Resource Management Plan and Final Environmental Impact Statement* (BLM 1994b, all), the *Department of the Interior Final Environmental Impact Statement Proposed Domestic Livestock Grazing Management Program for the Caliente Area* (BLM 1979, all), the *Draft Caliente Management Framework Plan Amendment and Environmental Impact Statement for the Management of Desert Tortoise Habitat* (BLM 1999a, all), and the *Proposed Las Vegas Resource Management Plan and Final Environmental Impact Statement* (BLM 1998, all).

The U.S. Air Force uses about 9 percent of the lands associated with the Caliente corridor. The corridor crosses the western boundary of the Nellis Air Force Range near Scotty's Junction. Detailed information on current and future uses of the Nellis Air Force Range is available in the *Renewal of the Nellis Air Force Range Land Withdrawal Department of the Air Force Legislative Environmental Impact Statement* (USAF 1999, all).

DOE uses about 2 percent of the lands associated with the Caliente corridor. The corridor enters the Nevada Test Site south of Beatty. Detailed information on current and future uses of the Nevada Test Site is available in the *Final Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada* (DOE 1996f, all).

Less than 1 percent of the land associated with the Caliente corridor is private. The corridor crosses private land near Caliente.

Carlin. Most of the lands associated with the Carlin corridor (about 85 percent) are public lands managed by the Battle Mountain and Las Vegas offices of the Bureau of Land Management. Detailed information on land use is available in the *Draft Management Plan and Environmental Impact Statement for the Shoshone-Eureka Resource Area, Nevada* (BLM 1983, all), the *Proposed Tonopah Resource Management Plan and Final Environmental Impact Statement* (BLM 1994b, all), and the *Proposed Las Vegas Resource Management Plan and Final Environmental Impact Statement* (BLM 1998, all).

The U.S. Air Force uses about 9 percent of the lands associated with the Carlin corridor. The combined Carlin/Caliente corridor crosses into the western portion of the Nellis Air Force Range near Scotty's Junction. Detailed information on current and future uses of the Nellis Air Force Range is available in USAF (1999, all).

DOE uses about 2 percent of the lands associated with the Carlin corridor. The combined Carlin/Caliente corridor enters the Nevada Test Site south of Beatty. Detailed information on current and future uses of the Nevada Test Site is available in DOE (1996f, all).

About 3 percent of the land associated with the Carlin corridor is private. The corridor crosses private roads in the northern part of the route, from Beowawe through Crescent Valley.

Caliente-Chalk Mountain. Most of the lands associated with the Caliente-Chalk Mountain corridor (about 57 percent) are public lands managed by the Ely office of the Bureau of Land Management. Detailed information on land use is available in BLM (1979, all) and BLM (1999a, all).

The U.S. Air Force uses about 16 percent of the lands associated with the Caliente-Chalk Mountain corridor. The corridor enters the Nellis Air Force Range west of Rachel, Nevada, and travels south through the range. Detailed information on current and future uses of the Nellis Air Force Range is available in USAF (1999, all).

DOE uses about 27 percent of the lands associated with the Caliente-Chalk Mountain corridor. The corridor crosses the northern border of the Nevada Test Site and travels to the Yucca Mountain site. Detailed information on current and future uses of the Nevada Test Site is available in DOE (1996f, all).

Less than 1 percent of the lands associated with the Caliente-Chalk Mountain corridor is private. The combined Caliente and Caliente-Chalk Mountain corridor crosses private lands near Caliente.

Jean. Most of the lands associated with the Jean corridor (about 83 percent) are public lands managed by the Las Vegas office of the Bureau of Land Management. Detailed information on land use is available in BLM (1998, all).

DOE uses about 12 percent of the lands associated with the Jean corridor. The corridor enters the Nevada Test Site near the Amargosa Valley traveling north to the Yucca Mountain site. Detailed information on current and future uses of the Nevada Test Site is available in DOE (1996f, all).

About 5 percent of the land associated with the Jean corridor is private. The corridor crosses private lands in the Pahrump Valley.

Valley Modified. Half of the lands associated with the Valley Modified corridor are public lands managed by the Las Vegas office of the Bureau of Land Management. Detailed information on land use is available in BLM (1998, all).

The U.S. Air Force uses about 14 percent of the lands associated with the Valley Modified corridor. The corridor crosses Nellis Air Force Base northeast of Las Vegas and the Nellis Air Force Range near Indian Springs. Detailed information on current and future uses of the Nellis Air Force Range is available in USAF (1999, all).

DOE uses about 33 percent of the lands associated with the Valley Modified corridor. The corridor enters the Nevada Test Site near Mercury, traveling northwest to the Yucca Mountain site. Detailed information on current and future uses of the Nevada Test Site is available in DOE (1996f, all).

The Fish and Wildlife Service manages about 3 percent of the lands associated with the Valley Modified corridor as part of the Desert National Wildlife Refuge, which was established in 1936 for the protection and preservation of desert bighorn sheep. Portions of this refuge overlap the Nellis Air Force Range and are controlled jointly by the Air Force and the Fish and Wildlife Service. Use and public access to the joint-use area of the Desert National Wildlife Refuge and Nellis Air Force Range are restricted by a memorandum of understanding (USAF 1999, Appendix C).

3.2.2.1.2 *Air Quality and Climate*

This section contains information on the existing air quality in areas through which the candidate rail corridors pass. It also provides background on the general climate in those areas.

Air Quality. The Caliente, Carlin, Caliente-Chalk Mountain, and Jean corridors pass through rural parts of Nevada that are either unclassifiable or in attainment for criteria pollutants (EPA 1999c, all). There are no State air-quality monitoring stations in these corridors (NDCNR 1999, pages A1-1 through A1-9).

The Valley-Modified rail corridor crosses central Clark County at the north end of the Las Vegas Valley and continues in a northwest direction toward the Nevada Test Site. The air quality in the part of the corridor that passes through the Las Vegas Valley and extends part of the way to Indian Springs is in nonattainment for particulate matter with a diameter of less than 10 micrometers (PM_{10}). Clark County adopted a plan for demonstrating PM_{10} attainment (Clark County 1997b, all) that includes a request to the Environmental Protection Agency to extend the year for attainment demonstration from 2001 to 2006. The plan includes proposals to reduce emissions of particulate matter from a variety of sources. The Las Vegas Valley is also a nonattainment area for carbon monoxide.

Climate. There are two general climate descriptions for the five rail corridors: one for the three corridors that approach the Yucca Mountain site from the north and one for the two corridors that approach the site from the south or southeast. The Caliente, Carlin, and Caliente-Chalk Mountain corridors approach from the north and cross a number of mountain ranges and valleys with elevations well above 1,500 meters (4,900 feet). Although much of Nevada is arid, in central Nye County the annual precipitation exceeds 20 centimeters (8 inches), and the annual snowfall exceeds 25 centimeters (10 inches); annual precipitation exceeds 40 centimeters (16 inches) in some mountainous areas, and snowfall exceeds 100 centimeters (40 inches) (Houghton, Sakamoto, and Gifford 1975, pages 45, 49, and 52). Occasional brief periods of intense rainfall at rates exceeding 5 centimeters (2 inches) an hour can occur in the summer.

The Jean and Valley Modified corridors approach the Yucca Mountain site from the south where precipitation is generally between 10 and 20 centimeters (4 and 8 inches) per year and snowfall is rare. Occasional brief periods of intense rainfall at rates exceeding 5 centimeters (2 inches) an hour can occur in the summer (Houghton, Sakamoto, and Gifford 1975, pages 45, 49, and 52).

3.2.2.1.3 *Hydrology*

This EIS discusses hydrologic conditions in terms of surface water and groundwater.

3.2.2.1.3.1 Surface Water. Researchers studied the alternative rail corridors for their proximity to sensitive environmental resources, including surface waters and riparian lands (TRW 1999k, Appendixes E, F, G, H, and I). The goal in planning the corridors was to avoid springs and riparian lands by 400 meters (1,300 feet) if possible. Table 3-34 summarizes potential surface-water-related resources along the candidate corridors. It lists resources within the 400-meter corridor or within a 1-kilometer (0.6-mile) region of influence along the corridor.

Potential hydrologic hazards along the rail corridors include flash floods and debris flow. All corridors have potential flash flooding concerns. DOE would design and build a rail line that would be able to withstand a 100-year flood event safely.

3.2.2.1.3.2 Groundwater. Groundwater basins that the candidate rail corridors cross represent part of the potentially affected environment. As described for groundwater in the immediate region of Yucca Mountain (Section 3.1.4.2.1), the State of Nevada has been divided into groundwater basins and sub-basins. The sub-basins are called hydrographic areas. A map of these areas (Bauer et al. 1996, page 543) was overlain with a drawing of the proposed rail corridors to produce a reasonable approximation of the areas that would be crossed by each corridor. Table 3-35 lists results of this effort. The table also lists estimates of the perennial yield for each hydrographic area crossed and if the area is a State Designated Groundwater Basin [a hydrographic area in which the permitted water rights approach or exceed the estimated perennial yield and the water resources are depleted or require additional administration, including a State declaration of preferred uses (municipal and industrial, domestic supply, agriculture, etc.)] (NDWP 1999b, Region 14). These are the areas where additional water demand would be most likely to produce an adverse effect on local groundwater resources. The table indicates that none of the corridors would completely avoid Designated Groundwater Basins. However, the Caliente-Chalk Mountain corridor would cross only two Designated Basins, one at Panaca Valley near the start of the corridor and one at Penoyer Valley where the Caliente and Caliente-Chalk Mountain corridors split.

Table 3-34. Surface-water-related resources along candidate rail corridors.[a]

Rail corridor	Distance from corridor (kilometers)[b]	Feature
Caliente		
Caliente to Meadow Valley	0.5	Springs – two unnamed springs, in Meadow Valley north of Caliente
	Within	Riparian area/stream – corridor crosses and is adjacent to stream and riparian area in Meadow Valley Wash
Meadow Valley to Sand Spring Valley	1.0	Spring – Bennett Spring, 3.2 kilometers southeast of Bennett Pass
	0.05 - 2.6	Springs – group of five springs (Deadman, Coal, Black Rock, Hamilton, and one unnamed) east of White River
	Within	Riparian/river – corridor parallels (and crosses) the White River for about 25 kilometers. August 1997 survey found river to be mostly underground with ephemeral washes above ground.
	0.8	Spring – McCutchen Spring, north of Worthington Mountains
Sand Spring Valley to Mud Lake	0.02	Spring – Black Spring, south of Warm Springs
Mud Lake to Yucca Mountain	Within - 2.5	Springs – numerous springs and seeps along Amargosa River in Oasis Valley
	Within	Riparian area – designated area east of Oasis Valley, flowing into Amargosa Valley
	0.3 - 1.3	Springs – group of 13 unnamed springs in Oasis Valley north of Beatty
	Within - 0.3	Riparian area/stream – Amargosa River, with persistent water and extensive wet meadows near springs and seeps
Carlin		
Beowawe to Austin	0.5	Spring – Tub Spring, northeast of Red Mountain
	0.8	Spring – Red Mountain Spring, east of Red Mountain
	0.9	Spring – Summit Spring, west of corridor and south of Red Mountain
	0.4	Spring – Dry Canyon Spring, west of Hot Springs Point
	0.8	Spring – unnamed spring on eastern slope of Toiyabe Range, southwest of Hot Springs Point
	1.0	Riparian area – intermittent riparian area associated with Rosebush Creek, in western Grass Valley, north of Mount Callaghan
	Within	Riparian/creek – corridor crosses Skull Creek, portions of which have been designated riparian areas
	Within	Riparian/creek – corridor crosses intermittent Ox Corral Creek; portions designated as riparian habitat. An August 1997 survey found creek dry with no riparian vegetation present
	0.1	Spring – Rye Patch Spring, at north entrance of Rye Patch Canyon, west of Bates Mountain
	Within	Riparian area – corridor crosses and parallels riparian area in Rye Patch Canyon
	0.7	Spring – Bullrush Spring, east of Rye Patch Canyon
Austin to Mud Lake	0.8	Springs – group of 35 unnamed springs, about 25 kilometers north of Round Mountain on east side of Big Smokey Valley
	0.6	Riparian area – marsh area formed from group of 35 springs
	0.6	Spring – Mustang Spring, south of Seyler Reservoir
	0.3	Riparian/reservoir – Seyler Reservoir, west of Manhattan
Mud Lake to Yucca Mountain		See Caliente corridor
Caliente-Chalk Mountain		
Caliente to Meadow Valley		See Caliente corridor
Meadow Valley to Sand Spring Valley		See Caliente corridor
Sand Spring Valley to Yucca Mountain	1.0	Spring – Reitman's Seep, in eastern Yucca Flat, east of BJ Wye
	0.8	Spring – Cane Spring, on north side of Skull Mountain on Nevada Test Site
Jean		None identified
Valley Modified		None identified

a. Source: TRW (1999k, Appendixes E, F, G, H, and I).
b. To convert kilometers to miles, multiply by 0.62137.

Table 3-35. Hydrographic areas (groundwater basins) crossed by candidate rail corridors.

Rail corridor	Hydrographic area[a] No.	Hydrographic area[a] Name	Perennial yield (acre-feet)[b,c,d]	Designated Groundwater Basin[e,f]
Caliente				
Caliente to Sand Spring Valley	204	Clover Valley	1,000	No
	203	Panaca Valley	9,000	Yes
	181	Dry Lake Valley	2,500	No
	208	Pahroc Valley	21,000	No
	171	Coal Valley	6,000	No
	172	Garden Valley	6,000	No
Sand Spring Valley to Mud Lake	170	Penoyer Valley (Sand Spring Valley)	4,000	Yes
	173A	Railroad Valley, southern part	2,800	No
	156	Hot Creek	5,500	No
	149	Stone Cabin Valley	2,000	Yes
	141	Ralston Valley	6,000	Yes
Mud Lake to Yucca Mountain	142	Alkali Spring Valley	3,000	No
	145	Stonewall Flat	100	No
	144	Lida Valley	350	No
	146	Sarcobatus Flat	3,000	Yes
	228	Oasis Valley	1,000	Yes
	229	Crater Flat	220	No
	227A	Fortymile Canyon and Jackass Flats	880[g]	No
Carlin				
Beowawe to Austin	54	Crescent Valley	16,000	Yes
	138	Grass Valley	13,000	No
Austin to Mud Lake – Via Big Valley	137B	Big Smokey Valley, northern part	65,000	Yes
	137A	Big Smokey Valley and Tonopah Flat	6,000	Yes
Mud Lake to Yucca Mountain	142 to 227A	See Caliente corridor		
Caliente-Chalk Mountain				
Caliente to Sand Spring Valley	204 to 170	See Caliente corridor		
Sand Spring Valley to Yucca Mountain	158A	Emigrant Valley and Groom Lake Valley	2,800	No
	159	Yucca Flat	350	No
	160	Frenchman Flat	16,000	No
	227A	Fortymile Canyon and Jackass Flats	880[g]	No
Jean				
Jean to Yucca Mountain	165	Jean Lake Valley	50	Yes
	164A	Ivanpah Valley, northern part	700	Yes
	163	Mesquite Valley (Sandy Valley)	2,200	Yes
	162	Pahrump Valley	12,000	Yes
	230	Amargosa Desert	24,000	Yes
	227A	Fortymile Canyon and Jackass Flats	880[g]	No
Valley Modified				
Dike Siding (north of Las Vegas) to Yucca Mountain	212	Las Vegas Valley	25,000	Yes
	211	Three Lakes Valley, southern part	5,000	Yes
	161	Indian Springs Valley	500	Yes
	225	Mercury Valley	250	Yes
	226	Rock Valley	30	No
	227A	Fortymile Canyon and Jackass Flats	880[g]	No

a. Source: Bauer et al. (1996, pages 542 and 543 with corridor map overlay).

b. Source: NDWP (1998, Regions 4, 10, 13, and 14), except hydrographic areas 225 through 230 for which the source is Thiel (1997, pages 6 to 12). The Nevada Division of Water Planning identifies a perennial yield of only 24,000 acre-feet (30 million cubic meters) for the combined area of hydrographic areas 225 through 230 (NDWP 1998, 1999b, hydrographic area 225; NDWP (1999b, hydrographic area 230).

c. Perennial yield is the estimated quantity of groundwater that can be withdrawn annually from a basin without depleting the reservoir.

d. To convert acre-feet to cubic meters, multiply by 1,233.49.

e. Source: NDWP (1999b, Regions 4, 10, 13, and 14).

f. "Yes" indicates the State of Nevada considers the area a Designated Groundwater Basin where permitted water rights approach or exceed the estimated perennial yield and the water resources are being depleted or require additional administration, including a State declaration of preferred uses (municipal and industrial, domestic supply, agriculture, etc.). Designated Groundwater Basins are also referred to as Administered Groundwater Basins.

g. The perennial yield value shown for Area 227A is the lowest estimated value presented in Thiel (1997, page 8) and is further broken down into 370,000 cubic meters (300 acre-feet) for the eastern third of the area and 715,000 cubic meters (580 acre-feet) for the western two-thirds.

There are a number of published estimates of perennial yield for many of the hydrographic areas in Nevada, and they often differ from one another by large amounts. This is the reason for listing a range of perennial yield values in Table 3-10 for the hydrographic areas in the Yucca Mountain region. For simplicity, the perennial yield values listed in Table 3-35 generally come from a single source (NDWP 1998, Regions 4, 10, 13, and 14) and, therefore, do not show a range of values for each area. The hydrographic areas in the Yucca Mountain region (that is, areas 225 through 230) are the exception to perennial yield values from the single source. The perennial yield values for these areas are from Thiel (1997, pages 6 to 12), which compiles estimates from several sources. The table lists the lowest values in that document.

The perennial yield value shown for Area 227A is the lowest estimated value presented in Thiel (1997, page 8) and is further divided into 300 acre-feet (370,000 cubic meters) for the eastern third of the area and 580 acre-feet (715,000 cubic meters) for the western two-thirds.

3.2.2.1.4 *Biological Resources*

The following sections describe biological resources along each of the candidate rail corridors. These environments include habitat types and springs and riparian areas located in a 400-meter (1,300-foot)-wide corridor along each route. Springs and riparian areas are important because they provide habitat for large numbers of plants, animals, and insects. Unless otherwise noted, this information is from the *Environmental Baseline File for Biological Resources* (TRW 1999k, all).

Caliente. From the beginning of the corridor at Caliente to Mud Lake, the Caliente rail corridor crosses Meadow, Dry Lake, Coal, Garden, Sand Spring, Railroad, Reveille, Stone Cabin, and Ralston Valleys. From Mud Lake, the corridor crosses Stonewall and Sarcobatus flats, the upper portion of the Amargosa River, the lower portion of Beatty Wash, and Crater and Jackass Flats. The valleys and flats along the corridor range in elevation from 900 to 1,900 meters (3,000 to 6,200 feet). The corridor also crosses several mountain ranges including the Highland, Seaman, Golden Gate, Worthington, and Kawich mountain ranges at elevations ranging from 1,400 to 1,900 meters (4,600 to 6,200 feet). The Caliente rail corridor is in the southern Great Basin from its beginning at Caliente to near Beatty Wash. The land cover types along this portion of the corridor include salt desert scrub (60 percent) and sagebrush (33 percent). South of Beatty Wash, the corridor crosses into the Mojave Desert. Predominant land cover types from Beatty Wash to Yucca Mountain include creosote-bursage (59 percent), Mojave mixed scrub (22 percent), and salt desert scrub (19 percent) (TRW 1999k, page 3-22).

The only resident threatened or endangered species in the Caliente rail corridor is the desert tortoise, which occurs only along the southern end of the corridor from about Beatty Wash to Yucca Mountain (Bury and Germano 1994, pages 57 to 72). This area is not critical habitat for desert tortoises (50 CFR 17.95) and their abundance in this area is low in relation to other areas in the range of the species in Nevada (Karl 1981, pages 76 to 92; Rautenstrauch and O'Farrell 1998, pages 407 to 411). The only other threatened or endangered species near the corridor is the Federally threatened (State of Nevada protected, Nevada Administrative Code 503.067) Railroad Valley springfish (*Crenichthys nevadae*), which occurs in Warm Springs about 3 kilometers (1.9 miles) north of the corridor in Hot Creek Valley (FWS 1996, all).

Four other species classified as sensitive by the Bureau of Land Management occur in the corridor (NNHP 1997, all). Unnamed subspecies of the Meadow Valley Wash speckled dace (*Rhinichthys osculus* ssp.) and Meadow Valley Wash desert sucker (*Catostomus clarki* ssp. 2) have been found in Meadow Valley Wash north of Caliente. In the Beatty area, the Nevada sanddune beardtongue (*Penstemon arenarius*) has been found on sandy soils 10 kilometers (6 miles) north of Springdale. A number of bats classified as sensitive by the BLM also may occur along the corridor and the southern end of the corridor is in the range of the chuckwalla (*Sauromalus obesis*).

The Caliente rail corridor crosses several areas designated as game habitat (BLM 1979, pages 2-27 through 2-36; BLM 1994b, Maps 9 through 13). A bighorn sheep (*Ovis canadensis*) winter forage area is in the Cedar Range, approximately 13 kilometers (8 miles) west of Crestline, and the corridor also crosses bighorn sheep habitat west of Goldfield near Stonewall Mountain. Mule deer also use the winter forage area in the Cedar Range, and the corridor crosses mule deer use areas in or near the Chief Mountains, Delamar Mountains, Reveille Range, Kawich Range/Quinn Canyon, Stonewall Mountain, and west of the Worthington Mountains. The corridor crosses pronghorn antelope (*Antilocapra americana*) habitat in the Sand Spring, Railroad, Reveille, and Stone Cabin Valleys, and from Mud Lake to Stonewall Mountain. Meadow Valley Wash north of Caliente is classified as habitat for waterfowl.

At least six springs or groups of springs and three streams or riparian areas are within 0.4 kilometer (0.25 mile) of the corridor (TRW 1999k, page 3-23). These might be wetlands or other waters of the United States, as defined in the Clean Water Act, although no formal wetlands delineation has been conducted along the corridor. Black Spring is near the corridor at the north end of the Kawich Range and an unnamed spring is near the corridor at the north end of the North Pahroc Range. An unnamed spring is 0.3 kilometer (0.2 mile) east of the corridor between Mud Lake and Yucca Mountain west of Willow Spring. A series of springs is in the corridor near the Amargosa River in Oasis Valley. The corridor crosses the Meadow Valley Wash south of Panaca. The corridor also crosses the White River between U.S. 93 and Sand Spring Valley and parallels the river for approximately 25 kilometers (16 miles). An August 1997 survey of that portion of the river found it was mostly dry with some standing water in stock waterholes. The corridor crosses the Amargosa River in the north end of the Oasis Valley, in an area designated as a riparian area by the Bureau of Land Management (BLM 1994b, Maps 14 and 15). The corridor also crosses a number of ephemeral streams that might be classified as waters of the United States under Section 404 of the Clean Water Act.

The Caliente rail corridor also crosses eight Bureau of Land Management-designated wild horse or wild horse and burro herd management areas (BLM 1979, pages 2-26 through 2-35; BLM 1994b, Maps 18 and 19). From U.S. Highway 93 to Sand Spring Valley, the corridor passes through a herd management area in the Chief Range. From Sand Spring Valley to Mud Lake, the corridor crosses the Saulsbury, Reveille, and Stone Cabin herd management areas, and from Mud Lake to Yucca Mountain the route crosses the Goldfield, Stonewall, and Bullfrog herd management areas.

Carlin. The Carlin rail corridor crosses Crescent and Grass Valleys, then passes through Big Smokey Valley to Mud Lake. From Mud Lake, the corridor crosses Stonewall and Sarcobatus Flats, the upper portion of the Amargosa River, the lower portion of Beatty Wash, and Crater and Jackass Flats. Elevations along the route range from 900 to 2,200 meters (3,000 to 7,200 feet).

The Carlin rail corridor is in the Great Basin from its start in Beowawe to near Beatty Wash. Land cover types along this portion of the corridor are dominated by salt desert scrub (57 percent), sagebrush (28 percent), and greasewood (7 percent). At Beatty Wash, the corridor crosses into the Mojave Desert. Predominant land cover types from Beatty Wash to Yucca Mountain include creosote-bursage (59 percent), Mojave mixed scrub (22 percent), and salt desert scrub (19 percent) (TRW 1999k, page 3-24).

The only resident threatened or endangered species in the Carlin rail corridor is the desert tortoise, which occurs only along the southern end of the corridor from about Beatty Wash to Yucca Mountain (Bury and Germano 1994, pages 57 to 72). This area is not critical habitat for desert tortoises (50 CFR 17.95) and their abundance in the region is low (Karl 1981, pages 76 to 92; Rautenstrauch and O'Farrell 1998, pages 407 to 411).

Three other species classified as sensitive by the Bureau of Land Management or as protected by Nevada occur along the Carlin rail corridor. A ferruginous hawk (*Buteo regalis*) (also classified as protected by Nevada) nesting area is east of Mount Callaghan. The San Antonio pocket gopher (*Thomomys umbrinus curtatus*) has been found in Big Smokey Valley northwest of the San Antonio Mountains. The Nevada sand dune beardtongue has been found in sandy soils 10 kilometers (6 miles) north of Springdale (NNHP 1997, all). A number of bats classified as sensitive by the Bureau of Land Management might occur along the corridor, and the southern end of the corridor is in the range of the chuckwalla.

The Carlin rail corridor crosses several areas designated as game habitat by the Bureau of Land Management (BLM 1983, Map 3-1; BLM 1994b, Maps 9 to 13; TRW 1999k, page 3-25). The corridor crosses an area designated as sage grouse (*Centrocercus urophasianus*) habitat in western Grass Valley and another at the southeast end of Rye Patch Canyon. The corridor enters pronghorn antelope habitat north of U.S. Highway 50 near Rye Patch Canyon, north of Toquima Range near Hickison summit, along most of Big Smokey Valley, and from Mud Lake to Stonewall Mountain. The corridor crosses mule deer habitat on the west side of Grass Valley, in the Simpson Park Range, and at Stonewall Mountain. The corridor crosses bighorn sheep habitat east of Goldfield and at Stonewall Mountain.

Three springs, seven riparian areas, and one reservoir are within 0.4 kilometer (0.25 mile) of the Carlin corridor (TRW 1999k, page 3-25). These areas might be wetlands or other waters of the United States, as defined by the Clean Water Act, although no formal wetlands delineation has been conducted along the corridor. Rye Patch Spring is on the edge of the corridor at the south end of the Simpson Park Mountains. An unnamed spring is 0.3 kilometer (0.2 mile) east of the corridor between Mud Lake and Yucca Mountain, west of Willow Spring. A series of springs is in the corridor near the Amargosa River in Oasis Valley. Seyler Reservoir is 0.2 kilometer (0.1 mile) from the corridor in the south end of Big Smokey Valley. Five of the riparian areas (Skull, Steiner, and Ox Corral creeks, and Water and Rye Patch canyons) are along the section of the route between Beowawe and Austin at the south end of Grass Valley. Two of these (Steiner and Ox Corral creeks, both at the south end of Grass Valley) are ephemeral and have little or no riparian vegetation where the route crosses them. The corridor crosses the Amargosa River in the north end of the Oasis Valley, in an area designated as a riparian area by the Bureau of Land Management. This corridor also crosses a number of ephemeral streams that might be classified as waters of the United States under Section 404 of the Clean Water Act.

The corridor crosses two wild horse or wild horse and burro herd management areas between Beowawe and Austin (Mount Callaghan and Bald Mountain), one in Big Smokey Valley (Hickison) and three between Mud Lake and Yucca Mountain (Goldfield, Stonewall, and Bullfrog) (BLM 1983, Map 2-4; BLM 1994b, Maps 18 and 19).

Caliente-Chalk Mountain. The Caliente-Chalk Mountain rail corridor begins near Caliente and is identical to the Caliente rail corridor from Caliente to Sand Spring Valley, crossing Meadow, Dry Lake, Coal, and Garden Valleys at elevations ranging from 1,400 to 1,600 meters (4,600 to 5,200 feet). This portion of the corridor also crosses the Highland, Seaman, Golden Gate, and Worthington mountain ranges at elevations of 1,500 to 1,800 meters (4,900 to 5,900 feet). After splitting from the Caliente rail corridor, the Caliente-Chalk Mountain rail corridor proceeds south through Sand Spring and Emigrant Valleys, over Groom Pass, and through Yucca and Jackass Flats to Yucca Mountain. The elevation along this portion of the route ranges from approximately 1,100 to 1,700 meters (3,600 to 5,600 feet).

Predominant land cover types between Caliente and Sand Spring Valley include sagebrush (50 percent) and salt desert scrub (47 percent). The vegetation along the route from Sand Spring Valley to Yucca Flat is typical of the southern portion of the Great Basin. From Yucca Flat to Yucca Mountain, the corridor passes through a zone of transition between the Mojave and Great Basin deserts. The predominant land cover types from Sand Spring Valley to the Yucca Mountain site are blackbrush (50 percent), salt desert scrub (31 percent), and sagebrush (9 percent).

The only resident threatened or endangered species in the Caliente-Chalk Mountain rail corridor is the desert tortoise, which occurs on the Nevada Test Site south of Yucca Flat. This area is not critical habitat for desert tortoises (50 CFR 17.95) and their abundance is low (Rautenstrauch and O'Farrell 1998, pages 407 to 411).

Seven species classified as sensitive by the Bureau of Land Management have been found in the corridor (NNHP 1997, all). Unnamed subspecies of the Meadow Valley Wash speckled dace and Meadow Valley Wash desert sucker have been found in Meadow Valley Wash. Ripley's springparsley (*Cymopterus ripleyi* var. *saniculoides*) has been reported between Sand Spring Valley and Yucca Mountain in Yucca Flat. The largeflower suncup (*Camissonia megalantha*) has been found in the corridor at three locations in Yucca Flat. Beatley's scorpionweed (*Phacelia beatleyae*) also has been reported at two locations in Yucca Flat. The long-legged myotis (*Myotis volans,* a bat) has been found in Jackass Flats and other bats classified as sensitive by the Bureau of Land Management also may occur near the corridor. Chuckwalla may occur in suitable habitat on the Nevada Test Site.

The Caliente-Chalk Mountain rail corridor crosses several areas designated as game habitat by the Bureau of Land Management (BLM 1979, pages 2-26 through 2-35; BLM 1994b, Maps 9, 10, 11). A bighorn sheep winter forage area is in the Cedar Range, approximately 13 kilometers (8 miles) west of Crestline. Mule deer also use the winter forage area in the Cedar Range, and the corridor crosses mule deer use areas in or near the Chief, Delamar, Worthington, and Quinn Canyon mountains. The corridor crosses pronghorn habitat in Sand Spring and Emigrant Valleys. Areas within 0.4 kilometer (0.25 mile) of springs, seeps, and livestock watering developments in Meadow Valley are classified as crucial areas for quail and portions of the area are classified as habitat for waterfowl.

Three springs and two streams occur within 0.4 kilometer (0.25 mile) of the corridor. These areas might be classified as wetlands or other waters of the United States (TRW 1999k, page 3-27), as defined in the Clean Water Act, although no formal wetlands delineation has been conducted. An unnamed spring is near the corridor at the north end of the North Pahroc Range. The corridor crosses Meadow Valley Wash south of Panaca. The corridor crosses the White River between U.S. 93 and Sand Spring Valley and parallels the river for approximately 25 kilometers (16 miles). An August 1997 survey of that portion of the river found it was mostly dry with some standing water in stock waterholes. This corridor also crosses a number of ephemeral streams or washes that might be classified as waters of the United States.

The Caliente-Chalk Mountain rail corridor passes through two wild horse or wild horse and burro herd management areas (BLM 1979, pages 2-42 and 2-43; BLM 1994b, Maps 18 and 19) in the Cedar Mountains south of Panaca and in the Chief Range west of Panaca.

Jean. The Jean rail corridor starts in Ivanpah Valley north of Jean and proceeds west of Wilson Pass to the Pahrump Valley. The corridor continues to the Yucca Mountain site through Pahrump Valley and across the Amargosa Desert and Jackass Flats. This corridor is in the Mojave Desert, with elevations ranging from about 850 to 1,500 meters (2,800 to 4,900 feet).

The predominant land cover types in the corridor are creosote-bursage (59 percent), Mojave mixed scrub (21 percent), and blackbrush (18 percent) (TRW 1999k, page 3-28).

The only resident threatened or endangered species in the Jean rail corridor is the desert tortoise. The entire corridor is in the range of this species (Bury and Germano 1994, pages 57 to 72). Along most of the corridor, especially the western portions from Pahrump to Yucca Mountain, the abundance of desert tortoises is low (Karl 1980, pages 75 to 87; Rautenstrauch and O'Farrell 1998, pages 407 to 411). However, some areas crossed by the corridor in Ivanpah, Goodsprings, Mesquite, and Pahrump Valleys have a higher abundance of tortoises (BLM 1992, Map 3-13). The corridor does not cross areas classified as critical habitat for desert tortoises (50 CFR 17.95).

One location of each of two subspecies of the pinto beardtongue (*Penstemon bicolor bicolor* and *P.b. roseus),* which is classified as sensitive by the Bureau of Land Management, is in the first 5 kilometers (3 miles) of the corridor near Jean (NNHP 1997, all). No other Bureau of Land Management sensitive species have been documented in the corridor, although chuckwalla, gila monsters (*Heloderma suspectus cinctum*), and a number of bat species classified as sensitive probably occur there in suitable habitat.

The Jean rail corridor crosses several areas the Bureau of Land Management designates as game habitat (BLM 1998, Maps 3-7, 3-8, and 3-9). The corridor crosses four areas designated as quail/chukar or quail habitat: at the intersection of State Highway 161, northeast of Goodsprings, south of Potosi Spring, and east of Pahrump. An additional quail habitat area is on the route from the town of Johnnie to Yucca Mountain. Designated mule deer habitat occurs in three places along the corridor: on the southern half of Potosi Mountain, northwest of Goodsprings, and south of the intersection with State Highway 161. Bighorn sheep winter areas occur south of the intersection of the corridor with State Highway 161. Bighorn sheep habitat is in the Wilson Pass area and to the north on Potosi Mountain. The corridor also crosses a potential bighorn sheep migration corridor from winter range in the Devils Hole Hills to historic but currently unoccupied habitat at the west end of the Spring Mountains.

There are no springs, perennial streams, or riparian areas within 0.4 kilometer (0.25 mile) of this corridor. The corridor crosses a number of ephemeral washes that might be classified as waters of the United States under Section 404 of the Clean Water Act.

There are three wild horse and burro herd management areas in the corridor (BLM 1998, Map 2-1). The Red Rock herd management area is southeast of the Spring Mountains and the Wheeler Pass and Johnnie herd management areas are west of the Spring Mountains.

Valley Modified. The Valley Modified rail corridor begins in the northeastern corner of the Las Vegas Valley, crosses the northern edge of the valley south of the Las Vegas Range, and continues northwest toward Indian Springs. The route continues across the southern portion of Three Lakes and Indian Springs Valleys to the Nevada Test Site and passes through Mercury Valley, Rock Valley, and Jackass Flats to the Yucca Mountain site. The corridor ranges in elevation from approximately 700 to 1,100 meters (2,300 to 3,600 feet).

This route is in the Mojave Desert and the predominant land cover types are creosote-bursage (79 percent) and Mojave mixed scrub (16 percent; TRW 1999k, page 3-29).

The only resident threatened or endangered species in the Valley Modified rail corridor is the desert tortoise. The entire corridor is in the range of this species (Bury and Germano 1994, pages 57 to 72). In general, the abundance of tortoises along this corridor through Las Vegas Valley, Indian Springs Valley, and the Nevada Test Site is low (BLM 1992, Map 3-13; Rautenstrauch and O'Farrell 1998, pages 407 to 411). This corridor does not cross areas classified as critical habitat for desert tortoises (50 CFR 17.95). The razorback sucker (*Xyrauchen texanus*), classified as threatened under the Endangered Species Act and as protected under Nevada Administrative Code, has been introduced into ponds at Floyd Lamb State Park, 4.2 kilometers (2.6 miles) south of the corridor (TRW 1999k, page 3-29). Refuge populations of the Pahrump poolfish (*Empetrichthys latos latos*), classified as endangered under the Endangered Species Act and Nevada Administrative Code, has been introduced into ponds in Floyd Lamb State Park and into the outflow of Corn Creek Springs, 4.5 kilometers (2.8 miles) northeast of the corridor (NNHP 1997, all; TRW 1999k, page 3-29).

Two other species classified as sensitive by the Bureau of Land Management occur in the corridor. Three populations of Parish's scorpionweed (*Phacelia parishii*) and a population of Ripley's springparsley have been reported on the Nevada Test Site in Rock Valley. No other Bureau of Land Management sensitive species have been documented in the corridor, although chuckwalla, gila monsters, and a number of bat species probably occur there in suitable habitat.

There are no herd management areas, Areas of Critical Environmental Concern, or designated game habitat in the Valley Modified rail corridor (TRW 1999k, page 3-29; BLM 1998, Maps 3-7, 3-8, and 3-9). No springs or riparian areas occur within 0.4 kilometer (0.25 mile) of this rail corridor. This corridor crosses a number of ephemeral streams or washes that might be classified as waters of the United States under Section 404 of the Clean Water Act.

3.2.2.1.5 *Cultural Resources*

The baseline environmental conditions presented in this section focus on the archaeological and historic resources associated with the candidate rail corridors. This section also discusses Native American interests in relation to two of the corridors. Unless otherwise noted, this information is from the *Environmental Baseline File for Archaeological Resources* (TRW 1999m, all). In addition, information from the *American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement* (AIWS 1998, all) was used.

Archaeological and Historic Resources. Archaeological data from the five rail corridors, including a 0.2-kilometer (0.1-mile)-wide buffer zone on either side of each corridor, are very limited. Based on a records search at the Desert Research Institute in Las Vegas and Reno, and at the Harry Reid Center at the University of Nevada, Las Vegas, archaeological surveys have been conducted in less than 1 percent of the total areas for the Caliente, Jean, and Valley Modified corridors, less than 3 percent of the total area for the Carlin corridor, and less than 5 percent of the total area for the Caliente-Chalk Mountain corridor. Although it is possible to identify areas in a corridor that are most likely to contain cultural resources based on such factors as general land forms and proximity to water, these predictions are highly uncertain and, therefore, are not included in this EIS.

Records indicate that a number of archaeological sites have been identified along the corridors and that some of these sites are recorded as potentially eligible for nomination to the *National Register of Historic Places*. Table 3-36 summarizes this information. The table also lists potentially eligible sites by type. For conservatism, this group includes sites not yet evaluated for eligibility. The sites recorded but not included in the potentially eligible group represent sites that had no recommendations about eligibility to the National Register.

DOE is implementing the stipulations and forms of a Programmatic Agreement (DOE 1988b, all) with the Advisory Council on Historic Preservation to address DOE's responsibilities under Sections 106 and 110 of the National Historical Preservation Act and the Council's implementing regulations. Although not a formal signatory to the Agreement, the Nevada State Historic Preservation Officer has the right at any time, upon request, to participate in monitoring DOE compliance with the Programmatic Agreement. In addition, DOE provides annual reports to the Advisory Council on Historic Preservation and the Nevada State Historic Preservation Officer describing the activities conducted by DOE each year to implement the stipulations of the Programmatic Agreement. This report includes a description of DOE coordinations and consultations with Federal and State agencies and Native American tribes concerning historic and culturally significant properties at Yucca Mountain.

Table 3-36. Number of archaeological sites along candidate rail corridors.

Category[a]	Caliente	Carlin	Caliente-Chalk Mountain	Jean	Valley Modified
Potentially eligible for nomination					
Temporary camps	--[b]	--	3	--	--
Extractive localities	--	--	3	--	--
Processing localities	--	--	--	--	--
Localities	--	1	16	--	--
Caches	--	--	--	--	--
Stations	--	--	--	--	--
Historic sites	--	--	3	--	--
Unknown type	7	20	3	--	7
Total potentially eligible	***7***	***21***	***28***	***0***	***7***
Not evaluated	29	26	6	2	4
Recorded sites (approximate total)	***97***	***110***	***100***	***6***	***19***

a. Section 3.1.6 contains the definitions of site types for potentially eligible for nomination sites (temporary camps, extractive localities, etc.).
b. -- = none identified.

DOE will continue to seek input from the Nevada State Historic Preservation Officer and the Advisory Council on Historic Preservation, and will interact appropriately to meet the reporting and other stipulations of the Programmatic Agreement.

There is some additional information available for the Carlin corridor. The northern part of this corridor is not well known archaeologically. The central part has been the subject of important archaeological and ethnographic investigations. Elston (1986, all) summarizes the region's prehistory. Archaeological research in Monitor Valley at the Gatecliff Shelter established important chronological data for this part of the Great Basin. In addition, there have been studies of settlement patterns in the Upper Reese River Valley west of the Carlin rail corridor.

Thomas, Pendleton, and Cappannari (1986, all) summarizes ethnographic studies in this region. The Big Smokey Valley, which the Carlin corridor crosses, was part of several ethnographic studies of the Western Shoshone. A part of the Pony Express route crosses the northern end of the Carlin rail corridor.

Native American Interests. Through the American Indian Writers Subgroup of the Consolidated Group of Tribes and Organizations, Native Americans have noted that, while transportation issues are of extreme interest to them, at present they cannot provide specific comments on any of the Nevada transportation project alternatives (AIWS 1998, pages 4-4 to 4-6) due to the absence of systematic ethnographic studies for any of the proposed project areas.

General concerns for potential transportation-related impacts raised by Native Americans include the following:

- Radioactive and hazardous waste transportation could have an adverse impact along rail or highway routes near existing or planned Native American communities, people, businesses, and resources.
- All of the proposed routes being considered pass through the traditional holy lands of the Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone peoples.
- Many of these routes correspond or are adjacent to ancient pathways and complex trail systems known to and used by Native American peoples.

- The Consolidated Group of Tribes and Organizations is aware of important culturally sensitive areas, traditional use areas, sacred sites, and other important resources that fall in the proposed transportation project areas, and will present this information when appropriate in the development of the Nevada transportation system.

These general concerns apply to the proposed rail corridors discussed in this section, and the proposed heavy-haul route alternatives and intermodal transfer station locations discussed in Section 3.2.2.2.5.

Native Americans live in the vicinity of two of the candidate rail corridors:

- *Jean.* The Pahrump Paiute Tribe is a non-Federally recognized tribe without a land base. The tribe consists of about 100 Southern Paiute people living in the Pahrump area (see Section 3.1.6.2). Individual members of the tribe live as close as 5 kilometers (3 miles) from the Jean corridor.

- *Valley Modified.* The Las Vegas Paiute Colony is a Federally recognized tribe consisting of about 100 people living on two separate tribal parcels in southern Nevada. One parcel near downtown Las Vegas consists of about 73,000 square meters (18 acres) of land with 21 homes and various businesses. This parcel is about 11 kilometers (7 miles) from the route of the Valley Modified rail corridor. The other parcel is in the northwest part of the Las Vegas Valley along U.S. 95. It consists of 16 million square meters (4,000 acres) with 12 homes and various business enterprises. This parcel is about 1.6 kilometers (1 mile) from the Valley Modified rail corridor.

3.2.2.1.6 *Socioeconomics*

Section 3.1.7 describes the socioeconomic backgrounds of the three counties (Clark, Lincoln, and Nye) most involved in the corridors. The Carlin corridor includes other counties— Esmeralda, Eureka, and Lander—in addition to Nye County. This section contains baseline socioeconomic information for Eureka, Esmeralda, and Lander Counties.

Socioeconomic effects from the construction of a rail line would be small and, for the most part, short-term. Therefore, the socioeconomic information for Esmeralda, Eureka, and Lander Counties is less detailed than the information for the counties in the repository site region of influence in Section 3.1.7.

Employment. Section 3.1.7.2 contains employment and economic information on Clark, Nye, and Lincoln Counties. Portions of the potential Carlin rail route pass through Esmeralda, Eureka, and Lander Counties. In 1994, Esmeralda, Eureka, and Lander Counties had average labor forces of about 670, 840, and 3,000, respectively, and average unemployment rates of 7.7, 9.5, and 10 percent (Bureau of the Census 1998, all). During the same year, the per capita income of Esmeralda, Eureka, and Lander Counties was about $33,000, $27,000, and $20,000, respectively (NDETR 1999, all). All three of these counties are small in economic terms and have chronically high unemployment.

Population. Section 3.1.7.1 contains population data on Clark, Lincoln, and Nye Counties. This section provides population background for the other counties potentially affected by the Carlin rail corridor (Esmeralda, Eureka, and Lander).

The population of Esmeralda County is 100 percent rural. The 1990 Census population for the county was about 1,300 persons. The two block groups that comprise the county had densities of 0.3 and 0.4 person per square mile. The Esmeralda County population projection for 2000 is about 1,400 (NSDO 1998, Esmeralda).

The population of Eureka County is 100 percent rural. The 1990 Census population of the county was about 1,500. Density at the block group level ranged from 0 to 5.3 persons per square mile. The projected population of Eureka County for 2000 is about 2,100 (NSDO 1998, Eureka).

The population of Lander County is 56 percent urban and 44 percent rural, with the urban population concentrated entirely in Battle Mountain. The 1990 Census population of the county was about 6,300 persons. The projected population of Lander County for 2000 is about 7,700 (NSDO 1998, Lander).

Housing. Section 3.1.7.4 contains housing data on Clark, Lincoln, and Nye Counties. Esmeralda, Eureka, and Lander Counties are rural areas. The housing stock of Esmeralda County in 1990 was about 1,000 units, of which about 590 were occupied (Bureau of the Census 1998, Esmeralda). The housing stock of Eureka County in 1990 was about 820 units, of which about 620 were occupied (Bureau of the Census 1998, Eureka). The housing stock of Lander County in 1990 was about 2,600 housing units, of which about 2,200 were occupied (Bureau of the Census 1998, Lander).

Economy. Section 3.1.7.2 contains employment and economic information on Clark, Lincoln, and Nye Counties. For the Esmeralda, Eureka, and Lander portions of the Carlin corridor. Esmeralda, Eureka, Lander, and Nye are very small counties in economic terms. Esmeralda County is particularly small, smaller even than Lincoln County in earnings and employment. Like Lincoln County, Esmeralda and Lander have lower per capita incomes than other Nevada counties and chronically high unemployment.

Public Services. Section 3.1.7.5 contains information on public services in Clark, Lincoln, and Nye Counties. Esmeralda, Eureka, and Lander Counties are rural areas. Public services (for example, hospitals, libraries, community centers) are available in small communities in the counties (for example, Battle Mountain, Ely, Eureka). Community water and sewer services are available in small communities; wells and septic tanks serve outlying areas.

3.2.2.1.7 *Noise*

Most of the proposed rail corridors pass through unpopulated desert with average day-night background sound levels of 22 to 38 A-weighted decibels (dBA). (A-weighted decibels are explained in Section 3.1.9.1.) However, each candidate corridor passes near small rural communities (see Figures 6-10 through 6-15). Noise levels in rural communities usually range from 40 to 55 dBA. DOE used computerized mapping programs to examine proposed transportation corridors for the presence and proximity to routes that could be designated for the transfer of nuclear material to the Yucca Mountain site. The process involved the examination of computerized maps at very high detail to determine the extent of road grids in communities and major road intersections. The analysis estimated the distance from the proposed rail corridor and the community to determine if the community was in the region of influence for rail transportation.

Caliente. Most of the Caliente corridor passes through undeveloped Bureau of Land Management land where background noise levels range from 22 to 38 dBA (Table 3-30), influenced primarily by wind. Noise levels of 40 to 55 dBA are present in the rural communities along the corridor including Goldfield, Panaca, and Caliente (Table 3-30).

Carlin. The Carlin rail corridor, from its origin at Beowawe to its terminus at Yucca Mountain, including the Monitor Valley option and other options south of Tonopah, traverses mostly unpopulated desert. The only town within 1.6 kilometers (1 mile) of the corridor is Hadley at the southern end of Big Smokey Valley (Monitor Valley option). Noise levels of 40 to 55 dBA are present in rural communities near the corridor, including Goldfield, Tonopah, Austin, and smaller communities between Tonopah and Battle

Mountain (Table 3-30). Occasional noise from military aircraft overflights occurs near the Nellis Air Force Range.

Caliente-Chalk Mountain. Almost half of the 345-kilometer (214-mile) Caliente-Chalk Mountain corridor is on Nellis Air Force Range or Nevada Test Site land; the remainder is on Bureau of Land Management land. Noise levels of 40 to 55 dBA are present in rural communities along the corridor including Panaca and Caliente (Table 3-30). Occasional noise from military aircraft overflights occurs near and in the Nellis Air Force Range.

Jean. The Jean rail corridor, with the Stateline option, passes through Bureau of Land Management land and a small section of private land. A large portion of this proposed corridor passes through unpopulated desert. Noise levels of 40 to 55 dBA are present in small communities along the corridor including Amargosa Valley, Goodsprings, Pahrump, and Jean (Table 3-30). Occasional noise from military aircraft overflights occurs near and in the Nellis Air Force Range.

Valley Modified. The Valley Modified rail corridor, and its various options, begins in the northeast end of the Las Vegas Valley, travels west across Nellis Air Force Base and the southern end of the Desert National Wildlife Range, and then closely parallels U.S. 95 to the vicinity of Mercury. Noise levels along stretches of unpopulated desert should range from 22 to 38 dBA, which are typical for a desert environment during calm and windy days (Brown-Buntin 1997, page 7). The corridor would pass 3 kilometers (2 miles) north of Floyd R. Lamb State Park and less than 5 kilometers (3 miles) south of Corn Creek Station, which is part of the Desert National Wildlife Range managed by the Fish and Wildlife Service. Noise levels at the state park and at Corn Creek would probably be only slightly higher than those in an unpopulated desert environment. Noise levels in the northern Las Vegas Valley can be as high as 60 dBA (Table 3-30). Noise levels in Indian Springs and Mercury probably range from 45 to 55 dBA (Table 3-30). Occasional noise from military aircraft overflights occurs near and in the Nellis Air Force Range.

3.2.2.1.8 *Aesthetics*

To assist in the management of public lands under its control, the Bureau of Land Management established land management guidelines based on the visual resources of an area. Visual resources include the natural and manmade physical features that give a particular landscape its character and value as an environmental factor. There are four visual resource classes. Classes I and II are the more highly valued. Class III is moderately valued, and Class IV is of least value. The majority of land in the potential rail corridors is under the jurisdiction of the Bureau of Land Management. The following paragraphs contain aesthetic baseline information for each of the rail corridors. Section 3.1.10 contains more information on the Bureau of Land Management visual resource classes and scenic quality classes. Unless otherwise noted, this information is from the *Environmental Baseline File: Aesthetics* (TRW 1999p, all).

Caliente. Section 3.2.2.1.4 describes the environmental setting along the Caliente corridor. The corridor passes through the Caliente, Schell, Tonopah, and Las Vegas Bureau of Land Management resource areas. The corridor crosses mostly Class IV lands, crosses Class III land near Caliente, and crosses or skirts the edges of Class II lands near Caliente and in the Seaman, Reveille and Kawich ranges, the Golden Gate Hills, and the Worthington Mountains. Lands crossed on the Nevada Test Site have scenic quality ratings of Class B or C (Figure 3-25).

Carlin. Section 3.2.2.1.4 describes the environmental setting of the Carlin corridor. The corridor passes through four Bureau of Land Management resource areas (Elko, Shoshone-Eureka, Tonopah, and Las

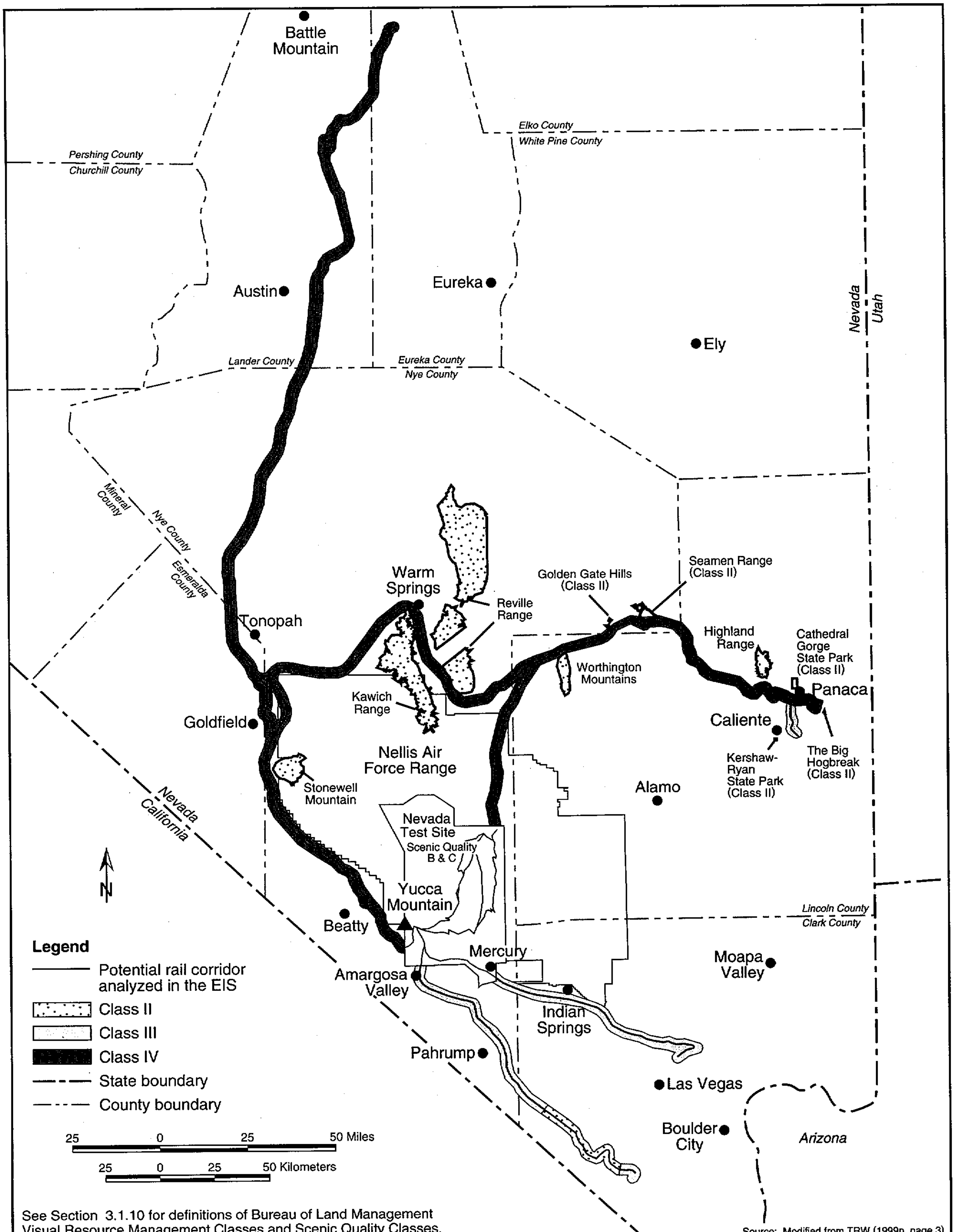


Figure 3-25. Visual Resource Management classes along the potential rail corridors.

Vegas). The route is on Class IV land from its beginning to the Nevada Test Site border. Lands crossed on the Nevada Test Site have scenic quality ratings of Class B or C (Figure 3-25).

Caliente-Chalk Mountain. Section 3.2.2.1.4 describes the environmental setting of the Caliente-Chalk mountain corridor. The corridor passes through the Caliente and Schell Bureau of Land Management resource areas. The route begins on Class III land east of Caliente, and crosses mostly Class IV land to the border of the Nevada Test Site (Figure 3-25). On the Nevada Test Site the corridor passes through lands with scenic quality Class B or C.

Jean. Section 3.2.2.1.4 describes the environmental setting of the Jean corridor. The corridor crosses the Las Vegas and the Northern and Eastern Mojave Bureau of Land Management resource areas. The Wilson Pass alternate passes through Class II land in Goodsprings Valley, but the rest of the route and west of the Stateline Pass secondary corridor cross Class III land. Approximately 10 kilometers (6 miles) of the route crosses lands in California; that area does not have Visual Resource Management class ratings. Lands crossed on the Nevada Test Site have scenic quality ratings of Class B or C (Figure 3-25).

Valley Modified. Section 3.2.2.1.4 describes the environmental setting of the Valley Modified corridor. The corridor crosses the Las Vegas Bureau of Land Management resource area. The entire route to the boundary of the Nevada Test Site crosses Class III land. Lands on the Nevada Test Site have scenic quality ratings of Class B or C (Figure 3-25).

3.2.2.1.9 *Utilities, Energy, and Materials*

All five primary rail corridors pass through typically remote Nevada countryside but are within the southern Nevada supply chain for the commodities required during construction and operation. Electric power, which would be available to a limited extent at nearby communities or other locations near power lines, probably would not be needed.

3.2.2.1.10 *Environmental Justice*

The five candidate rail corridors would not appreciably affect counties other than those through which they pass. Section 3.1.13 contains information on the minority and low-income communities in the three counties most involved in the corridors (Clark, Lincoln, and Nye). The Carlin corridor is the only route that passes through other counties (Esmeralda, Eureka, and Lander, in addition to Nye). This section contains baseline information on minority and low-income communities in Esmeralda, Eureka, and Lander Counties. Unless otherwise noted, the *Environmental Baseline File for Environmental Justice* (TRW 1999q, all) is the basis for the information in this section.

In 1990, the minority population (White Hispanic, Black, Asian/Pacific Islander, American Indian/ Eskimo/Aleut, and Other) of Esmeralda County was about 210, or 15 percent of the population. No block group in the county exceeded the threshold for identification as a minority community (Bureau of the Census 1992e, Tables P8 and P12). In 1990, there were about 210 persons living in poverty, or 15 percent of the population. No block group in Esmeralda County exceeded the threshold for identification as a low-income community (Bureau of the Census 1992e, Table P117). (Section 3.1.13 defines minority and low-income communities.)

In 1990, the minority population of Eureka County was about 170 persons, or 11 percent. No block group in the county exceeded the threshold for identification as a minority community (Bureau of the Census 1992f, Tables P8 and P12). In 1990, there were about 160 persons living in poverty, or 10 percent of the population. No block group in Eureka County exceeded the threshold for identification as a low-income community (Bureau of the Census 1992f, Table P117).

In 1990, the minority population of Lander County was about 1,100 persons, or 17 percent. No block group in the county exceeded the threshold for identification as a minority community (Bureau of the Census 1992g, Tables P8 and P12). In 1990, there were about 670 persons living in poverty, or 11 percent of the population. No block group in Lander County exceeded the threshold for identification as a low-income community (Bureau of the Census 1992g, Table P117).

Tables 3-37 and 3-38 list by county the number of census block groups with high minority and low-income populations, respectively, that the rail corridors pass through or near. Table 3-39 lists the number of census block groups with high minority populations, high low-income populations, or both that each rail corridor could affect. More than 300 block groups in the City of Las Vegas have either low-income or minority populations. However, the rail corridors do not intersect any of these block groups.

Ninety block groups in the City of Las Vegas have low-income or minority populations or both. However, the rail corridors do not intersect any of these block groups.

Table 3-37. High minority population census block groups near or crossed by rail corridors.

County	Crosses	Near
Eureka	0	0
Lander	0	0
Nye	0	1[a]
Esmeralda	0	0
Clark[b]	2	2
Lincoln	0	0

a. This block group is also a high low-income population block group included in Table 3-39.
b. Outside Las Vegas.

Table 3-38. High low-income population census block groups near or crossed by rail corridors.

County	Crosses	Near
Eureka	0	0
Lander	0	0
Nye	2	3[a]
Esmeralda	0	0
Clark[b]	0	0
Lincoln	0	0

a. One block group is also a high minority population block group included in Table 3-39.
b. Outside Las Vegas.

Table 3-39. High minority and high low-income population census block groups near or crossed by rail corridors.

Corridor	Minority	Low-income	Minority and low-income
Caliente	0	2 near, 3 crossed[a]	0
Carlin	0	2 crossed[a]	1 near[a]
Caliente-Chalk Mountain	0	0	0
Jean	0	1 near[a]	0
Valley Modified	2 crossed[b]	0	0

a. In Nye County.
b. In Clark County outside Las Vegas.

3.2.2.2 Heavy-Haul Truck Route and Intermodal Transfer Station Environmental Baseline

This section discusses the environmental characteristics of counties and land areas that could be affected by the construction and operation of an intermodal transfer station and the operation of heavy-haul trucks carrying spent nuclear fuel and high-level radioactive waste to the Yucca Mountain Repository on Nevada highways. The discussion describes existing environmental conditions in the candidate areas where an intermodal transfer station could be located along Nevada highway routes that could be used for the heavy-haul truck transportation of casks containing spent nuclear fuel and high-level radioactive waste. The candidate locations for an intermodal transfer station are near the communities of Caliente, Sloan, and Jean, and northeast of Las Vegas near Dry Lake on the Union Pacific Railroad Valley siding. These locations can be grouped into three general sites near existing rail lines and highways: near Caliente

(Caliente), southeast of Las Vegas (Sloan/Jean), and northeast of Las Vegas (Apex/Dry Lake). DOE is considering more than one site for the station in each general area.

The heavy-haul trucks would use existing highways that would be upgraded as necessary to accommodate such vehicles. There are five potential heavy-haul routes. Three of these routes (Caliente, Caliente-Chalk Mountain, and Caliente-Las Vegas) are associated with the Caliente intermodal transfer station site. The Sloan/Jean and Apex/Dry Lake intermodal transfer station sites are associated with one candidate route each.

To define the existing (or baseline) environment associated with the three candidate intermodal transfer station locations and along the five candidate heavy-haul truck routes, DOE has compiled environmental information for each of the following subject areas.

- *Land use and ownership:* The condition of the land, current land-use practices, and land ownership information (Section 3.2.2.2.1)
- *Air quality and climate:* The quality of the air and climate (Section 3.2.2.2.2)
- *Hydrology:* The characteristics of surface water and groundwater (Section 3.2.2.2.3)
- *Biological resources:* Important biological resources (Section 3.2.2.2.4)
- *Cultural resources:* Important cultural resources (Section 3.2.2.2.5)
- *Socioeconomic environments:* The existing socioeconomic environments (Section 3.2.2.2.6)
- *Noise:* The existing noise environments (Section 3.2.2.2.7)
- *Aesthetics:* The existing visual environments (Section 3.2.2.2.8)
- *Utilities, energy, and materials:* Existing supplies of utilities, energy, and materials (Section 3.2.2.2.9)
- *Environmental justice:* The locations of low-income and minority populations (Section 3.2.2.2.10)
- *Existing traffic on potential routes for heavy-haul trucks:* Existing traffic in terms of level of service (on the five alternative heavy-haul routes for trucks) (Section 3.2.2.2.11)

The HIGHWAY computer program (Johnson et al. 1993a, all) provided population distributions for the different population zones (urban, rural, and suburban) along the alternative highway routes for heavy-haul trucks. This approach, which Chapter 6 and Appendix J describe in detail, is consistent with the national transportation analysis. DOE expects the waste quantities generated by intermodal transfer station construction to be small in comparison to those from repository construction and operation. Therefore, this discussion does not include existing waste disposal infrastructure along the routes.

DOE evaluated potential impacts of the implementing alternatives in the region of influence for each of the following subject areas. Table 3-40 defines these regions, which are specific to the subject areas in which DOE could reasonably expect to predict potentially large impacts related to heavy-haul infrastructure construction and operations.

Table 3-40. Regions of influence for heavy-haul implementing alternatives.

Subject area	Region of influence
Land use and ownership	Land areas that would be disturbed or for which ownership or use would change as a result of construction and use of an intermodal transfer station and associated highway route
Air quality and climate	The Las Vegas Valley for implementing alternatives in which the construction and operation of an intermodal transfer station and associated heavy-haul route could contribute to the level of carbon monoxide and PM_{10} already in nonattainment of standards, and the atmosphere in the vicinity of sources of criteria pollutants that would be emitted during construction and operations
Hydrology	*Surface water:* areas where construction would take place that would be susceptible to erosion, areas affected by permanent changes in flow, and areas downstream of construction that would be affected by eroded soil or potential spills of construction contaminants
	Groundwater: aquifers that would underlie areas of construction and operations and that could be used to obtain water for construction
Biological resources	Habitat, including jurisdictional wetlands, that could be disturbed by construction and operation of an intermodal transfer station and associated heavy-haul route; habitat, including jurisdictional wetlands, and riparian areas that could be affected by permanent changes in surface-water flow
Cultural resources	Land areas that would be disturbed by the construction and operation of an intermodal transfer station and associated heavy-haul route
Socioeconomic environments	Clark, Lincoln, Nye, and other counties that a route for heavy-haul vehicles could traverse
Occupational and public health and safety	800 meters[a] on each side of the route for heavy-haul vehicles for incident-free transportation, 80-kilometer[b] radius for potential impacts from accidents
Noise	Inhabited commercial and residential areas where noise from the construction and operation of an intermodal transfer station and associated routes for heavy-haul vehicles could be a concern
Aesthetics	The landscapes along potential routes for heavy-haul vehicles and at potential locations for intermodal transfer station where aesthetic quality could be affected by construction and operation
Utilities energy, and materials	Local, regional, and national supply infrastructure that would be required to support construction and operation of an intermodal transfer station and associated route for heavy-haul vehicles
Environmental justice	Varies with the individual resource area

a. 800 meters = 0.5 mile.
b. 80 kilometers = 50 miles.

Caliente. DOE has identified two locations for an intermodal transfer station southwest of the City of Caliente. Table 3-41 lists the ownership of the land involved. Both sites would use a local road to provide access to U.S. 93, the starting point for all three of the heavy-haul routes associated with this intermodal transfer station. Both parcels being considered are in the Rainbow Canyon section of Meadow Valley Wash. This canyon is used for a variety of recreational purposes and is the route of the Union Pacific railroad. Kershaw-Ryan State Park is across Meadow Valley Wash about 0.4 kilometer (0.25 mile) east of the station sites (DOE 1998j, all). The northern parcel includes a wastewater treatment plant.

3.2.2.2.1 *Land Use and Ownership*

This section describes existing land use and ownership for the candidate intermodal transfer station locations and for the candidate heavy-haul routes. Table 3-41 summarizes the estimated land commitment for each site at the three candidate locations. The following paragraphs describe the candidate intermodal transfer station sites.

Sloan/Jean. DOE has identified three possible parcels in the area of Sloan and Jean for potential use as the location of an intermodal transfer station. Each provides adequate land area adjacent to the Union Pacific mainline and has access to existing roadways. Figure 2-29 in Chapter 2 shows these sites. The Bureau of Land Management controls all lands associated with these parcels through its Las Vegas Field Office. Detailed information on land use is available in the *Proposed Las Vegas Resource Management Plan and Environmental Impact Statement* (BLM 1998, all).

Table 3-41. Estimated land commitment areas for candidate intermodal transfer station sites (square kilometers).[a,b]

	Commitment		
		Percentage current ownership or control[c]	
Potential location	Total area	BLM	City of Caliente[d]
Caliente			
North Site	0.5		100
South Site	0.25		100
Sloan/Jean			
North Site	3.3	100	
Middle Site	3.1	100	
South Site	1	100	
Apex/Dry Lake			
North Site	3.5	100	
South Site	1	100	

a. Source: TRW (1999d, all).
b. To convert square kilometers to acres, multiply by 247.1.
c. Bureau of Land Management property is public land administered by the Bureau.
d. "City of Caliente" designates patented land owned by the city. A small undesignated portion of both Caliente sites is Bureau of Land Management land.

Apex/Dry Lake. DOE has identified two land parcels near the intersection of U.S. 93 and Interstate 15 at the Apex and Dry Lake areas northeast of Las Vegas for the possible location of an intermodal transfer station. Both provide adequate land area close to the Union Pacific mainline and have access to existing roadways. The Bureau of Land Management controls all lands associated with these parcels through its Las Vegas Field Office. Detailed information on land use is available in BLM (1998, all). The Moapa Indian Reservation is about 5 kilometers (3 miles) north of the proposed station site. The Dry Lake solar enterprise zone is almost 5 kilometers west of the site (DOE 1996f, page 4-227). The Apex industrial complex is about 16 kilometers (10 miles) to the southwest. Tenants at the complex include Kerr-McGee Chemical Corporation, Chemstar Inc., and Georgia Pacific Corporation. Silver State Disposal operates a waste landfill and waste-processing facilities east of I-15 about 5 kilometers south of the southernmost site.

Routes for Heavy-Haul Trucks. The five possible routes that heavy-haul trucks could use in Nevada—Caliente, Caliente-Las Vegas, Caliente-Chalk Mountain, Sloan/Jean, and Apex/Dry Lake—have existing highways in established rights-of-way. The routes use combinations of highways that, after improvement, heavy-haul trucks could use to travel from an intermodal transfer station at a mainline railroad to the repository.

3.2.2.2.2 *Air Quality and Climate*

This section summarizes existing air quality and climate conditions for each of the candidate intermodal transfer station sites and the five candidate heavy-haul routes.

Air Quality. Both the Caliente and Apex/Dry Lake sites are in areas that are either unclassified or in attainment for criteria pollutants (Fosmire 1999, all). The northern portion of the Sloan/Jean site is in the Las Vegas nonattainment area (Fosmire 1999 all; EPA 1999c, all). There are no State of Nevada air quality monitoring stations at or near either the Caliente or Apex/Dry Lake site (NDCNR 1999, pages A1-1 through A1-9). Clark County operates a particulate matter (PM_{10}) monitoring station at Jean.

The Caliente and Caliente-Chalk Mountain heavy-haul routes both pass through rural parts of Nevada. These areas are either unclassifiable or in attainment for criteria pollutants. The air quality in these areas is good. There are no State of Nevada air quality monitoring stations along these routes (NDCNR 1999, pages A1-1 through A1-9). These statements are also true for the Caliente-Las Vegas, Sloan/Jean, and Apex/Dry Lake routes before they enter and after they leave the Las Vegas Valley.

The air quality in the segments of the Caliente-Las Vegas, Sloan/Jean, and Apex/Dry Lake routes that pass through the Las Vegas Valley and extend part of the way to Indian Springs is in serious nonattainment for particulate matter (PM_{10}) (EPA 1999c, Region 9 PM_{10} Nonattainment Areas). Clark County adopted a plan for demonstrating PM_{10} attainment (Clark County 1997b, all) that includes a request to the Environmental Protection Agency to extend the year for attainment demonstration from 2001 to 2006. The plan includes proposals to reduce emissions of particulate matter from a variety of sources. In addition, the Las Vegas Valley is in serious nonattainment for carbon monoxide. Efforts are being made to bring the area into attainment status.

Climate. This section describes the climate affecting the candidate intermodal transfer station sites and heavy-haul routes.

The community of Caliente and the site of the proposed intermodal transfer station are in Meadow Valley Wash, a relatively narrow canyon that trends to the northeast. Small canyons enter Meadow Valley Wash from the east and west. The diurnal cycle of up-canyon winds during the daytime and down-canyon winds at night minimizes periods of calm conditions. The community of Caliente is about 1,300 meters (4,300 feet) above sea level. Average annual precipitation is about 22 centimeters (9.0 inches); average snowfall is about 35 centimeters (14 inches) (TRW 1997a, page A-14). The maximum single-day precipitation record is 5.4 centimeters (2.1 inches). Occasional brief periods of intense rainfall at rates exceeding 5 centimeters (2 inches) an hour can occur in the summertime. The mean maximum July temperature is 35°C (95°F), and the mean minimum January temperature is –8.2°C (18°F) (TRW 1997a, page A-14).

The climate at the Sloan/Jean and Apex/Dry Lake station sites is similar to Las Vegas (TRW 1997a, Section 4.1; Houghton, Sakamoto, and Gifford 1975, pages 45, 49, and 52). Precipitation in Las Vegas averages between 10 and 20 centimeters (4 and 8 inches) a year and snowfall is rare. Occasional brief periods of intense rainfall, at rates exceeding 5 centimeters (2 inches) an hour, can occur in the summertime. The maximum recorded daily precipitation is 6.6 centimeters (2.6 inches). The mean maximum July temperature is 40°C (104°F), and the mean minimum January temperature is 0.9°C (33°F).

The Caliente and Caliente-Chalk Mountain heavy-haul routes, and to a lesser extent the Caliente-Las Vegas route, cross mountain ranges and valleys with elevations well above 1,500 meters (4,900 feet). Although much of Nevada is arid, in central Nevada the annual precipitation exceeds 20 centimeters (8 inches), and the annual snowfall exceeds 25 centimeters (10 inches) in central White Pine and Nye Counties; annual precipitation exceeds 40 centimeters (16 inches) in some mountainous areas, and snowfall exceeds 100 centimeters (40 inches) (Houghton, Sakamoto, and Gifford 1975, pages 45, 49, and 52). The southern portion of the Caliente-Las Vegas route, through Clark County, is at low elevations where precipitation averages between 10 and 20 centimeters (4 and 8 inches) a year and snowfall is rare (Houghton, Sakamoto, and Gifford 1975, pages 45, 49, and 52). Along all three of these routes, occasional brief periods of intense rainfall at rates exceeding 5 centimeters (2 inches) an hour can occur in the summertime.

The Sloan/Jean and Apex/Dry Lake heavy-haul routes are at low elevations where precipitation averages between 10 and 20 centimeters (4 and 8 inches) a year and snowfall is rare (Houghton, Sakamoto, and Gifford 1975, pages 45, 49, and 52). However, occasional brief periods of intense rainfall, at rates exceeding 5 centimeters (2 inches) an hour, can occur in the summertime.

3.2.2.2.3 *Hydrology*

This section describes hydrologic conditions in terms of surface water and groundwater near the candidate intermodal transfer stations and along the candidate heavy-haul shipment routes.

3.2.2.2.3.1 Surface Water. DOE studied each of the candidate intermodal transfer station sites and associated highway routes for their proximity to sensitive environmental resources (TRW 1999k, Appendixes J, K, L, M, N, and O), including surface waters and riparian lands. Table 3-42 summarizes potential surface-water-related resources within a 1-kilometer (0.6-mile) region of influence from the station sites and highway routes that heavy-haul trucks would use. The table lists surface-water-related resources associated with the Caliente intermodal transfer station site and with each of the potential routes starting at that site. No surface-water-related resources were identified in the region of influence for either the Sloan/Jean or Apex/Dry Lake station site, and none were identified along the associated routes.

Intermodal Transfer Station Locations

Caliente. Flood Insurance Rate Maps published by the Federal Emergency Management Agency address the area in Meadow Valley Wash south of Caliente where the two proposed sites for the Caliente intermodal transfer stations are located. The maps (FEMA 1988a, all; FEMA 1988b, all) show two areas on the west side of the Union Pacific rail tracks that match up with the proposed sites. Both areas are outside the inundation boundary of the 100-year flood, but within the boundary of the 500-year flood.

Sloan/Jean. Based on Flood Insurance Rate Maps, the southernmost site proposed for the Jean intermodal transfer station (on the west site of the Union Pacific rail tracks) would be in the same general area as a 100-year flood inundation zone. The flood map (FEMA 1995a, all) shows three separate washes or drainage areas that originate in the area northwest of the intersection of State Route 161 (or State Route 53 on the map) and I-15. From their origins, the washes drain to the southeast, beneath I-15, and join a southwest drainage that parallels the rail tracks until it reaches the Roach Lake area to the south. The southern Jean intermodal transfer station site is in the area where the first southeast-draining channel curves around into a southwest-draining channel. The 100-year flood inundation areas appear to be about 150 meters (500 feet) wide for these drainage channels.

The northern site proposed for the Jean intermodal transfer station is on the east side of the tracks in an area where the map shows no inundation lines (FEMA 1995a, all). In fact, the map identifies this area with a Zone X designation, indicating it is outside the 500-year floodplain.

According to the Federal Emergency Management Agency Map Index for Clark County, Nevada, and Incorporated Areas (FEMA 1995b, all), the northernmost site for this area, the Sloan intermodal transfer station site, is in an area (Panel 32003C2925 D) with no printed map. The Map Index further describes these unprinted areas as Zone X, indicating they are outside the 500-year floodplain.

Apex/Dry Lake. Based on the Flood Insurance Rate Map for the area of the Apex/Dry Lake intermodal transfer station sites (FEMA 1995c, all), both proposed locations are outside any 100-year flood zone. The nearest flood zone identified on the map is for the Dry Lake area west of the sites. At its closest, the inundation area approaches to within about 300 meters (1,000 feet) of I-15, but the intermodal transfer station site would be on the other side (east side) of I-15. The northern site would appear to be at least

Table 3-42. Surface-water-related resources at potential intermodal transfer station sites and along candidate routes for heavy-haul trucks.[a]

Station or route	Distance from station or route (kilometers)[b]	Feature
Caliente station	0.5	Spring – unnamed spring, southwest of Caliente and northwest of station site
	0.2	Riparian/stream – perennial stream and riparian habitat along Meadow Valley Wash
Caliente route		
Caliente to Crystal Springs	0.3	Spring – unnamed, west of Caliente
	0.5	Spring – unnamed, in Newman Canyon
	0.8	Spring – unnamed, in Newman Canyon
Crystal Springs to Rachel	0.01 - 0.07	Spring – Crystal Springs, group of thermal springs near Town of Crystal Springs, flows along road
Rachel to Yucca Mountain (via Tonopah)	0.2	Springs – Twin Springs, 15 kilometers east of Warm Springs
	Within - 0.2	Springs – Warm Springs, group of thermal springs near town of Warm Springs, outflow crosses the route
	0.4	Spring – Fivemile Spring in Stone Cabin Valley
	1.0	Spring – Rabbit Spring, west of Goldfield
	0.1	Spring – unnamed, in upper Oasis Valley, northwest of Beatty
	0.3	Spring – unnamed, in upper Oasis Valley
	0.4	Spring – unnamed, in upper Oasis Valley, northwest of Beatty
	0.4	Spring – unnamed, east of U.S. 95 in upper Oasis Valley
	0.4	Spring – Fleur-de-lis Spring at Springdale
	0.1	Spring – unnamed, east of U.S. 95 in upper Oasis Valley
	0.1	Spring – unnamed, east of U.S. 95 north of Beatty
	0.9	Spring – unnamed, east of U.S. 95, north of Beatty
	0.9	Spring – Gross Spring, east of U.S. 95, north of Beatty
	Within	River – Amargosa River, parallels U.S. 95 for about 23 kilometers near Beatty
	0.2 - 0.3	Springs – group of thermal springs on east border of U.S. 95, north of Beatty
	0.3	Spring – Well Spring, west of U.S. 95, north of Beatty
	0.4	Spring – Ute Spring, north of Beatty
	0.6	Spring – unnamed, west of U.S. 95, north of Beatty
	0.3	Spring – Revert Spring in Beatty
	0.3	Spring – unnamed, east of U.S. 95, south of Beatty
Caliente-Chalk Mountain route		
Caliente to Crystal Springs	0.3	Spring – unnamed, west of Caliente
	0.4	Spring – unnamed, in Newman Canyon
	0.8	Spring – unnamed, in Newman Canyon
Crystal Springs to Rachel	0.01 - 0.07	Spring – Crystal Springs, group of thermal springs near Town of Crystal Springs, flows along road
Rachel to Yucca Mountain (via Nellis Air Force Range and Nevada Test Site)	0.9	Spring – Cane Spring, north of Skull Mountain on Nevada Test Site
Caliente-Las Vegas route		
Caliente to Crystal Springs	0.3	Spring – unnamed, west of Caliente
	0.4	Spring – unnamed, in Newman Canyon
	0.8	Spring – unnamed, in Newman Canyon
Crystal Springs to I-15 (via U.S. 93)	0.7	Spring – Pedretti Seeps, 3.5 kilometers southeast of Crystal Springs
	0.7	Spring – unnamed, west of route, just south of Pedretti Seeps
	0.8	Spring – Deacon Spring, 5 kilometers southeast of State Highway 375
	1.0	Spring – Brownie Spring, 5 kilometers southeast of State Highway 375
	0.1	Spring – Ash Springs, 7 kilometers southeast of State Highway 375, flows under road
	0.7	Spring – Grove Spring, 1.5 kilometers north of Upper Pahranagat Valley
	0.1	Lakes – route parallels Upper and Lower Pahranagat lakes and associated inundated areas (marshes) for about 15 kilometers
	0.1	Spring – unnamed, 0.2 kilometers west of U.S. 93 and Maynard Lake
	0.1	Lake – Maynard Lake, route borders for about 1 kilometer
	0.8	Spring – Coyote Springs, 21.5 kilometers north of junction with State Route 168
U.S. 93/I-15 junction to U.S. 95 (via the proposed northern beltway)		None
U.S. 95 to Yucca Mountain		None
Sloan/Jean station		None identified
Sloan/Jean route		None identified
Apex/Dry Lake station		None identified
Apex/Dry Lake route		None identified

a. Source: TRW (1999k, Appendixes J, K, L, M, N, and O).
b. To convert kilometers to miles, multiply by 0.62137.

300 meters from the inundation zone. Both areas are in Zone X (determined to be outside the 500-year floodplain).

Highway Routes for Heavy-Haul Trucks

Potential hydrologic hazards along a heavy-haul route include flash flooding and debris flow. All routes have potential flash flooding concerns. However, because of the required road upgrades, the robustness of the vehicle and shipping cask, and the en route safeguards (for example, escorts), flash flooding or standing water is not expected to be a serious threat to heavy-haul shipments.

3.2.2.2.3.2 Groundwater. As discussed in relation to the potential rail corridors, all of Nevada has been divided into groundwater basins and sub-basins, with these latter, smaller divisions termed hydrographic areas. The water resource planning and management information generated by the State of Nevada for these hydrographic areas provides the basis for groundwater information presented for both intermodal transfer station locations and the candidate highway routes that would be used by heavy-haul trucks. The following paragraphs provide an overview of the groundwater conditions at these sites and along the associated routes. Water demand at an intermodal transfer station would be small for both construction and operations. Water needs during operations would consist primarily of the needs of the personnel that staff the station. Water needs for construction and operations would be met by trucking water to the site, installing a well, or possibly by connection to a local water distribution system. This demand would be unlikely to cause noticeable change in water consumption rates for the area. Consequently, no baseline water-use information is provided.

Intermodal Transfer Station Locations

Caliente. The two sites southwest of Caliente being considered for the intermodal transfer station are close to one another and are located in Nevada's Colorado River Basin (designated Hydrographic Region 13). This hydrographic region covers about 32,000 square kilometers (12,000 square miles) and parts of four counties (NDWP 1999b, Region 13). The Colorado River Basin is further divided into 27 hydrographic areas including Lower Meadow Valley Wash (Area 205), where the Caliente sites are located. This area has been assigned a "Designated Groundwater Basin" status, which means that its permitted water rights approach or exceed the estimated perennial yield and its water resources are being depleted or require additional administration. The additional administration normally includes a State declaration of preferred uses (municipal and industrial, domestic supply, agriculture, etc.) for the groundwater from this area.

Sloan/Jean. The Jean sites being considered for the intermodal transfer station are in Nevada's Central Hydrographic Region (also designated Region No. 10). This is the largest hydrographic region in Nevada, encompassing about 120,000 square kilometers (46,000 square miles) and parts of 13 counties (NDWP 1999b, Region 10). The Central Region has 90 hydrographic areas and sub-areas, including Ivanpah Valley/Northern Part (Area 164A), where the Jean sites are located. This area has also been assigned a Designated Groundwater Basin status. The depth to groundwater in the vicinity of the candidate Jean sites is approximately 150 meters (490 feet) (Thomas, Welch, and Dettinger 1996, Plate 1).

The site near Sloan being considered for the intermodal transfer station is in Nevada's Colorado River Basin (Hydrographic Region 13), as described for the Caliente sites. The Sloan site is in the hydrographic area designated Las Vegas Valley (Area 212). This area has also been assigned a Designated Groundwater Basin status. The depth to groundwater at Sloan is approximately 240 meters (790 feet) (Thomas, Welch, and Dettinger 1996, Plate 1).

Apex/Dry Lake. The two sites near Apex/Dry Lake being considered for the intermodal transfer station are close to one another and are in Nevada's Colorado River Basin, as described for the Caliente sites.

The Apex/Dry Lake sites are in the hydrographic area designated Garnet Valley (Area 216). The estimated perennial yield for the groundwater in this area is only 490,000 cubic meters (400 acre-feet), but it is not a Designated Groundwater Basin. The depth to groundwater at Apex/Dry Lake is about 60 meters (200 feet) (Thomas, Welch, and Dettinger 1996, Plate 1).

Highway Routes for Heavy-Haul Trucks

The highway routes in Nevada that heavy-haul trucks could use cross through several hydrographic regions and a greater number of hydrographic areas. To identify groundwater that could potentially be affected, a map of these hydrographic areas (Bauer et al. 1996, page 543) was overlain with a drawing of the proposed highway routes to get a reasonable approximation of the areas that would be crossed. The results of this effort are listed in Table 3-43. This table also lists estimates of the perennial yield for each of the hydrographic areas crossed and if the area is a Designated Groundwater Basin. Basins with this designation are the areas where additional water demand would be most likely to adversely affect local groundwater resources. None of the candidate routes would totally avoid Designated Groundwater Basins. However, the Caliente-Chalk Mountain route would cross only two designated basins: one in the Lower Meadow Valley Wash at the beginning of the route and one at Penoyer Valley where the Caliente and Caliente-Chalk Mountain routes split.

There are a number of published estimates of perennial yield for many of the hydrographic areas in Nevada, and they often differ from one another by large amounts. This is the reason for listing a range of perennial yield values in Table 3-11. For simplicity, the perennial yield values listed in Table 3-43 generally come from a single source (NDWP 1998, Regions 10, 13, and 14) and, therefore, are not ranges of values. The hydrographic areas in the vicinity of Yucca Mountain (that is, Areas 225 through 230) are the exception to perennial yield values coming from the single source. The perennial yield values for these areas come from Thiel (1997, pages 6 to 12), which compiles estimates from several sources. The table lists the lowest values presented in that document.

3.2.2.2.4 *Biological Resources*

The existing biological environments described in this section includes the areas inside the boundaries of the intermodal transfer station sites and within 100 meters (about 330 feet) of the centerline of the heavy-haul routes. It also includes springs within 400 meters (0.25 mile) of the intermodal transfer sites and the routes. The section discusses environmental settings and important biological resources for each candidate station and associated heavy-haul routes. Unless otherwise noted, this information is from the *Environmental Baseline File for Biological Resources* (TRW 1999k, all).

Caliente Intermodal Transfer Station

The 0.7-square kilometer (170-acre) area DOE is considering for the Caliente intermodal transfer station is about 1 kilometer (0.6 mile) southwest of Caliente and less than 500 meters (1,600 feet) west of Meadow Valley Wash. This area is at an elevation of about 1,200 meters (3,900 feet). The land cover types at this site are primarily agricultural—pasture, 88 percent, and salt desert scrub, 12 percent.

No species classified as Federally threatened or endangered, as State protected, or as sensitive by the Bureau of Land Management occur in the proposed location of the Caliente intermodal transfer station. However, two species classified as sensitive by Bureau of Land Management, the Meadow Valley Wash speckled dace and the Meadow Valley Wash desert sucker (*Catostomus clarki* ssp.), occur in the adjacent Meadow Valley Wash (NNHP 1997, all). Nevada also classifies the Meadow Valley Wash desert sucker as sensitive.

Table 3-43. Hydrographic areas (groundwater basins) crossed by candidate routes for heavy-haul trucks.[a]

Route	Hydrographic area Number	Hydrographic area Name	Perennial yield[b,c] (acre-feet)[d]	Designated groundwater basin[e,f]
Caliente				
Caliente to Crystal Springs (near Hiko)	203	Panaca Valley	9,000	Yes
	181	Dry Lake Valley	2,500	No
	182	Delamar Valley	3,000	No
Crystal Springs to Rachel	209	Pahranagat Valley	25,000	No
	169A	Tikaboo Valley, Northern Part	1,300	No
Rachel to Yucca Mountain (via Tonopah)	170	Penoyer Valley (Sand Spring Valley)	4,000	Yes
	173A	Railroad Valley, Southern Part	2,800	No
	173B	Railroad Valley, Northern Part	75,000	No
	156	Hot Creek	5,500	No
	149	Stone Cabin Valley	2,000	Yes
	141	Ralston Valley	6,000	Yes
	137A	Tonopah Flat	6,000	Yes
	142	Alkali Spring Valley	3,000	No
	144	Lida Valley	350	No
	146	Sarcobatus Flat	3,000	Yes
	228	Oasis Valley	1,000	Yes
	230	Amargosa Valley	24,000	Yes
	229	Crater Flat	220	No
	227A	Fortymile Canyon and Jackass Flats	880[g]	No
Caliente-Chalk Mountain				
Caliente to Crystal Springs (near Hiko)	203 to 209	See Caliente Route		
Crystal Springs to Rachel	209 to 170	See Caliente Route		
Rachel to Yucca Mountain (via Nellis Air	170			
Force Range and Nevada Test Site)	158A	Emigrant Valley and Groom Lake Valley	2,800	No
	159	Yucca Flat	350	No
	160	Frenchman Flat	16,000	No
	227A	Fortymile Canyon and Jackass Flats	880[g]	No
Caliente-Las Vegas				
Caliente to Crystal Springs (near Hiko)	203 to 209	See Caliente Route		
Crystal Springs (near Hiko) to U.S. 93/I-15	209			
junction at Dry Lake	210	Coyote Springs Valley	18,000	Yes
	217	Hidden Valley	200	No
U.S. 93/I-15 junction at Dry Lake to U.S. 95 junction	216	Garnet Valley	400	No
U.S. 95 junction to Yucca Mountain	212	Las Vegas Valley	25,000	Yes
	211	Three Lakes Valley, Southern Part	5,000	Yes
	161	Indian Springs Valley	500	Yes
	225	Mercury Valley	250	No
	226	Rock Valley	30	No
	227A	Fortymile Canyon and Jackass Flats	880[g]	No
Sloan/Jean[h]				
Jean to U.S. 95 junction	164A	Ivanpah Valley, Northern Part	700	Yes
	165	Jean Lake Valley	50	Yes
U.S. 95 junction to Yucca Mountain	212 to 227A	See Caliente-Las Vegas route		
Apex/Dry Lake				
U.S. 93/I-15 junction at Dry Lake to U.S. 95 junction	216 to 212	See Caliente-Las Vegas route		
U.S. 95 junction to Yucca Mountain	212 to 227A	See Caliente-Las Vegas route		

a. Source: Bauer et al. (1996, pages 542 and 543 with route map overlay).
b. Perennial yield is the estimated quantity of groundwater that can be withdrawn annually from a basin without depleting the reservoir.
c. Source: NDWP (1998, Regions 10, 13, and 14); for Hydrographic Areas 225 through 230 the source is Thiel (1997, pages 6 to 12). The Nevada Division of Water Planning identifies a perennial yield of only 24,000 acre-feet for the combined area of hydrographic areas 225 through 230 (NDWP 1998, all; NDWP 1999a, page 9).
d. To convert acre-feet to cubic meters, multiply by 1,233.49.
e. "Yes" indicates that the State of Nevada considers the area a Designated Groundwater Basin where permitted water rights approach or exceed the estimated perennial yield, and the water resources are being depleted or require additional administration, including a State declaration of preferred uses (municipal and industrial, domestic supply, agriculture, etc.). Designated Groundwater Basins are also referred to as Administered Groundwater Basins.
f. Source: NDWP (1999b, Regions 10, 13, and 14).
g. The perennial yield value shown for Area 227A is the lowest estimated value in Thiel (1997, page 8), and is accompanied by the additional qualification: 370,000 cubic meters (300 acre-feet) for the eastern third of the area and 720,000 cubic meters (580 acre-feet) for the western two-thirds.
h. The hydrographic areas listed for the Sloan/Jean Route are based on the intermodal transfer station located at Jean. For the Sloan location, the route would begin with Hydrographic Area 212, then proceed as shown.

There is no designated game habitat in this area, but the adjacent Meadow Valley Wash is classified as important habitat for Gambel's quail (BLM 1979, pages 2-34 and 2-35).

There are no springs at the proposed station location, but moist areas in the proposed station location might be wetlands (TRW 1999k, pages 3-35 and 3-36). The adjacent perennial stream and riparian habitat along Meadow Valley Wash also might be classified as a wetlands or other waters of the United States, although there has been no formal wetlands delineation.

Caliente Route. This route passes through the southern Great Basin Desert from the beginning of the route in Caliente to near Beatty. From south of Beatty to Yucca Mountain, the route passes through the Mojave Desert. The predominant land cover types along the entire route are salt desert scrub (49 percent), sagebrush (14 percent), and creosote-bursage (13 percent).

Three threatened or endangered species occur within 100 meters (about 330 feet) of the Caliente heavy-haul route. The Hiko White River springfish (*Crenicthys baileyi grandis*, Federally endangered) occurs in Crystal Springs (FWS 1998, page 16), which is about 75 meters (250 feet) south of State Route 375 near the intersection with U.S. 93. The springs and outflow, which come within about 10 meters (33 feet) of State Route 375, are critical habitat for the Hiko White River springfish (50 CFR 17.95). A population of the Railroad Valley springfish (*Crenicthys nevadae*, Federal threatened) has been introduced into Warm Springs, the outflow of which crosses U.S. Highway 6 (FWS 1996, page 20). The southern part of the route, along U.S. 95 from Beatty to Yucca Mountain, is within the range of the desert tortoise (Bury and Germano 1994, pages 57 to 72). This area is not classified as critical habitat for desert tortoises (50 CFR 17.95), and the relative number of tortoises in this area is low (Karl 1981, pages 76 to 92; Rautenstrauch and O'Farrell 1998, pages 407 to 411).

Six species classified as sensitive by the Bureau of Land Management have been documented within 100 meters (about 330 feet) of the route (NNHP 1997, all). The Pahranagat speckled dace (*Rhinichthys osculus velfier*) occurs in Crystal Springs. The Railroad Valley tui chub (*Gila bicolor* ssp 7) (also classified as sensitive by Nevada) occurs in Twin Spring Slough along State Route 375. The Amargosa toad (*Bufo nelsoni*) and the Oasis Valley speckled dace (*Rhinichthys osculus* ssp 1) (both also classified as protected by Nevada) occur in the Amargosa River and elsewhere in the Oasis Valley. Two bats, the Townsend's big-eared bat (*Corynorhinus townsendii*) and fringed myotis (*Myotis thysanodes*), have been documented near the southern end of the route, and other bats classified as sensitive by the Bureau of Land Management might occur near the route. The chuckwalla lizard (*Sauromalus obesus*) also might occur in suitable habitat along the southern end of the route.

This route crosses eight areas designated as game habitat (BLM 1979, pages 2-27 to 2-36; BLM 1994b, Maps 9, 10, 12, and 13). Portions of Meadow Valley Wash are designated important habitat for Gambel's quail (*Callipepla gambelii*) and waterfowl. The route crosses mule deer habitat in Newman Canyon, in the Pahroc Range, in the Pahranagat Range, and northwest of the Groom Range. It also crosses bighorn sheep habitat in the Pahranagat Range, and pronghorn habitat northwest of the Groom Range and from west of Sand Spring Valley through Railroad, Stone Cabin, and Ralston Valleys.

Nineteen springs or riparian areas within 0.4 kilometer (0.25 mile) of the route might be considered wetlands or other waters of the United States under Section 404 of the Clean Water Act, although no formal wetlands delineation has been conducted. The route is adjacent to Meadow Valley Wash at the proposed location of the intermodal transfer station. There is an unnamed spring near U.S. 93 west of Caliente. Crystal Spring and its outflow are about 10 meters (33 feet) from State Route 375, which also passes within 250 meters (820 feet) of Twin and Warm Springs and crosses their outflows. Fivemile Spring is about 0.4 kilometer from U.S. 6 in Stone Cabin Valley. U.S. 95 passes within 0.4 kilometer of 12 springs or groups of springs in the Oasis Valley and along the Amargosa River, and crosses the

Amargosa River at Beatty. This route also crosses a number of ephemeral streams that might be classified as waters of the United States under Section 404 of the Clean Water Act.

The route also borders the Bureau of Land Management Oasis Valley Area of Critical Environmental Concern, which is designed to protect riparian areas and sensitive species in Oasis Valley south of Springdale (TRW 1999k, page 3-32).

Caliente-Chalk Mountain Route. From Caliente to Crystal Springs, this heavy-haul route crosses the Burnt Spring Range, Dry Lake Valley, Sixmile Flat, and the north end of the South Pahroc Range at elevations from 1,200 to 1,900 meters (3,900 to 6,200 feet). From Crystal Springs to Rachel the route crosses Hancock Summit and Tikaboo Valley at elevations ranging from about 1,300 to 1,700 meters (4,300 to 5,600 feet). From Rachel to Yucca Mountain the route passes through Sand Spring and Emigrant Valleys, and Yucca Flat, Frenchman Flat, and Jackass Flats, at elevations from 1,700 to 1,900 meters (5,600 to 6,200 feet). Along the entire route, the predominant land cover types are salt desert scrub (37 percent), blackbrush (16 percent), sagebrush (11 percent), and creosote-bursage (10 percent).

Two resident threatened or endangered species occur within 100 meters (about 330 feet) of the Caliente-Chalk Mountain heavy-haul route. The Hiko White River springfish (*Crenichthys baileyi grandis*, Federally endangered) occurs in Crystal Springs (FWS 1998, page 16). The springs and outflow, which come within about 10 meters (33 feet) of State Route 375, are critical habitat for the Hiko White River springfish (50 CFR 17.95). The part of the route from the northern end of Frenchman Flat to Yucca Mountain is within the range of the desert tortoise (Rautenstrauch, Brown, and Goodwin 1994, all). This area is not classified as critical habitat for desert tortoises (50 CFR 17.95), and the relative abundance of tortoises in this area is low (Rautenstrauch and O'Farrell 1998, pages 407 to 411).

Three species classified as sensitive by the Bureau of Land Management occur within 100 meters (about 330 feet) of this route (NNHP 1997, all). The Pahranagat speckled dace occurs in Crystal Springs, Ripley's springparsley (*Cymopterus ripleyi* var. *saniculoides*) occurs in a number of locations in Yucca Flat on the Nevada Test Site, and the fringed myotis has been observed in Fortymile Wash on the Nevada Test Site. A number of bats classified as sensitive by the Bureau of Land Management might occur along the route and the southern end of the route is within the range of the chuckwalla.

This route crosses six areas designated as game habitat (BLM 1979, pages 2-27 to 2-36; BLM 1994b, Maps 9, 10, 12, and 13). Meadow Valley Wash is designated important habitat for Gambel's quail and waterfowl. The route crosses mule deer habitat in four areas: west of Caliente, near Pahroc Summit Pass, in the Pahranagat Range, and in the Groom Range. It also crosses bighorn sheep habitat in the Pahranagat Range.

Three springs or riparian areas within 0.4 kilometer (0.25 mile) of the route might be wetlands or other waters of the United States under Section 404 of the Clean Water Act, including Meadow Valley Wash, an unnamed spring near U.S. 93 west of Caliente, and Crystal Springs and its outflow. No formal wetlands delineation has been conducted along this route. This route also crosses a number of ephemeral streams or washes that might be classified as waters of the United States under Section 404 of the Clean Water Act.

Caliente-Las Vegas Route. From Caliente to Crystal Springs, this candidate route crosses the Burnt Spring Range, Dry Lake Valley, Sixmile Flat, and the north end of the South Pahroc Range at elevations from 1,200 to 1,900 meters (3,900 to 6,200 feet). From Crystal Springs to Las Vegas, the route parallels the White River through Pahranagat Valley, and then through Coyote Springs, Hidden, Dry Lake, Las Vegas, Mercury, and Rock Valleys, and crosses Jackass Flats to Yucca Mountain. Elevations along the section from Crystal Springs to Yucca Mountain range from 610 to 1,200 meters (2,000 to 3,900 feet). Along the route the predominant land cover types are creosote-bursage (62 percent) and Mojave mixed scrub (16 percent).

Three resident threatened or endangered species occur within 100 meters (about 330 feet) of the Caliente-Las Vegas heavy-haul route. The section of the route from about Alamo to Yucca Mountain is within the range of the threatened desert tortoise (Bury and Germano 1994, pages 57 to 72). An approximately 100-kilometer (60-mile) section of U.S. 93 from Maynard Lake south to a point approximately 6 kilometers (4 miles) north of I-15 is critical habitat for the desert tortoise (50 CFR 17.95). The relative abundance of desert tortoises along the remainder of the route through Las Vegas Valley, Indian Springs Valley, and the Nevada Test Site is low (BLM 1992, Map 3-13; Rautenstrauch and O'Farrell 1998, pages 407 to 411). The White River springfish (*Crenichthys baileyi baileyi*, Federally endangered and Nevada protected) has been found in Ash Springs, less than 100 meters from U.S. 93 in northern Pahranagat Valley (FWS 1998, pages 12 to 14). The route crosses the outflow of Ash Springs, which is designated critical habitat for the White River springfish (50 CFR 17.95). The Pahranagat roundtail chub (*Gila robusta jordani*, Federally endangered and Nevada protected) occurs in Ash Springs, the outflow, and throughout Pahranagat Creek, but now is restricted to an approximately 3.5-kilometer (2.2-mile) length of Pahranagat Creek and approximately 2.5 kilometers (1.6 mile) of irrigation ditch in the area (FWS 1998, pages 11 to 12).

Nine other species classified as sensitive by the Bureau of Land Management have been documented within 100 meters (about 330 feet) of the route (NNHP 1997, all). The Pahranagat speckled dace occurs in Ash Springs. The Pahranagat pebblesnail (*Fluminicola merriami*), Pahranagat naucorid (*Pelocoris shoshone shoshone*), and the grated tryonia (*Tryonia clathrata*) occur in Ash Springs, and the Pahranagat Valley montane vole (*Microtus montanus fucosus*) has been observed near the route in Pahranagat National Wildlife Refuge. In addition, pinto beardtongue (*Penstemon bicolor bicolor* and *P. b. roseus*) occurs along U.S. 93 north of I-15, Ripley's springparsley and Parish's scorpionweed (*Phacelia parishii*) occur adjacent to Jackass Flats Road in eastern Rock Valley, and the fringed myotis has been observed in Fortymile Wash on the Nevada Test Site. A number of other bats classified as sensitive by the Bureau of Land Management occur along the route and most of the route south from Pahranagat Valley is within the range of the chuckwalla and gila monster (*Heloderma suspectus*).

Seven springs, streams, or lakes less than 0.4 kilometer (0.25 mile) from the route might be classified as wetlands under Section 404 of the Clean Water Act, including Meadow Valley Wash, Ash Springs and its outflow, unnamed springs on U.S. 93 west of Caliente and near Maynard Lake, Upper and Lower Pahranagat lakes and their associated marshes, and Maynard Lake. This route also crosses a number of ephemeral streams that might be classified as waters of the United States under Section 404 of the Clean Water Act.

The route crosses eight areas designated as game habitat (BLM 1979, pages 2-26 to 2-35; BLM 1998, Maps 3-7 to 3-9). Meadow Valley Wash and much of Pahranagat Valley are designated as habitat for Gambel's quail and waterfowl, and areas along U.S. 93 north of I-15 are designated as quail habitat. U.S. 93 crosses mule deer habitat west of Caliente and around Maynard Lake, two bighorn sheep migration routes, and crucial bighorn sheep habitat north of the U.S. 93 and I-15 junction.

Sloan/Jean Station and Route

The area that DOE is considering for the Sloan/Jean intermodal transfer station is in Ivanpah Valley. DOE is considering three sites in this valley: southwest of Sloan [3.2 square kilometers (800 acres)], northeast of Jean [3 square kilometers (750 acres)], and east of Jean [1 square kilometer (250 acres)]. These sites are at an elevation of about 910 meters (3,000 feet) and have vegetation typical of the Mojave Desert. The predominant land cover type is creosote-bursage (97 percent). Elevations along the associated Sloan/Jean heavy-haul route range from about 700 to 1,100 meters (2,300 to 3,600 feet). Predominant land cover types along the route include creosote-bursage (78 percent), Mojave mixed scrub (12 percent), and urban development (9 percent).

The three sites that DOE is considering for the Sloan/Jean intermodal transfer station are in the range of the threatened desert tortoise. The abundance of tortoises generally is moderate to high in Ivanpah Valley in relation to other areas in Nevada (Karl 1980, pages 75 to 87; BLM 1992, Map 3-13). This area is not critical habitat for desert tortoises (50 CFR 17.95).

One species classified by the Bureau of Land Management as sensitive, and by the State of Nevada as protected, occurs in the candidate Sloan/Jean station sites (NNHP 1997, all). The pinto beardtongue (*Penstemon bicolor* ssp. *roseus)* has been observed on the site southwest of Sloan and on the site east of Jean. There are no important game habitats (BLM 1998, Maps 2-1, 3-7, 3-8, and 3-9) and no springs, riparian areas, or other potential wetlands within 0.4 kilometer (0.25 mile) of these sites (TRW 1999k, page 3-36).

The only resident threatened or endangered species along the Sloan/Jean heavy-haul route is the desert tortoise. The entire route is within the range of the desert tortoise (Bury and Germano 1994, pages 57 to 72). The abundance of tortoises along the first part of the route in Ivanpah Valley is moderate to high in relation to other areas in Nevada (BLM 1992, Map 3-13). The abundance of tortoises along the remainder of the route through Las Vegas Valley, Indian Springs Valley, and the Nevada Test Site generally is low to very low (BLM 1992, Map 3-13; Rautenstrauch and O'Farrell 1998, pages 407 to 411). This route does not cross areas classified as critical habitat for desert tortoises (50 CFR 17.95).

Four species classified as sensitive by the Bureau of Land Management have been documented within 100 meters (about 330 feet) of this route (NNHP 1997, all). The pinto beardtongue (*Penstemon bicolor bicolor* and *P. b. roseus*) occurs in the Las Vegas Valley. Ripley's springparsley and Parish's scorpionweed occur adjacent to Jackass Flats Road in eastern Rock Valley on the Nevada Test Site, and the fringed myotis has been observed near the Yucca Mountain in Fortymile Wash. A number of other bats classified as sensitive by the Bureau of Land Management might occur along the route, and the route is within the range of the chuckwalla and gila monster.

The route crosses ephemeral streams that might be classified as waters of the United States under Section 404 of the Clean Water Act. The route does not cross designated game habitats (BLM 1998, Maps 3-7 to 3-9) and there are no springs, riparian areas, or other potential wetlands within 0.4 kilometer (0.25 mile).

Apex/Dry Lake Station and Route

The area that DOE is considering for the Apex/Dry Lake intermodal transfer station is northeast of Las Vegas in Dry Lake Valley. The Department is considering three sites in this area, two to the west of I-15 [0.18 and 3.6 square kilometers (45 and 890 acres)] and one east of the Interstate [0.95 square kilometer (240 acres)]. The elevation of these sites is about 610 meters (2,000 feet). This area is in the Mojave Desert and the predominant land cover type is creosote-bursage (100 percent). The associated route starts at the station area and crosses Las Vegas, Mercury, and Rock Valleys and Jackass Flats to Yucca Mountain at elevations ranging from 700 to 1,100 meters (2,300 to 3,600 feet). Predominant land cover types along this route are creosote-bursage (77 percent) and Mojave mixed scrub (16 percent).

The only resident threatened or endangered species along the Apex/Dry lake heavy-haul route is the desert tortoise. The entire route passes through desert tortoise habitat (Bury and Germano 1994, pages 57 to 72), and the relative abundance of tortoises along this route through the Las Vegas Valley, Indian Springs Valley, and the Nevada Test Site generally is low (BLM 1992, Map 3-13; Rautenstrauch and

O'Farrell 1998, pages 407 to 411). This route does not cross areas classified as critical habitat for desert tortoises (50 CFR 17.95).

Three species classified as sensitive by the Bureau of Land Management have been documented within 100 meters (about 330 feet) of this route (NNHP 1997, all). Ripley's springparsley and Parish's scorpionweed occur adjacent to Jackass Flats Road on the Nevada Test Site in eastern Rock Valley, and the fringed myotis has been observed near Yucca Mountain in Fortymile Wash. A number of other bats classified as sensitive by the Bureau of Land Management might occur along the route, and the route is within the range of the chuckwalla and gila monster.

The route crosses ephemeral streams that might be classified as waters of the United States under Section 404 of the Clean Water Act. The route does not cross designated game habitat (BLM 1998, Maps 3-7 to 3-9). There are no springs, riparian areas, or other potential wetlands within 0.4 kilometer (0.25 mile) of the intermodal transfer station area or the route.

3.2.2.2.5 *Cultural Resources*

The description of environmental conditions in this section focuses on archaeological and historic resources associated with the candidate intermodal transfer station areas and the associated heavy-haul routes. In addition, this section discusses Native American interests in relation to several of the heavy-haul truck routes. Unless otherwise noted, the *Environmental Baseline File for Archaeological Resources* (TRW 1999m, all) is the basis for the information in this section.

Archaeological and Historic Resources. Archaeological data from the candidate intermodal transfer station sites are very limited. Based on a records search at the Desert Research Institute in Las Vegas and Reno and at the Harry Reid Center at the University of Nevada, Las Vegas, four, seven, and two archaeological sites have been recorded at the Caliente, Sloan/Jean, and Apex/Dry Lake sites, respectively. These sites have not been evaluated with regard to their potential eligibility for listing in the *National Register of Historic Places.*

There is some relevant information about the candidate Caliente intermodal transfer location. Various cultural groups have occupied the Caliente/Meadow Valley Wash area for at least the past 11,000 years (Fowler et al. 1973, all; Fowler and Madsen 1986, all). Previously recorded prehistoric archaeological resources in the region include scattered lithic artifacts, rock shelters, temporary camps, and rock art (Kautz and Oothoudt 1992, all). Historic archaeological resources in the region typically consist of remains of late nineteenth- and early twentieth-century activities such as mining and ranching. The Caliente Railroad Depot is listed in the *National Register of Historic Places.*

In general, there are little or no current data for the presence of cultural resource sites in the existing road rights-of-way; with the exception of one route, field inventories have not been conducted. A few archaeological surveys have been conducted along or near the Caliente-Chalk Mountain heavy-haul route. An archival search of a 0.2-kilometer (0.1-mile)-wide corridor along this route identified five archaeological sites. Two of these sites are not considered eligible for inclusion on the National Register; the other three have not been evaluated.

Native American Interests. Section 3.2.2.1.5 discusses general Native American concerns about transportation routes.

The Moapa Paiute Indian Tribe is a Federally recognized tribe of about 290 Southern Paiute people. The tribe's reservation near the town of Moapa on I-15 and the Union Pacific Railroad's mainline contains homes and business enterprises. The reservation is about 6 kilometers (4 miles) east of the Caliente-Las

Vegas heavy-haul route and about 5 kilometers (3 miles) north of the Apex/Dry Lake station site (AIWS 1998, Chapter 4).

The Las Vegas Paiute Colony is a Federally recognized tribe of about 100 people living on two separate tribal parcels in southern Nevada (AIWS 1998, Chapter 4). One parcel near downtown Las Vegas consists of 73,000 square meters (18 acres) of land with 21 homes and various business enterprises. This parcel is about 11 kilometers (7 miles) from an overlapping portion of the Caliente-Las Vegas, Sloan/Jean, and Apex/Dry Lake heavy-haul routes (northern Las Vegas beltway for the Las Vegas and Apex/Dry Lake routes, and western Las Vegas beltway for the Sloan/Jean route). The other parcel is in the northwest part of the Las Vegas Valley along U.S. 95. It consists of 16.2 square kilometers (4,000 acres) with 12 homes and various business enterprises. An overlapping portion of the Caliente-Las Vegas, Sloan/Jean, and Apex/Dry Lake heavy-haul routes goes through a 1.6-kilometer (1-mile) corner of this parcel.

3.2.2.2.6 *Socioeconomics*

The candidate heavy-haul intermodal transfer station sites and routes would not appreciably affect counties other than those in which the facilities were located. Section 3.1.7 contains socioeconomic background information on the three counties (Clark, Lincoln, and Nye) most involved in the heavy-haul routes. The Caliente heavy-haul route is the only route involving a county outside the region of influence; it passes through Esmeralda County in addition to Lincoln and Nye Counties. Section 3.2.2.1.6 contains socioeconomic information for Esmeralda County.

3.2.2.2.7 *Noise*

Most of the proposed routes pass through unpopulated desert with background noise levels of 22 to 38 dBA. All routes pass through small rural communities (see Figures 6-10 through 6-15). Noise levels in rural communities usually range from 40 to 55 dBA (Table 3-30). Traffic noise along highways generally ranges from 5 to 15 dBA above natural background levels (EPA 1974, page D.5). Roadside noise levels are highly dependent on the volume of traffic, the road surface, composition of the traffic (trucks, automobiles, motorcycles, etc.), and vehicle speed. Measurements taken 90 meters (300 feet) from the centerline of U.S. 95 just outside the Nevada Test Site ranged from 45 to 55 dBA (Brown-Buntin 1997, pages 8 and 9). Less traveled rural highways would have lower 1-hour noise levels, possibly as low as 33 dBA at 90 meters (300 feet) from the centerline. Communities potentially affected by the candidate intermodal transfer stations and associated heavy-haul routes were identified by examining the proposed route of each corridor and estimating if construction or heavy-haul vehicle noise could affect area communities. Occasional noise from passing military aircraft occurs near and in the Nellis Air Force Range.

Caliente Station

DOE is considering two parcels of land in Meadow Valley Wash several miles south of Caliente for the intermodal transfer station. A water treatment plant adjacent to the larger parcel could contribute to background noise levels. The other parcel of land has no buildings. Estimated noise levels range from 22 to 45 dBA depending on traffic volume (based on Table 3-30).

Caliente Route. The Caliente heavy-haul route goes from Caliente to the Yucca Mountain site, passing through or near the towns of Caliente, Tonopah, Goldfield, Beatty, Hiko, Rachel, Warm Springs, and Amargosa Valley. Estimated noise levels in these communities range from 40 to 55 dBA (based on Table 3-30). This longest route travels on existing highways through predominantly Bureau of Land Management land.

Caliente-Chalk Mountain Route. The Caliente-Chalk Mountain heavy-haul route would use existing paved roads to a point in western Lincoln County where it would turn south through the Nellis Air Force Range and the Nevada Test Site. Caliente and Rachel are the only towns through which the heavy-haul route would pass. Estimated noise levels in these communities would range from 45 to 55 dBA (based on Table 3-30).

Caliente-Las Vegas Route. The Caliente-Las Vegas heavy-haul route follows U.S. 93 from Caliente to I-15, then into Las Vegas primarily on Bureau of Land Management land. The section of the route on the planned Northern Beltway to U.S. 95 would have the highest noise levels, biased toward the 55-dBA level. Traffic noise levels along U.S. 95 would range from 45 to 55 dBA (Brown-Buntin 1997, pages 8 and 9). Estimated noise levels in Caliente, Alamo, Indian Springs, and Mercury range from 40 to 55 dBA (based on Table 3-30).

Sloan/Jean Station

DOE is considering three parcels of land in the Sloan/Jean area. Some residences, a quarry, and a concrete plant are next to the northernmost site. The eastern parcel is along I-15 adjacent to several commercial enterprises. The third parcel is in the community of Jean and is close to two large casinos. Estimated noise levels in these areas, which are greater than levels encountered in unpopulated desert areas, range from 40 to 55 dBA (based on Table 3-30).

Sloan/Jean Route. The Sloan/Jean heavy-haul route would use existing paved roads from the intermodal transfer station to the Yucca Mountain site, and would pass through a number of small towns and the western and northern portions of the Las Vegas Valley. Existing noise levels in the Las Vegas Valley probably range from 52 to 74 dBA; estimated noise levels in Indian Springs and Mercury range from 40 to 55 dBA (based on Table 3-30).

Apex/Dry Lake Station

The candidate location for the Apex/Dry Lake intermodal transfer station is in an unpopulated part of Dry Lake Valley. Existing noise levels are probably somewhat higher than typical levels for a desert environment because of vehicles that travel along I-15 in this area. Depending on local meteorological conditions, noise from the Apex industrial site and passing trains would add to the existing acoustic environment at this site. The northern boundary of one possible location for an intermodal transfer station in the Apex/Dry Lake area is about 3 kilometers (2 miles) south of the Moapa Indian Reservation.

Apex/Dry Lake Route. The Apex/Dry Lake heavy-haul route would use existing paved roads from the intermodal transfer station to the Yucca Mountain site. It would pass through a number of small communities and the north end of the Las Vegas Valley. Existing noise levels in Indian Springs and Mercury probably range from 40 to 55 dBA (Table 3-30). Estimated noise levels in the Las Vegas Valley range from 52 to 74 dBA (based on Table 3-30).

3.2.2.2.8 *Aesthetics*

This section describes the existing aesthetic qualities associated with each of the intermodal transfer station sites and associated heavy-haul routes. Section 3.1.10 provides additional description of Bureau of Land Management visual resource classes and scenic quality classes. Unless otherwise noted, this information is from the *Environmental Baseline File: Aesthetics* (TRW 1999p, all).

Caliente Station

The proposed location for the Caliente facility is southeast of Caliente, on the western edge of Meadow Valley Wash. This area is in the Caliente Bureau of Land Management resource area and is classified Class III (Figure 3-26).

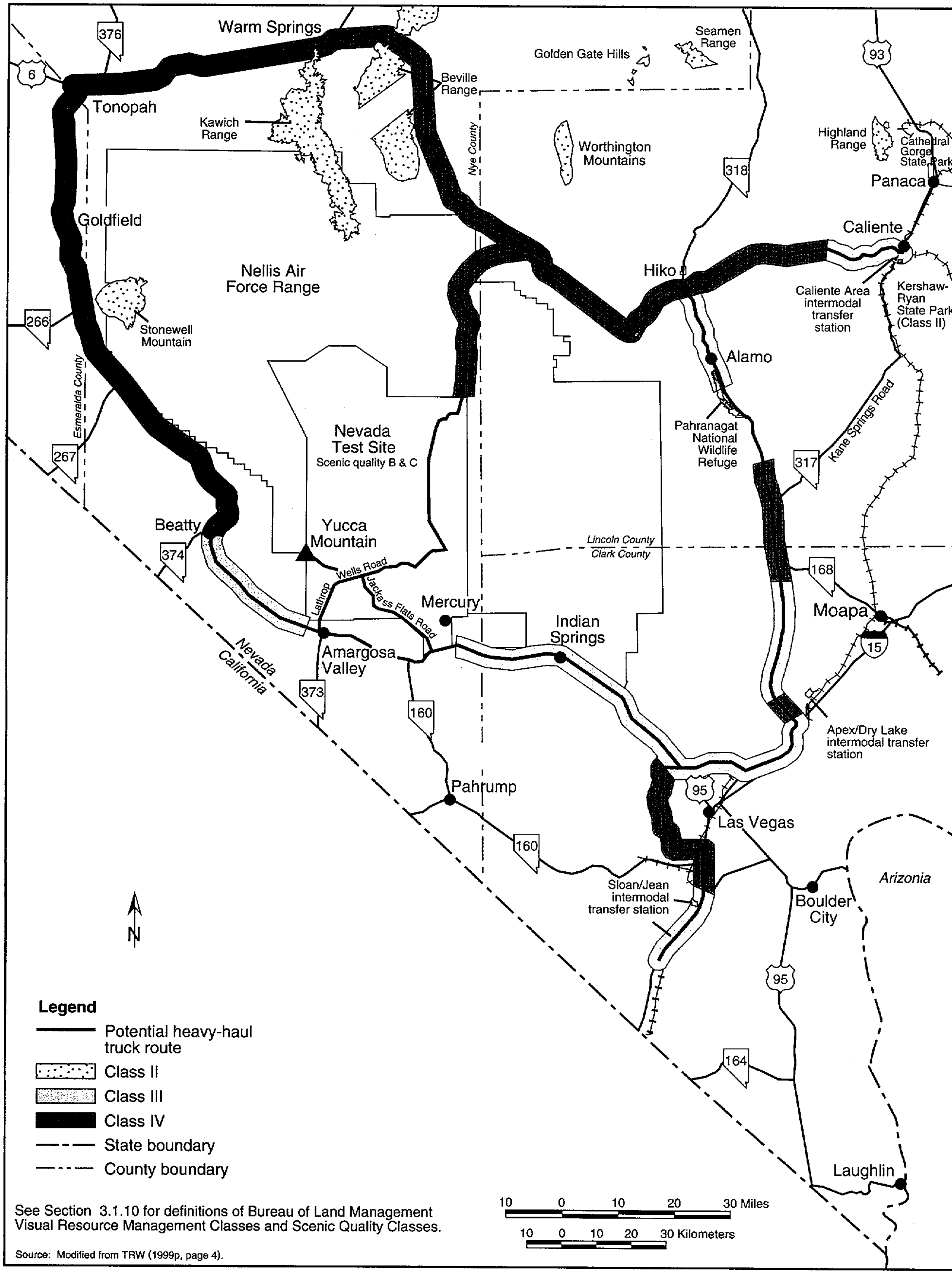


Figure 3-26. Visual Resource Management classes along the potential routes for heavy-haul trucks.

Caliente Route. Section 3.2.2.2.4 describes the environmental setting along the Caliente route. The route passes through the Caliente, Schell, Tonopah, and Las Vegas Bureau of Land Management resource areas. From Caliente to the south end of the Burnt Springs Range the route passes through Class III land, and then through Class IV land to Rachel. From Rachel to Tonopah the route crosses Class III land except portions of the Reveille and Kawich Ranges near Warm Springs, which are Class II areas. From Tonopah to Beatty, the route crosses Class IV land, then Class III land from Beatty to the Nevada Test Site boundary. Lands crossed on the Nevada Test Site have scenic quality ratings of Class B or Class C (Figure 3-26).

Caliente-Chalk Mountain Route. Section 3.2.2.2.4 describes the environmental setting along the route. The route passes through the Caliente and Schell Bureau of Land Management resource areas. From Caliente to the south end of Burnt Springs Range, the route passes through Class III land. From the Burnt Springs Range west through Crystal Springs to Rachel, the route passes through Class IV land. The route from Rachel south crosses Class III and VI land to the Nevada Test Site boundary. Lands crossed on the Nevada Test Site are rated Class B or Class C (Figure 3-26).

Caliente-Las Vegas Route. Section 3.2.2.2.4 describes the environmental setting along the Caliente-Las Vegas route. The route passes through the Caliente, Schell, and Las Vegas Bureau of Land Management resource areas. From Caliente to Crystal Springs the route crosses Class III and Class IV land. From Crystal Springs south to the Pahranagat National Wildlife Refuge, the route crosses Class III land. The refuge is rated Class II. The route from the south end of the refuge to I-15 crosses Class III and IV land. The remainder of the route along I-15, the Northern Beltway, and U.S. 95 passes through Class III land. Lands crossed on the Nevada Test Site are rated Class B or Class C (Figure 3-26).

Sloan/Jean Station and Route

Section 3.2.2.2.4 describes the environmental setting for the Sloan/Jean intermodal transfer station and associated route. The potential location for the Sloan/Jean intermodal transfer station has three parcels located some distance apart, two near Jean and one near Sloan. All portions of these parcels are in the Las Vegas Bureau of Land Management resource area and are designated as Class III lands. From Jean to Sloan the route travels through Class III lands. From Sloan along the Las Vegas Beltway to U.S. 95 is designated as Class IV lands. The portion of the route to the Nevada Test Site is through Class III lands. The remainder of the route on the Nevada Test Site is classified as scenic quality Class B and C (Figure 3-26).

Apex/Dry Lake Station and Route

Section 3.2.2.2.4 describes the environmental setting for the Apex/Dry Lake intermodal transfer station and route. Most of the land in the potential intermodal transfer areas is classified as Class IV lands. A small portion of the southern section of land is designated as Class III lands. The entire route passes through Class III lands from the Apex/Dry Lake siding (and the location of the intermodal transfer station) to the Nevada Test Site boundary. On the Nevada Test Site the route to the repository passes through lands with a scenic quality designated as Class B and C (Figure 3-26).

3.2.2.2.9 *Utilities, Energy, and Materials*

The implementation of the heavy-haul approach for transporting spent nuclear fuel and high-level waste to the repository would involve the construction and operation of an intermodal transfer station and upgrades of existing highways. The scope of the utilities, energy, and materials analysis includes consumption of electric power, fossil fuel, and construction materials such as concrete and steel to support these activities. The sites studied for the intermodal transfer station (Caliente, Sloan/Jean, and Apex/Dry Lake) are in areas with at least some light industrial activity or other activity that requires electric power. The sites would, therefore, have access to light industrial levels of electric power. The sites under consideration would also have access to the regional supply capability to provide fossil fuel and construction materials. Heavy-haul route upgrades would also use the southern Nevada regional supply system to provide materials for highway upgrades.

3.2.2.2.10 *Environmental Justice*

The candidate location for the Caliente intermodal transfer station is in Lincoln County and the associated heavy-haul routes go through Lincoln, Nye, and Esmeralda Counties for the Caliente route; Lincoln and Nye Counties for the Caliente-Chalk Mountain route; and Lincoln, Clark, and Nye Counties for the Caliente-Las Vegas route. Section 3.1.13 discusses minority and low-income populations in Clark, Lincoln, and Nye Counties; Section 3.2.2.1.10 discusses minority and low-income populations in Esmeralda County. Unless otherwise noted, the *Environmental Baseline File for Environmental Justice* (TRW 1999q, all) is the basis for the information in this section.

The candidate locations for both the Sloan/Jean and Apex/Dry Lake intermodal transfer stations are in Clark County; the associated heavy-haul routes both go through Clark and Nye Counties. Section 3.1.13 discusses minority and low-income populations in Clark and Nye Counties.

None of the proposed intermodal transfer station sites is in a census block group with high minority or low-income populations, though a facility in the Caliente area would be near a block group with a low-income population and a facility in the Apex/Dry Lake area would be near the Moapa Indian Reservation, a block group with a high minority population.

Ninety block groups in the City of Las Vegas have low-income or minority populations or both. However, the block groups are not near any of the possible sites for an intermodal transfer station. Tables 3-44 and 3-45 list by county the number of census block groups with high minority or low-income populations, respectively, near or through which the heavy-haul routes would pass. Table 3-46 lists the number of census block groups with high minority populations, high low-income populations, or both that each heavy-haul route could encounter.

Table 3-44. High minority population census block groups near or crossed by candidate routes for heavy-haul trucks.

County	Crosses	Near
Eureka	No route	No route
Lander	No route	No route
Nye	0	0
Esmeralda	0	0
Clark[a]	2	0
Lincoln	0	0

a. Outside Las Vegas.

Table 3-45. High low-income population census block groups near or crossed by candidate routes for heavy-haul trucks.

County	Crosses	Near
Eureka	No route	No route
Lander	No route	No route
Nye	2	1
Esmeralda	0	0
Clark[a]	0	0
Lincoln	1	0

a. Outside Las Vegas.

Table 3-46. High minority and high low-income population census block groups near or crossed by candidate routes for heavy-haul trucks.

Route	Minority	Low-income	Minority and low-income
Caliente	0	1[a]	0
Caliente-Chalk Mountain	0	0	0
Caliente-Las Vegas	2[b]	0	0
Apex/Dry Lake	2[b]	0	0
Sloan/Jean	1	0	0

a. Route passes near a low-income block groups in Nye County.
b. Route crosses two minority block groups in Clark County.

The transportation routes would not intersect any of the 90 block groups in the City of Las Vegas with low-income or minority populations or both.

3.2.2.2.11 *Existing Traffic on Candidate Routes for Heavy-Haul Trucks*

The description of the affected transportation environment characterizes routes in terms of traffic volume and roadway capability (DOE 1998m, pages 3-1 to 3-14). The potential for congestion and other problems on a roadway is expressed in terms of levels of service. The level of service scale ranges from A to F, as follows:

A Indicates free-flow conditions.

B Indicates free-flow, but the presence of other vehicles begins to be noticeable. Average travel speeds are somewhat lower than level of service A.

C Indicates a range in which the influence of traffic density on flow becomes marked. The ability to maneuver in the traffic stream and to select an operating speed is clearly affected by the presence of other vehicles.

D Indicates conditions in which speed and the ability to maneuver are severely restricted due to traffic congestion.

E Indicates full capacity; a disruption, no matter how minor, causes backups to form.

F Indicates breakdown of flow or stop-and-go traffic.

Each level is defined by a range of volume-to-capacity ratios. Level of service A, B, or C is considered good operating conditions in which minor or tolerable delays of service are experienced by motorists. Level of service D represents below average conditions. Level of service E corresponds to the maximum capacity of the roadway. Level of service F indicates a heavily congested or overburdened capacity. Roads outside the Las Vegas metropolitan area are generally level of service A or B; roads inside the Las Vegas metropolitan area are generally level of service E or F. Table 3-47 lists current levels of service on potential heavy-haul routes (excluding the planned Las Vegas Beltway).

Table 3-47. Existing levels of service along candidate routes for heavy-haul trucks.[a]

Route segment	Level of service
Caliente	
U.S. 93 to U.S. 6/U.S. 95 interchange	A
U.S. 95/U.S. 6 to Tonopah city limit	C
U.S. 95 (to Mercury, Nevada)	B
Caliente-Chalk Mountain	
Caliente to Rachel	A
Cost of route on U.S. Government facility	N/A
Caliente-Las Vegas	
U.S. 93 (between I-15 and Caliente)	A
I-15 (to Craig interchange)	A
I-15 (in Las Vegas)	E or F[b]
U.S. 95 (in Las Vegas)	E or F[b]
U.S. 95 (Las Vegas to Mercury)	B
Sloan/Jean	
I-15 (to and in Las Vegas)	C, F[b]
U.S. 95 (in Las Vegas)	C, F[b]
U.S. 95 (Las Vegas to Mercury)	B
Apex/Dry Lake	
I-15 (to Craig interchange	A
I-15 (in Las Vegas)	E and F[b]
U.S. 95 (in Las Vegas)	E and F[b]
U.S. 95 (Las Vegas to Mercury)	B

a. Source: DOE (1998m, pages 3-1 to 3-14).
b. Does not consider the Las Vegas Beltway.

3.3 Affected Environment at Commercial and DOE Sites

The No-Action Alternative analyzes the impacts of not constructing and operating a monitored geologic repository at Yucca Mountain. It assumes that the spent nuclear fuel and high- level radioactive waste would remain at commercial and DOE sites throughout the United States. For this alternative, this section describes the affected environment that reflect the average or mean conditions of the sites. The affected environment includes spent nuclear fuel and high-level radioactive waste inventories, climatic parameters, groundwater flowrates, downstream surface-water users, and downstream surface-water flowrates. In all cases, DOE used data from actual sites to develop the hypothetical sites.

To develop the hypothetical sites (see Appendix K for more information), DOE divided the 77 sites among five regions (Figure 3-27). Climate varies considerably across the United States. The radionuclide release rates would depend primarily on the interaction of climate and materials. DOE analyzed these release rates for a hypothetical site in each region that was a mathematical representation of the actual sites in that region. The development process for the hypothetical site used weighted values for material inventories, climate, and groundwater flow information from each actual site to ensure that the results of the analyses of the hypothetical site were comparable to the results for each actual site, if analyzed independently. Similarly, the process constructed downstream populations of water users and river flow for the hypothetical sites from population and river flow data for actual sites, so they reflect the populations downstream of actual storage facilities and the actual amount of water those populations use.

3.3.1 CLIMATIC FACTORS AND MATERIAL

DOE assumed that a single hypothetical site in each region would store all the spent nuclear fuel and high-level radioactive waste in each region. Such a site does not exist, but DOE used it for this analysis. To ensure that the calculated results of the regional analyses reflected the appropriate inventory, facility and material degradation, and radionuclide transport, DOE developed the spent nuclear fuel and high-level radioactive waste inventories, engineered barriers, and environmental parameters for the hypothetical site from data from the actual sites in that region. Weighting criteria accounted for the different amounts and types of spent nuclear fuel and high-level radioactive waste at each site, so the results of the analyses of the hypothetical site were representative of the sum of the results if DOE had modeled each actual site independently. If there are no storage areas in a particular part of a region, DOE did not analyze the environmental parameters of that part (for example, there are no storage facilities in the Upper Peninsula of Michigan, so the analysis for Region 3 did not include environmental parameters from cities in the Upper Peninsula). In addition, if the storage area would not affect drinking water (for example, groundwater near the Calvert Cliffs Nuclear Generating Plant outcrops to the Chesapeake Bay), the regional hypothetical storage facility did not include their fuel inventories.

The following climate parameters are important to material degradation times and rates of release:

- Precipitation rate (amount of precipitation per year)
- Rain days (percent of days with measurable precipitation)
- Wet days (percent of year that included rain days and days when the relative humidity was greater than 85 percent)
- Temperature
- Precipitation chemistry (pH, chloride anions, and sulfate anions)

Table 3-48 lists the regional values for each parameter. Appendix K contains more information on the selection and analysis of these parameters.

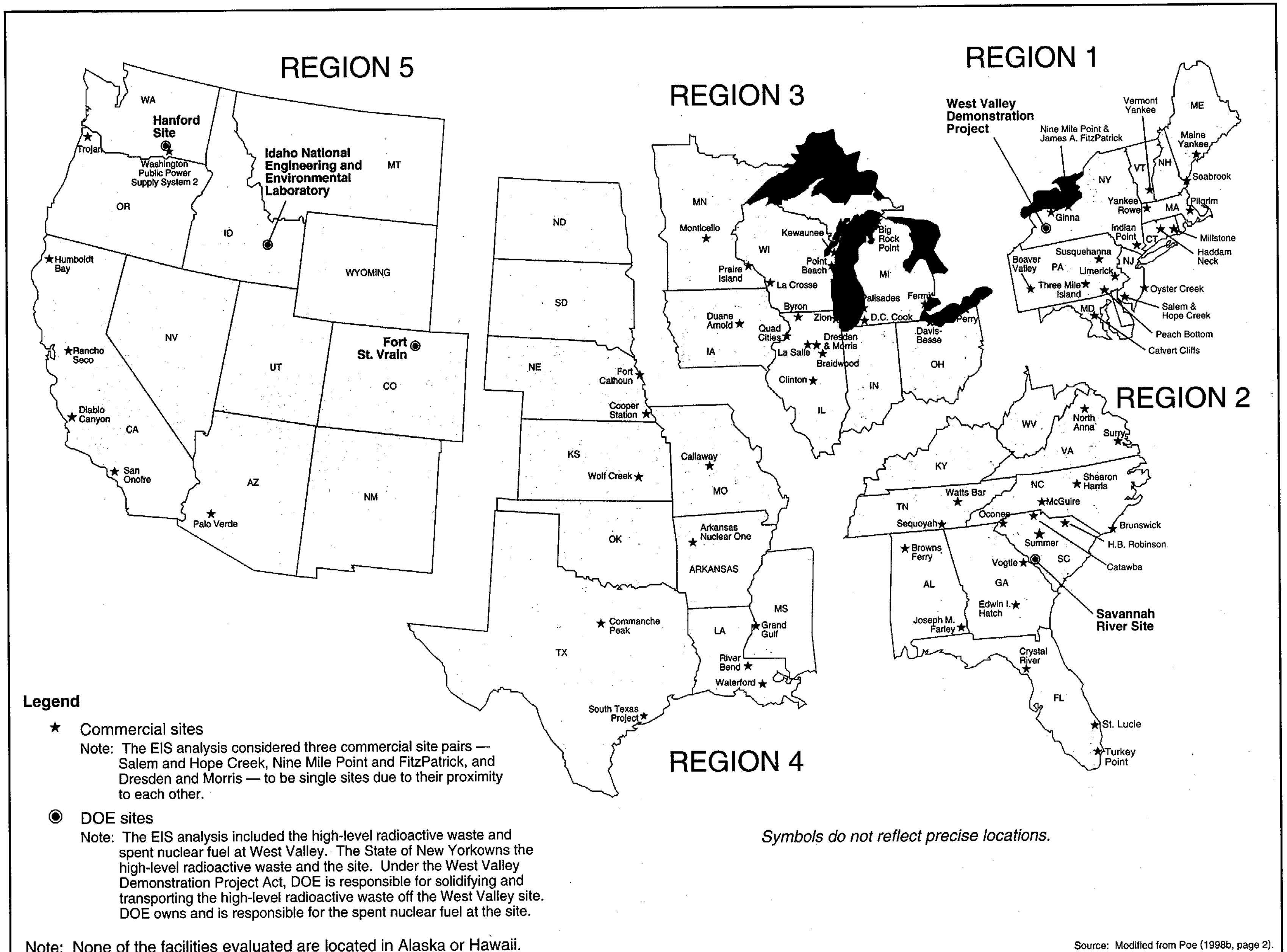


Figure 3-27. Commerical and DOE sites in each No-Action Alternative analysis region.

Table 3-48. Regional environmental parameters.

Region	Precipitation rate (centimeters per year)[a]	Percent rain days (per year)	Percent wet days (per year)	pH	Precipitation chemistry: Chloride anions (weight percent)	Precipitation chemistry: Sulfate anions (weight percent)	Average temperature (°C)[b]
1	110	30	31	4.4	6.9×10^{-5}	1.5×10^{-4}	11
2	130	29	54	4.7	3.9×10^{-5}	9.0×10^{-5}	17
3	80	33	42	4.7	1.6×10^{-5}	2.4×10^{-4}	10
4	110	31	49	4.6	3.5×10^{-5}	1.1×10^{-4}	17
5	30	24	24	5.3	2.1×10^{-5}	2.5×10^{-5}	13

a. To convert centimeters to inches, multiply by 0.3937.
b. To convert degrees Centigrade to degrees Fahrenheit, add 17.78 and then multiply by 1.8.

3.3.2 GROUNDWATER PARAMETERS

Most of the radioactivity and metals from degraded material would seep into the groundwater and flow with it to surface outcrops to rivers or streams. Therefore, the analysis had to account for the groundwater characteristics at each site, including the time it takes the water to move through the unsaturated zone and the aquifer. The analysis assumed that the storage facilities would be 490 meters (1,600 feet) up the groundwater gradient from the hypothetical reactor and used this assumption to calculate the time it would take contaminants to reach surface water. Table 3-49 lists the ranges of groundwater flow times in each region. Appendix K contains more information on the sources of groundwater data.

Table 3-49. Ranges of flow time (years) for groundwater and contaminants in the unsaturated and saturated zones in each region.

Region	Contaminant K_d[a] (milliliters per gram)	Unsaturated zone: Water flow time	Unsaturated zone: Contaminant flow time	Saturated zone: Groundwater flow time	Saturated zone: Contaminant flow time	Total contaminant flow time
1	0[b] - 100	0.7 - 4.4	0.4 - 2,100	0.3 - 56	10 - 5,000	10 - 6,000
2	10 - 250	0.6 - 10	35 - 5,000	3.3 - 250	11 - 310,000	460 - 310,000
3	10 - 250	0.5 - 14	32 - 1,500	1.3 - 410	9 - 44,000	65 - 45,000
4	10 - 100	0.2 - 7.1	110 - 2,300	3.9 - 960	300 - 520,000	460 - 520,000
5	0 - 10	0.9 - 73	14 - 4,700	1.7 - 170	0 - 25,000	200 - 26,000

a. K_d = equilibrium adsorption coefficient.
b. The K_d would be 0 if there was no soil at the site.

3.3.3 AFFECTED WATERWAYS

Most of the estimated population dose for the No-Action Alternative would be a result of drinking contaminated surface water. The first step in determining the population dose was to identify the waterways that receive groundwater from beneath existing storage facilities (Figure 3-28) and the number of public drinking water systems that draw water from the potentially contaminated waterways (Table 3-50). DOE calculated the river flow past each population center (Section 3.3.4) along each river, and used this number in the calculation to determine dose to the population.

Table 3-50. Public drinking water systems and the populations that use them in the five regions.[a]

Region	Drinking water systems	Population
1	85	10,000,000
2	150	5,600,000
3	150	12,000,000
4	95	600,000
5	6	2,800,000
Totals	**486**	**31,000,000**

a. Sources: Based on current information and the 1990 census.

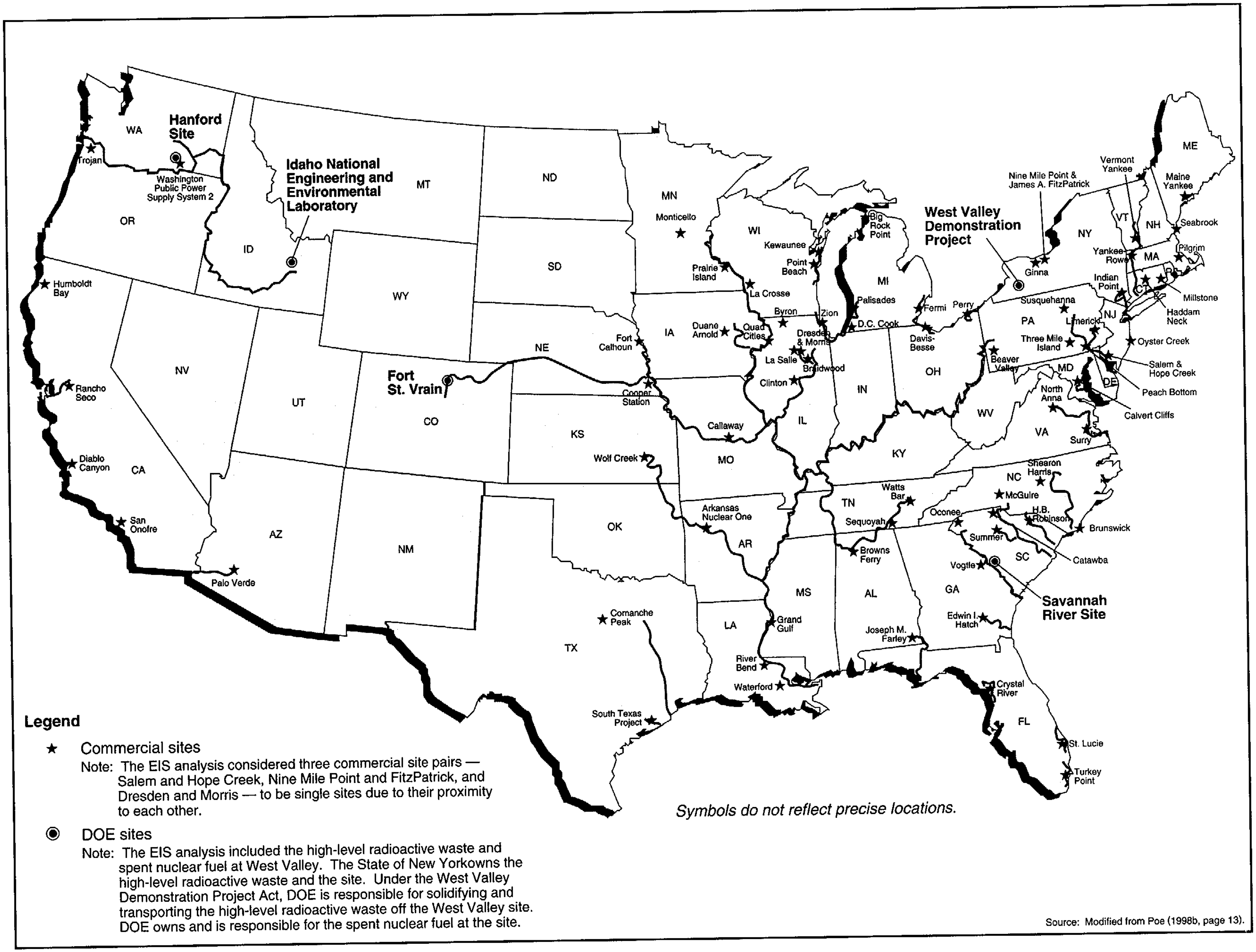


Figure 3-28. Major waterways near commercial and DOE sites.

3.3.4 AFFECTED POPULATIONS

After identifying the affected waterways, DOE identified the populations that get their drinking water from those waterways. The total population using the river was expressed as number of people per cubic foot per second. If a river system traverses more than one region (for example, the Mississippi drains three regions), weighting criteria accounted for materials received from storage facilities upstream of the region that would flow past several downstream population centers, as necessary. Table 3-50 lists the number of people using the public drinking water systems potentially affected by the degradation of radioactive materials.

4

Environmental Consequences of Repository Construction, Operation and Monitoring, and Closure

4. ENVIRONMENTAL CONSEQUENCES OF REPOSITORY CONSTRUCTION, OPERATION AND MONITORING, AND CLOSURE

This chapter describes short-term environmental consequences that could result from the implementation of the Proposed Action, which is 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. *Short-term* refers to the period up to and during the completion of repository closure. For purposes of analysis, the duration that the repository would remain open varied between 50, 100, and 300 years after receipt of the first spent nuclear fuel or high-level radioactive waste shipment. Chapters 5 and 6 discuss the environmental consequences of long-term repository performance and transportation, respectively. Chapter 7 discusses the environmental consequences of the No-Action Alternative.

Section 4.1 describes potential environmental impacts from required activities at the repository site to implement the Proposed Action, including continued site investigations (called *performance confirmation*), offsite manufacturing of disposal containers and shipping casks, and a floodplain assessment. The implementation of the Proposed Action could require performance confirmation in support of a U.S. Nuclear Regulatory Commission licensing process. Section 4.2.1 describes potential environmental impacts of retrieval if such an option became necessary. Section 4.2.2 describes the environmental impacts associated with the receipt of waste prior to the start of emplacement.

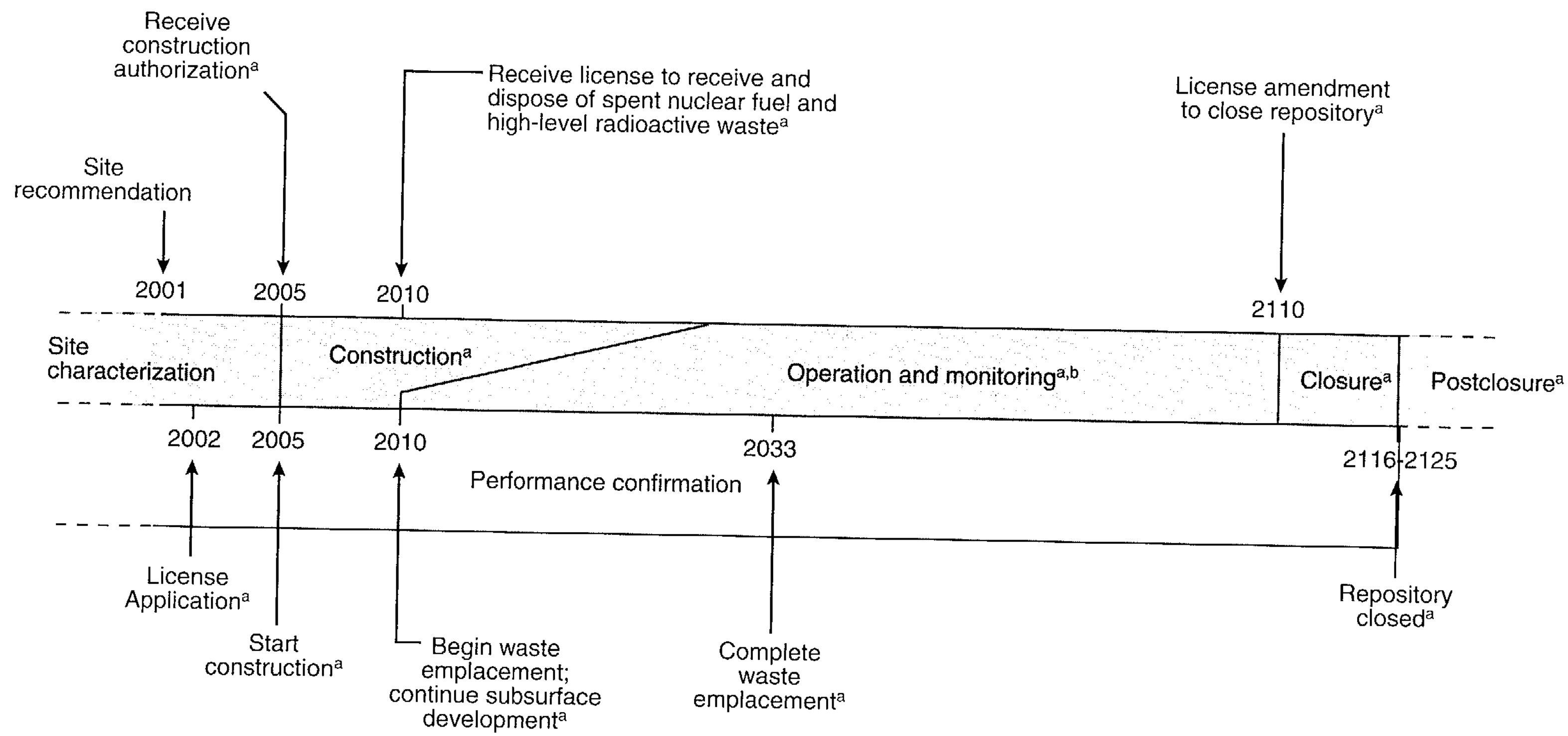
The U.S. Department of Energy (DOE) has developed the information about the potential environmental impacts that could result from either the Proposed Action or the No-Action Alternative to inform the Secretary of Energy's determination whether to recommend Yucca Mountain as the site of this Nation's first monitored geologic repository for spent nuclear fuel and high-level radioactive waste. This chapter contains information about short-term environmental impacts that would be directly associated with the construction, operation and monitoring, and eventual closure of a repository. In addition, DOE analyzed packaging and thermal load scenarios to cover a reasonable range of possible impacts.

4.1 Short-Term Environmental Impacts of Performance Confirmation, Construction, Operation and Monitoring, and Closure of a Repository

This section describes the short-term environmental impacts associated with the Proposed Action. DOE has described the environmental impacts according to the phases of the Proposed Action—construction, operation and monitoring, and closure—and the activities (some of which overlap) associated with them. The following paragraphs summarize the phases and activities that would occur, and the analytic scenarios evaluated in this environmental impact statement (EIS). Chapter 2 describes these scenarios in detail. Figure 4-1 shows the expected timeline for these phases. In addition, this section describes the impacts from the performance confirmation activities that DOE would perform before the start of repository construction in support of a Nuclear Regulatory Commission licensing process. These activities, which would continue through repository closure, could require surface or subsurface excavations and drill holes, testing, and environmental monitoring. As these activities revealed more scientific data, DOE would expect their level of effort to decrease.

PRECONSTRUCTION PERFORMANCE CONFIRMATION ACTIVITIES (2001 TO 2005)

The performance confirmation program would continue the current site characterization activities—tests, experiments, and analyses—for as long as required. DOE would continue these activities during all the phases of the repository project to evaluate the accuracy and adequacy of the information it used to



a. If Yucca Mountain is approved.

b. The EIS analysis assumed that waste emplacement would occur over a 24-year period ending in 2033.

Source: Modified from TRW (1999b, Figure 1.5-1, page 1-3).

Fig[illegible]-1. Expected monitored geologic repository milestones.

determine with reasonable assurance that the repository would meet the performance objective for the period after permanent closure.

INITIAL CONSTRUCTION ACTIVITIES (2005 TO 2010)

The construction of facilities would begin when and if the Nuclear Regulatory Commission authorized DOE to build the repository. Assuming this authorization, construction would begin in about 2005. Site preparation, including the layout and grading of surface facility locations, would be part of the initial construction activities; DOE would construct new surface facilities or modify facilities built to support site characterization. Initial subsurface construction would prepare the first emplacement drifts for the start of emplacement activities in 2010. As mentioned above, performance confirmation activities would be ongoing during this period.

CONTINUING CONSTRUCTION ACTIVITIES AND REPOSITORY OPERATION AND MONITORING (2010 TO 2110)

Repository operations would begin after DOE received a license from the Nuclear Regulatory Commission to receive and dispose of spent nuclear fuel and high-level radioactive waste. Assuming DOE received the license, emplacement of these materials in the repository would be likely to begin in 2010 and end in 2033. The development (construction) of the subsurface would continue during waste emplacement, and would end in about 2031 for the high or intermediate thermal load scenario or about 2032 for the low thermal load scenario.

Monitoring of the emplaced material and maintenance of the repository would start with the first emplacement of waste packages and would continue through the closure phase. After the completion of emplacement, DOE would maintain the repository in a configuration that would enable continued monitoring and inspection of the waste packages, continued investigations in support of predictions of long-term repository performance (the ability to isolate waste from the accessible environment), and the retrieval of waste packages, if necessary.

Monitoring activities would begin with the emplacement of the first waste package in 2010 and would last between 50 and 300 years. Future generations would need to decide whether to continue to maintain the repository in this open monitored condition or to close it. To ensure flexibility for future decisionmakers, DOE is designing the repository with the capability for closure as early as 50 years after the start (26 years after the completion) of waste emplacement or as late as 300 years after the start (276 years after the completion) of emplacement. However, the Department expects that a repository could be maintained in an open monitored condition, with appropriate maintenance, for as long as 300 years after the start of emplacement. For this analysis, the EIS evaluates closure starting 100 years after the start of emplacement, but also assesses impacts for closure starting 50 and 300 years after the start of emplacement.

As mentioned above, DOE would continue its performance confirmation activities during the construction, waste emplacement, and monitoring activities.

CLOSURE PHASE (2110 TO 2116 OR 2125)

Repository closure would occur after DOE applied for and received a license amendment from the Nuclear Regulatory Commission. Closure would take from 6 to 15 years, depending on the thermal load scenario. The closure of the repository facilities would include the following activities:

- Removing and salvaging valuable equipment and materials
- Potentially backfilling the main drifts, access ramps, ventilation shafts, and connecting openings

- Constructing monuments to mark the area
- Decommissioning and demolishing surface facilities
- Restoring the surface to its approximate condition before repository construction
- Continuing performance confirmation activities as necessary

REPOSITORY ANALYTIC SCENARIOS

As discussed in Chapter 2, the repository design is conceptual and continues to evolve. This evolution will continue throughout the process established by the Nuclear Regulatory Commission for license application and construction authorization. To present the range of short-term environmental impacts that could occur, DOE has selected a set of repository design scenarios (thermal loads) for evaluation in this EIS. Because it cannot predict the specific transportation option or mode (truck or rail) or the packaging option (canistered or uncanistered) for each shipment of spent nuclear fuel and high-level radioactive waste to the proposed repository, DOE has also identified a set of transportation and packaging scenarios for evaluation. Whether canistered or uncanistered, each shipment of spent nuclear fuel and high-level radioactive waste would be in a Nuclear Regulatory Commission-certified shipping cask.

DOE is considering three thermal load scenarios to represent the potential thermal loads that could be part of a license application to the Nuclear Regulatory Commission. These scenarios include a relatively high emplacement density of spent nuclear fuel and high-level radioactive waste (high thermal load), a relatively low emplacement density (low thermal load), and an emplacement density between the high and low thermal loads (intermediate thermal load). The emplacement density of spent nuclear fuel and high-level radioactive waste in the repository is referred to as the *areal mass loading* (the amount of material in a given area). The spacing of the emplacement drifts and the waste packages in those drifts would control the thermal load of the repository. The additional spacing required for lower thermal loads would increase the amount of subsurface area needed and, therefore, would require more excavation.

Because the specific mix of canistered and uncanistered spent nuclear fuel that would arrive at the repository is not known at this time, this EIS analyzes the following packaging scenarios to address the potential range of environmental impacts from surface facility operations:

- A mostly legal-weight truck, uncanistered commercial fuel receipt scenario (uncanistered scenario)
- A mostly rail, canistered commercial fuel receipt scenario (canistered scenario) that includes:
  - A disposable canister scenario
  - A dual-purpose canister scenario

4.1.1 IMPACTS TO LAND USE AND OWNERSHIP

This section describes potential land-use and ownership impacts from the performance confirmation, construction, operation and monitoring, and closure activities. DOE determined that information useful in an evaluation of land-use and ownership impacts should identify the current ownership of the land that repository-related activities could disturb, and the present and anticipated future uses of the land. The region of influence for land-use and ownership impacts is a land withdrawal area that DOE used for the EIS analysis. Congress would have to define the actual land withdrawal area. The analysis considered impacts from direct disturbances related to repository construction and operation. It also considered impacts from the transfer of lands to DOE control.

4.1.1.1 Impacts to Land Use and Ownership During Performance Confirmation and from Land Withdrawal

Performance confirmation activities would occur primarily on land managed by the Federal Government. As with site characterization, these activities would occur in the land withdrawal area that DOE analyzed in the EIS (see Section 3.1.1). DOE would seek to maintain the current administrative land withdrawal of 20 square kilometers (4,900 acres), current right-of-way reservations N-47748 [210 square kilometers (52,000 acres)] and N-48602 [about 75 square kilometers (19,000 acres)], and the existing management agreement between the Yucca Mountain Site Characterization Office and the DOE Nevada Operations Office (as described in Section 3.1.1) until Congress approved a permanent land withdrawal. The Nevada Operations Office operates the Nevada Test Site.

To develop the proposed Yucca Mountain Repository, DOE would need to obtain permanent control of the land surrounding the repository site. The Department believes that an area of approximately 600 square kilometers (150,000 acres) on Bureau of Land Management, U.S. Air Force, and DOE lands in southern Nevada would be sufficient (see Section 3.1).

Nuclear Regulatory Commission licensing conditions for a repository (10 CFR 60.121) include a requirement that DOE either own or have permanent control of the lands for which it is seeking a repository license. As noted above, portions of the area proposed for the repository are lands controlled by the Bureau of Land Management, the Air Force, and the DOE Nevada Operations Office.

Only Congress has the power to withdraw Federal lands permanently for the exclusive purposes of specific agencies. Through legislative action, Congress can authorize and direct a permanent withdrawal of lands such as those proposed for the Yucca Mountain Repository. In addition, Congress would determine any conditions associated with the land withdrawal. Nuclear Regulatory Commission regulations require that repository operations areas and postclosure controlled areas be free and clear of all encumbrances, if significant, such as (1) rights arising under the general mining laws, (2) easements or rights-of-way, and (3) all other rights arising under lease, rights of entry, deed, patent, mortgage, appropriation, prescription, or otherwise. If Congress approved withdrawal of lands for repository purposes, any other use of those lands would be subject to conditions of the withdrawal.

Repository construction, operation and monitoring, and closure activities would require the active use of a maximum of about 3.5 square kilometers (870 acres) composed of small noncontiguous areas in the larger 600-square-kilometer (150,000-acre) land withdrawal area used for purposes of analysis.

Chapter 2 describes activities that DOE would conduct in the Yucca Mountain site active-use area and the land withdrawal area.

The amount of land that DOE would need to support repository activities would vary little between the thermal load and packaging scenarios. Most of the surface facilities and disturbed land would be in the North and South Portal Operations Areas. Repository activities would not conflict with current land uses on adjacent Bureau of Land Management, Air Force, or Nevada Test Site lands.

4.1.1.2 Impacts to Land Use and Ownership from Construction, Operation and Monitoring, and Closure

During the construction and operation and monitoring phases, DOE would disturb or clear land for repository and surface facility construction. The Department would use this land for surface facilities, performance confirmation activities, and excavated rock storage. DOE does not expect conflicts with uses on surrounding lands because repository operations would occur in a confined, secure area over which DOE would have permanent control. Furthermore, this is public land, much of which has been used for site characterization for nearly two decades.

As described in Section 4.1, surface activities associated with closure would include constructing monuments, decommissioning and decontaminating facilities, and restoring the surface to its approximate preconstruction condition. DOE could use material from the excavated rock pile to backfill the repository tunnels (excluding the emplacement drifts), and would recontour the excavated material remaining after backfill and subsurface closure activities and cover it with topsoil. During closure, the Department would restore disturbed areas to their approximate condition before repository construction.

4.1.2 IMPACTS TO AIR QUALITY

This section describes possible nonradiological and radiological impacts to air quality from performance confirmation, construction, operation and monitoring, and closure. Sources of nonradiological air pollutants at the proposed repository site would include fugitive dust emissions from land disturbances and excavated rock handling, nitrogen dioxide, sulfur dioxide, and particulate matter emissions from fossil fuel consumption, and fugitive dust emissions from concrete batch plant operations. DOE used the Industrial Source Complex computer program to estimate annual and short-term (24-hour or less) nonradiological air quality impacts (EPA 1995, all). Nonradiological impacts evaluated include those from four criteria pollutants: nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter with an aerodynamic diameter of 10 micrometers or less (PM_{10}). In addition, potential impacts were evaluated for the possibly harmful mineral cristobalite, a form of silica dust that is the causative agent for silicosis and might be a carcinogen. The analysis did not consider the two other criteria pollutants, lead and ozone. There would be no sources of airborne lead at the repository, and very small sources of volatile organic carbon compounds, which are ozone precursors. The analysis did make a qualitative comparison to the new National Ambient Air Quality Standard for particulate matter with an aerodynamic diameter of 2.5 micrometers or less ($PM_{2.5}$). A Federal appeals court recently struck down the Environmental Protection Agency's new national ambient air quality standards for particulate matter (American Trucking v. EPA 1999, all). The Environmental Protection Agency has announced that it will appeal the decision. The EIS used these standards, among other air quality standards that were not at issue in that case, in analyzing the air quality impacts discussed in this section.

Radiological air quality impacts could occur from releases of radionuclides, primarily naturally occurring radon-222 and its radioactive decay products, from the rock into the subsurface facility and then into the ventilation air during all phases of the repository project. Radioactive noble gases, principally krypton-85, would be released from surface facilities during the handling of spent nuclear fuel. DOE used dose factors from NCRP (1996, Volume 1, pages 113 and 125) and ICRP (1994, page 24) to estimate doses to noninvolved workers (workers who could be exposed to air emissions from repository activities but who would not be directly associated with those activities) and offsite individuals from such releases. Appendix G provides more details on the methods used for air quality analysis.

The air quality analysis evaluated nonradiological air quality impacts at the potential locations of maximally exposed members of the public. It estimated radiological air quality impacts as the doses to maximally exposed individuals and populations of the public and to noninvolved workers. The analysis did not consider involved workers because they would be exposed in the workplace, as discussed in Section 4.1.7. Overall, the impacts to regional air quality from performance confirmation, repository construction, operation and monitoring, and closure would be small. Exposures of maximally exposed individuals to airborne pollutants would be a small fraction of applicable regulatory limits. Appendix G describes the methods, procedures, and basis of the analysis.

4.1.2.1 Impacts to Air Quality from Performance Confirmation (2001 to 2005)

Performance confirmation activities would generate particulate and gaseous emissions. Particulates would be generated by drilling, blasting, rock removal and storage, batch concrete plant operation, surface grading and leveling, wind erosion, and vehicle travel on paved and unpaved roads. Gaseous air pollutant emissions would consist of carbon monoxide, nitrogen oxides, sulfur oxides, and hydrocarbons. These pollutants would be produced by diesel- and gasoline-powered construction equipment and motor vehicles and by diesel-powered drilling engines and electric generators.

Air quality measurements at the repository site and in the repository site vicinity (see Section 3.1.2) have shown that site characterization activities similar to those described above have had a very small impact on the concentration levels of PM_{10} and of gaseous pollutants (carbon monoxide, nitrogen oxides, sulfur oxides, ozone). This analysis assumed that site characterization activities are representative of performance confirmation activities. As described in Section 3.1.2, pollutant levels have been below applicable National Ambient Air Quality Standards. Based on this experience, DOE does not expect large impacts to air quality from performance confirmation activities.

4.1.2.2 Impacts to Air Quality from Construction (2005 to 2010)

This section describes potential radiological and nonradiological air quality impacts during the initial construction of the Yucca Mountain Repository, which would last 5 years, from 2005 to 2010. Activities during this phase would include subsurface excavation to prepare the repository for initial emplacement operations and construction of surface facilities at the North Portal, South Portal, Emplacement Shaft, and Development Shaft Operations Areas.

4.1.2.2.1 *Nonradiological Impacts to Air Quality from Construction*

During the initial construction, repository activities would result in emissions of air pollutants. Subsurface excavation would release dust (particulate matter) from the ventilation exhaust (South Portal). The excavation of rock would generate dust in the drifts. The dust would be vented from the subsurface through the South Portal. Construction activities on the surface would result in the following air emissions:

- Fugitive dust from the placement and maintenance of excavated rock at a surface storage site
- Gaseous criteria pollutants (nitrogen dioxide, sulfur dioxide, etc.) and particulate matter from the operation of construction vehicles
- Gaseous criteria pollutants and particulate matter from a diesel-fueled boiler at the South Portal Operations Area
- Particulate matter from a concrete batch plant at the South Portal Operations Area
- Fugitive dust from land-disturbing activities on the surface

Table 4-1 lists the maximum estimated impacts to air quality at the boundary of the land withdrawal area used for purposes of analysis in this EIS. As listed in this table, maximum offsite concentrations of nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10} would be small. Criteria pollutant concentrations would be less than 2 percent of the applicable regulatory limits for all cases except one: the 24-hour PM_{10} concentrations for the three thermal load scenarios would be about 4 percent of the

Table 4-1. Estimated maximum construction phase concentrations of criteria pollutants and cristobalite at the analyzed land withdrawal area boundary (micrograms per cubic meter).[a]

			Thermal load					
			Maximum concentration[c]			Percent of regulatory limit		
Pollutant	Averaging time	Regulatory limit[b]	High	Intermediate	Low	High	Intermediate	Low
Nitrogen dioxide	Annual	100	0.36	0.36	0.39	0.36	0.36	0.39
Sulfur dioxide	Annual	80	0.088	0.088	0.091	0.11	0.11	0.12
	24-hour	365	1.0	1.0	1.0	0.28	0.28	0.29
	3-hour	1,300	6.3	6.3	6.5	0.49	0.49	0.50
Carbon monoxide	8-hour	10,000	3.8	3.8	4.1	0.037	0.037	0.040
	1-hour	40,000	23	23	25	0.058	0.058	0.062
PM_{10} ($PM_{2.5}$)	Annual	50 (15)	0.66	0.70	0.65	1.3	1.4	1.3
	24-hour	150 (65)	6.1	6.4	6.0	4.0	4.3	4.0
Cristobalite	[Annual[d]]	[10[d]]	0.022	0.026	0.011	0.22	0.26	0.11

a. All numbers except regulatory limits are rounded to two significant figures.

b. Regulatory limits for criteria pollutants are from 40 CFR 50.4 through 50.11, and Nevada Administrative Code 445B.391 (see Table 3-5).

c. Sum of highest concentrations at the accessible land withdrawal boundary regardless of direction. See Appendix G, Section G.1, for additional information.

d. There are no regulatory limits for public exposure to cristobalite, a form of crystalline silica. An Environmental Protection Agency health assessment (EPA 1996a, page 1-5) states that the risk of silicosis is less than 1 percent for a cumulative exposure of 1,000 (micrograms per cubic meter) × years. Using a 70-year lifetime, an approximate annual average concentration of 10 micrograms per cubic meter was established as a benchmark for comparison.

regulatory limit. In addition, DOE expects levels of $PM_{2.5}$ to be well below the applicable standard because a large fraction of the particulates for PM_{10} would be larger than 2.5 micrometers. The analysis did not consider standard construction dust suppression measures, which DOE would implement and which would further lower projected PM_{10} concentrations by reducing fugitive dust from surface-disturbing activities. These measures would not have a major effect on concentrations of $PM_{2.5}$ because fugitive dust is not a major source of $PM_{2.5}$.

Emissions of nitrogen dioxide, sulfur dioxide, and carbon monoxide would be somewhat higher under the low thermal load scenario during the construction phase because of higher consumption of diesel fuel and resultant vehicle emissions around the South Portal Operations Area. The additional consumption and emissions would be related mainly to the preparation and maintenance of the excavated rock pile. Under this scenario, the rock pile would be about 5 kilometers (3 miles) east of the South Portal Operations Area, rather than in that operations area as it would be for the high and intermediate thermal load scenarios. Because the pile would be away from the South Portal Operations Area, it would not be subject to the operations area height restrictions. DOE could make a higher pile, reducing the area that would be disturbed and creating a more favorable surface-to-volume ratio for limiting fugitive dust emissions. This pile location would also be 5 kilometers farther from the location of the maximally exposed individual, which would result in lower PM_{10} concentrations. The PM_{10} contribution from surface disturbance activities would be about the same for the three thermal load scenarios. Overall, the slight differences in estimated concentrations do not provide meaningful distinctions between the scenarios.

Cristobalite is one of several naturally occurring crystalline forms of silica (silicon dioxide) that occur in Yucca Mountain tuffs. Cristobalite is principally a concern for involved workers who could inhale it during subsurface excavation operations (see Section 4.1.7). Prolonged high exposure to crystalline silica might cause silicosis, a disease characterized by scarring of lung tissue. Research has shown an increased cancer risk to humans who already have developed adverse noncancer effects from silicosis, but the cancer risk to otherwise healthy individuals is not clear (EPA 1996a, page 1-5). The evaluation of exposure to cristobalite encompassed potential impacts from exposure to other forms of crystalline silica, including quartz and tridymite, that occur at Yucca Mountain. See Appendix F, Section F.1, for more information.

Cristobalite would be emitted from the subsurface in exhaust ventilation air during excavation operations and would be released as fugitive dust from the excavated rock pile, so members of the public and noninvolved workers could be exposed. Fugitive dust from the excavated rock pile would be the largest potential source of cristobalite exposure to the public. The analysis assumed that 28 percent of the fugitive dust released from this pile and from subsurface excavation would be cristobalite, reflecting the cristobalite content of the parent rock, which ranges from 18 to 28 percent (TRW 1999b, page 4-81). Using the parent rock percentage probably overestimates the airborne cristobalite concentration because studies of both ambient and occupational airborne crystalline silica have shown that most is coarse and not respirable, and that larger particles will rapidly deposit on the surface (EPA 1996a, page 3-26). Table 4-1 lists estimated cristobalite concentrations at the analyzed land withdrawal area boundary during the construction phase.

There are no regulatory limits for public exposure to cristobalite. An Environmental Protection Agency health assessment (EPA 1996a, page 1-5) states that the risk of silicosis is less than 1 percent for a cumulative exposure of 1,000 (micrograms per cubic meter) × years. Over a 70-year lifetime, this cumulative exposure benchmark would correspond to an annual average exposure concentration of about 14 micrograms per cubic meter. For added conservatism, this analysis used an annual concentration of 10 micrograms per cubic meter as the benchmark for comparison. The postulated annual average exposure of the hypothetical maximally exposed member of the public to cristobalite from construction activities would be small, about 0.025 microgram per cubic meter or less for the thermal load scenarios. DOE would use common dust suppression techniques (water spraying, etc.) to further reduce releases of fugitive dust from the excavated rock pile.

4.1.2.2.2 *Radiological Impacts to Air Quality from Construction*

No releases of manmade radionuclides would occur during the construction phase because such materials would not be present until the repository began operations. However, the air exhausted from the subsurface would contain naturally occurring radon-222 and its radioactive decay products. (Further references to radon in this discussion include its radioactive decay products.) Radon-222 is a noble gas and decay product of uranium-238 that occurs naturally in the rock. Exposure to radon-222 is ubiquitous (that is, it occurs everywhere). As described in Section 3.1.8, exposure to naturally occurring radon-222 results in an annual average individual dose in the United States of about 200 millirem. In the subsurface, radon-222 would leave the rock and enter the drifts, from which it would be exhausted as part of repository ventilation. The analysis based potential releases of radon-222 on observed concentrations of the gas in the Exploratory Studies Facility during working hours when the ventilation system was operating. The concentrations ranged from 0.65 to 163 picocuries per liter, with a median concentration of 24 picocuries per liter. Total estimated radon releases of 1,500, 1,600, or 1,600 curies would occur during the construction phase for the high, intermediate, or low thermal load scenario, respectively. These releases, and the potential doses that resulted from them, would be similar because the excavated volume of the repository and the repository flowrate would be similar under each scenario. Appendix G, Section G.2, describes the methods, procedures, and basis of analysis.

The dose to the offsite maximally exposed individual, about 20 kilometers (12 miles) south of the repository, would be no more than 2.1, 2.5, or 2.5 millirem for the 5-year initial construction period under the high, intermediate, or low thermal load scenario, respectively. As a point of reference, the annual dose to the offsite maximally exposed individual would be about 5 percent of the 10-millirem-per-year regulatory limit (40 CFR Part 61), although this limit does not apply to releases of radon. The offsite population dose would be 11, 13, or 13 person-rem, respectively. The median dose to the maximally exposed noninvolved repository worker would range from 4.7 to 5.4 millirem annually during the initial construction period for the three thermal load scenarios. The analysis assumed that this worker, while at the site, would be in an office about 100 meters (330 feet) from the South Portal. The noninvolved worker population exposed to radon-222 from exhaust ventilation would include all of the repository workers on the surface. Workers at the South Portal Operations Area, who would be near the ground-level releases of radon from this portal, would receive most of the population dose. The dose to the noninvolved worker population from the air pathway would not exceed 10 person-rem for any thermal load scenario (see Appendix G, Section G.2).

Table 4-2 lists estimated annual and initial construction period doses from radon-222 for the maximally exposed individuals (both public and noninvolved surface worker) and potentially affected populations from the air pathway. Section 4.1.7 discusses potential human health impacts from these doses.

Table 4-2. Estimated radiation doses to maximally exposed individuals and populations from subsurface radon-222 releases during initial construction period.[a,b]

	Thermal load					
	High		Intermediate		Low	
Impact	Total	Annual	Total	Annual	Total	Annual
Dose to public						
Offsite MEI[c] (millirem)	2.1	0.43	2.5	0.49	2.5	0.49
80-kilometer population[d] (person-rem)	11	2.3	13	2.6	13	2.6
Dose to noninvolved (surface) workers						
Maximally exposed noninvolved (surface) worker[e] (millirem)	23	4.7	27	5.4	27	5.4
Yucca Mountain noninvolved (surface) worker population[g] (person-rem)	9.0[f]	1.8[f]	10[f]	2.0[f]	10[f]	2.0[f]
Nevada Test Site noninvolved worker population[h] (person-rem)	0.012	0.0025	0.014	0.0028	0.014	0.0028

a. Numbers are rounded to two significant figures.
b. These releases were estimated using the average repository volume during the construction phase.
c. MEI = maximally exposed individual; public MEI location would be 20 kilometers (12 miles) south of the repository.
d. The population includes about 28,000 individuals within 80 kilometers (50 miles) of the repository (see Section 3.1.8).
e. The maximally exposed noninvolved worker location would be in the South Portal Operations Area.
f. Values are for the uncanistered packaging scenario. The dual-purpose and disposable canister packaging scenario values would be somewhat lower, due to differences in the number of surface facility construction workers.
g. The analysis included noninvolved workers at both the North and South Portal Operations Areas.
h. DOE workers at the Nevada Test Site [6,600 workers (DOE 1996f, page 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

4.1.2.3 Impacts to Air Quality from Continuing Construction, and Operation and Monitoring (2010 to 2110)

This section describes potential nonradiological and radiological air quality impacts from routine operation and monitoring at the Yucca Mountain Repository, which would last from 2010 to 2110. Activities during this phase would include the continued excavation of subsurface drifts (2010 to 2033), the receipt and packaging (handling) of spent nuclear fuel and high-level radioactive waste at the North Portal surface facilities (2010 to 2033), the emplacement of disposal containers in the repository (2010 to 2033), and the continued monitoring of the disposal containers and maintenance of repository facilities (2034 to 2110).

4.1.2.3.1 *Nonradiological Impacts to Air Quality from Continuing Construction, and Operation and Monitoring*

DOE evaluated nonradiological air quality impacts from activities from 2010 to 2033, when handling and continued subsurface development and emplacement activities would occur simultaneously. Continued subsurface development would result in the release of dust (particulate matter) from the ventilation exhaust (at the South Portal). Activities on the surface would result in the following air emissions during this period:

- Fugitive dust emissions from the placement and maintenance of excavated rock at a surface storage pile
- Gaseous criteria pollutants (nitrogen dioxide, sulfur dioxide, carbon monoxide) and particulate matter from vehicle operation
- Gaseous criteria pollutants and particulate matter from oil-fed boilers at the North and South Portal Operations Areas
- Particulate matter from a concrete batch plant at the South Portal Operations Area
- Cristobalite emissions from subsurface excavations and the excavated rock storage pile

The level of emissions would vary among the thermal load and packaging scenarios. The lower thermal loads would result in larger excavated rock piles on the surface, which in turn would result in larger fugitive dust emissions and necessitate larger vehicle fleets for operation and maintenance. The uncanistered packaging scenario would require larger facilities at the North Portal Operations Area, which would necessitate a larger boiler for heating.

Table 4-3 lists estimated maximum concentrations at the analyzed land withdrawal area boundary for the high, intermediate, and low thermal load scenarios. These impacts are based on surface facilities built for the uncanistered packaging scenario. Other packaging scenarios would have similar or slightly smaller impacts because they would require smaller boilers.

As listed in Table 4-3, the maximum offsite concentrations of nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10} would be very small. For all three thermal load scenarios, the public maximally exposed individual would receive no more than 1 percent of the applicable regulatory limits, with one exception: the 24-hour PM_{10} value would be about 2 percent. In addition, levels of $PM_{2.5}$ should be well below the applicable standard because a large fraction of the particulates listed for PM_{10} would be larger than 2.5 micrometers. The analysis did not consider standard construction dust suppression measures, which DOE would implement and which would further lower projected PM_{10} concentrations by reducing fugitive dust from surface-disturbing activities. The concentrations of $PM_{2.5}$ would not be as affected by these suppression measures because fugitive dust is not a major source of $PM_{2.5}$.

Table 4-3 also lists cristobalite concentrations at the analyzed land withdrawal area boundary. As discussed for the initial construction period (see Section 4.1.2.2.1), the analysis of the continuing construction, operation, and monitoring period assumed that 28 percent of the fugitive dust released from the excavated rock pile would be cristobalite. There are no public limits for exposure to cristobalite, so the analysis used an approximate annual average concentration of 10 micrograms per cubic meter as a benchmark. The estimated exposures to cristobalite from repository operations would be small, about 0.015 microgram per cubic meter or less for all three thermal load scenarios.

Table 4-3. Estimated maximum criteria pollutant and cristobalite concentrations at the analyzed land withdrawal area boundary from emplacement, receipt and packaging, and development activities (2010 to 2033) during the operation and monitoring phase (micrograms per cubic meter).[a]

Pollutant	Averaging time	Regulatory limit[b]	Maximum concentration[c]			Percent of regulatory limit		
			High	Intermediate	Low	High	Intermediate	Low
Nitrogen dioxide	Annual	100	0.45	0.45	0.82	0.46	0.46	0.83
Sulfur dioxide	Annual	80	0.14	0.14	0.16	0.18	0.18	0.23
	24-hour	365	1.8	1.8	2.1	0.50	0.50	0.57
	3-hour	1,300	11	11	13	0.87	0.87	1.0
Carbon monoxide	8-hour	10,000	4.2	4.2	7.3	0.041	0.041	0.072
	1-hour	40,000	28	28	46	0.070	0.070	0.11
PM_{10} ($PM_{2.5}$)	Annual	50 (15)	0.22	0.22	0.27	0.43	0.44	0.54
	24-hour	150 (65)	3.0	3.1	3.4	2.0	2.1	2.3
Cristobalite	[Annual[d]]	[10[d]]	0.0097	0.012	0.015	0.097	0.12	0.15

a. All numbers except regulatory limits are rounded to two significant figures.

b. Regulatory limits for criteria pollutants are from 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391 (see Table 3-5).

c. Sum of highest concentrations at the accessible land withdrawal boundary regardless of direction. See Appendix G, Section G.1, for additional information.

d. There are no regulatory limits for public exposure to cristobalite, a form of crystalline silica. An Environmental Protection Agency health assessment (EPA 1996a, page 1-5) states that the risk of silicosis is less than 1 percent for a cumulative exposure of 1,000 (micrograms per cubic meter) × years. Using a 70-year lifetime, an approximate annual average concentration of 10 micrograms per cubic meter was established as a benchmark for comparison.

Concentrations would differ between the construction phase and the emplacement and development activities. The rate of fugitive dust release and the subsequent PM_{10} concentrations would be higher during the construction phase than during emplacement and development activities because of the differing amount of land surface disturbance. Concentrations of cristobalite would be somewhat higher during construction because of the higher rate of excavation. Concentrations of gaseous criteria pollutants would increase during emplacement and development activities because two boilers rather than one would be operating, even though vehicle emissions would decrease during emplacement and development. The exception would be emissions of carbon monoxide, which would be related more to vehicle emissions than boiler emissions. For all pollutants, the slight differences in estimated concentrations do not provide meaningful distinctions between the scenarios.

After the completion of emplacement activities, DOE would continue monitoring and maintenance activities (from 2034 to 2110) at the repository until closure. During this period, air pollutant emissions would decrease. Subsurface excavation and handling activities would be complete, resulting in a lower level of emissions. Pollutant concentrations at the analyzed land withdrawal area boundary, therefore, would be lower than those listed in Table 4-3.

4.1.2.3.2 *Radiological Impacts to Air Quality from Continuing Construction, and Operation and Monitoring*

The handling of spent nuclear fuel and continued subsurface ventilation would result in radionuclide releases during the early years of the operation and monitoring phase (2010 to 2033). Radionuclides would be released during transfer of fuel assemblies from transportation casks to disposal containers. Releases of naturally occurring radon-222 from subsurface ventilation would continue.

After the completion of handling and emplacement operations, DOE would continue monitoring repository facility maintenance activities (2034 to 2110). During this period, the Department would continue to ventilate the subsurface. Releases of naturally occurring radon-222 from subsurface ventilation would continue.

Handling, Emplacement, and Continuing Development Activities (2010 to 2033). The main radionuclide released to the atmosphere from the handling of spent nuclear fuel assemblies in the Waste Handling Building would be krypton-85, a radioactive noble gas (NRC 1979, page 4-10). From 90 to 2,600 curies would be released annually, depending on the packaging scenario (TRW 1999a, page 75). Releases of other noble gas radionuclides would be very small. Estimated annual releases would be about 1.0×10^{-6} curie of krypton-81, 3.3×10^{-5} curie of radon-219, 1.4×10^{-2} curie of radon-220, 4.6×10^{-6} curie of radon-222, and very small quantities of xenon-127 (TRW 1999a, page 75). Releases of these radionuclides, which are noble gases, would not be affected by facility filtration systems. No releases of particulate or soluble radionuclides would be likely. These radionuclides would be captured in the water of the transfer pool or the Waste Handling Building air filtration system.

A continuing source of dose to members of the public and noninvolved (surface) workers would be releases of naturally occurring radon-222 from the subsurface. Estimated radon emissions during the continuing construction, operation, and monitoring period would be greater than those during the initial construction period because of the larger excavated volume, with more radon emanations from the repository walls and greater quantities exhausted by ventilation. The estimated differences in radon releases between the thermal load scenarios would be a function of the excavated repository volume, the exhaust ventilation flowrate, and the repository air exchange rate; the packaging scenario would not affect radon releases. The low thermal load scenario would have the largest excavated volume, largest exhaust flowrates and, therefore, the largest radon release. Appendix G, Section G.2, contains more information on repository volume, flowrates, and radon releases for the three thermal load scenarios.

Table 4-4 lists estimated annual doses and doses from 24 years of emplacement activities to the maximally exposed individuals (public and noninvolved worker) and potentially affected populations from radionuclide releases from surface and subsurface facilities. Appendix G, Section G.2, discusses the methods for calculating the doses, and Section 4.1.7 discusses potential human health impacts from these doses. Krypton-85 and the other noble gas radionuclides released from the surface facilities would be small contributors to the overall public dose in comparison to radon-222 decay products from the subsurface facilities. All the radionuclides released from the surface facilities would be very small contributors to the overall public dose with the largest, krypton-85, contributing less than 0.001 percent of the dose to the public and noninvolved workers.

The dose to the offsite maximally exposed individual, about 20 kilometers (12 miles) south of the repository, would be 19, 22, or 44 millirem for the 24 years of emplacement and development activities under the high, intermediate, or low thermal load scenario, respectively. For comparison, the annual dose to the offsite maximally exposed individual would be about 8, 9, or 18 percent, respectively, of the 10-millirem-per-year regulatory limit (40 CFR Part 61), although this limit does not apply to radon releases. The population dose would be 99, 120, or 230 person-rem, respectively. The dose to members of the public would vary by thermal load scenario but not by packaging scenario because naturally occurring radon-222 released from the subsurface would be the dominant dose contributor. Releases from surface facilities during spent nuclear fuel handling would make very small differences in the dose received.

The median dose to the maximally exposed noninvolved (surface) worker in an office about 100 meters (330 feet) from the South Portal would be about 82 millirem for 24 years of emplacement activities,

Table 4-4. Estimated radiation doses for maximally exposed individuals and populations during handling, emplacement, and development activities during operation and monitoring phase.[a,b]

	Thermal load					
	High		Intermediate		Low	
Impact	Total	Annual average[c]	Total	Annual average	Total	Annual average
Dose to public						
Offsite MEI[d] (millirem)	19	0.78	22	0.93	44	1.8
80-kilometer population[e] (person-rem)	99	4.1	120	4.9	230	10
Dose to noninvolved (surface) workers						
Maximally exposed noninvolved (surface) worker[f] (millirem)	82	3.4	82	3.4	82	3.4
Yucca Mountain noninvolved (surface) worker population[g] (person-rem)						
Uncanistered scenario	63	2.6	75	3.1	140	5.7
Disposable canister scenario	62	2.6	74	3.1	130	5.6
Dual-purpose canister scenario	62	2.6	74	3.1	130	5.6
Nevada Test Site noninvolved worker population[h] (person-rem)	0.12	0.005	0.14	0.0059	0.27	0.012

a. Numbers are rounded to two significant figures.
b. Emplacement activities during the operation and monitoring phase would last 24 years, from 2010 to 2033. Continued subsurface development activities would last 22 years.
c. Annual average values reflect the increasing repository volume and radon release during subsurface development.
d. MEI = maximally exposed individual; about 20 kilometers (12 miles) south of the repository.
e. The population includes about 28,000 individuals within 80 kilometers (50 miles) of the repository (see Section 3.1.8).
f. Maximally exposed noninvolved worker location would be in the South Portal Operations Area.
g. The analysis considered noninvolved workers at both the North and South Portal Operations Areas.
h. DOE workers at the Nevada Test Site [6,600 workers (DOE 1996f, page 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

regardless of the thermal load scenario. The doses would be constant across the thermal load scenarios because the volume of the development area ventilated in each scenario would be similar. The estimated number of noninvolved workers at the repository site, whom the analysis assumed would all be at the North Portal Operations Area, would vary among the packaging scenarios. The dose to the noninvolved worker population would vary in proportion to (1) the amount of radon-222 released from the subsurface, because radon-222 would dominate the radiation doses, and (2) the number of noninvolved (surface) workers. At the North Portal Operations Area, there would be about 1,300 workers for the uncanistered packaging scenario and about 1,000 workers for the disposable canister and dual-purpose canister packaging scenarios. There would be an estimated 70 additional workers at the South Portal Operations Area regardless of packaging scenario. The combination of the low thermal load scenario (which would have the largest radon release) and the uncanistered packaging scenario would result in the highest noninvolved worker population dose, 140 person-rem over the 24-year emplacement period. Workers at the South Portal Operations Area, who would be near the ground-level releases of radon from this portal, would receive most of the population dose. Section 4.1.7 discusses impacts to workers directly involved in handling, emplacement, and continuing development activities.

Monitoring and Maintenance Activities (2034 to 2110). Monitoring would continue and maintenance would begin immediately after the completion of emplacement activities. One of the first activities would be the decontamination of the surface material handling facilities. This activity, which would last 3 years, would have minimal potential impact on air quality during monitoring and maintenance activities, except there would be a larger population of noninvolved workers employed for decontamination and these workers would be exposed to naturally occurring radon ventilated from the subsurface. The potential for releases of radionuclides from the surface facilities during these activities would be minimal and impacts would be very small.

Table 4-5 lists estimated annual doses and total doses that would occur over the 76 years of monitoring and maintenance activities to maximally exposed individuals and potentially affected populations from subsurface radon releases. Section 4.1.7 discusses potential radiological impacts from these doses. The dose over the 70-year lifetime of the hypothetical offsite maximally exposed individual, about 20 kilometers (12 miles) south of the repository, would be 30, 36, or 88 millirem during monitoring and maintenance activities of the high, intermediate, or low thermal load scenario, respectively. For comparison, the annual dose to the offsite maximally exposed individual would be about 4, 5, or 13 percent, respectively, of the 10-millirem-per-year regulatory limit (40 CFR Part 61), although this limit would not apply to repository radon releases. The hypothetical offsite maximally exposed individual would receive a higher dose than the noninvolved worker maximally exposed individual because air would be removed from the repository through exhaust shafts, which would result in more radon being carried to the exposure point for the offsite individual than to that for the noninvolved worker.

Table 4-5. Estimated radiation doses to maximally exposed individuals and populations from radon-222 releases from subsurface monitoring and maintenance activities (including decontamination) during operation and monitoring phase.[a,b]

	Thermal load					
	High		Intermediate		Low	
Impact	Total	Annual	Total	Annual	Total	Annual
Dose to public						
Offsite MEI[c] (millirem)	30	0.43	36	0.51	88	1.3
80-kilometer population[d] (person-rem)	160	2.1	190	2.5	470	6.2
Dose to noninvolved (surface) workers						
Maximally exposed noninvolved (surface) worker[e] (millirem)	2.0	0.039	2.3	0.046	5.8	0.12
Yucca Mountain noninvolved (surface) worker population (person-rem)						
Uncanistered scenario	0.14	0.025, 0.00087[f]	0.16	0.029, 0.0010[f]	0.40	0.072, 0.0026[f]
Disposable canister scenario	0.12	0.018, 0.00087[f]	0.14	0.021, 0.0010[f]	0.34	0.052, 0.0026[f]
Dual-purpose canister scenario	0.12	0.019, 0.00087[f]	0.14	0.022, 0.0010[f]	0.35	0.055, 0.0026[f]
Nevada Test Site noninvolved worker population[g] (person-rem)	0.27	0.0035	0.32	0.0042	0.79	0.010

a. Numbers are rounded to two significant figures.
b. Decontamination of surface facilities during the operation and monitoring phase would last 3 years at the beginning of the 76 years of monitoring and maintenance activities, which would last until 2110.
c. MEI = maximally exposed individual; about 20 kilometers (12 miles) south of the repository. Values are for a 70-year lifetime.
d. The population includes about 28,000 individuals within 80 kilometers (50 miles) of the repository (see Section 3.1.8).
e. Maximally exposed noninvolved worker location would be at the South Portal Operations Area. Values are for a 50-year onsite working lifetime.
f. First value is for the 3 years of decontamination activities; second value is for the 73 years of monitoring and maintenance.
g. DOE workers at the Nevada Test Site [6,600 workers (DOE 1996f, page 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

The population dose for 76 years of monitoring and maintenance activities would be 160, 190, or 470 person-rem, respectively. The dose to the maximally exposed noninvolved (surface) worker, who would be at the South Portal, would be 2.0, 2.3, or 5.8 millirem for a 50-year working lifetime during monitoring and maintenance activities for the high, intermediate, or low thermal load scenario, respectively. The dose over 76 years to the repository noninvolved (surface) worker population, which would include all surface workers (most of whom would be at the North Portal Operations Area), would vary depending on the thermal load scenario and the packaging scenario. The combination of the low thermal load scenario (largest radon release) and the uncanistered packaging scenario (largest noninvolved worker population) would result in the highest noninvolved (surface) worker population dose, 0.40 person-rem for the 76-year monitoring and maintenance period. The extension of monitoring and maintenance activities to 276 years would extend these impacts to future generations of workers and the public. Section 4.1.7 discusses impacts to workers directly involved in monitoring and maintenance activities.

4.1.2.4 Impacts to Air Quality from Closure (2110 to 2125)

This section describes potential nonradiological and radiological air quality impacts during the closure phase of the proposed Yucca Mountain Repository, which would begin in 2110 and last 6, 6, or 15 years for the high, intermediate, or low thermal load scenario, respectively. Activities during this phase would include the closure of subsurface repository facilities, the decommissioning of surface facilities, and the reclamation of remaining disturbed lands.

4.1.2.4.1 *Nonradiological Impacts to Air Quality from Closure*

During the closure phase, nonradiological air emissions would result from the backfilling and sealing of the repository subsurface and the reclamation of disturbed surface lands. Air emission sources would include the following:

- Fugitive dust emissions from the handling, processing (in a backfill preparation plant), and transfer of excavated rock to the subsurface
- Releases of gaseous criteria pollutants (nitrogen dioxide, sulfur dioxide, etc.) and particulate matter from fuel consumption
- Particulate matter from a concrete batch plant
- Fugitive dust releases from demolishing buildings, removing debris, and reclaiming land
- Cristobalite releases associated with handling and storing excavated rock

Table 4-6 lists potential impacts at the location of the offsite maximally exposed individual from the closure of the repository for the high, intermediate, and low thermal load scenarios.

Gaseous criteria pollutants would result primarily from vehicle exhaust. The low thermal load scenario would have somewhat higher emissions because of a larger vehicle fleet. During the closure phase, the maximum offsite concentrations of nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10} would be small, with the gaseous criteria pollutant concentrations being less than 1 percent of the applicable regulatory limits. The 24-hour PM_{10} concentrations would be about 5 percent of the regulatory limit for all three thermal load scenarios. Levels of $PM_{2.5}$ should also be well below the applicable standard, because a large fraction of the particulates listed for PM_{10} would be larger than 2.5 micrometers. The analysis did not consider standard construction dust suppression measures, which DOE would implement and which would further lower projected PM_{10} concentrations by reducing fugitive dust from surface-disturbing activities. These measures would not affect the concentrations of $PM_{2.5}$ because fugitive dust is not a major source of $PM_{2.5}$.

As discussed for the construction phase (see Section 4.1.2.2.1), the analysis of the closure phase assumed that 28 percent of the fugitive dust released from the muck pile would be cristobalite. Table 4-6 lists

Table 4-6. Estimated maximum criteria pollutant and cristobalite concentrations at the analyzed land withdrawal area boundary during closure phase (micrograms per cubic meter).[a]

Pollutant	Averaging time	Regulatory limit[b]	Maximum concentration[c]			Percent of regulatory limit		
			Thermal load			Thermal load		
			High	Intermediate	Low	High	Intermediate	Low
Nitrogen dioxide	Annual	100	0.080	0.13	0.12	0.080	0.13	0.12
Sulfur dioxide	Annual	80	0.0076	0.013	0.011	0.097	0.016	0.014
	24-hour	365	0.57	0.093	0.082	0.016	0.025	0.022
	3-hour	1,300	0.045	0.74	0.66	0.035	0.057	0.050
Carbon monoxide	8-hour	10,000	0.67	1.1	0.98	0.0065	0.011	0.0095
	1-hour	40,000	4.1	6.6	5.9	0.010	0.017	0.015
PM_{10} ($PM_{2.5}$)	Annual	50 (15)	0.52	0.56	0.53	1.0	1.1	1.1
	24-hour	150 (65)	6.5	6.8	6.6	4.3	4.5	4.4
Cristobalite	[Annual[d]]	[10[d]]	0.010	0.014	0.0053	0.10	0.14	0.053

a. All numbers except regulatory limits are rounded to two significant figures.
b. Regulatory limits from 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391 (see Table 3-5).
c. Sum of the highest concentrations at the accessible land withdrawal boundary regardless of direction.
d. There are no regulatory limits for public exposure to cristobalite, a form of crystalline silica. An Environmental Protection Agency health assessment (EPA 1996a, page 1-5) states that the risk of silicosis is less than 1 percent for a cumulative exposure of 1,000 (micrograms per cubic meter) × years. Using a 70-year lifetime, an approximate annual average concentration of 10 micrograms per cubic meter was established as a benchmark for comparison.

estimated cristobalite concentrations to which the offsite maximally exposed individual would be exposed during closure. As noted in Section 4.1.2.2.1, there are no public limits for exposure to cristobalite, so the analysis used an approximate annual average concentration of 10 micrograms per cubic meter as a benchmark. The postulated exposure to cristobalite from closure activities would be small, about 0.014 microgram per cubic meter or less for all three thermal load scenarios. For all pollutants, the slight differences in estimated concentrations do not provide meaningful distinctions between any of the scenarios.

4.1.2.4.2 *Radiological Impacts to Air Quality from Closure*

During the closure phase the only doses from releases of radionuclides to the atmosphere would be from naturally occurring radon-222 and its radioactive decay products released from the continued ventilation of subsurface facilities. The analysis assumed that subsurface ventilation would continue for the duration of the closure phase, lasting 6, 6, or 15 years for the high, intermediate, or low thermal load scenario, respectively. Exposure to the noninvolved (surface) worker population and the public would occur during the 6-year period while this group was working on surface facility closure. For the low thermal load scenario, exposures to members of the public and noninvolved workers would occur during a 15-year period.

Table 4-7 lists estimated annual doses and total doses from radon-222 during the closure phase to maximally exposed individuals and potentially affected populations from radionuclide releases from subsurface facilities. Section 4.1.7 discusses potential radiological impacts from these doses. The total dose to the offsite maximally exposed individual about 20 kilometers (12 miles) south of the repository would be 2.6, 3.0, or 19 millirem for the 6, 6, or 15 years of closure activities under the high, intermediate, or low thermal load scenario, respectively. Although the limit does not apply to releases of radon, the annual dose to the offsite maximally exposed individual would be about 4, 5, or 12 percent, respectively, of the 10 millirem-per-year regulatory limit (40 CFR Part 61). The population dose would be 13, 15, or 93 person-rem, respectively, for the closure phase. The dose to the maximally exposed noninvolved (surface) worker at the South Portal would be 0.24, 0.28, or 1.7 millirem, respectively, for

Table 4-7. Estimated radiation doses to maximally exposed individuals and populations from radon-222 releases from the subsurface during closure phase.[a,b]

	Thermal load					
	High		Intermediate		Low	
Release	Total	Annual	Total	Annual	Total	Annual
Dose to public						
MEI[c] (millirem)	2.6	0.43	3.0	0.50	19	1.2
80-kilometer population[d] (person-rem)	13	2.1	15	2.5	93	6.2
Dose to noninvolved (surface) workers						
Maximally exposed noninvolved (surface) worker[e] (millirem)	0.24	0.039	0.28	0.046	1.7	0.12
Yucca Mountain noninvolved (surface) worker population (person-rem)						
Uncanistered scenario	0.041	0.0068	0.048	0.0080	0.12	0.020
Disposable canister scenario	0.029	0.0049	0.035	0.0058	0.086	0.014
Dual-purpose canister scenario	0.032	0.0053	0.037	0.0062	0.093	0.016
Nevada Test Site noninvolved worker population[f] (person-rem)	0.021	0.0035	0.025	0.0042	0.16	0.010

a. Numbers are rounded to two significant figures.
b. The closure phase would begin in 2110 and last 6, 6, or 15 years for the high, intermediate, or low thermal load scenario, respectively.
c. MEI = maximally exposed individual; public MEI location would be 20 kilometers (12 miles) south of the repository.
d. The population includes about 28,000 individuals within 80 kilometers (50 miles) of the repository (see Section 3.1.8).
e. Maximally exposed noninvolved worker location would be at the South Portal Operations Area.
f. DOE workers at the Nevada Test Site [6,600 workers (DOE 1996f, page 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

the entire closure phase. The dose to the noninvolved repository (surface) worker population would vary depending on the thermal load and packaging scenarios. The combination of the low thermal load scenario (largest radon releases) and the uncanistered packaging scenario (largest noninvolved worker population) would result in the highest total noninvolved worker population dose, 0.12 person-rem.

4.1.3 IMPACTS TO HYDROLOGY

The following sections describe environmental impacts to the hydrology of the Yucca Mountain region, first from performance confirmation activities (Section 4.1.3.1), then from construction, operation and monitoring, and closure actions. The latter actions are presented in terms of surface water (Section 4.1.3.2) and groundwater (Section 4.1.3.3). Chapter 5 discusses long-term postclosure impacts resulting from repository performance.

The analysis evaluated surface-water and groundwater impacts separately. The attributes used to assess surface-water impacts were the potential for introduction and movement of contaminants, potential for changes to runoff and infiltration rates, alterations in natural drainage, and potential for flooding to aggravate or worsen any of these conditions. The region of influence for surface-water impacts included areas near construction and operation activities that would be susceptible to erosion, areas affected by permanent changes in flow, and downstream areas that would be affected by eroded soil or potential spills of contaminants. The analysis of surface-water impacts considered known perennial and intermittent lakes, surface streams, and washes.

The analysis assessed groundwater impacts to determine the potential for a change in infiltration rates that could affect groundwater, the potential for introduction of contaminants, the availability of groundwater for use during construction and operations, and the potential that such use would affect other users. The region of influence for this analysis included aquifers under the areas of construction and operations that DOE could use to obtain water and downstream aquifers that repository use or long-term releases from the repository could affect. The evaluation of groundwater impacts considered perennial yields of groundwater resources in comparison to known uses and requirements.

The conclusions of the evaluations discussed in this section are as follows:

- Repository operation would result in minor changes to runoff and infiltration rates.
- Water demand under scenarios with the highest consumption would be below the Nevada State Engineer's ruling of perennial yield (the amount that can be withdrawn annually without depleting reserves) for the Jackass Flats groundwater basin. However, the highest demand scenario in combination with ongoing Nevada Test Site demand from the same basin would exceed the lowest estimates of perennial yield.
- The combined water demand of the repository and the Nevada Test Site would, at most, have minor impacts on the availability of groundwater in the Amargosa Desert in comparison to the quantities of water already being withdrawn there.
- The potential for flooding at the repository site is extremely small.

4.1.3.1 Impacts to Hydrology from Performance Confirmation

Performance confirmation activities would be unlikely to cause large impacts to the surface hydrology at the Yucca Mountain site, where there are no perennial streams or other permanent surface-water bodies. As during site characterization, DOE would design roads or other surface disturbances to minimize alterations to natural flowpaths and nearby washes (such as Drill Hole Wash). (See Section 4.1.4.2 and Chapter 11 for discussions of protection of waters of the United States.)

The performance confirmation studies would not adversely affect groundwater quality because DOE would use only limited quantities and types of hazardous materials, and activities involving such materials would be in strict accordance with applicable regulations and DOE Orders. State and Federal environmental, health, and safety regulations, as well as its own internal rules would require DOE to manage hazardous materials carefully and to clean up and report any measurable spills or releases promptly. Thus, the control of hazardous materials would be such that the potential for groundwater contamination would be very low.

DOE would use existing groundwater wells to support performance confirmation activities (for example, wells J-12 and J-13). In addition, it could use the existing C-well complex for aquifer testing and for a backup water supply. The Department expects water use from wells J-12 and J-13 to be similar to or less than that experienced during site characterization, which averaged about 0.093 million cubic meters (75 acre-feet) a year from 1993 through 1997 (not including test pumping at the C-well complex) (see Table 3-15). This would equal approximately 2 to 9 percent of the estimated perennial yield of the hydrographic basin (Jackass Flats) of 1.1 million to 4.9 million cubic meters (880 to 4,000 acre-feet) a year (see Table 3-11). Therefore, adverse effects on the quantity of groundwater resources would be unlikely. DOE could conduct pump tests of the aquifer at the C-well complex during performance confirmation activities. Under such tests, the amount pumped probably would be similar to that pumped during site characterization [about 0.23 million cubic meters (190 acre-feet) per year]. Even with this additional quantity, water demand would still be well below the lowest estimates of the basin's perennial yield, and DOE would manage water withdrawn from the C-well complex as part of aquifer testing in the same manner it has used for site characterization activities (that is, discharged to a spreading basin with State of Nevada concurrence and credit for groundwater recharge).

4.1.3.2 Impacts to Surface Water from Construction, Operation and Monitoring, and Closure

There are no perennial streams or other permanent surface-water bodies in the Yucca Mountain vicinity. The occurrence of natural surface water is limited to short periods when precipitation lasts long enough or is of high enough intensity to generate runoff to the natural drainage channels. In rare instances, runoff from the area of the proposed repository and support facilities could reach such channels as Drill Hole Wash, then flow to Fortymile Wash, and eventually reach the Amargosa River underground. Under most precipitation events, however, water simply soaks into the ground and is usually lost to evapotranspiration or, if there is enough to accumulate in drainage channels, soaks into the dry washes before traveling far, becoming potential recharge in these localized areas. Other potential sources of surface water associated with the Proposed Action, such as the water used for dust suppression, would be a result of pumping groundwater to the surface.

The surface-water impacts of primary concern are related to the following:

- Introduction and movement of contaminants
- Changes to runoff or infiltration rates
- Alterations of natural drainage
- Impacts to floodplains

Discharges of Water to the Surface

During the 5-year initial construction period (2005 to 2010), and during the emplacement and development activities of the continuing construction, operation, and monitoring period that would follow (2010 to 2033), sources of surface water other than precipitation would be limited primarily to the water DOE would use for dust suppression on the surface and below ground (with accumulations pumped back to the surface). Sanitary sewage, which would be piped to septic tank and drainage field systems, would not produce surface water. In addition, DOE would pump fresh water (groundwater) at the site and store it in tanks.

DOE has evaluated dust suppression actions during characterization efforts at the Yucca Mountain site for their potential to cause deep infiltration of water (DOE 1997i, pages 51 to 53 and 73). The evaluation concluded that the amount of water actually used for dust suppression activities during site characterization did not cause water to penetrate the underlying rock. Studies at the site on infiltration capacities of natural soils (Flint, Hevesi, and Flint 1996, pages 57 to 59), when combined with application rates measured during site characterization, show that runoff or deep infiltration would not occur as a result of water applications for dust suppression. DOE would establish controls as necessary to ensure that water application for subsurface and surface dust control did not affect repository performance or result in large impacts.

Water would be pumped from the surface facilities to the subsurface during the construction phase and operation and monitoring phase while subsurface development continued. DOE would collect excess water from dust suppression applications and water percolating into the repository drifts, if any, and pump it to the surface, generating another source of surface water. Water pumped from the subsurface would go to an evaporation pond at the South Portal Operations Area. The pond would be lined with heavy plastic to prevent infiltration or water loss. Table 4-8 lists discharge estimates to the South Portal

Table 4-8. Annual water discharges to South Portal evaporation pond for thermal load scenarios.[a,b]

Phase	High thermal load	Intermediate thermal load	Low thermal load
Construction			
Discharge (cubic meters)[c]	8,400	10,000	10,000
Duration (years)	5	5	5
Operation and monitoring			
Discharge (cubic meters)	7,900	9,500	33,000
Duration (years)	22	22	22

a. Source: TRW (1999b, pages 6-9 and 6-18).
b. Estimated at 13 percent of the process water pumped to the subsurface based on Exploratory Studies Facility construction experience.
c. To convert cubic meters to gallons, multiply by 264.18.

evaporation pond for the three thermal load scenarios. During the operation and monitoring phase, the quantity of water discharged would vary in proportion to the amount of subsurface excavation. DOE would also investigate the feasibility of recycling all, or a portion, of this water.

The operation of heating and air conditioning systems at the North Portal Operations Area would result in the generation of wastewater (primarily from cooling tower blowdown and water softener regeneration) that DOE would discharge to the North Portal evaporation pond, which would be lined with heavy plastic. Water collected from the emplacement side of the subsurface area, if any, would also be pumped to this pond after verification that it was not contaminated. Table 4-9 lists discharge estimates to the North Portal evaporation pond for each packaging scenario during the operation and monitoring phase.

Table 4-9. Annual water discharges to North Portal evaporation pond during operation and monitoring phase for each packaging scenario.[a]

	Packaging scenario[b]		
Factor	UC	DISP	DPC
Discharge (million liters)[c]	30	25	25
Duration (years)	24	24	24

a. Source: TRW (1999a, page 75).
b. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister.
c. To convert liters to gallons, multiply by 0.26418.

The South Portal evaporation pond would be double-lined with polyvinyl chloride and would have a leak detection system (TRW 1998f, page 16). The North Portal evaporation pond, which is intended primarily for cooling and heating process water, would, at a minimum, have a polyvinyl chloride liner (TRW 1998f, pages 16 and 28). With proper maintenance, both ponds should remain intact and would have no effect on the site. Section 4.1.4.2 discusses impacts to wildlife that could result from the presence of these ponds. Chapter 9 discusses mitigation measures associated with the Proposed Action.

Other uses of water during the continuing construction, operation, and monitoring period would occur in the repository facilities and would have little, if any, potential to generate surface water. These sources include the washdown stations and the pools in the Waste Handling Building. Water from either of these sources would be managed as liquid low-level radioactive waste and treated in the Waste Treatment Building. Water from the treatment process would be recycled to the extent practicable, and residues and solids would be prepared for offsite shipment and disposal.

The quantity of water discharges to the surface from monitoring and maintenance activities and from closure would be similar to or less than those discussed for the initial construction period and emplacement and development activities. The evaporation ponds would no longer be in use but other manmade sources of surface water should be very similar; water storage tanks would still be in use, there would be sanitary sewage, and dust suppression activities would occur.

Potential for Contaminant Spread to Surface Water

The potential for contaminants to reach surface water would generally be limited to the occurrence of a spill or leak followed by a rare precipitation or snow melt event large enough to generate runoff. DOE would design each facility that would contain radioactive material at the repository site such that flooding would not threaten material in the facility. Consistent with DOE Order 6430.1A, *General Design Criteria*, Nuclear Regulatory Commission licensing requirements, and national standards such as those of the American National Standards Institute, facilities in the Restricted Area (for the management of radioactive materials) would be built to withstand the probable maximum flood. For example, if the footprint of a facility in the Restricted Area was within the predicted natural inundation level of the probable maximum flood, one way to protect the facility would be to build up its foundation so it would be above the flood level and associated debris flows (TRW 1998f, pages 32 to 37). Other facilities would be designed and built to withstand a 100-year flood, consistent with common industrial practice. However, the inundation levels expected from a 100-year, 500-year, or regional maximum flood would represent little hazard to the proposed repository, the portals of which would be at higher elevations than the flood-prone areas (TRW 1999h, page 2-7).

DOE would minimize the potential for a contaminant spread by managing spills and leaks in the proper and required manner. Activities at the site would adhere to a spill prevention, control, and countermeasures plan [Kiewit (1997, all) is an example] to comply with environmental regulations and to ensure best management practices. The plan would describe the actions DOE would take to prevent, control, and remediate spills. It would also describe the reporting requirements that would accompany the identification of a spill. As an additional measure to reduce the potential for contaminant release to surface water, DOE would build two stormwater retention basins near the North Portal Operations Area, one for the Restricted Area and one for the balance-of-plant facilities. The basin for the Restricted Area would contain the runoff from a storm consistent with the probable maximum flood. The basin for the balance-of-plant area would contain the runoff from a storm consistent with a 100-year flood.

The primary sources of potential surface-water contaminants during both the construction and the operation and monitoring phases would be the fuels (diesel and gasoline) and lubricants (oils and greases) needed for equipment. Both the South and North Portal Operations Areas would contain fuel-oil storage tanks. These tanks would be in place relatively early in the construction phase. Each would be constructed with an appropriate containment structure (consistent with 40 CFR Part 112). Other organic materials such as paints, solvents, strippers, and concrete additives would be present during the construction phase but in smaller quantities and much smaller containers.

The operation and monitoring phase would involve the use of other chemicals, particularly in the Waste Treatment Building, where the liquid low-level radioactive waste treatment process, for example, would include the use of liquid sodium hydroxide and sulfuric acid. In addition, this phase would require relatively small quantities of cleaning solvents [about 480 to 1,300 liters (130 to 330 gallons) a year] (TRW 1999a, page 74). Because these materials would be used and stored inside buildings and managed in accordance with applicable environmental, health, and safety standards and best management practices, there would be little potential for contamination to spread through contact with surface water.

In addition, liquid low-level radioactive waste present in the Restricted Area would be treated in the Waste Treatment Building to stabilize such material with cement or grout before it left the facility. Similarly, hazardous waste and mixed waste would be maintained and moved in closed containers. These conditions would minimize the potential for spills and leaks that could lead to contaminant spread.

Radioactive materials present during the continuing construction, operation, and monitoring period would be managed in the Restricted Area of the North Portal Operations Area. This would include the

Carrier Parking Area and Carrier Preparation Building across Midway Valley Wash to the northeast. The radiological materials would always be in containers or casks except when they were in the Waste Handling and Waste Treatment Buildings. In those buildings, facility system and component design would prevent inadvertent releases to the environment; drainlines would lead to internal tanks or catchments, air emissions would be filtered, fuel pools would have secondary containment and leak detection, and other features would have similar safety or control components.

During the continuing construction, operation, and monitoring period a surface environmental monitoring system would monitor the surface areas and groundwater for radioactive and hazardous substance release (DOE 1998a, Volume 2, page 4-37). It would also monitor facility effluents and testing wells for the presence of radiological or other hazardous constituents that could indicate a release from an operation activity. The combination of minor sources of surface water and the prevention and control of contaminant releases would limit the potential for contaminant spread by surface water.

Monitoring and maintenance activities after the completion of emplacement would involve a decrease in general activities at the site and, accordingly, less potential for spills or releases to occur. Decontamination actions that would follow emplacement could present other risks, due to the possible presence of decontamination chemicals and the start of new work activities. DOE would continue to use controls, monitoring, response plans and procedures, and regulatory requirements to limit the potential for spills or releases to occur from these activities.

The potential for contaminant spread would be limited during the closure phase and would be reduced further during postclosure care of the site. As in the other phases, engineering controls, monitoring, and release response requirements would limit the potential for contaminants to reach surface water.

Potential for Changes to Surface Water Runoff or Infiltration Rates

Construction activities that disturbed the land surface would alter the rate at which water could infiltrate the disturbed areas. A maximum of about 2 square kilometers (500 acres) of land would be disturbed during the construction and operation and monitoring phases (see Chapter 2). Depending on the type of disturbance, the infiltration rate could increase (for example, in areas with loosened soil) or decrease (for example, in areas where construction activities had compacted the soil or involved the installation of relatively impermeable surfaces like asphalt pads, concrete surfaces, or buildings). Most of the land disturbance during construction would result in surfaces with lower infiltration rates; that is, the surfaces would be less permeable than natural soil conditions and would cause an increase in runoff. However, DOE expects the change in the amount of runoff actually reaching the drainage channels to be relatively minor, because repository construction would affect a relatively small amount of the natural drainage area. For example, one side of the proposed North Portal facilities is drained by Midway Valley Wash and the other is drained by Drill Hole Wash. The 0.6 square kilometer (150 acres) of disturbance at the North Portal area (of the total 2 square kilometers disturbed) would be small (less than 4 percent) in comparison to the estimated 18 square kilometers (4,400 acres) that comprise the drainage area for the Midway Valley and Drill Hole Washes by the time they reach the North Portal area (Bullard 1992, Table 5).

Monitoring and maintenance activities would not disturb additional land and, therefore, would have no notable impacts to runoff rates in the area. Reclamation of previously disturbed land would restore preconstruction runoff rates.

DOE anticipates that closure activities would disturb only land that had been previously disturbed during earlier phases. The removal of structures and impermeable surfaces would decrease runoff from these areas and should put them in a condition closer to that of the surrounding natural surfaces. Reclamation efforts such as topsoil replacement and revegetation should help restore the disturbed areas to nearly natural conditions in relation to infiltration and runoff rates. The construction of monuments as long-lasting markers of the site use would be likely to make their locations impervious to infiltration but, as described above, change in runoff from the relatively small impervious areas would be small in comparison to the total drainage area.

Potential for Altering Natural Surface-Water Drainage

Construction activities can alter natural drainage systems if they (1) increase the erosion and sedimentation process (material eroded from one location in the drainage system is subsequently deposited in another location), or (2) place a structure, facility, or roadway in a drainage channel or flood zone. Section 4.1.4.4 discusses erosion issues. The focus of this section is the planned construction of structures, facilities, or roadways over natural drainage channels.

Pursuant to Executive Order 11988, *Floodplain Management*, each Federal agency is required, when conducting activities in a floodplain, to take action to reduce the risk of flood damage; minimize the impact of floods on human safety, health, and welfare; and restore and preserve the natural and beneficial values served by floodplains. DOE regulations implementing this Executive Order are at 10 CFR Part 1022.

If DOE received authorization to construct, operate and monitor, and close a geologic repository at Yucca Mountain, it would ship spent nuclear fuel and high-level radioactive waste to the repository for a period of about 24 years beginning in 2010. Some transportation-related construction, operation, and maintenance actions associated with the DOE proposal would occur in the floodplains of as many as four washes in the Yucca Mountain vicinity. Other construction, operation, and maintenance actions could occur in floodplains or wetlands elsewhere in Nevada along one of five alternative rail corridors DOE could select to transport spent nuclear fuel and high-level radioactive waste to the repository. Construction, operation, and maintenance actions could also occur in floodplains or wetlands at one of three alternative intermodal transfer station sites in Nevada if DOE chose a heavy-haul truck route for transportation.

Construction, operation, and maintenance of a rail line, roadways, and bridges in the Yucca Mountain vicinity could affect the 100- and 500-year floodplains of Fortymile Wash, Busted Butte Wash, Drill Hole Wash, and Midway Valley Wash at Yucca Mountain. The floodplains affected and the extent of activities in the floodplains would depend on the route DOE selected.

Appendix L contains a floodplain/wetlands assessment that describes in detail the actions that DOE could take to construct, operate, and maintain a branch rail line or highway route in the Yucca Mountain vicinity. The assessment analyzed the potential effects of these actions on the floodplains of Fortymile Wash, Busted Butte Wash, Drill Hole Wash, and Midway Valley Wash. The analysis indicated that consequences of the actions DOE could take in or near the floodplains of these four washes would be minor and unlikely to increase the impacts of floods on human health and safety or harm the natural and beneficial values of the affected floodplains. It also indicated that there are no delineated wetlands at Yucca Mountain.

The assessment in Appendix L presents a programmatic comparison of what is known about the floodplains, springs, and riparian areas along the five alternative rail routes and at the three alternative intermodal transfer station sites. In general, wetlands have not been delineated along the rail routes or at the three station sites. If DOE selected a rail corridor or heavy-haul truck route to transport spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site, it would prepare a detailed floodplain/wetlands assessment of the selected alternative.

Repository-related structures could affect small drainage channels or washes. DOE expects to address these other washes with minor diversion channels, culverts, or similar drainage control techniques.

Closure of the repository should involve no actions that would alter natural drainage beyond those from the other phases. Areas where facilities were removed would be graded to match the natural topography to the extent practicable. Monuments would not be constructed in locations where they would alter important drainage channels or patterns and, in the process, back up or divert any meaningful volume of runoff.

4.1.3.3 Impacts to Groundwater from Construction, Operation and Monitoring, and Closure

This section identifies potential impacts to groundwater. Section 3.1.4 describes existing groundwater characteristics and uses in the Yucca Mountain vicinity. The potential impacts discussed in this section would be associated with the relatively short duration of the active life of the repository, which would include construction, operation and monitoring, and closure. The following impacts would be of primary concern during the active life of the repository:

- The potential for a change in infiltration rates that could increase the amount of water in the unsaturated zone and adversely affect the performance of waste containment in the repository, or decrease the amount of recharge to the aquifer
- The potential for contaminants to migrate to the unsaturated or saturated groundwater zones during the active life of the repository
- The potential for water demands associated with the repository to deplete groundwater resources to an extent that could affect downgradient groundwater use or users

This section discusses these potential impacts in general terms, primarily in relation to changes from existing conditions.

Infiltration Rate Changes

As discussed in Section 4.1.3.2, surface-disturbing construction activities would alter infiltration rates in the repository area. In the Yucca Mountain environment, water rarely travels long distances on the surface before infiltrating into the ground or evaporating. If construction activities resulted in disturbed land that was loose or broken up, local infiltration would increase and the amount of runoff reaching nearby drainage channels would decrease accordingly. Conversely, completed construction that involved either compacted soil or facility surfaces (concrete pads, asphalt surfaces, etc.) would result in less local infiltration and more water available to reach the drainage channels and then infiltrate into the ground. However, the location where infiltration takes place can have an effect on what happens to the water. That is, in some locations the water would be more likely to contribute to deep infiltration and possibly even to recharge to the aquifer.

In the semiarid environment in the Yucca Mountain vicinity, surface areas where meaningful recharge to the aquifer can occur are generally places such as Fortymile Wash (Section 3.1.4.2.2), which collects runoff from a large drainage area. Enough water can accumulate there to cause deep infiltration and occasional recharge. There is not enough precipitation or runoff in most other areas to generate infiltration deep enough to prevent its loss to evapotranspiration between precipitation events. In general, this will be the case even when land disturbance causes an increase in local infiltration. The most likely way that recharge could be affected would be for land disturbance to cause additional runoff (as from constructed facilities) that could accumulate in areas such as Fortymile Wash, and the effect would be a potential for increased 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.

Surface disturbances could change infiltration rates in areas where the layer of unconsolidated material is thin and the disturbance resulted in the exposure of fractured bedrock. Cracks and crevices in the bedrock could provide relatively fast pathways for the movement of water to deep parts of the unsaturated zone (TRW 1999h, pages 2-19 to 2-21), where the water would be less susceptible to evapotranspiration. These effects would be applicable to the Emplacement and Development Shaft Operations Areas, which would be on steeper terrain, uphill from the North and South Portal Operations Areas, where the depth of unconsolidated material is likely to be thin. However, the amount of disturbed land would be small in comparison to the surrounding undisturbed area, and any net change in infiltration would be small.

Subsurface activities would have the potential to affect the amount of water in the unsaturated zone that could infiltrate more deeply, possibly even as recharge to the aquifer. These activities would include measures to minimize the quantities of standing or infiltrating water in the repository by pumping it to the surface for evaporation. Potential sources of this water could include water percolating in from the unsaturated zone and water pumped from the surface for underground dust control measures. The latter should involve the largest volume by far, much of which would be brought to the surface with the excavated rock generated by tunnel boring machines. Excess water in the subsurface would evaporate (the underground areas would be ventilated), be collected and pumped to the surface, or be lost as infiltration to cracks and crevices in the rock. During excavation of the Exploratory Studies Facility, DOE tracked water use and used water tracers to help track its movement. The purpose of these actions was to minimize loss of this water to the subsurface environment and to ensure that subsurface water use did not adversely affect either future repository performance or ongoing site investigations (DOE 1997j, all). This careful use of water in the subsurface would continue during repository construction activities. Given the mechanisms to remove the water (excavated rock removal, ventilation, and pumping) and the careful use of water in the subsurface, along with the relatively minor importance of Yucca Mountain recharge to the local and regional groundwater system, DOE expects perturbations in recharge through Yucca Mountain to be small and of minimal consequence to the local and regional groundwater system.

No additional land disturbance would occur from monitoring and maintenance activities and, therefore, there would be no notable impacts to infiltration rates in the area. There would be no additional land disturbance during closure. The implementation of soil reclamation and revegetation would accelerate a return to more natural infiltration conditions. If DOE built a monument (or monuments) to provide a long-lasting marker for the site, its location could be impermeable and thus could generate minor amounts of additional runoff to drainage channels.

Potential for Contaminant Migration to Groundwater

Section 4.1.3.2 discusses the types of potential contaminants that could be present at the repository surface facilities during the various phases of its active life. It also discusses the possibility of spills or releases of these materials to the environment.

To pose a threat to groundwater, a contaminant would have to be spilled or released and then carried down either by its own volume or with infiltrating water. The depth to groundwater, the thickness of alluvium in the area, and the arid environment would combine to reduce the potential for a large contaminant migration, as would adherence to regulatory requirements and plans such as a Spill

Prevention Control and Countermeasure Plan (see Section 4.1.3.2). Section 4.1.8 further discusses the potential for onsite accidents that could involve a release of contaminants.

Groundwater Resources

The quantity of water necessary to support the Proposed Action would be greatest during the initial construction period and the continuing construction, operation, and monitoring period. Peak demand would occur while DOE was emplacing nuclear material in completed drifts (tunnels) at the same time it was developing other drifts. Table 4-10 summarizes the estimated water demands during these two phases and during closure. Water demand during construction would depend on the thermal load scenario because the emplacement of less spent nuclear fuel (that is, low thermal load) per foot of repository tunnel would require more excavation. Water demand during these phases would also depend on the packaging scenario.

Table 4-10. Annual water demand for construction, operation and monitoring, and closure.[a]

Phase	Proposed schedule	Water demand (acre-feet)[b] by thermal load		
		High	Intermediate	Low
Construction	2005 - 2010	150[c]	170[c]	170[c]
Operation and monitoring (by packaging scenario)				
Emplacement and development activities[d]	2010 - 2033			
Uncanistered		250	260	480
Disposable canister		220	230	450
Dual-purpose canister		220	230	450
Monitoring activities[e]	2033 - 2036			
Uncanistered		200	200	200
Disposable canister		160	160	160
Dual-purpose canister		160	160	160
Closure	2110 to varies			
Each packaging scenario		80	90	90

a. Source: TRW (1999a, pages 71, 74, 78, and 81); TRW (1999b, pages 6-3, 6-14, 6-21, 6-27, 6-28, and 6-37).
b. To convert acre-feet to cubic meters, multiply by 1,233.49.
c. Does not include water needed to construct a potential rail line.
d. Construction (or development) of the subsurface area during the operation and monitoring phase would take 22 years for the Proposed Action (emplacement would continue another 2 years). The values shown represent the highest demands projected for this phase and would occur during the period when both subsurface development and nuclear material emplacement were underway.
e. Values shown for monitoring activities are only applicable to the first 3 years (as shown by the schedule), when decontamination of surface facilities would be performed. Water demand for the 73 years that follow would be minimal.

As listed in Table 4-10, water demand during initial construction would range from about 0.19 million to about 0.21 million cubic meters (150 to 170 acre-feet) per year, depending on the thermal load scenario. Further, depending on the thermal load and packaging scenarios, demand during the emplacement and development period of the operation and monitoring phase could range from about 0.27 million to about 0.59 million cubic meters (220 to 480 acre-feet) per year. The first 3 years of the monitoring portion of the operation and monitoring phase would require water at a rate varying from 0.2 million to 0.25 million cubic meters (160 to 200 acre-feet) per year. The closure phase would require about 0.099 million to 0.11 million cubic meters (80 to 90 acre-feet) per year.

The water demand would be met by pumping from wells in the Jackass Flats hydrographic area, using existing wells J-12, J-13, and the C-well complex. Nevada Test Site activities in this same area also withdraw water from this hydrographic area. This ongoing demand from Nevada Test Site activities has an effect on the affected environment and would continue to represent part of the demand from the

Jackass Flats hydrographic area. Consequently, this additional water demand is discussed here and as part of the cumulative impacts in Chapter 8.

DOE evaluated potential impacts of the water demands on area groundwater resources by two methods:

- Consideration of impacts observed or measured during past water withdrawals
- Comparison of the proposed demand to the perennial yield of the aquifer supplying the water

During the initial construction period, the estimated water demand from the Jackass Flats Hydrographic Area would be about 0.53 million to about 0.55 million cubic meters (430 to 450 acre-feet) a year, including the ongoing demand from Nevada Test Site activities [projected to be 0.34 million cubic meters (280 acre-feet) a year (DOE 1998n, Table 11-2, page 11-6)]. This quantity is very similar to the roughly 0.49 million cubic meters (400 acre-feet) withdrawn from the Jackass Flats basin in 1996 (see Chapter 3, Table 3-15). The level of water demand during the construction phase probably would result in declines in water levels in the production wells and nearby. DOE expects the amount of decline to be similar to the groundwater level fluctuations discussed in Chapter 3, Section 3.1.4.2.2 (see Table 3-16), during which elevation decreases as large as 12 centimeters (4.8 inches) occurred in the production wells over a 6-year period. However, this decline would diminish to undetectable levels as the distance from the repository increased and would result in very small effects to the overall groundwater system.

During the continuing construction, operation, and monitoring period, groundwater withdrawal rates would increase as listed in Table 4-10. When combined with the ongoing demand from the Nevada Test Site, these rates would be sufficiently larger than those tracked from current activities (see Chapter 3, Table 3-15).

Perennial yield is the estimated quantity of groundwater that can be withdrawn annually from a basin without depleting the reservoir. As discussed in Chapter 3, Section 3.1.4.2, the estimated perennial yield of the aquifer in the Jackass Flats hydrographic area is between 1.1 million and 4.9 million cubic meters (880 and 4,000 acre-feet) (Thiel 1997, page 8). However, as indicated in footnote f to Table 3-11 in Chapter 3, the low estimate of perennial yield for Jackass Flats is accompanied by the qualification that 0.37 million cubic meters (300 acre-feet) is attributed to the eastern one-third of the area, and 0.72 million cubic meters (580 acre-feet) is attributed to the western two-thirds where wells J-12 and J-13 are located. This distinction was made to be consistent with the belief of some investigators that the two portions of Jackass Flats have different general flow characteristics. Assuming this is correct, the most conservatively low estimate of perennial yield applicable to the location of wells J-12 and J-13 would be 0.72 million cubic meters (580 acre-feet). The highest estimated water demand during the continuing construction, operation, and monitoring period would not exceed this lowest estimate of perennial yield, and it would represent only about 12 percent of the higher estimate of perennial yield.

A past DOE application for a water appropriation from Jackass Flats resulted in a State Engineer's ruling (Turnipseed 1992, pages 9 to 11) that described the perennial yield of Jackass Flats (Hydrographic Area 227A) as 4.9 million cubic meters (4,000 acre-feet). The same ruling identified the estimated annual recharge for the western two-thirds of this hydrographic area as 0.72 million cubic meters (580 acre-feet). Based on this information, the estimates of perennial yield for this hydrographic area range from consideration of only the amount of recharge that occurs in the area to inclusion of underflow that enters the area from upgradient groundwater basins. If the groundwater is basically in equilibrium under current conditions (which should be a reasonable assumption based on the stability of the water table elevation), then withdrawing more than 0.72 million cubic meters probably would result in additional underflow entering the immediate area to maintain the equilibrium level. Under this scenario, pumping more than 0.72 million cubic meters from the western portion of Jackass Flats would be unlikely to cause a depletion of the reservoir, and instead could result in shifting of the general groundwater flow patterns. Because the amount pumped would be much less than the upper estimates of perennial yield (that is, the total amount of available water moving through the area, not just the recharge from precipitation), changes in general flow patterns probably would be too small to estimate or detect.

With the addition of repository water usage to the baseline demands from Nevada Test Site activities, the highest estimated demand from the Jackass Flats area during the initial construction period would be about 0.55 million cubic meters (450 acre-feet) per year. This demand would be below the lowest estimate of the area's perennial yield [0.72 million cubic meters (580 acre-feet) for the western two-thirds of Jackass Flats]. However, repository water demands during the emplacement and development period (Table 4-10), when combined with the baseline demands from Nevada Test Site activities, would exceed the lowest perennial yield estimate under the low thermal load scenario for all packaging scenarios. The combined water demand under either the high or intermediate thermal load scenario would not exceed the lowest estimates of perennial yield. None of the water demand estimates would approach the high estimates of perennial yield [4.9 million cubic meters (4,000 acre-feet)].

On a regional basis in the Alkali Flat-Furnace Creek Ranch sub-basin, the heaviest water demand is in the Amargosa Desert. Over the long term, additional water consumption in upgradient hydrographic areas would to some extent decrease the availability of water in the valley (Buqo 1999, pages 37 and 51). That is, consumption would not necessarily exceed the perennial yield of the Jackass Flats hydrographic area, but it could reduce the long-term amount of underflow that would reach the Amargosa Desert, effectively decreasing the perennial yield of that hydrographic area. However, the maximum projected demands for the repository and the Nevada Test Site during the construction phase [about 0.55 million cubic meters (450 acre-feet) a year] and the operation and monitoring phase [about 0.93 million cubic meters (750 acre-feet)] would be small in comparison to the 17 million cubic meters (14,000 acre-feet) pumped in the Amargosa Desert annually from 1995 through 1997 (see Table 3-11). The demand of the repository and the Nevada Test Site would be even a smaller fraction of the perennial yield of 30 million to 40 million cubic meters (24,000 to 32,000 acre-feet) in the Amargosa Desert.

Water demand for monitoring and maintenance activities would be much less than that for emplacement and development activities, particularly after the completion of decontamination activities. Routine monitoring and maintenance activities would involve minimal water needs and, from a duration standpoint, would occupy most of the operation and monitoring phase.

The annual demand during closure for the high thermal load would be about one-third of that described for the high thermal load during the continuing construction, operation, and monitoring period and, similarly, would have minor impacts on groundwater resources.

4.1.4 IMPACTS TO BIOLOGICAL RESOURCES AND SOILS

The evaluation of impacts to biological resources considered the potential for affecting sensitive species (plants and animals) and their habitats, including areas of critical environmental concern; sensitive, threatened, or endangered species, including their habitats; jurisdictional waters of the United States, including wetlands; and riparian areas. The evaluation also considered the potential for impacts to migratory patterns and populations of game animals. DOE expects the overall impacts to biological resources to be very small. Biological resources in the Yucca Mountain region include species typical of the Mojave and Great Basin Deserts and generally are common throughout those areas. Neither the removal of vegetation from the small area required for the repository nor the very small impacts to some species would affect regional biodiversity and ecosystem function.

Section 4.1.4.1 describes potential impacts to biological resources and soils from performance confirmation activities. Section 4.1.4.2 describes potential impacts to biological resources from construction, operation and monitoring, and closure. Section 4.1.4.3 describes the evaluation of the severity of potential impacts to biological resources. Section 4.1.4.4 describes potential impacts to soils from construction, operation and monitoring, and closure.

4.1.4.1 Impacts to Biological Resources and Soils from Performance Confirmation

Performance confirmation activities could require additional land disturbance, and current vehicle traffic at the site of the proposed repository would continue. Impacts to biological resources from additional land disturbance and sustained traffic could consist of the loss of a small amount of available habitat for terrestrial plant and animal species, including desert tortoises, in widely distributed land cover types and the deaths of a small number of individuals of some terrestrial species. The actual amount of additional land disturbance, if any, is uncertain. DOE expects it to be much less than the quantity of disturbance during site characterization.

The limited habitat loss from additional land disturbance would have little impact on plant and animal populations because habitats similar to those at Yucca Mountain are widespread locally and regionally. Similarly, the deaths of small numbers of individuals of some species, primarily burrowing species of small mammals and reptiles, would have little impact on the regional populations of those species. The animal species at the Yucca Mountain site are generally widespread throughout the Mojave or Great Basin Deserts.

The desert tortoise, a threatened species, would continue to receive special consideration during land-disturbing activities at the site. DOE would continue to work with the Fish and Wildlife Service and implement the terms and conditions of the Biological Opinion for site characterization activities (Buchanan 1997, pages 19 to 24) to minimize impacts to desert tortoises at the site.

The potential for soil impacts such as erosion would increase slightly, but erosion control measures, such as dust suppression, would ensure that impacts were very small.

4.1.4.2 Impacts to Biological Resources from Construction, Operation and Monitoring, and Closure

This section describes potential short-term impacts to biological resources at the Yucca Mountain site from construction, operation and monitoring, and closure activities. The primary sources of such impacts would be related to habitat loss or modification during facility construction and operations and to human activities, such as increased traffic, associated with the repository. In addition, this section identifies and evaluates potential impacts to vegetation; wildlife; special status species; and jurisdictional waters of the United States, including wetlands, over the projected life of the project and during each phase of the project.

Routine releases of radioactive materials from the repository would consist of radioactive noble gases, principally isotopes of krypton and radon (TRW 1999a, page 75; see Section 4.1.2). These gases do not accumulate in the environment. The small quantities released would result in very small doses to plants and animals as the gases dispersed in the atmosphere. Estimated doses to humans working and living near the site would be very small (as described in Section 4.1.7). In a similar manner, assumed doses to plants and animals would be small and impacts from those doses would be unlikely to affect the population of any species because the doses would be much lower than the 100-millirad-per-day limit [for which there is no convincing evidence that chronic radiation exposure will harm plant or animal populations (IAEA 1992, page 54)]. Therefore, no detectable impacts to biological resources would occur as a result of normal releases of radioactive materials from the repository, and the following sections do not consider these releases.

Impacts to Vegetation

The construction of surface facilities and the disposition of rock excavated during subsurface construction would remove or alter vegetation. Much of the construction would occur in areas in which site characterization activities had already disturbed the vegetation; however, construction would also occur in undisturbed areas near the previously disturbed areas. Subsurface construction would continue after emplacement operations began, and the disposal of excavated rock would eliminate vegetation in the area covered by the excavated rock pile. The total amount of land cleared of vegetation would vary between the thermal load scenarios (Table 4-11).

Table 4-11. Land cover types in the analyzed land withdrawal area and the amount of each that repository construction and disposal of excavated rock would disturb (square kilometers).[a,b]

	Total area		Area to be disturbed[d]		
Land cover type[c]	In Nevada	In the analyzed withdrawal area	Low thermal load	Intermediate thermal load	High thermal load
Blackbrush	9,900	140	0.36	0.02	0.02
Creosote-bursage	15,000	300	1.11	0.72	0.62
Mojave mixed scrub	5,700	120	0.03	0.86	0.80
Sagebrush	67,000	16	0	0	0
Salt desert scrub	58,000	20	0	0	0
Previously disturbed	NA[e]	4	0.48	0.37	0.37
Totals[f]	**NA**	**600**	**2.0**	**2.0**	**1.8**

a. Source: Facility diagrams from TRW (1999b, all) and land cover types maps (Utah State University 1996, Gap Data) and vegetation associations (TRW 1998c, page 9) using a Geographic Information System.
b. To convert square kilometers to acres, multiply by 247.1.
c. A small area (0.016 square kilometer) of the pinyon-juniper-2 land cover type occurs in the analyzed land withdrawal area, but would not be affected.
d. As described in Chapter 2, the excavated rock pile would be in a different location for the low thermal load scenario.
e. NA = not applicable.
f. Totals might differ from sums due to rounding.

Six of the 65 different land cover types (defined primarily by dominant vegetation) identified in the State of Nevada (Utah State University 1996, Gap Data) occur in the approximately 600-square-kilometer (230-square-mile) analyzed land withdrawal area around the repository site (Table 4-11). Surface disturbances resulting from repository activities would occur in three of these land cover types and in previously disturbed areas (Table 4-11). Repository construction would disturb less than 1 percent of the withdrawal area, which would be an extremely small percentage of the undisturbed vegetation available in the withdrawal area.

Repository construction, including the disposal of material in the excavated rock pile after the start of emplacement, would occur primarily in areas dominated by creosote-bursage and Mojave mixed scrub or blackbrush (under the low thermal load scenario) land cover types. These types are widespread in the analyzed land withdrawal area.

Studies from 1989 to 1997 indicated that site characterization activities had very small effects on vegetation adjacent to the activities (TRW 1999k, pages 2-2 through 2-4). Therefore, impacts to vegetation from repository construction probably would occur only as a result of direct disturbance, such as during site clearing. Little or no disturbance of additional vegetation would occur as a result of monitoring and maintenance activities before closure. DOE would reclaim lands no longer needed for repository operation.

Activities associated with the closure of the repository could involve the removal of structures and reclamation of areas cleared of vegetation for the construction of surface facilities. Closure would involve minimal, if any, new disturbance of vegetation. Reclamation activities would enhance the recovery of vegetation in disturbed areas.

Impacts to Wildlife

The construction of surface facilities and excavated rock disposal would lead to habitat losses for some terrestrial species (Chapter 3, Section 3.1.5); however, habitats similar to those at Yucca Mountain (identified by land cover type) are widespread locally and regionally. In addition to habitat loss, the conversion of undisturbed land to industrial uses associated with the repository would result in the localized deaths of individuals of some species, particularly burrowing species of small mammals and reptiles. Birds, carnivores, and ungulates (mule deer or burros) at the repository site would be less likely to be killed during construction because they would be able to move away from areas of human activity.

The construction of new roads, surface facilities, and other infrastructure would lead to fragmentation of previously undisturbed habitat. Nevertheless, DOE anticipates impacts to wildlife populations to be very small because large areas of undisturbed and unfragmented habitat would be available away from disturbed areas.

Animal species present at the repository location are generally widespread throughout the Mojave or Great Basin Deserts and the deaths of some individuals due to repository construction and habitat loss would have little impact on the regional populations of those species. Site characterization activities had no detectable effect on populations of small mammals, side-blotched lizards, and desert tortoises in areas adjacent to the activities (TRW 1999k, pages 2-4, 2-5, 2-7, and 3-10 to 3-12).

In addition to direct losses due to the construction of surface facilities and excavated rock disposal, individuals of some species would be killed by vehicles traveling to and from the Yucca Mountain site during the construction, operation and monitoring, and closure phases (TRW 1999k, page 3-12). These losses would have a very small effect on populations because species at the site are widespread. No species would be threatened with extinction, either locally or globally.

Noise and ground vibrations generated during repository construction and operations could disturb wildlife and cause some animals to move away from or avoid the source of the noise. Impacts to wildlife from noise and vibration, if any, would decline as the distance from the source of the noise (the repository) increased. Noise levels would drop below the limit of human hearing at a distance of about 6 kilometers (3.7 miles) from the repository (see Section 4.1.9) and no noise-related impacts to wildlife would be likely at that distance. Animals may acclimate to the noise, limiting the area affected by repository-related noise to the immediate vicinity of the source of the noise (heavy equipment, diesel generators, ventilation fans, etc.).

Several animals classified as game species by the State of Nevada (Gambel's quail, chukar, mourning doves, and mule deer) are present in low numbers in the analyzed Yucca Mountain land withdrawal area. Adverse impacts to these species would be unlikely, and offsite hunting opportunities probably would not decline.

DOE would dispose of industrial wastewater in lined evaporation ponds in the North and South Portal Operations Areas. Wildlife would be attracted to the water in these ponds to take advantage of this otherwise scarce resource. Individuals of some species could benefit from the water, but some animals could become trapped in the ponds, depending on the depth and the slope of the sides. Monitoring at similar lined evaporation ponds on the Nevada Test Site has shown that a wide variety of animal species use the ponds and that DOE could avoid losses of animals by reducing the slopes of the ponds or by providing an earthen ramp at one corner of the lined pond (Bechtel 1997, page 31). Appropriate engineering would minimize potential losses to wildlife.

DOE does not anticipate adverse effects on wildlife that used the nonhazardous, nontoxic wastewater discharged to the evaporation ponds. Industrial wastewater routed to the evaporation pond at the North Portal would be nonhazardous. DOE anticipates that the primary chemical constituents in the water would be sodium and calcium carbonates, with smaller amounts of chlorides, sulfates, and fluorides. Metal constituents could include potassium, zinc, iron, magnesium, and manganese. Wastewater discharged to the South Portal evaporation pond would be nontoxic wastewater derived from dust suppression activities; it would contain small particles of mined rock along with Portland Cement and fine aggregate particles from concrete mix plants. DOE would maintain the pH of the water within a defined range through the addition of acceptable additives. Water quality would be monitored and appropriate measures to protect wildlife would be implemented.

DOE would construct a landfill for construction debris and sanitary solid waste. The landfill could attract scavengers such as coyotes and ravens. Frequent covering of the sanitary waste disposed of in the landfill could minimize use by scavenger species.

After the completion of emplacement, human activities and vehicle traffic would decline, as would impacts of those actions on wildlife, with further declines in activities and impacts after repository closure. Animal species would reoccupy the areas reclaimed during closure activities.

Impacts to Special Status Species

The desert tortoise is the only resident animal species in the analyzed land withdrawal area listed as threatened under the Endangered Species Act of 1973 (16 USC 1531, *et seq.*). There are no endangered or candidate animal species and no species that are proposed for listing (TRW 1999k, pages 3-11 and 3-12). Repository construction would result in the loss of a very small portion of the total amount of desert tortoise habitat at the northern edge of the range of this species in an area where the abundance of desert tortoises is low (TRW 1997b, pages 6 to 12; TRW 1999k, page 3-12).

Based on past experience, DOE anticipates that human activities at the site could directly affect individual desert tortoises. During site characterization activities, 28 tortoises and two tortoise nests were relocated because of threats from construction activities (TRW 1998h, pages 3 to 17; TRW 1999k, page 3-12). All but one of the 28 individual relocations and both nest relocations were successful. From 1989 to 1998, five tortoises (including the one unsuccessful relocation) were killed as a result of site characterization activities; all were killed by vehicles on roads (TRW 1999k, page 3-12). DOE would conduct surveys and would move tortoises that it found; however, based on experience from site characterization, DOE anticipates the deaths of small numbers of individual tortoises from vehicle traffic and construction activities during the repository construction, operation and monitoring, and closure phases. As required by Section 7 of the Endangered Species Act, DOE has initiated consultations with the Fish and Wildlife Service on the desert tortoise. The result of these consultations will be a Fish and Wildlife Service Biological Opinion containing terms and conditions for protection of the desert tortoise during repository construction and operation.

The bald eagle (threatened) and peregrine falcon (endangered, but proposed for delisting) have been observed once each on the Nevada Test Site and might migrate through the Yucca Mountain region. If present at all, these species would be transient and would not be affected.

Several animal species considered sensitive by the Bureau of Land Management [two bats—the long-legged myotis and fringed myotis—and the western chuckwalla, burrowing owl, and Giuliani's dune scarab beetle; (see Chapter 3, Section 3.1.5)] occur in the analyzed land withdrawal area. Impacts to the bat species would be very small because of their low abundance on the site and broad distribution. Impacts to the Western chuckwalla and burrowing owl would be very small because they are widespread regionally and are not abundant in the land withdrawal area. Giuliani's dune scarab beetle has been reported only in the southern portion of the land withdrawal area, away from any proposed disturbances.

Monitoring and closure activities at the repository would have little impact on desert tortoises, or Bureau of Land Management sensitive species. Over time, vegetation would recover on disturbed sites and indigenous species would return. As the habitat recovered over the long term, desert tortoises and other special status species at the repository site would recolonize areas abandoned by humans.

Impacts to Wetlands

There are no known naturally occurring jurisdictional wetlands (that is, wetlands subject to permitting requirements under Section 404 of the Clean Water Act) on the repository site, so no impacts to such wetlands would occur as a result of repository construction, operation and monitoring, or closure. In addition, repository construction, operation and monitoring, and closure would not affect the four manmade well ponds in the Yucca Mountain region. Repository-related structures could affect as much as 2.8 kilometers (1.7 miles) of ephemeral washes, depending on the size and location of such facilities as the excavated rock storage area. Although no formal delineation has been undertaken, some of these washes might be waters of the United States. After selecting the location of facilities, DOE would conduct a formal delineation, as appropriate, to confirm there are no wetlands at Yucca Mountain; formally delineate waters of the United States near the surface facilities; and, if necessary, develop a plan to avoid when possible, and otherwise minimize, impacts to those waters. If repository activities would affect waters of the United States, DOE would consult with the U.S. Army Corps of Engineers and obtain permit coverage for those impacts. If the activities were not covered under a nationwide permit, DOE would apply to the Corps of Engineers for a regional or individual permit. By implementing the mitigation plan and complying with other permit requirements, DOE would ensure that impacts to waters of the United States would be minimized.

4.1.4.3 Evaluation of Severity of Impacts to Biological Resources

DOE evaluated the magnitude of impacts to biological resources and classified the severity of potential impacts as none, very low, low, moderate, or high, as listed and described in Table 4-12.

4.1.4.4 Impacts to Soils from Construction, Operation and Monitoring, and Closure

This section identifies potential consequences to soils as a result of the Proposed Action. Soil-related issues associated with the Proposed Action include the following:

- Potential consequences of soil loss in disturbed areas, either from erosion or displacement
- Soil recovery from disturbances

Table 4-12. Impacts to biological resources.

Phase or period	Flora	Fauna	Special status species	Wetlands	Overall
Initial construction	Very low/low; removal of vegetation from as much as 2 square kilometers[a] in widespread communities	Very low; loss of small amount of habitat and some individuals of some species	Low; loss of small amount of desert tortoise habitat and small number of individual tortoises	None	Very low/low; loss of small amount of widespread but undisturbed habitat and small number of individuals
Construction, operation, and monitoring					
Emplacement and development	Very low/low; disturbance of vegetation in areas adjacent to disturbed areas	Very low; deaths of small number of individuals due to vehicle traffic and human activities	Low; potential deaths of very few individuals due to vehicle traffic	None	Very low new impacts to biological resources
Monitoring and maintenance	Very low; no new disturbance of natural vegetation	Very low; same as for operation, but smaller due to smaller workforce	Very low; same as for operation, but smaller due to smaller workforce	None	Very low; small numbers of individuals of some species killed by vehicles
Closure	Very low; decline in impacts due to reduction in human activity	Very low; decline in number of individuals killed by traffic annually	Very low; decline in number of individuals killed by traffic annually	None	Very low; decline in impacts due to reduction of human activity
Overall rating of impacts	Very low/low	Very low	Very low/low	None	Very low

a. 2 square kilometers = 500 acres.

- Potential for spreading contamination by relocating contaminated soils (if present)
- Structural stability of existing soils and their ability to support the proposed activities

Overall, impacts to soils would be minimal. DOE would use erosion control techniques to minimize erosion. Because soil in disturbed areas would be slow to recover, during the closure phase DOE would revegetate the area that it had not reclaimed after the temporary disturbances following construction.

Soil Loss

Land disturbed at the repository site could, at least for a short period, experience increased erosion. Erosion is a two-step process of (1) breaking away soil particles or small aggregates and (2) transporting those particles or aggregates. Land disturbance that removes vegetation or otherwise breaks up the natural surface would expose more small materials to the erosion process, making the soil more susceptible to wind and water erosion. Activities at the repository during the construction and operation and monitoring phases would disturb no more than about 2 square kilometers (500 acres) of land, including the excavated rock (see Chapter 2).

Site characterization activities at Yucca Mountain included a reclamation program with a goal to return the disturbed land to a condition similar to its predisturbance state (TRW 1999l, pages 6 and 7). One of the benefits of achieving such a goal would be the minimization of soil erosion. The program included the implementation and evaluation of topsoil stockpiling and stabilization efforts that would enable the use of topsoil removed during excavation in future reclamation activities. The results were encouraging enough to recommend that these practices continue. This action would reduce the construction loss of the most critical type of soil. Fugitive dust control measures including water spraying and chemical treatment would be used as appropriate to minimize wind erosion of the stockpiled topsoil and excavated rock. Based on site characterization experience and the continued topsoil protection and erosion control programs, DOE does not anticipate much soil erosion during the phases of the project.

If the Proposed Action was implemented, program planning developed for site characterization (DOE 1989a, pages 2 and 20) specifies that reclamation would occur in all areas disturbed during characterization activities that are not needed for the operation of the repository. As a result, prior land disturbances should represent minimal soil erosion concern during the Proposed Action.

Recovery

Studies performed during the Yucca Mountain site characterization effort (DOE 1989a, all; DOE 1995g, all) looked at the ability of the soil ecology to recover after disturbances. These studies and experience at the Nevada Test Site indicate that natural succession on disturbed arid lands would be a very slow process (DOE 1989a, page 17; DOE 1995g, page 1-5). Left alone, and depending on the type or degree of disturbance and the site-specific environmental conditions, the recovery of predisturbance conditions in this area could take decades or even centuries. With this in mind, soil recovery would be unlikely without reclamation. In general, soil disturbances would generally remain as areas without vegetation and, with the exception of built-up areas, would have an increased potential for soil erosion throughout the construction and operation and monitoring phases.

SOIL RECOVERY

The return of disturbed land to a relatively stable condition with a form and productivity similar to that which existed before any disturbance.

Contamination

Based on characterization efforts and activities that took place in the past (Chapter 3, Section 3.1.5.2), radiological and nonradiological characteristics of the site soils are consistent with the area background. Therefore, there would be no need for restrictions or concerns about contamination migration during construction or as a result of soil erosion. There would be a potential for spills or releases of contaminants to occur under the Proposed Action (as discussed in Section 4.1.3), but DOE would continue to implement a spill prevention and control plan [Kiewit (1997, all) is an example] to prevent, control, and remediate soil contamination.

4.1.5 IMPACTS TO CULTURAL RESOURCES

This section describes impacts to cultural resources from performance confirmation, operation and monitoring, and closure activities. The evaluation of such impacts considered the potential for disrupting or modifying the character of archaeological or historic sites and other cultural resources. The evaluation placed particular emphasis on identifying the potential for impacts to historic sites and other cultural resources important to sustaining and preserving Native American cultures. The region of influence for the analysis included land areas that repository activities would disturb and areas in the analyzed land withdrawal area where impacts could occur.

DOE assessed potential impacts to cultural resources from these activities by (1) identifying project activities that could directly or indirectly affect archaeological, historic, and traditional Native American resources possibly eligible for listing on the *National Register of Historic Places*; (2) identifying the known or likely eligible resources in areas of potential impact; and (3) determining if a project activity would have no effect, no adverse effect, or an adverse effect on potentially eligible resources (36 CFR 800.9). Direct impacts would be those from ground disturbances or activities that would destroy or modify the integrity of a given resource considered eligible for listing on the National Register. Indirect impacts would result from activities that could increase the potential for adverse impacts, either intentional or unintentional (for example, increased human activity near potentially eligible resources could result in illicit collection or inadvertent destruction).

4.1.5.1 Impacts to Cultural Resources from Performance Confirmation

Land disturbances associated with performance confirmation activities could have direct impacts to cultural resources in the Yucca Mountain region. Before activities began, therefore, DOE would identify and evaluate archaeological or cultural resources sites in affected areas for their importance and eligibility for inclusion in the *National Register of Historic Places*. DOE would avoid such sites if possible or, if it was not possible, would conduct a data recovery program of the sites in accordance with applicable regulatory requirements and input from the official tribal contact representatives and document the findings. The artifacts from and knowledge about the site would be preserved. Improved access to the area could lead to indirect impacts, which could include unauthorized excavation or collection of artifacts. Workers would have required training on the protection of these resources from excavation or collection.

4.1.5.2 Impacts to Cultural Resources from Construction, Operation and Monitoring, and Closure

Impacts to archaeological and historic sites could occur during the initial construction period and the continuing construction, operation, and monitoring period, when ground-disturbing activities would take place. Indirect impacts to archaeological and historic sites could occur during all phases of the Proposed Action.

Archaeological and Historic Resources

Potential impacts to *National Register*-eligible cultural resources from surface facility construction could occur in areas where ground-disturbing activities would take place. Repository development would disturb a maximum of about 2 square kilometers (500 acres) of previously undisturbed land at the site.

Archaeological investigations conducted in the immediate vicinity of the proposed surface facilities in support of previous and ongoing characterization studies and infrastructure construction have identified 826 archaeological and historic sites. These investigations have identified resource localities and provided mitigative relief for resources potentially subject to direct impacts (TRW 1999m, Table 2). In addition, ground-disturbing activities associated with potential nearby project actions (for example, upgrades to utility and road rights-of-way, rail access facilities, muck and other onsite storage areas) would occur in areas that had undergone field inventories and evaluations of cultural resources. Because the proposed locations of facilities and support areas are away from known archaeological sites, no direct impacts to known resources would occur.

Increases in both surface activities and numbers of workers at the repository site could increase the potential for indirect impacts at archaeological sites near repository surface facilities. Preliminary results from the monitoring of archaeological sites in the vicinity of Yucca Mountain activities since 1991 indicate that human activities and increased access could result in harmful effects, both advertent and inadvertent, to these fragile resources (TRW 1999m, Chapter 1). Indirect impacts are difficult to quantify and control, but they can include loss of surface artifacts due to illicit collection and inadvertent destruction (TRW 1999m, Chapter 1).

Even though there could be some indirect adverse impacts, the overall effect of the repository on the long-term preservation of the archaeological and historic sites in the analyzed land withdrawal area would be beneficial. Cultural resources in the area would be protected from most human intrusion.

Excavation activities at the repository site could unearth additional materials and features in areas that past archaeological surveys have examined only at the surface. Past surveys in the Yucca Mountain area indicated buried cultural materials at some sites with surface artifacts (TRW 1999m, Chapter 1). Thus, excavation activities could unearth previously undetected subsurface features or artifacts. If this happened, work would stop until a cultural resource specialist evaluated the importance of the discovery.

Native American Viewpoints

DOE would continue the existing Native American Interaction Program (see Chapter 3, Section 3.1.6.2) throughout the Proposed Action. This program promotes a government-to-government relationship with associated tribes and organizations. Continuance of this program during the Proposed Action would enhance the protection of archaeological sites and cultural items important to Native Americans.

The Native American view of resource management and preservation is holistic in its definition of "cultural resource," incorporating all elements of the natural and physical environment in an interrelated context. Moreover, this view includes little or no differentiation between types of impacts (direct versus indirect), but considers all impacts to be adverse and immune to mitigation. Section 4.1.13.4 contains an environmental justice discussion of a Native American viewpoint on the Proposed Action.

Previous studies (Stoffle et al. 1990, all; AIWS 1998, all) have delineated several Native American sites, areas, and resources in or immediately adjacent to the analyzed land withdrawal area. Construction activities for repository surface facilities would have no direct impacts on these locations. However, because of the general level of importance attributed to these places by Native Americans, and because they are parts of an equally important integrated cultural landscape, Native Americans consider the intrusive nature of the repository to be an adverse impact to all elements of the natural and physical environment (AIWS 1998, Chapter 2). In their view, the establishment of the protected area boundary and construction of the repository would continue to restrict the free access of Native American people to these areas. On the other hand, the Consolidated Group of Tribes and Organizations has recognized that past restrictions on public access due to site characterization have resulted in generally beneficial and protective effects for cultural resources, sacred sites, and potential traditional cultural properties (AIWS 1998, Chapter 2).

The potential for indirect impacts from construction activities and more workers in the area would increase, particularly to the physical evidence of past use of the cultural landscape (artifacts, cultural features, archaeological sites, etc.) important to Native American people. DOE would continue to provide training to workers to minimize the potential for indirect impacts.

Eventual closure of the repository would have the beneficial effect of returning much of the disturbed landscape to a natural setting. Some additional impacts could occur to resources or areas important to Native Americans if changes in land status or management that occurred after closure led to increased access by the public. The presence of a permanently entombed repository would represent an intrusion into what Native Americans consider an important cultural and spiritual place. Long-term monitoring features or activities would continue to affect these cultural viewpoints.

4.1.6 SOCIOECONOMIC IMPACTS

This section describes potential socioeconomic impacts from performance confirmation, construction, operation and monitoring, and closure activities. The evaluation of the socioeconomic environment in communities near the proposed repository site considered changes to employment, economic measures, population, housing, and public services. The evaluation used the Regional Economic Models, Inc. (REMI) model to estimate baseline socioeconomic conditions and economic and population changes caused by the Proposed Action. The potential for changes in the socioeconomic environment would be greatest in the Yucca Mountain region and in the communities where most of the repository workers would live. As discussed in Chapter 3, Section 3.1.7, this region of influence consists of Clark, Lincoln, and Nye Counties in southern Nevada.

DOE established a bounding case to examine the maximum potential employment levels it would need to implement design features and packaging scenarios. The combination of the low thermal load scenario and the uncanistered packaging scenario would produce the highest incremental change in employment and have the greatest potential to affect the environment.

The analysis determined that no great socioeconomic impacts to any of the areas in the region of influence would be likely. Employment and population changes in the region of influence would not exceed one-half of 1 percent between the projected baseline (employment without the repository project) and the increase from the maximum employment case of the project.

4.1.6.1 Socioeconomic Impacts from Performance Confirmation

The level of employment for performance confirmation activities would be similar to or less than the current level for site characterization, as described in Chapter 3, Section 3.1.7. Because population and employment changes between ongoing site characterization activities and future performance confirmation activities would be imperceptible, there would be no meaningful impacts to housing or community services.

4.1.6.2 Socioeconomic Impacts from Construction, Operation and Monitoring, and Closure

4.1.6.2.1 *Impacts to Employment*

In 2006 and 2007, the peak years of employment during the initial construction period, about 1,640 workers would be employed on the Yucca Mountain Repository Project. Figure 4-2 shows composite (direct and indirect) employment changes by place of residence during the construction phase. Incremental

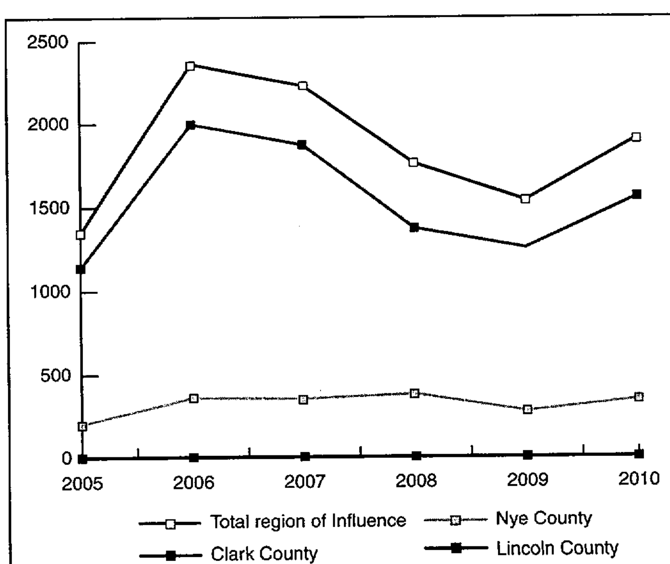


Figure 4-2. Increases in regional employment by place of residence during construction phase and onset of operation and monitoring phase: 2005 to 2010.

employment increases during the construction phase attributable to the repository would peak in 2006 with the addition of about 2,360 workers to the region of influence. This would increase overall employment in the region of influence from the projected baseline (employment without the repository project) of approximately 946,000 to slightly less than 948,000, a change of less than one-quarter of 1 percent. Table 4-13 summarizes repository peak year employment during the initial construction period by employment category. Table 4-14 lists the expected residential distribution of construction phase workers, which in the first year would exceed 1,600 workers (2006). The table also lists the estimated peak number of indirect jobs created in these communities. These tables do not list Lincoln County because historically no workers have resided there. DOE expects that few, if any, repository employees would live in Lincoln County due to the long commute (TRW 1998d, all).

Table 4-13. Expected peak year (2006) increase in construction employment by place of residence in selected communities in Nye and Clark Counties.[a,b,c]

Location	Direct jobs	Indirect jobs	Total jobs
Clark County			
Indian Springs	48	29	72
Rest of Clark County	1,270	780	1,925
Clark subtotals	*1,318*	*809*	*1,997*
Nye County			
Amargosa Valley	22	5	25
Beatty	3	1	4
Pahrump area	294	68	333
Nye subtotals	*319*	*74*	*362*
Totals	***1,637***	***883***	***2,359***[d]

a. Employment and population impacts distributed using residential patterns of Nevada Test Site and Yucca Mountain employees from DOE (1994b, all).

b. DOE anticipates approximately 80 percent of repository workers would live in Clark County and approximately 20 percent in Nye County; includes approximately 5 indirect jobs in Lincoln County.

c. Employment in 2006 includes 161 current workers.

d. Does not include the 161 current workers.

Table 4-14. Repository direct workforce during construction phase by expected county of residence: 2005 to 2009.[a,b]

County	2005	2006	2007	2008	2009
Clark	795	1,317	1,093	1,093	1,128
Nye	193	320	311	267	274
Totals	**988**	**1,637**	**1,404**	**1,360**	**1,402**

a. Sources: TRW (1999a, Section 6); TRW (1999b, Section 6).

b. DOE anticipates approximately 80 percent of repository workers would live in Clark County and approximately 20 percent in Nye County.

Construction employment would begin to decline in 2008; in 2010 operational employment would start to increase and would peak in 2012. Employment after 2012 would be essentially stable with an average annual workforce of about 1,600 through 2035. Although operational phase peak employment would occur in 2012 (about 1,780 workers), the overall peak in incremental regional employment related to repository activities would occur earlier, in 2010. Usually the creation of indirect jobs and associated population increases occur after the creation of direct jobs. In this case, the region would still be experiencing the results of the incremental jobs created during the initial construction period. The net increase of about 140 peak year operational jobs over the peak year construction employment level would not affect the regional economy as noticeably as when the relatively small number of site characterization workers increased to more than 1,600 construction workers.

As mentioned above, in 2012, the peak year of employment during the continuing construction, operation, and monitoring period, about 1,780 workers would be employed on the Yucca Mountain Repository Project (TRW 1999a, Section 6; TRW 1999b, Section 6). As a consequence, the analysis included information on repository residential distribution and employment levels for 2010.

Table 4-15 lists the expected residential distribution of repository workers in the peak year, 2010. The table also lists the estimated number of indirect jobs created in these communities during 2010. The direct and indirect employment in the region of influence would peak with the addition of approximately 1,900 workers. This would result in a total increase in employment from the projected baseline of about 1,002,000 to about 1,004,000, a change of less than one-quarter of 1 percent. Table 4-16 summarizes repository employment through the first 35 years of the operation and monitoring phase by employment category. These tables do not list Lincoln County because historically no workers have resided there. As mentioned above, DOE expects that few workers would live in Lincoln County due to the long commute (TRW 1998d, all). Figure 4-3 shows the direct and indirect regional employment differences between the maximum employment case and the projected baseline.

Table 4-15. Expected peak year (2010) increases in operations employment in selected communities in Nye and Clark Counties.

Location	Direct jobs[a]	Indirect jobs	Total jobs
Clark County			
Indian Springs	64	11	56
Rest of Clark County	1,326	286	1,501
Clark subtotals	*1,421*	*297*	*1,557*
Nye County			
Amargosa Valley	23	3	24
Beatty	3	0	3
Pahrump	311	37	319
Nye subtotals	*337*	*40*	*346*
Totals	***1,727***	*337*	***1,903***[b]

a. Employment in 2010 includes 161 current workers.
b. Does not include the 161 current workers.

Table 4-16. Repository direct employment during operation and monitoring phase by county of residence: 2010 to 2035.

County	2010	2015	2020	2025	2030	2035
Clark total	1,390	1,365	1,379	1,365	1,322	1,161
Nye total	337	332	335	332	322	282
Totals	**1,727**	**1,697**	**1,714**	**1,697**	**1,644**	**1,443**

The completion of emplacement activities would result in a decline from about 1,560 emplacement workers in 2031 to about 1,440 decontamination and decommissioning workers from 2034 to about 2036 to 120 monitoring and maintenance workers from 2037 to 2110 employed at the Yucca Mountain site. However, even without the repository, the baseline projection predicts a continued increase in employment in the region of influence. If the present economic growth continued in the region of influence, it could absorb declines in the repository workforce.

After the completion of emplacement and decontamination of surface facilities, an annual employment of about 120 workers would be required for ongoing monitoring and maintenance activities. These activities could last as few as 26 years or as many as 276 years. This study assumed that monitoring would end in 2110, 100 years after the start of emplacement. Because monitoring and maintenance activities would require so few workers, no socioeconomic impacts would be likely.

The closure phase would be from 2110 to between 2116 and 2124, depending on the thermal load scenario. Projected peak employment for this phase would be approximately 520 workers (TRW 1999a, Section 6; TRW 1999b, Section 6). Employment would be far less than the peak during the operation and monitoring phase and, therefore, would be unlikely to generate changes to the labor force and economic measures of less than one-half of 1 percent. There probably would be no perceptible repository-induced changes to the baseline employment in the region of influence. Regional impacts during the closure phase probably would be small.

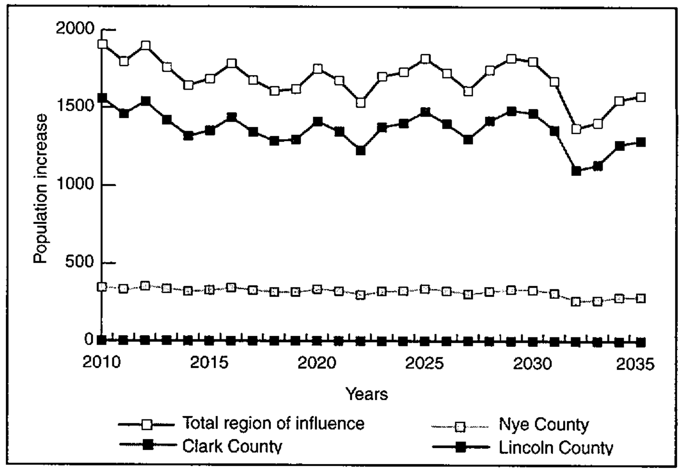


Figure 4-3. Increases in regional employment from operation and monitoring phase: 2010 to 2035.

4.1.6.2.2 *Impacts to Population*

From 2010, the projected year of peak employment, through 2035, the projected regional population will grow from about 1.9 million to more than 2.7 million people. The peak year population contribution attributable to the repository would be fewer than 4,000 people, a very small fraction of 1 percent. As a consequence, the Yucca Mountain Repository Project would be unlikely to alter the population growth to a great degree in the region of influence. Figure 4-4 shows the projected population increase as a result of the repository project.

Table 4-17 lists estimated incremental population increases that would occur as a result of repository activities to Clark and Nye Counties based on historic Nevada Test Site residential distribution patterns. As mentioned above, repository workers would be unlikely to reside in Lincoln County. The incremental population increase in Clark County would be almost imperceptible.

Table 4-17. Maximum expected population increase (2030).

Location	Population increase
Clark County	
Indian Springs	108
Rest of Clark County	2,882
Clark total	**2,990**
Nye County	
Amargosa Valley	50
Beatty	7
Pahrump	669
Nye total	**726**

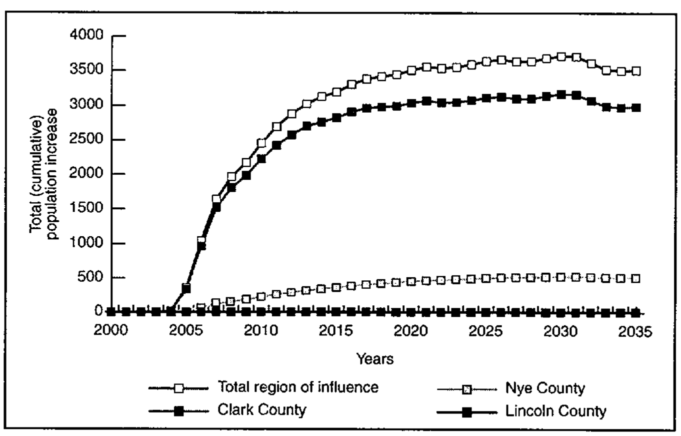


Figure 4-4. Regional population increases from construction and operations: 2000 to 2035.

The increase in the Nye County population would be less than 2 percent of the projected total population for the peak year for potential repository impacts. The Yucca Mountain Repository would not alter the population growth rate in Clark County in a measurable degree. Population growth associated with the repository would be more evident in Nye County. However, because the increases would occur over a long period, about 25 years, Nye County could accommodate them.

4.1.6.2.3 *Impacts to Economic Measures*

Table 4-18 lists changes in economic measures that would result from repository activities during the construction phase (expressed in 1992 dollars). The increases in real disposable income would peak in 2007 with an increase of about $57 million, while increases in Gross Regional Product would peak in 2006 at about $98 million. Regional expenditures by state and local governments would peak at $5.8 million in 2009. Economic measures for the region of influence would increase by less than one-quarter of 1 percent over the projected baseline (economic measures without the repository project).

Table 4-18. Increases in economic measures from repository construction: 2005 to 2009 (thousands of dollars).[a]

Jurisdiction	2005	2006	2007	2008	2009
Clark County					
Personal income	28,000	52,100	53,500	44,600	43,500
Gross Regional Product	46,500	84,000	79,100	59,400	47,800
State and local government expenditures	800	2,500	4,000	4,700	5,300
Nye County					
Personal income	1,700	3,100	3,100	2,400	2,800
Gross Regional Product	7,600	13,800	13,300	10,600	9,500
State and local government expenditures	100	200	300	400	500
Lincoln County					
Personal income	100	200	200	200	200
Gross Regional Product	100	100	100	100	100
State and local government expenditures	0	0	0	0	0
Total region of influence					
Personal income	29,800	55,400	56,800	47,200	46,500
Gross Regional Product	54,200	97,900	92,500	70,100	57,400
State and local government expenditures	900	2,700	4,300	5,100	5,800

a. Totals might differ from sums due to rounding.

GROSS REGIONAL PRODUCT

Value of goods and services produced in the region of influence.

Table 4-19 lists the changes in economic measures that would result from the repository project during the operation and monitoring phase. Increases in Gross Regional Product and in real disposable income would peak in 2029-2030, at about $70 million and $83 million, respectively. Increases in regional expenditures by state and local governments under the maximum employment case would also peak in 2030 at about $11 million. Economic measures for the region of influence would increase by less than one-half of 1 percent over the projected baseline.

4.1.6.2.4 *Impacts to Housing*

Repository-generated impacts to housing availability from changes in the population in the region of influence would be small. Given the size of the regional workforce, the number of workers inmigrating to work on the repository would be unlikely to be measurable.

The region of influence has an adequate supply of undeveloped land to meet future demands. Throughout most of the 1990s, the Bureau of Land Management has conducted land exchanges in Clark County. These exchanges have typically involved a trade of environmentally sensitive land outside the county for Bureau land in the county. The land in Clark County moves to the private sector for sale to land developers. This policy has helped to accommodate the population growth in the Las Vegas area.

Table 4-19. Increases in economic measures from emplacement and development activities: 2010 to 2035 (thousands of dollars).[a]

Jurisdiction	2010	2015	2020	2025	2030	2035
Clark County						
Personal income	53,200	57,400	64,300	70,300	74,700	73,000
Gross Regional Product	53,000	46,900	52,100	56,500	57,800	49,000
State and local government expenditures	5,900	7,700	8,400	8,800	9,100	8,800
Nye County						
Personal income	4,000	5,400	6,700	7,600	8,300	8,500
Gross Regional Product	11,000	10,600	11,400	11,900	11,800	10,000
State and local government expenditures	700	1,100	1,400	1,600	1,700	1,700
Lincoln County						
Personal income	200	200	200	200	300	200
Gross Regional Product	100	100	100	100	100	100
State and local government expenditures	0	100	100	100	100	100
Total region of influence						
Personal income	57,400	63,000	71,200	78,100	83,300	81,700
Gross Regional Product	64,100	57,600	63,600	68,500	69,700	59,100
State and local government expenditures	6,600	8,900	9,900	10,500	10,900	10,600

a. Totals might differ from sums due to rounding.

Workers and dependents who migrated to work on the repository probably would live in the many communities of Clark County, thereby dispersing the increased demand for housing. Southern Nye County, particularly Pahrump, would also experience some demand for housing. However, because the change in population would occur steadily over a long period, the county would be able to accommodate increases in housing demands. In Lincoln County, little or no demand would be likely, so housing availability would not be an issue.

4.1.6.2.5 *Impacts to Public Services*

Repository-generated impacts to public services from changes in the population in the region of influence would be small. Population changes in the region from the maximum repository-related employment case would be a small fraction of the anticipated job growth in the region. Even with the addition of repository jobs, the annual regional growth rate would increase by less than 2 percent, minimizing a possible need to alter plans already in place to meet projected growth.

As mentioned above, inmigrating workers probably would live in the many communities of Clark County, thereby dispersing the increased demand for public services. Southern Nye County, particularly Pahrump, also would experience some demand for public services. However, because the change in population would occur steadily over a long period, the county would be able to meet education, law enforcement, and fire protection demands. Impacts to public services would be unlikely in Lincoln County.

4.1.7 OCCUPATIONAL AND PUBLIC HEALTH AND SAFETY IMPACTS

This section describes short-term (prior to the completion of repository closure) health and safety impacts to workers (occupational impacts) and to members of the public from performance confirmation, construction, operation and monitoring, and closure activities. The analysis estimated health and safety impacts separately for involved workers and noninvolved workers for each repository phase. Involved workers are craft and operations personnel who would be directly involved in the activities related to facility construction and operations, including excavation activities; receipt, handling, packaging, and emplacement of spent nuclear fuel and high-level radioactive waste materials; and monitoring of the condition and performance of the waste packages. Noninvolved workers are managerial, technical, supervisory, and administrative personnel who would not be directly involved in construction, excavation, and operations activities.

The evaluation used engineering estimates of equivalent full-time years worked during each phase along with standard statistics on industrial accidents and incidents to estimate impacts to workers from nonradiological hazards. It used a similar approach for radiological worker hazards. The evaluation used engineering estimates of pollutant releases from repository operations along with standard modeling techniques to estimate impacts to members of the public.

The types of human health and safety impacts estimated for workers would include those from industrial hazards, exposure to radiation and radioactive material, and exposure to hazardous nonradioactive material. The hazardous nonradioactive materials would be cristobalite and erionite, naturally occurring minerals in the rock (welded tuff) of the planned repository location. All of the estimated human health impacts to members of the public are based on airborne exposures to naturally occurring radioactive and hazardous materials. The radiological doses and hazardous material concentrations on which the human health impacts are based are described in Section 4.1.2.

Appendix F describes the methodology, data, and data sources used for the calculations of health and safety impacts to workers and supporting detailed results. In addition, it contains a human health impacts primer.

4.1.7.1 Impacts to Occupational and Public Health and Safety from Performance Confirmation (2001 to 2005)

Performance confirmation activities would be similar to the activities performed during Yucca Mountain site characterization. Their purpose would be to ensure that systems, operations, and materials were functioning as predicted. These activities could include the construction of surface facilities to support performance confirmation, excavation of exploratory tunnels, and testing and monitoring activities in the drifts. Chapter 3 describes site characterization activities and the resulting affected environment.

Potential health and safety impacts that could occur during performance confirmation activities include those common to an industrial work setting, radiological impacts to the public and workers from exposure to radon-222 and its decay products, external radiation exposure of workers in the subsurface environment, and the potential for exposure to naturally occurring cristobalite and erionite generated by excavation activities. Section 4.1.7.2 contains additional information on these potential exposure pathways. No spent nuclear fuel and high-level radioactive waste would be present during performance confirmation activities, so radiation exposure of workers from this source would not occur.

Impacts are likely to be very small during performance confirmation activities. Incremental health and safety impacts to workers for the performance confirmation period would be less than 2 percent of those estimated for the construction, operations and monitoring, and closure phases, based on comparisons of worker activities and the number of worker-years between site characterization (TRW 1994a, all) and repository activities (see Appendix F). Potential radiological impacts to members of the public would be less than those estimated for the construction phase (Section 4.1.7.2). The probability of latent cancer fatality in the offsite maximally exposed individual would be about 0.000001. No latent cancer fatalities (less than 0.007) would be likely in the potentially exposed population (see Section 4.1.7.2.2).

4.1.7.2 Impacts to Occupational and Public Health and Safety from Initial Construction (2005 to 2010)

This section describes estimates of health and safety impacts to repository workers and members of the public for the 5-year initial construction period (2005 to 2010). During this period, DOE would build the surface facilities, excavate the main drifts, and excavate enough emplacement drifts to support initial emplacement activities. Potential health and safety impacts to workers would occur from industrial hazards, exposure to naturally occurring radionuclides, and exposure to naturally occurring cristobalite and erionite in the rock at the Yucca Mountain site. Potential health impacts to members of the public would be from exposure to airborne releases of naturally occurring radionuclides and hazardous materials.

4.1.7.2.1 *Occupational Health and Safety Impacts (Involved and Noninvolved Workers)*

Industrial Hazards. The analysis estimated health and safety impacts to workers from hazards common to the industrial setting (such as falling or tripping) in which they would be working using statistics for similar kinds of operations and estimates of the total number of full-time equivalent worker years that would be involved in the activities. The statistics that the analysis used are from the DOE Computerized Accident/Incident Reporting and Recordkeeping System (DOE 1999c, all). These statistics reflect recent DOE experience for these types of activities. Appendix F, Section F.2.2.2, contains more information on the selection of impact statistics.

The analysis based its estimates for the number of full-time worker years for the construction phase on the current repository design concepts described in Chapter 2. Estimates range from about 5,200 to about 6,300 worker years depending on the thermal load and packaging scenario (Appendix F, Table F-1). Table 4-20 lists estimated potential impacts from normal industrial hazards for involved and noninvolved workers for the construction phase. The table lists three types of industrial safety impacts: total recordable cases of injuries and illnesses that are work-related, total lost workday cases, and fatalities. (See the discussions in Appendix F, Section F.2.2.)

Table 4-20. Estimated impacts to workers from industrial hazards during initial construction period.[a,b]

Worker group and impact category	High thermal load			Intermediate thermal load			Low thermal load		
	UC[c]	DISP[d]	DPC[e]	UC	DISP	DPC	UC	DISP	DPC
Involved workers									
Total recordable cases	290	240	250	300	250	260	300	250	260
Lost workday cases	140	120	120	140	120	120	140	120	120
Fatalities	0.14	0.11	0.12	0.14	0.12	0.12	0.14	0.12	0.12
Noninvolved workers									
Total recordable cases	50	41	42	50	41	42	50	41	42
Lost workday cases	24	20	21	24	20	21	24	20	21
Fatalities	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
All workers (totals)[f]									
Total recordable cases	340	280	290	350	290	300	350	290	300
Lost workday cases	160	140	140	160	140	140	170	140	140
Fatalities	0.18	0.15	0.16	0.18	0.16	0.16	0.18	0.16	0.16

a. Source: Appendix F, Tables F-7 and F-8.
b. The analysis assumed that construction phase would last 44 months for surface activities and 60 months for subsurface activities.
c. UC = uncanistered packaging scenario.
d. DISP = disposable canister packaging scenario.
e. DPC = dual-purpose canister packaging scenario.
f. Totals might differ from sums due to rounding.

The surface facilities that would be required to handle each packaging scenario would be different, so the industrial safety impacts for construction would be different. Appendix F, Tables F-7 and F-8, contains industrial hazard impact tables for surface and subsurface workers.

Estimated fatalities would be of the magnitude of 0.2 for all scenarios. Industrial safety impacts (including total recordable cases and lost workday cases) would be largest for the uncanistered packaging scenario due to the more extensive surface facilities required and, hence, more worker years for construction.

Naturally Occurring Hazardous Materials. Two types of naturally occurring hazardous materials are present at the Yucca Mountain site—cristobalite, a form of crystalline silica (silicon dioxide, SiO_2), and erionite, a naturally occurring zeolite. Both occur in the subsurface rock at Yucca Mountain and have the potential to become airborne during repository operations. Cristobalite, which would occur at the repository level, would be released during tunneling operations. It could also be released with wind-blown dust from the excavated rock pile.

Dust generated during tunneling would come from welded tuff, which consists largely of silica-based minerals. Crystalline silica is a highly structured form of silica that includes quartz and cristobalite. It is a known causative agent for the disease called *silicosis,* which is a destructive lung condition caused by deposition of particulate matter in the lungs and characterized by scarring of lung tissue. It is contracted by prolonged exposure to high levels of respirable silica dust or to acute levels of respirable silica dust (EPA 1996a, Chapter 8). The welded tuff has an average cristobalite content of between 18 and 28 percent (TRW 1999b, page 4-81). Using the parent rock percentage probably will overestimate the airborne cristobalite concentration, because studies of both ambient and occupational airborne crystalline silica have shown that most airborne crystalline silica is coarse and not respirable, and that larger particles will deposit rapidly on the surface (EPA 1996a, page 3-26).

The International Agency for Research on Cancer has classified crystalline silica, when inhaled in the form of quartz or cristobalite from occupational sources, as a Class 1 (known) carcinogen (IARC 1997, pages 207 and 208). The Environmental Protection Agency has noted an increased cancer risk to humans who already have developed adverse noncancer effects from silicosis, but the cancer risk to otherwise healthy individuals is not clear (EPA 1996a, pages 8-7 to 8-9). To date, the Environmental Protection Agency has not issued the factors needed to estimate the risk of cancer from crystalline silica exposures.

The dust from mechanical rock excavation and dust pickup from the excavated rock pile would consist of a range of particle sizes. Dust particles with an aerodynamic diameter smaller than 10 micrometers have little mass and inertia in comparison to their surface area; therefore, they can remain suspended in dry air for long periods and humans can inhale them. DOE would use engineering controls during subsurface work to control exposures of workers to silica dust. Water would be applied during excavation activities to wet both the rock face and the broken rock to minimize airborne dust levels. Wet or dry dust scrubbers would capture dust that the water sprays did not suppress. The fresh air intake and the exhaust air streams would be separated to prevent increased dust concentrations in the drift atmosphere from recirculation. In addition, the ventilation system would be designed and operated to control ambient air velocities to minimize dust resuspension. DOE would monitor the working environment to ensure that workers were not exposed to dust concentrations higher than the applicable limits for cristobalite. If engineering controls were unable to maintain dust concentrations below the limits, subsurface workers would have to wear respirators until the engineering controls could establish acceptable conditions. Similar controls would be applied, if required, for surface workers. DOE expects that exposure of workers to silica dust would be below the applicable limits and potential impacts to subsurface and surface workers would be very small.

Erionite is a natural zeolite that occurs in the rock layers below the proposed repository level (see Chapter 3, Section 3.1.3). It might also occur in rock layers above the repository level but activities to date have not found it in those layers. Erionite could become a hazard during vertical boring operations if the operations passed through a rock layer containing erionite (which would be unlikely), and during excavation for access to the lower block as required for the low thermal load scenario. Erionite forms wool-like fibrous masses with a maximum fiber length of about 50 micrometers. The International Agency for Research on Cancer has determined that erionite is a carcinogen for humans, based on the very high mortality observed in three Turkish villages where erionite is mined (IARC 1987, all). DOE does not expect to encounter erionite layers either during vertical boring operations (which would be through rock layers above known erionite layers) or during excavation to provide access to the lower block and offset areas. Access excavation would be planned to avoid any identified layers of erionite (McKenzie 1998, all). If erionite was encountered during excavation for access to the lower block or during vertical boring operations, the engineering controls described above for cristobalite would be instituted and workers would be required to wear respiratory protection until acceptable conditions were reestablished. Appendix F, Section F.1.2, contains additional information on the impacts associated with inhalation of crystalline silica, cristobalite, and erionite.

Radiological Health Impacts. Potential radiological health impacts to involved and noninvolved workers in subsurface facilities during this phase would be from two sources: exposure to and inhalation of naturally occurring radon-222 and its decay products following emanation of the radon from the surrounding rock, and external radiation dose from naturally occurring radionuclides in the drift walls, principally potassium-40 and radionuclides in the uranium decay series (TRW 1999o, Sections 4 and 5). Radon-222 is a noble gas produced by the radioactive decay of naturally occurring uranium-238 in the rock. Because it is a noble gas, radon could emanate from the rock into the drifts, where elevated concentrations of radon-222 and its decay products could occur in the repository atmosphere (see Chapter 3, Section 3.1.8).

Studies during Exploratory Studies Facility activities indicated a dose rate from background sources of radionuclides in the drift walls of about 40 millirem per year, which is about the same as the cosmic and cosmogenic components from background radiation on the surface, 40 millirem per year in the Amargosa Valley region (see Chapter 3, Table 3-28). This analysis considers the underground ambient radiation dose to be part of the involved worker occupational exposure.

Workers in surface facilities would be exposed to airborne emissions of radon-222 and its decay products released in subsurface exhaust ventilation air. Spent nuclear fuel and high-level radioactive waste would not be present at the site during the construction phase and so would not contribute to radiological impacts.

Table 4-21 lists estimated potential doses and radiological health impacts for the 5 years of the construction phase to involved workers and noninvolved workers, and the sum for all workers. It lists estimated doses and radiological health impacts for the maximally exposed involved worker and for the involved worker population; radiological health impacts for the maximally exposed noninvolved worker and for the noninvolved worker population; and the estimated collective dose and radiological health impacts for the combined population of workers. Estimated doses were converted to estimates of latent cancer fatalities using a dose-to-risk conversion factor of 0.0004 latent cancer fatality per rem (see Appendix F, Section F.1.1.5). This conversion factor is based on a widely accepted international recommendation (ICRP 1991, page 22) and has been accepted for use by Federal agencies. The tables that follow list radiological health impacts for individuals as the increase in the probability of a latent cancer fatality occurring after the receipt of a dose for the maximally exposed individual worker.

Table 4-21. Estimated doses and radiological health impacts to workers during initial construction period.[a,b]

Worker group and impact category	High thermal load	Intermediate thermal load	Low thermal load
Involved workers			
Maximally exposed worker dose (millirem)	770	860	860
Latent cancer fatality probability	0.0003	0.0003	0.0003
Collective dose (person-rem)	350	420	420
Latent cancer fatality incidence	0.14	0.17	0.17
Noninvolved workers			
Maximally exposed worker dose (millirem)	580	640	640
Latent cancer fatality probability	0.0002	0.0003	0.0003
Collective dose (person-rem)	70	78	78
Latent cancer fatality incidence	0.03	0.03	0.03
All workers (totals)[c]			
Collective dose (person-rem)	420	500	500
Latent cancer fatality incidence	0.17	0.20	0.20

a. Source: Appendix F, Tables F-9 and F-10.
b. The construction phase would last 5 years. Results are for subsurface workers.
c. Totals might differ from sums due to rounding.

Radiological health impacts to populations are listed as the number of latent cancer fatalities estimated to occur in the exposed population.

During the initial construction period, radiological health impacts to the surface facility workforce would be much smaller than those to the subsurface facility workforce, so the numbers in Table 4-21 are those for subsurface workers (see Appendix F, Table F-5).

Table 4-21 indicates that the projected increase in the number of latent cancer fatalities for workers would be low (about 0.2); the calculated increase in the likelihood that an individual worker would die from a latent cancer fatality would also be low (less than about 0.0003).

4.1.7.2.2 *Public Health Impacts*

Naturally Occurring Hazardous Materials. Table 4-1 lists estimated annual average concentrations of cristobalite at the site boundary where members of the public could be exposed during the construction phase. The analysis estimated concentrations of less than 0.025 microgram per cubic meter for all thermal load scenarios, and health impacts to the public would be unlikely. Quantities and resultant concentrations of erionite, if present, would be much lower at locations of public exposure. Impacts would be very small.

Radiological Health Impacts. Potential radiological health impacts to the public during the construction phase would come from exposure to airborne releases of naturally occurring radon-222 and its decay products in the subsurface exhaust ventilation air. The analysis estimated doses and radiological health impacts for the offsite maximally exposed individual and the potentially involved population. The offsite maximally exposed individual is a hypothetical member of the public at a point on the land withdrawal boundary that would receive the largest annual dose and resultant radiological health impact. This location would be 20 kilometers (about 12 miles) south of the repository site. Section 4.1.2.2.2 provides additional information on the estimates of public doses. Estimated doses to members of the public were converted to estimates of latent cancer fatalities using a dose-to-risk conversion factor of 0.0005 latent cancer fatality per rem for members of the public (see Chapter 3, Section 3.1.8).

Table 4-22 lists the estimated doses and radiological health impacts to members of the public from the 5-year initial construction period. The values in the table indicate that radiological health impacts to the public from repository construction would be very small (0.006 latent cancer fatality for each of the thermal load scenarios). The estimated individual risk of contracting a latent cancer fatality for the maximally exposed individual would be about 0.000001 over the 5-year phase.

Table 4-22. Estimated doses and radiological health impacts from radon-222 to the public during the initial construction period.[a,b]

Dose or health effect	High thermal load	Intermediate thermal load	Low thermal load
Maximally exposed individual[c] dose (millirem)	2.1	2.5	2.5
Latent cancer fatality probability	1.1×10^{-6}	1.2×10^{-6}	1.2×10^{-6}
Collective dose (person-rem)[d]	11	13	13
Latent cancer fatality incidence	0.0057	0.0066	0.0066

a. Source: Table 4-2.
b. The initial construction period would last 5 years.
c. The individual was assumed to maintain continuous residence 20 kilometers (12 miles) south of the repository.
d. Dose to approximately 28,000 individuals within about 80 kilometers (50 miles) of the repository.

4.1.7.3 Occupational and Public Health and Safety Impacts for the Continuing Construction, Operation, and Monitoring Period (2010 to 2110)

This section discusses estimates of health and safety impacts to workers and members of the public for the operation and monitoring phase. The analysis assumed a 24-year period for the receipt, handling, packaging, and emplacement of spent nuclear fuel and high-level radioactive waste. There would be a concurrent 22-year period for drift development. A 76-year monitoring period would begin after the completion of emplacement. However, the monitoring period could be as short as 26 years and as long as 276 years (see Section 4.1). Appendix F, Table F-24, lists radiological health impacts for the shorter and longer monitoring periods.

4.1.7.3.1 *Occupational Impacts (Involved and Noninvolved Workers)*

Industrial Hazards. Table 4-23 summarizes health and safety impacts from common industrial hazards for the operation and monitoring phase. DOE performed separate analyses for surface operations, subsurface emplacement operations, subsurface drift development operations, and monitoring activities, and summed the values to obtain the results listed in this table. Appendix F (Tables F-11, F-12, and F-13) contains results of the impact analysis for each subphase.

The analysis predicted a range of 1.3 to 1.6 fatalities for the various combinations of thermal load scenarios and packaging scenarios. The largest number of workers (see Appendix F, Table F-1) and, therefore, the largest industrial health and safety impacts would be associated with the uncanistered packaging scenario.

Naturally Occurring Hazardous Material. As discussed in Section 4.1.7.2.1 for the construction phase, DOE would use engineering controls and, if necessary, administrative worker protection measures such as respiratory protection to control and minimize impacts to workers from releases of cristobalite and erionite during the operation and monitoring phase.

Radiological Health Impacts. This section discusses the estimates of the radiological health impacts to workers for the operation and monitoring phase. The overall radiological health impacts, which are listed in Table 4-24, are a combination of impacts to surface workers during operation, impacts to subsurface workers during operations, and impacts to surface and subsurface workers during monitoring.

Table 4-23. Estimated impacts to workers from industrial hazards during the continuing construction, operation, and monitoring period.[a,b]

Worker group and impact category	High thermal load			Intermediate thermal load			Low thermal load		
	UC[c]	DISP[d]	DPC[e]	UC	DISP	DPC	UC	DISP	DPC
Involved									
TRC[f]	1,360	1,150	1,160	1,360	1,150	1,160	1,400	1,180	1,200
LWC[g]	710	610	620	710	610	620	730	640	640
Fatalities	1.1	0.88	0.89	1.1	0.88	0.89	1.1	0.90	0.92
Noninvolved									
TRC	500	450	450	500	450	450	500	450	450
LWC	250	220	220	250	220	220	250	220	220
Fatalities	0.49	0.43	0.43	0.49	0.43	0.43	0.49	0.42	0.43
All workers (totals)[h]									
TRC	1,860	1,590	1,600	1,860	1,600	1,610	1,900	1,630	1,650
LWC	960	830	840	960	840	840	980	860	860
Fatalities	1.6	1.3	1.3	1.6	1.3	1.3	1.6	1.3	1.4

a. Source: Appendix F; sum of impacts listed in Tables F-11, F-12, F-13, F-19, F-20, and F-21.
b. The operation and monitoring phase would last 100 years.
c. UC = uncanistered packaging scenario.
d. DISP = disposable canister packaging scenario.
e. DPC = dual-purpose canister packaging scenario.
f. TRC = total recordable cases of accident or injury.
g. LWC = lost workday cases.
h. Totals might differ from sums due to rounding.

Table 4-24. Estimated dose and radiological health impacts to workers for the continuing construction, operation, and monitoring period.[a,b]

Worker group and impact category	High thermal load			Intermediate thermal load			Low thermal load		
	UC[c]	DISP[d]	DPC[e]	UC	DISP	DPC	UC	DISP	DPC
Involved									
MEI dose[f]	16,240	16,240	16,240	18,940	18,940	18,940	17,610	17,610	17,610
LCF[g] probability	0.006	0.006	0.006	0.008	0.008	0.008	0.007	0.007	0.007
CD[h]	8,120	5,330	5,380	8,450	5,660	5,710	8,530	5,740	5,790
LCF incidence	3.2	2.1	2.2	3.4	2.3	2.3	3.4	2.3	2.3
Noninvolved									
MEI dose	6,200	6,200	6,200	7,550	7,550	7,550	8,000	8,000	8,000
LCF probability	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.003
CD	350	330	330	380	360	360	400	390	390
LCF incidence	0.14	0.13	0.13	0.15	0.14	0.14	0.16	0.15	0.15
All workers (totals)[i]									
CD	8,470	5,660	5,710	8,830	6,020	6,070	8,930	6,130	6,180
LCF incidence	3.3	2.2	2.2	3.6	2.4	2.4	3.6	2.5	2.5

a. Source: The maximally exposed individual and latent cancer fatality probabilities are the maximums from Tables 4-25, 4-26, and 4-27. The collective dose and latent cancer fatality incidence are summed from the same tables.
b. The operation and monitoring phase would last 100 years.
c. UC = uncanistered packaging scenario.
d. DISP = disposable canister packaging scenario.
e. DPC = dual-purpose canister packaging scenario.
f. MEI dose = maximally exposed individual (worker) dose, in millirem. The subsurface facilities workers could incur the dose shown during the monitoring period.
g. LCF = latent cancer fatality.
h. CD = collective dose (person-rem).
i. Totals might differ from sums due to rounding.

With respect to overall radiological health impacts, the estimated health impacts to workers for the 100-year operation and monitoring phase would range from 2 to 4 latent cancer fatalities. Estimated radiological health impacts to the maximally exposed individual would be about the same as those from normal background radiation exposure in the Amargosa Valley region over a 70-year lifetime (about 25,000 millirem) during the 100-year operation and monitoring phase.

Tables 4-25 and 4-26 list health impacts to surface and subsurface workers, respectively, for 24 years of operations activities. Radiological health impacts to surface workers would be independent of the thermal load scenarios, and impacts to subsurface workers would be independent of the packaging scenario.

Table 4-25. Estimated dose and radiological health impacts to surface facility workers for the 24-year operation period.[a]

Worker group and impact category	Packaging scenario[b]		
	UC	DISP	DPC
Involved workers			
Maximally exposed worker dose (millirem)	9,600	9,600	9,600
LCF[c] probability	0.004	0.004	0.004
Collective dose (person-rem)	5,170	2,460	2,500
LCF incidence	2.1	1.0	1.0
Noninvolved workers			
Maximally exposed worker dose (millirem)	600	600	600
LCF probability	0.0002	0.0002	0.0002
Collective dose (person-rem)	100	90	90
LCF incidence	0.04	0.04	0.04
All workers (totals)[d]			
Collective dose (person-rem)	5,270	2,550	2,590
LCF incidence	2.1	1.0	1.0

a. Calculated from full-time equivalent worker year values in Appendix F, Table F-1 and dose rate values in Table F-5.
b. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister.
c. LCF = latent cancer fatality.
d. Totals might differ from sums due to rounding.

Table 4-26. Estimated dose and radiological health impacts to subsurface facilities workers during the 24-year operation period.[a]

Worker group and impact category	High thermal load	Intermediate thermal load	Low thermal load
Involved			
Maximally exposed worker dose (millirem)[b]	7,010	7,630	7,630
LCF[c] probability	0.003	0.003	0.003
Collective dose (person-rem)	900	950	1,010
LCF incidence	0.36	0.38	0.40
Noninvolved			
Maximally exposed worker dose (millirem)[b]	980	1,270	2,280
LCF probability	0.0004	0.0005	0.0009
Collective dose (person-rem)	120	120	140
LCF incidence	0.05	0.05	0.06
All workers (totals)[d]			
Collective dose (person-rem)	1,020	1,070	1,150
LCF incidence	0.41	0.43	0.46

a. Source: Appendix F; sum of impacts listed in Tables F-14, F-15, F-16, F-17, and F-18. The impacts listed would result from work lasting 22 to 24 years.
b. The subsurface facilities emplacement workers could incur the dose shown during the 24-year operation period (the development worker's maximum worker dose would be lower).
c. LCF = latent cancer fatality.
d. Totals might differ from sums due to rounding.

The basic dose rate data (Appendix F, Table F-5) used to calculate radiological impacts are conservatively high, particularly for workers in surface facility operations, and tend to overestimate potential impacts. These estimates are sufficiently conservative to include potential doses from other activities such as handling low-level radioactive waste generated during repository operations. The principal contributors to radiological health impacts would be surface facility operations, which would involve the receipt, handling, and packaging of spent nuclear fuel and high-level radioactive waste for emplacement, and subsurface monitoring activities (see Tables 4-25, 4-26, and 4-27). Radiological health impacts to workers would be highest for the combination of the uncanistered package scenario and the low thermal load scenario, with estimated radiological health impacts varying by about 50 percent from highest to lowest. Radiological health impacts from this combination of scenarios would be highest because it would involve the highest number of worker years. The variations are not large for a given shipping package scenario because impacts to subsurface workers would not depend on the shipping package scenario.

The largest component of the radiological impacts to subsurface workers during emplacement would be from inhalation of radon-222 and its decay products, particularly during the postemplacement monitoring period (see Appendix F, Table F-23).

Decontamination, Monitoring, and Maintenance Activities (2034 to 2110). The monitoring and maintenance activities of the operation and monitoring phase would last for 76 years and involve two types of activities leading to potential radiological health impacts. They are the decontamination of the surface facilities, which would take 2 to 3 years at the beginning of the monitoring period, and subsurface monitoring and maintenance activities. Table 4-27 lists estimated dose and radiological health impacts to workers for the surface facilities decontamination activities and the 76-year monitoring period.

Table 4-27. Estimated dose and radiological health impacts to workers for the 3-year decontamination period and the 76-year monitoring and maintenance period.[a,b]

Worker group and impact category	High thermal load			Intermediate thermal load			Low thermal load		
	UC[c]	DISP[d]	DPC[e]	UC	DISP	DPC	UC	DISP	DPC
Involved									
MEI dose[f] (millirem)	16,240	16,240	16,240	18,940	18,940	18,940	17,610	17,610	17,610
LCF[g] probability	0.006	0.006	0.006	0.008	0.008	0.008	0.007	0.007	0.007
CD[h] (person-rem)	2,050	1,990	1,980	2,330	2,250	2,260	2,350	2,270	2,280
LCF incidence	0.9	0.9	0.9	1.0	1.0	1.0	1.1	1.0	1.0
Noninvolved									
MEI dose (millirem)	6,200	6,200	6,200	7,550	7,550	7,550	8,000	8,000	8,000
LCF probability	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.003
CD (person-rem)	120	120	120	150	150	150	160	160	160
LCF incidence	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06
All workers (total)[i]									
CD (person-rem)	2,170	2,110	2,100	2,480	2,400	2,410	2,510	2,430	2,440
LCF incidence	1.0	1.0	1.0	2.1	1.0	1.0	1.1	1.0	1.0

a. Sources: Appendix F, Tables F-22 and F-23.
b. Monitoring period impacts would be independent of the packaging scenario; surface facility decontamination impacts would depend on the packaging scenario.
c. UC = uncanistered packaging scenario.
d. DISP = disposable canister packaging scenario.
e. DPC = dual-purpose canister packaging scenario.
f. MEI dose = maximally exposed individual (worker) dose, in millirem.
g. LCF = latent cancer fatality.
h. CD = collective dose.
i. Totals might differ from sums due to rounding.

Appendix F, Table F-22 lists the radiological health impacts associated with surface facility decontamination operations. The impacts would vary with the packaging scenario because of differences in the surface facility design to accommodate the different types of shipping packages.

Monitoring and maintenance would involve both surface and subsurface workers; however, the dose to surface workers would be very low in comparison to those to subsurface workers. Therefore, essentially all the radiological impacts would be to subsurface workers (see Appendix F, Table F-5 footnotes). Appendix F, Table F-23, lists doses and radiological health impacts to subsurface workers for the 76-year monitoring period. Estimated doses and radiological health impacts to the maximally exposed worker are based on a 50-year working lifetime. In addition, Appendix F describes dose and radiological health estimates for workers for a shorter monitoring period of 26 years and for a longer monitoring period of 276 years (see Appendix F, Table F-24).

4.1.7.3.2 *Public Health Impacts*

Naturally Occurring Hazardous Materials. Section 4.1.2.3.1 presents estimated annual average concentrations of cristobalite at the land withdrawal boundary where members of the public could be exposed during the operation and monitoring phase. The analysis estimated annual average concentrations of about 0.015 microgram per cubic meter or less for all thermal load scenarios. Health impacts to the public would be unlikely. Quantities and resultant concentrations of erionite, if present, would be much lower than for cristobalite at locations of public exposure. Impacts would be very small.

Radiological Health Impacts. Potential radiological health impacts to the public from the operation and monitoring phase could result from exposure to naturally occurring radon-222 and its decay products released in subsurface exhaust ventilation air, and from exposure to radioactive noble gas fission products, principally krypton-85, that could be released from the Waste Handling Building during spent nuclear fuel handling operations. Krypton-85 and other noble gas fission products would be very small contributors to dose and potential radiological impacts, less than 0.001 percent of the dose from radon-222 and its decay products (see Section 4.1.2.3.2).

Section 4.1.2.3.2 presents estimates of dose to the public for the continuing construction, operation, and monitoring period. Table 4-28 lists these doses and potential radiological health impacts to the public for that period.

Table 4-28. Estimated total dose and radiological health impacts over 50 years to the public for continuing construction, operation, and monitoring period.[a]

Impact category	High thermal load	Intermediate thermal load	Low thermal load
Maximally exposed individual[b] dose (millirem)	49	58	132
Latent cancer fatality probability	2.45×10^{-5}	2.3×10^{-5}	6.6×10^{-5}
Collective dose[c] (person-rem)	259	310	700
Latent cancer fatality incidence	0.13	0.15	0.35

a. Source: Tables 4-4 and 4-5.
b. Exposed for a 70-year lifetime; assumed first 24 years during operation and last 46 years during monitoring.
c. Dose to approximately 28,000 individuals within about 80 kilometers (50 miles) for 100 years of operation and monitoring.

Potential radiological health impacts to the public from radionuclides released during the operation and monitoring phase would be low, with 0.13 to 0.35 latent cancer fatality estimated for the thermal load scenarios. The probability of a latent cancer fatality to the maximally exposed individual would be about 0.00005 or less.

4.1.7.4 Impacts to Occupational and Public Health and Safety from Closure (2110 to 2125)

This section contains estimates of health and safety impacts to workers and to members of the public for the closure phase. The length of this phase would depend on the thermal load scenario. The values used for impact estimates are 6, 6, or 15 years for the high, intermediate, or low thermal load scenario, respectively.

4.1.7.4.1 *Occupational Impacts (Involved and Noninvolved Workers)*

Industrial Hazards. Table 4-29 lists impacts to workers from normal industrial workplace hazards for the closure phase.

Table 4-29. Estimated impacts to workers from industrial hazards during closure phase.[a,b]

Worker group and impact category	High thermal load			Intermediate thermal load			Low thermal load		
	UC[c]	DISP[d]	DPC[e]	UC	DISP	DPC	UC	DISP	DPC
Involved									
TRC[f]	180	150	150	180	150	150	300	270	270
LWC[g]	85	71	74	85	71	74	140	130	130
Fatalities	0.08	0.07	0.07	0.08	0.07	0.07	0.14	0.13	0.13
Noninvolved									
TRC	28	24	23	28	23	24	41	36	37
LWC	14	11	12	14	11	12	20	18	18
Fatalities	0.03	0.02	0.02	0.03	0.02	0.02	0.04	0.03	0.03
All workers (totals)[h]									
TRC	210	170	170	210	170	170	340	310	310
LWC	99	82	86	99	82	86	160	150	150
Fatalities	0.11	0.09	0.09	0.11	0.09	0.09	0.18	0.16	0.16

a. Source: Appendix F, Tables F-25 and F-26.
b. The closure phase would last for 6, 6, and 15 years for high, intermediate, and low thermal loads, respectively (Jessen 1999a).
c. UC = uncanistered packaging scenario.
d. DISP = disposable canister packaging scenario.
e. DPC = dual-purpose canister packaging scenario.
f. TRC = total recordable cases.
g. LWC = lost workday cases.
h. Totals might differ from sums due to rounding.

The estimated number of impacts from industrial hazards for the low thermal load scenario would be about double those for the intermediate and high thermal load scenarios because of the longer time required for closure and the associated larger number of worker years. The estimated number of fatalities would be much less than 1 for all thermal load scenarios.

Naturally Occurring Hazardous Material. Subsurface excavation would not occur during the closure phase, so the potential for exposure of workers to cristobalite and erionite would be much less. As necessary, DOE would use engineering controls and worker protection measures such as those discussed in Section 4.1.7.2.2 for the construction phase to control and minimize potential impacts to workers.

Radiological Health Impacts. During the closure phase, subsurface workers would be exposed to radon-222 in the drift atmosphere, to external radiation from radionuclides in the drift walls, and to external radiation emanating from the waste packages. Table 4-30 lists radiological impacts to workers for the closure phase. Because estimated doses and radiological impacts to surface workers would be

Table 4-30. Estimated dose and radiological health impacts to workers during closure phase.[a,b]

Worker group and impact category	High thermal load (6 years)	Intermediate thermal load (6 years)	Low thermal load (15 years)
Involved			
Maximally exposed individual dose[c] (millirem)	2,040	2,370	5,520
Latent cancer fatality probability	0.0008	0.0009	0.002
Collective dose (person-rem)	380	450	1,100
Latent cancer fatality incidence	0.15	0.18	0.44
Noninvolved			
Maximally exposed individual dose[c] (millirem)	1,090	1,340	3,540
Latent cancer fatality probability	0.0004	0.0005	0.001
Collective dose (person-rem)	48	59	160
Latent cancer fatality incidence	0.02	0.02	0.06
All workers (totals)[d]			
Collective dose (person-rem)	430	510	1,260
Latent cancer fatality incidence	0.17	0.20	0.50

a. Source: Appendix F, Tables F-27, F-28, and F-29.
b. Closure phase would last 6, 6, or 15 years for the high, intermediate, or low thermal load scenario, respectively (Jessen 1999a, all).
c. The subsurface facilities workers could incur the dose listed during the closure phase.
d. Totals might differ from sums due to rounding.

much smaller than those for subsurface workers (see Appendix F, Table F-5 footnotes), the impacts listed in this table are those for subsurface workers, which would be independent of the packaging scenario.

For the closure phase, the estimated number of latent cancer fatalities would range from 0.2 to 0.5. The probability of a latent cancer fatality for the maximally exposed individual worker would be 0.002 or less. The principal sources of exposure to subsurface workers would be from inhalation of radon-222 and its decay products.

4.1.7.4.2 *Public Health Impacts*

Naturally Occurring Hazardous Material. Section 4.1.2.4.1 presents estimated annual average concentrations of cristobalite during the closure phase at the land withdrawal boundary, where members of the public could be exposed. There would be no subsurface excavation during the closure phase, so cristobalite concentrations would be less than for earlier phases. Annual average concentrations of about 0.015 microgram per cubic meter or less were estimated for all thermal load scenarios, and health impacts to the public would be unlikely. Quantities and resultant concentrations of erionite, if present, would be much lower at locations of public exposure. Impacts would be very small.

Radiological Health Impacts. Potential radiation-related health impacts to the public from closure activities would result from exposure to radon-222 and its decay products released in the subsurface exhaust ventilation air. Section 4.1.2.4.2 presents estimates of dose to the public for the closure phase. Table 4-31 lists the estimated dose and radiological health impacts.

Radiological health impacts to the public would be low. The likelihood that the maximally exposed individual would experience a latent cancer fatality would be in the range of 0.000001 to 0.00001. The projected number of latent cancer fatalities would be 0.05 or less. The radiological health impacts to the public would be independent of the packaging scenario. Impacts to the public would be greatest for the low thermal load scenario, and would be about 6 to 7 times greater than for the intermediate and high thermal loads because of the larger radon release associated with the longer closure period for the low thermal load scenario.

Table 4-31. Estimated dose and radiological health impacts to public for the closure phase.[a]

Impact category	High thermal load	Intermediate thermal load	Low thermal load
Maximally exposed individual[b] dose (millirem)	2.6	3.1	19
Latent cancer fatality probability	1.3×10^{-6}	1.5×10^{-6}	9.4×10^{-6}
Collective dose (person-rem)[c]	13	15	93
Latent cancer fatality incidence	0.0064	0.0076	0.047

a. Source: Table 4-7.
b. For a person maintaining continuous residency during the entire closure phase.
c. Dose to approximately 28,000 individuals living within about 80 kilometers (50 miles).

4.1.7.5 Summary of Impacts to Occupational and Public Health and Safety

This section summarizes the potential human health and safety impacts to workers and members of the public from proposed activities at the Yucca Mountain repository. It describes the total impacts from activities during the construction, operation and monitoring, and closure phases for (1) impacts to workers from industrial hazards; (2) radiological health impacts to workers; and (3) radiological health impacts to members of the public. The three project phases would last 111, 111, and 120 years for the high, intermediate, and low thermal load scenarios, respectively. These differences in project duration are due to differences in the length of the closure phase for the three thermal load scenarios as described above.

4.1.7.5.1 *Impacts to Workers from Industrial Hazards in the Workplace for All Phases*

Table 4-32 lists the total impacts to workers from industrial hazards common to the workplace for all phases. For the approximately 110 to 120 years of repository activities, the estimated number of workplace fatalities would range from about 1.5 to 2. The estimated number of lost workday cases due to industrial injury or illness would range from about 1,060 to 1,280, depending on the combination of thermal load scenario and packaging scenario. About half of the industrial impacts would come from surface facility operations during the operation and monitoring phase because of the large number of worker years needed. The next largest contribution would be drift development during the operation and monitoring phase, which would account for as much as 15 percent of the impacts. The differences in impacts for the thermal load and shipping package combinations reflect differences in the number of full-time equivalent workers for the potential combinations.

4.1.7.5.2 *Radiological Impacts to Workers for All Phases*

Table 4-33 lists the total dose and radiological health impacts to workers for all phases. It lists dose and the potential radiological health impact to the maximally exposed individual worker for a 50-year working lifetime, and collective dose and potential radiological health impacts to the worker population for the 111, 111, or 120 years required to complete all phases for the high, intermediate, and low thermal load scenarios, respectively. The maximally exposed worker would have a probability of incurring a latent cancer fatality of 0.006 to 0.008 from radiation exposure over a 50-year working lifetime. The total estimated number of latent cancer fatalities in the repository workforce from the radiation exposure during all phases would range from about 2.5 to 4, depending on the combination of thermal load scenario and packaging scenario.

About 50 percent of the total worker radiation dose would be from the receipt, handling, and packaging of spent nuclear fuel in the surface facilities. Radiation from inhalation of radon-222 and its decay products by subsurface workers during construction, development, emplacement, monitoring, and closure

Table 4-32. Estimated impacts to workers from industrial hazards for all phases.[a]

Worker group and impact category	High thermal load			Intermediate thermal load			Low thermal load		
	UC[b]	DISP[c]	DPC[d]	UC	DISP	DPC	UC	DISP	DPC
Involved									
TRC[e]	1,820	1,540	1,560	1,830	1,550	1,570	1,990	1,700	1,730
LWC[f]	930	800	810	930	810	820	1,010	890	900
Fatalities	1.3	1.1	1.1	1.3	1.1	1.1	1.4	1.2	1.2
Noninvolved									
TRC	570	510	520	570	510	520	590	520	530
LWC	280	250	260	280	250	260	290	260	260
Fatalities	0.54	0.48	0.49	0.54	0.48	0.49	0.55	0.50	0.50
All workers (totals)[g]									
TRC	2,390	2,050	2,080	2,400	2,060	2,090	2,580	2,220	2,260
LWC	1,210	1,050	1,070	1,210	1,080	1,080	1,300	1,150	1,160
Fatalities	1.8	1.6	1.6	1.8	1.6	1.6	2.0	1.7	1.7

a. Source: Sum of impacts listed in Tables 4-20, 4-23, and 4-29.
b. UC = uncanistered packaging scenario.
c. DISP = disposable canister packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. TRC = total recordable cases.
f. LWC = lost workday cases.
g. Totals might differ from sums due to rounding.

Table 4-33. Estimated dose and radiological health impacts to workers for all phases.[a]

Worker group and impact category	High thermal load			Intermediate thermal load			Low thermal load		
	UC[b]	DISP[c]	DPC[d]	UC	DISP	DPC	UC	DISP	DPC
Involved									
MEI dose[e]	16,240	16,240	16,240	18,940	18,940	18,940	17,610	17,610	17,610
LCF[f] probability	0.006	0.006	0.006	0.008	0.008	0.008	0.007	0.007	0.007
CD[g]	8,850	6,060	6,110	9,320	6,530	6,580	10,060	7,270	7,320
LCF incidence	3.5	2.4	2.4	3.7	2.6	2.6	4.0	2.9	2.9
Noninvolved									
MEI dose[e]	6,200	6,200	6,200	7,550	7,550	7,550	8,000	8,000	8,000
LCF probability	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.003
CD	460	450	450	510	500	500	640	620	620
LCF incidence	0.19	0.18	0.18	0.21	0.20	0.20	0.25	0.25	0.25
All workers (totals)[h]									
CD	9,310	6,510	6,560	9,830	7,030	7,080	10,700	7,890	7,940
LCF incidence	3.7	2.6	2.6	3.9	2.8	2.8	4.3	3.2	3.2

a. Source: Tables 4-21, 4-24, and 4-30.
b. UC = uncanistered packaging scenario.
c. DISP = disposable canister packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. MEI dose = maximally exposed individual (surface facility worker) dose, in millirem.
f. LCF = latent cancer fatality.
g. CD = collective dose (person-rem).
h. Totals might differ from sums due to rounding.

would account for about 25 percent of the total worker dose, with another 10 to 15 percent of the total dose coming from subsurface worker exposure to radiation emanating from the waste packages.

Estimated dose and radiological health impacts to workers would be highest for the low thermal load scenario, with estimates 30 to 40 percent higher than those for the high thermal load scenario, because of the larger number of projected worker years. Dose and radiological health impacts would be one-third more for the uncanistered packaging scenarios than those for the other packaging scenarios because of the larger number of projected worker years. Accordingly, the combination of the low thermal load scenario and the uncanistered packaging scenario would have the highest estimated collective worker dose (10,700 person-rem) and highest estimated radiological impacts (4.3 latent cancer fatalities) over 120 years of repository activities.

4.1.7.5.3 *Radiological Health Impacts to the Public for All Phases*

Table 4-34 lists the estimated dose and radiological health impacts to the public for all phases. It lists dose and the potential radiological impact to the offsite maximally exposed individual for a 70-year lifetime with continuous residency about 20 kilometers (12 miles) south of the repository, and collective dose and potential radiological health impacts to the population within about 80 kilometers (50 miles) for the 111, 111, or 120 years required to complete all phases for the high, intermediate, and low thermal load scenarios, respectively.

Table 4-34. Estimated dose and radiological impacts to the public for all phases.[a,b]

Impact category	High thermal load	Intermediate thermal load	Low thermal load
Maximally exposed individual[c] (millirem)	38	46	100
Latent cancer fatality probability	1.9×10^{-5}	2.3×10^{-5}	5.1×10^{-5}
Collective dose[d] (person-rem)	280	340	810
Latent cancer fatality incidence	0.14	0.17	0.41

a. Source: Tables 4-22, 4-28, and 4-31.
b. Values are rounded to two significant figures.
c. Dose over a 70-year lifetime of the operation and monitoring phase, with continuous residency about 20 kilometers (12 miles) south of the repository.
d. Over all phases, lasting a total of 110, 111, or 120 years for the high, intermediate, or low thermal load scenario, respectively.

The offsite maximally exposed individual would have an increase in the probability of incurring a latent cancer fatality ranging from about 0.00002 to 0.00005 from exposure to radionuclides released from the repository facilities over a 70-year lifetime. The total estimated number of latent cancer fatalities in the potentially exposed population would range from 0.14 to 0.41 for the three thermal load scenarios. All doses and estimated radiological impacts would be from exposure to naturally occurring radon-222 and its decay products released from the subsurface facilities in exhaust ventilation air.

For comparison, the average individual radiation doses from natural sources of background radiation for Amargosa Valley and for the population of the United States are about 340 and 300 millirem per year, respectively (see Chapter 3, Table 3-28). Over a 70-year lifetime, individual dose from background radiation would be about 25,000 millirem, which is about 250 times larger than the offsite maximally exposed individual dose listed in Table 4-34. The highest annual dose to a member of the public from repository sources would be about 1.5 millirem or less. This radiation dose, essentially all from naturally occurring radon-222 and decay products, would be about 0.7 percent of the 200-millirem-per-year dose from radon-222 to members of the public in Amargosa Valley from ambient levels of naturally occurring radon (see Chapter 3, Section 3.1.8.2).

The Nevada cancer fatality rate in a population of 100,000 males is about 163 deaths per year (ACS 1998, page 6). Assuming this mortality rate is a baseline that would remain unchanged for the estimated population (in 2000) of about 28,000 within about 80 kilometers (50 miles) of the Yucca Mountain site, there would be about 50 cancer deaths per year from other causes and more than 5,000 cancer deaths over the period of the repository phases. The impact calculations in this EIS indicate that the additional cancer fatalities for the public from short-term activities would be less than 0.4, which would be an increase of about 0.01 percent.

4.1.8 ACCIDENT SCENARIO IMPACTS

This section describes the impacts from potential accident scenarios from performance confirmation, construction, operation and monitoring, and closure activities. The analysis is separated into radiological accidents (Section 4.1.8.1) and nonradiological accidents (Section 4.1.8.2). The analysis of radiological accident consequences used the MACCS2 computer code (Chanin and Young 1998, all). The receptors would be (1) the *maximally exposed individual,* defined as a hypothetical member of the public at the point on the land withdrawal boundary that would receive the largest dose from the assumed accident scenario, (2) the *involved worker,* a worker who would be handling the spent nuclear fuel or high-level radioactive waste when the accident occurred, (3) the *noninvolved worker*, a worker near the accident but not involved in handling the material, and (4) members of the public who reside within approximately 80 kilometers (50 miles) of the proposed repository. All analysis method details are provided in Appendix H.

ACCIDENT TYPES

Radiological accidents are unplanned events that could result in exposure of nearby humans to direct radiation or to radioactive material that would be ingested or inhaled.

Nonradiological accidents are unplanned events that could result in exposure of nearby humans to hazardous or toxic materials released to the environment as a result of the accident.

The impacts to offsite individuals from repository accidents would be small, with calculated doses as high as 0.013 rem to the maximally exposed offsite individual. Doses to a maximally exposed noninvolved worker would be higher, bounded by the worst-case accident scenarios at 31 rem.

4.1.8.1 Radiological Accidents

The first step in the radiological accident analysis was to examine the initiating events that could lead to facility accidents. These events 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 (plausible upper limit) 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 analysis used accident analyses previously performed by others for repository operation whenever possible to identify potential accidents. DOE reviewed these analyses for their applicability to the repository before using them (see Appendix H). The spectrum of accident scenarios evaluated in the analysis is based on the current conceptual design of the facility. Final facility design details are not available; the final designs could affect both the frequency and consequences of postulated accident s. For areas without final facility design criteria, DOE made assumptions to ensure that the analysis did not underestimate 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 (see Appendix A, Section A.2.1), DOE spent nuclear fuel (see Appendix A, Section A.2.2), DOE high-level radioactive waste incorporated in a glass matrix (see Appendix A, Section A.2.3), and weapons-grade plutonium either immobilized in high-level radioactive waste glass matrix or as mixed-oxide fuel (see Appendix A, Section A.2.4). Appendix H contains information on the radionuclide inventories in these materials. The analysis also examined accident scenarios involving the release of low-level waste generated and handled at the repository, primarily in the Waste Treatment Building.

The analysis used the radionuclide inventories from Appendix A for a typical fuel element to estimate the material that could be involved in an accident. It used the MACCS2 computer program, developed under the guidance of the Nuclear Regulatory Commission, to estimate potential radiation doses to exposed individuals (onsite and offsite) and population groups from postulated accidental releases of radionuclides. Appendix H contains additional information on the MACCS2 program and the models and assumptions incorporated in it.

The analysis considered radiological consequences of the postulated accidents for the following individuals and populations:

- *Involved worker.* A facility worker directly involved in activities at the location where the postulated accident could occur
- *Maximally exposed noninvolved worker (collocated worker).* A worker not directly involved with material unloading, transfer, and emplacement activities, assumed to be 100 meters (330 feet) downwind of the facility where the release occurs
- *Maximally exposed offsite individual.* A hypothetical member of the public at the nearest point to the facility at the site boundary. The analysis determined that the land withdrawal boundary location with the highest potential exposure from an accidental release of radioactive material would be about 11 kilometers (about 7 miles) from the accident location (at the western boundary of the land withdrawal area analyzed). The maximally exposed individual for a single-point release of material is different than those for a continuous release (see Section 4.1.2) because the frequency of wind in each direction enters the continuous release calculation of the maximally exposed individual.
- *Offsite population.* Members of the public within 80 kilometers (50 miles) of the repository site (see Chapter 3)

Sixteen accident scenarios were analyzed in detail. These scenarios bound the consequences 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, and the Waste Treatment Building. The scenarios consider drops and collisions involving shipping casks, fuel canisters, bare fuel assemblies, low-level radioactive waste drums, and the waste package transporter.

Table 4-35 lists the results of the radiological accident consequence analysis under median, or 50th-percentile meteorological conditions. Table 4-36 lists similar information based on unfavorable meteorological conditions (95th-percentile, or those conditions that would not be exceeded more than 5 percent of the time) that tend to maximize potential radiological impacts. Impacts to the noninvolved worker would result from the inhalation of airborne radionuclides and external radiation from the passing plume. Impacts to the maximally exposed offsite individual and the offsite population would result from

Table 4-35. Radiological consequences of repository operations accident scenarios for median (50th-percentile) meteorological conditions.

		Maximally exposed offsite individual		Population		Noninvolved worker		Involved worker	
Accident[a,b,c]	Frequency (per year)[a]	Dose (rem)	LCFi[d]	Dose (person-rem)	LCFp[d]	Dose (rem)	LCFi	Dose (rem)	LCFi
1. 6.9-meter drop of shipping cask in CTHA-61 BWR assemblies-no filtration	4.5×10^{-4}	1.9×10^{-3}	1.0×10^{-6}	5.5×10^{-2}	2.7×10^{-5}	9.4×10^{-1}	3.8×10^{-4}	76	3.0×10^{-2}
2. 7.1-meter drop of shipping cask in CTHA-26 PWR assemblies-no filtration	6.1×10^{-4}	2.3×10^{-3}	1.2×10^{-6}	6.6×10^{-2}	3.3×10^{-5}	1.1	4.4×10^{-4}	90	3.6×10^{-2}
3. 4.1-meter drop of shipping cask in CTHA-61 BWR assemblies- no filtration	1.4×10^{-3}	1.3×10^{-3}	6.5×10^{-7}	3.9×10^{-2}	2.0×10^{-5}	5.7×10^{-1}	2.3×10^{-4}	46	1.8×10^{-2}
4. 4.1-meter drop of shipping cask in CTHA-26 PWR assemblies-no filtration	1.9×10^{-3}	1.4×10^{-3}	7.0×10^{-7}	4.6×10^{-2}	2.3×10^{-5}	6.6×10^{-1}	2.6×10^{-4}	53	2.1×10^{-2}
5. 6.3-meter drop of MCO in CTS-10 N-Reactor fuel canisters-filtration	4.5×10^{-4}	3.7×10^{-7}	1.9×10^{-10}	1.1×10^{-5}	5.3×10^{-9}	1.1×10^{-4}	4.4×10^{-8}	(e)	(e)
6. 6.3-meter drop of MCO in CTS-10 N-reactor fuel canisters-no filtration	2.2×10^{-7}	1.2×10^{-3}	6.0×10^{-7}	3.4×10^{-2}	1.7×10^{-5}	3.6×10^{-1}	1.4×10^{-4}	(e)	(e)
7. 5-meter drop of transfer basket in ATS-8 PWR assemblies-filtration	1.1×10^{-2}	6.6×10^{-7}	3.3×10^{-10}	4.0×10^{-4}	2.0×10^{-7}	1.7×10^{-4}	6.8×10^{-8}	(e)	(e)
8. 5-meter drop of transfer basket in ATS-8 PWR assemblies-no filtration	2.8×10^{-7}	5.6×10^{-4}	2.8×10^{-7}	1.7×10^{-2}	8.6×10^{-6}	1.6×10^{-1}	6.4×10^{-5}	(e)	(e)
9. 7.6-meter drop of transfer basket in ATS-16 BWR assemblies-filtration	7.4×10^{-3}	5.1×10^{-7}	2.6×10^{-10}	2.9×10^{-4}	1.5×10^{-7}	1.3×10^{-4}	5.2×10^{-8}	(e)	(e)
10. 7.6-meter drop of transfer basket in ATS-16 BWR fuel assemblies-no filtration	1.9×10^{-7}	6.1×10^{-4}	3.1×10^{-7}	1.6×10^{-2}	8.2×10^{-6}	1.8×10^{-1}	7.2×10^{-5}	(e)	(e)
11. 6-meter drop of disposal container in DCHS-21 PWR assemblies-filtration	1.8×10^{-3}	1.8×10^{-6}	9.0×10^{-10}	1.0×10^{-3}	5.2×10^{-7}	5.0×10^{-4}	2.0×10^{-7}	(e)	(e)
12. 6-meter drop of disposal container in DCHS-21 PWR fuel assemblies-no filtration	8.6×10^{-7}	1.7×10^{-3}	8.5×10^{-7}	5.1×10^{-2}	2.5×10^{-5}	5.1×10^{-1}	2.0×10^{-4}	(e)	(e)
13. Transporter runaway and derailment in access tunnel-21 PWR assemblies-filtration-16-meter drop height equivalent	1.2×10^{-7}	4.3×10^{-3}	2.2×10^{-6}	1.1×10^{-1}	5.4×10^{-5}	1.5	6.0×10^{-4}	(f)	(f)
14. Earthquake - 375 PWR assemblies	2.0×10^{-5}	9.1×10^{-3}	4.6×10^{-6}	3.6×10^{-1}	1.8×10^{-4}	8.3	3.3×10^{-3}	(f)	(f)
15. Earthquake w/fire in WTB	2.0×10^{-5}	1.8×10^{-5}	9.0×10^{-9}	6.3×10^{-4}	3.2×10^{-7}	5.2×10^{-3}	2.1×10^{-6}	(f)	(f)
16. LLW drum rupture in WTB	0.59	6.1×10^{-10}	3.1×10^{-13}	2.1×10^{-8}	1.1×10^{-11}	1.4×10^{-7}	5.6×10^{-11}	7.0×10^{-5}	2.8×10^{-8}

a. Source: Appendix H.

b. CTHA = Cask Transfer/Handling Area, CTS = Canister Transfer System, ATS = Assembly Transfer System, DCHS = Disposal Container Handling System, WTB = Waste Treatment Building.

c. To convert meters to feet, multiply by 3.2808.

d. LCFi is the likelihood of a latent cancer fatality for an individual who receives the calculated dose. LCFp is the number of cancers probable in the exposed population from the collective population dose (person-rem). These values were computed based on a conversion of dose in rem to latent cancers as recommended by the International Council on Radiation Protection as discussed in this section.

e. For these cases, the involved workers are not expected to be vulnerable to exposure during an accident because operations are done remotely. Thus, involved worker impacts were not evaluated.

f. For these events, involved workers would likely be severely injured or killed by the event; thus, no radiological impacts were evaluated. For the seismic event, as many as 39 people could be injured or killed in the Waste Handling Building, and as many as 36 in the Waste Treatment Building based on current staffing projections (TRW 1998i, pages 17 and 18).

Table 4-36. Radiological consequences of repository operations accident scenarios for unfavorable (95th-percentile) meteorological conditions.

		Maximally exposed offsite individual		Population		Noninvolved worker		Involved worker	
Accident[a,b,c]	Frequency (per year)[a]	Dose (rem)	LCFi[d]	Dose (person-rem)	LCFp[d]	Dose (rem)	LCFi	Dose (rem)	LCFi
1. 6.9-meter drop of shipping cask in CTHA-61 BWR assemblies-no filtration	4.5×10^{-4}	7.2×10^{-3}	3.5×10^{-6}	1.7	8.6×10^{-4}	5.1	2.0×10^{-3}	76	3.0×10^{-2}
2. 7.1-meter drop of shipping cask in CTHA-26 PWR assemblies-no filtration	6.1×10^{-4}	8.0×10^{-3}	4.0×10^{-6}	2.1	1.1×10^{-3}	5.9	2.4×10^{-3}	90	3.6×10^{-2}
3. 4.1-meter drop of shipping cask in CTHA-61 BWR assemblies-no filtration	1.4×10^{-3}	4.3×10^{-3}	2.2×10^{-6}	1.3	6.5×10^{-4}	3.1	1.2×10^{-3}	46	1.8×10^{-2}
4. 4.1-meter drop of shipping cask in CTHA-26 PWR assemblies-no filtration	1.9×10^{-3}	5.2×10^{-3}	2.6×10^{-6}	1.5	7.8×10^{-4}	3.5	1.4×10^{-3}	53	2.1×10^{-2}
5. 6.3-meter drop of MCO in CTS-10 N-Reactor fuel canisters-filtration	4.5×10^{-4}	1.2×10^{-6}	6.0×10^{-10}	2.6×10^{-4}	1.3×10^{-7}	3.3×10^{-4}	1.3×10^{-7}	(e)	(e)
6. 6.3-meter drop of MCO in CTS-10 N-reactor fuel canisters-no filtration	2.2×10^{-7}	4.3×10^{-3}	2.2×10^{-6}	8.6×10^{-1}	4.3×10^{-4}	1.1	4.4×10^{-4}	(e)	(e)
7. 5-meter drop of transfer basket in ATS-8 PWR assemblies-filtration	1.1×10^{-2}	2.5×10^{-6}	1.3×10^{-9}	3.3×10^{-2}	1.6×10^{-5}	4.6×10^{-4}	1.8×10^{-7}	(e)	(e)
8. 5-meter drop of transfer basket in ATS-8 PWR assemblies-no filtration	2.8×10^{-7}	2.1×10^{-3}	1.1×10^{-6}	5.6×10^{-1}	2.8×10^{-4}	4.6×10^{-1}	1.8×10^{-4}	(e)	(e)
9. 7.6-meter drop of transfer basket in ATS-16 BWR assemblies-filtration	7.4×10^{-3}	2.1×10^{-6}	1.1×10^{-9}	2.4×10^{-2}	1.2×10^{-5}	3.8×10^{-4}	1.5×10^{-7}	(e)	(e)
10. 7.6-meter drop of transfer basket in ATS-16 BWR fuel assemblies-no filtration	1.9×10^{-7}	2.2×10^{-3}	1.1×10^{-6}	5.1×10^{-1}	2.6×10^{-4}	5.1×10^{-1}	2.0×10^{-4}	(e)	(e)
11. 6-meter drop of disposal container in DCHS-21 PWR assemblies-filtration	1.8×10^{-3}	7.3×10^{-6}	3.7×10^{-9}	8.6×10^{-2}	4.3×10^{-5}	1.3×10^{-3}	5.2×10^{-7}	(e)	(e)
12. 6-meter drop of disposal container in DCHS-21 PWR fuel assemblies-no filtration	8.6×10^{-7}	6.1×10^{-3}	3.1×10^{-6}	1.6	8.0×10^{-4}	1.3	5.2×10^{-4}	(e)	(e)
13. Transporter runaway and derailment in access tunnel-21 PWR assemblies-filtration-16-meter drop height equivalent	1.2×10^{-7}	1.3×10^{-2}	6.5×10^{-6}	3.2	1.6×10^{-3}	3.9	1.6×10^{-3}	(f)	(f)
14. Earthquake - 375 PWR assemblies	2.0×10^{-5}	3.2×10^{-2}	1.6×10^{-5}	14	7.2×10^{-3}	7.0	2.8×10^{-2}	(f)	(f)
15. Earthquake w/fire in WTB	2.0×10^{-4}	5.8×10^{-5}	2.9×10^{-8}	2.1	1.1×10^{-5}	5.2×10^{-3}	2.1×10^{-6}	(f)	(f)
16. LLW drum rupture in WTB	0.59	1.9×10^{-9}	9.5×10^{-13}	7.5×10^{-7}	3.7×10^{-10}	1.4×10^{-7}	5.6×10^{-11}	7.0×10^{-5}	2.8×10^{-8}

a. Source: Appendix H.

b. CTHA = Cask Transfer/Handling Area, CTS = Canister Transfer System, ATS = Assembly Transfer System, DCHS = Disposal Container Handling System, WTB = Waste Treatment Building.

c. To convert meters to feet, multiply by 3.2808.

d. LCFi is the likelihood of a latent cancer fatality for an individual who receives the calculated dose. LCFp is the number of cancers probable in the exposed population from the collective population dose (person-rem). These values were computed based on a conversion of dose in rem to latent cancers as recommended by the International Council on Radiation Protection, as discussed in this section.

e. For these cases, the involved workers are not expected to be vulnerable to exposure during an accident since operations are done remotely. Thus, involved worker impacts were not evaluated.

f. For these events, involved workers would likely be severely injured or killed by the event; thus, no radiological impacts were evaluated. For the seismic event, as many as 39 people could be injured or killed in the Waste Handling Building, and as many as 36 in the Waste Treatment Building based on current staffing projections (TRW 1998i, pages 17 and 18).

these exposure pathways and from long-term external exposure to radionuclides deposited on soil during plume passage, subsequent ingestion of radionuclides in locally grown food, and inhalation of resuspended particulates. The analysis did not consider interdiction by DOE or other government agencies to limit long-term radiation doses because none of these doses would be above the Environmental Protection Agency's Protective Action Guides. Interdiction would be likely to occur if the calculated accident doses exceeded these guides.

The most severe accident scenario (earthquake, Table 4-36, number 14) for the 95-percent weather conditions would result in an estimated 0.0072 additional latent cancer fatality for the same affected population. The more conservative summation of all potential accidents in Table 4-36 results in less than 0.02 additional latent cancer fatality for the exposed population. Thus, the estimated number of latent cancer fatalities for the individual receptors from accidents would be very small.

The results described in this section assumed that all commercial spent nuclear fuel would arrive at the repository either uncanistered or in canisters not suitable for disposal. In this base case scenario, all of the fuel would have to be handled as bare fuel assemblies in the Waste Handling Building and placed in disposal containers for disposal, as described above. As noted in Chapter 2, this EIS evaluates other packaging scenarios that include commercial spent nuclear fuel that would arrive at the repository in canisters suitable for disposal without being opened. The base case scenario, which assumes that all fuel would have to be handled as bare fuel assemblies, thus provides a bounding assessment of accident impacts for the packaging scenarios considered in Chapter 2 because accident scenarios involving damage to bare fuel assemblies during handling operations represent the bounding repository accident scenarios. The uncanistered fuel, as indicated in Tables 4-35 and 4-36, represents the more meaningful accident risk because of the additional handling operations required and the higher impacts associated with accidents involving bare assemblies. As a consequence, the base case evaluated in this section provides a bounding assessment of accident impacts in relation to the packaging scenarios.

The analysis evaluated accident scenario impacts during retrieval, and concluded that the transporter runaway and derailment accident scenarios evaluated for emplacement operation would bound other accident scenarios during retrieval operations that are credible. This conclusion is supported by the results of accident evaluations for above-ground dry storage at utility sites, as discussed in Appendix H.

4.1.8.2 Nonradiological Accidents

A potential release of hazardous or toxic materials during postulated operational accidents involving spent nuclear fuel or high-level radioactive waste at the repository would be very unlikely. Because of the large quantities of radioactive material, radiological considerations would outweigh nonradiological concerns. The repository would not accept hazardous waste as defined by the Resource Conservation and Recovery Act. Some potentially hazardous metals such as arsenic or mercury could be present in the high-level radioactive waste. However, they would be in a vitrified glass matrix that would make the exposure of workers or members of the public from operational accidents highly unlikely. Appendix A contains more information on the inventory of potentially hazardous materials.

Some potentially nonradioactive hazardous or toxic substances would be present in limited quantities at the repository as part of operational requirements. Such substances would include liquid chemicals such as cleaning solvents, sodium hydroxide, sulfuric acid, and various solid chemicals (see Section 4.1.3.2). These substances are in common use at other DOE sites. Section 4.1.7 describes potential impacts to workers from normal industrial hazards in the workplace (which includes industrial accidents). The statistics used in the analysis were derived from DOE accident experience at other sites. Impacts to members of the public would be unlikely because the chemicals would be mostly liquid and solid so that any release would be confined locally. (For example, chlorine at the site used for water treatment would be in powder form, so a gaseous release of chlorine would not be possible. Propane gas would not be stored at the site.)

Section 4.1.12.2 describes the quantities of solid hazardous waste generated during repository operations. The construction and closure phases would not generate liquid hazardous waste. The generation, storage, and shipment off the site of solid and liquid hazardous waste generated during operations would represent minimal incremental risk from accidents. Impacts to workers from industrial accidents in the workplace are part of the statistics presented in Appendix F, Section F.2.

4.1.8.3 Sabotage

The accident analysis separately considered sabotage as a potential initiating event. This event would be unlikely to contribute to impacts from the repository. The repository would not represent an attractive target to potential saboteurs due to its remote location and the low population density in the area. Furthermore, security measures DOE would use to protect the waste material from intrusion and sabotage (TRW 1999a, pages 63 to 65) would make such attempts unlikely to succeed. At all times the waste material would be either in robust shipping or disposal containers or inside the Waste Handling Building, which would have thick concrete walls. On the basis of these considerations, DOE concluded that sabotage events would be unlikely at the repository.

4.1.9 NOISE IMPACTS

This section describes possible noise impacts to the public (nuisance noise) and workers (occupational noise) from performance confirmation, construction, operation and monitoring, and closure activities. Repository areas that could generate elevated noise levels include the North Portal, South Portal, Emplacement Shaft, and Development Shaft Operations Areas. The following discussion identifies potential impacts that primarily would affect workers during routine operations. Overall, however, the potential for noise impacts to the public would be very small due to the distances of residences from these areas. Section 4.1.4.2 discusses noise impacts on wildlife.

4.1.9.1 Noise Impacts from Performance Confirmation

As part of site characterization, DOE has evaluated existing noise conditions in the Yucca Mountain region. The noise associated with site characterization activities, which has included that from construction, equipment, drilling equipment, and occasional blasting, has not resulted in large impacts. Because performance confirmation activities would be similar to those for site characterization, large impacts would be likely.

4.1.9.2 Noise Impacts from Construction, Operation and Monitoring, and Closure

Sources of noise in the analyzed land withdrawal area during the construction phase would include activities at the North Portal, South Portal, and Ventilation Shaft Operations Areas involving heavy equipment (bulldozers, graders, loaders, pavers, etc.), cranes, ventilation fans, and diesel generators. Sources of noise during the operation and monitoring phase would include transformer noise, compressors, ventilation fans, air conditioners, and a concrete batch plant. Ventilation fans would have silencers that would keep noise levels below 85 dBA (see Chapter 3, Section 3.1.9 for an explanation of noise measurements) at a distance of 3 meters (10 feet) (TRW 1997c, page 107). The Occupational Safety and Health Administration has identified that the maximum permissible continuous noise level that workers may be exposed to without controls is 90 dBA [29 CFR 1910.95(b)(2)].

The distance from the North Portal Operations Area to the nearest point on the boundary of the analyzed land withdrawal area analyzed would be about 11 kilometers (7 miles) due west. The distance from the South Portal Operations Area to the nearest point on the land withdrawal area boundary would also be about 11 kilometers due west. The point on the boundary closest to a Ventilation Shaft Operations Area would be about 7 kilometers (4 miles) (DOE 1997k, all).

To establish the propagation distance of repository-generated noise for analysis purposes, DOE used an estimated maximum sound level [132 decibels, A-weighted (dBA) for heavy construction equipment, although heavy trucks generate sound levels of between 70 and 80 dBA at 15 meters (50 feet)]. An analysis determined the distance at which that noise would be at the lower limit of human hearing (20 dBA). The calculated distance was 6 kilometers (3.7 miles). Thus, noise impacts would be unlikely at the analyzed land withdrawal area boundary.

Because the distance between repository noise sources and a hypothetical receptor at the analyzed land area withdrawal boundary would be large enough to reduce the noise to background levels and because there would be no residential or community receptors at the withdrawal area boundary [the nearest housing is in Lathrop Wells, about 22 kilometers (14 miles) from the repository site], DOE expects no large noise impacts to the public from repository construction and operations.

Workers at the repository site could be exposed to elevated levels of noise. Small impacts such as speech interference between workers and annoyance to workers would occur. However, worker exposures during all repository phases would be controlled such that impacts (such as loss of hearing) would be unlikely. Engineering controls would be the primary method of noise control. Hearing protection would be required, as needed, as a supplement to engineering controls.

Noise impacts associated with closure would be similar to those associated with construction and operations. Therefore, DOE expects no large noise impacts to the public and workers.

4.1.10 AESTHETIC IMPACTS

This section describes potential aesthetic impacts from performance confirmation, construction, operation and monitoring, and closure activities. These activities would not cause adverse impacts to aesthetic or visual resources in the region. The analysis of such impacts considered the natural and manmade physical features that give a particular landscape its character and value as an environmental factor. The analysis gave specific consideration to scenic quality, visual sensitivity, and distance from observation points.

Yucca Mountain has visual characteristics fairly common to the region (a scenic quality rating of C), and the visibility of the repository site from publicly accessible locations is low or nonexistent. The largest structure would be the Waste Handling Building at the North Portal Operations Area, which would be about 37 meters (120 feet) tall with a taller exhaust stack. Other buildings and structures would be smaller and at elevations equal to or lower than that of the Waste Handling Building. No building or structure would exceed the elevation of the southern ridge of Yucca Mountain [1,400 meters (4,600 feet)]. Therefore, no part of the repository would be visible to the public from the west. 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 Lathrop Wells and the Amargosa Valley, approximately 28 kilometers (17 miles) away. There is no public access to the north or east of the site to enable viewing of the facilities. DOE would provide lighting for operation areas at the repository. This lighting could be visible from public access points.

Closure activities, such as dismantling facilities and reclaiming the site, probably would improve the visual quality of the landscape. Adverse impacts to the visual quality due to closure would be unlikely.

4.1.11 IMPACTS TO UTILITIES, ENERGY, MATERIALS, AND SITE SERVICES

This section discusses potential impacts to residential water, energy, materials, and site services from performance confirmation, construction, operation and monitoring, and closure activities. 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. The analysis compared needs to available capacity. The region of influence would include the local, regional, and national supply infrastructure that would have to satisfy the needs. The analysis used engineering estimates of requirements for construction materials, utilities, and energy.

Construction activities would occur during both the construction and the operation and monitoring phases. Table 4-37 lists electric energy and fossil-fuel use during the different phases. Table 4-38 lists construction material use. Both tables list comparative values for all thermal load and packaging scenarios. DOE prorated impacts to site services, if any, with those to the commodity areas to produce an estimate of overall impacts.

Overall, DOE does not expect meaningful impacts to residential water, energy, materials, and site services from the Proposed Action. DOE would, however, have to enhance the electric power delivery system to the Yucca Mountain site.

4.1.11.1 Impacts to Utilities, Energy, Materials, and Site Services from Performance Confirmation

DOE would obtain utilities, energy, and materials for performance confirmation activities from existing sources and suppliers. Water would come from existing wells. Power would come from regional suppliers to the existing Nevada Test Site transmission system. Based on site characterization activities, performance confirmation activities would not cause meaningful impacts to regional utility, energy, and material sources. In addition, DOE would continue to use such existing site services as emergency medical support, fire protection, and security and law enforcement (as described in Chapter 3, Section 3.1.11.3) during performance confirmation.

4.1.11.2 Impacts to Utilities, Energy, Materials, and Site Services from Construction, Operation and Monitoring, and Closure

Residential Water

Population growth associated with the Proposed Action could affect regional water resources. Based on the information in Section 4.1.6, in 2030 the Proposed Action would result in a maximum population increase of about 3,700 in Clark and Nye Counties. About 80 percent of these people would live in Clark County and about 20 percent in Nye County. Whether domestic water needs were satisfied predominantly from surface-water sources, as is the case for most of Clark County, or from groundwater sources, as for most of Nye County, these relatively small increases in population would have very minor impacts on existing water demands.

The maximum project-related population increase for Clark County would amount to about 0.3 percent of the 1997 population (see Chapter 3, Section 3.1.7.1). This increase would be a smaller portion of the county's population in 2030 and, correspondingly, the associated increase in water demand in the county as a result of the proposed project would be very small. The population of Indian Springs in Clark

Table 4-37. Electricity and fossil-fuel use for the Proposed Action.[a]

Phase[b]	Time (years)	High thermal load			Intermediate thermal load			Low thermal load		
		UC[c]	DISP[d]	DPC[e]	UC	DISP	DPC	UC	DISP	DPC
Peak electrical power demand (megawatts)										
Construction	2005-2010	24	24	24	24	24	24	24	24	24
Operation and monitoring	2010-2110									
Development	2010-2032	19	19	19	19	19	19	19	19	19
Emplacement	2010-2033	22	18	19	22	18	19	22	18	19
Total development and emplacement	*2010-2033*	*41*	*38*	*38*	*41*	*38*	*38*	*41*	*38*	*38*
Decontamination	2034-2037	14	10	11	14	10	11	14	10	11
Monitoring	2034-2110	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7
	2034-2060	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7
	2034-2310	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7
Closure	2110+6-15	9.2	8.9	8.9	9.2	8.9	8.9	9.2	8.9	8.9
Electricity use (1,000 megawatt-hours)										
Construction	2005-2010	180	180	180	230	230	230	240	240	240
Operation and monitoring	2010-2110									
Development	2010-2032	650	650	650	890	890	890	2,200	2,200	2,200
Emplacement	2010-2033	2,600	2,100	2,100	2,600	2,100	2,100	2,600	2,100	2,200
Decontamination	2034-2037	250	190	200	250	190	200	250	190	200
Monitoring	2034-2110	2,000	2,000	2,000	2,400	2,400	2,400	3,500	3,500	3,500
	2034-2060	680	680	680	810	810	810	1,200	1,200	1,200
	2034-2310	7,200	7,200	7,200	8,600	8,600	8,600	13,000	13,000	13,000
Total 100-year phase	*2010-2110*	*5,500*	*4,900*	*5,000*	*6,100*	*5,600*	*5,600*	*8,600*	*8,000*	*8,100*
Closure	2110+6-15	250	240	240	370	370	370	560	560	560
Fossil-fuel use (million liters)[f]										
Construction	2005-2010	8.1	7.1	7.3	12	11	12	14	13	13
Operation and monitoring	2010-2110									
Development	2010-2032	19	19	19	20	20	20	83	83	85
Emplacement	2010-2033	230	180	190	230	180	190	230	180	190
Decontamination	2034-2037	33	26	27	33	26	27	33	26	27
Monitoring	2034-2110	11	11	11	15	15	15	15	15	15
	2034-2060	3.9	3.9	3.9	5.0	5.0	5.0	5.0	5.0	5.0
	2034-2310	41	41	41	53	53	53	53	53	53
Total 100-year phase	*2010-2110*	*290*	*240*	*240*	*290*	*250*	*250*	*360*	*310*	*310*
Closure	2110+6-15	5.1	4.5	4.6	9.4	8.8	8.9	15	14	15

a. Sources: TRW (1999a, Section 6); TRW (1999b, Section 6); TRW (1999c, pages 6-17 to 6-24).
b. Approximate periods for each phase would be construction, 5 years; operation and monitoring, 100 years; closure, 6-15 years.
c. UC = uncanistered packaging scenario.
d. DISP = disposable canister packaging scenario.
e. DPC = dual-purpose canister packaging scenario.
f. To convert liters to gallons, multiply by 0.26418.

Table 4-38. Construction material use for the Proposed Action.[a]

Phase[b]	Time (years)	High thermal load			Intermediate thermal load			Low thermal load		
		UC[c]	DISP[d]	DPC[e]	UC	DISP	DPC	UC	DISP	DPC
Concrete (1,000 cubic meters)[f]										
Construction	2005-2010	330	330	330	390	380	380	390	390	390
Operation and monitoring	2010-2110									
Development	2010-2032	420	420	420	480	480	480	1,700	1,700	1,700
Emplacement	2010-2033	27	27	27	27	27	27	66	66	66
Operation and monitoring total	*2010-2110*	*450*	*450*	*450*	*510*	*510*	*510*	*1,800*	*1,800*	*1,800*
Closure	2110+6-15	2	2	2	2	2	2	4	4	4
Project total		*780*	*780*	*780*	*900*	*890*	*890*	*2,200*	*2,200*	*2,200*
Steel (1,000 metric tons)[g]										
Construction	2005-2010	70	68	67	81	81	81	83	81	80
Operation and monitoring	2010-2034									
Development	2010-2032	90	90	90	140	140	140	610	610	610
Emplacement	2010-2033	42	42	42	42	42	42	110	110	110
Operation and monitoring total	*2010-2110*	*130*	*130*	*130*	*180*	*180*	*180*	*720*	*720*	*720*
Closure	2110+6-15	0.71	0.71	0.71	0.92	0.92	0.92	2	2	2
Project total		*200*	*200*	*200*	*260*	*260*	*260*	*800*	*800*	*800*
Copper (1,000 metric tons)										
Construction	2005-2010	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Operation and monitoring	2010-2110									
Development	2010-2032	0.1	0.1	0.1	0.1	0.1	0.1	0.9	0.9	0.9
Project total		*0.2*	*0.2*	*0.2*	*0.2*	*0.2*	*0.2*	*1.0*	*1.0*	*1.0*

a. Sources: TRW (1999a, Section 6); TRW (1999b, Section 6); TRW (1999c, pages 6-15 to 6-21).
b. Approximate periods for each phase would be construction, 5 years; operation and monitoring, 100 years; closure, 6-15 years.
c. UC = uncanistered packaging scenario.
d. DISP = disposable canister packaging scenario.
e. DPC = dual-purpose canister packaging scenario.
f. To convert cubic meters to cubic yards, multiply by 1.3079.
g. To convert metric tons to tons, multiply by 1.1023

County would increase by a projected maximum of about 110 as a result of the Proposed Action. This number represents about 10 percent of the 1997 Indian Springs population and, based on a Las Vegas Valley average demand for domestic water of 720 liters (190 gallons) per day per person (SNWA 1999, all), would require a quantity of water that is about 6 percent of the community's quasimunicipal groundwater withdrawal in 1997 [0.51 million cubic meters (410 acre-feet)] (NDCNR 1998, all). DOE expects the population of Indian Springs to be larger by 2030 and on a percentage basis, the contribution (and associated water demand) from project-related growth would be smaller than current numbers. However, this small community would be more likely to be affected by projected growth than other areas in Clark County.

In Nye County, estimates of domestic water demand for 1995 are about 750 liters (200 gallons) per day per person (Horton 1997, Table 10). At this demand, the project-related increase in Nye County population would result in an additional water demand of about 0.20 million cubic meters (160 acre-feet) of water per year. This represents about 0.2 percent of the water use in Nye County in 1995. As indicated in Section 4.1.6, most (about 92 percent) of the project-related growth in Nye County would occur in Pahrump. This would equate to adding about 0.18 million cubic meters (150 acre-feet) to Pahrump's annual water demand, which represents about 0.6 percent of the 1995 Pahrump water withdrawal of 30 million cubic meters (24,000 acre-feet). By 2030, when the peak population increases would occur, the project-related increase in water demand would be an even smaller percentage of the total Nye County and Pahrump water need. The increase in domestic water demand in Nye County as a result of the proposed project would be very small.

Residential Sewer

Sewer utilities could be affected by population growth associated with the Proposed Action. In Clark County, where most of the population growth would take place, the fact that the maximum project-related population increase would amount to about 0.3 percent of the 1997 population indicates that impacts to the populous areas of the county (that is, the Las Vegas Valley) would be very small. In Indian Springs, where project-related growth would be a more substantial portion of the community population, small treatment facilities designed for a specific area or individual household septic tank systems would accommodate wastewater treatment needs. In either case, the added population would not be likely to cause overloading to a sewer utility.

Growth in Nye Country from the Proposed Action would be likely to occur primarily in the Pahrump area. There is no reason to believe that project-related population increases would overload a sewer utility. Again, small, limited-service treatment facilities or individual septic tank and drainage field systems would provide the primary wastewater treatment capacities.

Electric Power

During the construction phase (2005 to 2010), the demand for electricity would increase as DOE operated two or three tunnel boring machines and other electrically powered equipment. The tunnel boring machines would account for more than half of the demand for electricity during the construction phase. The estimated peak demand for electrical power during the construction phase would be about 24 megawatts with use varying between about 180,000 and 240,000 megawatt-hours, depending on the thermal load scenario and the packaging scenario. Excavation activities for all three thermal load scenarios would use two or three tunnel boring machines. However, the operations time would increase for the low thermal load scenario because of the increased tunnel lengths.

As discussed in Chapter 3, Section 3.1.11.2, the current electric power supply line has a peak capacity of only 10 megawatts. DOE, therefore, is evaluating modifications and upgrades to the site electrical system, as discussed below.

During the early stages of the operation and monitoring phase (2010 to 2033), the development of emplacement drifts would continue in parallel with emplacement activities. During this period, the peak electric power demand would be between 38 and 41 megawatts, depending on the thermal load scenario and the packaging scenario.

Following the completion of excavation activities in about 2032, the demand for electric power would drop to about 20 megawatts and would continue to drop, following the completion of emplacement and decontamination activities in about 2037, to less than 15 megawatts for monitoring and maintenance activities. The closure phase would last from 6 to 15 years, depending on the thermal load scenario. The peak electric power demand would be less than 10 megawatts for any of the three thermal load scenarios during closure.

The repository demand for electricity would be well within the expected regional capacity for power generation. Nevada Power Company, for example, experienced a growth in peak demand of nearly 30 percent from 1993 to 1997 and has demonstrated the ability to meet customer demand in this high-growth environment through effective planning (*Las Vegas Review-Journal* 1998, all). Nevada Power's current planning indicates that it intends to maintain a reserve capacity of 12 percent. In 2010, at the beginning of the operation and monitoring phase, Nevada Power projects a net peak load of 5,950 megawatts and is planning a reserve of 714 megawatts (NPC 1997, Figures 2 and 4). The maximum 41-megawatt demand that the repository would require would be less than 1 percent of the projected peak demand in 2010, and less than 6 percent of the planned reserve. Thus, DOE expects that regional capacity planning would accommodate the future repository demand.

Repository Electric Power Supply Options

As discussed above, the estimated repository electric power demand would exceed the current electric supply capacity to the site after construction began in 2005. DOE would have to increase the electric power supply to the site to accommodate the initial demand of about 24 megawatts during the construction phase and to support the estimated peak demand of as much as 41 megawatts during the operation and monitoring phase. A range of options focusing on a modification or upgrade of the existing transmission and distribution system is under consideration to meet the repository electricity demand (TRW 1998e, all). DOE eliminated consideration of onsite generation of electricity in conjunction with the onsite plant that would generate steam for heating because the steam plant would be much smaller than a plant needed for power generation, and increasing the capacity of the steam plant would not be cost-effective with the availability of low-priced power in the southern Nevada region. Limited onsite generation capacity would use diesel-powered generators for emergency equipment.

As discussed in Chapter 3, Section 3.1.11.2, the repository site receives electricity through a feeder line from the Canyon Substation, which is rated at 69 kilovolts and has a capacity of 10 megawatts. The minimum modification would be to upgrade this line to 40 to 50 megawatts, modify the Nevada Test Site power loop to support repository operations in conjunction with other Test Site activities, and upgrade utility feeder lines to the Nevada Test Site. The existing Nevada Test Site power loop has a rated capacity of about 72 megawatts, but preliminary analysis of loop performance with the projected repository load (as much as 41 megawatts) indicated that unacceptable voltage reductions could occur at some Test Site locations. The minimum modification to the power loop to reduce the potential for unacceptable voltage reductions would be to install capacitors in the loop. Other options to obtain satisfactory performance for the power loop would include upgrading sections of the loop and the utility-owned feeder lines to the loop. Additional options, which would be variations of this approach, would include providing upgraded power lines directly from the utilities to the repository site.

As discussed in Chapter 3, Section 3.1.11.2, two commercial utility companies supply electricity to the Nevada Test Site feeder lines that power the Test Site power loop. Nevada Power Company owns and operates a 138-kilovolt line from the Las Vegas area to the Mercury Switching Station on the Test Site. Valley Electric Association owns and operates 138- and 230-kilovolt lines from the Las Vegas area to Pahrump and a 138-kilovolt line from Pahrump to the Jackass Flats substation on the Test Site near Lathrop Wells. The options DOE is evaluating include upgrading either or both of these lines. The options also include connecting both utility feeder lines directly to the repository with new 138- or 230-kilovolt lines to either the North or South Portal to obtain independent redundant power capability. DOE has considered adding Sierra Pacific Power Corporation as a supplier by constructing a new power line from the Tonopah/Anaconda area to Lathrop Wells through Beatty with a direct tie to the South Portal at the repository. All system modifications would include appropriate modifications to transformers and switchgear. The approach in all cases would be to use existing power corridors where possible to limit environmental impacts and to reduce the need for additional rights-of-way. Depending on the option chosen, additional National Environmental Policy Act analysis could be required.

Fossil Fuels

Fossil fuels used during the construction phase (2005 to 2010) would include diesel fuel and fuel oil. Diesel fuel would be used primarily to operate surface construction equipment and equipment to maintain the excavated rock pile. Fuel oil would fire a steam plant at the North Portal, which would provide building and process heat for the North Portal Operations Area. In addition, fuel oil would provide water heating and building heat to the South Portal and heat for curing precast concrete components. During construction the estimated use of diesel fuel and fuel oil would be 7.1 million to 14 million liters (1.9 million to 4 million gallons). The highest use would be associated with the combination of the low thermal load scenario and the uncanistered packaging scenario. The regional supply capacity of gasoline and diesel fuel is about 3.8 billion liters (1 billion gallons) per year for the State of Nevada, based on motor fuel use (BTS 1999a, all). About half of the State total is consumed in the three-county region of influence (Clark, Lincoln, and Nye Counties) with the highest consumption in Clark County, so yearly repository use during the construction phase would be less than 1 percent of the current regional consumption.

Fossil-fuel use during the operation and monitoring phase would be for onsite vehicles and for heating. It would range between about 240 million and 360 million liters (about 63 million and 95 million gallons) depending on the thermal load scenario and the packaging scenario. The annual use would be highest for emplacement and development operations (2010 to 2033) and would decrease substantially for monitoring and maintenance activities (2034 to 2110). The projected use of liquid fossil fuels would be within the regional supply capacity and should not cause meaningful impacts. As discussed above, motor fuel use in the State of Nevada in 1996 was about 3.8 billion liters (1 billion gallons) (BTS 1999a, all), which provides the baseline for the regional supply capacity. The highest annual use during the operations and monitoring phase would be less than 5 percent of the 1996 capacity in Clark, Lincoln, and Nye Counties.

During the closure phase, fossil-fuel use would be between 4.5 million and 15 million liters (1.2 million and 4 million gallons), depending on the thermal load scenario. Use during the closure phase would be similar to that for the construction phase.

Construction Material

The primary materials needed to construct the repository would be concrete, steel, and copper. Concrete, which consists of cement and aggregate, would be used for tunnel liners in the subsurface and for the construction of the surface facilities. Excavated rock would be used for the aggregate, and cement would be purchased regionally. During the construction phase the amount of concrete required would range from about 330,000 to 390,000 cubic meters (about 430,000 to 510,000 cubic yards), depending on the thermal load scenario and the packaging scenario. For this phase, as much as about 83,000 metric tons (92,000 tons) of steel would be required for a variety of uses including rebar, piping, vent ducts, and track, and 100 metric tons (110 tons) of copper for electrical cables. Because the subsurface configuration of the repository would differ substantially for the high, intermediate, and low thermal load scenarios, the relative amount of material used during the initial 5-year construction period might not be indicative of the amount required to complete the subsurface through the end of development. For example, the amount of steel used during the construction phase for each of the intermediate thermal load cases would be about the same as the amount for the corresponding low thermal load case, but the total amount of steel used for each intermediate case through the completion of development would be about one-quarter of the amount that would be used for the corresponding low thermal load case.

During the operation and monitoring phase, an additional 1.8 million cubic meters (2.4 million cubic yards) of concrete would be required for the low thermal load scenario and 450,000 cubic meters (590,000 cubic yards) would be required for the high thermal load scenario. The corresponding requirement for steel would be between about 720,000 and 130,000 metric tons (about 790,000 and 140,000 tons), and for copper it would be about 100 metric tons (110 tons).

For the low thermal load scenario, which would require the most concrete, the average yearly concrete demand for continued subsurface development during the operation and monitoring phase would be about 82,000 cubic meters (about 110,000 cubic yards). This quantity of concrete represents less than 3 percent of the cement consumed in Nevada in 1998 (Sherwood 1998, all).

Because the markets for steel and copper are worldwide in scope, DOE expects little or no impact from increased demand for steel and copper in the region.

The closure phase would require an estimated maximum of 4,000 cubic meters (5,200 cubic yards) of concrete for the low thermal load option. An estimated 2,000 metric tons (2,200 tons) of steel would be required for the low thermal load scenario and about 710 metric tons (780 tons) for the high thermal load scenario.

Site Services

During the construction phase, DOE would rely on the existing support infrastructure described in Chapter 3, Section 3.1.11.3, during an emergency at the repository. DOE would maintain these capabilities until the project could provide its own services on the site.

The primary onsite response would occur through the onsite Fire Station, Medical Center, and Health Physics facilities after their construction at the North Portal was complete. The Fire Station would maintain fire and rescue vehicles, equipment, and trained professionals to respond to fires, including radiological, mining, industrial, and accident events at the surface and subsurface. The Medical Center would be adjacent to the Fire Station, and would maintain a full-time doctor and nurse and medical supplies to treat emergency injuries and illnesses. These facilities would have the capability to provide complete response to most onsite emergencies. DOE would coordinate the operation of these facilities with facilities at the Nevada Test Site and in the surrounding area to increase response capability, if necessary.

A site security and safeguards system would include the surveillance and safeguards functions required to protect the repository from unauthorized intrusion and sabotage. The system would include the site security barriers, gates, and badging and automated surveillance systems operated by trained security officers. Support for repository security would be available from the Nevada Test Site security force and the Nye County Sheriff's Department, if needed.

The emergency response system would provide responses to accident conditions at or near the repository site. The system would maintain emergency and rescue equipment, communications, facilities, and trained professionals to respond to fire, radiological, mining, industrial, and general accidents above or below ground.

The planned onsite emergency facilities should be able to respond to and mitigate most onsite incidents, including underground incidents, without outside support. Therefore, no meaningful impact to the emergency facilities of surrounding communities or counties would be likely.

4.1.12 MANAGEMENT OF REPOSITORY-GENERATED WASTE AND HAZARDOUS MATERIALS

This section describes the management of the radioactive and nonradioactive waste that DOE would generate as a result of performance confirmation, construction, operation and monitoring, and closure activities. The evaluation of waste management impacts considered the quantities of nonhazardous industrial, sanitary, hazardous, mixed, and radioactive wastes that repository-related activities would generate. The evaluation assessed these quantities against current public and private capacity to treat and dispose of wastes. The overall impact of managing the Yucca Mountain repository waste streams would not differ among the thermal load scenarios and packaging scenarios. DOE would build onsite facilities to accommodate construction and demolition debris, sanitary and industrial solid wastes, sanitary sewage, and industrial wastewater. The Proposed Action would not cause meaningful impacts at offsite facilities for low-level radioactive and hazardous waste disposal. DOE would use less than 3 percent of the existing offsite capacity for low-level radioactive waste disposal and a very small fraction of the existing hazardous waste disposal capacity. In addition, the Department would build an onsite landfill. Although such activities are not currently planned, the use of existing Nevada Test Site landfills for the disposal of construction and demolition debris and sanitary and industrial solid waste would require the continuation of the operation of these facilities past their estimated lives of 70 and 100 years (DOE 1995f, pages 8 and 9) and probably would require the expansion of their capacities. Further review under the National Environmental Policy Act might be required to expand the capacity of the landfills at the Nevada Test Site.

4.1.12.1 Waste and Materials Impacts from Performance Confirmation

DOE expects performance confirmation activities to generate waste similar to and in about the same quantities as that generated during characterization activities with the exception that low-level radioactive waste would be generated in minimal qualities (TRW 1999a, page 17). Based on 1997 waste generation reports, performance confirmation activities should produce about 3,200 cubic meters (110,000 cubic feet) of nonhazardous construction debris and sanitary and industrial solid waste (Sygitowicz 1998, pages 2 and 4) and about 170 kilograms (380 pounds) (volume measurements were not available) of hazardous waste (Harris 1998, pages 3-6) that would require disposal. In addition, other waste would be recycled rather than disposed. Wastewater would be generated from runoff, subsurface activities, restrooms, and change rooms.

DOE would use current (as described in Chapter 3, Section 3.1.12) or similar methods to handle the waste streams generated by its performance confirmation activities. It would also use offsite landfills to dispose of solid waste and construction debris; accumulate and consolidate hazardous waste and transport it off the site for treatment and disposal; treat and reuse wastewater; and treat and dispose of

WASTE TYPES

Construction/demolition debris: Discarded solid wastes resulting from the construction, remodeling, repair, and demolition of structures, road building, and land clearing that are inert or unlikely to create an environmental hazard or threaten the health of the general public. Such debris from repository construction would include such materials as soil, rock, masonry materials, and lumber.

Industrial wastewater: Liquid wastes from industrial processes that do not include sanitary sewage. Repository industrial wastewater would include water used for dust suppression and process water from building heating, ventilation, and air conditioning systems.

Low-level radioactive waste: Radioactive waste that is not classified as high-level radioactive waste, transuranic waste, byproduct material containing uranium or thorium from processed ore, or naturally occurring radioactive material. The repository low-level radioactive waste would include such wastes as personal protective clothing, air filters, solids from the liquid low-level radioactive waste treatment process, radiological control and survey waste, and possibly used canisters (dual-purpose).

Sanitary sewage: Domestic wastewater from toilets, sinks, showers, kitchens, and floor drains from restrooms, change rooms, and food preparation and storage areas.

Sanitary and industrial solid waste: Solid waste that is neither hazardous nor radioactive. Sanitary waste streams include paper, glass, and discarded office material. State of Nevada waste regulations identify this waste stream as *household waste*.

Hazardous waste: Waste designated as hazardous by the Environmental Protection Agency or State of Nevada regulations. Hazardous waste, defined under the Resource Conservation and Recovery Act, is waste that poses a potential hazard to human health or the environment when improperly treated, stored, or disposed of. Hazardous wastes appear on special Environmental Protection Agency lists or possess at least one of the following characteristics: ignitability, corrosivity, toxicity, or reactivity. Hazardous waste streams from the repository could include certain used rags and wipes contaminated with solvents.

sanitary sewage. Based on site characterization experience, performance confirmation activities would cause no meaningful impacts to the regional waste disposal capacity.

4.1.12.2 Waste and Materials Impacts from Construction, Operation and Monitoring, and Closure

The construction phase (2005 to 2010) would generate nonhazardous, nonradioactive wastes and some hazardous waste from the use of such materials as resins, paints, and solvents. Nonhazardous, nonradioactive wastes would include sanitary and industrial solid wastes, construction debris, industrial wastewater, and sanitary sewage. Table 4-39 lists the estimated quantities of waste that the construction phase would generate. These estimates are based on construction experience, water use estimates, and Yucca Mountain Site Characterization Project experience with wastewater generation from dust suppression.

DOE could use existing Nevada Test Site landfills to dispose of nonrecyclable construction debris and sanitary and industrial solid waste. However, as part of the Proposed Action, DOE would construct a State-permitted landfill on the Yucca Mountain site to dispose of nonrecyclable construction debris and

Table 4-39. Estimated waste quantities from construction.[a]

	High thermal load			Intermediate thermal load			Low thermal load		
Waste type	UC[b]	DISP[c]	DPC[d]	UC	DISP	DPC	UC	DISP	DPC
Construction debris (cubic meters)[e]	3,000	2,400	2,400	3,000	2,400	2,400	3,000	2,400	2,400
Hazardous (cubic meters)	990	690	740	990	690	740	990	690	740
Sanitary and industrial solid (cubic meters)	10,000	8,500	8,700	10,000	8,500	8,700	10,000	8,500	8,700
Sanitary sewage (million liters)[f]	160	150	150	160	160	160	160	160	160
Industrial wastewater (million liters)	42	42	42	51	51	51	51	51	51

a. Sources: TRW (1999a, page 66); TRW (1999b, pages 6-8 and 6-9).
b. UC = uncanistered packaging scenario.
c. DISP = disposable canister packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. To convert cubic meters to cubic feet, multiply by 35.314.
f. To convert liters to gallons, multiply by 0.26418.

sanitary and industrial solid waste. The capacity of this landfill would be large enough to dispose of the projected volumes of this debris and waste for the entire Proposed Action. As listed in Table 4-39, DOE estimates a maximum of 3,000 cubic meters (110,000 cubic feet) of construction debris. If the Department chose not to build a landfill at the repository site, it could ship construction debris to the Test Site's Area 10C landfill, which has a disposal capacity of 990,000 cubic meters (35 million cubic feet) (DOE 1996f, page 4-37). The disposal of construction debris generated during the construction phase would consume less than one-half of 1 percent of the disposal capacity in this landfill. DOE could also ship repository-generated sanitary and industrial solid waste to the Test Site for disposal in the Area 23 landfill, which has a capacity of 450,000 cubic meters (16 million cubic feet) (DOE 1996f, page 4-37). The disposal of the maximum of 10,000 cubic meters (350,000 cubic feet) of sanitary and industrial solid waste generated during the construction phase at the Area 23 landfill would use about 2 percent of the disposal capacity.

Table 4-40 lists the estimated total waste quantities for repository activities associated with emplacement and development (2010 to 2033). Major waste-generating activities would include the receipt and packaging of spent nuclear fuel and high-level radioactive waste and continued development of subsurface emplacement areas. The thermal load scenarios would cause differences in nonradioactive waste quantities from subsurface activities due to the different workforce sizes and main drift lengths. The three packaging scenarios would affect the volumes of hazardous and low-level radioactive wastes generated at the surface facilities as a result of differences in handling the spent nuclear fuel and high-level radioactive waste. In addition, waste would be generated in personnel areas such as change rooms, restrooms, and offices. The dual-purpose canister packaging scenario could require the disposal of an additional estimated 44,000 cubic meters (1.6 million cubic feet) of low-level radioactive waste (not listed in Table 4-40) with an estimated weight of 240,000 metric tons (270,000 tons) (Koppenaal 1998a, all; TRW 1999a, page 75). DOE could decide to recycle the canisters if doing so would be more protective of the environment and more cost effective than direct disposal. Recycling would require melting and recasting of the canister metal to enable other uses.

DOE would package hazardous waste and ship it off the site for treatment and disposal. The Department could continue to dispose of such waste in conjunction with the Nevada Test Site, which has contracts with commercial facilities, or could contract separately with the same or another commercial facility. As listed in Table 4-39, DOE estimates the generation of no more than 990 cubic meters (35,000 cubic feet)

Table 4-40. Estimated waste quantities from emplacement and development activities (2010 to 2033).[a]

Waste type	High thermal load			Intermediate thermal load			Low thermal load		
	UC[b]	DISP[c]	DPC[d]	UC	DISP	DPC	UC	DISP	DPC
Hazardous (cubic meters)[e]	5,800	2,300	2,200	5,800	2,300	2,200	5,800	2,300	2,200
Sanitary and industrial solid (cubic meters)	50,000	41,000	42,000	50,000	41,000	42,000	70,000	61,000	62,000
Sanitary sewage (million liters)[f]	1,400	1,100	1,200	1,400	1,100	1,100	1,400	1,200	1,200
Industrial wastewater (million liters)	900	780	780	930	810	810	1,400	1,300	1,300
Low-level radioactive (cubic meters, after treatment)	67,000	18,000	26,000	67,000	18,000	26,000	67,000	18,000	26,000

a. Sources: TRW (1999a, pages 75 and 76); TRW (1999b, pages 6-17, 6-18, and 6-23).
b. UC = uncanistered.
c. DISP = disposable canister.
d. DPC = dual-purpose canister.
e. To convert cubic meters to cubic feet, multiply by 35.314.
f. To convert liters to gallons, multiply by 0.26418.

of hazardous waste during the construction phase. This maximum volume would result from the construction of facilities to accommodate the uncanistered packaging scenario. The Environmental Protection Agency's National Capacity Assessment Report (EPA 1996b, pages 32, 33, 36, 46, 47, and 50) indicates that the estimated 1993 to 2013 capacity for incineration of solids and liquids at permitted treatment, storage, and disposal facilities in the western states (including Nevada and other states to which repository waste could be shipped for treatment and disposal) is about seven times more than the demand for these services. The landfill capacity would be about 50 times the demand. Therefore, the impact to capacity from the treatment and disposal of hazardous waste from the construction phase would be very small.

DOE would treat and dispose of sanitary sewage and industrial wastewater at onsite facilities. Sanitary sewage from the North Portal Operations Area would go to an existing septic system. The Department would install another septic system to dispose of sanitary sewage from the South Portal Operations Area. The industrial wastewater from surface facilities would flow to an evaporation pond at the North Portal Operations Area and wastewater from the subsurface would flow to an evaporation pond at the South Portal Operations Area. Sludge would accumulate in the North Portal Operations Area evaporation pond so slowly that DOE would not need to remove it before the closure of the pond (TRW 1998g, pages 65 to 67). The accumulated sludge at the South Portal Operations Area evaporation pond, which would consist of mined rock, Portland Cement, and fine aggregate, would be removed as needed and added to the excavated rock pile (Koppenaal 1998b, page 3).

During the operation and monitoring phase (2010 to 2110), the receipt and packaging of spent nuclear fuel and high-level radioactive waste, the operation of support facilities, and the continued development of subsurface emplacement areas would generate radioactive and nonradioactive wastes and wastewaters and some hazardous waste. DOE does not expect to generate mixed waste. However, repository facilities would also have the capability to package and temporarily store mixed waste that operations could generate in unusual circumstances. In addition, the medical clinic would generate a small amount of medical waste that would be disposed of in accordance with applicable Federal and State of Nevada requirements.

Monitoring and maintenance activities after the completion of emplacement (2034 to 2110) would also generate wastes, but in much smaller quantities. The first few years after the completion of emplacement would generate greater quantities of waste due to the decontamination and decommissioning of surface nuclear facilities. DOE estimates as much as 520 cubic meters (18,000 cubic feet) of low-level radioactive waste and as much as 260 cubic meters (9,200 cubic feet) of hazardous waste from this activity (TRW 1999a, page 78), depending on the packaging scenario.

Monitoring and maintenance activities over 26 years would generate a maximum of about 9,900 cubic meters (350,000 cubic feet) of sanitary and industrial solid waste and about 230 million liters (60 million gallons) of sanitary sewage. Ongoing monitoring and maintenance activities for 76 years would generate a maximum of about 20,000 cubic meters (710,000 cubic feet) of sanitary and industrial solid waste and about 450 million liters (120 million gallons) of sanitary sewage. Ongoing monitoring and maintenance activities for 276 years (closure 300 years after the start of emplacement) would generate a maximum of about 61,000 cubic meters (about 2.2 million cubic feet) of sanitary and industrial solid waste and about 1.3 billion liters (340 million gallons) of sanitary sewage (TRW 1999a, page 85; TRW 1999b, pages 6-28 and 6-29).

During the operation and monitoring phase DOE would dispose of sanitary sewage and industrial wastewater in the onsite wastewater systems and sanitary and industrial solid waste in the onsite landfill or at the Nevada Test Site. The sanitary sewage disposal system would be able to handle the estimated daily sewage flows, and the industrial wastewater facilities would be able to handle the estimated annual wastewater flows. DOE would use the onsite landfill to dispose of sanitary and industrial solid waste, or it could use the existing Nevada Test Site landfill in Area 23 to dispose of such waste. The Area 23 landfill has an estimated 100-year capacity for the disposal of waste generated at the Test Site (DOE 1995f, page 9); the addition of repository-generated waste during the operation and monitoring phase would necessitate its expansion.

DOE would treat low-level radioactive waste in the Waste Treatment Building (see Section 2.1.2.1). After treatment, DOE would need to dispose of an estimated maximum 68,000 cubic meters (2.4 million cubic feet) of low-level radioactive waste generated during emplacement activities and the decontamination of surface nuclear facilities (TRW 1999a, pages 72 and 78). This waste would be disposed of at the Nevada Test Site. The Test Site accepts low-level radioactive waste for disposal from other DOE sites. It has an estimated disposal capacity of 3.15 million cubic meters (110 million cubic feet) (DOE 1998l, page 2-19) (see Section 3.1.12). The impact to the total capacity at the Nevada Test Site from the disposal of repository low-level radioactive waste would be 2.2 percent.

During the operation and monitoring phase repository-generated hazardous waste would be shipped off the site for treatment and disposal in a permitted facility. DOE would need to dispose of an estimated maximum of 6,100 cubic meters (220,000 cubic feet) of hazardous waste generated by emplacement activities and the decontamination of surface facilities (TRW 1999a, pages 72 and 78). The estimated maximum annual rate of hazardous waste treatment or disposal would be 260 cubic meters (9,200 cubic feet) (TRW 1999a, page 78). At present, a number of commercial facilities are available for hazardous waste treatment and disposal, and DOE expects similar facilities to be available until the closure of the repository. The National Capacity Assessment Report (EPA 1996b, pages 32, 33, 36, 46, 47, and 50) indicates that the estimated 20-year available capacity for incineration of solids and liquids at permitted treatment, storage, and disposal facilities in the western states is about seven times more than the demand for these services. The estimated landfill capacity is about 50 times the demand. Therefore, the impact to capacity from the treatment and disposal of repository-generated hazardous waste during the operation and monitoring phase would be very small.

If unusual activities generated mixed waste, DOE would package such waste for offsite treatment and disposal. The estimated maximum annual quantity would be about 1 cubic meter (35 cubic feet) (TRW 1999a, page 74), which would have a very small impact on the receiving facility. At present, there is commercial capacity (for example, at Envirocare of Utah, with which the Department has a contract for the treatment and disposal of mixed waste). DOE is also pursuing a permit for a mixed waste disposal facility at the Nevada Test Site that would accept mixed waste from other DOE sites for disposal (DOE 1996f, page 4-36). This facility has a planned annual capacity of 13,000 cubic meters (460,000 cubic feet) (DOE 1997b, Volume 1, page 6-6).

Closure activities, such as the final decontamination and demolition of the repository structures and the restoration of the site, would generate waste and recyclable materials. Table 4-41 lists estimated waste quantities for the closure phase. The ranges of quantities result from more waste generated from more years to complete closure with the low thermal load scenario and differences in surface facilities for the packaging scenarios.

Table 4-41. Estimated waste quantities from closure.[a]

Waste type	Quantity
Demolition debris (cubic meters)[b]	100,000 - 150,000
Hazardous (cubic meters)	440 - 630
Sanitary and industrial (cubic meters)	4,400 - 10,000
Sanitary sewage (million liters)[c]	83 - 200
Industrial wastewater (million liters)	42 - 105
Low-level radioactive (cubic meters, after treatment)	2,100 - 3,500

a. Sources: TRW (1999a, page 81); TRW (1999b, pages 6-38 and 6-39).
b. To convert cubic meters to cubic feet, multiply by 35.314.
c. To convert liters to gallons, multiply by 0.26418.

DOE would dispose of demolition debris and sanitary and industrial solid waste in the onsite landfill (or at the Nevada Test Site), and sanitary sewage and industrial wastewater in the onsite septic systems and industrial wastewater system. After disposing of the waste and wastewater, DOE would close the landfill and evaporation ponds in a manner that met applicable requirements.

The Nevada Test Site landfills would have to continue operating past their estimated lives and to expand as needed. The 10C landfill, which accepts demolition debris, has an estimated 70-year operational life; the Area 23 landfill, which is used for sanitary and industrial solid waste disposal, has a 100-year estimated life (DOE 1995f, pages 8 and 9).

DOE would continue to dispose of hazardous and low-level radioactive wastes off the site. The Department would ship hazardous waste to an offsite vendor with the appropriate permits and available treatment and disposal capacity and would ship low-level radioactive waste to a Nevada Test Site disposal facility. The National Capacity Assessment Report (EPA 1996b, pages 32, 33, 36, 46, 47, and 50) shows that the available capacity for hazardous waste treatment and disposal in the western states would far exceed the demand for many years to come. Therefore, hazardous waste generated during closure activities would be likely to have a very small impact on the capacity for treatment and disposal at commercial facilities. The disposal of low-level radioactive waste generated during repository closure at the Nevada Test Site would affect the disposal capacity about one-tenth of 1 percent.

Table 4-42 lists the waste types that repository activities would generate from construction through closure and the total estimated waste quantities for the nine thermal load scenario and packaging combinations. The table summarizes waste quantities for all phases of the Proposed Action.

If not recycled, dual-purpose canisters would add an estimated 44,000 cubic meters (1.6 million cubic feet) of low-level waste under each of the dual-purpose canister packaging scenarios (Koppenaal 1998a, all; TRW 1999a, page 76).

Table 4-42. Estimated waste quantities for Proposed Action.[a]

	High thermal load			Intermediate thermal load			Low thermal load		
Waste type	UC[b]	DISP[c]	DPC[d]	UC	DISP	DPC	UC	DISP	DPC
Construction and demolition debris (cubic meters)[e]	150,000	100,000	120,000	150,000	100,000	120,000	150,000	100,000	120,000
Hazardous (cubic meters)	7,700	3,500	3,500	7,700	3,500	3,500	7,700	3,500	3,500
Sanitary and industrial solid (cubic meters)	85,000	73,000	74,000	85,000	73,000	74,000	110,000	98,000	99,000
Sanitary sewage (million liters)[f]	2,000	1,800	1,800	2,000	1,800	1,800	2,200	1,900	2,000
Industrial wastewater (million liters)	980	870	870	1,000	900	900	1,600	1,500	1,500
Low-level radioactive (cubic meters after treatment)	71,000	21,000	29,000	71,000	21,000	29,000	71,000	21,000	29,000

a. Sources: TRW (1999a, Section 6); TRW (1999b, Section 6).
b. UC = uncanistered.
c. DISP = disposable canister.
d. DPC = dual-purpose canister.
e. To convert cubic meters to cubic feet, multiply by 35.314.
f. To convert liters to gallons, multiply by 0.2641.

4.1.12.3 Impacts from Hazardous Materials

The operation of the Yucca Mountain Repository would require the use of hazardous materials including paints, solvents, adhesives, sodium hydroxide, dry carbon dioxide, aluminum sulfate, sulfuric acid, and compressed gases. DOE has programs and procedures in place to procure and manage hazardous materials (DOE 1996h, all), ensuring their procurement in the appropriate quantities and storage under the proper conditions. At the repository, DOE would use an automated inventory management program (TRW 1999a, page 62) to control and track inventory.

4.1.12.4 Waste Minimization and Pollution Prevention

DOE would develop a waste minimization and pollution prevention awareness plan similar to the plan it has used during site characterization activities at Yucca Mountain (DOE 1997h, all). The goal of this new plan would be to minimize quantities of generated waste and to prevent pollution. To achieve this goal, DOE would establish requirements for each onsite organization and identify methods and activities to reduce waste quantities and toxicity.

DOE would recycle materials to the extent that it was cost-effective, feasible, and environmentally sound. Table 4-43 lists estimated quantities of materials that DOE would recycle during the life of the repository.

DOE has identified pollution prevention opportunities in the repository conceptual design process. The Waste Treatment Building design includes recycling facilities for the large aqueous low-level radioactive waste stream [690,000 liters (182,000 gallons) per year for the uncanistered packaging scenario] (DOE 1997l, page 23) that would result from decontamination activities. Wastewater recycling would greatly reduce water demand by repository facilities, as well as the amount of wastewater that would otherwise require disposal. In addition, DOE would use practical, state-of-the-art decontamination techniques such as pelletized solid carbon dioxide blasting that would generate less waste than other techniques.

In addition, DOE would use automated maintenance tracking and inventory management programs that would interface with the procurement system (TRW 1999a, page 62). These systems would assist in ensuring the proper maintenance of equipment through a preventive maintenance approach, which could

Table 4-43. Estimated recyclable material quantities.[a]

Material	UC[b]	DISP[c]	DPC[d]
High thermal load			
Recyclables (cubic meters)[e,f]	210,000	170,000	180,000
Steel (metric tons)[g]	37,000	27,000	31,000
Dual-purpose canisters[h] (cubic meters)	NA[i]	NA	44,000
Oils and lubricants (liters)[j]	28,000,000	28,000,000	28,000,000
Intermediate thermal load			
Recyclables (cubic meters)	210,000	170,000	180,000
Steel (metric tons)	37,000	27,000	31,000
Dual-purpose canisters (cubic meters)	NA	NA	44,000
Oils and lubricants (liters)	39,000,000	39,000,000	39,000,000
Low thermal load			
Recyclables (cubic meters)	260,000	230,000	240,000
Steel (metric tons)	37,000	27,000	31,000
Dual-purpose canisters (cubic meters)	NA	NA	44,000
Oils and lubricants (liters)	63,000,000	63,000,000	63,000,000

a. Sources: TRW (1999a, Section 6); TRW (1999b, Section 6).
b. UC = uncanistered packaging scenario.
c. DISP = disposable canister packaging scenario.
d. DPC = dual-purpose canister packaging scenario.
e. Nonhazardous, nonradioactive materials such as paper, plastic, glass, and nonferrous metals.
f. To convert cubic meters to cubic feet, multiply by 35.314.
g. To convert metric tons to tons, multiply by 1.1023.
h. Dual-purpose canisters would be recycled if appropriate, with regard to protection of the environment and cost-effectiveness. Estimated weight is 220,000 metric tons.
i. NA = not applicable.
j. To convert liters to gallons, multiply by 0.26418.

lead to less waste generation. Inventory management would prevent overstocking that could allow chemicals and other items to exceed their shelf lives and become waste.

4.1.13 ENVIRONMENTAL JUSTICE

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations,* directs Federal agencies to identify and address the potential for their activities to cause disproportionately high and adverse impacts to minority or low-income populations. This section uses the results of analyses from other disciplines to determine if disproportionately high and adverse impacts to human health or the environment on minority or low-income populations are likely to occur from repository performance confirmation, construction, operation and monitoring, and closure activities.

4.1.13.1 Methodology and Approach

The environmental justice analysis brings together the results of analyses from different technical disciplines that focus on consequences to certain resources, such as air, land use, socioeconomics, air quality, noise, and cultural resources, that in turn could affect human health or the environment. If any of these analyses were to predict high and adverse impacts to the human population in general, then an environmental justice analysis would determine if those impacts could occur in a disproportionately high and adverse manner to minority or low-income populations. The basis for making this determination is a comparison of the areas of large impacts with maps that indicate high percentages of minority or low-income populations as reported by the Bureau of the Census.

The potential for environmental justice concerns exists if the following could occur:

- *Disproportionately high and adverse human health effects:* Adverse health effects would be risks and rates of exposure that could result in latent cancer fatalities and other fatal or nonfatal adverse impacts to human health. Disproportionately high and adverse human health effects occur when the risk or rate for a minority or low-income population from exposure to a potentially large environmental hazard appreciably exceeds or is likely to appreciably exceed the risk to the general population and, where available, to another appropriate comparison group (CEQ 1997, all).

- *Disproportionately high and adverse environmental impacts to minority or low-income populations:* An adverse environmental impact is one that is unacceptable or above generally accepted norms. A disproportionately high impact is an impact (or the risk of an impact) to a low-income or minority community that significantly exceeds the corresponding impact to the larger community (CEQ 1997, all).

The EIS definition of a minority population is in accordance with the basic racial and ethnic categories reported by the Bureau of the Census. A minority population is one in which the percent of the total population comprised of a racial or ethnic minority is meaningfully greater than the percent of such groups in the total population [for this EIS, a minority population is one in which the percent of the total population comprised of a racial or ethnic minority is 10 percentage points or more higher than the percent of such groups in the total population (CEQ 1997, all)]. Nevada has a minority population of 21 percent (Bureau of the Census 1992a, Tables P8 and P12). For this EIS, therefore, one focus of the environmental justice analysis is the potential for construction, operation and monitoring, and closure of the proposed repository to have disproportionately high and adverse impacts on the populations in census tracts in the region of influence (principally in Clark, Nye, and Lincoln Counties) having a minority population of 31 percent or higher.

Nevada has a low-income population of 10 percent. Using the approach described in the preceding paragraph for minority populations, a low-income population is one in which 20 percent or more of the persons in a census block group live in poverty, as reported by the Bureau of the Census in accordance with Office of Management and Budget requirements (OMB 1999, all). Therefore, the second focus of the environmental justice analysis for this EIS is the potential for construction, operation and monitoring, and closure of the proposed repository to have disproportionately high and adverse impacts on the populations in census block groups having a low-income population of 20 percent or higher.

The environmental justice analysis involves a two-stage assessment of the potential for disproportionately high and adverse impacts on minority and low-income populations:

- First, a review of the activities included in the Proposed Action to determine if they are likely to result in any high and adverse human health impacts

- Second, if the first-stage review identified any high and adverse impacts to human populations in general, an analysis of whether minority or low-income populations would be affected disproportionately

The EIS analyses determined that the impacts that could occur to public health and safety would be small on 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 disproportionate impacts.

4.1.13.2 Performance Confirmation, Construction, Operation and Monitoring, and Closure

Cultural Resources

DOE has implemented a worker education program on the protection of these resources to limit direct impacts to cultural resources, especially inadvertent damage and illicit artifact collecting. If significant data recovery (artifact collection) were required during construction and operation, DOE would initiate additional consultations with Native American groups to determine appropriate involvement. Further, archaeological resources and potential data recovery would be managed and conducted through consultations with the State Historic Preservation Officer or the Advisory Council on Historic Preservation.

Public Health and Safety

DOE has identified potential impacts to public health and safety from repository construction and operation (Section 4.1.7). However, DOE expects such impacts to be small. Because contamination of edible plants and animals would be unlikely from construction, operation and monitoring, and eventual closure of the repository, impacts to persons leading subsistence lifestyles would be unlikely.

Land Use

Direct land-use impacts from the Proposed Action would be low on members of the public because of the existing restriction of site access. There are no communities with high percentages of minority or low-income populations near the proposed repository site.

Socioeconomics

Because of the large population and workforce in the region of influence, socioeconomic impacts from repository construction and operation would be small. During the construction phase and the operation and monitoring phase, the regional workforce would increase less than 0.5 percent above the baseline level (see Section 4.1.6). Changes to the baseline regional population would not be greater than 0.5 percent for the duration of the entire project. Because the Proposed Action would generate minimal impacts to employment and population, potential socioeconomic impacts would be small.

DOE would continue its Native American Interaction Program to help manage cultural resources during construction and operation.

Air Quality

Impacts to air quality from the Proposed Action would be small. Furthermore, DOE would use best management practices for all activities, particularly ground-disturbing activities that could generate fugitive dust and construction activities that could produce vehicle emissions.

Noise

Impacts to sensitive noise receptors from the Proposed Action would not be likely because no sensitive noise receptors live in the Yucca Mountain region. Furthermore, there are no low-income or minority communities adjacent to the site.

4.1.13.3 Environmental Justice Impact Analysis Results

This analysis uses information from Sections 4.1.1 through 4.1.9. Those sections address impacts from all phases of the Proposed Action—construction, operation and monitoring, and closure. As noted above, DOE expects that the impacts of the Proposed Action would be small on the population as a whole. DOE has not identified any subsection of the population, including minority and low-income populations, that would receive disproportionate impacts. Accordingly, DOE has concluded that no disproportionately high and adverse impacts would result from the Proposed Action.

4.1.13.4 A Native American Perspective

In reaching the conclusion that there would be no disproportionately high and adverse impacts on minorities or low-income populations, DOE acknowledges that people from many Native American tribes have used the area proposed for the repository as well as nearby lands (AIWS 1998, page 2-1), 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 repository site. DOE acknowledges that Native American people living in the Yucca Mountain vicinity have concerns about the protection of traditions and the spiritual integrity of the land that extend to the propriety of the Proposed Action.

Native American people living in the Yucca Mountain vicinity hold views and beliefs about the relationship between the proposed repository and the surrounding region that they have expressed in *American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement* (AIWS 1998, all). Concerning the approach to daily life, the authors of that document, who represent the Western Shoshone, Owens Valley Paiute and Shoshone, Southern Paiute, and other Native American organizations, state:

> *...we have the responsibility to protect with care and teach the young the relationship of the existence of a nondestructive life on Mother Earth. This belief is the foundation for our holistic view of the cultural resources, i.e., water, animals, plants, air, geology, sacred sites, traditional cultural properties, and artifacts. Everything is considered to be interrelated and dependent on each other to sustain existence (AIWS 1998, page 2-9).*

The authors discuss the cultural significance of Yucca Mountain lands to Native American people:

> *American Indian people who belong to the CGTO (Consolidated Group of Tribes and Organizations) consider the YMP lands to be as central to their lives today as they have been since the creation of their people. The YMP lands are part of the holy lands of Western Shoshone, Southern Paiute, and Owens Valley Paiute and Shoshone people (AIWS 1998, page 2-20).*

and:

> *The lack of an abundance of artifacts and archaeological remains does not infer that the site was not used historically or presently and considered an integral part of the cultural ecosystem and landscape (AIWS 1998, page 2-10).*

The authors address the continuing denial of access to Yucca Mountain lands:

> *One of the most detrimental consequences to the survival of American Indian culture, religion, and society has been the denial of free access to their traditional lands and resources (AIWS 1998, page 2-20).*

and:

> *No other people have experienced similar cultural survival impacts due to lack of free access to the YMP area (AIWS 1998, page 2-20).*

The authors recognize that past restrictions on access have resulted in generally beneficial and protective effects for cultural resources, sacred sites, and potential traditional cultural properties (AIWS 1998, Section 3.1.1). However, the authors express concerns of Native American people regarding use of the repository:

> *The past, present, and future pollution of these holy lands constitutes both Environmental Justice and equity violations. No other people have had their holy lands impacted by YMP-related activities (AIWS 1998, page 2-20).*

and:

> *Access to culturally significant spiritual places and use of animals, plants, water and lands may cease because Indian people's perception of health and spiritual risks will increase if a repository is constructed (AIWS 1998, page 3-1).*

Even after closure and reclamation, the presence of the repository would represent an irreversible impact to traditional lands and other elements of the natural environment in the view of Native Americans.

Regarding the transportation of spent nuclear fuel and high-level radioactive waste, the authors state:

> *...health risks and environmental effects resulting from the construction and operation of the proposed intermodal transfer facility (ITF) and the transportation of high-level waste and spent nuclear fuel is considered by Indian people to be disproportionately high. This is attributed primarily to the consumption patterns of Indian people who still use these plants and animals for food, medicine, and other related cultural or ceremonial purposes (AIWS 1998, page 2-19).*

and:

> *The anticipated additional noise and interference associated with an ITF* [Intermodal Transfer Facility] *and increased transportation may disrupt important ceremonies that help the plants, animals, and other important cultural resources flourish, or may negatively impact the solitude that is needed for healing or praying (AIWS 1998, page 2-19).*

DOE recognizes that Native American tribal governments have a special and unique legal and political relationship with the Government of the United States, as established by treaty, statute, legal precedent, and the U.S. Constitution. For this reason DOE will consult with tribal governments and will work with representatives of the Consolidated Group of Tribes and Organizations to ensure the consideration of tribal rights and concerns before making decisions or implementing programs that could affect tribes; to continue the protection of Native American cultural resources, sacred sites, and potential traditional cultural properties; and to implement any appropriate mitigation measures.

4.1.14 IMPACTS OF THERMAL LOAD AND PACKAGING SCENARIOS

This section summarizes and compares the short-term environmental impacts for the three thermal load scenarios. These scenarios for the repository are high thermal load (85 MTHM per acre), intermediate thermal load (60 MTHM per acre) and low thermal load (25 MTHM per acre).

Overall the EIS analysis found that differences in environmental impacts for the three thermal load scenarios would be low and that the differences between the scenarios would be small. More specifically:

- All of the short-term impacts from repository activities would be small, both to workers and to the public.

- Long-term impacts to the public for the three thermal load scenarios would be essentially the same for collective dose and for latent cancer fatalities. They would be low (0.005 to 0.02 latent cancer fatality). Over the first 10,000 years, the risk of a latent cancer fatality to the maximally exposed individual would also be low (from 0.000001 to 0.000003) at 20 kilometers (about 12 miles) downgradient from Yucca Mountain. Individual dose rates would be highest for the high thermal load scenario and lowest for the low thermal load scenario.

- Short-term impacts for the surface-water, biological and soil, cultural, aesthetics, noise, and environmental justice resource areas would be small regardless of the thermal load scenario.

Short-term environmental impacts for activities at the repository as a function of packaging scenarios include:

- The greatest impacts for repository-related activities would be associated with the uncanistered packaging scenario with the exception of the generated volumes of solid and industrial wastes. For these wastes, the greatest impacts would result from the dual-purpose and disposable shipping packaging scenarios because these two types of shipping package would eventually become waste.

- Differences in impacts among the packaging scenarios would not be large, generally between 10 and 20 percent.

4.1.15 IMPACTS FROM MANUFACTURING DISPOSAL CONTAINERS AND SHIPPING CASKS

This section discusses the potential environmental impacts from the manufacturing of disposal containers and shipping casks required by the Proposed Action to dispose of spent nuclear fuel and high-level radioactive waste permanently at a monitored geologic repository at Yucca Mountain. This analysis considers transportation overpacks that would provide radiation shielding in the same manner as a shipping cask but that DOE would use only in conjunction with disposable canisters and dual-purpose canisters to be shipping casks without baskets or other internal configurations.

4.1.15.1 Overview

DOE followed the overall approach and analytical methods used for the environmental evaluation and the baseline data directly from the *Department of the Navy Final Environmental Impact Statement for a Container System for the Management of Naval Spent Nuclear Fuel* (USN 1996a, all). DOE's evaluation focuses on ways in which the manufacture of the disposal containers and shipping casks could affect environmental attributes and resources at a representative manufacturing site. It is not site-specific because more than one manufacturer probably would be required to meet the production schedule requirements for component delivery, and the location of the companies chosen to manufacture disposal containers and shipping casks is not known. The companies and, therefore, the actual manufacturing sites would be determined by competitive bidding.

The analysis used a representative manufacturing site based on five facilities that produce casks, canisters, and related hardware for the management of spent nuclear fuel. The concept of a representative site was used in the Navy EIS (USN 1996a, page 4-1), and the representative site used in this analysis was defined in the same way, using the same five existing manufacturing facilities with the same attributes. The facilities used to define the representative site are in Westminster, Massachusetts; Greensboro, North Carolina; Akron, Ohio; York, Pennsylvania; and Chattanooga, Tennessee (USN

1996a, page 4-17). All of these facilities make components for firms with cask and canister designs approved by the Nuclear Regulatory Commission.

The analysis assumed that the manufacturing facilities and processes being used are similar to the facilities and processes that would produce disposal containers and shipping casks for the Yucca Mountain Repository. Therefore, the analysis considered the manufacturing processes used at these facilities and the total number of disposal containers and shipping casks required to implement each packaging scenario. The analysis assumed that the manufacture of disposal containers and shipping casks would occur at one representative site, but DOE recognizes that it probably would occur at more than one site. The assumption of one manufacturing site is conservative (that is, it tends to overestimate impacts) because it concentrates the potential impacts.

In addition, the analysis of disposal container and cask manufacturing evaluated the use of materials and the potential for impacts to material markets and supplies.

Section 4.1.15.3 describes the disposal containers and shipping casks. Section 4.1.15.4 discusses pertinent information on environmental settings for air quality, health and safety, and socioeconomics. Section 4.1.15.5 describes environmental impacts on air quality, health and safety, socioeconomics, material use, waste generation, and environmental justice.

4.1.15.2 Components and Production Schedule

Table 4-44 lists the quantities of disposal containers and shipping casks analyzed for the packaging scenarios described in Chapter 2. Table 4-44 includes disposal containers for naval spent nuclear fuel that would be emplaced in Yucca Mountain but does not include shipping casks for naval spent nuclear fuel. Shipping casks for naval spent nuclear fuel are owned and managed by the Navy. USN (1996a, all) analyzed environmental impacts for production of naval spent nuclear fuel canisters and shipping casks. Because naval spent nuclear fuel represents less than 4 percent of the inventory to be emplaced in the repository, the production of naval spent nuclear fuel casks would not add much to the impacts described in the following sections.

Table 4-44. Quantities of disposal containers and shipping casks for the Yucca Mountain Repository.[a]

Component	Description	Packaging scenario[b]		
		UC	DISP	DPC
Disposal containers[c]	Containers for disposal of SNF and HLW[d]	10,200	11,400	10,200
Rail shipping casks or overpacks[f]	Storage and shipment of SNF and HLW	0	100	110
Legal-weight truck shipping casks[f]	Storage and shipment of uncanistered fuel	120	10	10

a. The number of containers is an approximation but is based on the best available estimates.
b. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister.
c. Source: TRW (1999c, Section 6); values have been rounded.
d. SNF = spent nuclear fuel; HLW = high-level radioactive waste.
e. A larger number of disposal containers is required for disposable canisters because they cannot be packed as densely as other canisters.
f. Cask fleet developed from Ross (1998, all); JAI (1996, all); TRW (1998j, Table 12, pages 17 and 18).

As currently planned, all of the components listed in Table 4-44 would be manufactured over 24 years to support emplacement in the repository. Manufacturing activity would build up during the first 5 years, then would remain nearly constant through the remainder of the 24-year period.

4.1.15.3 Components

Disposal Containers

The disposal container would be the final outside container used to package the spent nuclear fuel and high-level radioactive waste emplaced in the repository. The basic design calls for a cylindrical vessel with an outer layer of A 516 carbon steel that would be 100 millimeters (3.9 inches) thick and an inner liner of corrosion-resistant high-nickel alloy (C-22) that would be 20 millimeters (0.8 inch) thick (TRW 1999c, Section 6.0, page 6-1). The flat end pieces would be 110-millimeter (4.3-inch)-thick carbon steel and 25-millimeter (1-inch)-thick high-nickel alloy. The bottom end pieces would be welded to the cylindrical body at the fabrication shop, and the top end pieces would be welded in place after the placement of spent nuclear fuel or high-level radioactive waste in the container at the repository. About 16 different disposal container designs would be used for different types of spent nuclear fuel and high-level radioactive waste. The designs would vary in length from 3.8 to 6.2 meters (12 to 20 feet) and the outside diameters would range from 1.3 to 2 meters (4.3 to 6.6 feet). In addition, the internal configurations of the containers would be different to accommodate different uncanistered spent nuclear fuel configurations and a variety of spent nuclear fuel and high-level radioactive waste disposable canisters. The mass of an empty disposal container would range from about 21 to 38 metric tons (23 to 42 tons) (TRW 1999c, Section 4.0, pages 4-16 to 4-21).

Casks for Rail and Legal-Weight Truck Shipments

DOE would use two basic kinds of shipping cask designs—rail and truck—to ship spent nuclear fuel and high-level radioactive waste to the repository. The design of a specific cask would be tailored to the type of material it would contain. For example, rail and truck casks that could be used to ship commercial spent nuclear fuel would be constructed of stainless- or carbon-steel plate materials formed into cylinders and assembled to form inner and outer cylinders (USN 1996a, pages 4-3 and 4-4). A depleted uranium or lead liner would be installed between the stainless- or carbon-steel cylinders, and a vessel bottom with lead or depleted uranium between the inner and outer stainless- or carbon-steel plates would be welded to the cylinders. A support structure that could contain neutron-absorbing material would be welded into the inner liner, if required. A polypropylene sheath would be placed around the outside of the cylinder for neutron shielding. After spent nuclear fuel assemblies were inserted into the cask, a cover with lead or depleted uranium shielding would be bolted to the top of the cylinder to close and seal it. Transportation overpacks would be very similar in design and construction to shipping casks but would not have an internal support structure for the spent nuclear fuel because they would be used only for dual-purpose or disposable canisters.

For commercial spent nuclear fuel, casks and overpacks are typically 4.5 to 6 meters (15 to 20 feet) long and about 0.5 to 2 meters (1.6 to 6.6 feet) in diameter. These casks are designed to be horizontal when shipped. Rail casks presently used to ship naval spent nuclear fuel are shorter and are designed to sit upright on railcars. Empty truck casks typically weigh from 21 to 2 metric tons (about 23 to 24 tons). Empty rail casks (or overpacks) for commercial spent nuclear fuel typically weigh from 59 to 91 metric tons (65 tons to a little over 100 tons). The corresponding weights when loaded with spent nuclear fuel range between 22 and 24 metric tons (24 and 26 tons) for truck casks and between 64 and 110 metric tons (70 and 120 tons) for rail casks. For protection during shipment, large removable impact limiters of aluminum honeycomb or other crushable impact-absorbing material would be placed over the ends (JAI 1996, all).

4.1.15.4 Existing Environmental Settings at Manufacturing Facilities

Because there are facilities that could meet the projected manufacturing requirements, the assessment concluded that no new construction would be necessary and that there would be no change in land use for the manufacture of disposal containers and shipping casks. Similarly, cultural, aesthetic, and scenic resources would remain unaffected. Ecological resources, including wetlands, would not be affected because existing facilities could accommodate the manufacture of disposal containers and shipping casks and new or expanded facilities would not be required. Some minor increases in noise, traffic, or utilities would be likely, but none of these increases would result in impacts on the local environment.

Water consumption and effluent discharge during the manufacture of disposal containers and shipping casks would be typical of a heavy manufacturing facility and would represent only a small change, if any, from existing rates. Similarly, effluent discharges would not increase enough to cause difficulty in complying with applicable local, state, and Federal regulatory limits, and would be unlikely to result in a discernible increase in pollutant activity.

Accordingly, the following paragraphs contain information on environmental settings for air quality, health and safety, and socioeconomics. Section 4.1.15.5 evaluates the environmental impacts to these resource areas for a representative site.

Air Quality

The analysis evaluated the ambient air quality status of the representative manufacturing location by examining the air quality of the areas in which the reference manufacturing facilities are located. The principal criteria pollutants for cask manufacturing facilities are ozone, carbon monoxide, and particulate matter (PM_{10}). Areas where ambient air quality standards are not exceeded, or where measurements have not been made, are considered to be in attainment. Areas where the air quality violates Federal or state regulations are in nonattainment and subject to more stringent regulations. Typical existing container and cask manufacturing facilities are in nonattainment areas for ozone and in attainment areas for carbon monoxide and particulate matter.

Because most of the existing typical manufacturing facilities are in nonattainment areas for ozone, the analysis assumed that the representative site would be in nonattainment for ozone and that ozone would be the criteria pollutant of interest. Volatile organic compounds and nitrous oxides are precursors for ozone and are indicators of likely ozone production. For the areas in which the reference manufacturing facilities are located, an average of 3,400 metric tons (approximately 3,800 tons) of volatile organic compounds and 39,000 metric tons (approximately 43,000 tons) of nitrous oxides were released to the environment in 1990, the latest year for which county-level data are available (USN 1996a, page 4-5).

Health and Safety

Data on the number of accidents and fatalities associated with cask and canister fabrication at the representative manufacturing location were based on national incidence rates for the relevant sector of the economy. In 1992, the last year for which statistics are available, the occupational fatality rate for the sector that includes all manufacturing was 3 per 100,000 workers; the occupational illness and injury rate for fabricated plate work manufacturing in 1992 was 6.3 per 100 full-time workers (USN 1996a, page 4-5).

The manufacture of hardware for each of the packaging scenarios would be likely to be in facilities that have had years of experience in rolling, shaping, and welding metal forms, and then fabricating large containment vessels similar to the required disposal containers and shipping casks for nuclear materials. Machining operations at these facilities would involve standard procedures using established metal-working equipment and techniques. Trained personnel familiar with the manufacture of large, multiwall, metal containment vessels would use the equipment necessary to fabricate such items. Because of this experience and training, DOE anticipates that the injury and illness rate would be equal to or lower than the industry rates.

Socioeconomics

Each of the five manufacturing facilities examined in this analysis is in a Metropolitan Statistical Area. The counties comprising each Metropolitan Statistical Area define the affected socioeconomic environment for each facility. The populations of the affected environments associated with the five facilities ranged from about 430,000 to 970,000 in 1992 (USN 1996a, page 4-6). In 1995 output (the value of goods and services produced in the five locations) ranged from $18 billion to $55 billion, income (wages, salaries, and property income) ranged from $9 billion to $26 billion, employment ranged from 245,000 to 670,000 in 1995, and plant employment ranged from 25 to 995 (USN 1996a, page 4-6). Based on averages of this information, the representative manufacturing location has a population of about 640,000 and the facility employs 480. Local output in the area is $30 billion, local income is $15 billion, and local employment is 390,000.

4.1.15.5 Environmental Impacts

As mentioned in Section 4.1.15.4, this evaluation considered only existing manufacturing facilities, so environmental impact analyses are limited to air quality, health and safety, waste generation, and socioeconomics. In addition, this section contains a qualitative discussion of environmental justice.

4.1.15.5.1 *Air Quality*

The analysis used the baseline data and methods developed in USN (1996a, Section 4.3) to estimate air emissions from manufacturing sites for the production of disposal containers and shipping casks. Criteria pollutants and hazardous air pollutants were considered, and predicted emissions were compared with typical regional or county-wide emissions to determine potential impacts of the emissions on local air quality.

Potential emissions were evaluated for a representative manufacturing location using the ambient air quality characteristics of typical manufacturing facilities, as described in Section 4.1.15.4. The analysis assumed that the representative location used for this analysis would be in a nonattainment area for ozone and in attainment areas for carbon monoxide and particulate matter. Therefore, ozone was the only criteria pollutant analyzed. Ozone is not normally released directly to the atmosphere, but is produced in a complex reaction of precursor chemicals (volatile organic compounds and nitrous oxides) and sunlight. This section evaluates the emissions of these precursors.

The reference air emissions associated with the manufacture of disposal containers and shipping casks were developed using the emissions resulting from manufacturing similar components (USN 1996a, page 4-6) and were normalized based on the number of work hours required for the manufacturing process. The analysis prorated these reference emissions on a per-unit basis to calculate annual emissions at the reference manufacturing site, assuming emissions from similar activities would be proportional to the number of work hours in the manufacturing process. To provide reasonable estimates of emissions, the analysis assumed that the volatile organic compounds used as cleaning fluids would evaporate fully into the atmosphere as a result of the cleaning processes used in manufacturing. The estimates of emissions were based on the total number of disposal containers and shipping casks manufactured over 24 years for each packaging scenario.

Table 4-45 lists the estimated annual average and estimated total 24-year emissions from the manufacture of disposal containers and shipping casks at the representative facility for each packaging scenario. Estimated annual average emissions of volatile organic compounds would vary from 0.58 to 0.61 metric ton (approximately 0.64 to 0.67 ton) a year. Nitrous oxides would be the largest emission, varying from 0.75 to 0.78 metric ton (approximately 0.83 to 0.86 ton) a year for the packaging scenarios. Annual

Table 4-45. Ozone-related air emissions (metric tons)[a] at the representative manufacturing location for the different packaging scenarios.

Compound	Measure	Packaging scenario[b]		
		UC	DISP	DPC
Volatile organic compounds	Annual average	0.60	0.61	0.58
	24-year total	15	15	14
	Percent of *de minimis*[c]	6.6%	6.7%	6.4%
Nitrogen oxides	Annual average	0.78	0.78	0.75
	24-year total	19	19	18
	Percent of *de minimis*[c]	8.6%	8.6%	8.2%

a. To convert metric tons to tons, multiply by 1.1023.
b. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister.
c. *De minimis* level for an air quality region in extreme nonattainment for ozone is 9.1 metric tons per year of volatile organic compounds or nitrogen oxides (40 CFR 51.853).

average emissions from disposal container and shipping cask manufacturing under any of the scenarios would be less than 0.02 percent of regional emissions of volatile organic compounds and 0.002 percent of regional emissions of nitrous oxides. Emissions from the manufacture of disposal containers and shipping casks would contain a relatively small amount of ozone precursors compared to other sources.

The examination of the packaging scenarios assumed that the emissions of volatile organic compounds and nitrous oxides were new sources; these emissions were compared with emission threshold levels (emission levels below which conformity regulations do not apply). There are different categories of ozone nonattainment areas based on the sources of ozone and amount of air pollution in the region. The different categories have different emission threshold levels (40 CFR 51.853).

For an air quality region to be in extreme nonattainment for ozone (most restrictive levels), the emission threshold level for both volatile organic compounds and nitrous oxides is 9.1 metric tons (10 tons) per year. Table 4-45 also lists the percentage of volatile organic compounds and nitrous oxides from the manufacture of disposal containers and shipping casks in relation to the emission threshold level of an extreme ozone nonattainment area. Air emissions from the manufacture of disposal containers and shipping casks would vary depending on the packaging scenario, with ranges of 6.4 to 6.7 percent and 8.2 to 8.6 percent of the emission threshold levels for volatile organic compounds and nitrous oxides, respectively. In all of the packaging scenarios, component manufacturing would not be likely to fall under the conformity regulations because the predicted emissions of volatile organic compounds and nitrous oxides would be well below (less than 10 percent of) the emission threshold level of 9.1 metric tons per year. However, DOE would ensure the implementation of the appropriate conformity determination processes and written documentation for each designated manufacturing facility.

States with nonattainment areas for ozone could place requirements on many stationary pollution sources to achieve attainment in the future. This could include a variety of controls on emissions of volatile organic compounds and nitrous oxides. Various options such as additional scrubbers, afterburners, or carbon filters would be available to control emissions of these compounds to comply with limitations.

4.1.15.5.2 *Health and Safety*

The analysis used data on the metal fabrication and welding industries from the Bureau of Labor Statistics to compile baseline occupational health and safety information for industries that fabricate steel and steel objects similar to disposal containers and shipping casks (USN 1996a, page 4-8). The expected number of injuries and fatalities were computed by multiplying the number of work years by the injury and fatality rate for each occupation.

Table 4-46 lists the expected number of injuries and illnesses and fatalities for each packaging scenario based on the work years required to produce the number of disposal containers and shipping casks needed over 24 years. Injuries and illnesses would range from 265 to 276. Fatalities would be unlikely.

Table 4-46. Injuries, illnesses, and fatalities over 24 years at the representative manufacturing location for the packaging scenarios.

Parameter	Packaging scenario[a] UC	DISP	DPC
Injuries and illnesses	275	276	265
Fatalities	0.13	0.13	0.13

a. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister.

The required number of disposal containers and shipping casks would not place unusual demands on existing manufacturing facilities. Thus, none of the packaging scenarios would be likely to lead to a deterioration of worker safety and a resultant increase in accidents. In addition, nuclear-grade components are typically built to higher standards and with methods that are more proceduralized, both of which lead to improved worker safety.

4.1.15.5.3 *Socioeconomics*

The assessment of socioeconomic impacts from manufacturing activities involved three elements:

- Per-unit cost data for disposal containers (TRW 1999c, Sections 5 and 6) and per-unit cost of shipping casks (TRW 1998j, Table 12, pages 17 and 18)
- Total number of disposal containers and shipping casks to be manufactured (TRW 1999c, Section 6)
- Economic data for the environmental setting for each facility to calculate the direct and secondary economic impacts of disposal container and shipping cask manufacturing on the local economy (BEA 1992, all)
  - Direct effects would occur as manufacturing facilities purchased materials, services, and labor required for manufacturing.
  - Secondary effects would occur as industries and households supplying the industries that were directly affected adjusted their own production and spending behavior in response to increased production and income, thereby generating additional socioeconomic impacts.

Impacts were measured in terms of output (the value of goods and services produced), income (wages, salaries, and property income), and employment (number of jobs).

The socioeconomic analysis of manufacturing used state-level economic multipliers for fabricated metal products (BEA 1992, all). To perform the analysis, DOE obtained the product, income, and employment multipliers for the states where the five existing manufacturing facilities are located. (Multipliers account for the secondary effects on an area's economy in addition to providing direct effects on its economy). The multipliers were averaged to produce composite multipliers for a representative manufacturing location. The composite multipliers were used to analyze the impacts of each alternative. Table 4-47 lists the state-specific multipliers and the composite multipliers.

The analysis was limited to estimating the direct and secondary impacts of manufacturing activities. No assessment was made of the impacts of manufacturing activities on local jurisdictions. Such an analysis would include the estimation of impacts on county and municipal government and school district revenues and expenditures. Because the production of disposal containers and shipping casks probably

Table 4-47. Economic multipliers for fabricated metal products.[a]

State	Final demand multiplier ($)		Direct effect multiplier (number of jobs)
	Products	Earnings	
Massachusetts	1.8927	0.5555	2.2050
North Carolina	1.9145	0.5426	2.1544
Ohio	2.6019	0.7260	3.1064
Pennsylvania	2.5697	0.7194	2.8552
Tennessee	2.1379	0.6107	2.5314
Composite	2.2233	0.6308	2.5705

a. Source: Bureau of the Census (1992h, all).

would occur at existing facilities alongside existing product lines, a substantial population increase due to workers moving into the vicinity of the manufacturing sites in a given year under a packaging scenario would be unlikely. Due to this lack of demographic impacts, meaningful change in the disposition of local government or school district revenues and expenditures would be unlikely. Because substantial population increases would not be likely, the analysis did not consider impacts on other areas of socioeconomic concern, such as housing and public services.

The analysis calculated average annual impacts for the manufacturing period. The impacts of each packaging scenario were compared to the baseline at the representative location in 1995, with results expressed in millions of 1998 dollars. No attempt was made to forecast local economic growth or inflation rates for the representative location because of the non-site-specific nature of the analysis.

Table 4-48 lists the impacts of each packaging scenario on output, income, and employment at the representative manufacturing location. The impacts include the percent of each scenario in relation to overall output, income, and employment in the economy.

Table 4-48. Socioeconomic impacts for packaging scenarios at the representative manufacturing location.

Packaging scenario	Average annual output[a]		Average annual income		Average annual employment	
	$ (millions)	Percent impact[b]	$ (millions)	Percent impact	Person-years	Percent impact
Uncanistered	360	1.2	102	0.68	470	0.12
Dual-purpose canister	365	1.2	104	0.69	450	0.12
Disposable canister	310	1.0	89	0.59	470	0.12

a. Annual output and income impacts are expressed as millions of 1998 dollars.
b. Percent impact refers to the percentage of the baseline data discussed in Section 4.1.14.4 for the representative site.

Local Output

The average annual output impacts of each scenario would range from about $310 million to about $365 million (Table 4-48). Output generated from each scenario would increase total local output from between 1.0 percent and 1.2 percent, on average, over the 24-year manufacturing period.

Local Income

The average annual income impacts of each packaging scenario would range from about $89 million to about $104 million (Table 4-48). Income generated from each scenario would increase total local income by between 0.59 percent and 0.69 percent, on average, over the 24-year manufacturing period.

Local Employment

The average annual employment impacts of each packaging scenario would range from about 450 to about 470 work years (Table 4-48). Employment generated from any of the packaging scenarios would increase total local employment about 0.12 percent, on average, over the 24-year manufacturing period.

4.1.15.5.4 *Impacts on Material Use*

To the extent available, DOE based the calculations of the quantities of materials it would use for the manufacture of each disposal container and shipping cask on engineering specifications for each hardware component. This information was provided by the manufacturers of systems either designed or under licensing review (USN 1996a, Sections 3.0, 4.1.1, and Appendix D; TRW 1999c, all), or from conceptual design specifications for technologies still in the planning stages (JAI 1996, all). Data on per-unit material quantities for each component were combined with information on the number of disposal containers and shipping casks to be manufactured during each packaging scenario. In addition, the analysis assessed the impact of component manufacturing for each scenario on the total U.S. production (or availability in the United States, if not produced in this country) of each relevant input material. The results of the assessment are expressed in terms of percent impacts on total U.S. domestic production of most commodities.

Table 4-49 lists estimated total quantities of materials that DOE would need for each packaging scenario during the 24-year period along with the annual average requirement for each material. For each scenario the largest material requirement by weight would be steel, ranging from about 260,000 to about 280,000 metric tons (280,000 to 310,000 tons).

Table 4-49. Material use (metric tons)[a] for packaging scenarios.

	Basic material use per scenario[b]					
	UC		DISP		DPC	
Material	Total	Annual	Total	Annual	Total	Annual
Aluminum	1,500	63	77	3	1,500	63
Chromium[c]	14,000	590	12,000	500	15,000	620
Copper	36	1	146	6	95	4
Depleted uranium	880	37	1,300	55	120	5
Lead	430	18	1,500	63	3,000	139
Molybdenum[d]	6,000	250	6,600	280	6,000	260
Nickel[e]	29,000	1,200	29,000	1,200	30,000	1,200
Steel	280,000	12,000	260,000	11,000	280,000	12,000

a. To convert metric tons to tons, multiply by 1.1023.
b. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister.
c. Chromium estimated as 29 percent of stainless steel and 22 percent of high-nickel alloy.
d. Molybdenum estimated as 13.5 percent of high-nickel alloy.
e. Stainless steel assumed to be 18.5 percent nickel and high-nickel alloy assumed to be 58 percent nickel.

Table 4-50 compares the annual U.S. production capacity to the annual requirements for the materials each scenario would use. With the exception of chromium and nickel, consumption for each scenario for the 24-year manufacturing period would be less than 0.5 percent of the annual U.S. production.

Therefore, the use of aluminum, copper, lead, molybdenum, or steel would not produce a noteworthy increased demand and should not have a meaningful effect on the supply of these materials.

The annual requirement for chromium as a component in stainless-steel and high-nickel alloy ranges from about 0.48 percent to about 0.59 percent of the annual U.S. production. Most chromium, which is

Table 4-50. Annual amount (metric tons)[a] of material required for manufacturing, expressed as a percent of annual U.S. domestic production, for each packaging scenario.

		Packaging scenario[b]					
		UC		DISP		DPC	
Material	Production[c]	Annual	Percent	Annual	Percent	Annual	Percent
Aluminum	5,000,000	63	0.0013	3	0.0001	63	0.0013
Chromium	104,000	590	0.57	500	0.48	620	0.59
Copper	1,900,000	1	0.0001	6	0.0003	4	0.0002
Depleted uranium	14,700[d]	37	0.25	55	0.38	5	0.034
Lead	430,000	18	0.0042	63	0.015	140	0.032
Molybdenum	57,000	250	0.45	280	0.48	260	0.045
Nickel	14,600	1,200	8.3	1,200	8.3	1,200	8.4
Steel	91,500,000	12,000	0.013	11,000	0.012	12,000	0.013

a. To convert metric tons to tons, multiply by 1.1023.
b. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister.
c. Source: Bureau of the Census (1997, Table 1155, page 700, and Table 1244, page 756).
d. Source: USN (1996a, page 4-10).

an important constituent of many types of stainless steel, is imported into the United States and is classified as a Federal Strategic and Critical Inventory material. For comparative purposes, the maximum total 24-year program requirement of about 14,000 metric tons (17,000 tons) can be evaluated as a percentage of the 1994 strategic chromium inventory of 1.04 million metric tons (1.15 million tons) (Bureau of the Census 1997, Table 1159, page 702). The total repository program need would be about 1.5 percent of the strategic inventory. With the strategic inventory to support the program demand, chromium use should not cause any market or supply impacts.

Annual nickel use as a component in stainless steel and corrosion-resistant high-nickel alloys appears, relatively, the most important in comparison to U.S. production. The magnitude of the comparison is the result of low U.S. production because the United States imports most of the nickel it uses. Although the annual U.S. production of nickel is only 14,600 metric tons (16,100 tons), the annual U.S. consumption is 158,000 metric tons (174,000 tons) (Bureau of Census 1997, Table 1155, page 700). This annual consumption is supported by a robust world production of 1.04 million metric tons (1.15 million tons) (Bureau of the Census 1997, Table 1158, page 702). The maximum annual program need is a little less than 1 percent of the U.S. consumption and about 0.1 percent of world production. Canada is a major world supplier of nickel. DOE does not anticipate that the maximum program demand would affect the U.S. or world nickel markets.

The annual amount of depleted uranium used over 24 years would range from 0.25 percent to 0.38 percent of the total U.S. annual production. These requirements would be small. Given the limited alternative uses of this material and the large current inventory of surplus depleted uranium hexafluoride owned by DOE, such impacts should be considered to be positive (USN 1996a, page 4-10).
Lead or steel could be substituted for depleted uranium for radiation shielding in some cases. If those materials were used for this purpose, the thickness of the substituted material would increase in inverse proportion to the ratio of the density of the substituted material to the density of depleted uranium. If lead or steel were used, the shielding thickness would increase by about 170 percent or 240 percent, respectively, resulting in a much larger container (USN 1996a, page 4-10).

4.1.15.5.5 *Impacts of Waste Generation*

The component materials used in the manufacture of disposal containers and shipping casks would be carbon steel, high-nickel alloy, and stainless steel, with either depleted uranium or lead used for shielding. The manufacture of shielding would generate hazardous or low-level radioactive waste, depending on the material used. Other organic and inorganic chemical wastes generated by the manufacture of disposal containers and shipping casks and the amounts generated have also been identified.

Based on data in USN (1996a, page 4-13), the analysis estimated annual volumes and quantities of waste produced for each packaging scenario per disposal container and shipping cask manufactured at the representative site. The potential for impacts was evaluated in terms of existing and projected waste handling and disposal procedures and regulations. In addition to relevant state regulatory agencies, the Environmental Protection Agency and the Occupational Safety and Health Administration regulate the manufacturing facilities.

Manufacturing to support the different packaging scenarios would produce liquid and solid wastes at the manufacturing locations. To control the volume and toxicity of these wastes, manufacturers would comply with existing regulations. Pollution prevention and reduction practices would be implemented. The analysis evaluated only waste created as a result of the manufacturing process to produce disposal containers and casks from component materials. It did not consider the waste produced in mining, refining, and processing raw materials into component materials for distribution to the manufacturer. The analysis assumed that the component materials, or equivalent component materials produced from the same raw materials, would be available from supplier stock, which would be available without regard to the status of the Yucca Mountain project.

Liquid Waste

The liquid waste produced during manufacturing would consist of used lubricating and cutting oils from machining operations and the cooling of cutting equipment. This material is currently recycled for reuse. Ultrasonic weld testing would generate some unpotable water-containing glycerin. Water used for cooling and washing operations would be treated for release by filtration and ion exchange, which would remove contaminants and permit discharge of the treated water to the sanitary system.

Table 4-51 lists the estimated amounts of liquid waste generated by the shaping, machining, and welding of the vessels required for each packaging scenario. The annual average amount of liquid waste generated would range from 3.4 to 3.8 metric tons (approximately 3.7 to 4.2 tons) per year. The small quantities of waste produced during manufacturing would not exceed the capacities of the existing equipment for waste stream treatment at the manufacturing facility.

Table 4-51. Annual average waste generated (metric tons)[a] at the representative manufacturing location for packaging scenarios.

	Packaging scenario[b]		
Waste	UC	DISP	DPC
Liquid	3.4	3.8	3.4
Solid	0.47	0.52	0.47

a. To convert metric tons to tons, multiply by 1.1023.
b. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister.

Solid Waste

Table 4-51 lists the solid waste that manufacturing operations would generate. The annual average amount of solid waste would range from 0.47 to 0.52 metric ton (approximately 0.52 to 0.57 ton) per year. The primary waste constituents would be steel and components of steel including nickel, manganese, molybdenum, chromium, and copper. These chemicals could be added to existing steel product manufacturing waste streams for treatment and disposal or recycling.

The analysis assumed that depleted uranium to be incorporated in the components would be delivered to the manufacturing facility properly shaped to fit as shielding for a shipping cask. As a result, depleted uranium waste would not be generated or recycled at the representative manufacturing site and would not pose a threat to worker health and safety. Lead used for gamma shielding would be cast between stainless-steel components for the shipping casks. Although the production of a substantial quantity of lead waste under any of the packaging scenarios would be unlikely, such waste would be recycled.

4.1.15.5.6 *Environmental Justice*

The purpose of this environmental justice assessment is to determine if disproportionately high and adverse health or environmental impacts associated with the manufacture of disposal containers and shipping casks would affect minority or low-income populations, as outlined in Executive Order 12898 and the President's accompanying cover memorandum. Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations,* directs Federal agencies to identify and address disproportionately high and adverse human health or environmental effects of their programs and activities on minority and low-income populations. A disproportionately high impact would be an impact (or risk of an impact) in a minority or low-income community that exceeded the corresponding impact on the larger community to a meaningful degree. The analysis discussed below is the analysis used in USN (1996a, Section 4.8), which was adapted to the manufacturing of components for the Yucca Mountain Repository.

The environmental justice assessment considered human health and environmental impacts from the examination of impacts on air quality, waste generation, and health and safety for each scenario. The assessment used demographic data to provide information on the degree to which a scenario would affect minority or low-income populations disproportionately. The evaluation identified as areas of concern those in which disproportionately high and adverse impacts could affect minority or low-income populations.

This evaluation considered the characteristics of the five facilities that manufacture casks or canisters for spent nuclear fuel. For each facility the analysis considered a region defined by an approximately 16-kilometer (10-mile) radius around the site. The percentages of minority and low-income persons comprising the population of the states where the facilities are located were used as a reference.

To explore potential environmental justice concerns, this assessment examined the composition of populations living within approximately 16 kilometers (10 miles) of the five manufacturing facilities to identify the number of minority and low-income individuals in each area. DOE selected this radius because it would capture the most broadly dispersed environmental consequences associated with the manufacturing activities, which would be impacts to air quality. The number of persons in each target group in the defined area was compared to the total population in the area to yield the proportion of minority and low-income persons within approximately 16 kilometers of each facility.

A geographic information system was used to define areas within approximately 16 kilometers (10 miles) of each facility. Linked to 1990 census data, this analytical tool enabled the identification of block groups within 16 kilometers. In cases where the 16-kilometer limit divided block groups, the system calculated the fraction of the total area of each group that was inside the prescribed distance. This fraction provided the basis for estimating the total population in the area as well as the minority and low-income components.

The analysis indicated that in one location the proportion of the minority population in the area associated with the manufacturing facility is higher than the proportion of the minority population in the state. The difference between the percentage of the minority population living inside the 16-kilometer (10-mile) radius and the state is 1.5 percent (USN 1996a, page 4-18). DOE anticipates very small impacts for the total population from manufacturing activities associated with all the scenarios, so there would be no disproportionately high and adverse impacts to the minority population near this facility.

In addition, the percentage of the total population that consists of low-income families living within about 16 kilometers (10 miles) of a manufacturing facility would exceed that of the associated state in one instance. The difference in this case was 0.9 percent (USN 1996a, page 4-18). DOE anticipates very small impacts to individuals and to the total population, and no special circumstances would cause disproportionately high and adverse impacts to the low-income population living near the facility.

The EIS analysis determined that only small human health and environmental impacts would occur from the manufacture of disposal containers and shipping casks. Disproportionately high and adverse impacts to minority or low-income populations similarly would be unlikely from these activities.

4.2 Short-Term Environmental Impacts from the Implementation of a Retrieval Contingency or Receipt Prior to the Start of Emplacement

4.2.1 IMPACTS FROM RETRIEVAL CONTINGENCY

Section 122 of the NWPA requires DOE to maintain the ability to retrieve emplaced waste for at least 50 years after the start of emplacement. Because of this requirement, the EIS includes an analysis of the impacts of retrieval. Although DOE does not anticipate retrieval and it is not part of the Proposed Action, DOE would maintain the ability to retrieve the waste for at least 100 years and possibly for as long as 300 years in the event of a decision to retrieve the waste either to protect the public health and safety or the environment or to recover resources from spent nuclear fuel. This EIS evaluates retrieval as a contingency action and describes potential impacts if it were to occur. The analysis in this EIS assumes that under this contingency DOE would retrieve all the waste and would place it on a surface storage pad pending future decisions about its ultimate disposition. Storage of spent nuclear fuel and high-level radioactive waste on the surface would be in compliance with applicable regulations.

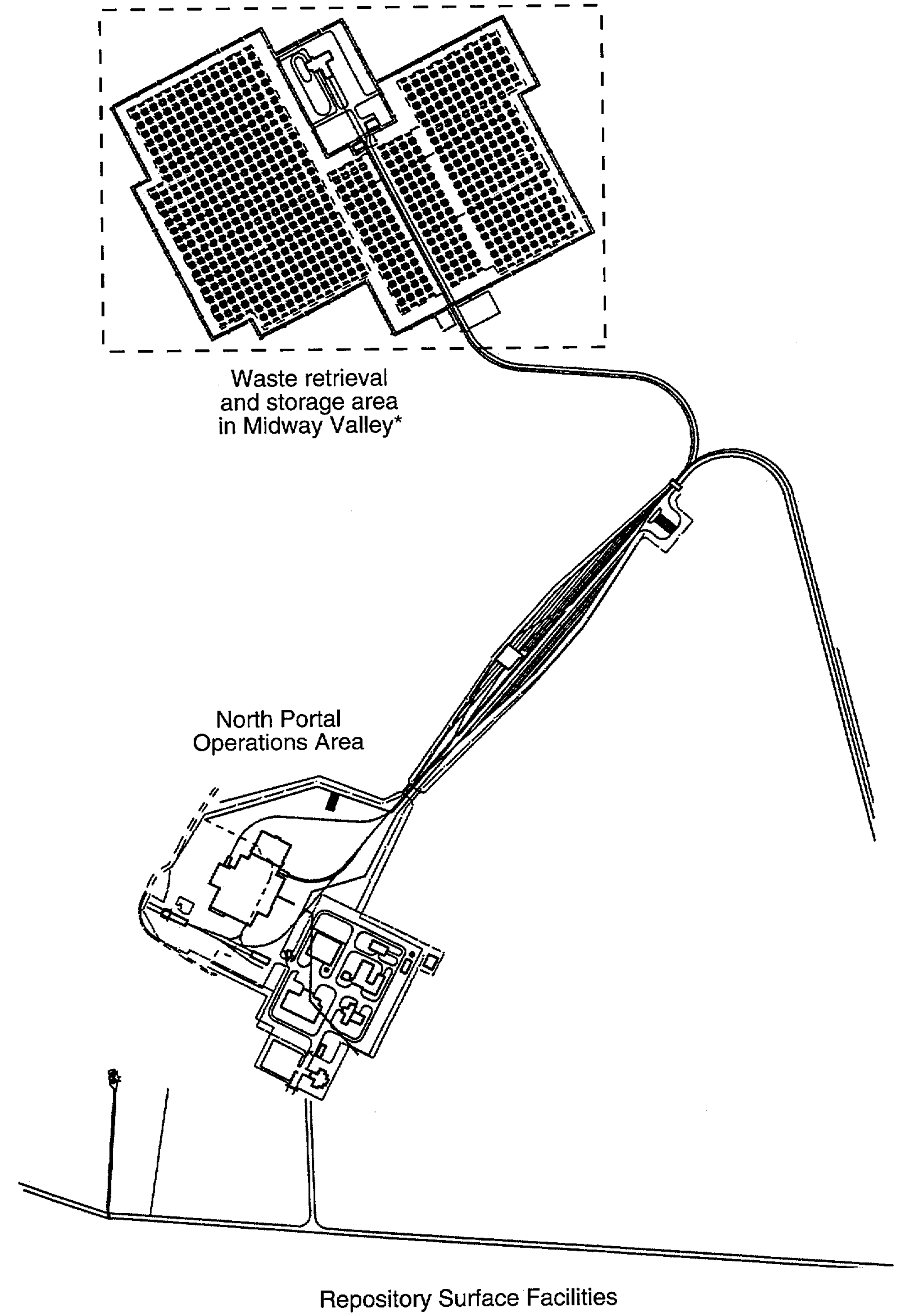
4.2.1.1 Retrieval Activities

If there were a decision to retrieve spent nuclear fuel and high-level radioactive waste from the repository, DOE would move the waste packages from the emplacement drifts to the surface. Operations in the subsurface facilities to remove the waste packages would be the reverse of emplacement operations and would use the same types of equipment (see Section 2.1.1.2).

On the surface, the retrieved waste packages would be loaded on a vehicle for transport to a Waste Retrieval and Storage Area in Midway Valley, about 3.7 kilometers (2.3 miles) from the North Portal Operations Area, to which DOE would build a rail line or roadway. Figure 4-5 shows the relationship between these areas. The Waste Retrieval and Storage Area would include a Waste Retrieval Transfer Building, support facilities, and a number of concrete storage pads. To retrieve and store 70,000 MTHM of spent nuclear fuel and high-level radioactive waste, these facilities would cover about 1 square kilometer (250 acres) (TRW 1999a, Attachment I, page I-8).

DOE based selection of Midway Valley Wash as the site for retrieval activities on the following site selection criteria:

- Proximity to the repository North Portal Operations Area
- Retrieval of the waste in the shortest possible timeframe



*See Figure 3-12 for more specific location of Midway Valley.

Source: TRW (1999a, Attachment I, Figure I-1).

Figure 4-5. Location of the Waste Retrieval and Storage Area in relation to the North Portal Operations Area.

- Adequate space for dry storage of 70,000 MTHM of waste
- No ground displacements due to earthquakes
- Siting outside the probable maximum flood zone
- Minimum costs for construction
- Minimum impacts to the environment

In the Waste Retrieval Transfer Building, the waste packages would be removed and placed in concrete storage modules (one container per module). The concrete module would protect the container and provide shielding. The module and container would then move to a concrete storage pad near the Waste Retrieval Transfer Building, where it would remain awaiting ultimate disposition. Figure 4-6 shows a concrete storage module design concept.

Studies of the strategies and options for retrieval (TRW 1997d, all) indicate it would take about 10 years after a decision to retrieve the emplaced material to plan the operation, procure the necessary equipment, and prepare the Waste Retrieval and Storage Area; about 3 years would involve the construction of facilities and storage areas. To accomplish retrieval would require another 11 years, including additional storage area construction. DOE performed an impact analysis for the retrieval contingency only for the high thermal load scenario. The analysis of impacts for this scenario is sufficient to describe the types and magnitudes of impacts that would occur if DOE implemented the retrieval contingency.

4.2.1.2 Impacts of Retrieval

The following sections present the results of the environmental impact analysis for the retrieval contingency. They consider the construction of the Waste Retrieval and Storage Area, retrieval of the waste packages and their movement to the surface and to the Waste Retrieval and Storage Area, and the loading of the waste packages in concrete storage modules and their placement on concrete storage pads.

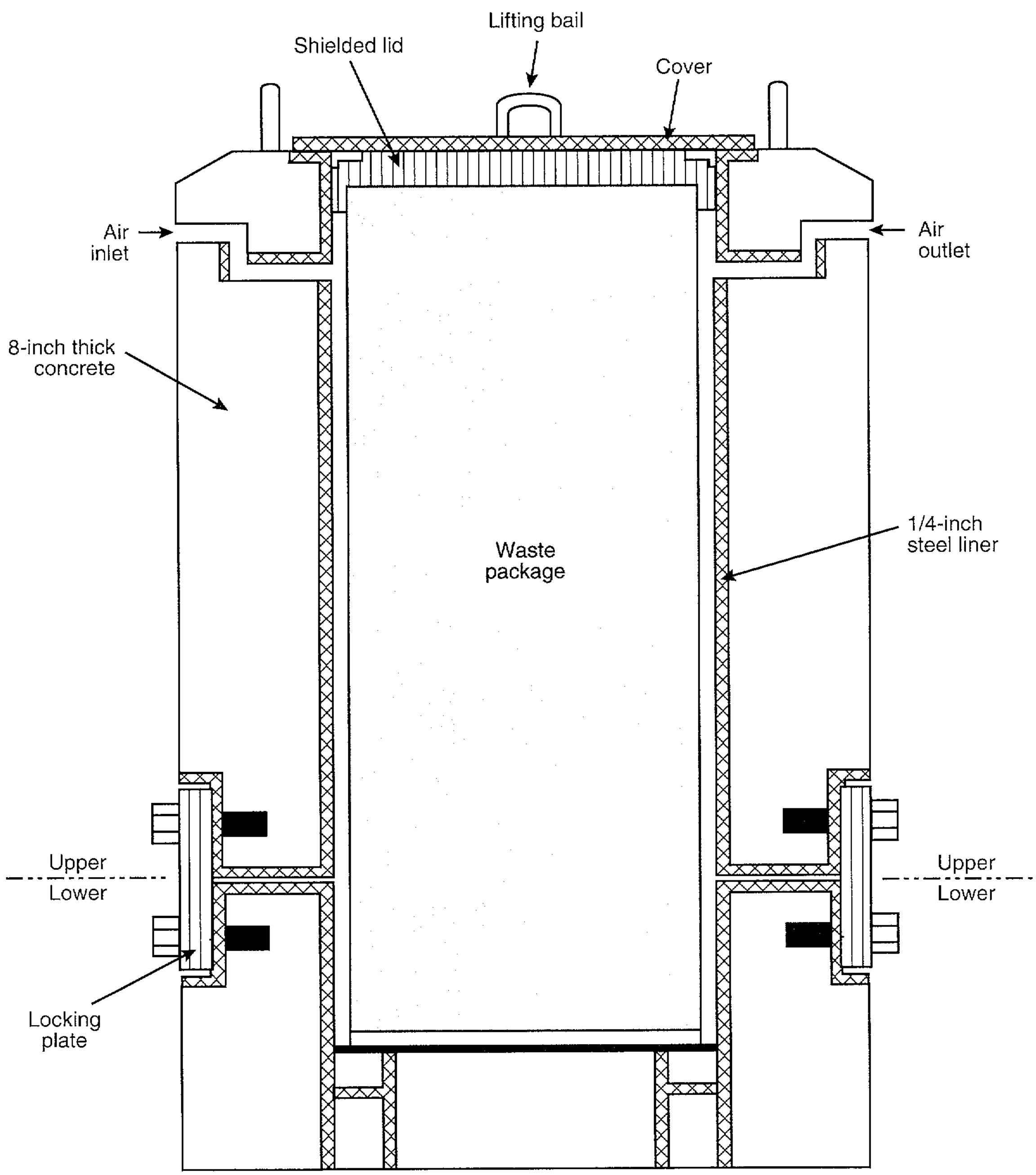
4.2.1.2.1 *Impacts to Land Use and Ownership from Retrieval*

Retrieval would cause no land-use impacts during the construction of the Waste Retrieval and Storage Area. DOE would develop a 1-square-kilometer (250-acre) area approximately 3.7 kilometers (2.3 miles) north of the North Portal Operations Area in Midway Valley (see Figure 4-5) on lands already withdrawn from public use.

4.2.1.2.2 *Impacts to Air Quality from Retrieval*

The construction of the Waste Retrieval and Storage Area and the movement of the spent nuclear fuel and high-level radioactive waste to the surface would result in air quality impacts. The analysis considered both radiological and nonradiological impacts. No radiological air quality impacts would occur during the placement of the storage containers in concrete storage modules, assuming the containers remained intact and free from leaks during handling. However, radon-222 would be released from the active ventilation of the subsurface.

Nonradiological Air Quality Impacts. DOE evaluated nonradiological air quality impacts from the retrieval of materials from the repository for (1) the construction of a Waste Retrieval and Storage Area and (2) the retrieval process. Construction and retrieval activities would result in releases of nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10}. Retrieval activities would not involve subsurface excavation or result in disturbance of the excavated rock pile, so no releases of cristobalite would occur.



Source: TRW (1999a, Figure I-4).

Figure 4-6. Typical concrete storage module design, vertical view.

Construction equipment would release nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10} from fuel consumption and PM_{10} in the form of fugitive dust. The analysis did not take credit for the standard construction dust suppression measures that DOE would implement to lower the projected PM_{10} concentrations. Table 4-52 lists calculated concentrations for criteria pollutant impacts to the public maximally exposed individual and compares these concentrations to regulatory limits. The nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10} concentrations at the location of the maximally exposed individual would be less than 1 percent of the applicable regulatory limits in all cases.

Table 4-52. Criteria pollutant impacts to public maximally exposed individual from retrieval (micrograms per cubic meter).[a,b]

Pollutant	Averaging time	Regulatory limit[c]	Maximum concentration[d]	Percent of regulatory limit
Nitrogen dioxide	Annual	100	0.23	0.23
Sulfur dioxide	Annual	80	0.022	0.028
	24-hour	365	0.18	0.049
	3-hour	1,300	1.4	0.11
Carbon monoxide	8-hour	10,000	2.1	0.020
	1-hour	40,000	13	0.033
Particulates (PM_{10}) ($PM_{2.5}$)	Annual	50 (15)	0.12	0.23
	24-hour	150 (65)	0.83	0.55

a. Appendix G (Section G.1) contains additional information on air quality.
b. All numbers except regulatory limits are rounded to two significant figures.
c. Regulatory limits from 40 CFR 50.4 through 50.11, and Nevada Administrative Code 445B.391 (see Table 3-5).
d. Sum of the highest concentrations at the accessible site boundary regardless of direction.

Radiological Air Quality Impacts. During retrieval activities subsurface ventilation would continue, resulting in releases of naturally occurring radon-222 and its decay products in the ventilation exhaust. Subsurface ventilation would continue for the duration of retrieval, about 14 years (3 years of initial construction, followed by 11 years of retrieval operations). Table 4-53 lists estimated annual and total doses from 14 years of retrieval activities to maximally exposed individuals and potentially affected populations from radon-222 released from subsurface facilities.

4.2.1.2.3 *Impacts to Hydrological Resources from Retrieval*

4.2.1.2.3.1 Surface Water. The retrieval activity that could have surface-water impacts would be the construction of the Waste Retrieval and Storage Area, which would disturb an area of 1 square kilometer (250 acres).

Potential for Runoff Rate Changes. The total disturbed area would include areas cleared to support construction equipment and materials, facilities, and concrete storage pads. If DOE retrieved all the waste, the storage pad area would account for about 0.43 square kilometer (107 acres) of the disturbed land (TRW 1999a, page I-14). Including the areas covered by facilities, roadways, and queuing areas, most of the land disturbance would result in surface areas that would provide almost no infiltration, so precipitation would result in runoff from the Waste Retrieval and Storage Area. As described in Section 4.1.3.2, if precipitation did not generate runoff from surrounding areas, the runoff from the storage area could travel to otherwise empty drainage channels, but would not go far. If precipitation generated runoff everywhere, there would be little difference in the quantity produced in the storage area; it just would occur earlier in the storm. In addition, a comparison of the 1 square kilometer (250 acres) of disturbed land to the estimated 12 square kilometers (3,000 acres) that make up the Midway Valley Wash drainage area (Bullard 1992, Table 5) indicates that changes in runoff and infiltration rates should have little impact on how the entire drainage area responded to precipitation events.

Table 4-53. Estimated radiation doses to maximally exposed individuals and populations from subsurface radon-222 releases during retrieval operations.[a,b]

Impact	Total	Annual
Dose to public		
Maximally exposed individual[c] (millirem)	5.5	0.43
80-kilometer[d] population[e] (person-rem)	28	2.1
Dose to noninvolved (surface) workers		
Maximally exposed noninvolved (surface) worker[f] (millirem)	0.51	0.039
Yucca Mountain noninvolved worker population (person-rem)	0.72	0.23/0.0067[g]
Nevada Test Site noninvolved worker population[h] (person-rem)	0.046	0.0035

a. Appendix G contains detailed information about the air quality analysis.
b. Construction and retrieval activities would last 13 years.
c. About 20 kilometers (12 miles) south of the repository.
d. 80 kilometers = 50 miles.
e. Approximately 28,000 individuals within 80 kilometers of the repository (see Section 3.1.8).
f. Maximally exposed noninvolved worker would be at the South Portal Operations Area.
g. First value is dose for construction workforce; second value is dose for retrieval workforce.
h. DOE workers at the Nevada Test Site [6,600 workers (DOE 1996f, page 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

Potential for Altering Natural Drainage. The proposed location for the Waste Retrieval and Storage Area does not cross or intercept well-defined drainage channels with the exception of the northwest corner, which could be close to, or possibly overlay, a short stretch of the upper Midway Valley Wash. Other portions of the facility would be in an area where simple overland flow probably would dominate runoff events. Design layouts of the proposed facility call for the construction of an interceptor trench along the upstream (north) side of the area, extending down either side; this would prevent runoff from entering the storage facility and could be an alteration to existing drainage. If flow in this short stretch of the upper Midway Valley Wash was intercepted, it would be diverted around the facility and then back to the existing course. Siting criteria for this proposed facility state that it will be outside the probable maximum flood zone (TRW 1999a, page I-8). Therefore, a probable maximum flood in this small wash will avoid the facility.

Potential for Flooding. The location for the Waste Retrieval and Storage Area would be outside the probable maximum flood zone, and the interceptor trench on the north side of the facility would accommodate the highest quantities of runoff that could reasonably be present. Therefore, there would be no reasonable potential for flooding to affect the storage facility.

4.2.1.2.3.2 Groundwater. The retrieval activities that could have impacts on groundwater would be the construction of the Waste Retrieval and Storage Area and the retrieval of the emplaced material.

Potential for Infiltration Rate Changes. Most of the disturbed land would be covered by facilities, roadways, queuing areas, and storage pads. These facilities would be relatively impermeable to water, and would cause an additional amount of runoff to drainage channels in comparison to natural conditions. This additional runoff could cause a net increase in the amount of water to infiltrate these natural channels. The additional infiltration would move into the unsaturated zone and represent potential recharge to the aquifer, but it would be a minor amount in comparison to natural infiltration.

Impacts to Groundwater Resources. The estimated annual groundwater demand during retrieval would peak at about 110,000 cubic meters (90 acre-feet) a year (TRW 1999a, page I-22; TRW 1999b, page 6-32). No adverse impacts would be likely from this demand, which would be well within historic use rates.

4.2.1.2.4 *Impacts to Biological Resources and Soils*

The retrieval activity that could affect biological resources and soils would be the construction of the Waste Retrieval and Storage Area.

4.2.1.2.4.1 Impacts to Biological Resources from Retrieval

Impacts to Vegetation. The construction of retrieval facilities would disturb vegetation in an area that is presently undisturbed. The predominant land cover types in Midway Valley are blackbrush and Mojave mixed scrub, both of which are extensively distributed regionally and in the State of Nevada.

Impacts to Wildlife. Impacts to wildlife from the retrieval contingency would be similar to those described for the construction and operation of the repository. They would consist of limited habitat loss and the deaths of individuals of some species as a result of construction activities and vehicle traffic, and would be in addition to those associated with repository construction and operation.

Impacts to Special Status Species. Impacts to special status species from the retrieval contingency would be similar, and in addition to, those described for repository construction. They would consist of loss of a small portion of locally available habitat for the desert tortoise and the deaths of individual tortoises due to construction activities and vehicle traffic.

Impacts to Wetlands. No wetlands would be affected by activities associated with retrieval.

4.2.1.2.4.2 Impacts to Soils from Retrieval. Concrete pads, facilities, and roadways at the Waste Retrieval and Storage Area would eventually cover most of the disturbed land, but a sizable portion would remain as disturbed soil.

Soil Loss. Erosion concerns during the construction of the retrieval facilities would be the same as those described for the construction of the repository facilities (see Section 4.1.4.4). The types of soils encountered would be similar to, if not the same as, those encountered during the construction at the North and South Portal Operations Areas. As during other project activities, DOE would use dust suppression measures to reduce the disturbed land's erodibility.

After the construction of the retrieval facilities, much of the area would no longer be exposed to erosion forces because structures would cover the soil. However, the uncovered disturbed areas would be more susceptible to erosion than the surrounding natural areas. This would be the case until the disturbed land had time to reach equilibrium, including the reestablishment of vegetation. Erosion, if it occurred, probably would involve small amounts of soil from small areas. The amount of soil that could move downwind or downgradient should not present unusual concerns.

Recovery. DOE would reclaim disturbed lands when they were no longer needed for retrieval operations.

4.2.1.2.5 *Impacts to Cultural Resources from Retrieval*

The activity that could affect cultural resources would be the construction of the Waste Retrieval and Storage Area. The following sections discuss archaeological and historic resources and Native American interests in relation to retrieval.

Archaeological and Historic Resources. The results of earlier archaeological fieldwork indicate that there are no National Register-eligible archaeological resources on land recommended for the Waste Retrieval and Storage Area or near the proposed rail or road construction. Therefore, construction activities associated with retrieval probably would not result in direct impacts to National Register-eligible archaeological resources. As during repository construction and operation, increased activities and numbers of workers could increase the potential for indirect impacts to archaeological sites near the construction work.

Native American Interests. A Waste Retrieval and Storage Area in Midway Valley would be 500 meters (1,600 feet) west of the Yucca Wash local use area and Alice Hill. As described in AIWS (1998, all), these areas have cultural importance to Native Americans. There could be some direct or indirect impacts to these areas, depending on the specific locations of Native American significance boundaries.

4.2.1.2.6 *Impacts to Socioeconomics from Retrieval*

Waste retrieval activities would increase the repository workforce above that for ongoing monitoring and maintenance activities. A maximum annual employment of about 1,600 workers (TRW 1999a, page I-22; TRW 1999b, page 6-32) would be required during retrieval operations and concurrent storage pad construction. Retrieval would be a short-term operation, lasting about 14 years. The repository workforce would decrease to a small maintenance staff after completion of retrieval. Employment during retrieval would be less than the peak during the operation and monitoring phase and, therefore, would be unlikely to generate meaningful changes to the region of influence labor force or economic measures. Regional impacts from retrieval operations would probably be small.

4.2.1.2.7 *Occupational and Public Health and Safety Impacts from Retrieval*

The analysis of health and safety impacts to workers divided the retrieval period into two subperiods, as follows:

- A construction subperiod during which DOE would build (1) the surface facilities necessary to handle retrieved waste packages and enclose them in concrete storage units in preparation for their placement on concrete storage pads, and (2) the concrete storage pads (see Section 4.2.1.1). No radioactive materials would be involved in the construction subperiod, so health and safety impacts would be limited to those associated with industrial hazards in the workplace. DOE expects this subperiod to last from 2 to 3 years, although construction of the concrete storage pads probably would continue as needed during most of the operations subperiod. No health and safety impacts to the public would be likely during the initial 2- to 3-year construction subperiod.

- An operations subperiod during which DOE would retrieve the waste packages and move them to the Waste Retrieval Transfer Building. Surface facility workers would unload the waste package from the transfer vehicle and place it on a concrete base. The waste package would be enclosed in a concrete storage unit that, with the waste package inside, would be placed on the concrete storage pad. This subperiod would last about 11 years. The analysis estimated the health and safety impacts from both industrial hazards and from radiological hazards for the operations subperiod for both surface and subsurface workers. Radiological impacts to the public could occur during the operations subperiod when radon-222 and its decay products would be released to the environment in the exhaust stream from the subsurface ventilation system.

The methods used to estimate health and safety impacts to workers and the public were the same as those used to estimate such impacts for the Proposed Action (see Appendix F, Section F.2.1). Additional information pertinent to health and safety impact analysis for retrieval is contained in Appendix F, Section F.4. Section F.4.3 contains detailed information on health and safety impacts which supports the impact summary tables in this section.

Construction Subperiod

As noted above, the only health and safety impacts for this subperiod would be those from industrial hazards during normal workplace activities.

Table 4-54 summarizes these impacts. Projected fatality would be about 0.05 and projected lost workday cases would be about 40.

Table 4-54. Industrial hazards health and safety impacts for surface facility workers for retrieval construction subperiod.[a]

Worker group and impact category	Impact
Involved workers	
Total recordable cases	69
Lost workdays	33
Fatalities	0.03
Noninvolved workers	
Total recordable cases	14
Lost workdays	7
Fatalities	0.01
All workers (totals)	
Total recordable cases	83
Lost workdays	40
Fatalities	0.04

a. Sources: Impact rates from Table F-46 and full-time equivalent work years from Table F-45.

Operations Subperiod

Industrial Hazard Impacts to Workers.
Table 4-55 lists estimated impacts from industrial hazards for both surface and subsurface workers for the operations subperiod. Because the impact estimates would not vary greatly with the thermal load scenario, the table lists only one set of impact values (for the low thermal load). Impacts would be small and about twice those for the construction subperiod.

Table 4-55. Industrial hazards health and safety impacts for retrieval operations subperiod.[a]

Worker group and impact category	Impact
Involved workers	
Total recordable cases	35
Lost workday cases	15
Fatalities	0.03
Noninvolved workers	
Total recordable cases	35
Lost workday cases	17
Fatalities	0.04
All workers (totals)	
Total recordable cases	70
Lost workday cases	32
Fatalities	0.07

a. Sources: Tables F-48 and F-49.

Radiological Health Impacts to Workers.
Table 4-56 lists radiological health impacts for both surface and subsurface workers for the retrieval contingency as well as the total radiological impact. Appendix F contains additional details on the radiological exposure components for the subsurface worker exposure. Impacts would be small, with the latent cancer fatality likelihood for the maximally exposed individual being about 0.003. The calculated latent cancer fatality incidence to workers for retrieval would be 0.19.

Radiological Health Impacts to the Public. See Table 4-53 for estimated radiological impacts to the public from releases of radon-222 and its decay products through the subsurface ventilation system exhaust.

Table 4-57 lists estimated radiological health impacts to the public over the operations subperiod. The calculated radiological health impacts to members of the public from a retrieval operation would be small. The calculated likelihood of a latent cancer fatality for the maximally exposed individual would be about 2.8×10^{-6}. The calculated latent cancer fatality incidence would be about 0.014.

Table 4-56. Radiological health impacts from retrieval operations.[a,b]

Worker group and impact category	Surface facility workers	Subsurface facility workers	Total/High
Involved workers			
Maximally exposed individual dose[c]	4,400	6,950	6,950[d]
Latent cancer fatality probability	0.002	0.003	0.003[d]
Collective dose (person-rem)	75	380	455
Latent cancer fatality incidence	0.03	0.15	0.18
Noninvolved workers			
Maximally exposed individual dose	280	1,290	1,370[d]
Latent cancer fatality probability	0.0001	0.0005	0.0005[d]
Collective dose (person-rem)	6	22	28
Latent cancer fatality incidence	0.002	0.009	0.01
All workers (totals)[e]			
Collective dose (person-rem)	81	400	480
Latent cancer fatality incidence	0.03	0.16	0.19

a. Sources: Appendix F, Tables F-51 and F-52.
b. There would be no radiological health impacts to the public during the construction subperiod.
c. For 11-year period of operation (millirem).
d. Values are not totals, but the largest of the compounds.
e. Totals might differ from sums of values due to rounding.

Table 4-57. Radiological health impacts to the public for retrieval operations period.[a,b]

Worker group and impact category	Impact
Individual	
Maximally exposed individual (millirem)	5.5
Latent cancer fatality probability	2.8×10^{-6}
Population	
Collective dose (person-rem)	28
Latent cancer fatality incidence	0.014

a. Source: Table 4-49.
b. There would be no radiological health impacts to the public during the construction subperiod.

Radiological Health Impacts to the Public. The potential for exposure of members of the public to radiological materials released as a result of retrieval operations would exist only during the operations subperiod. These impacts are summarized in Table 4-57. The predicted incidence of latent cancer fatality would be about 0.1.

4.2.1.2.8 *Impacts from Accidents During Retrieval*

During retrieval operations, activities at the repository would be essentially the reverse of waste package emplacement, except operations in the Waste Handling Building would not be necessary because the waste packages would not be opened.

Summary of Impacts

Industrial Health and Safety Impacts to Workers for Retrieval. Table 4-58 summarizes the industrial health and safety impacts to workers from the retrieval construction and operations subperiods. Estimated fatalities would be low, about 0.1, with about 72 lost workday cases.

Radiological Impacts to Workers. Radiological impacts to workers from retrieval would occur primarily during the operations subperiod, as summarized in Table 4-56.

Table 4-58. Overall industrial hazards health and safety impacts for retrieval.[a]

Worker group and impact category	Impact
Involved workers	
Total recordable cases	100
Lost workday cases	48
Fatalities	0.07
Noninvolved workers	
Total recordable cases	48
Lost workday cases	24
Fatalities	0.04
All workers (totals)	
Total recordable cases	150
Lost workday cases	72
Fatalities	0.11

a. Sources: Tables 4-58 and 4-59

The handling accident scenario applicable for these operations would be bounded by the transporter runaway accident scenario evaluated in Section 4.1.8. The waste packages would be retrieved remotely from the emplacement drifts, transported to the surface, and transferred to a Waste Retrieval and Storage Area (DOE 1997m, all). This area would include a Waste Retrieval Transfer Building where the waste packages would be unloaded from the transporter, transferred to a vertical concrete storage unit, and moved to a concrete storage pad.

Because the retrieval operations would be essentially the same as the emplacement operations (in reverse), the accident scenarios involving the waste package during operations would bound the retrieval operation. The bounding accident scenario during emplacement would be a transporter runaway and derailment accident in a main drift (see Appendix H, Section H.2.1.4). For above-ground storage accidents, the accident analysis for the continued storage analysis would apply. Recent analyses have found that the only credible accident with meaningful consequences would be an aircraft crash into one of the above-ground storage facilities. However, the aircraft penetration potential would not be sufficient to breach the thickness of the waste package (Davis 1998, all).

The analysis assumed that above-ground storage following retrieval would be licensed in compliance with Nuclear Regulatory Commission requirements (10 CFR Part 72). These requirements specify that storage modules must be able to withstand credible accident-initiating events.

4.2.1.2.9 *Aesthetic Impacts from Retrieval*

Retrieval activities would not be likely to produce adverse impacts on the visual quality of the landscape surrounding Yucca Mountain. Retrieval would essentially be the reverse of emplacement and would use the same types of equipment. Impacts from emplacement would be small. The only difference from the emplacement activities would be the construction of a Waste Retrieval and Storage Area in Midway Valley north of the North Portal Operations Area with a connecting transportation corridor. These activities would occur in the repository area and in Class C scenic quality lands away from the public view and, therefore, would have no impact on the existing visual character of the landscape.

4.2.1.2.10 *Noise Impacts from Retrieval*

The analysis in Section 4.1.9 shows that there would be no appreciable noise impacts for the construction, operation and monitoring, and closure phases of repository operations. Noise impacts associated with retrieval would be less than those associated with repository operations because of the reduced scope of activities and the smaller number of workers required. Worker traffic noise levels would also be less because fewer workers would commute to the site. Thus, noise impacts from retrieval operations would be small.

4.2.1.2.11 *Impacts to Utilities, Energy, Materials, and Site Services from Retrieval*

The following sections discuss utility, energy, materials, and site service impacts.

Utilities and Energy. The estimated electric power demand for retrieval would be less than 10 megawatts. This demand would be well within the capacity that would be available at the repository.

The fossil-fuel use estimated for retrieval activities would approach 25 million liters (6.6 million gallons). This consumption level is less than 0.1 percent of the annual consumption in the State of Nevada.

Materials. For the Waste Retrieval and Storage Area, DOE would build a concrete pad and retrieval support facilities. Construction would require about 540,000 cubic meters (410,000 cubic yards) of concrete and 42,000 metric tons (46,000 tons) of steel, which would not affect the regional supply capacity. About 10,000 concrete storage modules would be required. The concrete would be obtained from offsite sources or the onsite batch plant would be used. The storage modules would be relatively simple concrete vessels with a 0.64-centimeter (0.25-inch) steel liner. About 110,000 cubic meters (140,000 cubic yards) of concrete would be required to build 10,000 modules, which probably would be manufactured commercially. Material usage impacts would be small. The impacts of shipping about 10,000 concrete storage modules to the site would be comparable to those for shipping about 10,000 storage containers to the site (see Section 6.2.5).

Site Services. The onsite emergency response capability and the security, medical, and fire protection units that would support operations would be available to support retrieval, so no additional impacts would be likely.

Table 4-59 summarizes impacts to utilities, energy, and materials.

Table 4-59. Utilities, energy, and materials for retrieval.[a,b,c]

	Electric		Fossil fuel	Construction materials	
Location	Peak (MW)[d,e]	Use (1,000 MWh)[f]	Liquid fuels (million liters)[g]	Concrete (1,000 cubic meters)[h]	Steel (1,000 metric tons)[i]
Surface	1.2	82	20	540	42
Subsurface	7.7	270 - 520	2.5	0	0
Totals	**8.9**	**350 - 600**	**22.5**	**540**	**42**

a. Sources: TRW (1999a, pages I-22 to I-24); TRW (1999b, page 6-35).
b. All entries except peak electric power are cumulative totals for the entire period.
c. Approximate retrieval period would be 11 years.
d. Peak electric power is the peak demand that would occur during the period.
e. MW = megawatts.
f. MWh = megawatt-hours.
g. To convert liters to gallons, multiply by 0.26418.
h. To convert cubic meters to cubic yards, multiply by 1.3079.
i. To convert metric tons to tons, multiply by 1.1023.

4.2.1.2.12 *Impacts to Waste Management from Retrieval*

The construction of the Waste Retrieval and Storage Area would generate an estimated 12,000 cubic meters (420,000 cubic feet) of construction debris, 2,400 cubic meters (85,000 cubic feet) of sanitary and industrial solid waste, and 450 cubic meters (16,000 cubic feet) of hazardous waste (TRW 1999a, page I-22). Based on operations generation rates (TRW 1999a, page 76; TRW 1999b, page 6-34), the retrieval of the storage containers would generate an estimated 5,100 cubic meters (180,000 cubic feet) of sanitary and industrial solid waste. Throughout the construction of the retrieval facilities and retrieval operations, the workforce would generate sanitary sewage. After the spent nuclear fuel and high-level radioactive waste were placed in the concrete storage modules and on the concrete storage pads, waste generation would continue due to the presence of a workforce. Surveillance and monitoring activities would generate sanitary and industrial solid and low-level radioactive waste.

Construction debris and sanitary and industrial solid waste would be disposed of at onsite facilities or at the Nevada Test Site. Sanitary sewage would be disposed of at onsite facilities. Low-level radioactive waste would be disposed of at the Nevada Test Site or another government or commercial facility in accordance with applicable Federal and state requirements. Hazardous waste would be shipped off the site for treatment and disposal at a permitted commercial facility. The National Capacity Assessment

Report (EPA 1996b, pages 32, 33, 36, 46, 47, and 50) shows that the available capacity for hazardous waste treatment and disposal in the western states would far exceed the demand for many years to come. Therefore, hazardous waste possibly generated during retrieval activities would have a very small impact on the capacity for treatment and disposal at commercial facilities.

4.2.1.2.13 *Impacts to Environmental Justice from Retrieval*

Workers at the Yucca Mountain site would be representative of the population mix in the surrounding areas of Nevada. Hence, there would be no disproportionate impacts to minority or low-income populations in the Yucca Mountain region or to the workers during retrieval operations. In addition, because disproportionate impacts to minority or low-income populations from repository construction and operation would be unlikely, none would be likely from retrieval.

4.2.2 IMPACTS FROM RECEIPT PRIOR TO THE START OF EMPLACEMENT

Repository operations would begin after DOE received a license from the Nuclear Regulatory Commission to receive and possess spent nuclear fuel and high-level radioactive waste. For this EIS, DOE assumed that the receipt and emplacement of spent nuclear fuel and high-level radioactive waste would begin in 2010 and that emplacement would occur over a 24-year period ending in 2033 (70,000 MTHM at approximately 3,000 MTHM per year). The EIS considers the potential for the transport of spent nuclear fuel or high-level radioactive waste to the Yucca Mountain site several years before the waste was actually emplaced in the repository. DOE recognizes that regulatory changes would have to occur for the receipt of spent nuclear fuel and high-level radioactive waste before the start of emplacement, and would have to build a facility similar to that described as part of the retrieval contingency (Section 4.2.1.1) for the receipt of these materials pending their emplacement.

Such a facility would consist of a series of concrete pads in the Midway Valley Wash area (the same area described for the retrieval contingency). The facility would be capable of storing as much as 10,000 MTHM of spent nuclear fuel and high-level radioactive waste in concrete storage modules.

The types of impacts resulting from the construction and operation of a Waste Staging Facility would be similar to those from the implementation of a retrieval contingency, described in Section 4.2.1. The impacts would include land disturbance, emission of particulate and gaseous pollutants, and radiation doses from the handling of spent nuclear fuel and high-level radioactive waste. However, because the amounts of these materials would be smaller than those analyzed for the retrieval contingency, the overall impacts from the Waste Staging Facility would be smaller than those described in Section 4.2.1.