Final

Supplemental Environmental Impact Statement

for a

Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada

Summary

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

DOE/EIS-0250F-S1

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TITLE: *Final Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F-S1) (Repository SEIS).

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ABSTRACT: DOE's Proposed Action is to construct, operate, monitor, and eventually close a geologic repository at Yucca Mountain for the disposal of spent nuclear fuel and high-level radioactive waste. Under the Proposed Action, spent nuclear fuel and high-level radioactive waste in storage or projected to be generated at 72 commercial and 4 DOE sites would be shipped to the repository by rail (train), although some shipments would arrive at the repository by truck. The Repository SEIS evaluates (1) the potential environmental impacts from the construction, operations, monitoring, and eventual closure of the repository; (2) potential long-term impacts from the disposal of spent nuclear fuel and high-level radioactive waste; (3) potential impacts of transporting these materials nationally and in the State of Nevada; and (4) potential impacts of not proceeding with the Proposed Action (the No-Action Alternative).

COOPERATING AGENCIES: Nye County, Nevada is a cooperating agency in the preparation of the Repository SEIS.

PUBLIC COMMENTS: In preparing this Repository SEIS, DOE considered written comments received by letter, electronic mail, and facsimile transmission, and oral and written comments given at public hearings at six locations in Nevada, one location in California, and in Washington, DC.

FOREWORD

The U.S. Department of Energy (DOE or Department) has prepared three analyses under the National Environmental Policy Act (NEPA) associated with the proposed disposal of spent nuclear fuel and high-level radioactive waste in a geologic repository at the Yucca Mountain Site in Nye County, Nevada. The first analysis, the Final Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada (DOE/EIS-0250F-S1) (Repository SEIS), evaluates the potential environmental impacts of constructing and operating the Yucca Mountain repository under the proposed repository design and operational plans. It supplements the *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE/EIS-0250F) (Yucca Mountain FEIS) prepared by the Department in 2002.

The second and third analyses are set forth in the Final Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada – Nevada Rail Transportation Corridor (DOE/EIS-0250F-S2) (Nevada Rail Corridor SEIS) , and the Final Environmental Impact Statement for a Rail Alignment for the Construction and Operation of a Railroad in Nevada to a Geologic Repository at Yucca Mountain, Nye County, Nevada (DOE/EIS-0369) (Rail Alignment EIS). These analyses evaluate the potential environmental impacts of constructing and operating a railroad for shipments of spent nuclear fuel and high-level radioactive waste from an existing rail line in Nevada to the repository at Yucca Mountain, in order to help the Department decide whether to construct and operate a railroad, and if so, within which corridor and along which alignment. Because both the Nevada Rail Corridor SEIS and the Rail Alignment EIS address potential environmental impacts associated with the proposed construction and operation of a railroad, they are bound together in one document for the convenience of the reader.

Background and Context

The Nuclear Waste Policy Act, as amended (NWPA, 42 U.S.C. 10101 *et seq.)* directs the Secretary of Energy, if the Secretary decides to recommend approval of the Yucca Mountain site for development of a repository, to submit a final EIS with any recommendation to the President. To fulfill that requirement, the Department prepared the Yucca Mountain FEIS.

On February 14, 2002, the Secretary transmitted to the President the Secretary's recommendation (including the Yucca Mountain FEIS) for approval of the Yucca Mountain site for development of a geologic repository. The President considered the site qualified for application to the NRC for construction authorization and recommended the site to the U.S. Congress. Subsequently, Congress passed a joint resolution of the U.S. House of Representatives and the U.S. Senate designating the Yucca Mountain site for development as a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste. On July 23, 2002, the President signed the joint resolution into law (Public Law 107-200). As required by the NWPA [Section 114(b)], the Department has submitted an application to the NRC seeking authorization to construct the repository

Since completion of the Yucca Mountain FEIS in 2002, DOE has continued to develop the repository design and associated construction and operational plans. As now designed, the surface and subsurface facilities would allow DOE to operate the repository following a primarily canistered approach in which

most commercial spent nuclear fuel would be packaged at the reactor sites in transportation, aging, and disposal (TAD) canisters. Any commercial spent nuclear fuel arriving at the repository in packages other than TAD canisters would be repackaged by DOE at the repository into TAD canisters. DOE would construct the surface and subsurface facilities over a period of several years (referred to as phased construction) to accommodate an increase in spent nuclear fuel and high-level radioactive waste receipt rates as repository operational capability reaches its design capacity.

To address the modifications to repository design and operational plans, the Department announced its intent to prepare a Supplement to the Yucca Mountain FEIS, consistent with NEPA and the NWPA (Notice of Intent to prepare *Supplement to the Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, NV*; 71 FR 60490, October 13, 2006). The Repository SEIS supplements the Yucca Mountain FEIS by considering the potential environmental impacts of the construction, operation and closure of the repository under the modified repository design and operational plans, and by updating the analysis and potential environmental impacts of transporting spent nuclear fuel and high-level radioactive waste to the repository, consistent with transportation-related decisions the Department made following completion of the Yucca Mountain FEIS.

On April 8, 2004, the Department issued a Record of Decision announcing its selection, both nationally and in the State of Nevada, of the mostly rail scenario analyzed in the Yucca Mountain FEIS as the primary means of transporting spent nuclear fuel and high-level radioactive waste to the repository (*Record of Decision on Mode of Transportation and Nevada Rail Corridor for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, NV*; 69 FR 18557, April 8, 2004). Implementation of the mostly rail scenario ultimately would require the construction of a rail line to connect the repository site at Yucca Mountain to an existing rail line in the State of Nevada. To that end, in the same Record of Decision, the Department also selected the Caliente rail corridor from several corridors considered in the Yucca Mountain FEIS as the corridor in which to study possible alignments for a rail line. On the same day DOE selected the Caliente corridor, it issued a Notice of Intent to prepare an EIS under NEPA to study alternative alignments within the Caliente corridor (the Rail Alignment EIS; DOE/EIS-0369) (*Notice of Intent to Prepare an Environmental Impact Statement for the Alignment, Construction, and Operation of a Rail Line to a Geologic Repository at Yucca Mountain, Nye County, NV*; 69 FR 18565, April 8, 2004).

During the subsequent public scoping process, DOE received comments suggesting that other rail corridors be considered, in particular, the Mina route. In the Yucca Mountain FEIS, DOE had considered but eliminated the Mina route from detailed study because a rail line within the Mina route could only connect to an existing rail line in Nevada by crossing the Walker River Paiute Reservation, and the Tribe had informed DOE that it would not allow nuclear waste to be transported across the Reservation.

Following review of the scoping comments, DOE held discussions with the Walker River Paiute Tribe and, in May 2006, the Tribal Council informed DOE that it would allow the Department to consider the potential impacts of transporting spent nuclear fuel and high-level radioactive waste across its reservation. On October 13, 2006, after a preliminary evaluation of the feasibility of the Mina rail corridor, DOE announced its intent to expand the scope of the Rail Alignment EIS to include the Mina corridor (*Amended Notice of Intent to Expand the Scope of the Environmental Impact Statement for the Alignment, Construction, and Operation of a Rail Line to a Geologic Repository at Yucca Mountain, Nye County, NV*; 71 *FR* 60484). Although the expanded NEPA analyses, referred to as the Nevada Rail Corridor SEIS

and Rail Alignment EIS, evaluate the potential environmental impacts associated with the Mina corridor, DOE has identified the Mina alternative as non-preferred because the Tribe has withdrawn its support for the EIS process.

Relationships Among the EISs

Although the Yucca Mountain FEIS, the Repository SEIS and the Nevada Rail Corridor SEIS and Rail Alignment EIS are all related to the proposal to construct and operate the Yucca Mountain repository, they consider actions involving the jurisdiction of more than one federal agency. The Repository SEIS supplements the Yucca Mountain FEIS and considers the potential environmental impacts associated with the construction and operation of the Yucca Mountain repository. The responsibility for issuing construction authorization and a license to receive and possess radioactive materials at the repository rests with the Nuclear Regulatory Commission (NRC). Should the NRC authorize development of the repository, DOE would be the federal agency responsible for constructing and operating the repository.

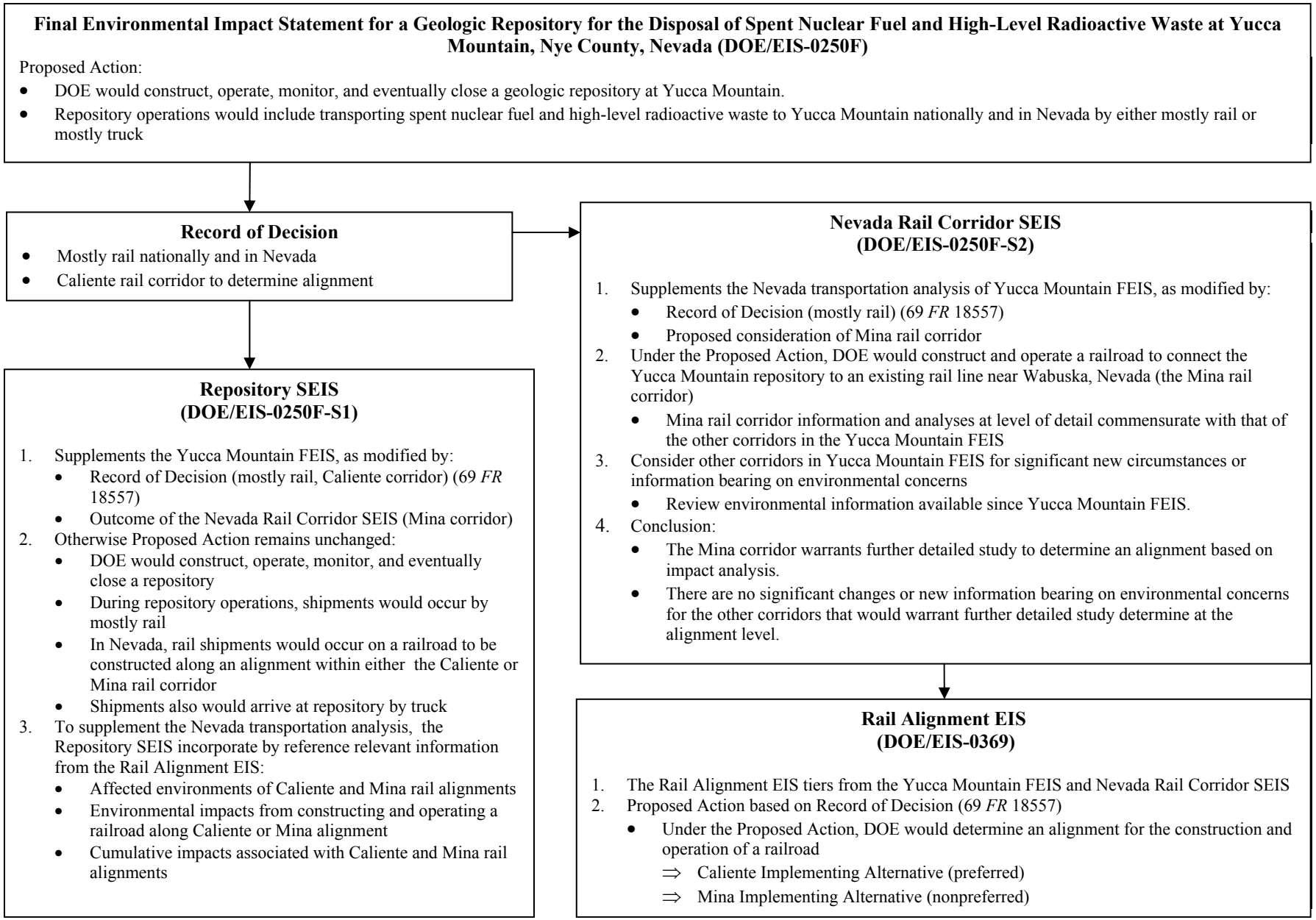
The Nevada Rail Corridor SEIS, which supplements the rail corridor analysis in the Yucca Mountain FEIS, analyzes the potential environmental impacts associated with constructing and operating a railroad within the Mina corridor. The Nevada Rail Corridor SEIS analyzes the Mina corridor at a level of detail commensurate with that of the rail corridor analysis in the Yucca Mountain FEIS, and concludes that the Mina corridor warrants further study in the Rail Alignment EIS to identify an alignment for the construction and operation of a railroad.

The Nevada Rail Corridor SEIS also updates relevant information regarding three other rail corridors previously analyzed in the Yucca Mountain FEIS (Carlin, Jean, and Valley Modified). The update demonstrates that there are no significant new circumstances or information relevant to environmental concerns associated with these three rail corridors, and that they do not warrant further consideration in the Rail Alignment EIS. The Caliente-Chalk Mountain rail corridor, which also was included in the Yucca Mountain FEIS, would intersect the Nevada Test and Training Range, and was eliminated from further consideration because of U.S. Air Force concerns that a rail line within the Caliente-Chalk Mountain corridor would interfere with military readiness testing and training activities.

The Rail Alignment EIS tiers from the broader corridor analysis in both the Yucca Mountain FEIS and the Nevada Rail Corridor SEIS, consistent with the Council on Environmental Quality regulations (see 40 CFR 1508.28). Under the Proposed Action considered in the Rail Alignment EIS, DOE analyzes specific potential impacts of constructing and operating a rail line along common segments and alternative segments within the Caliente and Mina corridors for the purpose of determining an alignment in which to construct and operate a railroad for shipments of spent nuclear fuel and high-level radioactive waste from an existing rail line in Nevada to a geologic repository at Yucca Mountain. If DOE were to decide that a railroad should be constructed, it would be the federal agency charged with responsibility for carrying out the actions necessary to construct and operate the railroad.

The Repository SEIS includes the potential environmental impacts of national transportation, as well as the potential impacts in Nevada from the construction and operation of a rail line along specific alignments in either the Caliente or the Mina corridor, to ensure that the Repository SEIS considers the full scope of potential environmental impacts associated with the proposed construction and operation of the repository. Accordingly, the Repository SEIS incorporates by reference appropriate portions of the Nevada Rail Corridor SEIS and the Rail Alignment EIS. To ensure consistency, the Repository SEIS,

and the Nevada Rail Corridor SEIS and Rail Alignment EIS use the same updated inventory of spent nuclear fuel and high-level radioactive waste and the same number of rail shipments for analysis. Thus, the associated occupational and public health and safety impacts within the Nevada rail corridors under consideration are the same in the Repository SEIS, and in the Nevada Rail Corridor SEIS and Rail Alignment EIS. Furthermore, to promote conformity, consistent analytical approaches were used where appropriate to evaluate common resource areas.



Foreword Figure 1. Relationship among the Repository SEIS, and the Nevada Rail Corridor SEIS and Rail Alignment EIS.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SUMMARY

S.1 Purpose and Need for Agency Action

S.1.1 WHY THE YUCCA MOUNTAIN REPOSITORY IS NEEDED

For many years, civilian and defense-related activities have produced spent nuclear fuel and high-level radioactive waste. These materials have accumulated—and continue to accumulate—at 72 commercial and 4 U.S. Department of Energy (DOE or the Department) sites across the United States. Figure S-1 shows the locations of these sites. Because these materials are highly radioactive, they must be isolated from the accessible environment. More than 25 years ago, in the *Nuclear Waste Policy Act of 1982* (the Act), Congress adopted the overwhelming consensus view in the scientific community that the best option for permanently isolating these materials would be disposing of them in a deep underground repository.

The Act established an open, science-based, and orderly process for the identification, characterization, and approval of a site for a permanent geologic repository, and for its licensing by the U.S. Nuclear Regulatory Commission (NRC). The Act assigned lead responsibility to the Secretary of Energy. After DOE considered nine sites and recommended three for detailed evaluation, Congress amended the Act in 1987 to select Yucca Mountain as the single site for further study, and it directed the Secretary to determine whether to recommend that the President approve the Yucca Mountain site for development of a repository. (The amended Act is referred to as the NWPA.)

The Secretary's February 2002 recommendation that the President approve the site followed more than two decades of scientific investigations. As required by the NWPA, the Secretary submitted the *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (Yucca Mountain FEIS) with his recommendation.

On July 23, 2002, the President signed into law a joint congressional resolution designating the Yucca Mountain site for development as a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste. This action concluded the site selection process stipulated by the NWPA. As required by the NWPA, the Department has submitted an application seeking NRC authorization to construct a repository.

S.1.2 BACKGROUND

The Proposed Action defined in the Yucca Mountain FEIS is to construct, operate, monitor, and eventually close a geologic repository at Yucca Mountain to dispose of spent nuclear fuel and high-level radioactive waste. The Proposed Action includes transportation of these materials from commercial and DOE sites to the repository.

In the Yucca Mountain FEIS, DOE considered the potential environmental impacts of a repository design for surface and subsurface facilities, a range of canister packaging scenarios and repository thermal operating modes, and plans for the construction, operations, monitoring, and eventual closure of the repository. The FEIS also described and evaluated the transportation of spent nuclear fuel and high-level radioactive waste from commercial and DOE sites to the repository by two principal modes—mostly truck and mostly rail. Since completion of the Yucca Mountain FEIS in 2002, the repository design

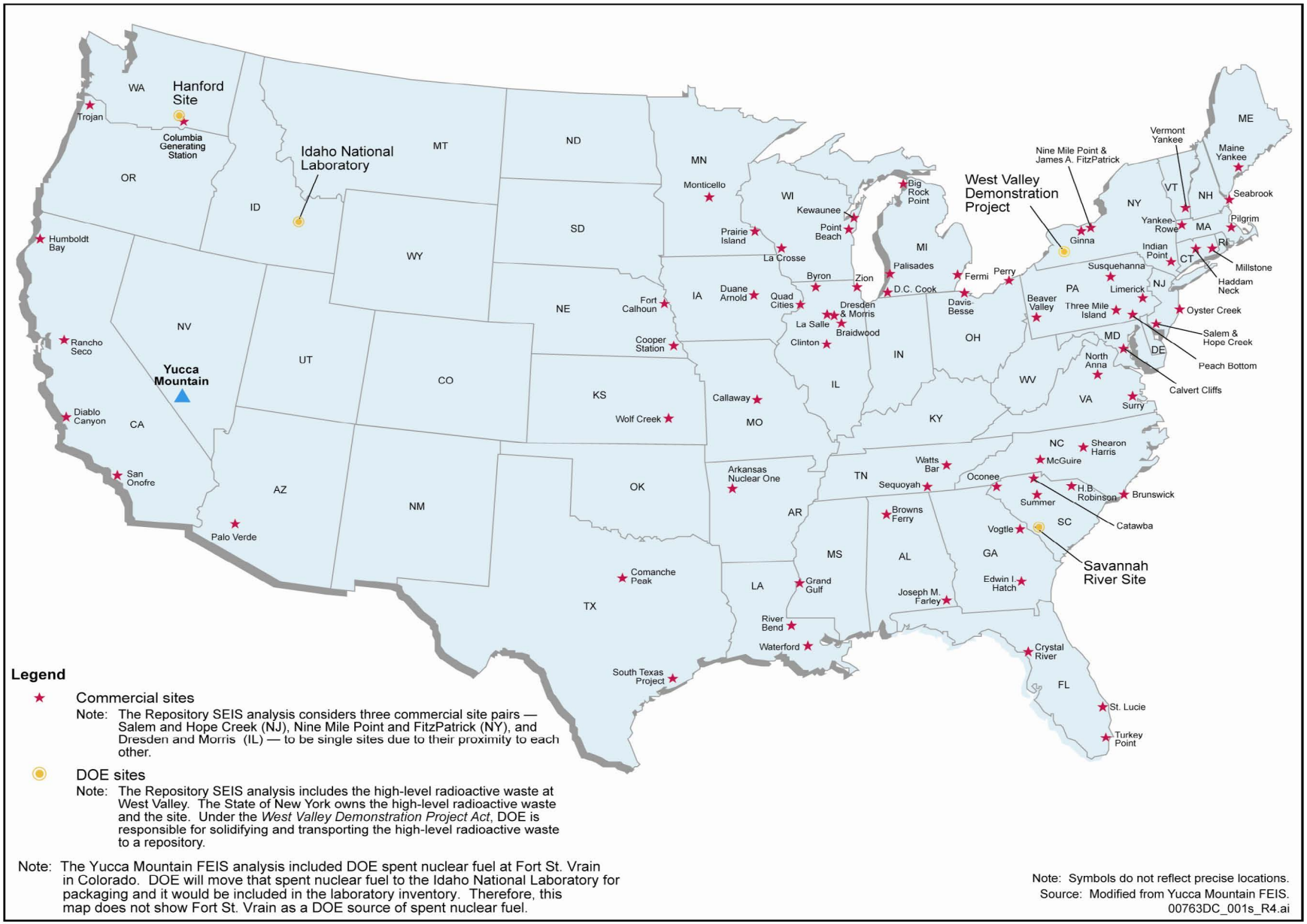


Figure S-1. Commercial and DOE sites from which DOE would ship radioactive materials to Yucca Mountain.

and associated construction and operational plans have continued to evolve, and additional information and updated analytic tools relevant to estimating potential environmental impacts have become available.

The repository design and associated plans considered in this *Final Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (Repository SEIS) include the construction of up to eight waste handling facilities over a period of several years, whereas in the Yucca Mountain FEIS DOE envisioned constructing a single waste handling building and associated facilities at the same time. The repository considered in this Repository SEIS would be operated following a primarily canistered approach in which most spent nuclear fuel and high-level radioactive waste would be packaged at the reactor and DOE sites in canisters suitable for transport to, and aging and disposal at, the repository. DOE also has announced its decision to ship most materials to the repository by rail, both nationally and in Nevada (more details can be found in Section S.2). The details of the infrastructure required for construction and operations (access road, power lines, and support facilities) have matured since the FEIS was issued, providing the basis for a further analysis of the potential impacts of implementing the proposed infrastructure activities.

DOE used these design and operational plans to develop information and data necessary to estimate potential environmental impacts of implementation of the Proposed Action in this Repository SEIS. The Department has developed new estimates of land disturbance, water demand, workforce requirements, equipment emissions, materials (concrete, steel, copper) required, and quantities of each waste type generated (solid waste, sanitary waste) and uses them in the analyses described herein. Potential health and safety impacts have been reanalyzed using population projections to 2067 (as opposed to 2035 in the Yucca Mountain FEIS).

DOE also has revised the inventory of spent nuclear fuel and high-level radioactive waste to reflect the primarily canistered approach, as well as the capabilities of the commercial sites to handle truck or rail casks. A more recent model, the Total System Model, was used to evaluate these data rather than the model used in the Yucca Mountain FEIS (CALVIN). The revised inventory is reflected in the number of shipments, by truck and train, to the repository, and in the potential radiological and nonradiological impacts to workers and the public from such shipments, and from materials handling and disposal at the repository.

As part of the reanalysis of the environmental impacts throughout this Repository SEIS, the Department updated many of the analytic tools or selected new tools to estimate potential impacts. Representative rail and truck routes and the size of the population affected by these routes were determined, in part, through use of WebTRAGIS, which has been updated since 2002 (other changes relevant to transportation are discussed in Sections S.2 and S.3.3).

Potential radiological impacts to workers and the public from atmospheric releases during normal operations are now based, in part, on CAP-88 rather than GENII. DOE now uses a computer model endorsed by the U.S. Environmental Protection Agency (EPA), AERMOD, rather than ISC-3 to estimate nonradiological air quality impacts to workers and the public.

DOE estimated potential postclosure radiological impacts using the same Total System Performance Assessment (TSPA-LA) model for both the Repository SEIS and the application DOE has submitted to the NRC seeking construction authorization. The TSPA-LA comprises a series of updated computational

models that represent the inventory, and natural and engineered barriers and their interactions to produce an estimate of a radiological dose to an individual (more details on the changes in the evaluation of postclosure performance are discussed in Section S.3.2).

This Repository SEIS also contains new analyses and updated information that result from comments received during the SEIS public scoping process. For example, DOE has included an evaluation of the potential environmental impacts that would result if (1) a higher percentage of the workforce would reside in Nye County than DOE had assumed in the Yucca Mountain FEIS, and (2) the repository received a lower percentage of commercial spent nuclear fuel in transportation, aging, and disposal canisters than the percentage DOE had used as a planning basis.

DOE is issuing this Final Repository SEIS after considering the comments it received during the public comment period on the Draft Repository SEIS. The Final SEIS includes (1) information necessary to respond to public comments, (2) updated information consistent with the application for a construction authorization, (3) DOE-identified improvements to clarify or better explain information from the Draft Repository SEIS, and (4) information on developments in other DOE Programs.

S.1.3 COOPERATING AGENCY

Council on Environmental Quality regulations encourage agency cooperation early in the *National Environmental Policy Act* (NEPA) process and allow a lead agency to seek assistance from agencies that possess special expertise about issues considered in an EIS.

The Yucca Mountain site is in Nye County, Nevada. County personnel have special expertise on the relationship of DOE's Proposed Action to the objectives of regional and local land use plans, policies, and controls, and to the County's current and planned infrastructure, including public services and traffic conditions.

Council on Environmental Quality regulations and guidance provide that agencies that accept the purpose of and need for agency action and the scope, definition, description, and analysis of such can participate as cooperating agencies in the development of the EIS. DOE invited Nye County to participate as a cooperating agency in the development of this Repository SEIS, and county personnel have contributed to it. This participation is consistent with the stated county policy of constructive engagement with DOE and with the objectives of the County's Community Protection Plan.

S.1.4 THE YUCCA MOUNTAIN SITE

The Yucca Mountain site is in a remote area of the Mojave Desert in Nye County in southern Nevada, about 145 kilometers (90 miles) northwest of Las Vegas, Nevada (Figure S-2). DOE would build a repository inside Yucca Mountain that would consist primarily of an underground network of horizontal tunnels, called emplacement drifts. The drifts would total about 68 kilometers (42 miles) in length and would be able to accommodate about 11,000 waste packages containing spent nuclear fuel and high-level radioactive waste. DOE would rely on the natural features of the site and on engineered barriers as a total system to help ensure the long-term isolation of the materials from the accessible environment (Figure S-3).

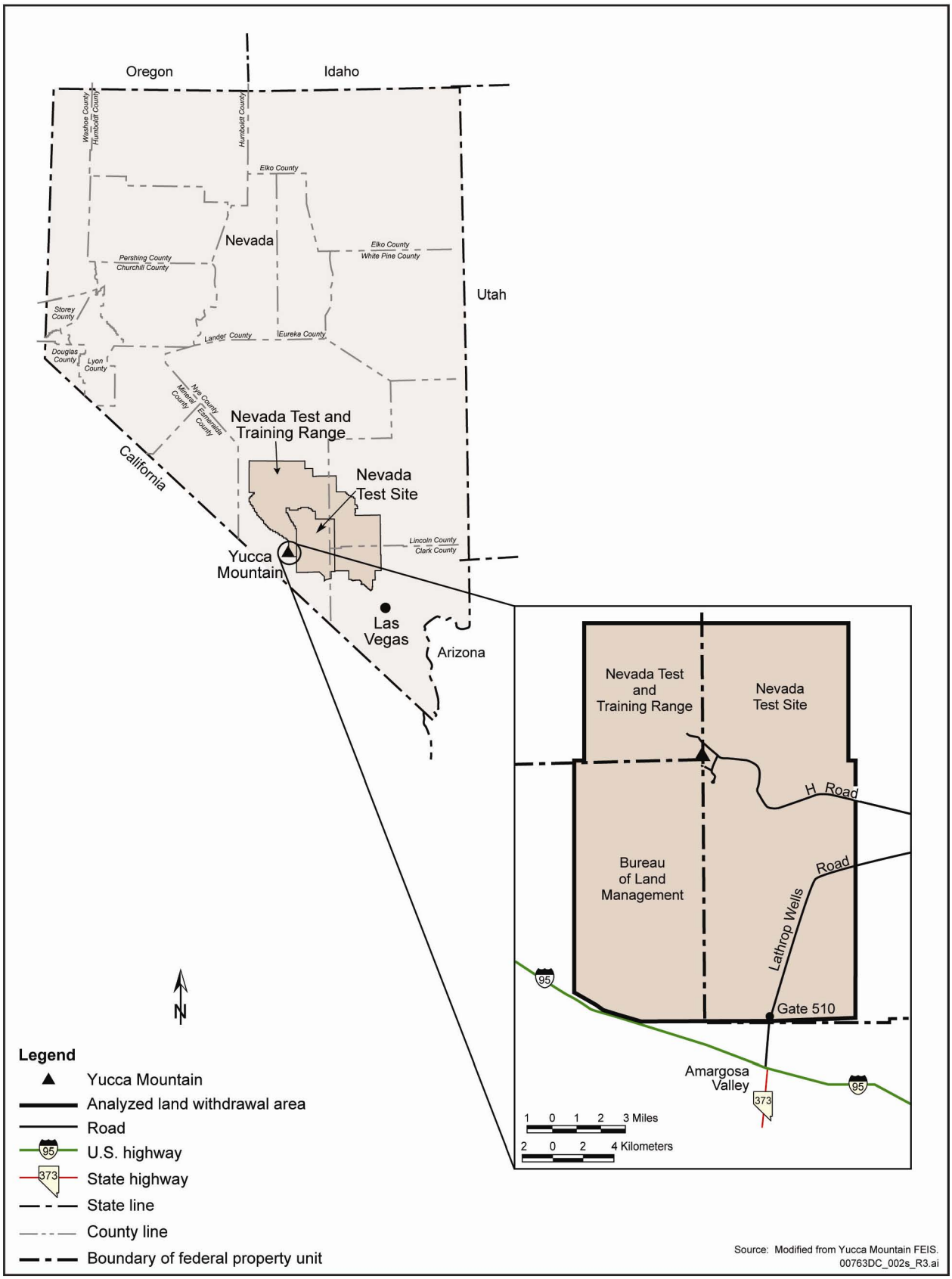


Figure S-2. Land withdrawal area used for analytical purposes.

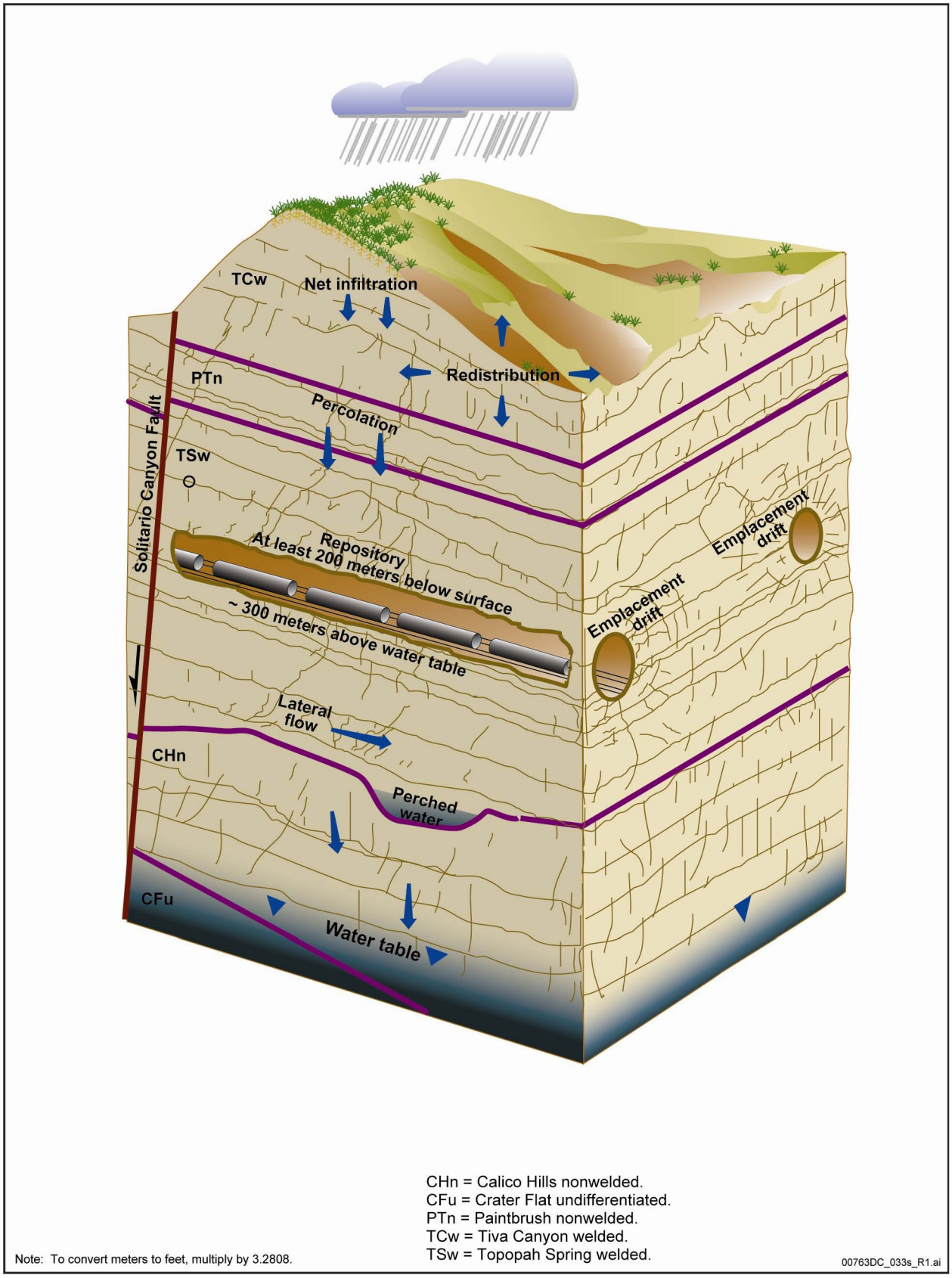


Figure S-3. Components of the natural system.

The site has several characteristics that would limit potential long-term impacts from the disposal of spent nuclear fuel and high-level radioactive waste. It is isolated from concentrations of human population and human activity and is likely to remain so. It is on land controlled by the Federal Government. A repository at Yucca Mountain would benefit from the semiarid conditions at the site—an important consideration because limiting the amount of water that reached waste packages would limit their corrosion and delay mobilization and transport of radionuclides to the accessible environment. The Yucca Mountain region is one of the driest in the United States. Little water could move through the mountain, contact waste materials, and move down to the water table. Waste packages would sit at least 200 meters (700 feet) below the surface of the mountain and approximately 300 meters (1,000 feet) above the water table, a location that would further isolate them from water. Groundwater beneath Yucca Mountain flows into a "closed" hydrogeologic basin from which it cannot flow to any river or ocean. This would prevent radionuclides from spreading to other areas.

10 CFR 63.121 provides that the geologic repository operations area must be located in and on lands that are either acquired lands under the jurisdiction and control of DOE, or lands permanently withdrawn and reserved for its use. Portions of this land are now managed by the Bureau of Land Management, U.S. Air Force (Nevada Test and Training Range), and DOE (Nevada Test Site). The geologic repository operations area would occupy a small portion of a larger area (230 square miles or approximately 150,000 acres), which would include a buffer zone. Because Congress has not withdrawn this land, this Repository SEIS refers to the 230 square miles (approximately 150,000 acres) as the analyzed land withdrawal area.

S.2 Proposed Action

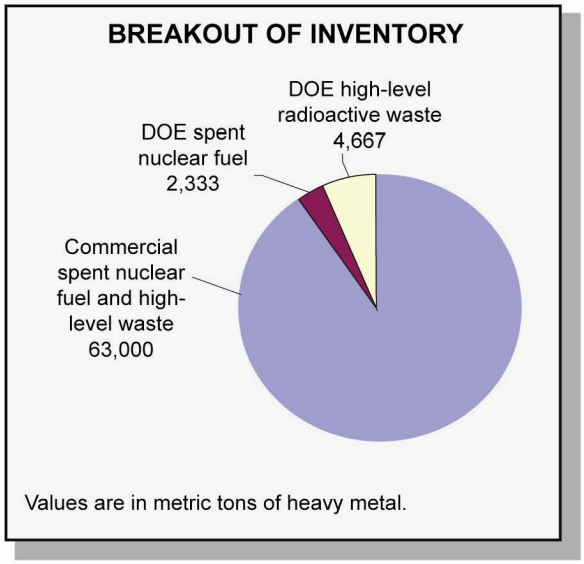
The Proposed Action analyzed in this Repository SEIS is for DOE to construct, operate, monitor, and eventually close a geologic repository at Yucca Mountain for the disposal of 70,000 metric tons of heavy metal (MTHM) of spent nuclear fuel and high-level radioactive waste. Under the Proposed Action, most spent nuclear fuel and high-level radioactive waste would be shipped from 72 commercial and 4 DOE sites to the repository on trains dedicated to these shipments. Naval spent nuclear fuel would be shipped on railcars in general freight service or on dedicated trains. The balance of the shipments would be made by truck. All materials would be in NRC-certified transportation casks.

At the repository, DOE would emplace spent nuclear fuel and high-level radioactive waste sealed in waste packages underground at least 200 meters (700 feet) below the surface and approximately 300 meters (1,000 feet) above the water table. The natural features of the site and the engineered barriers would work together as a total system to help ensure the long-term isolation of the materials from the accessible environment. To prevent inadvertent intrusion by and exposures to members of the public, DOE would use active institutional controls, such as controlled access, inspection, and maintenance, through the end of the repository closure period, after which it would use monitoring and passive institutional controls such as markers.

NRC, through its licensing process, would regulate repository construction, operations, monitoring, and closure.

S.2.1 MATERIALS CONSIDERED FOR DISPOSAL

The NWPA limits how much spent nuclear fuel and high-level radioactive waste DOE could emplace in the first geologic repository to 70,000 MTHM until a second repository is in operation. The materials proposed for disposal under the Proposed Action would include about 63,000 MTHM of commercial spent nuclear fuel and high-level radioactive waste. The remaining 7,000 MTHM would consist of about 2,333 MTHM of DOE spent nuclear fuel (including naval spent nuclear fuel) and the equivalent of 4,667 MTHM of DOE high-level radioactive waste.



This inventory could include surplus weapons-usable plutonium, which DOE could immobilize and dispose of as part of the high-level radioactive waste inventory, or use to produce mixed uranium and plutonium oxide fuel (called mixed-oxide fuel). Utilities would use the fuel to generate electricity in commercial nuclear reactors, and DOE would later dispose of that fuel as commercial spent nuclear fuel.

S.2.2 DOE'S APPROACH TO DISPOSAL

In the Yucca Mountain FEIS, DOE evaluated the receipt of commercial spent nuclear fuel under two packaging scenarios. These included the mostly canistered scenario, in which most commercial spent nuclear fuel would be received in dual-purpose (storage and transportation) canisters, and the mostly uncanistered scenario, in which most commercial spent nuclear fuel would be received uncanistered. In the mostly canistered scenario, the dual-purpose canisters would be opened at the repository and the spent nuclear fuel repackaged into waste packages. In the mostly uncanistered scenario, spent nuclear fuel would be transferred from transportation casks to waste packages. In both scenarios, DOE would handle the commercial fuel at the repository in an uncanistered condition prior to loading it into waste packages for emplacement. In the FEIS, all of the DOE materials (spent nuclear fuel and high-level radioactive waste) would be packaged in disposable canisters at the generator sites. These disposable canisters would not have to be opened at the repository and would be placed directly into waste packages for emplacement.

For this Repository SEIS, DOE's approach to managing commercial spent nuclear fuel would rely on a single canister design for three functions: transportation, aging, and disposal (referred to as a TAD canister). Figure S-4 shows a schematic of a TAD canister. Under this approach, the shippers would seek NRC certification of the TAD canister design for surface storage at commercial sites and for transportation. In its application for construction authorization, DOE is seeking NRC approval to use TAD canisters for spent nuclear fuel transfer, aging, and geologic disposal at the repository. TAD canisters would not substitute for waste packages. They would be placed in waste packages for disposal, as explained below.

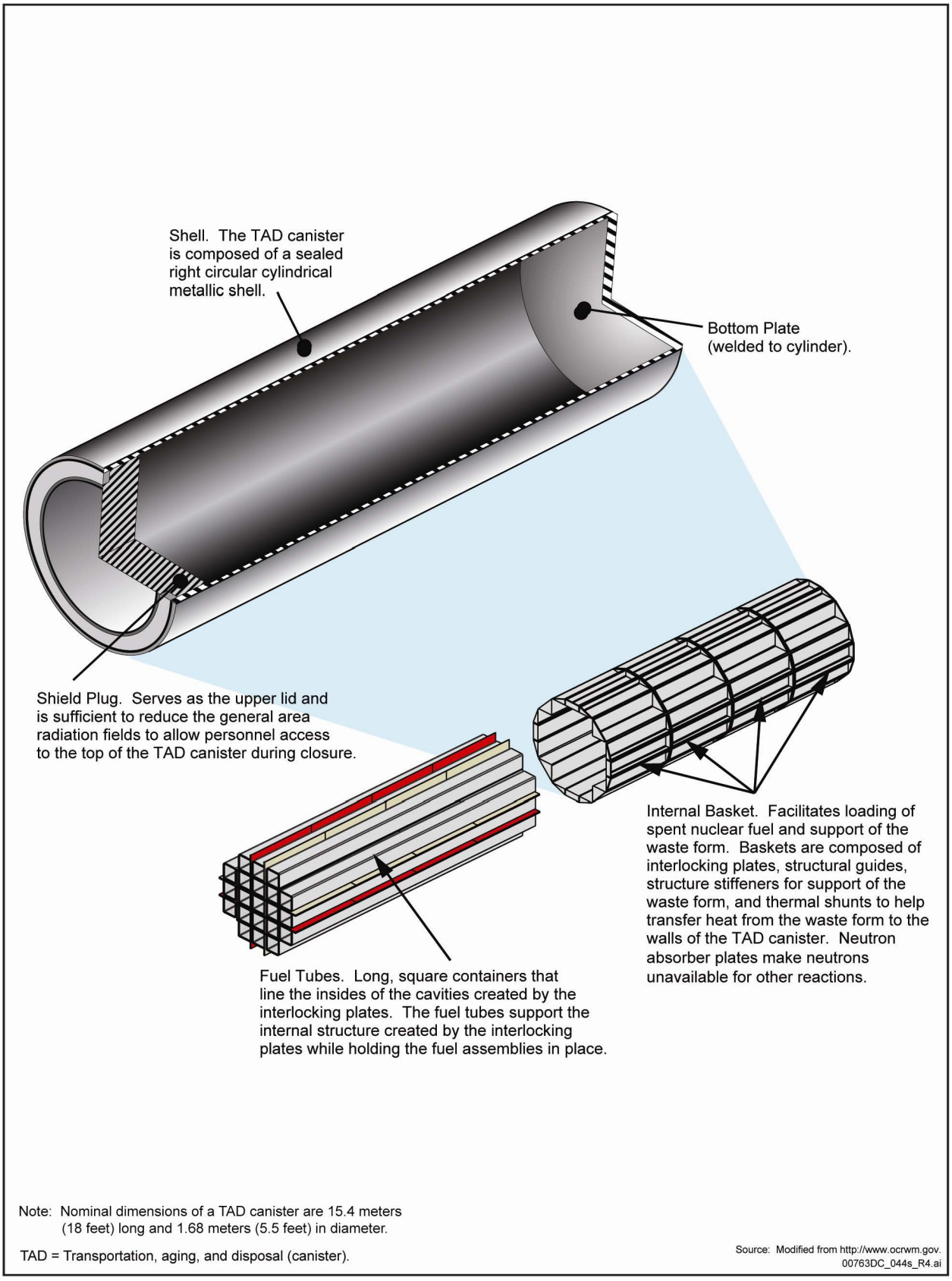


Figure S-4. TAD canister schematic (artist's concept).

At commercial reactor sites, the generators would package most of their spent nuclear fuel (potentially as much as 90 percent) in TAD canisters. Once sealed, the canisters would not have to be reopened. This would minimize the handling of individual spent fuel assemblies and limit the need for more complex repository surface facilities. Because the approach relies on practices familiar to the nuclear industry and NRC, it would simplify repository design, construction, and operation. At DOE sites, most materials destined for the repository would continue to be packaged in disposable canisters, as was considered in the Yucca Mountain FEIS.

DEFINITIONS OF PRECLOSURE ANALYTICAL PERIODS

To evaluate the repository's potential environmental impacts through its final closure, this Repository SEIS analyzes the Proposed Action around four preclosure time periods—construction, operations, monitoring, and closure. Some activities would span more than one time period.

- **Construction analytical period: 5 years**—Begins upon receipt of the construction authorization from the NRC and ends prior to receipt of a license to receive and possess radiological materials. Activities would include site preparation, surface construction, and subsurface development.
- **Operations analytical period: 50 years**—Begins upon receipt of a license to receive and possess radiological materials and ends upon emplacement of the final waste package. Activities would include receipt, handling, aging, emplacement, and monitoring of waste, as well as continued construction of surface and subsurface facilities.
- **Monitoring analytical period: 50 years**—Begins upon emplacement of the final waste package. Activities would include maintaining active ventilation of the repository for as long as 50 years, remotely inspecting waste packages, and continuing investigations in support of predictions related to postclosure performance.
- **Closure analytical period: 10 years**—Overlaps the last 10 years of the monitoring period and includes activities that would begin upon receipt of a license amendment to close. Activities would include decommissioning and demolishing surface facilities, emplacing drip shields, backfilling subsurface-to-surface openings, restoring the surface to its approximate condition before repository construction, and constructing monuments to mark the site.

At the repository, some commercial spent nuclear fuel would be aged to reduce its thermal output, as part of a strategy to manage temperatures within and between emplacement drifts to divert water from them. Managing temperatures is important to DOE's strategy to allow water to drain freely in the rock between the emplacement drifts. As part of this strategy, which would employ a "thermal energy density concept," DOE would place some TAD canisters in aging overpacks and place the overpacks on aging pads at the Aging Facility. When heat output had declined to an appropriate level, the canisters would be placed directly in waste packages for disposal. Those TAD canisters not placed on the aging pads would be placed in waste packages for disposal, as would all disposable canisters containing DOE spent nuclear fuel and high-level radioactive waste.

S.2.3 REPOSITORY FACILITIES AND OPERATIONS

The handling and disposal of spent nuclear fuel and high-level radioactive waste at the repository would take place in the geologic repository operations area (Figure S-5). The surface portion of the area would include the facilities necessary to receive, package, and support emplacement of spent nuclear fuel and high-level radioactive waste in the repository. The subsurface portion would include the facilities necessary for emplacement and disposal. Figure S-6 illustrates DOE's operational plans.

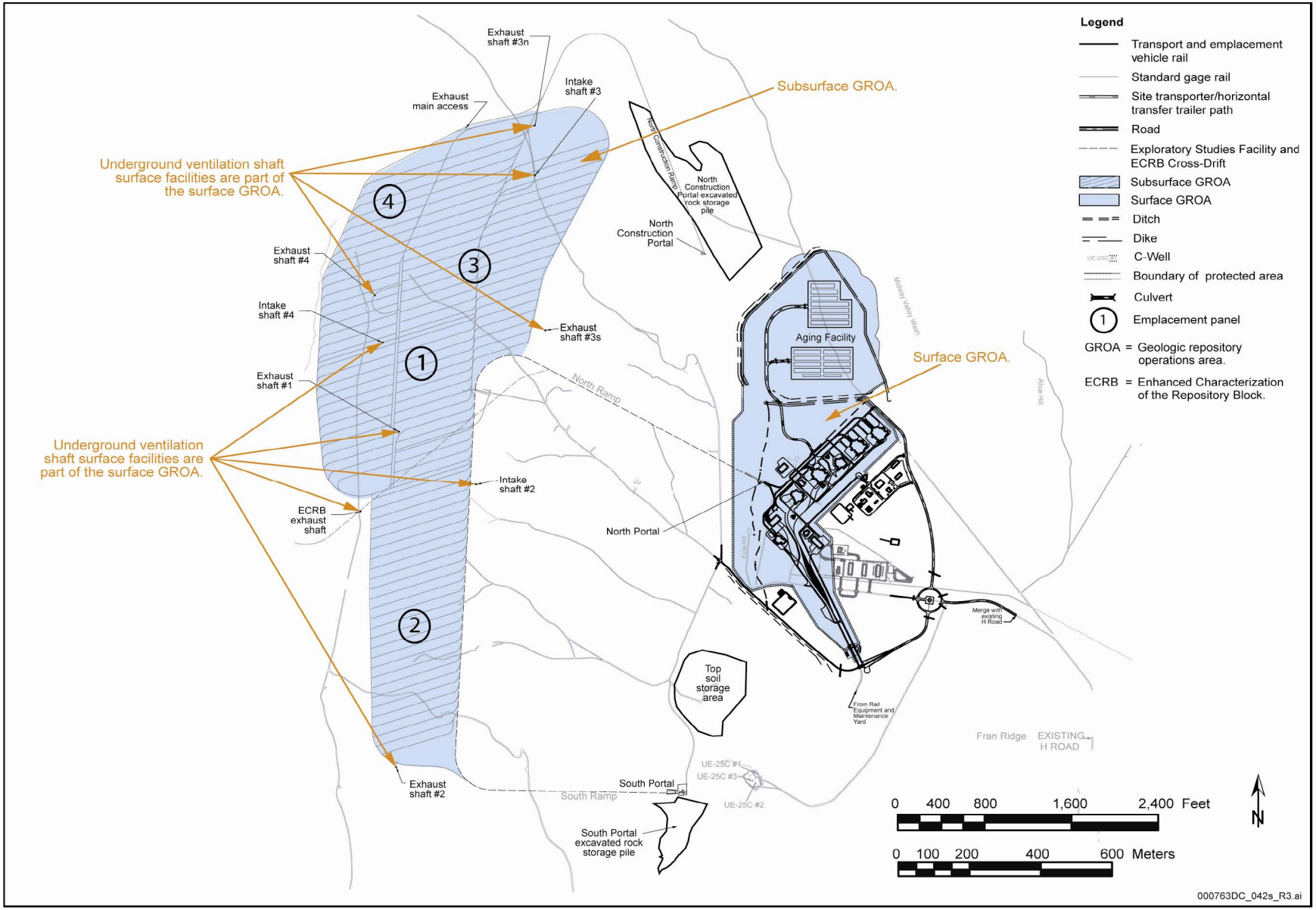


Figure S-5. Geologic repository operations area.

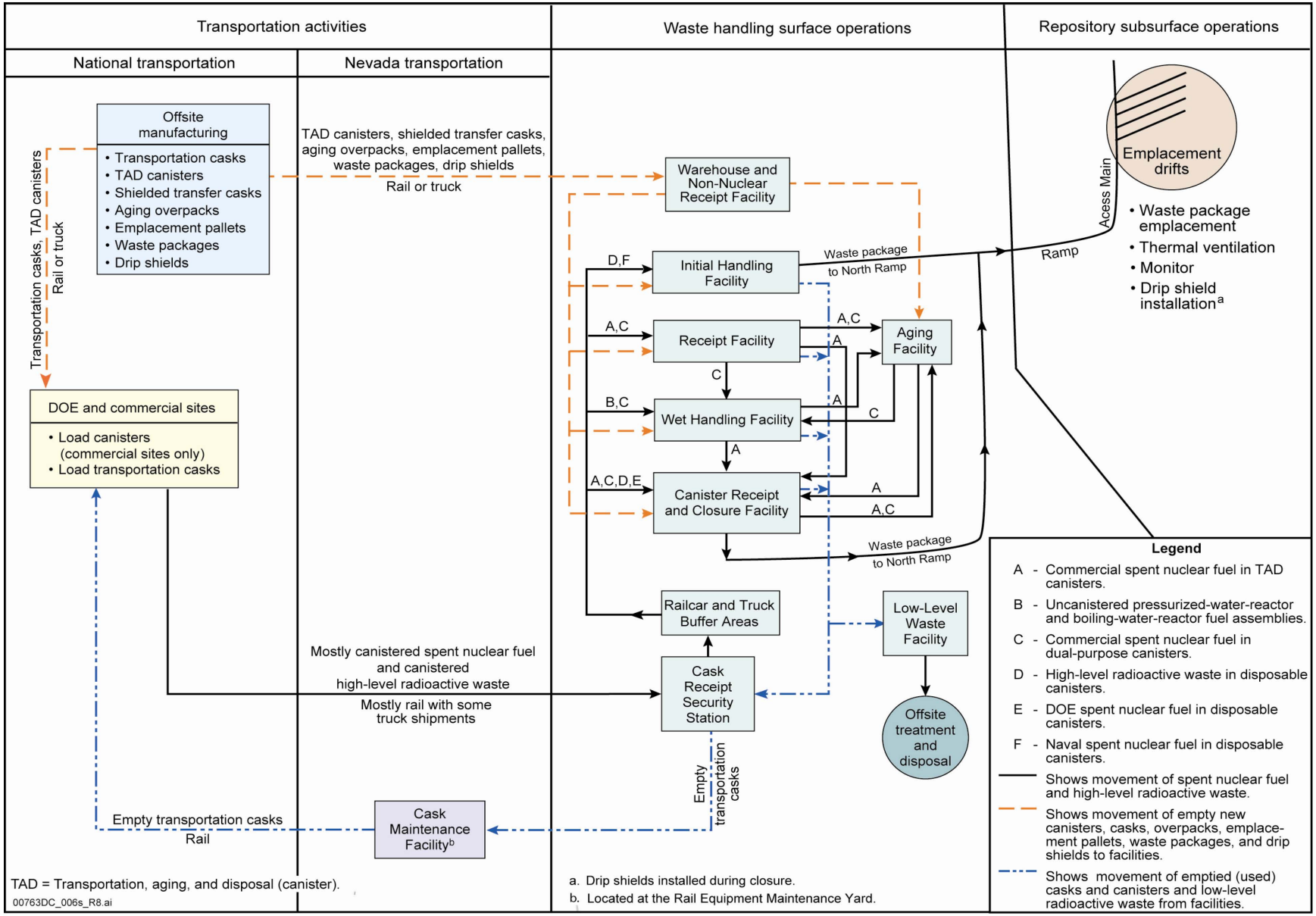


Figure S-6. Overview flowchart for typical operations of the Proposed Action.

DOE organized its analyses of the potential impacts of the Proposed Action around preclosure (short-term) and postclosure (long-term) impacts, and it analyzed potential preclosure impacts for four time frames: construction analytical period, operations analytical period, monitoring analytical period, and closure analytical period.

S.2.3.1 Waste Handling Surface Facilities and Operations

DOE would use the following types of surface facilities or areas for waste handling: an Aging Facility, three Canister Receipt and Closure Facilities, an Initial Handling Facility, Receipt Facility, and a Wet Handling Facility.

PRIMARY FUNCTIONS OF WASTE PREPARATION AND HANDLING FACILITIES

Aging Facility:
Provides two aging pads and associated equipment to age commercial spent nuclear fuel as necessary to meet waste package thermal limits.

Canister Receipt and Closure Facilities:
Receive DOE disposable canisters and TAD canisters, load canisters into waste packages, and close the waste packages.

Cask Receipt Security Station:
Perform initial waste receipt and inspection.

Initial Handling Facility:
Receive high-level radioactive waste and naval spent nuclear fuel canisters, load canisters into waste packages, and close the waste packages.

Receipt Facility:
Transfer TAD and dual-purpose canisters, as appropriate, to the Wet Handling Facility, a Canister Receipt and Closure Facility, or the Aging Facility.

Wet Handling Facility:
Handle uncanistered commercial spent nuclear fuel and open and unload dual-purpose canisters; essential purpose is loading TAD canisters.

Surface facilities would be constructed in phases. This means that, for several years, radiological operations would be occurring while construction of surface facilities continued. When surface construction was complete, full operational capability would be achieved. The site layout facilitates concurrent construction and operations in the geologic repository operations area.

The purpose of the waste preparation and handling facilities would be to ensure that commercial spent nuclear fuel received at the repository met waste package thermal limits, as explained below, and that all waste forms were packaged in sealed waste packages for emplacement. This would be accomplished as follows:

- Most commercial spent nuclear fuel would arrive in TAD canisters that had been loaded and sealed by the commercial nuclear utilities. Transportation casks that contained commercial spent nuclear fuel in TAD canisters that required aging to reduce the fuel's heat output, would be unloaded in the Receipt Facility or a Canister Receipt and Closure Facility. The TAD canisters would be transferred

to aging overpacks and moved to the Aging Facility for thermal management. Once the thermal heat output decayed to an acceptable level, DOE would move the aging overpacks to a Canister Receipt and Closure Facility, where TAD canisters would be placed in waste packages for subsurface emplacement. TAD canisters that did not require aging would be sent to a Canister Receipt and Closure Facility for packaging in a waste package.

- A small amount of commercial spent nuclear fuel could arrive in transportation casks as uncanistered spent nuclear fuel assemblies. DOE would move these transportation casks to the Wet Handling Facility, where the fuel would be placed in TAD canisters and subsequently managed as described above.

- Some commercial spent nuclear fuel could arrive in sealed dual-purpose canisters inside transportation casks. These canisters would be unloaded at the Receipt Facility and either be transferred to the Aging Facility or to the Wet Handling Facility, where they would be opened and the fuel would be transferred to TAD canisters.

- High-level radioactive waste, naval spent nuclear fuel, and DOE spent nuclear fuel would arrive at the repository in disposable canisters, inside transportation casks. Different waste types would be segregated and placed in appropriate waste packages. Casks containing naval spent nuclear fuel canisters would be unloaded in the Initial Handling Facility, where the canisters would be placed in waste packages. Casks containing DOE spent nuclear fuel would be sent to a Canister Receipt and Closure Facility, where the canisters would be unloaded and transferred to waste packages. Casks containing high-level radioactive waste would be unloaded at either the Initial Handling Facility or a Canister Receipt and Closure Facility. High-level radioactive waste would be codisposed with DOE spent nuclear fuel canisters. However, a naval spent nuclear fuel canister would be placed in a waste package by itself.

DOE would conduct waste transfer operations in these facilities using mostly remotely operated equipment. Thick, reinforced concrete shield walls, shielded canister transfer, and controlled access techniques would protect workers from radiation exposure. DOE would use a site transportation network to move transportation casks and waste packages between the waste handling facilities and eventually to the subsurface facility.

S.2.3.2 Subsurface Facilities and Operations

Once the various types of wastes received at the repository were sealed in waste packages, the waste packages would be transferred to the subsurface portion of the geologic repository operations area.

The subsurface facilities would consist of three access mains that would provide access to smaller, dedicated drifts in which the waste would be placed. Emplacement drifts would be excavated horizontally in a series of four emplacement panels that would be developed and made operational over a period of years, coinciding with the schedule for receipt of waste (Figure S-5).

Under the repository design, the area required to accommodate 70,000 MTHM would total about 6 square kilometers (1,500 acres), with approximately 68 kilometers (42 miles) of emplacement drifts. About 11,000 waste packages and their emplacement pallets would be placed in these drifts. DOE would use tunnel boring machines to excavate the drifts.

DEFINITIONS OF PACKAGING TERMS

Aging overpack:
A cask specifically designed for aging spent nuclear fuel at the repository. TAD canisters and dual-purpose canisters would be placed in aging overpacks for aging at the Aging Facility.

Disposable canister:
A metal vessel for commercial and DOE spent nuclear fuel assemblies (including naval spent nuclear fuel) or solidified high-level radioactive waste suitable for storage, shipping, and disposal. At the repository, DOE would remove the disposable canister from the transportation cask and place it in a waste package. There are a number of types of disposable canisters, including DOE standard canisters, multicanister overpacks, naval spent nuclear fuel canisters, and TAD canisters.

Dual-purpose canister:
A metal vessel suitable for storing (in a storage facility) and shipping (in a transportation cask) commercial spent nuclear fuel assemblies. At the repository, DOE would remove dual-purpose canisters from the transportation cask and open them. DOE would remove the spent nuclear fuel assemblies from the dual-purpose canister and place them in a TAD canister before placement in a waste package. The opened canister would be recycled or disposed of off the site as low-level radioactive waste.

Uncanistered spent nuclear fuel:
Commercial spent nuclear fuel assemblies not placed in a canister before placement into a transportation cask. At the repository, DOE would remove spent nuclear fuel assemblies from the transportation cask and place them in a TAD canister before placement in a waste package or aging overpack.

Shielded transfer cask:
A metal vessel used to transfer canisters between waste handling facilities.

Transportation, aging, and disposal (TAD) canister:
A canister suitable for storage, shipping, aging, and disposal of commercial spent nuclear fuel. Commercial spent nuclear fuel would be placed into a TAD canister at the commercial reactor. At the repository, DOE would remove the TAD canister from the transportation cask and place it into a waste package or an aging overpack. The TAD canister is one of a number of types of disposable canisters.

Transportation cask:
A vessel that meets applicable regulatory requirements for transport of spent nuclear fuel or high-level radioactive waste via public transportation routes.

Waste package:
A container that consists of the corrosion-resistant outer container (Alloy 22 outer cylinder) and structural inner container (stainless-steel inner cylinder) baskets, and shielding integral to the container. Waste packages would be ready for emplacement in the repository when the inner and outer lid welds were complete and the volume of the inner container had been evacuated and filled with helium gas to achieve an inert condition.

The waste package and emplacement pallet are two of the engineered barriers that would contribute to waste containment and isolation. Waste packages would be supported on emplacement pallets and aligned end-to-end on the drift floor. Figure S-7 shows emplacement pallets loaded with waste packages in an emplacement drift. The waste packages would consist of two concentric cylinders. The inner cylinder would be made of Stainless Steel Type 316, and the outer cylinder would be made of

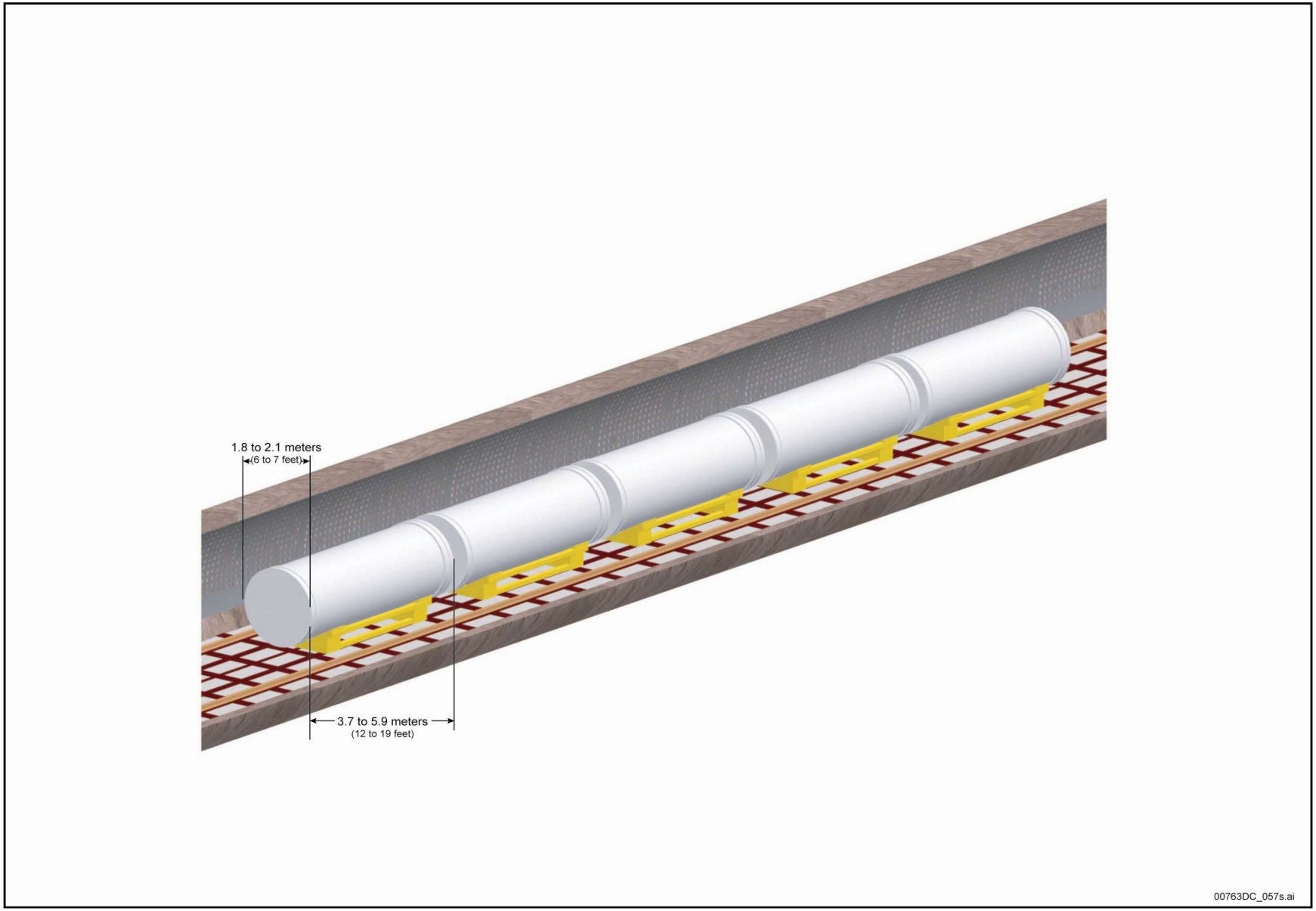


Figure S-7. Emplacement pallets loaded with waste packages in an emplacement drift (artist's concept).

corrosion-resistant, nickel-based Alloy 22. Emplacement pallets would be fabricated from Alloy 22 plates and stainless steel. The current waste package design differs only in minor ways from that in the Yucca Mountain FEIS.

In addition to being radioactive, spent nuclear fuel and high-level radioactive waste give off heat from radioactive decay. This is referred to as thermal energy or thermal output. When placed in a confined space, such as an emplacement drift, where heat cannot readily dissipate, these materials would heat the surrounding area. In a repository, the thermal output of the waste packages would heat the rock surrounding the emplacement drifts to a temperature higher than the boiling point of water at the repository elevation, 96° Celsius (205° Fahrenheit). This would cause the small amounts of water in the rock to turn into steam, which would move away from the drifts to a point where temperatures are below boiling. There, steam would condense back to water.

To provide a path that would divert the mobilized liquid water downward past the emplacement drifts and away from the waste packages, DOE has designed the repository to include regions between the drifts (the midpillar region) that would remain below the boiling point of water. To accomplish this, DOE would manage the thermal output of the waste packages by selecting for emplacement only those that would keep the temperature in the midpillar region below the boiling point of water, as shown in Figure S-8.

The evaluation of whether a waste package is too thermally hot for emplacement would employ a concept called *thermal energy density*, which is a measure of how heat is distributed over an area. By knowing the thermal characteristics of waste packages already emplaced in specific drifts in the repository and the thermal characteristics of waste packages available for emplacement, DOE can select those appropriate for emplacement. DOE would make the selections based on calculations of how the added thermal energy of the additional waste packages would affect the goal of maintaining the temperature of the midpillar region below the boiling point of water. Managing an upper limit to the thermal energy density for emplacement thus would rely on selecting or blending waste packages with specific thermal characteristics.

After emplacement was complete, the drifts would remain open and ventilated for a nominal period of 50 years, so ventilation would remove much of the heat and humidity from the drifts. After DOE closed and sealed the subsurface facility, the rock around the emplacement drifts would dry, further minimizing, for hundreds of years, the amount of water that could come into contact with the waste packages. A portion of the rock between the drifts would remain at temperatures below boiling, which would continue to promote drainage of water through the portions of the rock between the drifts rather than into the drifts themselves.

S.2.4 TRANSPORTATION

The Yucca Mountain FEIS considered the potential environmental impacts of transporting spent nuclear fuel and high-level radioactive waste from commercial and DOE sites by two principal modes—mostly truck and mostly rail. Since it completed the FEIS, the Department has decided to transport most spent nuclear fuel and high-level radioactive waste by rail both nationally and in Nevada. This Repository SEIS updates transportation analyses to reflect the mostly rail scenario.

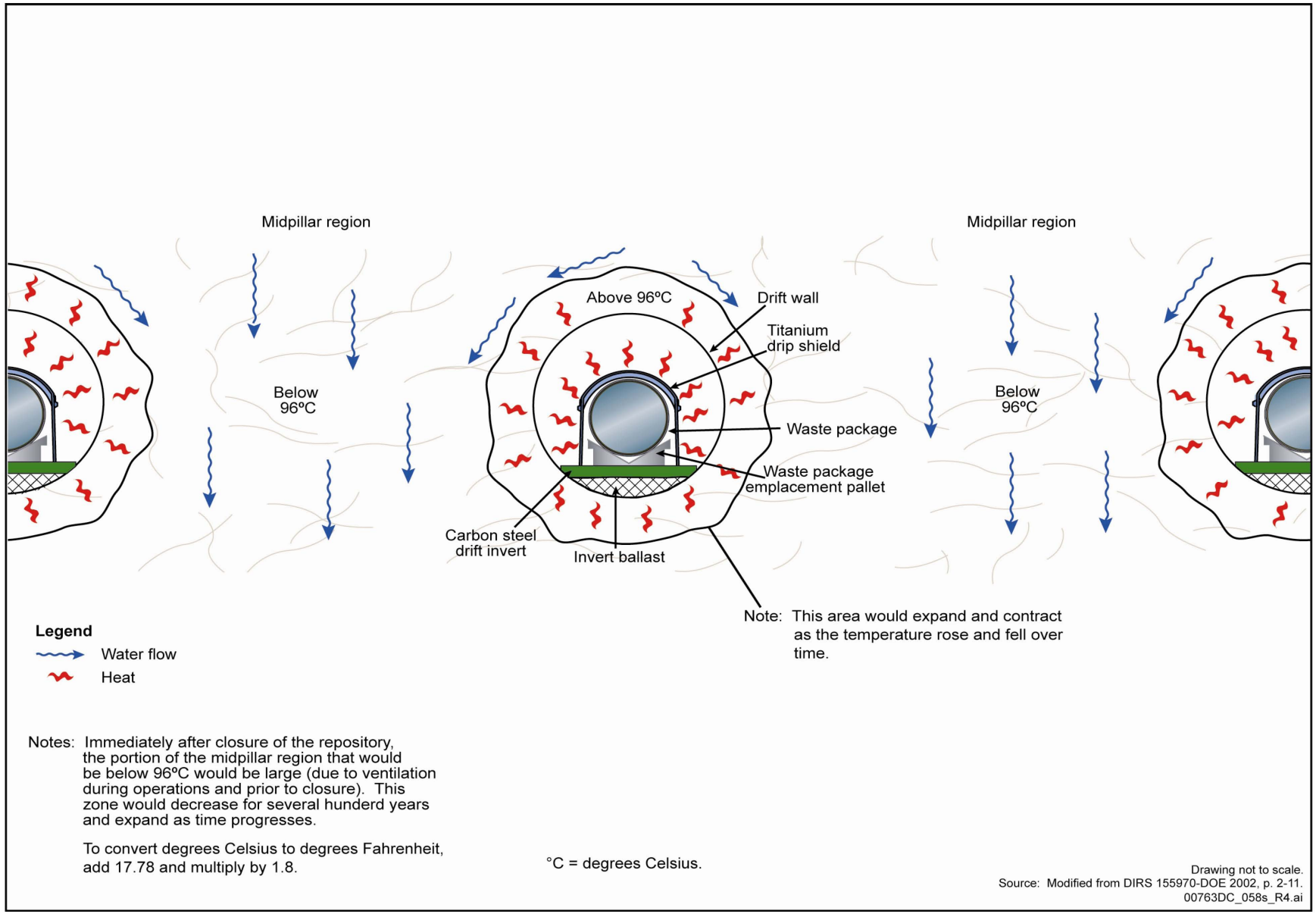


Figure S-8. Management of waste package emplacement using thermal energy density (artist's concept).

DOE cannot use rail transport exclusively because some commercial nuclear generating sites do not have the ability to load large-capacity rail shipping casks. Those sites would use overweight trucks to ship material to the repository. Commercial sites that could load the rail shipping casks but lacked rail access could use heavy-haul trucks or barges to ship spent nuclear fuel to the nearest rail line. Figure S-9 shows the commercial and DOE sites and Yucca Mountain in relation to the railroad system over which the railcars could travel.

Because no rail service currently extends to the Yucca Mountain site, DOE would have to build a railroad linking the site to the terminus of an existing rail line in Nevada. As explained in the Foreword, to evaluate the potential impacts of constructing and operating a railroad in Nevada, DOE has prepared a Rail Alignment EIS that it published coincident with this Repository SEIS. The Rail Alignment EIS analyzes the potential impacts of constructing and operating a railroad along specific alignments in the Caliente and Mina rail corridors. Under that Proposed Action, DOE would determine a rail alignment in which to construct and operate a railroad for shipments of spent nuclear fuel, high-level radioactive waste, and other materials from an existing rail line in Nevada to a geologic repository at Yucca Mountain.

The railroad would approach Yucca Mountain from a point east of U.S. Highway 95 north of Beatty, trending generally southeast for 40 kilometers (25 miles) from Oasis Valley to Beatty Wash, across Crater Flat to a point near the southern end of the actual surface feature of Yucca Mountain. It would then turn northeast for about 11 kilometers (7 miles), passing Busted Butte on its eastern side then trend north on the west side of Fran Ridge to the terminus at the southern end of the Rail Equipment Maintenance Yard. The geologic repository operations area would be on the north end of the Rail Equipment Maintenance Yard, another 1.6 kilometers (1 mile) northeast. The geologic repository operations area interface would consist of a double-track spur for delivery of casks and supplies to the surface geologic repository operations area.

The Department identifies the Caliente Implementing Alternative as its preferred alternative, and identifies its preferred rail alignment segments starting in Caliente and ending at Yucca Mountain. The Department also indicates that it prefers the Shared-Use Option, that is, DOE would make its rail line available to commercial shippers for shipments of general freight.

The Rail Alignment EIS also includes a No-Action Alternative under which DOE would not determine an alignment or construct and operate a railroad within the Caliente or Mina rail corridor. The Repository SEIS summarizes and incorporates by reference Chapter 3, Section 3.2 and 3.3, and Chapters 4, 5, and 8 of the Rail Alignment EIS, as appropriate.

Other elements of DOE's national transportation plan that have evolved since completion of the Yucca Mountain FEIS include the following:

- Rail shipments would be made on dedicated trains. (This policy would not apply to shipments of naval spent nuclear fuel.)

- Armed security escorts would accompany all shipments.

- Trucks carrying transportation casks could be overweight rather than legal weight. Overweight trucks would be subject to permitting requirements in each state through which they traveled.

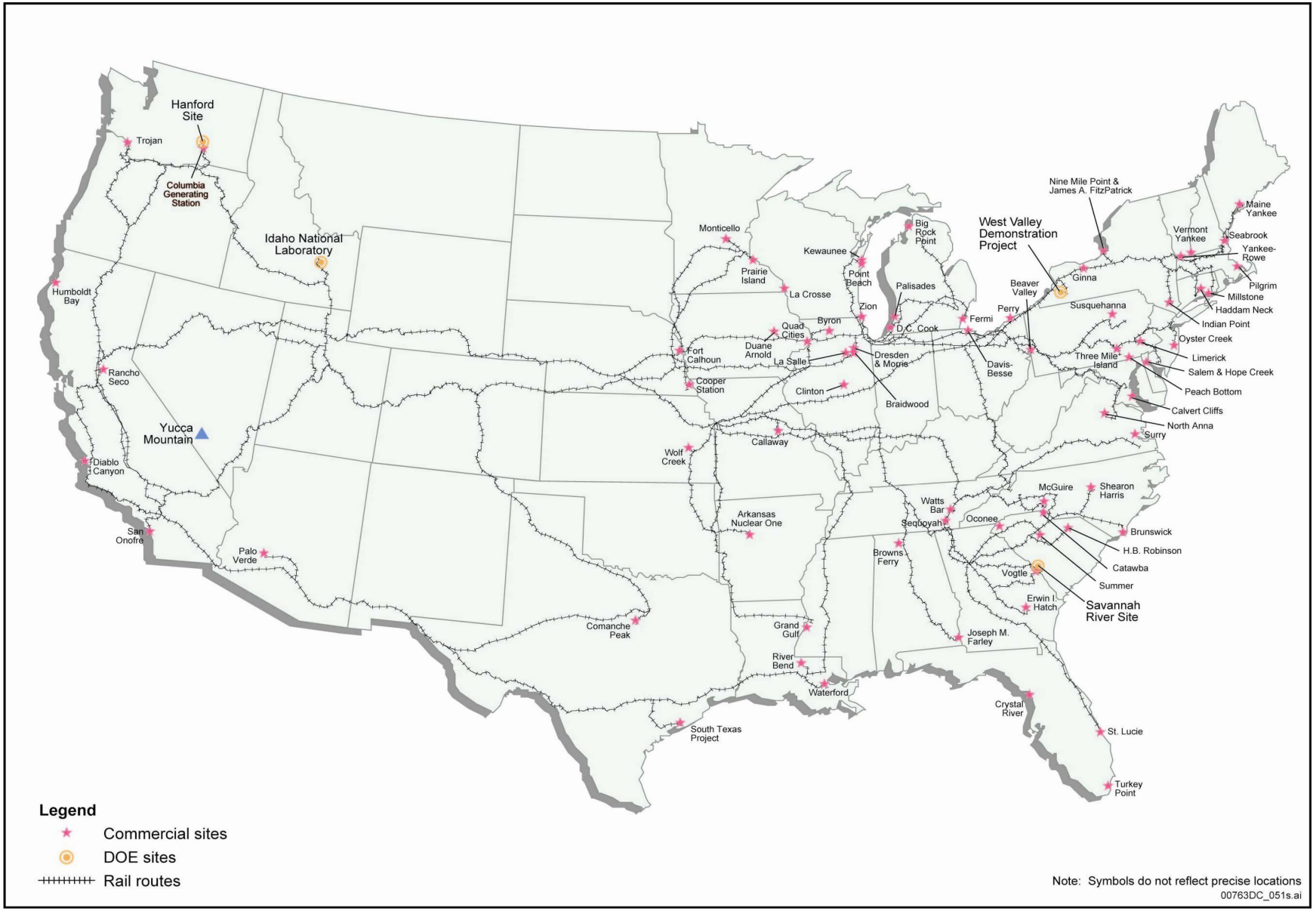


Figure S-9. Representative national rail routes considered in the analysis for this Repository SEIS.

The Yucca Mountain FEIS analyzed the shipment of about 9,600 rail casks and 1,100 truck casks under the mostly rail shipping scenario. This Repository SEIS analyzes the shipment of about 9,500 rail casks and 2,700 truck casks of spent nuclear fuel and high-level radioactive waste. The increased number of truck shipments in the Repository SEIS is primarily due to the revised information on the cask handling capabilities at commercial reactor sites. The FEIS assumed that the reactor sites that did not currently have the ability to load large rail casks would modify their facilities to obtain that ability. This SEIS does not make that assumption.

S.3 Changes from the Draft Repository SEIS

S.3.1 PUBLIC COMMENT PERIOD

On October 12, 2007, DOE announced in the *Federal Register* (72 FR 58071) the availability of three draft NEPA analyses related to its Yucca Mountain Project: the Draft Repository SEIS, and the Draft Nevada Rail Corridor SEIS and the Draft Rail Alignment EIS. The Notice of Availability invited interested parties to comment on the NEPA documents during a 90-day public comment period ending on January 10, 2008, and announced the schedule for public hearings. DOE made the NEPA documents available on the Internet and sent copies to other federal agencies, members of Congress, American Indian tribal governments, state and local governments, and organizations and individuals who are known to have an interest in the analyses.

DOE held eight public hearings on the documents at the following locations:

- Hawthorne, Nevada – Hawthorne Convention Center, 932 East Street, November 13, 2007
- Caliente, Nevada – Caliente Youth Center, U.S. Highway 93, November 15, 2007
- Reno/Sparks, Nevada – Reno/Sparks Convention Center, 4590 South Virginia Street, November 19, 2007
- Amargosa Valley, Nevada – Longstreet Inn and Casino, Nevada State Highway 373, November 26, 2007
- Goldfield, Nevada – Goldfield School Gymnasium, Hall and Euclid, November 27, 2007
- Lone Pine, California – Statham Hall, 138 North Jackson Street, November 29, 2007
- Las Vegas, Nevada – Cashman Center, 850 North Las Vegas Boulevard, December 3, 2007
- Washington, D.C. – Marriott at Metro Center, 775 12th Street, NW, December 5, 2007

Approximately 518 people attended the hearings and 110 people provided oral comments. In total, DOE received approximately 4,000 comments on the NEPA documents from nearly 1,100 commenters. Approximately 2,600 of these comments were on the Repository SEIS. DOE has prepared a Comment-Response Document (Volume III of this Final Repository SEIS) that addresses the issues raised during the public comment period. This Final Repository SEIS reflects changes as a result of public comments received on the Draft Repository SEIS.

S.3.2 ISSUES RAISED BY THE PUBLIC ON THE DRAFT REPOSITORY SEIS

The comments received from the public on the Draft Repository SEIS during the comment period addressed a number of key issues. DOE identified the issues as "key" based on:

- The extent to which an issue concerned fundamental aspects of the Proposed Action,

- The nature of the comments as characterized by the commenters, and
- The extent to which DOE changed the Repository SEIS in response to the comments.

The Comment-Response Document contains the comments DOE received on the Draft Repository SEIS, and the DOE responses to those comments. The key issues are summarized in italics below, followed by the DOE responses.

In addition to the following issues, DOE received comments on a number of other key issues—environmental justice, mitigation measures and compensation, No-Action Alternative, the Mina rail corridor, the appropriate lead agency, and others—that are pertinent to the Nevada Rail Corridor SEIS or the Rail Alignment EIS. The Comment-Response Documents for those NEPA analyses discuss those issues and include the DOE responses.

S.3.2.1 Repository Design and Operational Details

The design and operational details of the Proposed Action in the Repository SEIS are insufficient to allow an adequate and meaningful NEPA evaluation.

The suggestion that DOE must await the availability of additional, more detailed design and operational details is not consistent with the requirements of NEPA and Council on Environmental Quality regulations. DOE has used the best available information in this Repository SEIS to provide an analysis of the potential reasonably foreseeable environmental impacts of the Proposed Action. The policies and procedures of DOE and the Council that implement the requirements of NEPA call for environmental impact analyses early in the process of development of a proposed federal project. In particular, the need to prepare an EIS early in the process is stressed throughout Council regulations (40 CFR 1500.5, 1501.2, 1502.5, and 1508.23). In addition, there are processes for determining if there is a need for additional NEPA analyses if an agency proposes substantial changes to a proposed action, or there are significant new circumstances or information relevant to environmental concerns and bearing on the proposed action or its impacts.

This information is sufficient to perform an adequate and meaningful evaluation of the proposed project.

S.3.2.2 EPA and NRC Final Regulations

DOE should not issue the Final Repository SEIS until both the EPA regulations and the conforming NRC licensing regulation are in final form concerning the individual radiation protection standard for the post-10,000-year period at Yucca Mountain. DOE should then redraft the SEIS to comply with these regulations once they are finalized. The Final SEIS must use the same TSPA model that is used to calculate long-term repository performance as that used in the license application in order for the NRC to be able to adopt the Final SEIS. The DOE TSPA for the Draft Repository SEIS is markedly different from that used in the 2002 Yucca Mountain FEIS, and DOE is continuing to modify it for use in its license application to the NRC.

This Repository SEIS analyzes repository performance in the context of the proposed EPA and NRC regulations to provide a perspective on the potential radiological impacts of the repository during the period of geologic stability (as long as 1 million years). If the Repository SEIS postclosure analysis is

inconsistent with any requirement of the final EPA or NRC regulation, the Department would perform any required additional analysis.

DOE has continued to refine the TSPA model since it completed the 2002 Yucca Mountain FEIS. The differences in the results of the TSPA analyses in the Final Repository SEIS and the FEIS are largely attributable to the proposed EPA and NRC regulations, which were issued after 2002. The proposed regulations set forth requirements on how to calculate repository performance during the period of geologic stability, and requirements concerning the use of health physics information that is more current than that required in the 2001 NRC rule (see Chapter 5 of this SEIS). The version of the TSPA model that DOE used in this Repository SEIS to estimate potential postclosure radiological impacts is the same version used in DOE's application for construction authorization.

S.3.2.3 Water Appropriations

The State of Nevada has been resistant to issuing water permits for the Yucca Mountain Project.

As with any major construction project, the building and operation of the repository would require an adequate supply of water. This water would be necessary for construction materials such as concrete, for control of dust, and for emergency use such as fire suppression. DOE submitted its application to the State of Nevada for the necessary water in 1997. The State denied the application in 2000 on the basis of state law, and the matter is currently the subject of litigation pending in the Federal District Court in Nevada. The Department will continue to pursue the litigation, which the District Court has stayed, and to work with the state to obtain the water necessary to support the repository program.

S.3.2.4 Sabotage and Terrorism

The consideration of terrorist attacks is incomplete and requires additional analysis.

Whether acts of sabotage or terrorism would occur, and the exact nature and location of the events or the magnitude of the consequences of such acts if they were to occur, is inherently uncertain—the possibilities are infinite. Nevertheless, this Repository SEIS takes a hard look at the consequences of potential acts of sabotage or terrorism at the repository and during the transport of spent nuclear fuel and high-level radioactive waste by evaluating two fundamentally different scenarios: one involving aircraft and one involving a weapon or device that struck a transportation cask loaded with commercial spent nuclear fuel. DOE estimated the consequences of these scenarios without regard to their probability of occurrence; that is, DOE assumed the scenarios would occur and under conditions that would reasonably maximize the consequences.

As with any aspect of environmental impact analysis, it is always possible to postulate scenarios that could produce higher consequences than previous estimates. In eliminating the requirement that agencies conduct a worst-case analysis, the Council on Environmental Quality has pointed out that "one can always conjure up a worse 'worst case'" by adding more variables to a hypothetical event, and that "'worst case analysis' is an unproductive and ineffective method…one which can breed endless hypothesis and speculation." As indicated in the Council on Environmental Quality regulations that implement NEPA, an agency has a responsibility to address reasonably foreseeable significant adverse effects. The evaluation of impacts is subject to a "rule of reason" ensuring analysis based on credible

scientific evidence useful to the decisionmaking process. In applying the rule of reason, an agency does not need to address remote and highly speculative consequences in its EIS.

Since the terrorist attacks of September 11, 2001, the NRC has issued safeguards advisories and orders to enhance the security of spent nuclear fuel transportation and shipments of large quantities of radioactive material. Enhancements include more preplanning and coordination with affected states, additional advance notification of shipments, additional control and monitoring, trustworthiness checks for individuals who have access to a shipment or information about a shipment, and more stringent security measures for shipment routes and schedules. In addition, the NRC issued orders that require enhanced security measures for spent nuclear fuel shipments from reactors.

Crash of a commercial jetliner into surface facilities is not a substitute for a thorough review of the potential impacts of sabotage or terrorism.

This Repository SEIS presents the potential impacts for a scenario that would approximate the consequences of a major sabotage event, in which a large commercial aircraft filled with jet fuel would crash into and penetrate the repository facility with the largest inventory of radioactive material vulnerable to damage from such an event.

As discussed in this Repository SEIS, DOE has analyzed plausible threat scenarios, required enhanced security measures to protect against these threats, and developed emergency planning requirements that would mitigate potential consequences. Further, DOE believes that the safeguards applied to the proposed repository should involve a dynamic process of enhancement to meet threats, which could change over time. Repository planning activities will include a continuing effort to identify safeguards and security measures that would further protect fixed facilities from terrorist attack and other intentional destructive acts.

Failure to address the potential for a nuclear criticality during a terrorist attack.

The presence of water could increase the likelihood of criticality. Therefore, spent nuclear fuel shipping casks are specifically designed to remain subcritical, even when filled with water. It is highly unlikely that a terrorist event would cause the contents of a shipping cask to achieve a nuclear criticality, even if the event disrupted the contents of the cask.

S.3.2.5 Global Nuclear Energy Partnership Inventory

Explain the relationship between the proposed repository and the Department's Global Nuclear Energy Partnership (GNEP) program.

Since the issuance of the Draft Repository SEIS, DOE has been engaged in further defining the programmatic and project-specific alternatives that the Department will evaluate in the Global Nuclear Energy Partnership Programmatic EIS. The purpose of GNEP, which is a domestic and international program, is to support expansion of nuclear energy production while advancing nonproliferation goals and reducing the impacts of spent nuclear fuel disposal.

The programmatic alternatives DOE will consider in the GNEP Programmatic EIS vary by reactor and fuel type, and by whether they would incorporate recycling of commercial spent nuclear fuel to recover usable materials for reuse in reactor fuels. Depending on the programmatic alternative, the resultant

radiological materials requiring geologic disposal could range from only high-level radioactive waste from the recycling of spent nuclear fuel to only spent nuclear fuel (in varying amounts, depending on the reactor type alternative and the nuclear power growth scenario). The estimates of spent nuclear fuel vary widely among the alternatives.

Some of the proposed GNEP programmatic alternatives assume the recycling of commercial spent nuclear fuel. By 2010, commercial reactors will have discharged 63,000 MTHM of spent nuclear fuel, the same as the amount in the Repository SEIS Proposed Action inventory. Although many uncertainties are associated with implementation of the GNEP program, it is possible that commercial spent nuclear fuel that exceeds the 63,000 MTHM analyzed in the Proposed Action could be recycled using one of the technologies considered by GNEP. The high-level radioactive waste that would result from this recycling, rather than the spent nuclear fuel, would require geologic disposal. As a result, DOE has modified the Repository SEIS evaluation of the additional inventory modules to assess the potential environmental impacts associated with various GNEP alternatives under consideration.

S.3.3 CHANGES MADE TO THE DRAFT REPOSITORY SEIS

This Final Repository SEIS reflects changes made to the Draft Repository SEIS due to public comments and the availability of new and updated information. Substantive changes in this SEIS are indicated in the margins with change bars. Examples of these changes include:

- Update of impact analyses related to occupational and public health and safety and potential accidents to reflect more recent information that is included in the Safety Analysis Report, which was part of the application DOE recently submitted to the NRC for construction authorization.

- Assessment of the greenhouse gases potentially released as a result of the Proposed Action, including repository construction and operations, the transportation of spent nuclear fuel and high-level radioactive waste to the repository, transportation of construction and other materials, and commuting workers.

- Discussion of Inyo County, California, research and findings on the behavior and characteristics of the lower carbonate aquifer as it relates to future postclosure repository performance.

- Inclusion of an integrated schedule that provides DOE's analytical basis for consideration of impacts during the construction and operation of the repository in relation to the proposed railroad and site infrastructure.

- Additional explanatory text and graphics that illustrate the differences between overweight, legal-weight, and heavy-haul trucks for transportation of spent nuclear fuel or high-level radioactive waste.

- Assessment of potential impacts to regional traffic as a result of the Proposed Action.

- Discussion of highway routing alternatives that could be used by shippers if the States of Nevada and California exercised their prerogative to designate alternate preferred highway routes for the transportation of spent nuclear fuel or high-level radioactive waste. DOE first presented this analysis in the Yucca Mountain FEIS and has summarized this analysis in this Repository SEIS.

- Discussion of a process (including establishment of mitigation advisory boards) that DOE could implement to address regional impacts associated with the Proposed Action.

- Update of the cumulative impacts analysis of Inventory Modules 1 and 2 to account for potential environmental impacts associated with the GNEP program.

- Addition of a list of interagency and intergovernmental interactions related to this Repository SEIS.

S.4 Potential Environmental Impacts of the Proposed Action

The discussion of potential impacts of the Proposed Action in this Repository SEIS summarizes, incorporates by reference, and/or updates corresponding sections of the Yucca Mountain FEIS, as appropriate. The SEIS explains where and why DOE has modified its analytic approach or assumptions and where it has updated information.

To assess potential impacts, DOE assessed baseline conditions that the repository design and operational plans for a repository could affect. DOE organized its assessment around 12 resource areas that include features of the natural environment and matters of social, cultural, and economic concern. For each resource area, DOE defined a region of influence in which impacts could occur as a geographic area that encompasses the environmental, social, cultural, and economic features of interest. Regions of influence vary considerably to account for the different nature of the various resources.

DOE used the following timeframes to assess impacts:

- Preclosure or short-term impacts would encompass construction, operations, monitoring, and closure.

- Postclosure or long-term impacts would occur after closure was complete. This Repository SEIS analyzes health effects for two periods: the period during the first 10,000 years after closure and the period from 10,000 years after closure to 1 million years after closure (the post-10,000-year period). The term "period of geologic stability" refers to the period of up to 1 million years after disposal.

DOE has characterized potential impacts as direct or indirect, and has quantified them where possible. Otherwise, DOE has provided qualitative assessments with these descriptors:

- Small. Environmental effects would not be detectable or would be so minor that they would not destabilize or noticeably alter any important attribute of the resource.
- Moderate. Environmental effects would noticeably alter but not destabilize important attributes.
- Large. Environmental effects would be clearly noticeable and would destabilize important attributes.

The potential impacts reported in this Repository SEIS are likely to be higher than the actual impacts for several reasons. For example, DOE did not take into consideration best management practices for dust suppression in the analyses for air quality, and did not take credit for proven remediation and reclamation techniques in the disturbed land analysis. Similarly, in the estimation of potential health effects in the preclosure period, DOE did not apply administrative restrictions for limiting radiological exposure in calculating potential doses to the hypothetical maximally exposed worker, who would handle spent nuclear fuel at the repository surface for an entire working lifetime of up to 50 years. Further, DOE

assumed that the hypothetical maximally exposed member of the public would reside continuously for 70 years at the site boundary in the prevailing downwind direction. In the postclosure period, DOE assumed that the reasonably maximally exposed individual (who is a hypothetical individual with characteristics defined by 40 CFR Part 197) would live above the highest concentration of radionuclides in the plume of groundwater contamination, drink 2 liters (0.5 gallon) of water per day drawn from contaminated groundwater, and carry on a lifestyle that would maximize exposure.

S.4.1 POTENTIAL PRECLOSURE IMPACTS OF THE REPOSITORY

S.4.1.1 Land Use and Ownership

To develop a repository at Yucca Mountain, DOE would have to obtain permanent control of the geologic repository operations area, currently under the control of DOE (National Nuclear Security Administration), the U.S. Department of Defense (U.S. Air Force), and the U.S. Department of the Interior (Bureau of Land Management). This would require congressional action. The geologic repository operations area would occupy a small portion of a larger area (230 square miles or approximately 150,000 acres) which would include a buffer zone. Because Congress has not withdrawn this land, this Repository SEIS refers to the 230 square miles as the analyzed land withdrawal area.

To analyze potential impacts on land use and ownership, DOE defined the region of influence as the analyzed land withdrawal area (Figure S-2) and an area to the south that DOE proposes to use for offsite facilities and a new access road from U.S. Highway 95 to the Yucca Mountain site.

The Bureau of Land Management now administers approximately 180 square kilometers (44,000 acres) of the analyzed land withdrawal area. With the exception of about 17.2 square kilometers (4,300 acres) near the site of the proposed repository and an existing patented mining claim on private land, these lands are available for public uses such as mineral exploration and recreation. Congress granted these rights under various federal laws, such as the *Federal Land Policy and Management Act of 1976*.

To construct, operate, and monitor the repository, DOE would disturb or clear a total of approximately 9 square kilometers (2,200 acres) of land, inside and outside the analyzed land withdrawal area. Overall, impacts on land use would be small. During repository closure, DOE would restore disturbed areas that were no longer needed to their approximate condition before construction.

S.4.1.2 Air Quality

DOE analyzed potential impacts to the public from releases of nonradiological air pollutants. Air pollutants were assessed against the EPA National Ambient Air Quality Standards, which define permissible average and maximum concentration levels of pollutants for periods ranging from 1 hour to a year. DOE evaluated impacts for maximally exposed individual members of the public at the nearest points of unrestricted public access outside the analyzed land withdrawal area. Its analysis examined five criteria pollutants—carbon monoxide, nitrogen dioxide, sulfur dioxide, ozone, and particulate matter (PM), for which EPA defines two particle sizes: $PM_{2.5}$, which has an aerodynamic diameter of 2.5 micrometers or less, and PM_{10}, which has an aerodynamic diameter of 10 micrometers or less. Fugitive dust from land disturbances contains PM_{10}. DOE would use common dust suppression measures to reduce releases, but did not take credit for these actions in the analyses.

DOE also analyzed potential impacts of cristobalite, a form of silica dust that causes silicosis and might be carcinogenic. Cristobalite would be emitted during subsurface excavation in fugitive dust. The highest level that would reach a member of the public would be only 0.5 percent of the benchmark DOE used in its analysis.

In all cases, the highest concentrations of criteria pollutants except PM_{10} would be less than 3 percent of applicable standards. The highest concentrations of PM_{10} from activities in the analyzed land withdrawal area would be 40 percent of the 24-hour regulatory limit during construction. Most air quality impacts would result from construction.

This Final Repository SEIS includes an assessment of the potential impacts from greenhouse gases that would be released as a result of the Proposed Action. The burning of fossil fuels such as diesel and gasoline emits greenhouse gases, primarily carbon dioxide. Greenhouse gases can trap heat in the atmosphere and have been associated with global climate change. Unlike criteria pollutants, impacts of greenhouse gas emissions are global in nature; thus, greenhouse gas emissions from the Proposed Action would add a small increment to other greenhouse gas emissions, contributing cumulatively to these emissions. However, DOE is not aware of any methodology to correlate the emissions from the Proposed Action to any specific impact of global climate change. For perspective, this Repository SEIS reports that the maximum amount of annual carbon dioxide emissions from the Proposed Action would be less than 0.15 percent of the reported releases in the State of Nevada in 2004.

S.4.1.3 Hydrology

This Repository SEIS identifies and evaluates potential surface- and groundwater impacts separately, as the Yucca Mountain FEIS did. The regions of influence and criteria for evaluating impacts are the same as those in the FEIS.

S.4.1.3.1 *Surface Water*

The region of influence includes construction and operations sites susceptible to erosion, areas that could be affected by permanent changes in water flow near these sites, and downstream areas that could be affected by eroded soil or spills of contaminants. There are no perennial streams or other permanent surface-water bodies in the region of influence, and precipitation and runoff are seldom sufficient to generate flowing water in drainage channels.

During all project phases, the potential for uncontrolled or contaminated discharges to the surface would be small. DOE would store water in tanks and would pipe sanitary sewage to septic tanks and leach fields. Water used for other purposes would be collected after use and pumped to lined evaporation ponds. Water used for dust suppression would not produce runoff or infiltration. DOE would manage water contaminated with radionuclides as low-level radioactive waste. Throughout the project, DOE would manage potential contaminants in compliance with regulatory requirements and its *Spill Prevention, Control, and Countermeasures Plan for Site Activities*, and would monitor to detect contaminants.

Repository-related activities would disturb as much as 9 square kilometers (2,200 acres) of land. Because DOE would compact many surface areas or cover them with impermeable materials, infiltration rates would generally decline and surface-water runoff would increase. The increased runoff that reached

drainage channels would be small and have negligible impacts, primarily because stormwater detention ponds would be integral to repository design. Moreover, the total land disturbed would constitute only around 1 percent of the natural drainage area in which it would lie, and the drainage channels are so remote that minor changes in runoff could not affect downstream facilities.

S.4.1.3.2 *Groundwater*

A supply of groundwater would be essential to repository construction and operation. DOE would use most of the water to compact surface soil and suppress dust and for subsurface development. The region of influence for groundwater includes aquifers from which DOE could obtain water and the downstream aquifers that DOE's use of water could affect. The Yucca Mountain FEIS summarized DOE's efforts to obtain water rights from the State of Nevada to meet projected water needs. DOE is currently engaged in litigation with the State of Nevada with regard to these water rights.

DOE would track the volume of water it pumped to the subsurface for dust suppression and tunnel boring, and would collect the excess water and remove it. Water pumped to the subsurface probably would have little effect on aquifer recharge. No additional land disturbance would occur during monitoring, maintenance, or closure, so further effects on infiltration rates would be unlikely. Soil reclamation and revegetation would accelerate a return to more natural infiltration conditions. Overall, repository construction and operations would result in minor changes to runoff and infiltration rates.

DOE would pump groundwater from wells in the Jackass Flats hydrographic area. Groundwater from that area flows into Amargosa Desert aquifers. Because those aquifers meet most of the regional water demand, the potential effects of DOE groundwater use on this downgradient use is of particular concern.

Figure S-10 shows that water demand for the Proposed Action would peak during initial construction. The Nevada Test Site would require groundwater from Jackass Flats wells during the same period; for the peak demand years, the estimated additional demand from the Test Site would be 83,000 cubic meters (67 acre-feet). Figure S-10 does not show the Test Site use, but DOE analyzed the combined impacts and concluded in this Repository SEIS that they would not noticeably affect nearby groundwater users.

Perennial yield is the estimated quantity of groundwater that can be withdrawn annually from a basin without depleting its aquifers. The State of Nevada uses estimates of perennial yield as one of several tools in evaluating requests for groundwater appropriations. DOE's analysis focused on the following hydrographic areas:

- Jackass Flats. Estimates of perennial yield in groundwater studies and the Nevada State Engineer's rulings range from 1.1 million to 4.9 million cubic meters (880 to 4,000 acre-feet), depending on assumptions about aquifer flow characteristics. In a conservative scenario, DOE's water demand is compared with the lowest estimate of perennial yield. This low estimate can be further reduced by attributing 720,000 cubic meters (580 acre-feet) to the western two-thirds of this hydrographic area where DOE's wells are located. Peak annual demand would be below the lowest estimates of perennial yield. Adding annual demand for the Nevada Test Site activities in the same hydrographic area would still result in groundwater withdrawals below the lowest estimate, and this total represents only 13 percent of the highest estimate. If demand exceeded local recharge for a few years (longer durations would be unlikely), general flow patterns in the area could shift, but only slightly.

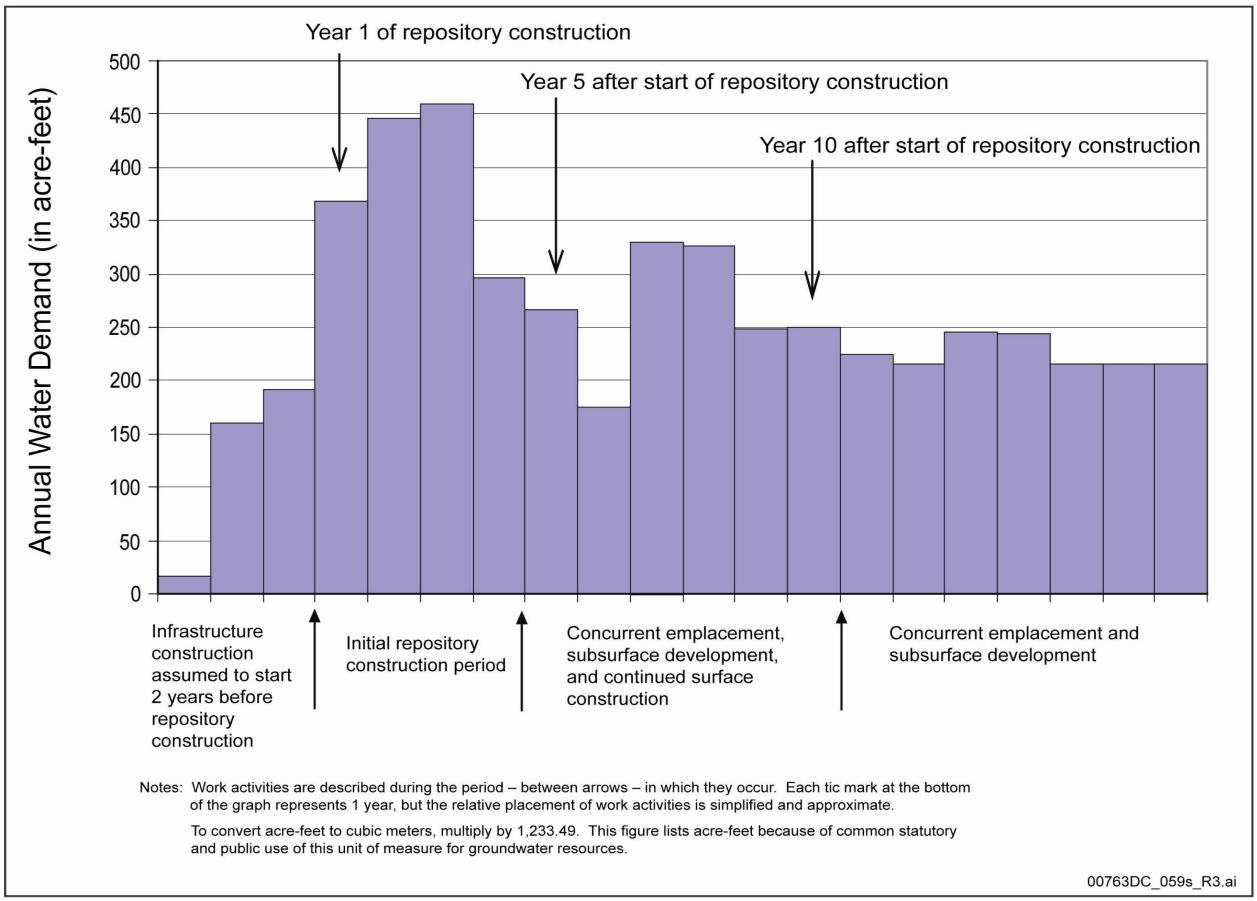


Figure S-10. Annual water demand during the repository construction period and the initial phases of operations.

- Amargosa Desert. While water demand would decrease the availability of water in this downgradient area, the combined peak annual demand for the Proposed Action and the Nevada Test Site would be only about 4 percent of the average annual water pumped in the Amargosa Desert from 2000 to 2004, and an even smaller fraction of the estimated perennial yield for the Amargosa Desert. In recent years, groundwater in the Amargosa Desert has been over-appropriated compared with many estimates of perennial yield, but the amount actually withdrawn each year has averaged only about half of the total appropriations. If, however, spring discharges in the Ash Meadows area were combined with groundwater withdrawals, lower estimates of perennial yield in Amargosa Desert would be exceeded.

The Yucca Mountain FEIS described modeling that estimated how DOE's water demand would affect groundwater elevations and flow patterns. DOE's current projections of annual demand peaks for 2 years at quantities above the long-term withdrawal rate assumed by those models, but averages below the assumed rate so the models' predicted results remain very conservative. Water demand for the Proposed Action and Nevada Test Site activities in Jackass Flats together would have, at most, small impacts on the availability of groundwater in the Amargosa Desert area compared with the quantities already being withdrawn there.

S.4.1.4 Biological Resources and Soils

S.4.1.4.1 *Biological Resources*

Biological resources include species that are typical of the Mojave and Great Basin deserts and generally common throughout those areas. DOE evaluated the potential for impacts to sensitive, threatened, or endangered species and their habitats. DOE also considered potential impacts to the migratory patterns and populations of game animals. Overall impacts would be small. The removal of vegetation from the area required for the repository and the small impacts to some wildlife species from disturbance or loss of individuals would not affect regional biodiversity and ecosystem function.

Impacts to vegetation from repository construction would occur as a result of direct disturbance. Repository-related activities have disturbed approximately 2.5 square kilometers (620 acres) and would disturb as much as 6.5 more square kilometers (1,600 acres). Construction could induce further colonization by invasive plant species already present, which could suppress native species and increase the fire-fuel load. However, because the vegetated area that would be disturbed is relatively small, and because DOE would reclaim areas no longer in use, impacts would be small.

Direct impacts to wildlife would occur through loss of habitat from construction; deaths of individuals of some species, particularly burrowing species of small mammals and reptiles, and deaths of individuals hit by vehicles; fragmentation of undisturbed habitat that created a barrier to wildlife movement; and displacement of wildlife because of noise and activity. Impacts would be small for many reasons. Habitats similar to those at Yucca Mountain are widespread locally and regionally. The animal species of concern are generally widespread in the region, and the impact of individual deaths on regional populations or biodiversity would be small. Large areas of undisturbed and unfragmented habitat would remain available. Impacts from noise and vibration would decline with distance, and some species would acclimate to the noise. No species would be threatened with extinction locally or regionally.

The Mojave population of the desert tortoise is listed as threatened under the *Endangered Species Act*. Construction would result in the loss of a small portion of tortoise habitat in an area where tortoise density is already low. DOE has had success relocating tortoises and their nests to safer terrain. Based on past experience, DOE estimates that the number of tortoises killed by vehicles and construction would be small and would not affect the species' long-term survival locally or regionally. As required by the *Endangered Species Act*, DOE has consulted with the U.S. Fish and Wildlife Service to ensure that the project's effects on the desert tortoise are minimized. This consultation would continue.

S.4.1.4.2 *Soils*

During construction, disturbing the land would make soil more susceptible to wind and water erosion. Because natural succession is slow on disturbed desert soils, recovery would require reclamation. Continuing its current reclamation program, DOE would stockpile the topsoil it removed during excavation. It would use fugitive dust control measures to protect the stockpile from wind erosion. Minimizing the extent of areas disturbed and using engineering practices to stabilize them would minimize erosion. During closure, DOE would revegetate, as practicable, areas it had not already reclaimed to reduce the loss of the most critical types of topsoil. Based on past experience, DOE expects little erosion during any project phase.

Spills or releases of contaminants could occur, but DOE's continued implementation of its *Spill Prevention, Control, and Countermeasures Plan for Site Activities* would prevent, control, and remediate soil contamination. DOE would train workers to manage hazardous materials. Fueling operations and storage of hazardous materials and other chemicals would take place in bermed areas away from floodplains.

S.4.1.5 Cultural Resources

Cultural resources are nonrenewable, and the values they represent could be diminished by physical disturbance. This Repository SEIS evaluates the potential for damage or modification to the character of archaeological and historic sites and other cultural resources, with particular emphasis on those important to sustaining and preserving American Indian cultures. Overall, impacts to cultural resources would be small.

Direct impacts could result from ground disturbances and activities that would destroy or modify the integrity of archaeological or cultural resource sites. Indirect impacts could result from activities that increased the potential for intentional or unintentional adverse impacts, for example illicit collection or inadvertent destruction. Although some indirect impacts could occur, the repository project's overall long-term effect would be beneficial because limits on access to and uses of the analyzed land withdrawal area would protect cultural resources from most human intrusion.

Because DOE would strive to avoid archaeological resources and would mitigate impacts to them, direct adverse impacts would be small. While easier physical access to the land withdrawal area could result in unauthorized excavation and collection of artifacts, DOE would mitigate such indirect impacts by training workers, monitoring archaeological sites, and establishing long-term management of the sites.

DOE, the Advisory Council on Historic Preservation, and the Nevada State Historic Preservation Officer have prepared a programmatic agreement to manage cultural resources during characterization of the Yucca Mountain site. The agreement is undergoing revision as part of negotiations with the State Historic Preservation Office. DOE will continue to work under the current agreement until a new one is in place.

S.4.1.5.1 *American Indian Viewpoint*

The Yucca Mountain FEIS summarized the American Indian view of resource management and preservation. Holistic in its concept of cultural resources, that view integrates elements of the natural and physical environment into a unified value system. To enhance the protection of archaeological sites and cultural items important to American Indians, DOE would maintain its commitment to its Native American Interaction Program throughout the implementation of the Proposed Action.

Because American Indians regard Yucca Mountain as integral to a valued cultural landscape, they consider the repository program to be intrusive and to constitute an adverse impact. Meetings with the Consolidated Group of Tribes and Organizations held since the completion of the Yucca Mountain FEIS indicate that this viewpoint has not changed.

S.4.1.6 Socioeconomics

DOE evaluated how the Proposed Action could affect employment, population, economic measures (real personal disposable income, spending by state and local governments, and Gross Regional Product), housing, and some public services. The operations period would result in the highest impacts to employment, population, Gross Regional Product, real disposable personal income, and government spending.

DOE's analysis of impacts on employment is inherently complex. For example, it must discriminate between new workers and those who are already part of the employment baseline, and between total employment and incremental additions, and it must make assumptions about how many workers will in-migrate to work at the repository and how many already reside locally. However, impacts to employment in Clark and Nye counties from repository-related construction and operations would be small. The number of jobs created directly and indirectly would peak in 2021 in both counties at around 1,300, a 0.09-percent increase above the projected employment baseline for that year. Indirect jobs would result from project expenditures, such as procurement of goods and services, and personal expenditures by directly employed workers.

DOE used the Regional Economic Models, Inc. (REMI) model, *Policy Insight,* and State of Nevada Demographer data to project that regional population would grow steadily from about 2.48 million residents in 2012 to about 5.13 million in 2067. The peak year contribution due to project workers and their households, in 2035, would be about 2,280 people, or about 0.06 percent of the 3.63-million-person baseline. In general, increases in population occur several years after increases in employment because some workers delay relocation. Based on historical data, DOE assumes that 80 percent of the construction and operations workforce would live in Clark County and 20 percent would live in Nye County.

The proposed repository would increase real disposable personal income, spending by state and local government, and Gross Regional Product by less than one-tenth of 1 percent over projected regional baselines, in 2006 dollars. Gross Regional Product would peak in 2034 because of consumption of goods and services due to construction. The estimated increase would be about $168 million or 0.08 percent of the baseline, with about $98.7 million spent in Clark County and $68.9 million in Nye County.

DOE analyzed potential impacts to housing only at the county level because demand at the community level is inherently hard to predict. The increase in population due to the repository would occur over a long period and the housing market could readily respond. Given the region's large housing inventory, baseline population growth would mask changes due to the repository. Impacts would be more pronounced in Nye County, particularly in Pahrump, where recent growth has been rapid and largely unanticipated and unmanaged, the housing stock is limited, and much of the infrastructure to support housing development is at capacity.

Impacts to services such as schools, police and fire protection, and medical services would be small because repository-related population changes would be a small fraction of population growth in the region. Because most in-migrating workers would probably live in the many communities of metropolitan Clark County, their demand for public services would be dispersed.

In southern Nye County, particularly Pahrump, public services are currently at capacity, and the county is medically underserved. Because population changes would occur steadily over a long period, the county would be able to meet increased demands on services as its revenue base grew. Pahrump's new hospital and the ample medical services in the metropolitan Las Vegas area would help meet the need for medical services.

S.4.1.7 Health and Safety of Workers and the Public

The design of the repository is based on multiple safety principles and on proven nuclear industry precedent. Facility components are designed with robust margins, and they employ diverse and redundant systems. Mechanical handling, shielding, and related safety equipment are based on proven technology. The safety philosophy is based on design approaches and features for the prevention of events rather than consequence mitigation or administrative controls, on passive features rather than active features, and on automatic initiation rather than manual initiation of control.

The results of the preclosure safety analyses confirm that the Yucca Mountain site characteristics combined with the repository design provide an inherently safe facility that meets the preclosure performance objectives with substantial margin.

DOE estimated health and safety impacts to workers and to members of the public for each repository analytical period.

S.4.1.7.1 *Nonradiological Impacts*

Impacts to workers could include those from common industrial hazards, naturally occurring nonradioactive airborne hazardous materials, and unexploded ordnance. To estimate the impacts of industrial hazards for this Repository SEIS, DOE used the methods and the data source it had used in the Yucca Mountain FEIS. The data source is the DOE Computerized Accident/Incident Reporting System (CAIRS). A compilation of data from DOE and DOE contractor operations, CAIRS contains annual numbers of total recordable cases and lost workday cases and the incidence rates per 100 full-time equivalent worker years. It also contains the annual number of total fatalities, which is used to calculate the fatality incident rate per 100,000 worker years. DOE applied these incident rates to estimate impacts to repository workers from industrial hazards.

Throughout the project, workers and the public could be exposed to naturally occurring cristobalite, a form of silica in rock that, as dust, causes silicosis and might be carcinogenic, and erionite, an uncommon zeolite mineral that forms wool-like fibrous masses and can be inhaled as dust. This Repository SEIS estimated that public exposures to cristobalite and public and worker exposures to erionite would be very small.

The project would last 105 years. DOE calculated total impacts to workers from industrial hazards for the entire project. For all workers, this SEIS estimated 1,800 total recordable cases, 800 lost workday cases, and less than 1 fatality.

S.4.1.7.2 *Radiological Impacts*

Since it completed the Yucca Mountain FEIS, DOE has modified its analysis of radiological impacts. The primary modifications include:

- Population distribution data. DOE assumes operations would start in 2017 and last for as many as 50 years, so its analysis uses population projections updated to 2067. This is in contrast to the FEIS's population projections to the year 2035.

- Updated latent cancer fatality conversion factors. Measures of latent cancer fatality express the risk that a given dose of radiation would produce an additional cancer in an exposed population. To reflect current DOE guidance for converting worker and public doses to health effects, DOE used a conversion factor of 0.0006 latent cancer fatality per person-rem. The Yucca Mountain FEIS used two different latent cancer fatality conversion factors: for workers, 0.0004 per person-rem, and for the public, 0.0005 per person-rem. This would result in a 50-percent and 20-percent impact increase from the FEIS for workers and the public, respectively, for the same radiation dose.

POPULATION DOSE AND FUTURE POPULATION SIZE

Population dose is a summation of the doses received by individuals in an exposed population (the unit of measure is person-rem). The population dose depends on the number of people at a given location. If the number increases, the population dose estimate does, too. The individual dose remains the same.

Construction of subsurface facilities would begin at the same time as construction of surface facilities. Disturbance of rock would result in releases of naturally occurring radon-222 and its decay products, which subsurface exhaust ventilation would pump to the surface. Throughout the project, workers and members of the public would be exposed to these releases. They could also be exposed to releases from radioactive materials at the site during the operations analytical period.

In the analysis of radiological impacts, this Repository SEIS calculates an annual dose to an individual or to a population and converts these doses to probabilities of latent cancer fatalities to express potential health effects. The impact for maximally exposed workers and offsite individuals is measured by the increase in the probability of a latent cancer fatality. For exposed populations, it is the estimated number of latent cancer fatalities in that population that would result from the collective doses.

For workers, DOE estimated doses for maximally exposed involved workers and worker populations. About 80 percent of the doses to workers would occur during operations, principally from surface handling of spent nuclear fuel and subsurface monitoring and maintenance activities. The maximally exposed worker is modeled as a cask operator who handled spent nuclear fuel at the surface and whose entire working lifetime spanned the 50-year operations period (an unlikely, and therefore conservative, assumption). The dose to that worker over a 50-year period without administrative limits would be about 30 rem, with an increase in latent cancer fatality risk of about 0.02. The total number of latent cancer fatalities for workers over the course of 105 years (project lifetime) would be about 4. DOE expects that workers would receive a dose much below that estimated in this Repository SEIS, in keeping with DOE's administrative limits for annual exposure, safety goals and practices, and experience with radioactive material handling at existing DOE facilities.

For the public, DOE estimated impacts to the maximally exposed offsite individual who would reside continuously for 70 years at the site boundary in the prevailing downwind direction. About 99.8 percent of the impact would be from exposure to airborne radon-222 and its decay products. The increase in probability of a latent cancer fatality during the preclosure period would be about 3 in 10,000. The highest annual dose would be 7.6 millirem, less than 4 percent of the annual average 200-millirem dose to members of the public from ambient levels of radon-222 and its decay products.

Over 105 years, the collective dose for the population within 84 kilometers (52 miles) would be 13,000 person-rem. This dose can be compared with 2.5 million person-rem the same population would receive from ambient levels of naturally occurring radon-222 and its decay products (not attributable to the repository). The estimated health effects from this additional exposure to radioactivity would be 8 latent cancer fatalities.

S.4.1.8 Accidents and Sabotage Events

S.4.1.8.1 *Accidents*

DOE estimated impacts from reasonably foreseeable accidents for (1) the maximally exposed offsite individual (an individual at the analyzed land withdrawal boundary who would receive the largest radiation dose from the accident), (2) the noninvolved worker [a worker 60 meters (200 feet) from the point of release from the accident], and (3) members of the public residing within 84 kilometers (52 miles) of the repository. Because waste handling operations would be performed remotely, involved workers would be in enclosed facility operating rooms isolated from the waste. Doses to the noninvolved worker could be as high as 3.5 rem. Impacts to offsite individuals from repository accidents would be small, with calculated doses of 35 millirem or less to the maximally exposed individual.

Since DOE completed the Yucca Mountain FEIS, it has acquired new information and analytical tools that contribute to the understanding of potential impacts of accidents. For this Repository SEIS, DOE has applied them to the evaluation of the accident scenarios.

With the repository design and operational plans as its starting points, DOE considered external and internal events that could initiate accidents. External events would originate outside the repository 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 events would originate in the repository and would include human errors, equipment failures, or a combination of these factors.

DOE defined various accident scenarios that entail drops and collisions involving shipping casks, TAD canisters, dual-purpose canisters, and uncanistered fuel assemblies; a fire that involved low-level radioactive waste and a transportation cask on a truck; and a seismic event. The analysis presents consequences for average and unfavorable meteorological conditions (which would be exceeded only 5 percent of the time).

The accident scenario with the highest consequences would involve a seismic event that caused the release of radioactive material from high-efficiency particulate air filters, ducts, and low-level radioactive waste. Potential impacts to the offsite population would be less than 1 additional latent cancer fatality (0.19) in a population of approximately 104,000 in the south-southeast direction within an 84-kilometer (52-mile) radius of the site. The maximum dose to workers could be 3.5 rem, which could result in an increased latent cancer fatality risk of 0.0021.

S.4.1.8.2 *Sabotage Events*

In response to the terrorist attacks of September 11, 2001, and to intelligence information that has been obtained since then, the U.S. Government has initiated nationwide measures to reduce the threat of

sabotage. These measures include security enhancements intended to prevent terrorists from gaining control of commercial aircraft.

Over the long term (after closure), deep geologic disposal of spent nuclear fuel and high-level radioactive waste would provide optimal security by emplacing the material in a geologic formation that would provide protection from inadvertent and intentional human intrusion, including potential terrorist activities. The use of robust metal waste packages to contain the spent nuclear fuel and high-level waste at least 200 meters (700 feet) below the surface would offer significant impediments to any attempt to retrieve or otherwise disturb the emplaced materials.

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

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

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

Whether acts of sabotage or terrorism would occur, and the exact nature and location of the events, or the magnitude of the consequences of such acts if they were to occur is inherently uncertain—the possibilities are infinite. Nevertheless, in response to public comments and to evaluate a scenario that would approximate the consequences of a major sabotage event, DOE analyzed a hypothetical scenario in which a large commercial jet aircraft crashed into and penetrated the repository facility with the largest inventory of radioactive material vulnerable to damage from such an event.

The analysis conservatively estimated (that is, tended to overstate the risk) that the aircraft impact would compromise the confining capability of the building, and the resulting fire would convert 42 spent nuclear fuel assemblies to an oxide powder. The results of this analysis indicate that the maximally exposed offsite individual could receive a dose of 3.0 rem, resulting in an estimated likelihood of a latent cancer fatality of 0.0018, and the offsite public in the highest population sector (south-southeast), which in 2067 would consist of an estimated 104,000 individuals, could receive a collective dose of 9,900 person-rem for average weather conditions, resulting in an estimated 5.9 latent cancer fatalities.

S.4.1.9 Noise

The region of influence for noise includes the Yucca Mountain site and existing and future residences south of the analyzed land withdrawal area. Sources of noise during construction would be heavy equipment, ventilation fans, and diesel generators. Sources during operations and monitoring would include diesel generators, cooling towers, ventilation fans, air conditioners, and concrete batch plant activities. Ventilation fans would have suppressors to maintain noise levels below 85 A-weighted decibels (dBA). The National Institute for Occupational Safety and Health and the American Conference of Governmental Industrial Hygienists both recommend an exposure limit of 85 dBA for an 8-hour exposure. Because the distance between repository noise sources and an individual at the boundary of the analyzed land withdrawal area would be great enough to reduce noise to background levels or below, and because there would be no residential or community receptors at the boundary, DOE expects no noise impacts to the public.

At times, workers at the repository site would be exposed to elevated levels of noise. DOE would use engineering controls to control noise levels and worker exposures, so impacts such as hearing loss would be unlikely. Workers would use personal hearing protection as necessary.

Sources of offsite noise would include construction of the access road from U.S. Highway 95 and facilities south of the Yucca Mountain site near Gate 510. Typical construction equipment would intermittently generate noise levels of about 85 dBA at 15 meters (50 feet). Because of the distance between construction activities and potential receptors and the temporary and intermittent nature of construction noise, DOE does not expect noise impacts to the public. Traffic on the access road would not significantly add to existing noise on U.S. Highway 95. Noise from offsite facilities would be typical of commercial environments and would not cause impacts.

S.4.1.10 Aesthetics

DOE's analysis of aesthetic impacts considered the natural and manmade physical features that give a particular landscape its character and value, specifically scenic quality, visual sensitivity, and distance from observation points.

From publicly accessible locations, visibility of Yucca Mountain is limited. DOE identified two general locations from which the public could see repository facilities. One is approximately 22 kilometers (14 miles) to the south of the repository, near the intersection of Nevada State Route 373 and U.S. Highway 95. The other is west of the repository. From the latter location, repository ventilation exhaust stacks could be visible.

The low elevation of the southern end of Yucca Mountain and Busted Butte would obscure the view of repository facilities from the south, and therefore the repository would cause a weak degree of contrast with the landscape. Exhaust ventilation stacks on the crest of Yucca Mountain would cause a moderate degree of contrast, and American Indians would consider the presence of the stacks an adverse aesthetic impact. Because of the height of the stacks, the U.S. Air Force might require DOE to install flashing beacon lights on top of them. Such beacons could be visible for several miles, especially to the west of Yucca Mountain, but would not be visible from Death Valley National Park.

Construction of the access road from U.S. Highway 95 and of offsite facilities near Gate 510 would be a source of short-term visual impacts. DOE would reclaim disturbed areas when they were no longer needed. Best management practices would ensure that construction created only a weak degree of contrast. When construction was complete, the access road and offsite facilities would cause a weak degree of contrast.

Closure activities, such as dismantling of facilities and site reclamation, would reduce the repository's visual contrast with the landscape.

S.4.1.11 Utilities, Energy, Materials, and Site Services

DOE calculated its needs for electricity, fossil fuel, oil, lubricants, construction materials, and services such as emergency medical support, fire protection, and security and law enforcement, and compared them with available supplies and capacity.

In general, quantities of utilities, energy, and materials the project would use would be small in comparison with the regional supply capacity and would be unlikely to affect regional supplies or prices. A major reason is that the repository schedule would extend over decades.

As its repository program proceeded, DOE would examine how it could modify its engineering, construction, and operational plans to take advantage of emerging green technologies to reduce its consumption of nonrenewable resources, including fossil fuels.

S.4.1.12 Repository-Generated Waste and Hazardous Materials

Repository construction, operations, monitoring, and closure would generate waste and entail the use of hazardous materials. DOE identified types of waste and hazardous materials and estimated the maximum quantities it would generate for each project period. The types include construction and demolition debris, industrial wastewater, low-level radioactive waste, sanitary sewage, sanitary and industrial waste, and hazardous waste.

DOE could build onsite solid waste facilities to accommodate nonhazardous waste or dispose of such waste at offsite facilities. DOE would manage industrial wastewater with onsite evaporation ponds. DOE would dispose of construction and demolition debris and sanitary and industrial waste either at an onsite landfill or at offsite facilities. Hazardous waste and low-level radioactive waste would be disposed of in offsite facilities. The Department does not anticipate generation of mixed or transuranic waste but, if generation of either type occurred, DOE would dispose of it in an appropriate offsite facility. The impact on offsite disposal facilities of the amounts of waste generated during all project periods would be small because current capacities could readily accommodate estimated quantities. Best management practices would reduce the amount of waste generated.

S.4.1.13 Environmental Justice

As in the Yucca Mountain FEIS, this Repository SEIS does not identify any high and adverse impacts to members of the general public. Further, DOE has not identified subsections of the population, including minority or low-income populations, that would receive disproportionate impacts, and it has identified no unique exposure pathways, sensitivities, or cultural practices that would expose minority or low-income

populations to disproportionately high and adverse impacts. Therefore, this SEIS concludes that no disproportionately high and adverse impacts would result from the Proposed Action.

In the Yucca Mountain FEIS, DOE acknowledged that members of American Indian tribes have used lands around the Yucca Mountain site that contain cultural, animal, and plant resources important to them. The FEIS presented views and beliefs about those lands that tribal members had expressed. DOE continues to recognize that the Proposed Action would conflict with the viewpoint expressed by the American Indian Writers Subgroup in *American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement*.

S.4.2 POTENTIAL POSTCLOSURE IMPACTS OF THE REPOSITORY

S.4.2.1 Analytical Framework and Tools for Assessment

S.4.2.1.1 *The Regulatory Framework*

In 2001, both EPA and NRC adopted public health and safety standards for radioactive materials disposed of in the Yucca Mountain repository based on a dose not to be exceeded for the reasonably maximally exposed individual (RMEI) during the first 10,000 years after disposal.

In 2004, in response to legal challenges, the U.S. Court of Appeals for the District of Columbia Circuit struck down the portions of those standards that required DOE to demonstrate compliance for only 10,000 years following disposal and remanded the provisions to the federal agencies for revision.

WHO AND WHERE IS THE "RMEI"?

A hypothetical "reasonably maximally exposed individual (RMEI)" is defined for the purpose of assessing potential doses that could result from releases of radioactivity from a repository.

Under applicable regulations, the RMEI is located 18 kilometers (11 miles) from the repository.

In 2005, EPA proposed new standards to address the court's decision. The proposed EPA standards incorporate multiple compliance criteria applicable at different times for protection of individuals and the environment, and in circumstances involving human intrusion into the repository. Because the *Energy Policy Act of 1992* requires the NRC to modify its technical requirements for licensing of the Yucca Mountain repository to be consistent with the standards promulgated by EPA, the NRC also proposed new standards in 2005 to implement the proposed EPA standards.

To obtain NRC authorization to construct the Yucca Mountain Repository, DOE must demonstrate that the proposed repository meets the regulatory individual radiation protection standards set by EPA and the NRC. Under the existing standards, estimated repository performance will be compared with a mean annual dose of 15 millirem for the first 10,000 years after closure. Under the proposed standards, estimated repository performance will be compared with a median annual dose of 350 millirem for the post-10,000-year period. In this Repository SEIS, comparison with the existing and proposed standards is intended to provide a perspective on potential health impacts.

S.4.2.1.2 *Estimating Repository Performance in the Postclosure Period*

DOE estimates postclosure repository performance by means of probabilistic modeling in computer simulations using numerical data. The model that DOE has developed to estimate repository performance after closure is called the TSPA. The version of the model used to calculate postclosure repository

performance in this Repository SEIS is the same as that used to calculate postclosure repository performance for DOE's application to the NRC for construction authorization, and is referred to as the TSPA-LA. The TSPA-LA reflects modifications made to repository design since the completion of the Yucca Mountain FEIS, the acquisition of more scientific data, and the refinement of the TSPA model, which serve to reduce further the levels of uncertainty associated with assessments of postclosure repository performance.

WHY 10,000 YEARS AND 1 MILLION YEARS?

The TSPA-LA model provides estimates of potential radiological impacts (doses) for two periods: the estimated dose at times up to 10,000 years after closure and a dose at times after 10,000 years and up to 1 million years after closure. The TSPA-LA model assessed annual individual doses in each of these periods.

DOE could have performed the analyses for this Repository SEIS for any number of periods. So why these two? The main reason is that Environmental Protection Agency and Nuclear Regulatory Commission (NRC) have existing and proposed dose limits for the annual individual dose in each period. While these dose limits will provide a regulatory limit against which NRC could evaluate DOE's application for construction authorization, they also provide a context in which to consider the potential environmental impacts of the Proposed Action.

The results of assessments of postclosure repository performance for this Repository SEIS and those of the Yucca Mountain FEIS are different. The differences are due to the use in this Repository SEIS of a TSPA model that is consistent with proposed EPA standards, as well as to the incorporation of additional data and enhancements in the description of engineered and natural components. In addition, the TSPAs for the Yucca Mountain FEIS and the Repository SEIS used different representations for earthquakes, climate change, and volcanism. As a result of these differences, several qualitative observations can be made about the FEIS results.

- The FEIS described future climates in terms of discrete alternating climate states with a precise timing of climate change. The spikes in the dose curves in the FEIS (for example, FEIS, page 5-26, Figure 5-4) result from imposed climate changes at fixed times and assumed percolation fluxes. These spikes are responsible for the maximum levels of the individual dose. The proposed EPA standards require DOE to represent long-term climate using a probabilistic distribution for a constant-in-time but uncertain long-term average climate for Yucca Mountain specified by the NRC. Inclusion of these changes in the FEIS would have resulted in a significant lowering of the projected dose values.

- The proposed EPA standards require DOE to use revised International Commission on Radiation Protection weighting factors for calculation of individual doses. In general, biosphere dose conversion factors for actinides are lower, whereas biosphere dose conversion factors for fission products are higher. Actinides were the dominant contributors to dose in the FEIS. Notably, the biosphere dose conversion factors for neptunium, which was the dominant nuclide contributing to doses in the FEIS, decreased by approximately 80 percent from the FEIS to the SEIS with the Commission's revisions. Sensitivity studies referenced in the FEIS (FEIS page 5-31) indicate that dose estimates would be significantly lower if DOE applied the revised Commission methods.

COMPARISON OF DOSES IN THE YUCCA MOUNTAIN FEIS AND IN THIS REPOSITORY SEIS

For the post-10,000-year period, the maximum mean annual individual dose reported in the Yucca Mountain FEIS was 154 millirem per year, while the maximum mean annual individual dose reported in the Repository SEIS is 2.0 millirem per year. Any comparison of these two numbers must take into account the differences in the modeling that resulted in the two results. Specifically, the modeling for this Repository SEIS reflects regulatory direction in the proposed U.S. Environmental Protection Agency standards, and also reflects U.S. Department of Energy's (DOE) assessment with regard to the appropriate assumptions to use in demonstrating compliance under a reasonable expectation standard. The maximum annual individual dose in this Final Repository SEIS is the same as that submitted to U.S. Nuclear Regulatory Commision (NRC) as part of the application for construction authorization. It should be noted, however, that various elements of DOE's modeling approach may be challenged as part of the NRC licensing process. Depending on the outcome of any such challenges, the maximum annual individual dose ultimately considered by NRC in making its decision to authorize construction may be higher or lower than the maximum annual individual doses reported in the Yucca Mountain FEIS or this Repository SEIS.

- Waste package and drip shield lifetimes are longer in the SEIS. The increase in waste package lifetimes is due in part to the increase in thickness of the Alloy 22 outer barrier to accommodate the TAD canister. Inclusion of temperature dependence of Alloy 22 corrosion rates in the SEIS results in substantially longer waste package lifetimes. Inclusion of new titanium corrosion data in the SEIS results in lower corrosion rates, reduced uncertainty, and longer drip shield lifetimes. Inclusion of these enhanced models in the FEIS would have resulted in a significant lowering of the projected dose values.

DOE has made other refinements to the TSPA model to improve the treatment of uncertainties, incorporate new data and understanding of processes, and reduce conservatism in the projection of repository performance.

S.4.2.1.3 *The Focus of Analyses*

In this Repository SEIS, DOE's analysis examines potential impacts on human health from radioactive and nonradioactive materials (hazardous and carcinogenic chemicals in the engineered barriers) released to the environment, biological and environmental impacts from radiological and chemical groundwater contamination, and biological impacts from heat due to decay of radioactive materials. DOE considered all pathways through which releases could reach human populations. The principal pathways are groundwater, surface water, and the atmosphere.

Radioactive releases and groundwater are of primary concern. Groundwater is of concern because rainwater could migrate into the repository, dissolving or mobilizing material in it and carrying contaminants down through the groundwater system to an aquifer (Figures S-3 and S-11). Through a well or at a surface-water discharge point, humans would draw that water for use as drinking water or for irrigation and watering livestock, through which contaminants could enter the human food chain.

The TSPA-LA evaluates radiological impacts over two timeframes: the first 10,000 years and from 10,000 years up to 1 million years after repository closure. The potential impact is expressed as an estimate of an annual dose to an individual, expressed in millirem. Converting doses to the probability of latent cancer fatalities provides an estimate of health effects.

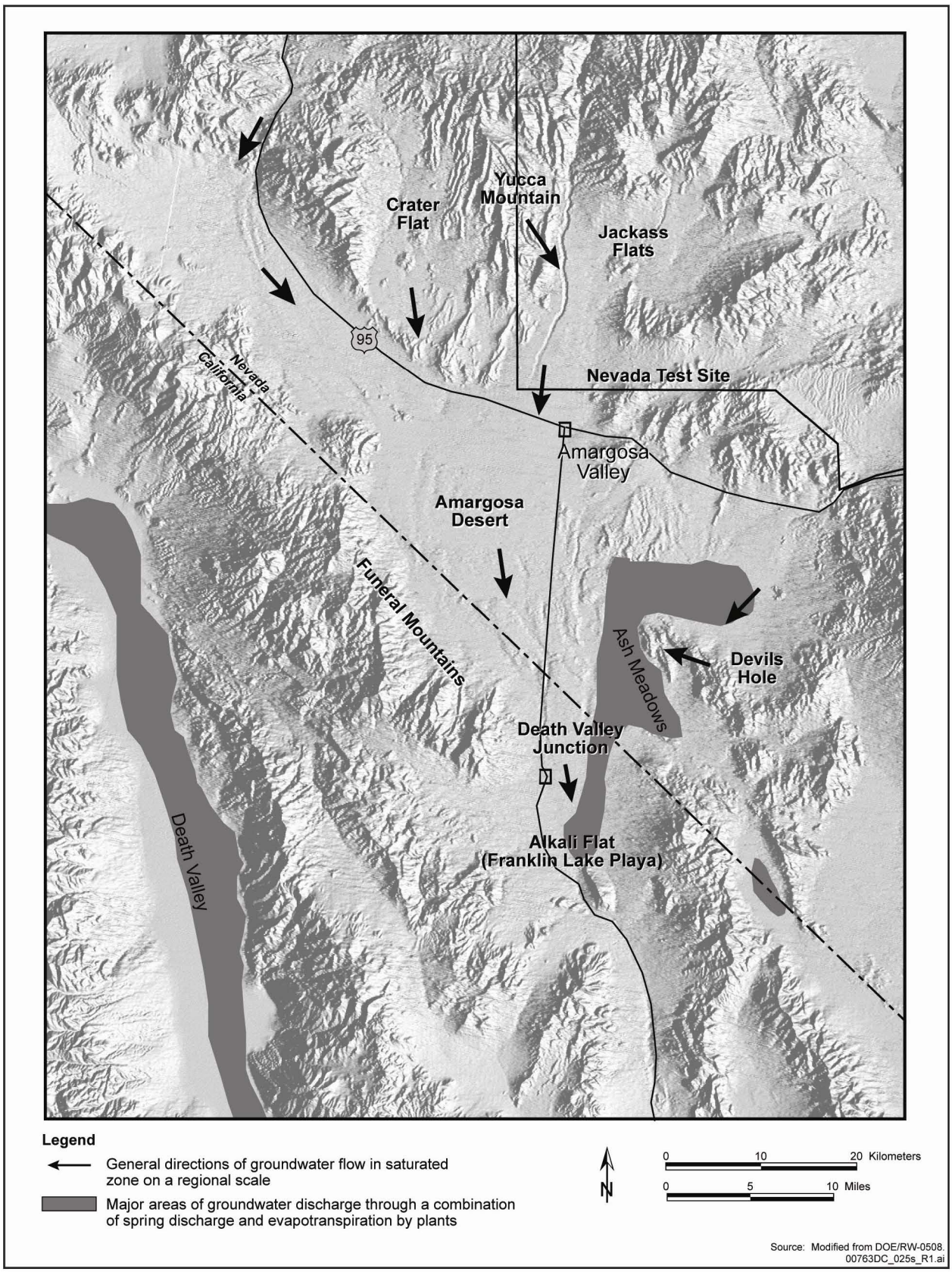


Figure S-11. Map of the saturated groundwater flow system.

The Repository SEIS examines the annual dose to the RMEI at a location 18 kilometers (11 miles) south of Yucca Mountain in the direction of groundwater flow. The RMEI is a hypothetical individual who lives above the highest concentration of radionuclides in the plume of radioactive contamination, drinks 2 liters (0.5 gallon) of water per day from wells drilled into the groundwater at that location, and carries on a lifestyle that maximizes exposure. DOE estimated the annual RMEI dose and groundwater impacts using a representative volume of 3,000 acre-feet (3.7 million cubic meters) of groundwater, consistent with the regulatory requirements applicable to projections of repository performance for Yucca Mountain to calculate the concentration of radionuclides. The TSPA-LA model collected the radionuclides released at a given time and used that number to project the concentration of radionuclides released from the Yucca Mountain disposal system into the representative volume. That concentration of radionuclides is used to determine the annual dose to the RMEI, which is expressed in millirem.

S.4.2.1.4 *The Nature of Analyses*

DOE performed 300 model simulations using TSPA-LA for the RMEI location. The DOE analyses examine the possible effects of "scenario classes" that include such expected processes as corrosion and degradation of waste packages and drip shields, degradation and dissolution of waste forms, flow through the saturated and unsaturated zones, and changing climate. They also consider early waste package and drip shield failure mechanisms, igneous and seismic events, and such disturbances as exploratory drilling and criticality.

The analysis draws from comprehensive data on engineered barriers and studies of the natural features of the site. But many parameters about the latter cannot be exactly quantified or known, and the more complex and variable a system is and the further into the future a forecast extends, the greater the level of uncertainty. DOE uses a variety of analytic techniques to gauge how sensitive end results are to uncertainties and data limitations, and thus how much they matter. Where assumptions must be made, they are generally conservative. DOE also draws upon expert opinion. Its analysis explicitly accounts for uncertainty and expresses results as ranges of potential consequences.

The goal is a cautious but reasonable projection of what might occur. The Repository SEIS explains sources of uncertainty and how DOE handles it in modeling. Continued testing and monitoring at the Yucca Mountain site and analyses of findings in the future will further reduce uncertainty.

S.4.2.2 Postclosure Radiological Impacts

The safe, long-term isolation of nuclear waste in the Yucca Mountain Repository would result from the performance of multiple natural and engineered features of the site and the system, acting in concert, to prevent or delay the transport of radioactive materials to points at which the public could eventually be exposed to them. Each of the barriers in the system would work individually and together to limit the movement of water and the release and movement of radionuclides. Yucca Mountain's geologic and hydrologic characteristics form effective natural barriers to the flow of water and to the potential movement of radionuclides. The underground environment in the natural setting is conducive to the design and construction of components that would prevent or reduce the movement of water or the potential release and transport of radionuclides. The Engineered Barrier System would consist of components designed to function in the natural environment of the unsaturated rock units, and it would use materials chosen to perform their intended functions for many thousands of years. Analyses indicate

that a Yucca Mountain Repository could isolate waste effectively for tens of thousands to hundreds of thousands of years.

CALCULATION OF MEAN, MEDIAN, AND 95TH-PERCENTILE RESULTS

Because of the probabilistic nature of the TSPA results, it is informative to examine the mean and median results, which are measures of central tendencies or average values, and the 95th percentiles, which represent the high extreme values.

DOE selected the Yucca Mountain site and designed the repository to take advantage of the attributes of the natural setting at Yucca Mountain. Because water is the primary medium by which radionuclides could be released from the repository, the beneficial characteristics of the repository primarily relate to the ability of the site and the design to limit the movement of water into and out of repository emplacement drifts. The attributes of the disposal system that are particularly important to postclosure performance include an unsaturated zone and facility design that would limit water entering emplacement drifts, long-lived drip shields and waste packages that would prevent or limit the contact of water and waste, other engineered features that would contribute to limiting radionuclide release, natural features that would delay and reduce the concentration of radionuclides, and a disposal system concept that would result in low mean annual radiological doses even when potentially disruptive events are considered.

The performance analysis for the first 10,000 years after closure indicates that there would be very limited combined releases with small radiological impacts for the total of all scenario classes. For the first 10,000 years after repository closure, the mean annual individual dose would be approximately 0.24 millirem. This is less than 2 percent of the existing EPA standard, which allows up to a 15-millirem annual committed effective dose equivalent during the first 10,000 years.

Analyses indicate that for the post-10,000-year period, the median annual individual doses would be approximately 0.96 millirem. The median value is about 0.3 percent of the proposed EPA standard, which allows up to a 350-millirem annual committed effective dose equivalent for the post-10,000-year period. In addition, the mean and 95th-percentile values are well below the proposed EPA standard (Figures S-12 and S-13).

S.4.2.2.1 *Human Intrusion*

A human intrusion scenario, in which a driller would penetrate a waste package without realizing it, is difficult to envision because of the design of the drip shields and waste packages. It is more plausible that the engineered barriers would deflect or divert a borehole that penetrated the repository. It is also more plausible that the drillers would recognize the intrusion. DOE adopted a simple conservative calculation method to estimate the earliest time at which a drilling intrusion could occur, based on the fact that the waste package would be susceptible to drilling once the drip shield failed. DOE conservatively assumed that waste package failure and inadvertent drilling would occur at the same time.

Based on this analysis, the earliest time that this could happen is estimated to be 200,000 years after closure.

DOE conducted a TSPA calculation for the drilling intrusion scenario for all environmental pathways to represent the dose from a single waste package. The mean and median annual individual doses from human intrusion both would be approximately 0.01 millirem and would occur approximately 2,000 years

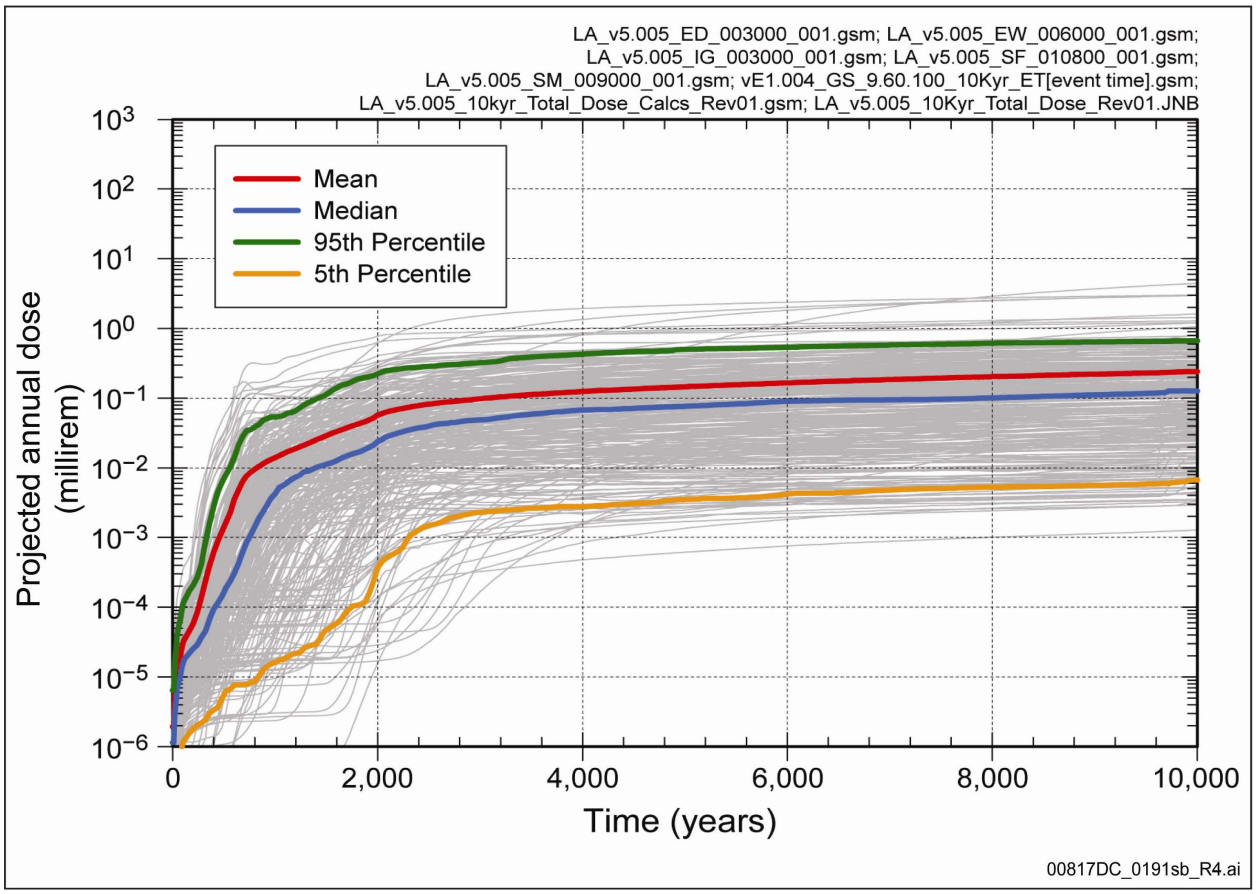


Figure S-12. Projected total annual dose for the first 10,000 years after repository closure—combined drip shield early failure, waste package early failure, igneous intrusion, volcanic eruption, seismic ground motion, and seismic fault displacement modeling cases.

after intrusion. These results indicate that the repository would be sufficiently robust to limit releases from human intrusion to values well below the proposed individual protection standard of 350-millirem annual individual dose for human intrusion for intrusions in the post-10,000-year period.

S.4.3 TRANSPORTATION IMPACTS

After DOE completed the Yucca Mountain FEIS in 2002, it issued a Record of Decision that selected the mostly rail scenario for the transportation of spent nuclear fuel and high-level radioactive waste to the proposed repository. Since completing the FEIS, DOE has continued to develop the repository design and associated operational plans. The Department plans to operate the repository with the use of a primarily canistered approach that calls for the packaging of most commercial spent nuclear fuel at the commercial sites in TAD canisters and most DOE materials in disposable canisters at the DOE sites. There have also been changes to some of the data DOE used to estimate radiation doses and radiological impacts. Changes unique to the analysis of potential impacts from transportation are described below.

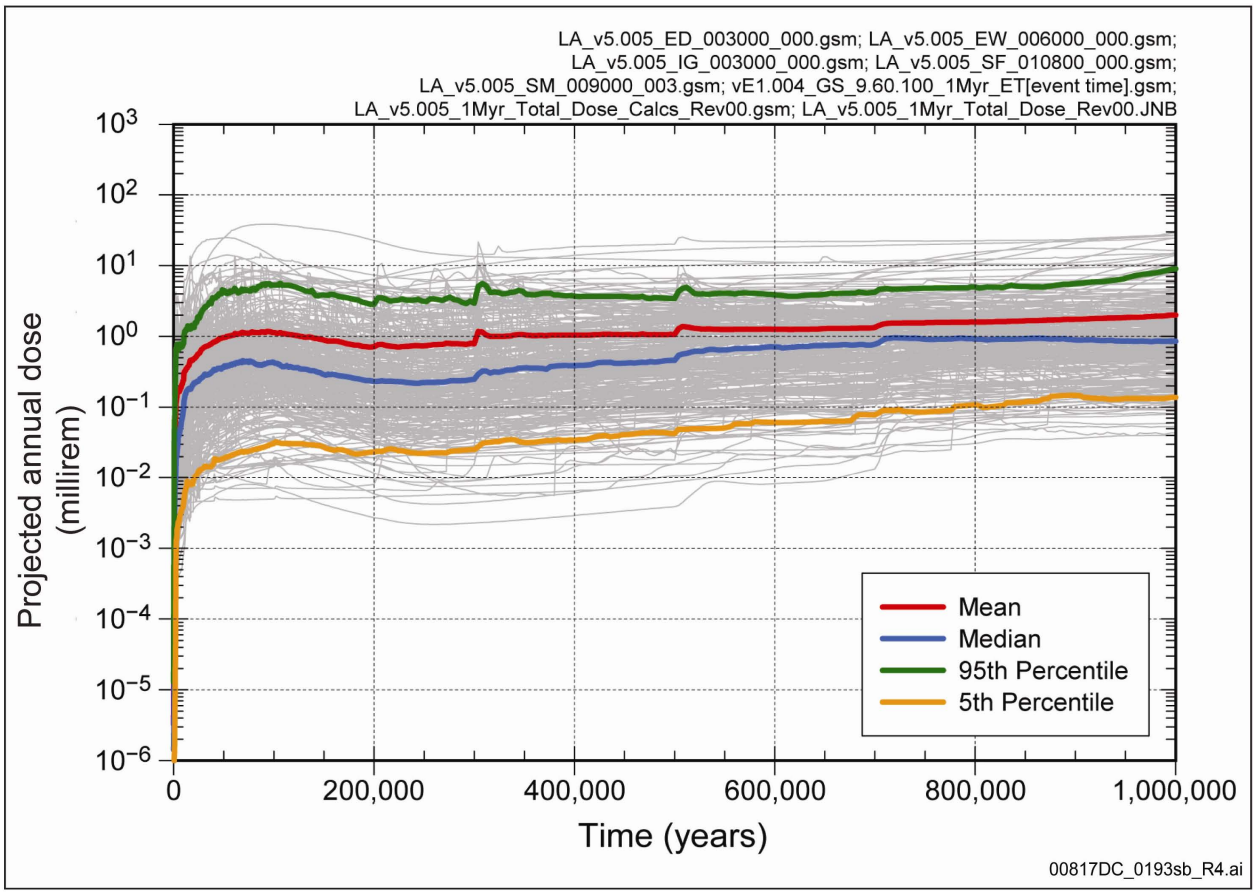


Figure S-13. Projected total annual dose for the post-10,000-year period—combined drip shield early failure, waste package early failure, igneous intrusion, volcanic eruption, seismic ground motion, and seismic fault displacement modeling cases.

- 2000 Census population density data and updated rail and truck transportation networks. DOE used the TRAGIS computer program to determine representative transportation routes to the repository. The Department used 2000 Census data to estimate population densities along the routes. In the FEIS, the TRAGIS program used 1990 Census data, which was escalated on a state-by-state basis to reflect the then-most-current basis.

  This Repository SEIS evaluates the impacts of severe transportation accidents and sabotage events for an urban area. The Department based the population density in this urban area on the population densities in the 20 most populous urban areas using 2000 Census data.

- Shipment estimates. DOE has developed updated estimates of shipments that incorporate the use of TAD canisters at each commercial reactor site. The Department based shipment estimates on 90 percent (by MTHM) of the commercial spent nuclear fuel being shipped in rail casks that contained TAD canisters. Shipment of the remaining 10 percent of the commercial spent nuclear fuel would be in rail casks that contained other types of canisters, such as dual-purpose canisters, or as uncanistered spent nuclear fuel in truck casks.

  These new estimates project the shipment of approximately 9,500 rail casks and 2,700 truck casks of spent nuclear fuel and high-level radioactive waste to the repository. Shipping 9,500 rail casks would

require about 2,800 trains. As identified in Section S.2.4, the FEIS analyses projected 9,600 rail cask shipments and 1,000 truck cask shipments. The increase in estimated truck shipments over that analyzed in the Yucca Mountain FEIS was primarily a result of using more recent data regarding the handling capabilities at the generator sites.

- Radionuclide inventories. DOE has updated the radionuclide inventory for commercial spent nuclear fuel to incorporate the inventories from *Characteristics for the Representative Commercial Spent Nuclear Fuel Assembly for Preclosure Normal Operations*, which is included in the application for construction authorization submitted to the NRC.

- Sabotage. DOE reanalyzed impacts from potential sabotage events using spent nuclear fuel release fraction data that were not available at the time the Yucca Mountain FEIS was prepared.

S.4.3.1 National Transportation Impacts

Shipments of spent nuclear fuel and high-level radioactive waste would represent a very small fraction of total national highway and railroad annual traffic (less than 0.1 percent).

The analysis of potential impacts associated with national transportation of spent nuclear fuel and high-level radioactive waste includes evaluation of incident-free impacts (normal operations), transportation risk (an assessment of potential accident consequences taking into account the probabilities of each accident), and the estimated consequences of a maximum reasonably foreseeable accident. The overall national transportation impacts include those that would be expected at the generator sites from loading TAD canisters and transportation casks and address projected exposures of workers and the public to both radiological and nonradiological hazards (traffic accidents and vehicle emissions).

For incident-free transportation, DOE estimated that about 4 latent cancer fatalities could occur in the population of transportation workers exposed to radiation from the shipments. Because many workers would be involved, the risk for an individual worker would be small. DOE estimated that there would be about 1 latent cancer fatality among members of the public who would be exposed to radiation. Because this estimate is for the entire population of individuals who would be exposed along the transportation routes over the course of shipments to the repository, the risk for a single individual would be small.

The estimated radiological accident risk of a single latent cancer fatality for the entire population within 80 kilometers (50 miles) of the rail and truck transportation routes would be about 0.0025 (1 chance in 400) during as many as 50 years of shipments to the repository. Because this risk is for the entire population of individuals along the transportation routes, the risk for any single individual would be small.

The estimated nonradiological impacts of accidents (traffic fatalities) would be 3 fatalities during as many as 50 years of shipments to the proposed repository.

The maximum reasonably foreseeable transportation accident analyzed in this Repository SEIS is estimated to occur with a frequency of about 8×10^{-6} per year. This accident would involve a long-duration, high-temperature fire that would engulf a rail cask. If the accident occurred in an urban area, DOE estimated that there would be 9 latent cancer fatalities in the exposed population. If the accident

occurred in a rural area, DOE estimated that the probability of a single latent cancer fatality in the exposed population would be 0.012 (1 chance in 80) in the exposed population.

In response to the terrorist attacks of September 11, 2001, and to intelligence information that has been obtained since then, the U.S. Government has initiated nationwide measures to reduce the threat of sabotage. These measures include security enhancements intended to prevent terrorists from gaining control of commercial aircraft and additional measures imposed on foreign passenger carriers and domestic and foreign cargo carriers, as well as charter aircraft.

The Federal Government has also greatly improved the sharing of intelligence information and the coordination of response actions among federal, state, and local agencies. DOE has been an active participant in these efforts. In addition to its domestic efforts, DOE is a member of the International Working Group on Sabotage for Transport and Storage Casks, which is investigating the consequences of sabotage events and exploring opportunities to enhance the physical protection of casks.

The Department, as required by the NWPA, would use NRC-certified shipping casks. Spent nuclear fuel is protected by the robust metal structure of the shipping cask, and by cladding that surrounds the fuel pellets in each fuel rod of an assembly. Further, the fuel is in a solid form, which would tend to reduce dispersion of radioactive particulates beyond the immediate vicinity of the cask, even if a sabotage event were to result in a breach of the multiple layers of protection.

In addition, the NRC has promulgated rules (10 CFR 73.37) and interim compensatory measures (67 FR 63167, October 10, 2002) specifically to protect the public from harm that could result from sabotage of spent nuclear fuel casks. The Department has committed to following these rules and measures (69 FR 18557, April 8, 2004).

For the reasons stated above, under general credible threat conditions the probability of a sabotage event that would result in a major radiological release would be low. Nevertheless, because of the uncertainty inherent in the assessment of the likelihood of a sabotage event, DOE has evaluated events in which a military jet or commercial airliner would crash into a spent nuclear fuel cask or a modern weapon (a high energy density device) would penetrate a spent nuclear fuel cask.

In the Yucca Mountain FEIS (Appendix J, Section J.3.3.1), DOE evaluated the ability of large aircraft parts to penetrate shipping casks and found that that neither the engines nor shafts would penetrate a cask or cause a release of radiological materials if an aircraft were to crash into a spent nuclear fuel cask.

In the Yucca Mountain FEIS, DOE estimated the potential consequences of a sabotage event in which a high energy density device penetrated a rail or truck cask. For this Repository SEIS, DOE obtained more recent estimates of the fraction of spent fuel materials that would be released (release fractions). Based on the more recent information, DOE estimated for a truck cask (which bounds the rail cask scenario) that there would be 28 latent cancer fatalities in the exposed population if the sabotage event occurred in an urban area. If the sabotage event took place in a rural area, DOE estimated that the probability of a single latent cancer fatality in the exposed population would be 0.055 (1 chance in 20). For sabotage events involving penetration of a spent nuclear fuel rail cask with a high energy density device, DOE estimated that there would be 19 latent cancer fatalities in the exposed population if the sabotage event occurred in an urban area. If the sabotage event took place in a rural area, DOE estimated that the probability of a single latent cancer fatality in the exposed population would be 0.029 (1 chance in 30).

S.4.3.2 Nevada Transportation Impacts

This Repository SEIS includes the potential environmental impacts of national transportation, as well as the potential impacts in Nevada from construction and operation of a railroad in Nevada, to ensure that this SEIS considers the full scope of potential environmental impacts from the proposed construction and operation of the repository. Therefore, this SEIS summarizes and incorporates by reference Chapter 3, Section 3.1 and 3.2, and Chapters 4, 5, and 8 of the Rail Alignment EIS. The Rail Alignment EIS analyzes the potential impacts of railroad construction and operation within the Caliente and Mina rail corridors for the purpose of determining an alignment for the construction and operation of a railroad for shipments of spent nuclear fuel, high-level radioactive waste, and other materials from an existing rail line in Nevada to a geologic repository at Yucca Mountain. DOE has included the impacts of constructing and operating the railroad within these corridors in the summary tables in Section S.10.1. The Rail Alignment EIS contains additional detail on the impacts of constructing and operating a railroad in Nevada.

S.5 No-Action Alternative and Its Impacts

Under the No-Action Alternative, DOE would not construct a repository at Yucca Mountain. Consistent with Section 113(c)(3) of the NWPA, DOE would curtail work at the site and undertake site reclamation to mitigate any significant adverse environmental impacts.

This Repository SEIS summarizes, incorporates by reference, and updates the Yucca Mountain FEIS analysis of environmental impacts associated with the No-Action Alternative. To assess potential health and safety impacts, DOE has used updated radiation dose coefficients and an updated latent cancer fatality conversion factor.

For this Repository SEIS, DOE has reconsidered its evaluation of the No-Action Alternative analytical scenarios and has elaborated on the uncertainties, and therefore unpredictability, of future actions under them. It has also considered developments related to a potential private fuel storage facility in Utah.

The immediate impacts of the No-Action Alternative are straightforward. Decommissioning and reclamation of the Yucca Mountain site would begin as soon as practicable and could take several years to complete. DOE would remove or shut down surface and subsurface facilities and restore disturbed lands. Short-term impacts on resource areas would be small.

Beyond that timeframe, developments become speculative because DOE cannot predict the future course that Congress, commercial utilities, and other parties would take in the absence of a repository. The possibilities could include:

- Continued storage of spent nuclear fuel and high-level radioactive waste at each generator site in expanded onsite storage facilities,
- Storage of these materials at one or more centralized locations,
- Study and selection of another site for a geologic repository,
- Development of new technologies, and

- Reconsideration of alternatives to geologic disposal.

Because the uncertainties and range of possibilities are so large, the Yucca Mountain FEIS focused its analysis on the potential impacts of two scenarios:

- No-Action Scenario 1. DOE would continue to manage its spent nuclear fuel and high-level radioactive waste in above- or below-ground dry storage facilities at four sites. Commercial utilities would continue to manage their spent fuel at current locations. All sites would remain under institutional control, which would ensure protection of workers and the public under current federal regulations. Storage facilities would undergo one major repair during the first 100 years and replacement every 100 years after that. Replacement facilities would be sited next to existing facilities.

- No-Action Scenario 2. For the first 100 years, this scenario would be identical with Scenario 1. The scenario assumes no institutional control beyond that time. After about 100 years and up to 10,000 years, storage facilities at all sites would begin to deteriorate and would eventually release radioactive materials to the environment.

This Repository SEIS estimates the potential impacts of the No-Action Alternative at commercial and DOE sites for both scenarios for the first 10,000 years and for the period up to a million years. Under Scenario 1, which assumes the existence of institutional controls, the estimated radiological health impacts to workers and the public for the first 10,000 years would be about 18 latent cancer fatalities. For Scenario 2, which assumes the lack of institutional controls after 100 years, the evaluation of the 10,000-year period in the Yucca Mountain FEIS found that the original storage facility and containment vessels would be compromised. Radionuclides would enter the accessible environment with eventual catastrophic consequences for human health. This SEIS estimates the radiological health impacts to the public during the 10,000-year period to be over 1,000 latent cancer fatalities.

For estimates of impacts up to 1 million years for Scenario 1, the integrated impacts over the million-year period would be approximately 100 times those of the estimated 10,000-year impacts. For Scenario 2, however, the projection of estimated impacts would be more speculative. Beyond 10,000 years, the unchecked deterioration and dissolution of the materials would continue and increase impacts even further than those estimated for the 10,000-year period. The increasing uncertainty (for example, actual locations of radiological materials, climate changes, and degree of institutional control) over this extended period, however, does not provide a meaningful basis for quantitative impact analyses because of the limitless number of scenarios that could occur.

S.6 Cumulative Impacts of the Proposed Action

For this Repository SEIS, DOE updated the Yucca Mountain FEIS evaluation of cumulative preclosure impacts from the construction, operation and monitoring, and closure of a geologic repository at Yucca Mountain, and cumulative postclosure impacts. DOE also updated the evaluation of cumulative impacts from transportation of spent nuclear fuel and high-level radioactive waste to the repository nationally and in the State of Nevada. The SEIS analysis reflects the longer period assumed for repository operations and transportation, DOE's decision to ship most waste by rail, and updated assumptions about waste inventories.

CUMULATIVE IMPACTS

A cumulative impact is "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such other actions" (Council on Environmental Quality Regulations, 40 CFR 1508.7). Cumulative impacts can result from individually minor but collectively potentially significant actions that occur over time.

DOE's assessment of the environment around the Yucca Mountain site took into account the cumulative impacts of past and present actions in the area the Proposed Action would affect. Reasonably foreseeable future actions include the disposal of inventories of spent nuclear fuel and high-level radioactive waste that exceed the Proposed Action inventory of 70,000 MTHM, along with activities at the Nevada Test and Training Range and Nevada Test Site, DOE waste management and transmission/distribution activities, and Nye County activities, including the implementation of the Gateway Area Concept Plan, designed to manage the development of land south of the analyzed land withdrawal area.

DOE is preparing the *Programmatic Environmental Impact Statement for the Global Nuclear Energy Partnership*. GNEP is a domestic and international program designed to support expansion of nuclear energy production while advancing nonproliferation goals and reducing the impacts of spent nuclear fuel disposal.

The GNEP Programmatic EIS will evaluate the impacts of domestic programmatic alternatives that would reduce the volume, thermal output, and radiotoxicity of spent nuclear fuel and wastes requiring geologic disposal in the future. It will also evaluate a project-specific proposal to pursue the implementation of an Advanced Fuel Cycle Facility at one or more of five DOE sites in the continental United States.

Because of developments involving the forthcoming GNEP Programmatic EIS, DOE has modified the analysis of Inventory Modules 1 and 2 from that in the Draft Repository SEIS. Because some of the GNEP programmatic alternatives assume the recycling of commercial spent nuclear fuel, rather than disposing of the Module 1 inventory of spent nuclear fuel at Yucca Mountain, the commercial spent nuclear fuel in excess of the Proposed Action could be recycled using one of the available technologies. In this case, the high-level radioactive waste that resulted from this recycling, rather than the spent nuclear fuel, would require geologic disposal.

This Final Repository SEIS evaluates two disposal cases (A and B) for Inventory Modules 1 and 2. Case A represents the inventory modules without any recycling. This is the same as that evaluated in the Draft Repository SEIS. Case B represents the inventory modules that assume the use of one of the recycling technologies through the implementation of a GNEP programmatic alternative. Thus, DOE would dispose of a quantity of 63,000 MTHM of commercial spent nuclear fuel as spent nuclear fuel, as in the Proposed Action. The balance of the commercial spent nuclear fuel inventory (67,000 MTHM) would be recycled and the resultant high-level radioactive waste form would be transported and disposed of at Yucca Mountain in engineered waste packages.

S.6.1 INVENTORY MODULES 1 AND 2

Section 114(d) of the NWPA provides that no more than 70,000 MTHM of spent nuclear fuel and high-level radioactive waste may be disposed of in a first repository until a second repository is operating. DOE evaluated the emplacement of the total projected inventory of commercial spent nuclear fuel and

DOE spent nuclear fuel and high-level radioactive waste (Inventory Module 1) and emplacement of that total inventory plus the inventories of commercial Greater-Than-Class-C waste and DOE Special-Performance-Assessment-Required waste (also referred to by DOE as "Greater-Than-Class-C-like" waste) (Inventory Module 2). This Repository SEIS updates the inventories of the modules evaluated in the Yucca Mountain FEIS. As mentioned above, this Final Repository SEIS evaluates a disposal case for Modules 1 and 2 in which DOE would recycle more than half of the projected commercial spent nuclear fuel using one of the recycling technologies being evaluated in the GNEP Programmatic EIS.

INVENTORIES

Proposed Action

- 63,000 MTHM of commercial spent nuclear fuel and a very small quantity of commercial high-level radioactive waste
- 2,333 MTHM of DOE spent nuclear fuel
- 4,667 MTHM (9,334 canisters) of DOE high-level radioactive waste

Inventory Module 1 Case A

- 130,000 MTHM of commercial spent nuclear fuel
- 2,500 MTHM of DOE spent nuclear fuel
- 36,000 canisters of DOE high-level radioactive waste

Inventory Module 1 Case B

- 63,000 MTHM of commercial spent nuclear fuel
- 2,500 MTHM of DOE spent nuclear fuel
- 36,000 canisters of DOE high-level radioactive waste
- 13,400 to 29,000 canisters of commercial high-level radioactive waste (from recycling 67,000 MTHM of commercial spent nuclear fuel)

Inventory Module 2 Case A

- 130,000 MTHM of commercial spent nuclear fuel
- 2,500 MTHM of DOE spent nuclear fuel
- 36,000 canisters of DOE high-level radioactive waste
- Approximately 36,000 cubic meters (1.3 million cubic feet) of Greater-Than-Class-C or Greater-Than-Class-C-like low-level radioactive waste

Inventory Module 2 Case B

- 63,000 MTHM of commercial spent nuclear fuel
- 2,500 MTHM of DOE spent nuclear fuel
- 36,000 canisters of DOE high-level radioactive waste
- 13,400 to 29,000 canisters of commercial high-level radioactive waste (from recycling 67,000 MTHM of commercial spent nuclear fuel)
- Approximately 176,000 cubic meters (6.2 million cubic feet) of Greater-Than-Class-C or Greater-Than-Class-C-like low-level radioactive waste (most of which would result from the recycling effort)

The recycling of commercial spent nuclear fuel could generate an additional Greater-Than-Class-C waste stream. The preliminary estimate of the volume of the Greater-Than-Class-C waste generated as a result of recycling 67,000 MTHM of commercial spent nuclear fuel could be approximately 140,000 cubic meters (183,000 cubic yards). For various reasons, the disposal of this volume of Greater-Than-Class-C wastes in the Yucca Mountain Repository in the assumed configurations (robust waste packages and TAD canisters) would be highly uncertain, and DOE does not provide a quantitative evaluation of the environmental impacts of Module 2 Case B.

The emplacement of Inventory Module 1 or 2 at Yucca Mountain would require legislative action by Congress. The emplacement of commercial Greater-Than-Class-C and DOE Special-Performance-Assessment-Required wastes could require either legislative action or a determination by the NRC to classify these materials as high-level radioactive waste.

The emplacement of Inventory Module 1A, 1B, or 2A would increase the size of the subsurface repository facilities and, thus, the amount of land disturbed. Because DOE would handle more than twice as much radiological materials during the emplacement of Inventory Module 1 or 2, these actions would produce greater health impacts to workers and the public, increase energy use, create larger amounts of waste, and increase transportation impacts. Impacts in all resource areas would still be low; the specific impacts to health and safety at the repository and from transportation are discussed below.

S.6.2 IMPACTS TO WORKERS AND THE PUBLIC

Impacts from industrial hazards. The total estimated impacts from industrial hazards for Inventory Module 1A or 2A would be 65 percent or 120 percent larger than those for the Proposed Action, respectively. The impacts from Module 1B would be smaller than those of Module 1A due to the decreased number of waste package handling operations. The potential number of reportable injuries and illnesses for Modules 1A and 2A could be about 3,000 and 4,000, respectively, and the estimated number of fatalities would be 1.5 and 2.0, respectively.

Radiological impacts to workers. Latent cancer fatalities for repository workers during the construction, operations, monitoring, and closure periods for Module 1A or 2A could be about 7.9 or 12 fatalities, respectively. The estimated number of latent cancer fatalities for Module 1B would be less than that for Module 1A (7.6) due to the reduced number of waste package handling operations.

Preclosure radiological impacts to the public. The likelihood that the maximally exposed individual would experience a latent cancer fatality would be approximately 0.00074 for emplacement of Inventory Module 1A, and 0.0011 for Module 2A. Module 1B would be less than Module 1A (0.00070) due to the decreased number of waste packages. Similar to the Proposed Action, more than 99 percent of this impact would result from the release of naturally occurring radon.

Postclosure radiological impacts. Postclosure cumulative impacts to public health could occur from radionuclides released from Yucca Mountain; from past weapons testing on the Nevada Test Site; and from past, present, and future disposal of radioactive waste in disposal sites on the Nevada Test Site and in regulated facilities near Beatty, Nevada. The mean annual dose estimated to occur within 10,000 years from disposal of the Proposed Action inventory would be 0.24 millirem per year to the RMEI. Because the Module 1 inventory of commercial spent nuclear fuel would be approximately twice that of the Proposed Action, the estimated mean annual dose from disposal of the Module 1A inventory would also double. Because Module 1B would result in fewer waste packages relative to Module 1A, the mean annual individual dose for Module 1B would be no greater than that of Module 1A. Module 2A impacts would add an additional fraction of 1 percent to the Module 1 impacts. As illustrated in the Yucca Mountain FEIS, the past weapons testing and radioactive waste disposal actions would be unlikely to make an additional noticeable contribution to the cumulative postclosure radiological impacts.

S.6.3 TRANSPORTATION

This Repository SEIS analysis assumes that to ship Inventory Module 1 or 2 to the repository, DOE would use the transportation routes described for the Proposed Action and would make a larger number of shipments over a longer period. This could result in increased industrial hazards, traffic fatalities, and latent cancer fatalities. Estimated impacts for national transportation for the Proposed Action would be about 8 total fatalities. The Department estimated there could be about 18 total fatalities for Module 1A, about 20 total fatalities for Module 1B, and about 26 total fatalities for Module 2A. As with the Proposed Action, the majority of these fatalities would be from worker radiation exposures and traffic fatalities. For Module 1B, the national transportation impacts would include impacts from transporting 67,000 MTHM of commercial spent nuclear fuel that would be recycled, and the impacts from transporting 29,000 canisters of high-level radioactive waste that would result from the recycling.

Additional impacts could result from transportation of construction materials, repository components, and consumables to the repository; workers who commuted to the repository; and transportation of site-generated waste from the repository. Under the Proposed Action, DOE estimated there would be about 13 fatalities from exposure to vehicle emissions and 44 to 46 traffic fatalities. With the increased transportation of other material, personnel, and repository-generated wastes for Module 1A, 1B, or 2A, these transportation impacts could increase to about 14 to 15 fatalities from exposure to vehicle emissions and 47 to 51 traffic fatalities.

During the national transportation of radioactive materials not associated with the Proposed Action from 1943 to 2073, the cumulative impacts analyses in this Repository SEIS estimate that there would be about 228 latent cancer fatalities among exposed workers and about 210 latent cancer fatalities among exposed members of the public. When these impacts are combined with the impacts of the Proposed Action, Module 1, and Module 2, this SEIS estimates that there would be up to 240 latent cancer fatalities among exposed workers and about 210 latent cancer fatalities among exposed members of the public, dependent upon the inventory module.

During the national transportation of radiological materials not associated with the Proposed Action from 1943 to 2073, the cumulative impacts analyses in ths Repository SEIS estimate that there would be about 120 traffic fatalities. When these impacts are combined with the impacts of the Proposed Action, Module 1, and Module 2, this SEIS estimates that there would be about 120 to 130 traffic fatalities.

S.7 Mitigating Potential Adverse Environmental Impacts

DOE views the best management practices and management actions discussed in this Repository SEIS as representing the initial step in a longer-term, iterative process to develop, detail, and eventually implement these practices and actions. The practices and actions would be further developed and detailed through (1) the regulatory compliance process, (2) development of the final design and associated specifications, and (3) consultation with directly affected parties. The process is iterative, in that DOE intends to consult with directly affected parties as the practices and actions advanced from the conceptual to the more detailed, as engineering of the repository advances from preliminary through final design, and during implementation and monitoring of their effectiveness.

DOE based this process, in part, on the use of an adaptive management approach described, in summary, as: consider the magnitude of potential impacts, mitigate, implement, monitor, and adapt. Using this

approach, DOE could respond to unanticipated changes in local conditions or subsequently developed information, for example, and thus make cost-effective adjustments to its best management practices and management actions as necessary.

As part of the planning process, DOE would establish measurable environmental objectives and set measurable goals and targets tailored to the Proposed Action (for example, pollution prevention goals for reductions in waste generation). DOE would then implement programs, procedures, and controls for monitoring and measuring progress. It would document progress and, if appropriate, institute corrective actions.

In implementing the Proposed Action, DOE would adhere to NRC safety requirements in 10 CFR Part 63 for the construction, operations, monitoring, and eventual closure of a geologic repository and meet or exceed the requirements of 10 CFR Part 71 for the transportation of spent nuclear fuel and high-level radioactive waste. The incorporation of safety factors and controls in the engineering design and operational procedures would help prevent accidents and thereby minimize potential releases to the environment.

Best management practices are integral to the design, construction, and operation of the Yucca Mountain Repository, and the repository design incorporates them. DOE has defined best management practices for this SEIS as the processes, techniques, procedures, or considerations it would employ to avoid or reduce the potential environmental impacts of its Proposed Action in a cost-effective manner while meeting the Yucca Mountain Repository project objectives. While best management practices are not regulatory requirements, they can overlap and support such requirements. Use of best management practices would not replace any local, state, or federal requirements. Specific management actions DOE would take to mitigate potential adverse impacts of the Proposed Action include compliance with other government agency stipulations or specific guidance, coordination with government agencies or interested parties, implementation of DOE policy decisions, monitoring of relevant ongoing and future activities and, if appropriate, instituting corrective actions. Corrective actions would include, for instance, limiting the degree or magnitude of the action; reducing or eliminating the impact over time by preservation and maintenance operations; and repairing, rehabilitating, or restoring the affected environment.

DOE would undertake this mitigation process in consultation with federal, state, and local regulatory authorities having jurisdiction over the construction and operation of the proposed repository and railroad, and in consultation with directly affected parties. To that end, DOE is proposing to charter one or more Mitigation Advisory Boards, each to be led by the governmental entities through which the *rail line* would pass or in which it would construct and operate the repository. For example, as the situs county of the Proposed Action for this Repository SEIS, the Board for Nye County would provide advice on the development of mitigation measures for the construction, operations, monitoring, and closure of the Yucca Mountain Repository and the construction and operation of the railroad.

S.8 Unavoidable Adverse Impacts; Short-Term Uses and Long-Term Productivity; and Irreversible or Irretrievable Commitments of Resources

The construction, operations, monitoring, and eventual closure of the proposed Yucca Mountain Repository and the associated transportation of spent nuclear fuel and high-level radioactive waste could

produce some environmental impacts that DOE could not mitigate. Similarly, some aspects of the Proposed Action could affect the long-term productivity of the environment or would require the permanent use of some resources.

- The permanent control of approximately 600 square kilometers (150,000 acres) of land for the repository could prevent human use of the lands for other purposes.
- Death or displacement of individual members of some animal species, including the desert tortoise, as a result of site clearing and vehicle traffic would be unavoidable.
- Injuries to workers or worker fatalities could result from facility construction and operation.
- Transportation of spent nuclear fuel and high-level radioactive waste would have the potential to affect workers and the public through exposure to radiation and vehicle emissions, and through traffic accidents.
- Electric power, fossil fuels, and construction materials would be irreversibly committed to the project.
- DOE would use fossil fuel from the nationwide supply system to transport spent nuclear fuel and high-level radioactive waste to the repository.

Further, in the view of American Indian tribes in the Yucca Mountain region, construction of the proposed repository and related facilities would further degrade the environmental setting. Even after repository closure and site reclamation, the presence of the repository would, from their perspective, result in an irreversible impact to traditional lands.

S.9 Statutory and Other Applicable Requirements

Many statutes and regulations would apply to the licensing, development, operation, and closure of a geologic repository. These include the NWPA, NEPA, the *Atomic Energy Act*, the *Federal Land Policy and Management Act of 1976,* site-specific public health and environmental radiation protection standards established by EPA, site-specific technical licensing regulations established by the NRC, and site suitability guidelines established by DOE.

DOE is subject to other requirements, including those promulgated under the *Clean Air Act; Clean Water Act; Emergency Planning and Community Right-to-Know Act of 1986; National Historic Preservation Act; Archaeological Resources Protection Act; Endangered Species Act;* and applicable Nevada statutes and regulations. In accordance with federal authorities, DOE would apply for new permits, licenses, and approvals to construct, operate, monitor, and eventually close the proposed Yucca Mountain Repository.

Under the authority of the *Atomic Energy Act*, DOE is responsible for establishing a comprehensive health, safety, and environmental program for its activities and facilities. Under Executive Order 13148, DOE is responsible for developing and implementing an Environmental Management System. The Department has established a framework for managing its facilities through the promulgation of regulations and the issuance of DOE Orders. In general, DOE Orders set forth policies, programs, and procedures for implementing policies. Many DOE Orders contain specific requirements in the areas of radiation protection, nuclear safety and safeguards, and security of nuclear material. Because the NRC is

authorized to license the proposed Yucca Mountain repository, DOE issued Order 250.1 exempting such a repository from compliance with provisions of DOE Orders that overlap or duplicate NRC licensing requirements.

DOE has interacted with agencies authorized to issue permits, licenses, and other regulatory approvals, as well as those responsible for protecting such significant resources as endangered species, wetlands, or historic properties. DOE also has coordinated with the affected units of local government, the NRC, U.S. Air Force, U.S. Navy, U.S. Department of Agriculture, U.S. Department of Transportation, EPA, U.S. Department of the Interior including its Bureaus (U.S. Fish and Wildlife Service, National Park Service, and Bureau of Land Management), the Council on Environmental Quality, Nevada Department of Transportation, and American Indian tribes.

S.10 Conclusions

S.10.1 MAJOR CONCLUSIONS OF THE REPOSITORY SEIS

The Repository SEIS estimates the potential preclosure and postclosure environmental impacts from construction, operations, monitoring, and eventual closure of the repository. Table S-1 lists the preclosure and postclosure impacts from the repository. Table S-2 lists potential impacts from the transportation of spent nuclear fuel and high-level radioactive waste nationally and in Nevada. These impacts include those estimated for the construction and operation of a railroad in Nevada.

Table S-1 presents an estimated mean and median annual individual dose of 0.24 millirem and 0.13 millirem, respectively, to the RMEI for the first 10,000 years after disposal. The analysis of the post-10,000-year period resulted in a mean and median annual individual dose of 2.0 millirem and 0.96 millirem, respectively, to the RMEI. DOE would not expect any significant adverse health effects to individuals from these very small estimated doses.

Table S-3 lists estimated impacts of the No-Action Alternative to provide a basis of comparison with the Proposed Action.

Table S-4 compiles all preclosure impacts resulting from the repository and national and Nevada transportation. The table indicates the aggregation of impacts in each resource area that overlap in the repository region of influence.

Considering the preclosure and postclosure impacts presented in this Repository SEIS, DOE concludes that the potential impacts associated with the current repository design and operational plans are similar in scale to impacts in the Yucca Mountain FEIS.

S.10.2 AREAS OF CONTROVERSY

In the Yucca Mountain FEIS, DOE acknowledged that areas of controversy exist about the Proposed Action and the analyses of its impacts. Several of these areas remain of concern and reflect differing points of view or irreducible uncertainties.

S.10.2.1 American Indian Viewpoint

Certain American Indian tribes believe that the repository itself, regardless of its respective impacts, would adversely disturb the natural and cultural environment.

S.10.2.2 Transportation

Disagreement exists about factors relevant to the analyses of the potential environmental impacts from the transportation of spent nuclear fuel and high-level radioactive waste including, for example, the specific routing chosen for analysis and the definition of the maximum reasonably foreseeable accident.

S.10.2.3 Evaluation of Postclosure Performance

Uncertainty exists about how best to represent the behavior of natural systems and complex engineered barriers in estimating repository performance over a very long period extending hundreds of thousands of years into the future.

S.10.2.4 Water Rights

Water use and water development projects will continue to be a major concern in the region of influence regardless of the water demands associated with the proposed repository or the railroad. Growth in water demand in Nevada has been very rapid; water use against the backdrop of regional water transfer plans remains an overarching controversial issue.

S.10.3 ISSUES TO BE RESOLVED

For DOE to implement the Proposed Action, these issues would have to be resolved:

- NRC would have to grant DOE construction authorization and a license to receive and possess radioactive material.
- DOE would have to decide whether to construct a railroad and, if so, select a rail alignment in which to construct and operate the railroad.
- DOE would have to acquire lands that either would be under its jurisdiction and control or permanently withdrawn and reserved for its use for the geologic repository operations area.
- EPA and the NRC would have to finalize their proposed individual radiation protection standards.

Table S-1. Potential preclosure and postclosure impacts associated with the repository.

Resource area	Preclosure impacts	Postclosure impacts
Land use and ownership	Small; about 9 km^2 (2,200 acres) of disturbed land; 600 km^2 (150,000 acres) of land withdrawn from public use.	Small; potential for limited access into the area; reclamation of disturbed land would restore preconstruction conditions; the only surface features remaining would be markers.
Air quality	Small; concentrations well below regulatory limits (less than 3 percent) for all criteria pollutants except particulate matter. Maximum concentrations of PM_{10} would be 40 percent of limit at land withdrawal area boundary. Maximum annual releases of carbon dioxide, a greenhouse gas, from the burning of fossil fuels and the manufacture of concrete would be about 69,000 metric tons (76,000 tons). This would be less than 0.15 percent of the 2004 State of Nevada total carbon dioxide emissions.	Small; population doses from release of gaseous radionuclides would be approximately 1×10^{-8} person-rem in the 84-km (52-mile) radius around the repository.
Hydrology		
Surface water	Small; land disturbance would result in minor changes to runoff and infiltration rates; minimal potential for contaminants to be released and reach surface water; only ephemeral drainage channels would be affected. DOE would construct facilities above flood zones or dikes, and diversion channels would be constructed to keep floodwaters away; floodplain assessment concluded impacts would be small.	Small; potential sources for surface-water contamination would no longer be present.
Groundwater	Small to moderate; minimal potential to change recharge rates and for released contaminants to reach groundwater; peak water demand (460 acre-feet per year)[a] below the lowest estimate of the groundwater basin's perennial yield (580 acre-feet); after construction, water demand would decrease to 330 acre-feet per year or less. Groundwater would be withdrawn from existing wells and possibly a new well to support Gate 510 facilities.	Estimated releases over the first 10,000 years would result in a mean and median annual individual dose that would not exceed 0.24 millirem and 0.13 millirem, respectively, to an RMEI hypothetically located 18 kilometers (11 miles) from the repository. The analysis of the post-10,000-year period resulted in a mean and median annual individual dose that would not exceed 2.0 millirem and 0.96 millirem, respectively, to the RMEI at the same location. Expected uptakes from nonradioactive hazardous chemicals would all be less than the oral reference doses for any of these substances.
Biological resources and soils	Small; loss of up to 9 km^2 (2,200 acres) of desert soil, habitat, and vegetation, but no loss of rare or unique habitat or vegetation; adverse impacts to individual threatened desert tortoises and loss of a small amount of low-density tortoise habitat, but no adverse impacts to the species as a whole; reasonable and prudent measures would minimize impacts; no adverse impacts to wetlands.	Small; slight increase in surface soil temperature directly over repository, lasting from approximately 200 to 10,000 years, could result in a temporary shift in plant and animal communities in the affected area; impacts to individual threatened desert tortoises would decrease as activity level at repository decreased; temperature-driven change in desert tortoise sex ratio would be unlikely; sediment load in ephemeral water courses could temporarily increase coincident with changes to soil and vegetation characteristics.

Table S-1. Potential preclosure and postclosure impacts associated with the repository (continued).

Resource area	Preclosure impacts	Postclosure impacts
Cultural resources	Small; ground disturbances and activities that could destroy or modify the integrity of archaeological or cultural resource sites would be minimized through avoidance of sites and mitigation. Indirect impacts that could result from easier physical access to the land withdrawal area, such as unauthorized excavation and collection of artifacts, would be mitigated by training, monitoring and establishing long-term management of sites. Opposing Native American viewpoint exists.	Small; potential for limited access into the area; opposing American Indian viewpoint.
Socioeconomics		
New jobs (percent of workforce in affected counties)	Construction: Small impacts in region; peaks are 0.05 percent above baseline in Clark County and 1.5 percent above baseline in Nye County. Operations: Small impacts in region; peaks are 0.06 percent above baseline in Clark County and 2.0 percent above baseline in Nye County.	Small; very few workers.
Peak real disposable personal income (million dollars)	Construction: Small impacts in region; peaks are $41.7 million (0.05-percent increase) in Clark County and $17.1 million (1.16-percent increase) in Nye County. Operations: Small impacts in region; peaks are $58.3 million (0.05-percent increase) in Clark County and $27.7 million (1.15-percent increase) in Nye County.	Small; very few workers.
Peak incremental Gross Regional Product (million dollars)	Construction: Small impacts in region; peaks are $58.9 million (0.05-percent increase) in Clark County and $22.7 million (1.42-percent increase) in Nye County. Operations: Small impact in region; peaks are $98.7 million (0.05-percent increase) in Clark County and $68.9 million (2.65-percent increase) in Nye County.	Small; very few workers.
Occupational and public health and safety		
Public, Radiological		
MEI (probability of an LCF)	0.00032	1.4×10^{-7}
Population (LCFs)	8.0	Not calculated.

Table S-1. Potential preclosure and postclosure impacts associated with the repository (continued).

Resource area	Preclosure impacts	Postclosure impacts
Occupational and public health and safety (continued)		
Public, Nonradiological		
Fatalities due to emissions	Small; exposures well below regulatory limits.	Small; exposures well below regulatory limits.
Workers (involved and noninvolved)		
Radiological (LCFs)	3.5	Small; very few workers.
Nonradiological fatalities (includes commuting traffic fatalities)	38	Small; very few workers.
Accidents, Radiological		
Public MEI (probability of an LCF)	2.6×10^{-11} to 2.1×10^{-5}	Less than 1×10^{-7} probability.
Public Population (LCFs)	9.0×10^{-7} to 1.9×10^{-2}	Less than 1×10^{-7} probability.
Workers	5.8×10^{-4} to 3.5 rem (3.5×10^{-7} to 2.1×10^{-3} LCF)	Less than 1×10^{-7} probability.
Noise and vibration	Small; impacts to public would be small due to large distances to residences; workers exposed to elevated noise levels—controls and protection would be used as necessary.	Small; minimal activities, therefore, minimal noise or ground vibration.
Aesthetics	Small; the presence of exhaust ventilation stacks on the crest of Yucca Mountain could be an aesthetic aggravation to American Indians. If the Federal Aviation Administration required beacons atop the stacks, they could be visible for several kilometers, especially west of Yucca Mountain.	Small; the only constructed surface features remaining would be markers.
Utilities, energy, materials, and site services	Small; use of materials would be small in comparison to amounts used in the region; electric power delivery system to the Yucca Mountain site would need enhancement.	Small; minimal use of materials or energy.

Table S-1. Potential preclosure and postclosure impacts associated with the repository (continued).

Resource area	Preclosure impacts	Postclosure impacts
Waste and hazardous materials	Construction/demolition debris – 476,000 cubic meters (620,000 cubic yards) Industrial wastewater – 1.2 million cubic meters (320 million gallons) Sanitary sewage – 2.0 million cubic meters (530 million gallons) Sanitary/industrial waste – 100,000 cubic meters (130,000 cubic yards) Hazardous waste – 8,900 cubic meters (12,000 cubic yards) Low-level radioactive waste – 74,000 cubic meters (97,000 cubic yards) None of the projected volumes of waste would exceed regional capacities for disposal or management.	Small; minimal waste generated or hazardous materials used.
Environmental justice	No identified disproportionately high and adverse potential impact to any population; no identified subsections of the population, including minority or low-income populations that would receive disproportionate impacts. DOE acknowledges the opposing American Indian viewpoint.	Small; no disproportionately high and adverse impacts to minorities or low-income populations; DOE acknowledges the opposing American Indian viewpoint.
Airspace restrictions	Small; if necessary, DOE would obtain exclusive control of a lightly used 48-km^2 (19-square-mile) airspace and implement specific restrictions to the Nevada Test Site restricted airspace; airspace restrictions could be lifted once operations were complete.	Not applicable.
Manufacturing repository components		
Air quality	Small; annual pollutant emissions from component manufacturing would be 0.4 percent or less of the regional emissions for a typical manufacturing location.	Not applicable.
Occupational and public health and safety	Small; 1,700 reportable occupational injuries and illnesses and 0.61 fatality over entire manufacturing campaign.	Small.
Socioeconomics	Moderate; the area of a typical manufacturing site could see increases of up to 4.7 percent in the average annual output; up to 2.6 percent in the average annual income; and up to 0.63 percent in the average annual employment.	Not applicable.

Table S-1. Potential preclosure and postclosure impacts associated with the repository (continued).

Resource area	Preclosure impacts	Postclosure impacts
Manufacturing repository components (continued)		
Materials use	Moderate; annual use of nickel in component manufacturing would each be 3.6 percent of U.S. imports in 2007 when there was no significant domestic production, but almost as much was recovered from nickel scrap as was imported. Annual use of palladium would be 59 percent of U.S. production in 2007, but when imports are included, annual use would be reduced to 6.8 percent of the palladium used in the United States in 2007. Annual use of titanium would be 22 percent of U.S. imports in 2007 when there was limited domestic production, but increased domestic production is forecast for the future.	Not applicable.
Waste generation	Small; a typical manufacturing facility would generate as much as 7.5 metric tons (8.3 tons) of liquid waste and 1 metric ton (1.1 tons) of solid waste per year.	Small.
Environmental justice	Disproportionately high and adverse impacts to minority or low-income populations would be unlikely from the manufacturing activities.	Not applicable.

a. To convert acre-feet to cubic meters, multiply by 1,233.49. This table lists acre-feet because of common statutory and public use of this unit of measure for groundwater resources.

km = kilometer.
km^2 = square kilometer.
LCF = Latent cancer fatality.
MEI = Maximally exposed individual.
PM_{10} = Particulate matter with an aerodynamic diameter of 20 micrometers or less.
RMEI = Reasonably maximally exposed individual.

Table S-2. Potential impacts from national and Nevada transportation.

Resource area	National transportation	Nevada transportation[a]	
		Caliente Implementing Alternative	Mina Implementing Alternative
Corridor length		Total length (all new construction): 528 to 541 km (328 to 336 mi).	Total length: 452 to 502 km (281 to 312 mi).
Land use and ownership	Small[b]	Total surface disturbance: 55 to 61 km^2 (14,000 to 15,000 acres); would result in topsoil loss and increased potential for erosion.	Total surface disturbance: 40 to 48 km^2 (9,900 to 12,000 acres) would result in topsoil loss and increased potential for erosion.
		Loss of prime farmland soils: 1.2 to 1.8 km^2 (300 to 440 acres). Less than 0.1 percent of prime farmland soils in Lincoln and Nye counties.	Loss of prime farmland soils: 0.011 to 0.015 km^2 (2.6 to 3.6 acres). Less than 3 percent of the prime farmland soils of the Walker River Paiute Reservation.
		Land use change on public lands for operations right-of-way.	Land use change on public lands and on Walker River Paiute Reservation for operations right-of-way.
		Private parcels the rail line would cross: 7 to 66. Area of affected private land: 0.49 to 1.25 km^2 (120 to 310 acres).	Private parcels the rail line would cross: 1 to 39. Area of affected private land: 0.21 to 0.81 km^2 (52 to 199 acres).
		Private land needed for facilities: 0.65 to 0.89 km^2 (159 to 219 acres).	
		Active grazing allotments the rail line would cross: 23 to 25. Animal unit months lost: 999 to 1,034. [An animal unit month equates to approximately 360 kilograms (800 pounds) of forage and is a measure of the forage needed to support one cow, one cow/calf pair, one horse, or 5 sheep for 1 month.]	Active grazing allotments the rail line would cross: 6 to 9. Animal unit months lost: 179 to 199.
		Sections with unpatented mining claims that would be crossed: 37 to 42.	Sections with unpatented mining claims that would be crossed: 43 to 50.
Air quality	Small[b]	Rail line construction would not result in exceedances of the NAAQS in Esmeralda, Lincoln, or Nye counties, with the possible exception of 24-hour PM_{10} in Nye County near a potential quarry.	Rail line construction would not result in exceedences of the NAAQS in Churchill, Lyon, Esmeralda, or Nye counties. In Mineral County, the potential exists for exceedances of the NAAQS for PM_{10} and $PM_{2.5}$.
		Rail line operations would add less than about 20 percent to the 2002 countywide burden of all criteria air pollutants for Lincoln County, less than 6 percent for Esmeralda County, and less than 40 percent for Nye County. Rail line operations would not lead to an exceedance of air quality standards. Construction and operation of a proposed quarry in Lincoln County would not result in exceedances of the NAAQS.	Rail line operation would add less than about 35 percent to the 2002 countywide burden of all criteria air pollutants for both Esmeralda and Nye counties and less than about 1 percent of the 202 countywide burden of all criteria air pollutants for Churchill and Lyon counties. Rail line operations would lead to an exceedance of air quality standards.

Table S-2. Potential impacts from national and Nevada transportation (continued).

Resource area	National transportation	Nevada transportation[a]	
		Caliente Implementing Alternative	Mina Implementing Alternative
Air Quality (continued)		Construction and operation of a proposed quarry in Nye County could result in exceeding 24-hour PM_{10} limit, but measures required by the Surface Disturbance Permit would greatly reduce PM_{10} emissions, making an exceedance of the NAAQS unlikely. Churchill County. Not applicable. Lyon County. Not applicable. Mineral County. Not applicable.	Operation of a proposed quarry in Esmeralda County near Hawthorne could result in exceeding the 24-hour PM_{10} standard. Construction of the Staging Yard at Hawthorne in Mineral County could result in exceeding 24-hour PM_{10} and $PM_{2.5}$ standards and annual PM_{10} standards. Rail line construction near Mina could result in exceeding the 24-hour PM_{10} standard. Rail line construction near Schurz could result in exceeding 24-hour PM_{10} and $PM_{2.5}$ standards and annual PM_{10} standards. Operating restrictions in the required Surface Disturbance Permit would likely reduce PM_{10} and $PM_{2.5}$ emissions, making exceedances of the NAAQS unlikely. Lincoln County. Not applicable.
Hydrology			
Surface water	Small[b]	Up to approximately 0.225 km^2 (56 acres) of wetlands could be filled.	Not more than 28 m^2 (0.007 acre) of wetlands would be filled.
Groundwater	Small[b]	Physical impacts to existing groundwater resource features such as existing wells or springs from railroad construction and operation would be small. Groundwater withdrawals during construction would not be expected to impact groundwater resources or users except in a few specific locations. However, mitigation measures such as reducing the pumping rate or relocating some of the proposed wells would minimize these impacts. The impact of proposed groundwater withdrawals on groundwater quality would be small to negligible. The proposed withdrawals would not conflict with water quality standards protecting groundwater resources.	Physical impacts to existing groundwater resource features such as existing wells or springs from railroad construction and operation would be small. Groundwater withdrawals during construction would not be expected to impact groundwater resources or users except in a few specific locations. However, in such instances, mitigation measures such as reducing the pumping rate or relocating some of the proposed wells would minimize these impacts. The impact of proposed groundwater withdrawals on groundwater quality would be small to negligible. The proposed withdrawals would not conflict with water quality standards for groundwater resources.
Biological resources	Small[b]	Short-term impact to 0.014 to 0.28 km^2 (3.4 to 69 acres) wetland/ riparian habitat. Long-term impacts to 0.011to 0.18 km^2 (2.7 to 45 acres) wetland/riparian habitat.	Short-term impacts to 0.013 to 0.035 km^2 (3.19 to 8.7 acres) wetland/ riparian habitat. Long-term impacts to 0 to 0.0015 km^2 (0 to 0.37 acre) wetland/riparian habitat.

Table S-2. Potential impacts from national and Nevada transportation (continued).

Resource area	National transportation	Nevada transportation[a]	
		Caliente Implementing Alternative	Mina Implementing Alternative
Biological resources (continued)		Impacts would vary by alternative segment, be localized, and could include: • Short-term moderate impact on riparian and wetland vegetation • Small to moderate impacts on raptor nesting sites • Short-term moderate impacts to desert bighorn sheep	Impacts would vary by alternative segment, be localized, and could include: • Short-term moderate impact on riparian and wetland vegetation • Small to moderate impacts on raptor nesting sites • Short-term moderate impacts to desert bighorn sheep • Small to moderate long-term impacts to Inter-Mountain Mixed Salt Desert Scrub and Inter-Mountain Basins Greasewood Flat and land cover types • Small short-term and long-term impacts to Western snowy plover • Moderate impact to winterfat communities • Long-term moderate impacts to Inter-Mountain Basins Mixed Salt Desert Scrub and Inter-Mountain Basins Big Sagebrush Shrubland land cover types
Cultural resources	Small[b]	Numerous archaeological sites identified along segments of alignments subject to sample inventory. Construction could result in impacts to the early Mormon colonization cultural landscape, Pioche-Hiko silver mining community route, 1849 Emigrant Trail campsites, American Indian trail systems, and more than 50 sites identified as eligible for the *National Register of Historical Places* along segments of alignments subjected to sample inventory. Indirect effects to a National Register-eligible rock art site are likely from two quarry sites. No direct impacts to known paleontological resources.	Numerous archaeological sites, including more than 60 *National Register*-eligible sites, identified along segments of alignments subject to sample inventory. Potential direct and indirect impacts to sites eligible for the *National Register of Historical Places* and to other sites that might be identified during the complete survey. No direct impacts to known paleontological resources.
Socioeconomics			
New jobs (percent of workforce in affected counties)	Small[b]	Construction: Ranges from 0.1-percent increase in Clark County to 5.6-percent increase in Lincoln County. Operation: Ranges from less than 0.1-percent increase in Clark County to 3.9-percent increase in Lincoln County.	Construction: Ranges from 0.02-percent increase in Lyon County to 14-percent increase in Esmeralda County. Operation: Ranges from 0.01-percent increase in Lyon County to 14-percent increase in Esmeralda County.
Peak real disposable personal income	Small[b]	Construction: Ranges from 0.2-percent increase in Clark County to 7.6-percent increase in Esmeralda County. Operation: Ranges from less than 0.1-percent increase in Clark County to 4.7-percent increase in Lincoln County.	Construction: Ranges from 0.03-percent increase in Lyon County to 27-percent increase in Esmeralda County. Operation: Ranges from 0.01-percent increase in Lyon County to 10 -percent increase in Esmeralda County.

Table S-2. Potential impacts from national and Nevada transportation (continued).

Resource area	National transportation	Nevada transportation[a]	
		Caliente Implementing Alternative	Mina Implementing Alternative
Socioeconomics (continued)			
Peak incremental Gross Regional Product	Small[b]	Construction: Ranges from 0.2-percent increase in Clark County to 28-percent increase in Lincoln County. Operation: Ranges from less than 0.1-percent increase in Clark County to 5.2-percent increase in Lincoln County.	Construction: Ranges from 0.04-percent increase in Lyon County to 57-percent increase in Esmeralda County. Operation: Ranges from less than 0.01-percent increase in Lyon County to 24-percent increase in Esmeralda County.
Occupational and public health and safety[c]			
Public, Radiological			
MEI (probability of an LCF)	1.3×10^{-4}	4.7×10^{-6}	4.7×10^{-6}
Population (LCFs)	0.73 to 0.79	6.3×10^{-5} to 1.5×10^{-4}	8.2×10^{-4} to 8.6×10^{-4}
Workers (involved and noninvolved)			
MEI (probability of an LCF)[d]	0.015	0.015	0.015
Radiological (LCFs)	9.9 to 10	0.78	0.77 to 0.79
Nonradiological fatalities (includes commuting traffic and vehicle emissions fatalities)	63 to 65	21	22
Maximum reasonably foreseeable transportation accident (LCFs)	0.012 (rural area) to 9.4 (urban area)	0.0012 (rural area) to 0.46 (suburban area) (no urban areas exist along the Caliente Implementing Alternative)	0.0089 (rural area) to 1.2 (suburban area) (no urban areas exist along the Mina Implementing Alternative)
Noise and vibration	Small[b]	Noise from construction activities in Caliente would exceed Federal Transit Administration guidelines. Noise from rail construction would be temporary. Noise from operations would create adverse impacts at three noise-sensitive receptors in Caliente. There would be no adverse vibration impacts from construction trains or from operational train activity.	Noise from construction would cause temporary adverse impacts at two locations. Noise from operations would create adverse noise impacts at eight noise-sensitive receptors in Silver Springs and one noise-sensitive receptor in Wabuska. There would be no vibration impacts from construction trains or from operational train activity.
Aesthetics	Small[b]	Small to large impact along rail alignment (depending on segment) from operations and the installation of linear track, signals, communications towers, power poles connecting to the grid, access roads, Staging Yard, and quarries.	Small to large impact along rail alignment (depending on segment) from operations and the installation of linear track, signals, communications towers, power poles connecting to the grid, access roads, Staging Yard, and quarries.

Table S-2. Potential impacts from national and Nevada transportation (continued).

Resource area	National transportation	Nevada transportation[a]	
		Caliente Implementing Alternative	Mina Implementing Alternative
Utilities, energy, materials, and site services	Small[b]	Utility interfaces: Potential for short-term interruption of service during construction. No permanent or long-term loss of service or prevention of future service area expansions.	Utility interfaces: Potential for short-term interruption of service during construction. No permanent or long-term loss of service or prevention of future service area expansions.
		Public water systems: Most water would be supplied by new wells; small effect on public water systems from population increase attributable to construction and operation employees.	Public water systems: Most water would be supplied by new wells; small effect on public water systems from population increase attributable to construction and operation employees.
		Wastewater systems: Dedicated wastewater treatment systems would be provided at construction camps and operations facilities; small impact on public systems from population increase attributable to construction and operation employees.	Wastewater systems: Dedicated wastewater treatment systems would be provided at construction camps and operations facilities; small impact on public systems from population increase attributable to construction and operation employees.
		Fossil fuels: Fossil-fuel demand would be approximately 6.5 percent of statewide use during construction and less than 0.25 percent of statewide use during operation. Demand could be met by existing regional supply systems and suppliers. For the Shared-Use Option, demand would be less than 0.3 percent of statewide use during operation. Demand could be met by existing regional supply systems and suppliers.	Fossil fuels: Fossil-fuel demand would be approximately 6 percent of statewide use during construction and less than 0.25 percent of statewide use during operation. Demand could be met by existing regional supply systems and suppliers. For the Shared-Use Option, demand would be less than 0.3 percent of statewide use during operation. Demand could be met by existing regional supply systems and suppliers.
		Materials: Material requirements such as steel, concrete, and ballast would generally be very small in relation to supply capacity.	Materials: Material requirements such as steel, concrete, and ballast would generally be very small in relation to supply capacity.
Hazardous materials and waste	Small[b]	Small (Apex Landfill) to moderate (smaller landfills) impacts from nonhazardous waste (solid and industrial and special waste) disposal.	Small (Apex Landfill) to moderate (smaller landfills) impacts from nonhazardous waste (solid and industrial and special waste) disposal.
		Small impacts from use of hazardous materials.	Small impacts from use of hazardous materials.
		Small impacts from hazardous waste disposal.	Small impacts from hazardous waste disposal.
		Small impacts from low-level radioactive waste disposal for wastes that would be generated at the Cask Maintenance Facility.	Small impacts from low-level radioactive waste disposal for wastes that would be generated at the Cask Maintenance Facility.

Table S-2. Potential impacts from national and Nevada transportation (continued).

Resource area	National transportation	Nevada transportation[a]	
		Caliente Implementing Alternative	Mina Implementing Alternative
Environmental justice	Small[b]	Constructing and operating the proposed rail line along the Caliente rail alignment would not result in disproportionately high and adverse impacts to minority or low-income populations.	Constructing and operating the proposed rail line along the Mina rail alignment would not result in disproportionately high and adverse impacts to minority or low-income populations.

a. Short-term impacts for the Rail Alignment EIS would occur during the construction phase (4 to 10 years). Long-term impacts would occur throughout and beyond the life of the railroad operations phase (up to 50 years).

b. With the exception of occupational and public health and safety impacts, because shipments of spent nuclear fuel and high-level radioactive waste would comprise only small fractions of total national highway and rail traffic, the environmental impacts of the shipments on land use and ownership; hydrology; biological resources and soils; cultural resources; socioeconomics; noise and vibration; aesthetics; utilities, energy, and materials; and waste management would be small in comparison with the impacts of other nationwide transportation activities.

c. Impacts are composed of the industrial safety and transportation impacts from Chapter 4 of the Rail Alignment EIS and Chapters 4 and 6 of this Repository SEIS. Included in the impacts are radiation-related latent cancer fatalities, nonradiological industrial accident fatalities, vehicle emission fatalities, and traffic fatalities, as appropriate. Impacts may occur nationally or in Nevada. Impacts may include workers or members of the public.

d. Based on a worker who would receive the administrative dose limit of 500 millirem per year (DIRS 156764-DOE 1999, p. 2-3).

CO = Carbon monoxide.
km = kilometer.
km^2 = square kilometer.
LCF = Latent cancer fatality.
MEI = Maximally exposed individual.
NAAQS = National Ambient Air Quality Standards.
NO_x = Nitrous oxides.
$PM_{2.5}$ = Particulate matter with an aerodynamic diameter of 2.5 micrometers or less.
PM_{10} = Particulate matter with an aerodynamic diameter of 10 micrometers or less.
SO_2 = Sulfur dioxide.
VOC = Volatile organic compounds.

Table S-3. Potential impacts from the No-Action Alternative.

Resource area	Repository	Commercial and DOE sites		
		Short-term	Long-term (100 to 10,000 years)	
		100 years	Scenario 1	Scenario 2
Land use and ownership	DOE would require no new land to support decommissioning and reclamation. Decommissioning and reclamation would include removal or shutdown of existing surface and subsurface facilities and restoration of disturbed lands, including soil stabilization and revegetation of disturbed areas.	Small; storage would continue at existing sites.	Small; storage would continue at existing sites.	Large; potential contamination of 0.04 to 0.4 km^2 (10 to 100 acres) around each of the existing commercial and DOE sites.
Air quality	Dismantling and removal of existing structures, recontouring, and revegetation would generate fugitive dust that would be below the regulatory limit.	Small; releases and exposures well below regulatory limits.	Small; releases and exposures well below regulatory limits.	Small; degraded facilities would preclude large atmospheric releases.
Hydrology				
Surface water	Recontouring of terrain to restore the natural drainage and managing potential surface-water contaminant sources would minimize surface-water impacts.	Small; minor changes to runoff and infiltration rates.	Small; runoff during storage and reconstruction would be controlled in stormwater holding ponds; active monitoring would ensure quick response to leaks or releases; commercial and DOE sites for storage likely would be outside of flood zones.	Large; potential for radiological releases and contamination of drainage basins downstream of commercial and DOE sites (concentrations potentially exceeding current regulatory limits).
Groundwater	DOE would use a small amount of groundwater during the decommissioning and reclamation.	Small, use would be small in comparison with other site use.	Small; use would be small in comparison with other site use.	Large; potential for radiological contamination of groundwater around the commercial and DOE sites.
Biological resources and soils	Reclamation would result in the restoration of 1.4 km^2 (346 acres) of habitat. Site reclamation would include soil stabilization and revegetation of disturbed areas. Some animal species could take advantage of abandoned tunnels for shelter. Decommissioning and reclamation could produce adverse impacts to the threatened desert tortoise.	Small; storage would continue at existing sites.	Small; storage would continue at existing sites.	Large; potential adverse impacts at each of the sites from subsurface contamination of 0.04 to 0.4 km^2 (10 to 100 acres).

Table S-3. Potential impacts from the No-Action Alternative (continued).

Resource area	Repository	Commercial and DOE sites		
		Short-term	Long-term (100 to 10,000 years)	
		100 years	Scenario 1	Scenario 2
Cultural resources	Leaving roads in place after decommissioning could have an adverse impact on cultural resources by increasing public access to the site. Preserving the integrity of important archeological sites and resources important to American Indians could be difficult.	Small; storage would continue at existing sites; limited potential of disturbing sites.	Small; storage would continue at existing sites; limited potential of disturbing sites.	Small; no construction or operation activities; therefore, no impacts.
Socioeconomics	Loss of approximately 4,700 jobs (1,800-person workforce for decommissioning and reclamation, 1,400-person engineering and technical personnel in locations other than the repository site, and 1,500 indirect jobs) in the socioeconomic region of influence. Nye County collects most of the federal monies associated with the repository project. The No-Action Alternative would result in the loss of payments-in-lieu-of-taxes to Nye County.	Small; population and employment changes would be small compared with totals in the regions.	Small; population and employment changes would be small compared with totals in the regions.	No workers; therefore, no impacts.
Occupational and public health and safety				
Public – Radiological MEI (probability of an LCF)	None	0.0000052[a]	0.0000016[a]	(b)
Public – Population (LCFs)	0.001	0.49[a]	3.1[a]	1,000[c]
Public – Nonradiological (fatalities due to emissions)	Small; exposures well below regulatory limits or guidelines.	Small; exposures well below regulatory limits or guidelines.	Small; exposures well below regulatory limits or guidelines.	Moderate to large; substantial increases in releases of hazardous substances and exposures to the public.
Workers – Radiological (LCFs)	0.09	24[a]	15[a]	No workers; therefore, no impacts.
Workers – Nonradiological fatalities (includes commuting traffic fatalities)	Less than 0.15.	9	1,080	No workers; therefore, no impacts.

Table S-3. Potential impacts from the No-Action Alternative (continued).

Resource area	Repository	Commercial and DOE sites		
		Short-term	Long-term (100 to 10,000 years)	
		100 years	Scenario 1	Scenario 2
Accidents				
Public – Radiological MEI (probability of an LCF)	None.	None.	None.	Not applicable.
Public – Population (LCFs)	None.	None.	None.	4 to 16[d]
Workers	Accident impacts would be limited to those from traffic and typical industrial hazards during construction or excavation activities. These were estimated at 94 total recordable cases and 45 lost workday cases.	Large; for some unlikely accident scenarios workers probably would be severely injured or killed; however, DOE or NRC would manage facilities safely during continued storage operations.	Large; for some unlikely accident scenarios workers would probably be severely injured or killed.	No workers; therefore, no impacts.
Traffic and transportation	Less than 0.15 traffic fatality would be likely during decommissioning and reclamation.	Small; local traffic only.	Small; local traffic only.	No activities; therefore, no traffic.
Noise and vibration	Noise levels would be no greater than the current baseline noise environment at the Yucca Mountain site.	Small; transient and not excessive, less than 85 dBA.	Small; transient and not excessive, less than 85 dBA.	No activities; therefore, no noise.
Aesthetics	Site decommissioning and reclamation would improve the scenic value of the site, which DOE would return as close as possible to its predisturbance state.	Small; storage would continue at existing sites; expansion as needed.	Small; storage would continue at existing sites, with expansion as needed.	Small; aesthetic value would decrease as facilities degraded.
Utilities, energy, materials, and site services	Decommissioning would consume electricity, diesel fuel, and gasoline. The amounts of use would not adversely affect the utility, energy, or material resources of the region.	Small; materials and energy use would be small in comparison with total regional use.	Small; materials and energy use would be small in comparison with total regional use.	No use of materials or energy; therefore, no impacts.
Waste management	Decommissioning would generate some waste that would require disposal in existing Nevada Test Site or regional landfills. DOE would minimize waste by salvaging most equipment and many materials.	Small; waste generated and materials used would be small in comparison with total regional generation and use.	Small; waste generated and materials used would be small in comparison with total regional generation and use.	No generation of waste or use of hazardous materials; therefore, no impacts.

Table S-3. Potential impacts from the No-Action Alternative (continued).

		Commercial and DOE sites		
		Short-term	Long-term (100 to 10,000 years)	
Resource area	Repository	100 years	Scenario 1	Scenario 2
Environmental justice	The No-Action Alternative at the repository location would not result in disproportionately high and adverse impacts to minority or low-income populations.	The No-Action Alternative during the first 100 years at commercial and DOE sites would not result in disproportionately high and adverse impacts to minority or low-income populations.	The No-Action Alternative under Scenario 1 at commercial and DOE sites would not result in disproportionately high and adverse impacts to minority or low-income populations.	The No-Action Alternative under Scenario 2 at commercial and DOE sites could result in disproportionately high and adverse impacts to minority or low-income populations.

a. Updated using a conversion factor of 0.0006 latent cancer fatality per person-rem; no change to external dose coefficients.
b. With no effective institutional controls, the maximally exposed individual could receive a fatal dose of radiation within a few weeks to months. Death could be caused by acute direct radiation exposure.
c. Updated using a conversion factor of 0.0006 latent cancer fatality per person-rem and ingestion dose coefficients that overall are about 25 percent of the coefficients for the Yucca Mountain FEIS.
d. Updated using a conversion factor of 0.0006 latent cancer fatality per person-rem and inhalation dose coefficients that are approximately the same as coefficients for the Yucca Mountain FEIS.

dBA = A-weighted decibels.
DOE = U.S. Department of Energy.
km^2 = square kilometer.
LCF = Latent cancer fatality.
MEI = Maximally exposed individual.
NRC = U.S. Nuclear Regulatory Commission.

Table S-4. Summary of potential preclosure impacts of the Proposed Action.[a]

Resource area	Summary of all preclosure impacts (all preclosure impacts resulting from the repository, national transportation, and Nevada transportation)	Summary of repository and Nevada transportation impacts that occur within overlapping regions of influence
Land use and ownership	Approximately 49 to 70 km^2 (12,000 to 17,000 acres) of total disturbed land; 600 km^2 (150,000 acres) of land withdrawn from public use. Loss of prime farmland soils would range from 0.011 to 1.8 km^2 (2.6 to 440 acres), which would be less than 0.1 percent of prime farmland soils in Lincoln and Nye counties and less than 3 percent of the prime farmland soils of the Walker River Paiute Reservation. Land use change would occur on public lands and on Walker River Paiute Reservation for operations right-of-way. Private parcels the rail line would cross would range from 1 to 66; area of private land affected would range from 0.21 to 1.25 km^2 (52 to 310 acres). Private land needed for facilities: 0.65 to 0.89 km^2 (159 to 219 acres). Active grazing allotments the rail line would cross would range from 6 to 25. Animal unit months lost would range from 179 to 1,034. Sections with unpatented mining claims that would be crossed would range from 37 to 50.	About 12 km^2 (3,000 acres) of disturbed land; 600 km^2 (150,000 acres) of land withdrawn from public use.
Air quality	Releases from construction and operations of the repository would be well below regulatory limits (less than 3 percent) for all criteria pollutants except particulate matter. Maximum releases of PM_{10} would be 40 percent of limit at boundary of land withdrawal area. Rail line construction emissions would be distributed over the entire length of the rail alignment; therefore, no air quality standard would be exceeded. Rail line operations would not lead to an exceedence of air quality standards.	Nye County is the only location where Nevada transportation impacts would overlap the repository region of influence. The Nevada transportation emissions would be distributed over the entire county and only the southern portion of the emissions from Nye County would be within the repository region of influence. Modeled concentrations of criteria pollutants at the boundary of the land withdrawal area would not exceed regulatory limits during simultaneous construction of the repository and railroad. Concentrations of all criteria pollutants except for particulate matter would be less than 6 percent of the regulatory limit. Concentrations of $PM_{2.5}$ would not exceed 37 percent, and concentrations of PM_{10} would not exceed 87 percent of the regulatory limit. The simultaneous operation of the repository and railroad would not exceed regulatory limits.

Table S-4. Summary of potential preclosure impacts of the Proposed Action (continued).[a]

Resource area	Summary of all preclosure impacts (all preclosure impacts resulting from the repository, national transportation, and Nevada transportation)	Summary of repository and Nevada transportation impacts that occur within overlapping regions of influence
Hydrology		
Surface water	Repository land disturbance would result in minor changes to runoff and infiltration rates. At repository site, potential for contaminants to be released and reach surface water would be minimal; only ephemeral drainage channels would be affected; there are no other surface-water resources at the site. Repository facilities would be above flood zones or constructed dikes and diversion channels would keep floodwaters away; floodplain assessment concluded impacts would be small.	Construction of repository surface facilities would affect at least two drainage channels and floodplains (Busted Butte Wash and Drill Hole Wash) that the rail line would cross.
	Up to 0.225 km^2 (56 acres) of wetlands could be filled.	
Groundwater	Potential for repository actions to change recharge rates and for contaminants to be released and reach groundwater would be minimal.	Water identified for rail line construction includes 572 acre-feet (over 4 years) plus 6 acre-feet per year for operations, all from the same groundwater basin as for repository activities.
	Physical impacts to existing groundwater resource features such as existing wells or springs from railroad construction and operation would be small.	A peak annual water demand of 470 acre-feet would result from the combined Nevada transportation and repository needs, assuming primary construction periods did not overlap. This high level would last only 2 years and would occur during the second and third years after start of repository construction. The average annual water demand for the combined construction period would be 400 acre-feet.
	Repository peak water demand (460 acre-feet per year)[b] would be below the lowest estimate of perennial yield (580 acre-feet) for the western two-thirds of the groundwater basin; after construction water demand would decrease to 330 acre-feet per year or less.	All of the combined water demand levels would be below the lowest estimate of perennial yield (580 acre-feet) for the western two-thirds of the groundwater basin. The two years of highest water demand would not result in a well drawdown that could affect the nearest public or private wells. Modeling for the Yucca Mountain FEIS showed small to moderate impacts from the Proposed Action groundwater withdrawals that are still applicable. The model's assumed withdrawal rate of 430 acre-feet per year is lower than the peak water demand, but over the life of the project is still conservatively high.
	Groundwater withdrawals during rail construction in some areas could affect existing groundwater resources and users. However, mitigation measures such as reducing the pumping rate or relocating some of the proposed wells would minimize these impacts.	
	Groundwater for repository facility use would be withdrawn from wells in Jackass Flats. Groundwater for rail construction would be mostly withdrawn from new wells.	

Table S-4. Summary of potential preclosure impacts of the Proposed Action (continued).[a]

Resource area	Summary of all preclosure impacts (all preclosure impacts from the repository, national transportation, and Nevada transportation)	Summary of repository and Nevada transportation impacts in overlapping regions of influence
Biological resources and soils	Loss of between 49 to 70 km^2 (12,000 to 17,000 acres) of desert soil, habitat, and vegetation. Adverse impacts to desert big horn sheep and special-status species including western snowy plover and desert tortoise. Short-term impact of up to 0.28 km^2 (69 acres) wetland/riparian habitat. Long-term impact of up to 0.18 km^2 (45 acres) wetland/riparian habitat.	Loss of up to 12 km^2 (3,000 acres) of desert soil, habitat, and vegetation, but no loss of rare or unique habitat or vegetation; adverse impacts to individual threatened desert tortoises and loss of a small amount of low-density tortoise habitat, but no adverse impacts to the species as a whole; reasonable and prudent measures would minimize impacts.
Cultural resources	Numerous archaeological sites, up to 60 eligible for the *National Register of Historic Places* along segments of alignments subject to sample inventory and 3 sites in the repository region of influence. Opposing American Indian viewpoint. Construction could result in impacts to the early Mormon colonization cultural landscape, Pioche-Hiko silver mining community route, 1849 Emigrant Trail campsites, and American Indian trail systems. Indirect effects to a National Register-eligible rock art site are likely from two quarry sites. No direct impacts to known paleontological resources.	Small potential for impacts; three prehistoric sites eligible for the *National Register of Historic Places*; opposing American Indian viewpoint.
Socioeconomics		
New jobs (percent of workforce in affected counties)	Construction: Peaks range from 0.05 percent above baseline in Clark County to 14-percent increase in Esmeralda County. Operations: Peaks range from 0.01-percent increase in Lyon County to 14-percent increase in Esmeralda County.	Peak increases would be small, less than 1 percent in the region, Clark County, and Nye County when construction of repository and rail overlap.
Peak real disposable personal income	Construction: Peak percent increases are: • Nye: 1.16 (repository); 0.4 to 0.9 (rail) • Clark: 0.05 (repository); 0.1 (rail) • Lincoln: 4.1 (rail) • Esmeralda: 7.6 to 27 (rail) • Lyon: 0.03 (rail) • Walker River Paiute Reservation: up to $386,000 • Mineral: 4.5 (rail) • Washoe County/Carson City: less than 0.3 (rail)	For Repository: In Clark County (2034), $58.3 million; in Nye County (2035) $27.5 million. For Rail: In Clark County (2011) $100.6 million; in Nye County (2012) $9.6 million.

Table S-4. Summary of potential preclosure impacts of the Proposed Action (continued).[a]

Resource area	Summary of all preclosure impacts (all preclosure impacts from the repository, national transportation, and Nevada transportation)	Summary of repository and Nevada transportation impacts in overlapping regions of influence
Socioeconomics (continued)	Operations: Peak percent increases are: • Nye: 1.15 (repository); 0.1 to 0.3 (rail) • Clark: 0.05 (repository); less than 0.1 (rail) • Lincoln: 4.7 (rail) • Esmeralda: 2.9 to 10 (rail) • Lyon: 0.01 (rail) • Walker River Paiute Reservation: included in Mineral County • Mineral: 2.8 (rail) • Washoe County/Carson City: less than 0.1 (rail)	
Peak incremental Gross Regional Product	Construction: Peak percent increases are: • Nye: 1.42 (repository); 1.0 to 3.5 (rail) • Clark: 0.05 (repository); less than 0.1 to 0.1 (rail) • Lincoln: 28 (rail) • Esmeralda: 9.5 to 57 (rail) • Lyon: 0.04 (rail) • Walker River Paiute Reservation: up to $1.4 million • Mineral: 14 (rail) • Washoe County/Carson City: less than 0.3 (rail) Operations: Peak percent increases are: • Nye: 2.65 (repository); 0.2 to 0.5 (rail) • Clark: 0.05 (repository); less than 0.1 (rail) • Lincoln: 5.2 (rail) • Esmeralda: 3.8 to 24 (rail) • Lyon: 0.01 (rail) • Walker River Paiute Reservation: included in Mineral County • Mineral: 1.9 (rail) • Washoe County/Carson City: less than 0.1 (rail)	For Repository: In Clark County (2034), $98.7 million; in Nye County (2034) $68.9 million. For Rail: In Clark County (2012), $154.5 million; in Nye County (2012), $42.8 million.

Table S-4. Summary of potential preclosure impacts of the Proposed Action (continued).[a]

Resource area	Summary of all preclosure impacts (all preclosure impacts from the repository, national transportation, and Nevada transportation)	Summary of repository and Nevada transportation impacts in overlapping regions of influence
Occupational and public health and safety		
Public, Radiological		
MEI (probability of an LCF)	3.2×10^{-4} (repository) 1.3×10^{-4} (transportation)	2.9×10^{-4} (repository) 1.3×10^{-4} (transportation)
Population (LCFs)	8.7 to 8.8 (total)	8.0
Public, Nonradiological		
Fatalities due to emissions	Small; exposures well below regulatory limits.	Small; exposures well below regulatory limits.
Workers (involved and noninvolved)		
Radiological (LCFs)	13 to 14	4.4 to 4.9
Nonradiological fatalities (includes commuting traffic and vehicle emissions fatalities)	64 to 66 (total)	56 to 59
Maximum reasonably foreseeable transportation accident (LCFs)	0.012 (rural area) to 9.4 (urban area)	0.012 (rural area) to 9.4 (urban area)
Accidents		
Public, Radiological		
MEI (probability of an LCF)	2.6×10^{-10} to 2.1×10^{-5} (repository accidents)	2.6×10^{-10} to 2.1×10^{-5} (repository accidents)
Population (LCFs)	9.0×10^{-7} to 1.9×10^{-2} (repository accidents)	9.0×10^{-7} to 1.9×10^{-2} (repository accidents)
Workers, Radiological	5.8×10^{-4} to 3.5 rem (3.5×10^{-7} to 2.1×10^{-3} LCF) (repository accidents)	5.8×10^{-4} to 3.5 rem (3.5×10^{-7} to 2.1×10^{-3} LCF) (repository accidents)
Noise and vibration	Impacts to public would be small due to large distances from the repository to residences; workers exposed to elevated noise levels – controls and protection used as necessary. Noise from rail construction activities in Caliente would exceed Federal Transit Administration guidelines in two locations. Noise from rail construction would be temporary. Noise from operations would create adverse impacts at a maximum of nine noise-sensitive receptors. There would be no adverse vibration impacts from construction or operations.	Impacts to public would be small due to large distances from the repository to residences; workers exposed to elevated noise levels – controls and protection used as necessary.

Table S-4. Summary of potential preclosure impacts of the Proposed Action (continued).[a]

Resource area	Summary of all preclosure impacts (all preclosure impacts from the repository, national transportation, and Nevada transportation)	Summary of repository and Nevada transportation impacts in overlapping regions of influence
Aesthetics	The exhaust ventilation stacks on the crest of Yucca Mountain would be seen as an adverse aesthetic impact by American Indians. If the Federal Aviation Administration required beacons atop the stacks, they could be visible for several kilometers, especially west of Yucca Mountain. Aesthetic impacts would range from small to moderate along rail alignments (depending on segment) from operations and the installation of linear track, signals, communications towers, power poles connecting to the grid, access roads, Staging Yard, and quarries.	The exhaust ventilation stacks on the crest of Yucca Mountain would be seen as an adverse aesthetic impact by American Indians. If the Federal Aviation Administration required beacons atop the stacks, they could be visible for several kilometers, especially west of Yucca Mountain.
Utilities, energy, materials, and site services	Use of materials would be small in comparison with regional use; some effect on public water systems and public wastewater treatment facilities due to population growth from construction and operations employment; annual fossil-fuel use would be less than 7 percent of statewide use during construction and less than 2 percent of statewide use during operation; electric power delivery system to the Yucca Mountain site would have to be enhanced.	Use of materials would be small in comparison with regional use; some effect on public water systems and public wastewater treatment facilities due to population growth from construction and operations employment; annual fossil-fuel use would be less than 7 percent of statewide use during construction and less than 2 percent of statewide use during operation; electric power delivery system to the Yucca Mountain site would have to be enhanced.
Waste and hazardous materials	Small impacts from nonhazardous waste (solid and industrial waste) disposal to regional solid waste facilities. Small impacts from use of hazardous materials. Small impacts from hazardous-waste disposal to regional licensed hazardous-waste facilities. Small impacts from low-level radioactive waste disposal to a DOE low-level waste disposal site, Agreement State site, or an NRC-licensed site.	Small impacts from nonhazardous waste (solid and industrial waste) disposal to regional solid waste facilities. Small impacts from use of hazardous materials. Small impacts from hazardous-waste disposal to regional licensed hazardous-waste facilities. Small impacts from low-level radioactive waste disposal to a DOE low-level waste disposal site, Agreement State site, or an NRC-licensed site.
Environmental justice	No identified high and adverse impact to population; no identified subsections of the population, including minority or low-income populations that would receive disproportionate impacts. (Section 4.1.13) DOE acknowledges the opposing American Indian viewpoint.	Constructing and operating the proposed geologic repository at Yucca Mountain and constructing and operating the railroad to transport spent nuclear fuel and high-level radioactive waste from commercial and DOE sites to the repository would not result in disproportionately high and adverse impacts to minority or low-income populations.

Table S-4. Summary of potential preclosure impacts of the Proposed Action (continued).[a]

Resource area	Summary of all preclosure impacts (all preclosure impacts from the repository, national transportation, and Nevada transportation)	Summary of repository and Nevada transportation impacts in overlapping regions of influence
Manufacturing repository components	Small impacts to all resources with the exception of moderate socioeconomic and materials impacts.	Not applicable.
Airspace restrictions	Small impact to airspace use; airspace restriction could be lifted once operations have been completed.	Small impacts to airspace use; airspace restriction could be lifted once operations have been completed.

a. Short-term impacts for the Rail Alignment EIS are impacts limited to the construction phase (4 to 10 years). Long-term impacts for the Rail Alignment EIS are impacts that could occur throughout and beyond the life of the railroad operations phase (up to 50 years).

b. To convert acre-feet to cubic meters, multiply by 1,233.49. This table lists acre-feet because of common statutory and public use of this unit of measure for groundwater resources.

DOE = U.S. Department of Energy.
km^2 = square kilometer.
LCF = Latent cancer fatality.
MEI = Maximally exposed individual.
NRC = U.S. Nuclear Regulatory Commission.
$PM_{2.5}$ = Particulate matter with an aerodynamic diameter of 2.5 micrometers or less.
PM_{10} = Particulate matter with an aerodynamic diameter of 10 micrometers or less.

CONVERSION FACTORS

Metric to English			English to Metric		
Multiply	by	To get	Multiply	by	To get
Area					
Square kilometers	247.1	Acres	Acres	0.0040469	Square kilometers
Square kilometers	0.3861	Square miles	Square miles	2.59	Square kilometers
Square meters	10.764	Square feet	Square feet	0.092903	Square meters
Concentration					
Kilograms/sq. meter	0.16667	Tons/acre	Tons/acre	0.5999	Kilograms/sq. meter
Milligrams/liter	1[a]	Parts/million	Parts/million	1[a]	Milligrams/liter
Micrograms/liter	1[a]	Parts/billion	Parts/billion	1[a]	Micrograms/liter
Micrograms/cu. meter	1[a]	Parts/trillion	Parts/trillion	1[a]	Micrograms/cu. meter
Density					
Grams/cu. centimeter	62.428	Pounds/cu. ft.	Pounds/cu. ft.	0.016018	Grams/cu. centimeter
Grams/cu. meter	0.0000624	Pounds/cu. ft.	Pounds/cu. ft.	16,025.6	Grams/cu. meter
Length					
Centimeters	0.3937	Inches	Inches	2.54	Centimeters
Meters	3.2808	Feet	Feet	0.3048	Meters
Micrometers	0.00003937	Inches	Inches	25,400	Micrometers
Millimeters	0.03937	Inches	Inches	25.40	Millimeters
Kilometers	0.62137	Miles	Miles	1.6093	Kilometers
Temperature					
Absolute					
Degrees C + 17.78	1.8	Degrees F	Degrees F – 32	0.55556	Degrees C
Relative					
Degrees C	1.8	Degrees F	Degrees F	0.55556	Degrees C
Velocity/Rate					
Cu. meters/second	2,118.9	Cu. feet/minute	Cu. feet/minute	0.00047195	Cu. meters/second
Meters/second	2.237	Miles/hours	Miles/hour	0.44704	Meters/second
Volume					
Cubic meters	264.17	Gallons	Gallons	0.0037854	Cubic meters
Cubic meters	35.314	Cubic feet	Cubic feet	0.028317	Cubic meters
Cubic meters	1.3079	Cubic yards	Cubic yards	0.76456	Cubic meters
Cubic meters	0.0008107	Acre-feet	Acre-feet	1,233.49	Cubic meters
Liters	0.26418	Gallons	Gallons	3.78533	Liters
Liters	0.035316	Cubic feet	Cubic feet	28.316	Liters
Liters	0.001308	Cubic yards	Cubic yards	764.54	Liters
Weight/Mass					
Grams	0.035274	Ounces	Ounces	28.35	Grams
Kilograms	2.2046	Pounds	Pounds	0.45359	Kilograms
Kilograms	0.0011023	Tons (short)	Tons (short)	907.18	Kilograms
Metric tons	1.1023	Tons (short)	Tons (short)	0.90718	Metric tons
English to English					
Acre-feet	325,850.7	Gallons	Gallons	0.000003046	Acre-feet
Acres	43,560	Square feet	Square feet	0.000022957	Acres
Square miles	640	Acres	Acres	0.0015625	Square miles

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

METRIC PREFIXES

Prefix	Symbol	Multiplication factor		
exa-	E	1,000,000,000,000,000,000	=	10^{18}
peta-	P	1,000,000,000,000,000	=	10^{15}
tera-	T	1,000,000,000,000	=	10^{12}
giga-	G	1,000,000,000	=	10^{9}
mega-	M	1,000,000	=	10^{6}
kilo-	K	1,000	=	10^{3}
deca-	D	10	=	10^{1}
deci-	D	0.1	=	10^{-1}
centi-	C	0.01	=	10^{-2}
milli-	M	0.0 001	=	10^{-3}
micro-	μ	0.000 001	=	10^{-6}
nano-	N	0.000 000 001	=	10^{-9}
pico-	P	0.000 000 000 001	=	10^{-12}