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Volume 1 of 3

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Nuclear Waste Policy Act
(Section 112)

Environmental Assessment

Yucca Mountain Site, Nevada Research and Development Area, Nevada

Volume I

May 1986

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

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Washington, DC 20585

FOREWORD

The Nuclear Waste Policy Act of 1982 (the Act) established a process for the selection of sites for the disposal of spent nuclear fuel and high-level radioactive waste in geologic repositories. The first steps in this process were the identification of potentially acceptable sites and the development of general guidelines for siting repositories. In February 1983, the DOE identified nine sites in six States as potentially acceptable for the first repository. The Yucca Mountain site in Nye County, Nevada, was identified as one of those sites. The general guidelines were issued in November 1984 as Title 10 of the Code of Federal Regulations, Part 960. The DOE is now proceeding with the next step in the site-selection process for the first repository: the nomination of at least five of the nine potentially acceptable sites as suitable for site characterization, which is a program of detailed studies.

The Act requires that site nomination be accompanied by an environmental assessment (EA). The DOE has prepared EAs for the nominated sites through a process that provided opportunity for public input. Public hearings were held during March, April, and May 1983 to obtain recommendations on the issues to be addressed in an EA. All such recommendations were considered in preparing the EAs. The DOE issued draft EAs for public review and comment in December 1984 and conducted a series of public hearings in February and March 1985. The issues raised in the comment letters and hearings were considered in preparing the final EAs. These issues are addressed in a comment-response document appended to the final EAs (Appendix C).

The information presented in the EAs is derived from hundreds of technical reports containing more-detailed data and analyses. All of these reference documents are available to the public in various libraries and reading rooms; a listing of their locations is given in Appendix B.

After the nomination, the Secretary is required by the Act to recommend to the President not fewer than three of the nominated sites for characterization as candidate sites for the first repository. This recommendation will be submitted and documented in a separate report that is being issued separately from this environmental assessment. After submittal, the Act provides the President 60 days to approve or disapprove the candidate sites. The President may delay his decision for up to six months if he determines that the information supplied with the recommendation of the Secretary is insufficient to permit a decision within the 60-day period. If the President does not approve, disapprove, or delay the decision, the candidate sites shall be considered approved. After the President approves the candidate sites, the DOE will start site characterization.

ABSTRACT

In February 1983, the U.S. Department of Energy (DOE) identified the Yucca Mountain site in Nevada as one of nine potentially acceptable sites for a mined geologic repository for spent nuclear fuel and high-level radioactive waste. The site is in the Great Basin, which is one of five distinct geohydrologic settings considered for the first repository. To determine their suitability, the Yucca Mountain site and the eight other potentially acceptable sites have been evaluated in accordance with the DOE's General Guidelines for the Recommendation of Sites for the Nuclear Waste Repositories. These evaluations were reported in draft environmental assessments (EAs), which were issued for public review and comment. After considering the comments received on the draft EAs, the DOE prepared the final EAs.

On the basis of the evaluations reported in this EA, the DOE has found that the Yucca Mountain site is not disqualified under the guidelines. The DOE has also found that it is suitable for site characterization because the evidence does not support a conclusion that the site will not be able to meet each of the qualifying conditions specified in the guidelines. On the basis of these findings, the DOE is nominating the Yucca Mountain site as one of five sites suitable for characterization.

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EXECUTIVE SUMMARY

1. INTRODUCTION

By the end of this century, the United States plans to begin operating the first geologic repository for the permanent disposal of commercial spent nuclear fuel and high-level radioactive waste. Public law 97-425, the Nuclear Waste Policy Act of 1982 (the Act), specifies the process for selecting a repository site, and constructing, operating, closing, and decommissioning the repository. Congress approved geologic disposal by declaring that one of the key purposes of the Act is "to establish a schedule for the siting, construction, and operation of repositories that will provide reasonable assurance that the public and the environment will be adequately protected from the hazards posed by high-level radioactive waste and such spent nuclear fuel as may be disposed of in a repository" [Section 111(b)(1)].

A geologic repository can be viewed as a large underground mine with a complex of tunnels occupying roughly 2,000 acres at a depth between 1,000 and 4,000 feet. To handle the waste received for disposal, surface facilities will be developed which will occupy about 400 acres. The repository will be operational for about 25 to 30 years. After the repository is closed and sealed, waste isolation will be achieved by a system of multiple barriers, both natural and engineered, that will act together to contain and isolate the waste as required by regulations. The natural barriers include the geologic, hydrologic, and geochemical environment of the site. The engineered barriers consist of the waste package and the underground facility. The waste package includes the waste form, the waste disposal container, and materials placed over and around the containers. The underground facility consists of underground openings and backfill materials, not associated with the waste package, that are used to further limit ground-water circulation around the waste packages and to impede the subsequent transport of radionuclides into the environment.

In February 1983, the DOE carried out the first requirement of the Act by formally identifying nine sites in the following locations as potentially acceptable sites for the first repository (the host rock of each site is noted in parentheses):

1. Vacherie dome, Louisiana (domal salt)
2. Cypress Creek dome, Mississippi (domal salt)
3. Richton dome, Mississippi (domal salt)
4. Yucca Mountain, Nevada (welded tuff)
5. Deaf Smith County, Texas (bedded salt)
6. Swisher County, Texas (bedded salt)
7. Davis Canyon, Utah (bedded salt)
8. Lavender Canyon, Utah (bedded salt)
9. Reference repository location, Hanford Site, Washington (basalt flows).

The locations of these sites are shown in Figure 1.

Figure 1. Potentially acceptable sites for the first repository.

After identifying these potentially acceptable sites, the DOE published draft General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories (the guidelines) in accordance with the Act. The draft guidelines were revised in response to extensive comments and received the concurrence of the Nuclear Regulatory Commission (NRC) in June 1984. Final guidelines were published in December 1984 as 10 CFR Part 960.

The Act requires the DOE to nominate at least five sites as suitable for site characterization--a formal information-gathering process that will include the sinking of one or more shafts at the site and a series of experiments and studies underground. The DOE must then recommend not fewer than three of those sites for characterization as candidate sites for the first repository. After site characterization is completed, one of the characterized sites will be recommended for development as a repository.

The Act also requires the DOE to prepare environmental assessments (EAs) to serve as the basis for site-nomination decisions. These EAs contain the following information and evaluations consistent with the requirements of Section 112 of the Act:

- A description of the decision process by which the site is being considered for nomination (EA chapters 1 and 2).
- A description of the site and its surroundings (EA Chapter 3).
- An evaluation of the effects of site characterization activities on public health and safety and the environment and a discussion of alternative activities that may be taken to avoid such effects (EA Chapter 4).
- An assessment of the regional and local effects of locating the proposed repository at the site (EA Chapter 5).
- An evaluation as to whether the site is suitable for site characterization (EA Chapter 6).
- An evaluation as to whether the site is suitable for development as a repository (EA Chapter 6).
- A reasonable comparative evaluation of the site with other sites that have been considered (EA Chapter 7).

This executive summary highlights the important information and evaluations found in the accompanying EA. Section 2 of this executive summary presents a summary of the decision process and findings leading to the nomination of the Yucca Mountain site. Sections 3 through 7 summarize the results of evaluations contained in corresponding chapters in the EA.

2. DECISION PROCESS AND PRELIMINARY CONCLUSIONS

2.1 DECISION PROCESS

The guidelines require the DOE to implement the following seven-part evaluation and decision process for nominating and recommending sites for characterization:

1. Evaluate the potentially acceptable sites against the disqualifying conditions specified in the guidelines.

2. Group all potentially acceptable sites according to their geohydrologic settings.

3. For those geohydrologic settings that contain more than one potentially acceptable site, select the preferred site on the basis of a comparative evaluation of all potentially acceptable sites in the setting.

4. Evaluate each preferred site within a geohydrologic setting and decide whether such site is suitable for the development of a repository under the qualifying condition of each applicable guideline.

5. Evaluate each preferred site within a geohydrologic setting and decide whether such site is suitable for site characterization under the qualifying condition of each applicable guideline.

6. Perform a reasonable comparative evaluation under each guideline of the sites proposed for nomination.

7. Consider an order of preference of the nominated sites as recommended sites and, on the basis of this order of preference, recommend not fewer than three sites for characterization to the President.

The DOE prepared a draft EA for each of the nine potentially acceptable sites to give all interested parties an opportunity to review the full evaluation of all sites considered. In preparing the final EAs for the five nominated sites, the DOE considered all comments that were received, as documented in Appendix C.

With the issuance of the final EAs, the DOE will formally nominate five sites as suitable for characterization. The Secretary of Energy will then recommend not fewer than three of these sites to the President as candidate sites for characterization. After the President approves the Secretary's recommendation, characterization activities will begin at those sites. After characterization is completed, the DOE will again evaluate each site against the guidelines and, after completing an environmental impact statement, will recommend one site to the President for the first repository. The President may then recommend the site to Congress. At this point, the host State may issue a notice of disapproval that can be overridden only by a joint resolution of both Houses of the U.S. Congress. If the notice of disapproval is not overridden, the President must submit another repository site recommendation with 12 months. If no notice of disapproval is submitted, or if Congress overrides the notice of disapproval, then the site designation is effective, and the DOE will file an application with the NRC to obtain a construction authorization for a repository at that site.

2.2 PRELIMINARY FINDINGS AND DETERMINATIONS

Summarized below are the DOE's preliminary findings and determinations that apply to the Yucca Mountain site.

2.2.1 EVALUATION AGAINST THE DISQUALIFYING CONDITIONS

The evidence does not support the disqualification of the Yucca Mountain site under the guidelines; nor are any of the other eight potentially acceptable sites found to be disqualified.

2.2.2 GROUPING OF SITES BY GEOHYDROLOGIC SETTING

The nine potentially acceptable sites are contained within five distinct geohydrologic settings as defined by the U.S. Geological Survey. The sites are grouped by the DOE's geohydrologic designations as follows:

Geohydrologic setting	Site
Columbia Plateau	Reference repository location, Hanford Site, Washington
Great Basin	Yucca Mountain, Nevada
Permian Basin	Deaf Smith County and Swisher County, Texas
Paradox Basin	Lavender Canyon and Davis Canyon, Utah
Gulf Interior Region of the Gulf Coastal Plain	Vacherie Dome, Louisiana; Cypress Creek Dome and Richton Dome, Mississippi

The Yucca Mountain site is hydrologically distinct from the other sites. The proposed repository horizon at the site is in the unsaturated zone about 200 to 400 meters (656 to 1,300 feet) above the water table. The proposed horizons at the other eight sites are all situated well below the water table.

2.2.3 SELECTION OF THE PREFERRED SITE IN THE GREAT BASIN

The Yucca Mountain site is the only potentially acceptable site identified in the Great Basin. The process by which it was identified as the preferred site in that setting is described in Chapter 2 of the Yucca Mountain EA.

2.2.4 SUITABILITY OF THE YUCCA MOUNTAIN SITE FOR DEVELOPMENT AS A REPOSITORY

Section 112(b) of the Act requires the DOE to evaluate the suitability of a site for development as a repository under each guideline that does not require site characterization as a prerequisite for the application of such guideline. The intent is to preclude the investment of money and effort in sites that could be disqualified under those guidelines for which substantial information is available for site evaluations. The guidelines that do not require characterization address mainly those characteristics of a site that are related to the effects of a repository on public health and safety, the quality of the environment, and socioeconomic conditions during the operating period, before the repository is closed and sealed.

For a site to be suitable for repository development under each of those guidelines that do not require site characterization, no disqualifying conditions can be present, and each of the qualifying conditions must be met. A final determination of suitability for repository development cannot be made until site characterization is complete. However, at this stage, the evidence does not support a finding that the Yucca Mountain site is disqualified. Furthermore, the evidence does not support a finding that the Yucca Mountain site is not likely to meet all the qualifying conditions under those guidelines that do not require site characterization.

2.2.5 SUITABILITY OF THE YUCCA MOUNTAIN SITE FOR CHARACTERIZATION

To determine whether a site is suitable for characterization, the DOE must evaluate the site against all the guidelines, including those that require site characterization. To judge that a site is suitable, the DOE must conclude that the evidence does not support a finding that the site is not likely to meet all of the guidelines. The evaluations against the guidelines have led to a preliminary conclusion that the Yucca Mountain site is suitable for characterization.

2.2.6 DECISION ON NOMINATION

Having made the above findings, the DOE has decided to nominate the Yucca Mountain site as suitable for characterization. The other potentially acceptable sites selected for nomination are Davis Canyon, Utah; Deaf Smith, Texas; the reference repository location at the Hanford site, Washington; and the Richton dome, Mississippi.

3. THE SITE

The Yucca Mountain site is in Nye County, Nevada, on and adjacent to the southwest portion of the Nevada Test Site, about 137 kilometers (85 miles) by air northwest of Las Vegas (Figure 2). The Yucca Mountain site is on three adjacent parcels of Federal land, each under the separate control of the DOE, the U.S. Air Force, and the Bureau of Land Management.

Yucca Mountain is in the southern part of the Great Basin, a part of the Basin and Range Physiographic Province in which all surface waters drain into closed basins rather than flowing into the ocean. As shown in Figure 3, the rocks in this province can be divided into four groups in order of decreasing geologic age: (1) Precambrian crystalline basement rocks; (2) Upper Precambrian and Paleozoic sedimentary rocks that have been folded, faulted, and uplifed to form large mountain ranges that eventually eroded to a gentle plain; (3) Tertiary tuffaceous volcanic material such as that which forms Yucca Mountain; and (4) alluvium derived from the erosion of the surrounding mountains. The tuffaceous rocks occur in layers at least 2,000 meters (6,500 feet) thick.

Faulting and volcanism that produced the early features of the Basin and Range Province took place concurrently approximately 10 to 40 million years ago. In the vicinity of Yucca Mountain, tectonic activity has steadily decreased over the last 10 million years. Minor volcanic activity has continued during basin filling and, most recently, produced thin, areally restricted flows and cones of basaltic material on Crater Flat, west of Yucca Mountain. Some faults in the vicinity of Yucca Mountain show evidence of continued movement during the last 2 million years. Investigations to date covering an 1,100 square-kilometer (425 square-mile) area around the site have found thirty-two faults that offset or fracture Quaternary deposits. Quaternary faults have been divided into three broad age groups: 5 faults last moved between 270,000 and 40,000 years ago; 4 other faults last moved about 1 million years ago; and 23 faults last moved probably between 2 million and 1.2 million years ago. Recently available but unevaluated thermoluminescence dates may indicate on the order of 1 to 10 centimeters (2.54 to 25.4 inches) of fault displacement in eastern Crater Flat less than 6,000 years ago. Yucca Mountain and areas to the west and south have had a relatively low level of seismicity throughout the historical record.

The hydrologic system of the southern part of the Great Basin is characterized by low precipitation, deep water tables, and closed topographic and ground-water basins that contain all surface-water flow within the region. Ground water is recharged by the slow infiltration and percolation of rain and surface water through intergranular pores and perhaps through fractures in the rocks overlying the water table. At Yucca Mountain, most of the annual precipitation of 150 millimeters (5.91 inches) is returned to the atmosphere through evaporation and plant transpiration before it can infiltrate deep enough to become percolation and finally ground-water recharge. Only a small fraction (3 percent or less) of the annual precipitation reaches the depth proposed for the repository.

At Yucca Mountain, a repository would be constructed in the unsaturated zone 200 to 400 meters (656 to 1,300 feet) above the water table. The movement of ground water in the unsaturated zone is typified by a very low

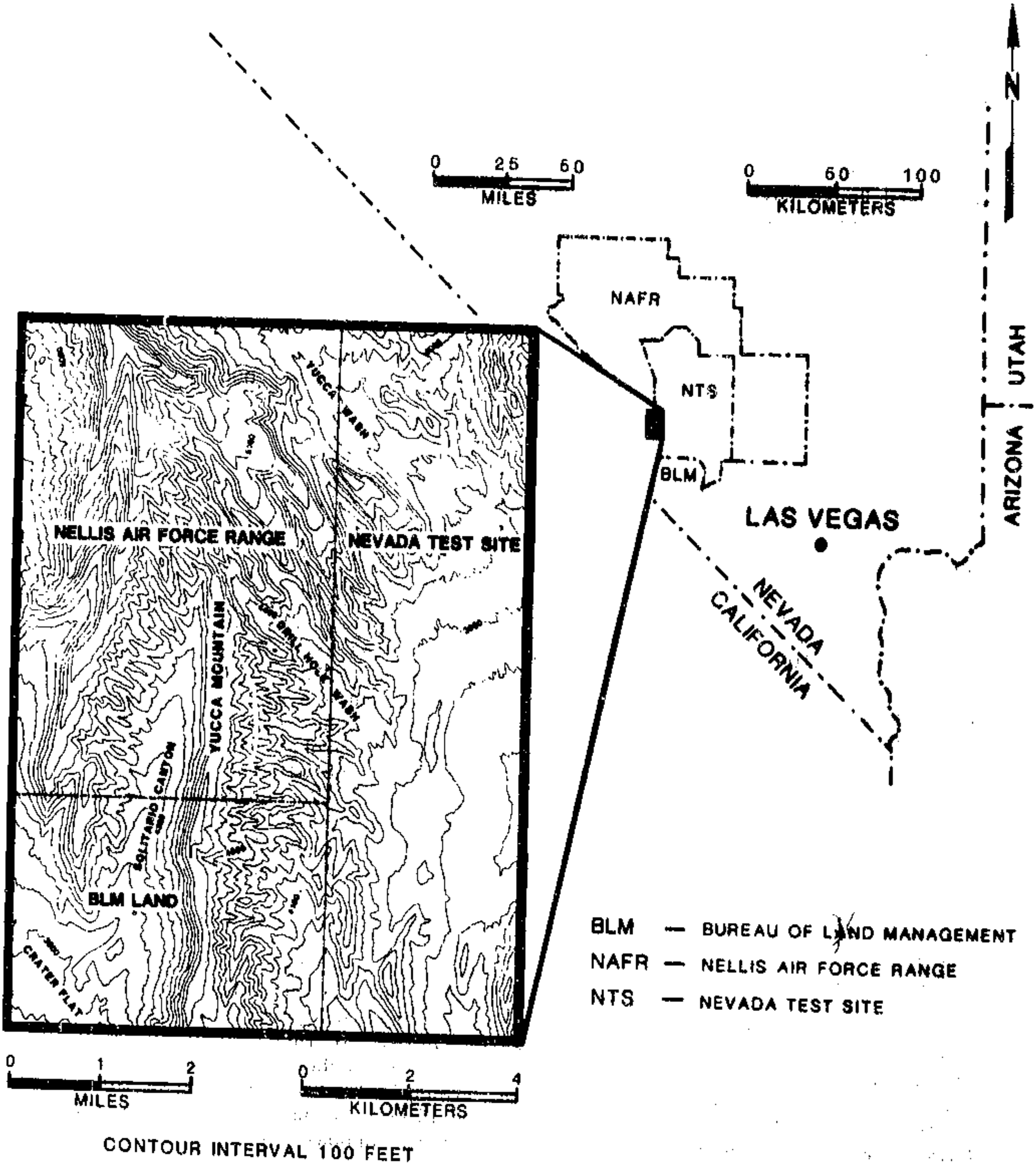

Figure 2. Yucca Mountain site in southern Nevada.

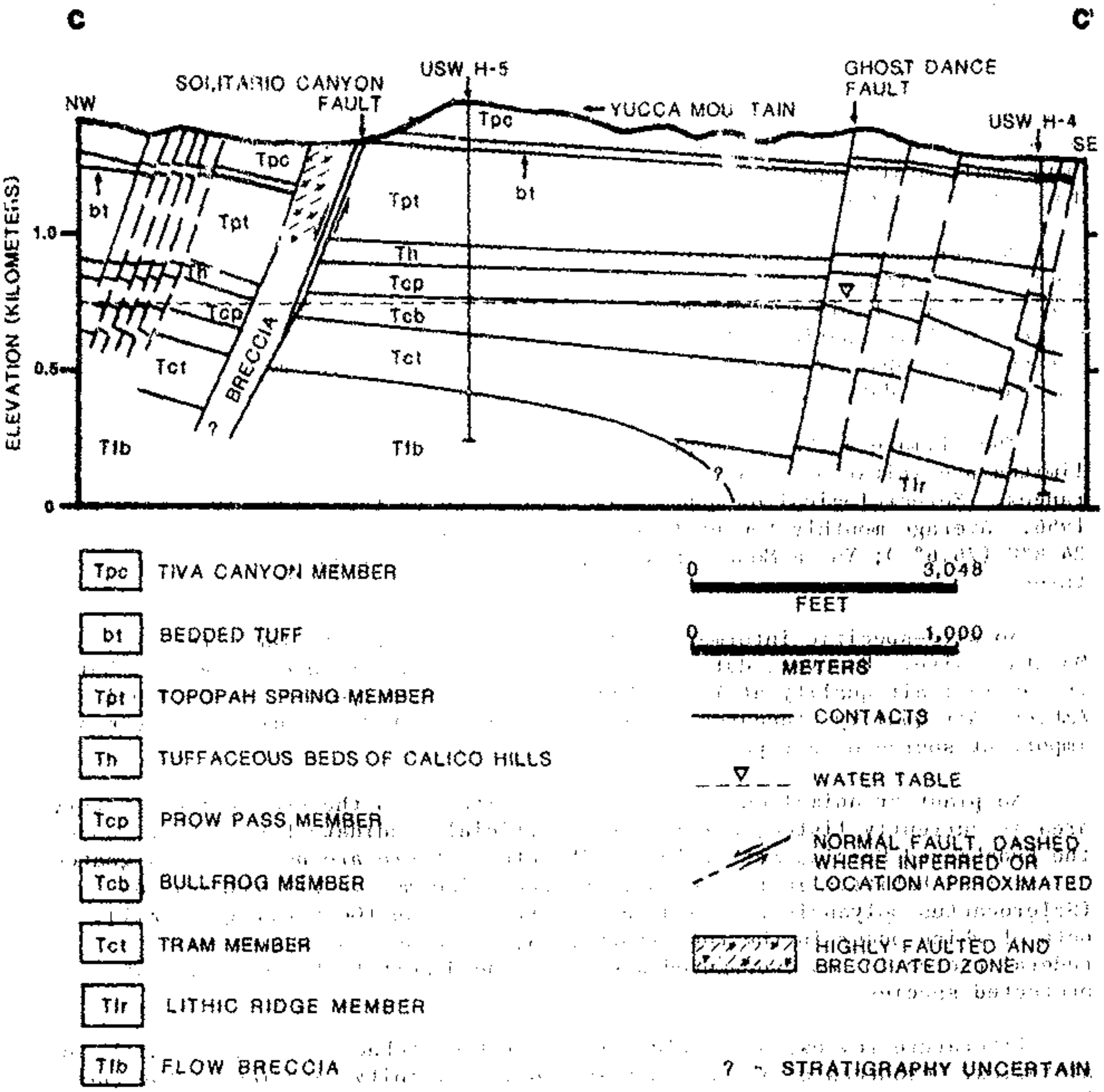

Figure 3. Geologic cross section of the Yucca Mountain site.

flux of water moving downward primarily through the intergranular pores of the tuff layers. In the saturated zone below, water moves laterally through fractures and pores in both the tuffs and in the underlying carbonate-rock aquifers.

There is no evidence that the Yucca Mountain site contains any commercially attractive geothermal, uranium, hydrocarbon, oil shale, or coal resources, although low-grade uranium and geothermal resources are found in the general area of the site. Under foreseeable economic conditions and in spite of the many small mining operations in the area, there is no potential at the site for extracting the limited mineral resources.

No perennial streams occur at or near Yucca Mountain. The only reliable sources of surface water are springs in Oasis Valley, Amargosa Desert, and Death Valley. Rapid run-off during heavy precipitation fills the normally dry washes for brief periods of time. Local flooding can occur where the water exceeds the capacity of the channels. The terminal playas may contain standing water for days or weeks after severe storms.

The climate at Yucca Mountain is characterized by high solar insolation, limited precipitation, low relative humidity, and large diurnal temperature ranges. Meteorological data have been collected at the Nevada Test Site since 1956. Average monthly temperatures at Yucca Flat vary from 1.8°C (35.3°F) to 24.8°C (76.6°F); Yucca Mountain is expected to have slightly lower temperatures.

No site-specific information about air quality is available for the Yucca Mountain site. However, data from similar remote desert areas suggest that the ambient air quality at Yucca Mountain probably surpasses the National Ambient Air Quality Standards. Suspended particulates are probably the most important source of air pollution at Yucca Mountain.

No plant or animal on the Nevada Test Site or in the proposed repository area is currently listed, nor is one an official candidate for listing, under the Endangered Species Act of 1973. Therefore, there are no areas designated as critical habitats in the repository area. The Mojave fishhook cactus (Sclerocactus polyancistrus) and the desert tortoise (Gopherus agassizii), both of which occur in the repository area, are under consideration for Federal protection as endangered species. The desert tortoise is a State-protected species.

Literature reviews and field surveys of the archaeological, cultural, and historical resources of Yucca Mountain and its vicinity have led to the identification of 178 prehistoric aboriginal sites. These sites are evidence that the area of Yucca Mountain was used by small and highly mobile groups or bands of aboriginal hunter-gatherers.

Social and economic impacts are expected to occur in areas where repository-related expenditures would be made and where the inmigrating repository-related work force would reside. Historical settlement patterns of workers at the Nevada Test Site (NTS), located in Nye County, provide a reasonable indication of where repository workers and their families would settle. Data on recent settlement patterns of these workers indicate that most (96 percent) of the repository-related population would likely settle in Nye and Clark counties. Therefore, the areas expected to experience socioeconomic effects consist of Nye County, where the site is located, and neighboring Clark County.

Nye County is largely rural, with a population density of 0.5 person per square mile. The three unincorporated towns in southern Nye County closest to the proposed site are Amargosa Valley, Beatty, and Pahrump. The total population of Nye County in 1980 was 9,048.

The 1980 population of Clark County was 463,087, with a density of 58.8 persons per square mile. Approximately 96 percent of this population resides in the Las Vegas valley. Incorporated cities in the Las Vegas valley include Henderson, Las Vegas, and North Las Vegas. Unincorporated towns and communities in the Las Vegas valley are East Las Vegas, Enterprise, Grandview, Lone Mountain, Paradise, Spring Valley, Sunrise Manor, and Winchester.

4. EFFECTS OF SITE CHARACTERIZATION

To obtain the information necessary for evaluating the suitability of the Yucca Mountain site for a repository, the DOE will conduct a site characterization program of underground testing. To carry out this program, the DOE will construct two shafts (one shaft for exploration and one for emergency egress), excavate drifts at the proposed repository depth, and construct support structures on the surface. In addition to the tests performed underground and in the exploratory shaft, geologic field studies will be conducted to characterize underground conditions. This site characterization program will require the clearing of about 285 hectares (705 acres) of land.

Concurrent with geologic site characterization activities, the DOE will study the environment of the site and its vicinity, including weather conditions, air quality, noise, plant and animal communities, and archaeological and cultural resources. Social and economic conditions will also be investigated in the area expected to be affected by the repository.

The site characterization program will last several years. At the end of this period, if the site is found to be unsuitable for a repository, the exploratory shaft facility would be either decommissioned or preserved for other uses. Decommissioning could include the backfilling and sealing of the underground openings and shafts, and restoration of the surface area.

Site characterization activities are expected to result in minimal localized environmental effects on geologic and hydrologic conditions; land use; surface soils; ecosystems; air quality; noise levels; aesthetic quality; and cultural, historical, and archaeological resources. However, some potentially adverse effects that would result from site characterization have been identified.

One adverse impact of site characterization would be the effects on wildlife populations resulting from the removal of wildlife habitat. Approximately 285 hectares (705 acres) of habitat would be disturbed by drill pads, roads, utility lines, trenches, seismic lines, off-road driving, and construction. Wildlife in the surrounding areas could also be disturbed by human presence and activity. In addition, some roadkills are expected. Measures will be taken to mitigate adverse effects. For example, sensitive areas, such as habitats for the Mojave fishhook cactus, could be avoided. Reclamation of the disturbed lands would be undertaken. However, because the site and its immediate surroundings do not support any ecologically unique communities and because the area to be cleared is small compared to the tens of thousands of acres of relatively undisturbed desert surrounding Yucca Mountain, the ecological effects on a regional level will be minimal.

Adverse effects on air quality may result from the particulate and gaseous emissions from construction and operation of the exploratory shaft and concomitant site characterization activities. Because Yucca Mountain is in an area where the existing air quality is considered to be better than State and Federal ambient air-quality standards, site characterization would be subject to regulations designed to prevent a significant deterioration of the ambient air quality.

The effect of noise is expected to be insignificant on a regional level. Analyses indicate that wildlife may be affected within 0.6 kilometer (0.4 mile) of the exploratory shaft construction site and within 1.5 kilometers (1 mile) of a surface blast site. No wildlife impacts are expected from underground blasting or from operation of the exploratory shaft facility. The potential effects of noise on wildlife is speculative and based on laboratory experiments. Residents of the nearest town (Amargosa Valley) are not expected to be adversely affected by noise produced by site characterization activities.

Because of site-characterization activities and increased human activities in the area, there is a potential for unauthorized nonscientific excavation of archaeological sites or the collection of artifacts. To mitigate this effect, sensitive sites will be identified in cultural-resource surveys and avoided or protected where possible. An archaeologist will supervise the collection of artifacts in the areas directly affected by site-characterization activities and where sites cannot be avoided or adequately protected. Four significant sites have been identified. Systematic collections of the cultural remains at the sites have been completed to mitigate the potential adverse impact of site characterization.

The social and economic impacts of site characterization are expected to be small and insignificant. Some social effects may result from an increase in public awareness of the repository project. Selection of Yucca Mountain for site characterization could induce changes in social organization associated with the formation of support and opposition groups, disputes within existing groups, and focusing of attention on repository-related issues.

A potentially significant fiscal effect of recommending Yucca Mountain for site characterization would be an increase in the State and local participation in planning activities. However, the Act explicitly recognizes the fiscal implications of State participation and provides a mechanism for financial assistance.

5. REGIONAL AND LOCAL EFFECTS OF REPOSITORY DEVELOPMENT

To determine the effects of developing a two-stage repository at Yucca Mountain, three periods of repository development were examined: (1) construction, (2) operations, and (3) decommissioning and closure.

All of the Stage 1 and a portion of the Stage 2 facilities would be constructed and some of the subsurface facilities would be excavated during the first 4.3 years of the 7-year construction period. The Stage 2 facilities would be completed in the last 3 years of the construction period, which would overlap with the first 3 years of the operations period. The operations period, which would last for 50 years, would consist of two phases. Radioactive waste would be received and emplaced during the 28-year emplacement phase. The underground facilities and surrounding environment would be monitored during this phase. The 22-year caretaker phase would follow completion of waste-emplacement operations; the facilities, as well as the surrounding environment, would continue to be monitored, and the retrievability option would be maintained in compliance with NRC requirements (10 CFR Part 60, 1983) for ensuring retrievability at any time up to 50 years after waste emplacement begins. If a decision to retrieve the waste were made during the caretaker phase, the lifetime of the project would be extended approximately 30 years during which actual waste retrieval would be accomplished. A decision to close and decommission the repository could be made at any time during the caretaker phase. The decommissioning and closing of the repository would last for an 8-year period under the vertical-emplacement alternative or a 3-year period under the horizontal-emplacement alternative. During closure and decommissioning, shafts and boreholes would be closed and sealed, land-use controls would be instituted, the surface facilities would be decontaminated and decommissioned, and permanent markers or monuments would be erected at the site to warn future generations about the presence of the underground repository.

Both beneficial and adverse effects could result from development of a repository at Yucca Mountain. Locating a repository at Yucca Mountain is expected to have minimal impact on the geologic environment, the hydrologic environment, and land use.

Possible adverse effects on ecosystems are greatest for the construction period, and are a result of removing vegetation and increasing transportation in the vicinity of the site. The primary ecological effect would be the removal of approximately 680 hectares (1,680 acres) of vegetation. Clearing this land is not expected to be ecologically significant because the affected areas are very small compared to the surrounding undisturbed areas of similar vegetation.

Indirect ecological effects of construction may also be caused by combustion emissions, fugitive dust, sedimentation, and noise.

The potentially adverse effects on ambient air quality would be due largely to the particulates generated by site clearing, construction activities, traffic, and wind erosion. The projected concentrations of the combustion emissions are not considered high enough to cause any significant adverse effects to the plants and animals in the region. However, fugitive dust deposition on the leaves of desert shrubs can increase the loss of leaves and the death of shrubby vegetation near disturbed areas. Mitigative measures, such as wetting the surfaces of disturbed areas, can be used to minimize fugitive dust. Ambient levels of regulated pollutants are expected to be below State and Federal standards for ambient air quality; however, a more precise determination of air-quality effects and the measures that can be taken to reduce them will be made during site characterization.

Repository workers, who are protected by worker safety regulations, and wildlife are the only sensitive noise receptors in the vicinity of Yucca Mountain. The effects of noise on wildlife are speculative. No significant noise effects are expected, but any impacts to wildlife should be limited to the immediate vicinity of the site during construction, U.S. Highway 95 during transportation of men and materials to the site, and in the vicinity of the repository during operations. Noise from rail transport could affect humans at Indian Springs, Floyd R. Lamb State Park, and Mercury. No significant impacts are expected in Amargosa Valley or Indian Springs from road traffic.

The construction and operation of the repository may lead to the physical disturbance of archaeological sites and possibly the loss of data that are crucial for interpreting these sites. Several mitigating measures would be used to protect known sites where such impacts could occur; for example, fences could be erected around significant sites and a professional archaeologist could be employed to monitor construction within sensitive locations.

Transportation effects would result from increased commuter traffic and the hauling of supplies and radioactive waste. Radiological risks would result from the direct external radiation emitted by the radioactive waste as a shipment is transported. Nonradiological risks are traffic accidents and the health effects that result from the pollutants emitted by combustion engines; they would occur regardless of the cargo carried by the railcar or truck. In general, both types of risk will vary with the distance traveled and with the mode of transportation (road or rail).

Transportation accidents severe enough to release radioactive materials from a shipping container are extremely unlikely. On a national basis, the radiological impacts associated with truck shipment are much greater than those for rail, and the use of a monitored retrievable storage (MRS) facility would reduce the total radiological impact of transporting nuclear wastes, especially if rail is used as a shipping mode between the waste generation point and the MRS. As in the case of national impacts, the radiological risk on a regional basis from truck shipment is significantly greater than for rail shipment, but the risk of transporting nuclear waste within the State of Nevada is very low regardless of the mode of shipment or the use of an MRS facility.

Certain nonradiological risks are inherent in any large-scale transportation program, regardless of whether nuclear materials are involved or not. Nonradiological effects include the potential induction of cancer by nonradioactive pollutants emitted by the truck or train and the fatalities or injuries resulting from railcar or truck accidents. On a national scale the results follow the same general pattern as that of radiological impacts when waste is shipped directly to the repository in that truck shipments represent a greater risk than do rail shipments. The difference in nonradiological risk between shipping modes is significantly reduced if an MRS facility is assumed. For the regional case involving no MRS, the total nonradiological risk is low; the risk associated with truck shipments is greater than that for train shipments; and the largest fraction of the risk for truck shipments is incurred along the Interstate 15 southbound route. If an MRS facility is assumed, the total nonradiological risk also is low and the risk associated with train shipment is greater than that for truck shipment.

Total national risk is a function of the number of shipments made and whether an MRS facility is used in the waste-management system. In all cases nonradiological fatalities and injuries far exceed those due to the radiological nature of the cargo. The four scenarios are ranked according to risk in the following manner, with the highest risk first:

1. Truck transport of spent fuel to an MRS facility with a dedicated train from the MRS facility to Yucca Mountain.

2. Direct truck transport to Yucca Mountain.

3. Rail transport of spent fuel to an MRS facility with a dedicated train from the MRS facility to Yucca Mountain.

4. Direct rail transport to Yucca Mountain.

From a regional standpoint the safest scenario is direct transport from origin to Yucca Mountain by rail. The highest risk is associated with direct transport of western fuel from origin to Yucca Mountain by truck with eastern fuel being transported from the MRS facility by dedicated rail. However, as previously noted, all scenarios produce extremely low risk within the State of Nevada.

Access routes would be relatively easy to construct at the Yucca Mountain site and would traverse flat terrain, thereby reducing the risk of accidents. These routes would also bypass local towns and communities, providing direct access to regional and national transportation networks.

Total employment (direct plus indirect) induced by the project would increase and decrease over time in relation to the size of the direct project work force. Total annual employment would reach a peak of about 4,800 jobs in 1998. Near the end of the construction period in 1999, this number would decline to about 4,150. The average level of total employment would be about 4,260 for the 25-year emplacement phase through 2024. Labor market impacts would depend upon the local and regional availability of workers at various phases of the project, particularly during the construction period (from 1993 through 2000) when direct work force requirements would reach their peak. Labor market impacts could include inmigration of workers having mining and construction skills and an increase in wages and salaries to induce these workers to relocate to the area. Peak annual direct and indirect wage expenditures are expected to be between $95.37 and $110.04 million dollars during the overlap of the construction and operations periods. Additional revenues would result from local repository-related purchases.

During peak employment in 1998, the project could cause a worst-case population increase of about 16,100 over baseline projections for the bicounty area, which is about 2 percent of the baseline bicounty population. If direct and indirect workers follow the settlement patterns of workers recently employed by the DOE and its contractors at the Nevada Test Site, Clark County would receive 83 percent of the maximum annual project-related population increase or a maximum of about 13,940 people. Nye County, which would receive about 13 percent of the total, would experience a maximum influx of about 2,180 people.

Potential community-service impacts would be mainly on county-wide service providers that are more likely to have the resources for managing growth than are the unincorporated towns of Nye and Clark counties. However, available information on the current adequacy of community services indicates that repository-related population growth in the sparsely populated areas of Nye and Clark counties could contribute to existing community service supply problems in some communities. These problems would be small in urban areas of Clark County. The specific details of the effects on community services and net government revenues are not certain at this time; however, the Act provides for mitigation assistance where needed.

In Nye County, the maximum service requirements increase over those projected for the future baseline would be about 5 percent in 1998. During most of the project, service requirements would be less than 4 percent higher than the projected baseline. In Clark County, it is not expected that the requirements for increased services would exceed forecast baseline service levels by more than 1.7 percent during the period of greatest impact, which is the combined construction-operations period from 1998 to 2000. In other periods, the incremental service requirements associated with the repository in Clark County would range from about 0.1 to 1.4 percent over those expected due to projected baseline growth.

6. EVALUATIONS OF SITE SUITABILITY

The DOE has evaluated the Yucca Mountain site to determine its suitability as a candidate for site characterization. This evaluation was based mainly on the siting guidelines, but it was also based in part on the expected effects of site characterization and of repository development, as summarized in the preceding sections.

6.1 THE STRUCTURE OF THE GUIDELINES

The guidelines are divided into two sets: postclosure (the period after the repository is permanently closed) and preclosure (the period of repository siting, construction, operation, closure, and decommissioning). The postclosure and preclosure guidelines contain both technical and system guidelines. The technical guidelines address the specific characteristics of the site that are considered to have a bearing on preclosure and postclosure performance of the repository. The system guidelines address the expected performance of the total system, including its engineered components; their objective is to protect public health and safety and to preserve the quality of the environment.

The postclosure technical guidelines address the characteristics that could affect the long-term ability of the site to isolate waste from the accessible environment. In particular they cover geohydrologic conditions, geochemical conditions, rock characteristics, climatic changes, erosion, dissolution, tectonics, and human interference. The postclosure system guideline requires the site to contain and isolate waste from the accessible environment in accordance with the standards and regulations specifically promulgated for repositories by the Environmental Protection Agency (EPA) and the Nuclear Regulatory Commission (NRC). In order to achieve the specified level of containment and isolation, the site must allow for the use of engineered barriers.

The preclosure guidelines are divided into three groups: (1) preclosure radiological safety; (2) environment, socioeconomics, and transportation; and (3) the ease and cost of siting, construction, operation, and closure. A preclosure system guideline is specified for each of these groups. The associated technical guidelines address site suitability in terms of population density and distribution, site ownership and control, meteorology, offsite installations and operations, environmental quality, socioeconomics, transportation, surface characteristics, rock characteristics, hydrology, and tectonics.

6.2 SUMMARY OF SITE EVALUATIONS AGAINST THE POSTCLOSURE GUIDELINES

Features of the Yucca Mountain site that contribute to its long-term ability to isolate waste from the accessible environment include (1) an unsaturated environment, (2) the probable occurrence of zeolite minerals along the paths of ground-water flow to the accessible environment, and (3) a low potential for human intrusion.

Ground-water flow is a mechanism by which radionuclides could travel from the repository to the accessible environment after closure. The unsaturated zone at Yucca Mountain is the most significant barrier to waste migration because the amount of water available for corrosion of waste disposal containers and radionuclide transport is very limited in this zone. Furthermore, the climate of the region is very arid. The present low flux of water through the unsaturated zone is not expected to change sufficiently to compromise isolation over the next 10,000 years--the time required for waste isolation.

The occurrence of zeolite minerals along probable flow paths to the accessible environment provides a barrier to radionuclide migration because of the radionuclide-sorption capacity of zeolites. The characteristics of the probable flow paths, coupled with the characteristics of the unsaturated zone, would substantially limit the movement of radionuclides.

No economic deposits of oil, gas, or mineral resources have been found at the site, and none are expected to be found. Thus, there is very little potential for inadvertent human interference to disrupt the isolation capabilities of the Yucca Mountain site.

A condition that may adversely affect the ability of the natural barriers at the site to isolate waste is the presence of oxidizing ground water. At

Yucca Mountain, oxidizing ground water is present in the saturated zone and is expected in the unsaturated zone. The presence of oxidizing waters is of concern mainly because it may increase corrosion rates of waste disposal containers and the solubility and mobilization of radionuclides. However, because the repository would be in the unsaturated zone and thus have little exposure to ground water, the presence of oxidizing ground water may not significantly affect the lifetime of the container or the movement of radionuclides. In addition many container materials, when exposed to oxidizing conditions, form protective coatings that would prolong the lifetime of the container.

With respect to the possibility of disruptive events that would affect repository performance, the Yucca Mountain site is in a geologic setting where earthquakes of greater magnitude than those recorded in the geologic setting could occur. However, if these events do occur, they are not expected to affect the waste-isolation capabilities of the site, because such events are not likely to alter the natural characteristics of the unsaturated zone, which is the primary mechanism for controlling radionuclide migration.

In order to meet the EPA standard for long-term waste containment and isolation, the NRC requires that the waste package provide substantially complete containment of waste for a minimum of 300 years and that, after this period of containment, the radionuclide-release rate not exceed one part in 100,000 per year of the inventory calculated to be present after 1,000 years. The lifetime of waste packages at the Yucca Mountain site is expected to be more than 3,000 years. After the period of containment, the fractional rate of radionuclide release from the engineered-barrier system is estimated to be within the NRC regulatory limits. The average time of ground-water travel from the disturbed zone to the accessible environment is conservatively estimated to be 43,270 years. Preliminary assessments of engineered-barrier performance based on realistic but conservative assumptions indicate that the EPA limit on the release rate to the accessible environment would be met at the Yucca Mountain site.

6.3 SUMMARY OF SITE EVALUATIONS AGAINST THE PRECLOSURE GUIDELINES

The evaluations of the Yucca Mountain site against the three groups of preclosure guidelines are summarized below.

6.3.1 RADIOLOGICAL SAFETY

Preliminary preclosure assessments for the Yucca Mountain site indicate that radioactivity releases would not exceed any of the applicable radiation standards during repository operation and closure. In addition the site was evaluated against the four technical guidelines that address the radiological impacts of repository operation: population density and distribution, site ownership and control, meteorology, and the effects of operations and accidents at nearby installations.

The Yucca Mountain site is on Federal lands remote from populated areas. It is about 137 kilometers (85 miles) by air from the Las Vegas urban area, which is the nearest population center. The population density of Nye County is only 0.5 person per square mile. As a result, it is unlikely that radioactive releases from the repository could affect large numbers of people.

The weather conditions at the site are such that an atmospheric release of radioactive material, should a release occur, is not expected to be preferentially transported toward population centers. Also, there is little probability of operational accidents from weather and other natural phenomena.

There is little potential for the disruption of repository operations as a result of accidents at the Nevada Test Site. However, routine weapons testing at the test site would temporarily disrupt operations at the repository, because during such testing the repository workers would not be allowed to enter the underground area for safety reasons.

6.3.2 ENVIRONMENT, SOCIOECONOMICS, AND TRANSPORTATION

Three technical guidelines address the environmental, socioeconomic, and transportation effects of repository siting, construction, operation, closure, and decommissioning. These effects, which would be both beneficial and adverse, are summarized in sections 4 and 5 above. Preliminary analyses indicate that there are no significant adverse environmental impacts that cannot be mitigated; the socioeconomic welfare of the public can be preserved; transport of wastes can be conducted in compliance with regulations; the public and the environment will be adequately protected from the hazards posed by radioactive waste disposal.

With respect to the system guideline on the environment, socioeconomics, and transportation, the evidence does not support a finding that the Yucca Mountain site is not likely to meet the qualifying condition of protecting the public and the environment from the potential hazards of waste disposal.

6.3.3 EASE AND COST OF SITING, CONSTRUCTION, OPERATION, AND CLOSURE

Four technical guidelines address the ease and cost of siting, construction, operation, and closure: surface characteristics, rock characteristics, hydrology, and tectonics. The characteristics of the tuff at Yucca Mountain are favorable. For example, underground openings are expected to require minimal support, such as light rock-bolting and wire mesh. There appears to be no requirement for extensive maintenance to keep passageways open to the required dimensions. It is expected that excavated openings would remain stable enough to allow the retrieval of the waste, if necessary.

Information indicates that the current usable primary repository area at the Yucca Mountain site offers limited lateral flexibility and adequate vertical flexibility for designing and constructing the repository. Additional area is available and can be added to the usable area during site characterization. The predicted peak seismicity of the site is within the range that allows the use of reasonably available technology for design of surface and underground repository facilities.

These preliminary evaluations indicate that the repository can be constructed and operated with reasonably available technology and that the costs would be comparable to the costs of construction a repository at the other potentially acceptable sites. Therefore, there is no evidence to support a finding that the site is not likely to meet the qualifying condition of the system guideline on the ease and cost of siting, construction, operation, and closure.

7. COMPARATIVE EVALUATION OF NOMINATED SITES

7.1 PURPOSE AND REQUIREMENTS

Chapter 7 presents a comparative evaluation of the five sites nominated as suitable for site characterization: Davis Canyon, Deaf Smith County, Hanford, Richton Dome, and Yucca Mountain. Each site is a preferred site within a geohydrologic setting: Davis Canyon is in the bedded salt of the Paradox Basin in Utah; Deaf Smith County is in the bedded salt of the Permian Basin in Texas; Hanford is in basalt in the Columbia Plateau in Washington; Richton is a salt dome in Mississippi; and Yucca Mountain is in tuff in the Southern Great Basin in Nevada.

The purpose of this chapter is to present a comparative evaluation of the nominated sites in order to satisfy the following:

1. Section 112(b)(1)(E)(iv) of the Nuclear Waste Policy Act of 1982, which requires that a "reasonable comparative evaluation" be included in the environmental assessments that accompany site nomination, and

2. Section 960.3-2-2-3 of the DOE's siting guidelines (10 CFR Part 960), which requires that a reasonable comparative evaluation be made and that a summary of evaluations with respect to the qualifying condition for each guideline be provided to "allow comparisons to be made among sites on the basis of each guideline."

This comparative evaluation is intended to allow the reader to compare the more detailed suitability evaluations of the individual sites that are presented in Chapter 6 of each environmental assessment. The comparison should assist the reader in understanding the basis for the nomination of five sites as suitable for characterization [112(b)(1)(A)]; it is not intended to directly support the subsequent recommendation of three sites for characterization as candidate sites.

7.2 APPROACH AND ORGANIZATION

This comparative evaluation of the five nominated sites is based on the postclosure and preclosure guidelines (10 CFR Part 960, Subparts B and C, respectively). The evaluation presented in this chapter includes the system guidelines and the technical guidelines. The approach used to compare the sites with respect to each system and technical guideline in summarized below.

7.2.1 TECHNICAL GUIDELINES

Major considerations that could be used to compare the sites on the basis of the qualifying condition of each technical guideline were derived by identifying the favorable, potentially adverse, and disqualifying conditions that deal with the same general topic. Contributing factors that represent the characteristics of the site that are potentially important in evaluating the sites with respect to each major consideration were also identified. The relative importance of the major considerations was determined primarily by the degree to which they contribute to the qualifying condition; that is, the stronger the tie between the consideration and the qualifying condition, the greater the importance of the consideration.

The purpose of identifying major considerations for each guidelines is to combine closely related site conditions so that the balance of the favorable and potentially adverse conditions can be considered directly. Most guidelines that contain a disqualifying condition have one or more potentially adverse conditions that relate to the disqualifying condition. Since these potentially adverse conditions are considered in the formulation of a major consideration, the important aspects of the disqualifying conditions indirectly enter the comparative evaluation. Where a major consideration that is needed to evaluate the qualifying condition does not have a related favorable or potentially adverse condition, the consideration is derived directly from the qualifying or disqualifying condition.

The comparative evaluation of the sites with respect to each guideline, using the approach described above, is summarized in Sections 7.2 and 7.3 for the postclosure and preclosure guidelines, respectively.* These sections are organized in the following manner:

1. For each guideline, the major consideration(s) and associated contributing factors are identified.

2. The evaluation of each site on the basis of each major consideration is then summarized. The evaluation of each site with respect to each major consideration is presented in alphabetical order, by site.

3. The sites are then compared on the basis of the qualifying condition. This comparative evaluation describes the sites with the

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*Since the comparative evaluations in Section 7.2 and 7.3 are already a summary of information in Chapter 6, this executive summary does not attempt to further abstract the substance of the comparative evaluation. The DOE believes that a further synopsis of Section 7.2 and 7.3 for the purpose of this executive summary would distort the information and possibly mislead the reader.

most favorable combination of characteristics first and those with a less favorable combination of characteristics last in order to allow easier comparison of the suitability evaluation of the site presented in Chapter 6 with sites having other combinations of characteristics.

7.2.2 SYSTEM GUIDELINES

The comparison of sites on the basis of the individual technical guidelines uses the major considerations to incorporate the favorable and potentially adverse conditions in an evaluation of a site's standing on the qualifying conditions for each technical guideline. It is not appropriate, however, to use this approach for a comparative evaluation of sites on the basis of the system guidelines. The qualifying conditions for the system guidelines do not lend themselves to the identification of major considerations in the way that the qualifying conditions for the technical guidelines do. The system guidelines for postclosure repository performance and preclosure radiological safety are stated in terms of regulatory requirements of the NRC and EPA. The evaluations of these two system guidelines are based on preliminary performance assessments that consider the associated technical guidelines as the elements of the system. These evaluations are summarized directly from Sections 6.3.2 and 6.2.2.1 of each environmental assessment.

The system guidelines for environment, socioeconomics, and transportation, and for ease and cost of repository construction, operation, and closure are not stated as regulatory standards, and they cannot be evaluated by a performance assessment as are the other two system guidelines. Instead, they are evaluated by considering the individual guidelines that make up these two system guidelines collectively to determine whether each site meets the qualifying condition of the relevant system guidelines. The evaluation of these system guidelines is summarized from Section 6.2.2.2 and 6.3.4, in each environmental assessment.

Chapter 1

PROCESS FOR SELECTING SITES FOR GEOLOGIC REPOSITORIES

1.1 INTRODUCTION

By the end of this century, the United States plans to begin the operation of a geologic repository for the permanent disposal of commercial spent nuclear fuel and high-level radioactive waste.* Public Law 97-425, the Nuclear Waste Policy Act of 1982 (the Act), specifies the process for selecting a repository site and assigns to the U.S. Department of Energy (DOE) the responsibility for siting, constructing, operating, closing, and decommissioning the repository.

A number of alternative methods for disposing of spent nuclear fuel and high-level radioactive waste have been studied during the past 10 years (DOE, 1980a; EPA, 1979; Interagency Review Group, 1979; Schneider and Platt, 1974). After an extensive evaluation of these alternatives, as documented in the final environmental impact statement on the management of commercially generated radioactive waste (DOE, 1980a), the DOE chose disposal in mined geologic repositories as the preferred method and documented this decision in a notice published in the Federal Register (Vol. 46, p. 2667, May 14, 1981). Congress endorsed this preference by declaring that one of the key purposes of the Act is "to establish a schedule for the siting, construction, and operation of repositories that will provide reasonable assurance that the public and the environment will be adequately protected from the hazards posed by high-level radioactive waste and such spent nuclear fuel as may be disposed of in a repository" (Section 111(b)(1)).

1.1.1 THE GEOLOGIC REPOSITORY CONCEPT

A geologic repository will be developed much like a large mine. Shafts will be constructed to allow for the removal of excavated material and to permit the construction of tunnels and disposal rooms at depths between 1,000 and 4,000 feet underground. Other shafts will be constructed to allow for the transfer of waste. Surface facilities will be provided for receiving and

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*High-level radioactive waste means (1) the highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations, and (2) other highly radioactive material that the U.S. Nuclear Regulatory Commission (NRC), consistent with existing law, determines by rule requires permanent isolation. The terms "radioactive waste" and "waste" are used for both spent fuel and high-level radioactive waste.

preparing the waste for emplacement underground. The surface and underground facilities will occupy about 400 and 2,000 acres of land, respectively. When the repository has been filled to capacity and its performance has been shown to be satisfactory, the surface facilities will be decommissioned and all shafts and boreholes will be backfilled and permanently sealed. A more detailed description of a conceptual design for a repository is presented in Section 5.1.

A repository can be viewed as a system of multiple barriers, both natural and engineered, that act together to contain and safely isolate the waste. The engineered barriers will include the waste package, the underground facility, and shaft and tunnel backfill materials. The waste package will consist of the waste form, either spent nuclear fuel or solidified high-level waste, a metal container, and specially designed backfill material to separate the waste container from the host rock. The waste package will contribute to long-term isolation by delaying eventual contact between the waste and the geologic environment. The underground facility will consist of underground openings and backfill materials not associated with the waste package. These barriers will further limit any ground-water circulation around the waste packages and impede the subsequent transport of radionuclides into the environment.

The geologic, hydrologic, and geochemical features of the site constitute natural barriers to the long-term movement of radionuclides to the accessible environment. These natural barriers will provide waste isolation by impeding radionuclide transport through the ground-water system to the accessible environment and will possess characteristics that will reduce the potential for human interference in the future.

Although the DOE plans to use engineered barriers--as required by both the Nuclear Regulatory Commission (NRC) in 10 CFR Part 60 and the Environmental Protection Agency (EPA) in 40 CFR Part 191--the DOE places primary reliance on the natural barriers for waste isolation. Therefore, in evaluating the suitability of sites, the use of an engineered-barrier system will be considered to the extent necessary to meet the performance requirements specified by the NRC and the EPA but will not be relied on to compensate for deficiencies in the natural barriers.

1.1.2 THE NUCLEAR WASTE POLICY ACT OF 1982

The search for suitable repository sites has been under way for about 10 years, although preliminary screening began in the mid-1950s. With the passage of the Act, a specific process for siting and licensing repositories was established. Through provisions for consultation and cooperation as well as financial assistance, the Act also established a prominent role in the siting process for potential host States, affected Indian Tribes, and the public. To pay the costs of geologic disposal, the Act provides for a Nuclear Waste Fund through which commercial electric utility companies are charged a fee that is based on the amount of electricity they produce in nuclear power plants. The DOE's strategy for implementing the Act is discussed in detail in the Mission Plan for the Civilian Radioactive Waste Management Program (DOE, 1985).

In February 1983, the DOE carried out the first requirement of the Act by formally identifying potentially acceptable sites in the following locations (the host rock of each site is shown in parentheses):

1. Vacherie Dome, Louisiana (salt dome)
2. Cypress Creek Dome, Mississippi (salt dome)
3. Richton Dome, Mississippi (salt dome)
4. Yucca Mountain, Nevada (welded tuff)
5. Deaf Smith County, Texas (bedded salt)
6. Swisher County, Texas (bedded salt)
7. Davis Canyon, Utah (bedded salt)
8. Lavender Canyon, Utah (bedded salt)
9. Reference repository location, Hanford Site, Washington (basalt flows)

The location of these sites in their host States is shown in Figure 1-1.*

The Act further requires the DOE to issue general guidelines to be used in determining the suitability of sites. In February 1983, the DOE published draft General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories (DOE, 1983). The DOE revised the guidelines after receiving extensive comments from the NRC, the States, Indian Tribes, other Federal agencies, and the public. The NRC concurred with the revised guidelines in June 1984, and the final guidelines were promulgated in December 1984 (DOE, 1984a).

The Act requires that, after the guidelines are issued, the DOE nominate at least five sites as suitable for site characterization. The DOE must then recommend not fewer than three of those sites for characterization as candidate sites for the first repository. During site characterization, the DOE will construct exploratory shafts for underground testing to determine whether geologic conditions will allow the construction of a repository that will safely isolate radioactive waste. The Act requires the DOE to prepare site-characterization plans for review by the NRC, States, Indian Tribes, and the public. After site characterization and an environmental impact statement are completed, the DOE will recommend one of the characterized sites for development as the first repository.

1.1.3 THE ENVIRONMENTAL ASSESSMENT

The Act requires the DOE to prepare environmental assessments to serve as the basis for site nominations. Although not required by the Act, draft environmental assessments were prepared for each of the nine potentially acceptable sites and issued for comment by the NRC and other Federal agencies, the States, affected Indian Tribes, and the public. The DOE has considered the comments received on these drafts before making final decisions about

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*In Texas, the DOE first identified two locations that were up to 300 square miles in area. These were subsequently narrowed to 9 square miles. The other potentially acceptable sites identified in February 1983 were on the order of tens of square miles.

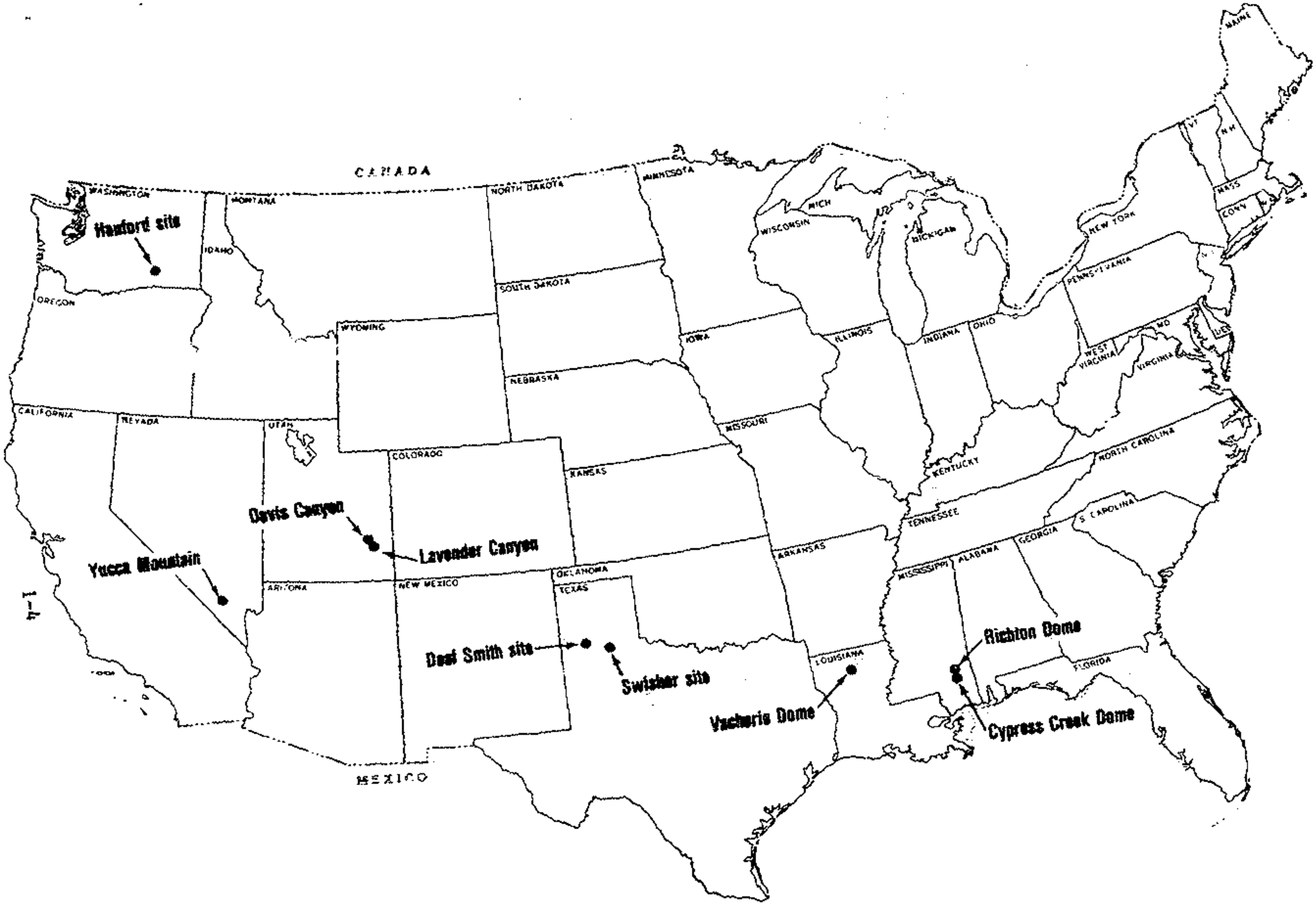

Figure 1-1. Potentially acceptable sites for the first repository.

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nomination and recommendation. The issues raised by the comments and the DOE's responses are presented in Appendix C.

The final environmental assessments contain the following kinds of information and evaluations to meet the requirements of Section 112 of the Act:

- A description of the decision process by which the site being considered for nomination was selected (Chapter 2).
- A description of the site and its surroundings (Chapter 3).
- An evaluation of the effects of site characterization on the health and safety of the public and the environment as well as a discussion of alternative activities that may be taken to avoid such impacts (Chapter 4).
- An assessment of the regional and local impacts of locating the proposed repository at the site (Chapter 5).
- An evaluation as to whether the site is suitable for site characterization (Chapter 6).
- An evaluation as to whether the site is suitable for development as a repository (Chapter 6).
- A reasonable comparative evaluation of the five nominated sites (Chapter 7).

1.2 SUMMARY OF THE OVERALL DECISION PROCESS

In seeking sites for geologic repositories, the DOE divides the siting process into the following phases: (1) screening, (2) site nomination, (3) recommendation for characterization, (4) site characterization, and (5) site selection (recommendation for development as a repository). This section describes the site-screening process that led to the identification of the nine potentially acceptable sites listed in Section 1.1 and reviews how the process of site nomination is implemented under the guidelines.

1.2.1 SITE SCREENING

During the screening phase, the DOE identified potentially acceptable sites for characterization. This phase provided the information needed for judging which of these sites appear to justify the investment in characterizing them. Screening consisted of as many as four stages, each of which progressively narrowed the study area to a smaller land unit. These stages were as follows:

1. A survey of the nation or <u>geologic provinces</u>, narrowing to <u>regions</u>. Regions are generally smaller than provinces but may extend across several States and occupy tens of thousands of square miles.

2. A survey of the regions, narrowing to areas, which encompass hundreds to thousands of square miles. For the salt sites, the regional screening phase was completed with the publication of regional characterization reports and area-recommendation reports.

3. A survey of the areas, narrowing to locations, which usually occupy an area smaller than 100 square miles. This phase was completed with the publication of location-recommendation reports for bedded salt and site-recommendation reports for salt domes.

4. A survey of the locations, narrowing to sites, which are generally smaller than 10 square miles. Although a location may be large enough to contain several sites, only one or two potential sites were usually identified in a particular location.

During each screening phase for the first repository, the DOE identified as many potentially suitable land units as were judged to be necessary for an adequate sample to be studied in the next stage. Only the regions and areas believed most likely to contain suitable sites received further study; the evaluation of all others was deferred.

Data for comparing regions, areas, and locations became increasingly detailed as progressively smaller land units were considered and as exploration and testing were concentrated on them. National, province, and regional surveys were based on the distribution of potential host rocks, published geologic maps, maps of earthquake epicenters, land use, available geohydrologic information, and other information available in the open literature. Area and location surveys required more-thorough investigations that included field exploration and testing and drilling of boreholes to investigate subsurface hydrologic, stratigraphic, and geochemical conditions. The field studies were supported by laboratory studies that focused on the waste-isolation and the engineering characteristics of potential host rocks.

The bedded-salt sites under consideration in Texas and Utah were identified by the general siting process described above, beginning with national surveys and progressively narrowing to areas, locations, and sites. The salt domes were selected by a screening that began with more than 200 domes and ended with the one site being nominated.

The screening of sites in basalt and tuff was initiated when the DOE began to search for suitable repository sites on some Federal lands where radioactive materials were already present. This approach was recommended by the Comptroller General of the United States (1979). Although land use was the beginning basis for this screening of Federal lands, the subsequent progression to smaller land units was based primarily on evaluations of geologic and hydrologic suitability. These studies began at roughly the area stage.

The technical factors used to guide site-screening decisions have evolved throughout the screening phase and are specified in a number of published documents (Brunton and McClain, 1977; DOE, 1981; DOE, 1982a; International Atomic Energy Agency, 1977; NAS-NRC, 1978).

The sections that follow summarize how the DOE applied the screening process outlined above to determine that the nine sites listed in Section 1.1.2 are potentially acceptable. Section 2.2 of each environmental assessment discusses in detail how the DOE conducted site screening in specific geohydrologic settings.

1.2.2 SALT SITES

Salt was first recommended as a potentially suitable host rock for waste disposal in 1955, after the National Academy of Sciences-National Research Council evaluated many options (NAS-NRC, 1957). This recommendation was reaffirmed in subsequent reports (e.g., American Physical Society, 1978; NAS-NRC, 1970). Rock salt, which occurs both as bedded salt and in salt domes, has several characteristics that are favorable for isolating radioactive waste, including the following:

- Salt deposits that are sufficiently deep, thick, and laterally extensive to accommodate a repository are widespread in the United States and generally occur in areas of low seismic and tectonic activity.
- Many salt bodies have remained undisturbed and water-free in comparison with other rock types for tens of millions to several hundred million years.
- Because of its high thermal conductivity, rock salt can dissipate the heat that will be generated by the waste.
- Since salt is relatively plastic under high confining pressure, the fractures that might develop at repository depth would tend to close and seal themselves.
- Rock salt undergoes only minor, highly local change as a result of exposure to radiation.
- Rock salt has excellent radiation-shielding properties.

Screening of the entire United States in the 1960s and 1970s resulted in the identification of four large regions that are underlain by rock salt of sufficient depth and thickness to accommodate a repository and represent diverse geohydrologic conditions (Johnson and Gonzales, 1978; Pierce and Rich, 1962). The four regions are as follows:

- Bedded salt in the Michigan and the Appalachian Basins of southern Michigan, northeastern Ohio, western Pennsylvania, and western New York (also called the "Salina Basin").
- Salt domes within a large part of the Gulf Coastal Plain in Texas, Louisiana, and Mississippi.
- Bedded salt in the Permian Basin of southwestern Kansas, western Oklahoma, northwestern Texas, and eastern New Mexico.

- Bedded salt in the Paradox Basin of southeastern Utah, southwestern Colorado, and northernmost Arizona and New Mexico.

This screening at the national level served as the basis for all subsequent screening in salt. After proceeding to the area phase, further screening of the salt deposits in the Salina Basin was deferred. The studies of the Salina region were not specific enough to judge that any part of the region was suitable or unsuitable for a repository. They did reveal a number of unfavorable characteristics, including a high population density associated with the concentration of urban areas in Ohio, Michigan, and New York, and an abundance of natural resources, especially oil and gas. In view of these unfavorable conditions, the DOE decided to concentrate its siting efforts on more-promising areas in the remaining three regions.

1.2.2.1 Salt domes in the Gulf Coast salt-dome basin of Mississippi and Louisiana

There are more than 500 salt domes in the Gulf Coast salt-dome basin of Texas, Louisiana, Mississippi, and areas offshore from these States. An initial screening by the U.S. Geological Survey (USGS) eliminated all offshore domes because siting a repository under water would probably not be feasible. The application of this criterion eliminated about half the domes. The USGS also evaluated the remaining 263 onshore domes (i.e., Gulf interior domes) and identified 36 as being potentially acceptable for a repository and another 89 that were worthy of further study (Anderson et al., 1973). The USGS screening factors were the depth to the top of the dome and present use for gas storage or hydrocarbon production.

The DOE and its predecessor agencies conducted regional studies of the 125 salt domes identified in the above-mentioned USGS screening. All but 11 of the domes were eliminated on the basis of three screening factors: the depth to the salt, the lateral extent of the dome, and the history of use for hydrocarbon production or storage (NUS, 1978; BNI and LETCO, 1980). Three of the 11 domes were removed from consideration on the basis of environmental factors, and a fourth was eliminated because solution mining at the site contributed to a collapse of strata above the dome.

Area-characterization studies were completed for the seven remaining dome areas: Rayburn's and Vacherie Domes in Louisiana; Cypress Creek, Lampton, and Richton Domes in Mississippi; and Keechi and Oakwood Domes in Texas. The geologic field work conducted during this phase included the drilling of deep holes to collect rock cores from the aquifers and other strata for laboratory tests of their properties and geophysical surveys to determine the underlying rock structures. The area environmental studies included descriptions of the plant and animal communities, surface- and ground-water systems, weather conditions, land use, and socioeconomic characteristics. An evaluation of the seven domes on the basis of the DOE's criteria is summarized in a location-recommendation report (ONWI, 1982a).

In the area-characterization studies, the DOE chose a repository-size criterion that was more restrictive than the one used in earlier screening studies. The application of this stricter criterion resulted in the elimination of Keechi, Rayburn's, and Lampton Domes (ONWI, 1982a). Thus, at the conclusion of area characterization, the Vacherie, Richton, Oakwood, and Cypress Creek Domes were recommended for further screening. After further review of the area-characterization studies, the Oakwood Dome was deferred from further consideration because of uncertainties raised by large-scale petroleum exploration.

In accordance with the Act, the DOE identified the Cypress Creek, Richton, and Vacherie Domes as potentially acceptable sites in February 1983.

1.2.2.2 Bedded salt in Davis Canyon and Lavender Canyon, Utah

Screening criteria were developed for the bedded salt of the Paradox Basin, which the USGS had identified as worthy of further investigation (Pierce and Rich, 1962). The following factors were applied to identify areas for further investigation (Brunton and McClain, 1977; DOE, 1981): the depth to, and the thickness of, the salt; mapped faults; surface igneous features; hydrocarbon and mineral resources, and potential for flooding. The results of this screening were integrated with the results of screening for environmental and socioeconomic factors, such as proximity to urban areas and the presence of certain dedicated lands. On the basis of this regional screening, four areas were recommended for further study: Gibson Dome, Elk Ridge, Lisbon Valley, and Salt Valley (ONWI, 1982b).

The primary screening factors used to identify potentially favorable locations within the four areas were the depth to the salt, the thickness of the salt, proximity to faults and boreholes, and proximity to the boundaries of dedicated lands (ONWI, 1982c). These screening factors were judged to have the strongest potential for differentiating possible locations within the areas.

Salt Valley and Lisbon Valley were both deferred from further consideration because all areas with an adequate depth to the salt were too close to zones of mapped surface faults and, for Lisbon Valley, existing boreholes (ONWI, 1982c).

Application of the screening factors to the Gibson Dome showed a location of 57 square miles near the center of the area that contained appropriately deep and thick salt deposits and was sufficiently far from faults or exploration boreholes that would make a site unsuitable. It was also outside the boundaries of the Canyonlands National Park. This location is referred to as the Gibson Dome location (ONWI, 1982c). The Elk Ridge area contained one location of about 6 square miles and several smaller ones, each less than 3 square miles, that met the screening criteria (ONWI, 1982c). The smaller locations were not large enough for a repository and were therefore excluded from further consideration. The larger location was designated the Elk Ridge location.

Further comparisons of the Gibson Dome and the Elk Ridge locations were made on the basis of more-refined criteria that discriminated between them. The thickness of the salt, the thickness of the shale above and below the depth of a repository, and the minimum distance to salt-dissolution features were considered the most critical geologic discriminators. Archaeological sensitivity and site accessibility were considered the most important environmental factors. The Gibson Dome location was judged to be superior to the Elk Ridge location in terms of the number and relative importance of favorable factors and was selected as the preferred location (ONWI, 1982c).

During 1982 and 1983 three sites were identified for further evaluation: Davis Canyon, Lavender Canyon, and Harts Draw. Since much of the intrinsic value of southeastern Utah stems from its scenic and aesthetic character, a study of visual aesthetics was performed to evaluate the three sites (Bechtel Group Inc., 1984). Harts Draw was found to be less desirable than the sites at Davis Canyon and Lavender Canyon because it affords a greater total area of visibility, and it was eliminated from further consideration. In February 1983, Davis Canyon and Lavender Canyon were identified as potentially acceptable sites.

1.2.2.3 Bedded salt in Deaf Smith and Swisher Counties, Texas

In 1976, the Permian bedded-salt deposits in the Texas Panhandle and western Oklahoma that had been identified in the USGS study (Pierce and Rich, 1962) were evaluated to determine whether they contained any areas that might be suitable for waste disposal (Johnson, 1976). This screening focused on five subbasins: the Anadarko, Palo Duro, Dalhart, Midland, and Delaware Basins. The primary screening factors were the depth to, and the thickness of, the salt; faults; seismic activity; salt dissolution; boreholes; underground mines; proximity to aquifers; mineral resources; and conflicting land uses, such as historical sites and State or national parks. All the subbasins contain salt beds of adequate thickness and depth. The Palo Duro and the Dalhart Basins had far less potential for oil and gas production and have not been penetrated as extensively by drilling as have the Anadarko, the Delaware, and the Midland Basins. Therefore, the Palo Duro and the Dalhart Basins were judged to be preferable to the other three and were recommended for further studies at the area stage (ONWI, 1983a). These two basins rated higher on six major screening factors: the depth to, and the thickness of, the salt; seismicity; known oil and gas deposits; the presence of exploratory boreholes; and evidence of salt dissolution.

More-detailed geologic and environmental studies of the Palo Duro and the Dalhart Basins began in 1977, and screening criteria were developed to define locations with favorable characteristics. The screening criteria that were most useful in the area-to-location screening were the following: salt depth and thickness, salt purity, existing and abandoned oil and gas fields, flooding, urban areas, and conflicting land use. Six locations in parts of Deaf Smith, Swisher, Oldham, Briscoe, Armstrong, Randall, and Potter Counties, Texas, met the screening criteria. A second set of criteria was then applied to further differentiate among the six locations: distance from the margins of the Southern High Plains, distance from known oil and gas fields, more than one potential repository horizon, depth of salt, number of boreholes that penetrate the repository horizon, a large geographic area, low population densities, and potential land-use conflicts. After applying these criteria, the DOE decided to focus on the two locations that had the greatest likelihood of containing a suitable site, one in northeastern Deaf Smith and southeastern

Oldham Counties and one in northcentral Swisher County. All other locations in the Palo Duro Basin were deferred from further consideration (ONWI, 1983b). In February 1983, the DOE identified parts of Deaf Smith County and Swisher County as potentially acceptable sites and subsequently narrowed the size of the two sites to be considered at each location to 9 square miles each (DOE, 1984b).

1.2.3 SITES IN BASALT AND TUFF

In 1977, the waste-disposal program was expanded to consider previous land use as an alternative basis for site screening. This approach considered the advantages of locating a repository on land already withdrawn from public use and committed to long-term institutional control. Because both the Hanford Site and the Nevada Test Site are dedicated to nuclear operations, will remain under Federal control, have a large geographic area, and are underlain by potentially suitable rocks, screening was initiated in these two areas.

1.2.3.1 Basalt lava in the Pasco Basin, Washington

The DOE and its predecessor agencies have investigated the geologic and hydrologic characteristics of the Pasco Basin since 1977 as a continuation of studies conducted for the defense-waste management program between 1968 and 1972 (Gephart et al., 1979; Myers et al., 1979). These investigations showed that the thick formations of basalt lava in the Pasco Basin are suitable for further investigation as a geologic repository for the following reasons:

- Several basalt flows more than 2,100 feet below ground apparently are thick enough to accommodate a geologic repository.

- The slow rate of deformation of the basalt ensures the long-term integrity of a repository at the Hanford Site. Also, there are synclines where structural deformation appears to be limited.

- The potential for renewed volcanism at the Hanford Site is very low.

- The likely geochemical reactions between the basalt rock, ground water, and the materials that would be emplaced in the repository are favorable for long-term isolation.

The Pasco Basin was selected for screening to provide a broader scope from which to study processes that might affect the Hanford Site and to determine whether there are any obviously superior sites in the natural region outside, but contiguous with, the Hanford Site (Woodward-Clyde Consultants, 1980, 1981).

The first step in screening was to define the candidate area. The screening factors used at this step were fault rupture, ground motion, aircraft traffic, ground transportation, operational radiation releases from nuclear facilities at the Hanford Site, protected ecological areas, culturally important areas, and site-preparation costs. The DOE identified a candidate area that included the central part of the Hanford Site and adjacent land east of the Hanford Site.

The second step in the screening was to define subareas (locations). The siting factors used in this step were fault rupture, flooding, ground failure, erosion, the presence of hazardous facilities, induced seismicity, and site-preparation costs. This step eliminated approximately half the candidate area.

Locations were identified through an evaluation of the subareas inside and adjacent to the Hanford Site. On the basis of land use, hydrologic conditions, and bedrock dip, subareas outside the Hanford Site were eliminated because they were not obviously superior to those found within the Hanford Site. After these subareas were eliminated, five locations were identified within the boundaries of the Hanford Site.

The identification of sites from among the five locations was based on an evaluation of 23 parameters (Rockwell, 1980). Nine sites were identified, seven of which lay in the Cold Creek Syncline, a major structural feature of the Pasco Basin. This syncline was selected partly because it is not as extensively deformed as nearby anticlines and is underlain by relatively horizontal strata. Since the other two sites were not technically superior to those in the Cold Creek Syncline and were closer to the Columbia River, they were removed from further study. To avoid some geophysical anomalies of uncertain source, the DOE identified three other sites that were largely superimposed on parts of the original seven sites in the Cold Creek Syncline (Myers and Price, 1981).

Since preliminary evaluations of the resulting 10 partly overlapping sites indicated that the sites were too closely matched to be differentiated by routine ranking, a formal decision analysis was used to identify the best site (Rockwell, 1980). Decision criteria were derived from the following siting factors: bedrock fractures and faults, lineaments, potential earthquake sources, ground-water travel times, contaminated soil, surface facilities, the thickness of the proposed repository horizon, the repetitive occurrence of columnar-jointed zones (colonnades) within the host flow, natural vegetative communities, unique microhabitats, and special species. The analysis showed that two approximately coincident sites rated higher than the other sites. These two sites were combined and designated the reference repository location. In February 1983, the DOE identified the reference repository location as a potentially acceptable site.

1.2.3.2 Tuff in the southern Great Basin, Nevada

At the same time that the DOE was considering the Nevada Test Site (NTS) on the basis of land use, the USGS proposed that the NTS be considered for investigation as a potential repository site for a variety of geotechnical reasons, including the following:

- Southern Nevada is characterized by closed hydrologic basins. This means that ground water does not discharge into rivers that flow to major bodies of surface water.

- Long flow paths occur between potential repository locations and ground-water discharge points.

- Many of the rocks occurring at the NTS have geochemical characteristics that are favorable for waste isolation.

- The NTS is located in an arid region (6 to 8 inches per year of rainfall). With the very low rate of recharge, the amount of moving ground water is also low, especially in the unsaturated zone.

In 1977, the geologic medium of prime interest at the NTS was argillite (a clay-rich rock), which occurs under the Syncline Ridge near the center of the NTS. Geologic investigations and exploratory drilling there revealed a complex geologic structure in the center of the area being considered (Hoover and Morrison, 1980; Ponce and Hanna, 1982). It was decided in July 1978 that the geologic complexity of the area would make characterization prohibitively difficult, and further evaluation was deferred.

A question then arose concerning the compatibility of a repository with the testing of nuclear weapons--the primary purpose of the NTS. A task group formed to evaluate this issue determined in 1978 that a repository located in other than the southwest portion of the NTS might be incompatible with weapons testing. At that time the program refocused on the area in and around the southwestern corner of the NTS, which subsequently was named the Nevada Research and Development Area (NRDA). The entire area then being evaluated included land controlled by the Bureau of Land Management west and south of the NRDA and a portion of the Nellis Air Force Range west of the NRDA.

In August 1978, a preliminary list of potential sites in and near the southwestern part of the NTS was compiled. The areas initially considered were Calico Hills, Skull Mountain, Wahmonie, Yucca Mountain, and Jackass Flats. Of these five areas, Calico Hills, Wahmonie, and Yucca Mountain were considered the most attractive locations for preliminary borings and geophysical testing.

The Calico Hills location was known to contain argillite. It was of particular interest because a geophysical survey showed that granite might occur approximately 1,600 feet below the surface. The first exploratory hole for waste-disposal studies at the NRDA was drilled in 1978 in an attempt to confirm the existence of granite beneath the Calico Hills. Drilling was discontinued at a depth of 3,000 feet without reaching granite (Maldonado et al., 1979). Additional geophysical surveys indicated that the argillite at Calico Hills is probably very complex structurally, comparable with that at Syncline Ridge (Hoover et al., 1982). Because the granite was considered too deep and the argillite appeared too complex, further consideration of the Calico Hills was suspended in the spring of 1979.

Concurrent with drilling at Calico Hills, geophysical studies and surface mapping conducted at Wahmonie indicated that the granite there may not be large enough for a repository, that any granite within reasonable depths may contain deposits of precious metals, and that faults in the rock may allow vertical movement of ground water (Hoover et al., 1982; Smith et al., 1981). For these reasons, Wahmonie was eliminated from consideration in the spring of 1979.

Surface mapping of Yucca Mountain indicated the existence of a generally undisturbed structural block large enough for a repository. In 1978, the first exploratory hole drilled at Yucca Mountain confirmed the presence of thick, highly sorptive units of tuff (Spengler et al., 1979). Because tuff previously had not been considered as a potential host rock for a repository, a presentation was made to the National Academy of Sciences (NAS) Committee for Radioactive Waste Management in September 1978 to solicit its views on the potential advantages and disadvantages of tuff as a repository host rock. The NAS committee supported the concept of investigating tuff as a potential host rock, and the USGS subsequently pointed out the considerable advantages of locating a repository in the unsaturated zone. After comparing the results of preliminary exploration at Calico Hills, Wahmonie, and Yucca Mountain, the USGS recommended that attention be focused on Yucca Mountain. A technical peer-review group supported the DOE's decision to concentrate exploration efforts on the tuffs of Yucca Mountain (DOE, 1980b).

Because the foregoing process of selecting Yucca Mountain for early exploration was not highly structured, a more thorough, formal analysis was begun in 1980 to evaluate whether Yucca Mountain was indeed appropriate for further exploration. This analysis was conducted in a manner compatible with the area-to-location phase of site screening described in the national siting plan (DOE, 1982b), which was used by the DOE before the passage of the Act and the formulation of the guidelines. Details of the formal analysis are presented by Sinnock and Fernandez (1984). In brief, this formal decision analysis evaluated 15 potential locations and concluded that Yucca Mountain was indeed the preferred location. Several potentially suitable horizons were identified in the saturated and unsaturated zones. Therefore, the DOE identified Yucca Mountain as a potentially acceptable site in February 1983.

1.2.4 NOMINATION OF SITES FOR CHARACTERIZATION

The guidelines, in 10 CFR Part 960.3, require the DOE to implement the following six-part decision process in selecting sites for nomination from among the potentially acceptable sites:

1. Evaluate the potentially acceptable sites in terms of the disqualifying conditions specified in the guidelines.

2. Group all potentially acceptable sites according to their geohydrologic settings.

3. For those geohydrologic settings that contain more than one potentially acceptable site, select the preferred site on the basis of a comparative evaluation of all potentially acceptable sites in that setting.

4. Evaluate each preferred site within a geohydrologic setting and decide whether such site is suitable for the development of a repository under the qualifying condition of each applicable guideline.

5. Evaluate each preferred site within a geohydrologic setting and decide whether such site is suitable for site characterization under the qualifying condition of each applicable guideline.

6. Perform a reasonable comparative evaluation under each guideline of the sites proposed for nomination.

Section 1.3 presents the results of evaluating the nine potentially acceptable sites against the disqualifying conditions of the guidelines (step 1) and explains how the DOE has grouped the potentially acceptable sites by geohydrologic setting (step 2). Chapter 2 begins with a detailed description of the geohydrologic setting in which the Yucca Mountain site is located and provides the basis for the identification of a preferred site in that geohydrologic setting (step 3). Chapter 6 evaluates the site against the guidelines and presents the findings required in steps 4 and 5. Chapter 7 provides a comparative evaluation of the sites proposed for nomination (step 6).

Having issued the final EAs, the DOE will formally nominate five sites as suitable for characterization. The Secretary of Energy will then recommend three of these sites to the President as candidate sites for characterization. The Secretary's recommendation is presented and documented in a separate report that is being issued simultaneously with this environmental assessment.

1.2.5 FINAL STEPS IN THE SITE-SELECTION PROCESS

After the President approves the sites recommended by the Secretary, characterization activities will begin at those sites. If site characterization reveals new information that shows that a site is unsuitable for development as a repository under the guidelines, the DOE will eliminate that site from further consideration and take steps to reclaim the site and to mitigate any significant adverse impacts caused by site characterization. In the event that a site is eliminated from further consideration during characterization, the DOE does not expect to substitute another site for characterization.

After characterization is completed, the DOE will again evaluate each site against the guidelines, prepare an environmental impact statement, and recommend one site to the President for the first repository. The President may then recommend the site to the Congress. At this point, the Governor or the legislature of the host State may submit to the Congress a notice of disapproval that can be overridden only by a joint resolution of both Houses of the Congress. If the notice of disapproval is not overridden, the President must submit another repository-site recommendation within 12 months. If no notice of disapproval is submitted, or if the notice of disapproval is overridden, then, as prescribed by the Act, the site designation is effective, and the DOE will proceed to file an application with the NRC to obtain a construction authorization for a repository at that site.

1.3 EVALUATION OF POTENTIALLY ACCEPTABLE SITES AGAINST THE DISQUALIFYING CONDITIONS OF THE GUIDELINES AND GROUPING INTO GEOHYDROLOGIC SETTINGS

1.3.1 EVALUATION AGAINST THE DISQUALIFYING CONDITIONS

Having evaluated the nine potentially acceptable sites against the disqualifying conditions in the guidelines, the DOE has found no evidence to support a finding that any site is disqualified. Details of this analysis are contained in Chapter 6, and a summary of findings for each disqualifying condition is presented in Section 2.3.

1.3.2 DIVERSITY OF GEOHYDROLOGIC SETTINGS AND TYPES OF HOST ROCK

Sections 960.3-1-1 and 960.3-1-2 specify that, to the extent practicable, sites recommended as candidate sites for characterization shall be located in different geohydrologic settings and shall have different types of host rock. This guideline-mandated diversity of geohydrologic settings and host rocks is consistent with similar requirements in the NRC's rule governing the disposal of high-level radioactive waste, 10 CFR Part 60. This requirement will protect against the possibility that future investigations might reveal a generic deficiency in a given rock type or within a given regional geohydrologic environment. Such deficiencies might lead to the disqualification of sites in that setting or rock type. If one rock type or geohydrologic environment were viewed initially as the most favorable for a repository, site nomination and recommendation might be dominated by sites in that type of host rock or geohydrologic environment. If later analyses revealed an unacceptable weakness in either the host rock or in the characteristics of the geohydrologic environment, all candidate sites might have to be eliminated. This could leave the program with no viable alternatives available without lengthy additional site exploration.

The guidelines (Part 960.2) define "geohydrologic setting" as a system of geohydrologic units located within a geologic setting. They further define "geohydrologic unit" as an aquifer, a confining unit, or a combination of aquifers and confining units comprising a framework for a reasonably distinct geohydrologic system. A "geologic setting" encompasses thousands to hundreds of thousands of square miles and is characterized by general similarities in physiography, stratigraphy, structural style, and ground-water flow.

For the intents and purposes of the analyses contained in this environmental assessment, the term "geohydrologic setting" refers to a large and relatively distinct major geohydrologic province of the United States commonly identified and accepted in the technical literature. Such a geohydrologic province has recognizable distinct geologic, hydrologic, and geochemical characteristics and boundaries that distinguish it from other geohydrologic settings.

1.3.2.1 Geohydrologic classification system

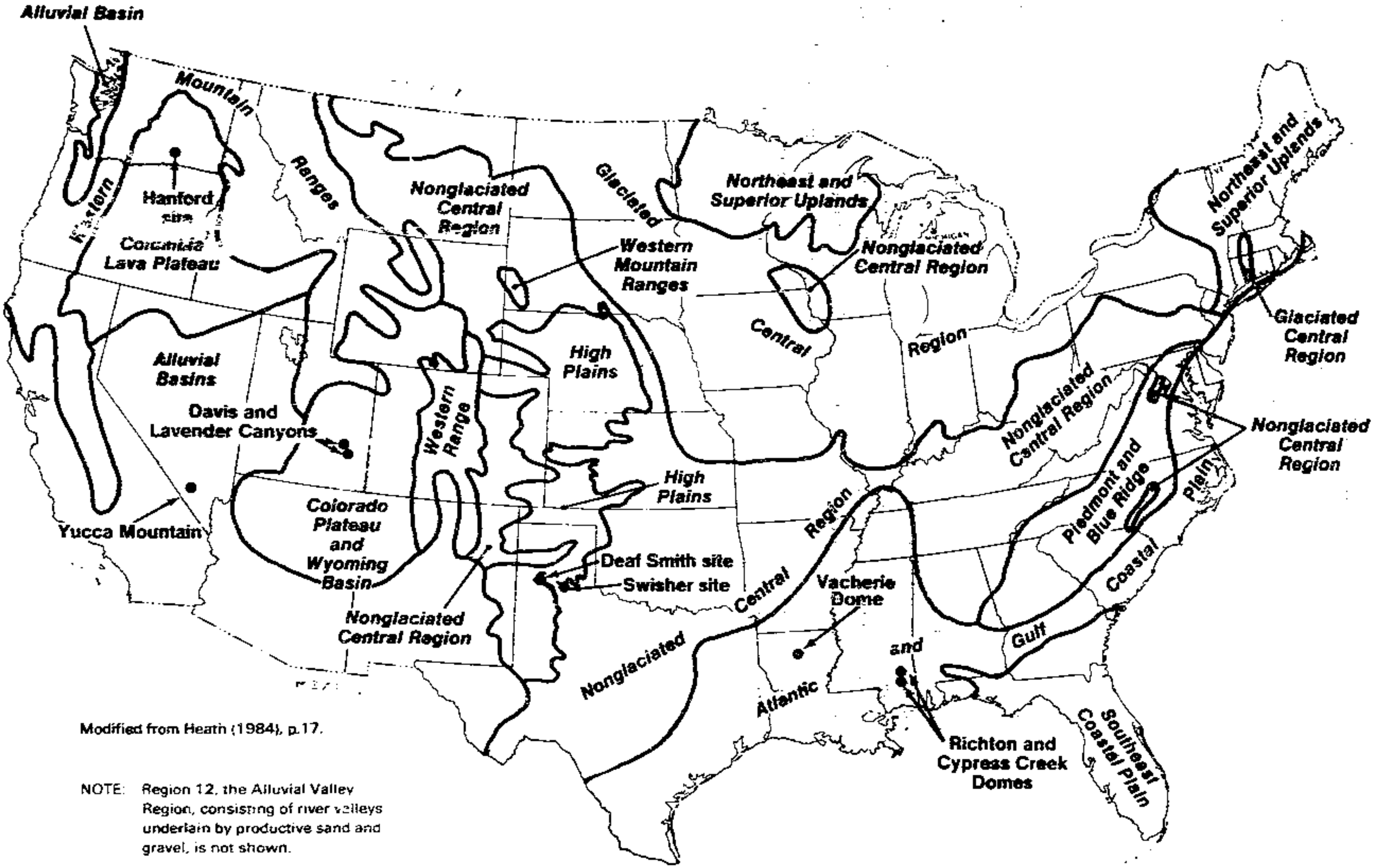
In a report entitled "Ground-Water Regions of the United States" (Heath, 1984), the USGS presents a classification that meets these broad criteria for geohydrologic settings. The USGS applied a logical set of criteria for classifying major geohydrologic regions that considers aquifers and confining units of the system, the nature of water-bearing openings in the rocks, the composition of the rocks, the water-transmitting and water-storage properties of the rocks, and the nature and location of recharge and discharge areas. These characteristics are also those that relate to repository performance (ground-water pathways, rates of radionuclide migration, and other factors important to waste isolation). Therefore, these general criteria appear suitable for application to this guideline requirement.

The USGS classification resulted in the delineation of 12 geohydrologic regions in the contiguous United States (see Figure 1-2). The specific rationale for the delineation and characteristics of each region is described in Heath's report.

It is within the framework of the USGS geohydrologic regions that the nine potentially acceptable sites were examined and classified as to their particular geohydrologic setting. In addition to the general criteria used in the USGS classification, other considerations were used to further subdivide the regions on the basis of tectonic activity, geologic structure, subbasins within the regions, and so on. Accordingly, the DOE has determined that the nine sites fall within the following five distinct geohydrologic settings (the name of the region within which each geohydrologic setting is located is listed in parentheses):

Geohydrologic setting	Site
Columbia Plateau (Columbia Lava Plateau)	Reference repository location as on the Hanford Site, Washington
Great Basin (Alluvial Basins)	Yucca Mountain, Nevada
Permian Basin (High Plains)	Deaf Smith County and Swisher County, Texas
Paradox Basin (Colorado Plateau and Wyoming Basin)	Lavender and Davis Canyons, Utah
Gulf Coastal Plain (Atlantic and Gulf Coastal Plain)	Vacherie Dome, Louisiana; Cypress Creek Dome and Richton Dome, Mississippi

The fundamental distinguishing characteristics associated with these settings as they relate to waste isolation are briefly described below. More-specific details on the characteristics of each of the geohydrologic settings are presented in Section 2.1.



Modified from Heath (1984), p.17.

NOTE: Region 12, the Alluvial Valley Region, consisting of river valleys underlain by productive sand and gravel, is not shown.

Figure 1-2. Geohydrologic regions of the contiguous United States.

1.3.2.2 Distinct differences among the geohydrologic settings and host rocks

The major distinguishing differences among the five geohydrologic settings of the nine potential repository sites are summarized below.

The Hanford and the Yucca Mountain sites are clearly unique in terms of the host rock, the geologic conditions, and the hydrologic conditions that make up the geohydrologic setting. The Hanford site is located within the Pasco Basin, which is a subunit of the Columbia Lava Plateau geohydrologic setting as defined by Heath (1984). It is underlain by a thick, extensive sequence of rocks composed entirely of basalt lava flows in the lower part and of increasing amounts of interbedded, sedimentary deposits in the upper part. Aquifers generally are in the upper parts of the lava flows and in the interbeds. Ground-water drainage is to the Columbia River or its tributaries.

The Yucca Mountain site is located in a region composed of alternating sequences of block-faulted mountains and alluvium-filled valleys of the Alluvial Basins geohydrologic setting as defined by Heath. Yucca Mountain is a typical small fault-block mountain in this region and is composed entirely of volcanic rocks called tuff. The site is in the relatively dry unsaturated welded zone, well above the water table. This is a unique geohydrologic setting in comparison with the other sites, which are all situated well below the water table. The Hanford site will rely principally on the interaction of the low permeability of the dense basalts, the ion-exchange characteristics of the host rock, and a long ground-water flow path for waste isolation. The Yucca Mountain site will rely principally on a very low water flux through unsaturated rocks in a very arid environment, the natural ability of this type of system to exclude flowing or standing water from the repository, and the sorption characteristics of the minerals in the host rock.

The salt-site settings are also clearly distinguishable from one another, but perhaps not as obviously as the nonsalt sites. The first distinction among the salt settings is between salt domes and bedded salt. Although both bedded and dome salt have salt as a host rock, the properties of the two types of salt are quite different, and the hydrologic framework of salt differs greatly from setting to setting. Bedded salt occurs as sedimentary layers of salt and impurities and is typically bounded by aquifers above or below the salt units or both. The domes are anomalous piercements of the thick unconsolidated to semiconsolidated sedimentary clays, silts, and sands that make up the Atlantic and Gulf Coastal Plain, as defined by Heath. The domes are surrounded by aquifers at different depths. Thus, the geohydrologic conditions around the domes are distinctly different from that of bedded salt.

The pathways and mechanisms by which radionuclides might reach the accessible environment are also quite different for bedded and dome salt because of their fundamental structural and stratigraphic differences. Salt domes originated from thick beds of deeply buried salt. When sediments were deposited on these salt beds, the salt was forced upward, forming a dome. Some domes have risen as much as 20,000 feet above their source rock. The salt rock was intensely deformed and "kneaded" during this intrusive rise of the salt dome; as a result, nearly all of the water originally contained in the salt was squeezed out. Consequently, salt domes contain less water than salt beds. In addition, and largely because of the different mode of formation, the following differences between the two types of salt rock are noteworthy:

- Because of its higher water content, bedded salt has a lower strength than dome salt.

- At equal depths of burial, bedded salt has lower geothermal temperatures than dome salt.

- Bedded salt tends to have a faster rate of creep than dome salt.

- Bedded salt has a more variable chemical composition than dome salt.

- Bedded salt has a simpler structure than salt domes.

Some of the most important of the above factors affecting waste isolation at salt sites are related to the chemical composition and configuration of the host rock. All salt sites would rely primarily on the extremely low permeability of the salt and the isolation of the host rock from surrounding aquifers. One significant potential failure mechanism in salt that can affect ground-water flow is the dissolution of the salt in ground water, whether initiated by inadvertent human intrusion or by unexpected salt deformation. The nature and the relative importance of this failure mechanism differ significantly for bedded and dome salt in their respective geohydrologic environments. For example, at salt domes dissolution would occur along the flanks by ground water from surrounding sedimentary strata. The dissolution of bedded salt could be induced by laterally migrating dissolution fronts, inter-salt-bed sedimentary aquifers, or vertically circulating water in fault zones.

Finally, although the Paradox Basin in Utah and the Permian Basin in Texas are both bedded-salt settings, they also have significant differences that warrant considering them as separate and distinct geohydrologic settings. The bedded-salt sites in Swisher and Deaf Smith counties, Texas, are located in the High Plains setting as defined by the USGS. This setting is underlain by relatively horizontal bedded sedimentary rocks that are capped by the partially unconsolidated sands, gravels, and clays of the Ogallala Formation. The geohydrologic system is dominated by the High Plains aquifer (the Ogallala Formation). Other aquifers, such as the Triassic Dockum Group, occur in deeper strata, but they produce poor-quality water in comparison with the Ogallala.

The bedded-salt sites of Davis Canyon and Lavender Canyon, Utah, on the other hand, are located in the Paradox Basin, which is a subsetting of the Colorado Plateau and the Wyoming Basin and is characterized by a broad uplifted plateau consisting of gently folded sedimentary sandstones, shales, carbonates, and evaporites. The stratigraphic sequence includes a few low-yield aquifers that generally contain poor-quality water. Ground water generally flows toward drainage systems in deeply dissected canyons of the region. Other specific differences include the following:

- Because of overburden and tectonic stresses, the Paradox Basin salt deposits have been structurally deformed into anticlines and synclines (thickened and thinned zones) much more than the Permian Basin salt deposits have.

- The recharge and discharge patterns of ground water in the two settings are expected to be significantly different.

- The age, stratigraphic sequence, depositional history, and mineral composition of the salts and interbeds in two settings are different.

- The elevation, climate, and physiography of the two settings are significantly different.

- The ground-water system of the Paradox Basin sites is dominated by a deep aquifer well below the repository level, of low yield and poor water quality, whereas the ground-water system at the Permian Basin sites is dominated by a shallow productive aquifer well above the repository level.

On the basis of the criteria and known site characteristics presented above, the DOE has concluded that the nine potentially acceptable sites lie within five distinctly different geohydrologic settings, as indicated, and four distinctly different types of host rock (basalt, welded tuff, bedded salt, and dome salt).

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10 CFR Part 960, "General Guidelines for the Recommendation of Sites for the Nuclear Waste Repositories," Code of Federal Regulations, Title 10, Part 960.

40 CFR Part 191, "Environmental Standards for the Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes," Code of Federal Regulations, Title 40, Part 191.

Chapter 2

DECISION PROCESS BY WHICH THE SITE PROPOSED FOR NOMINATION WAS IDENTIFIED

The Nevada Nuclear Waste Storage Investigations (NNWSI) Project was established in 1977 by the U.S. Department of Energy Nevada Operations Office. The Project objective was to evaluate the Nevada Test Site (NTS) and contiguous area for sites suitable for a geologic repository. The NTS and its vicinity seemed attractive as a potential repository location because the land was withdrawn from public use, the NTS itself was under DOE control, and some of the land was contaminated with radioactive material from nuclear-weapons tests. However, the NNWSI Project search for sites was directed mainly at suitable geologic conditions, rather than land-use considerations.

Nine types of rock and 15 alternative locations at or near the NTS were identified as potentially suitable for a repository. Eventually, a rigorous program of screening led to the selection of welded tuff and Yucca Mountain in southern Nye County, Nevada, as the preferred host rock and the preferred location, respectively. Among the attractive attributes of Yucca Mountain were its location in a closed hydrologic basin, the ability to locate the repository in the unsaturated zone (above the water table), and the excellent thermomechanical and radionuclide-retardation properties of tuff.

After Yucca Mountain was selected as the preferred location from the 15 alternative locations at or near the NTS, geologic and hydrologic investigations were continued to collect information about the suitability of the site. The data thus collected indicated that the site was indeed suitable for both long-term and near-term objectives, and in February 1983, in accordance with the Nuclear Waste Policy Act of 1982 (NWPA, 1983), the DOE notified the State of Nevada that the site was potentially acceptable for a repository (Hodel, 1983).

The Yucca Mountain site is about 160 kilometers (100 miles) by road northwest of Las Vegas, Nevada (Figure 2-1). The site is on Federal land under the control of three separate agencies. Most of the site is part of the Nellis Air Force Range (NAFR); a smaller portion is part of the NTS and managed by the U.S. Department of Energy (DOE). The remaining portion is managed by the Bureau of Land Management (BLM).

This chapter outlines the general process by which Yucca Mountain was identified as a potentially acceptable site. Section 2.1 describes the regional setting of the site to place in context the general types of alternatives from which Yucca Mountain was selected. The screening process by which Yucca Mountain was identified is described in Section 2.2. This discussion is followed by Section 2.3, which evaluates the Yucca Mountain site against the disqualifying conditions in the DOE siting guidelines (10 CFR Part 960, 1984). Both the Nuclear Waste Policy Act (NWPA, 1983) and the DOE siting guidelines (10 CFR 960.3-2, 1984) require such an evaluation as a step in the nomination process that must be applied to all potentially acceptable sites.

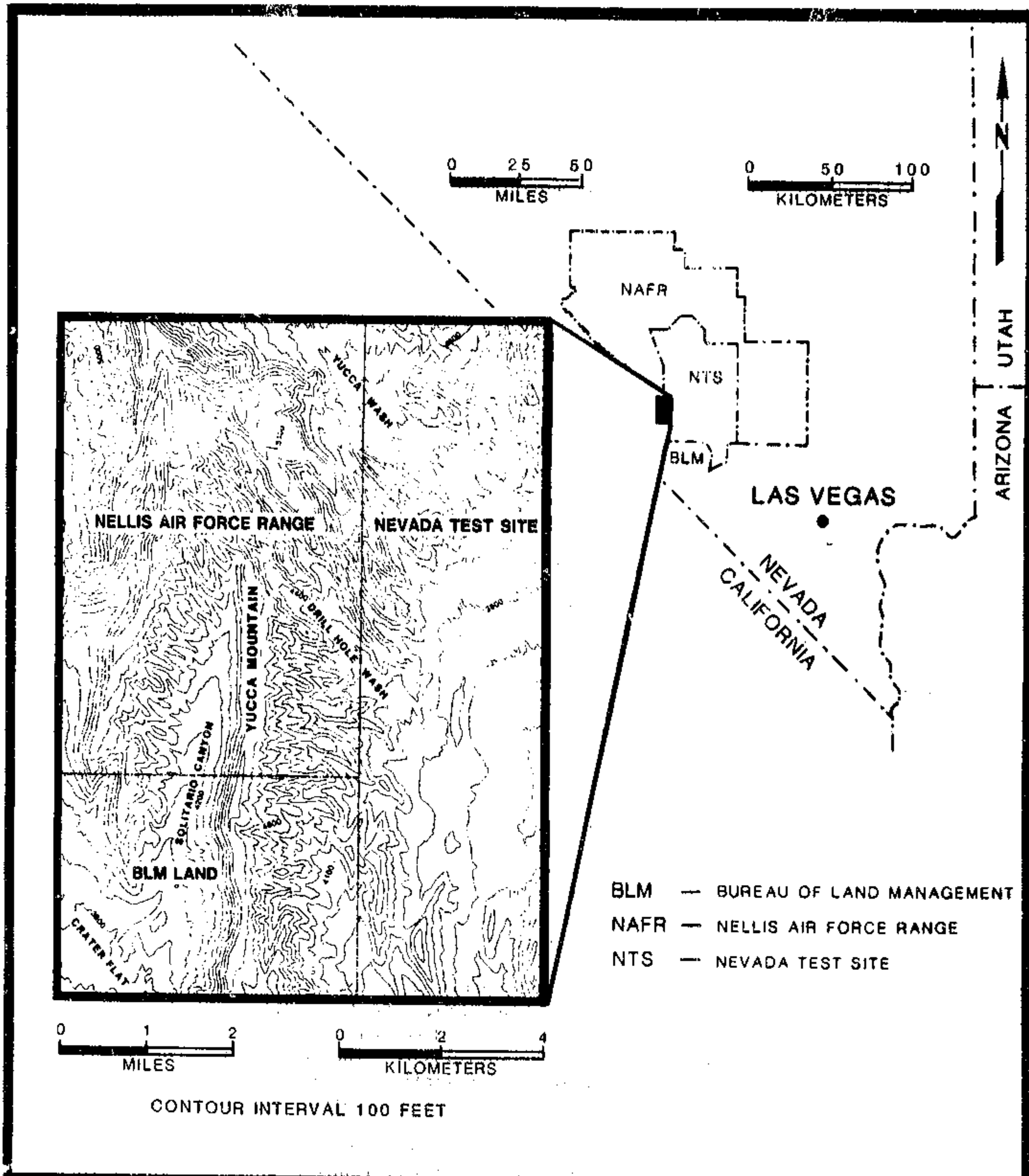

Figure 2-1. Location of the Yucca Mountain site in southern Nevada. Proposed repository and surface facilities would be located within the outline shown above. Modified from USGS (1984).

2.1 REGIONAL SETTING OF YUCCA MOUNTAIN

The Yucca Mountain site is located within a broad desert region known as the Great Basin. The Great Basin is characterized by generally linear mountain ranges and intervening valleys. Few streams or rivers flow out of the region. Primarily because of the scarcity of easily accessible water, few people live in this vast desert. The few communities that do exist are generally located around mining districts, water sources, or tourist attractions. Agricultural production is very limited because of the severe aridity and low nutrient value of the rocky desert soils. Irrigation is practiced only in a few areas where the ground water is shallow enough to be tapped by wells and where soils are suitable for tillage. As a result of the sparse population, paved roads are widely spaced, commonly more than 80 kilometers (50 miles) apart.

The basins and intervening mountain ranges of the region strongly influence the climate, vegetation, and surface drainage of local areas. Most precipitation falls on the cooler mountainous terrain, whereas the basins are relatively warmer and dryer. As a result, the higher ranges generally support coniferous forests, while the basins and lower mountain ranges, such as Yucca Mountain (Figure 2-2), are covered with sparse desert vegetation. Because of the large number of basins and ranges of various elevations, the region contains several ecological communities.

The mountain ranges are formed by fault blocks that rise above the intervening basins. On the basis of exposed rocks in the mountain ranges and basins, the rocks can be divided into four major groups. The oldest are a billion or more years old and are made up of hard crystalline material, such as gneiss and granite. These rocks, where present, are part of the crystalline shield of the North American continent. Stratigraphically above the shield rocks is the second major group of rocks, a thick sedimentary sequence composed mainly of carbonates, quartzite, shale, and argillite. These rocks were deposited between about 800 and 250 million years ago in a large trough-like basin, called the Cordilleran Geosyncline, that existed along the western edge of the continent. From about 250 to 100 million years ago, these sedimentary rocks were strongly squeezed, folded, and faulted in a process that created the early mountains. During this time, granitic masses were intruded deep within the buried roots of local parts of these ancient mountains. Small outcrops of granite in the northern part of the Nevada Test Site attest to this episode of granite formation.

From about 100 to 40 million years ago, the mountain building waned and the ancient ranges were eroded to a gentle rolling plain. Beginning about 40 million years ago, a third major group of rocks was formed on this plain when volcanic activity spread thick deposits of tuffaceous volcanic material over portions of the area. This volcanism lasted from about 40 to 10 million years ago. Yucca Mountain was formed during the last 10 to 15 million years of this 30-million-year period.

Faulting that produced the current basins and ranges took place at the same general time as the volcanism. In the last 10 million years, volcanic activity has shifted toward the margins of the Great Basin (Christiansen and McKee, 1978), and the basins have been partly filled with alluvium derived from the erosion of the surrounding ranges, forming the fourth type of rock

Figure 2-2. View of Yucca Mountain looking northeast. Modified from USGS (1968).

in the area. Minor volcanism continued during basin filling, most recently producing thin, locally restricted sheets and cones of basaltic material in Crater Flat, just west of Yucca Mountain.

Deposition, folding, faulting, intrusion of granite masses, and eruption of volcanic material over time produced a complicated geologic pattern in the rocks of this area. This complexity is evident in the three regional cross sections shown in Figure 2-3.

The hydrologic systems of the southern Great Basin are characterized by deep water tables and closed ground-water basins; ground-water basins do not necessarily correspond with topographic basins. At some places in the southern Great Basin, including parts of Yucca Mountain, ground water is more than 500 meters (1,640 feet) deep. The deep water table provides a unique opportunity for placing a repository in the unsaturated zone where there is limited water available. Recharge occurs predominantly by the slow percolation of surface water through the unsaturated zone that overlies the water table. Most of this recharge is restricted to higher elevations where precipitation is greatest.

Generally, ground water in the southern Great Basin flows through major aquifers, which are deep beneath the surface of the ranges and most valleys. Winograd and Thordarson (1975) recognized six major aquifers in southern Nevada that transmit water and four major aquitards that retard the flow of water and act as barriers to ground-water movement. The lower and upper carbonate aquifers of the sedimentary sequences (Figure 2-4) and the welded-tuff and lava-flow aquifers of the volcanic sequence transmit water primarily through fractures. Because the fractures are related to both the brittleness of the rock and the location of major structural features, local and regional flow is determined largely by the complex stratigraphic and structural conditions outlined above. Bedded-tuff units within the welded-tuff aquifers and valley-fill aquifers, in contrast, store and transmit water chiefly through interstitial pores.

The Yucca Mountain site is part of the Death Valley ground-water system, which is composed of several more or less distinct basins. The site is in the Alkali Flat-Furnace Creek Ranch ground-water basin at a position midway between the Ash Meadows and Oasis Valley basins, as shown in Figure 2-5 (Waddell, 1982). The Alkali Flat-Furnace Creek Ranch basin discharges at seeps in Alkali Flat and possibly at springs in Death Valley. Some of the spring discharge areas in the Death Valley National Monument are near tourist facilities, although exact sources of discharge are unknown. Regional flow east of the site is through the Ash Meadows basin and occurs principally in the lower carbonate aquifer (Figure 2-6). This basin partially discharges at the 30 or so springs in Ash Meadows where the lower clastic aquitard apparently is raised along a fault and blocks the flow through the aquifer, forcing water to rise to the surface. Some of the water may seep through the aquitard, eventually discharging at Death Valley. West of the site, local flow from recharge at Timber Mountain and Pahute Mesa occurs through the tuff aquifer and discharges at springs in Oasis Valley, just north of Beatty. This small flow system forms the Oasis Valley basin.

In summary, the southern Great Basin is generally characterized by sparse vegetation, low precipitation, few population centers, varied geologic

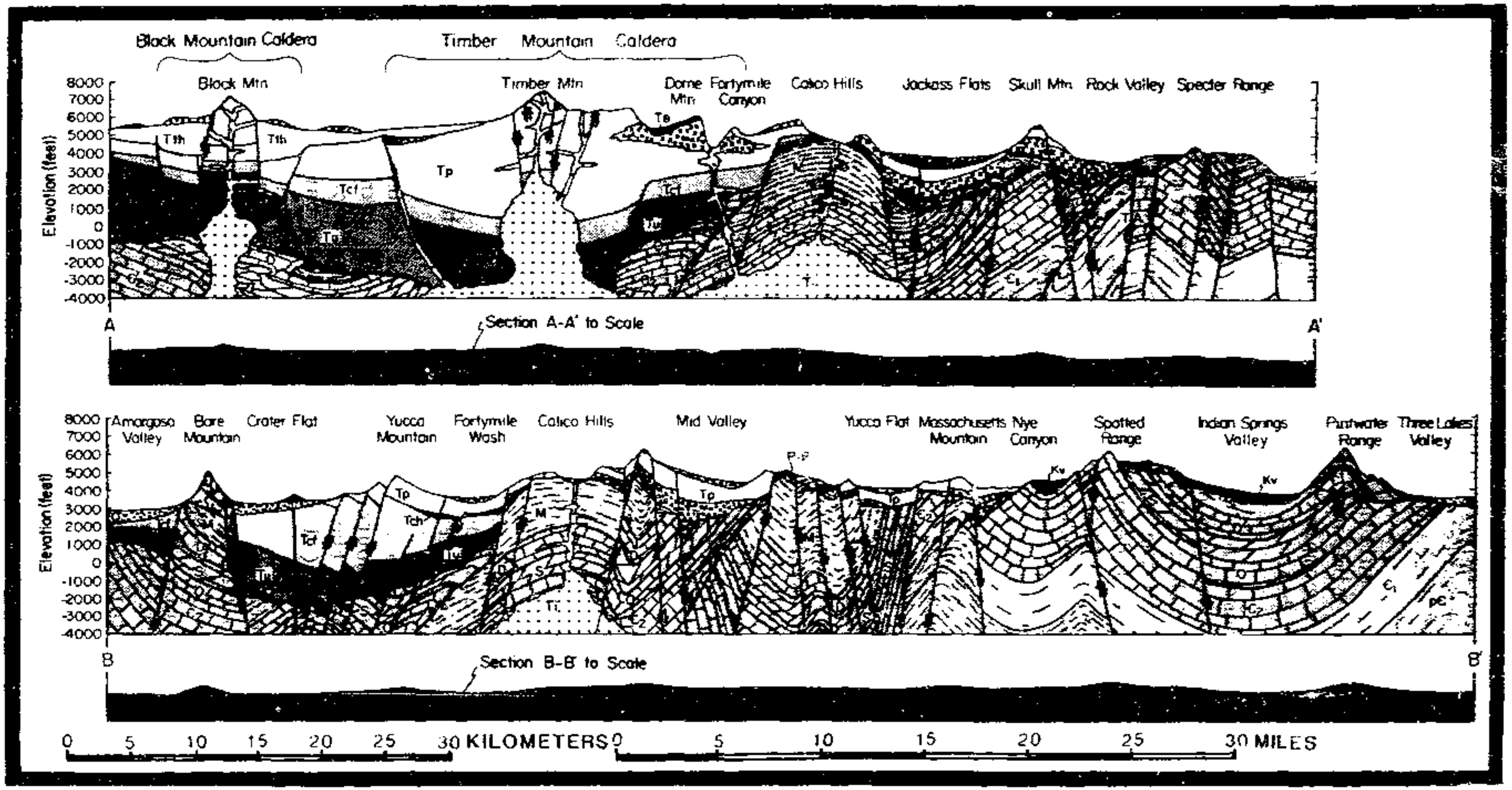

Figure 2-3. Schematic cross sections portraying the geologic complexity surrounding Yucca Mountain in south-western Nevada and showing the style of faulting and caldera complexes. Modified from Sinnock (1982).

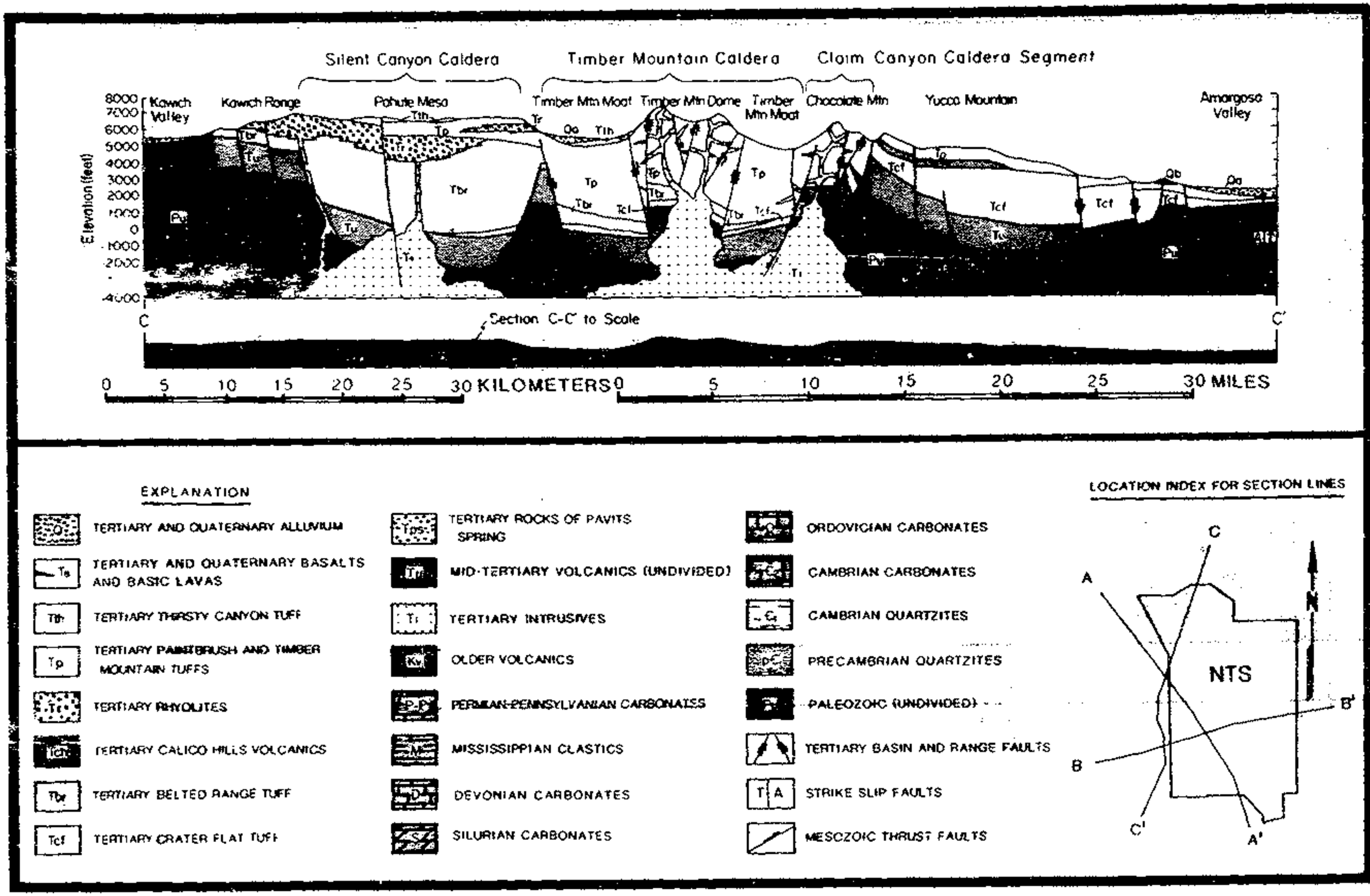

Figure 2-3. Schematic cross sections portraying the geologic complexity surrounding Yucca Mountain in south-western Nevada and showing the style of faulting and caldera complexes. Modified from Sinnock (1982). (continued)

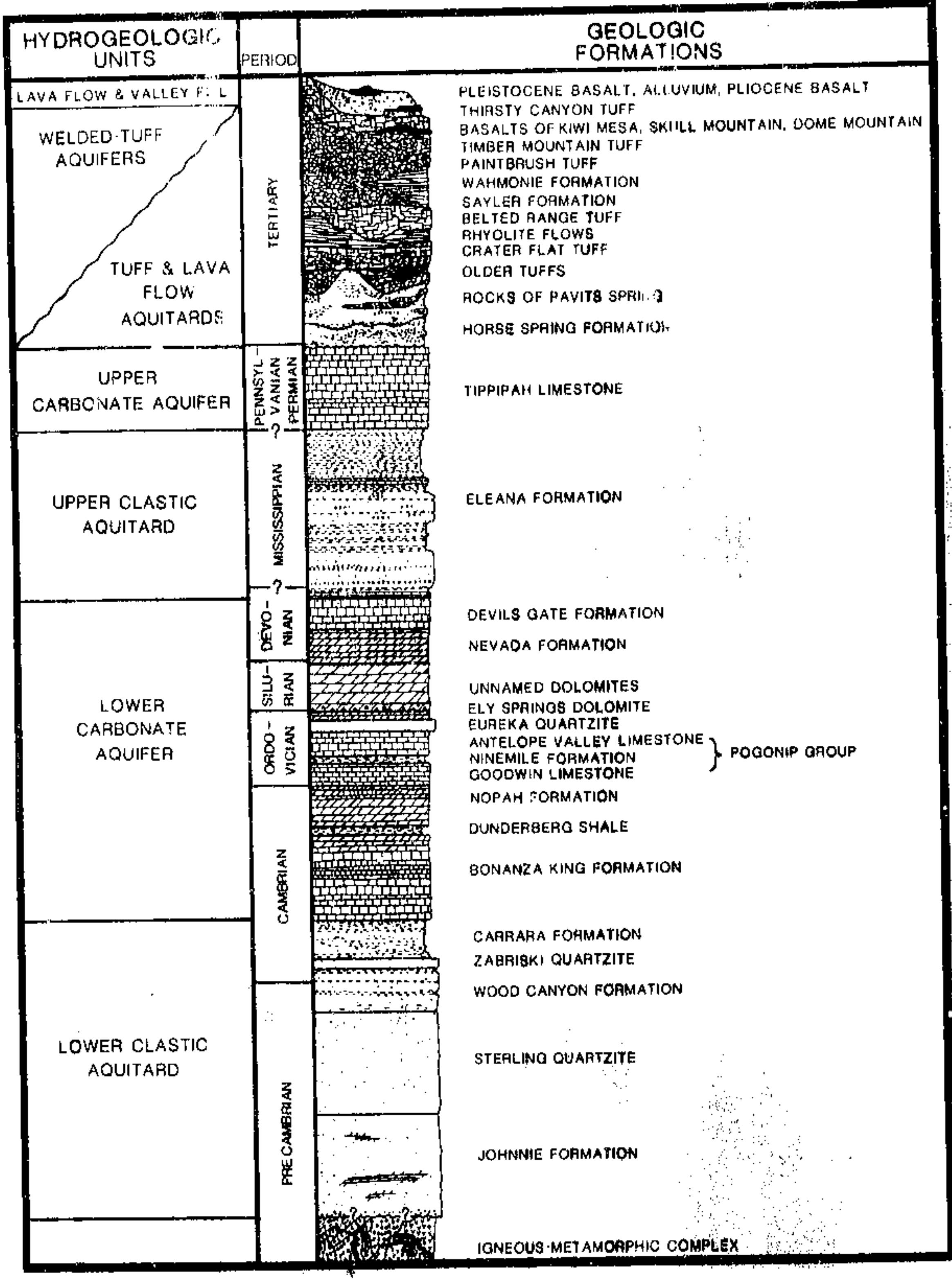

Figure 2-4. General relationships among hydrogeologic units and geologic formations in the southern Great Basin. The question marks refer to an uncertain boundary. Modified from Sinnock (1982).

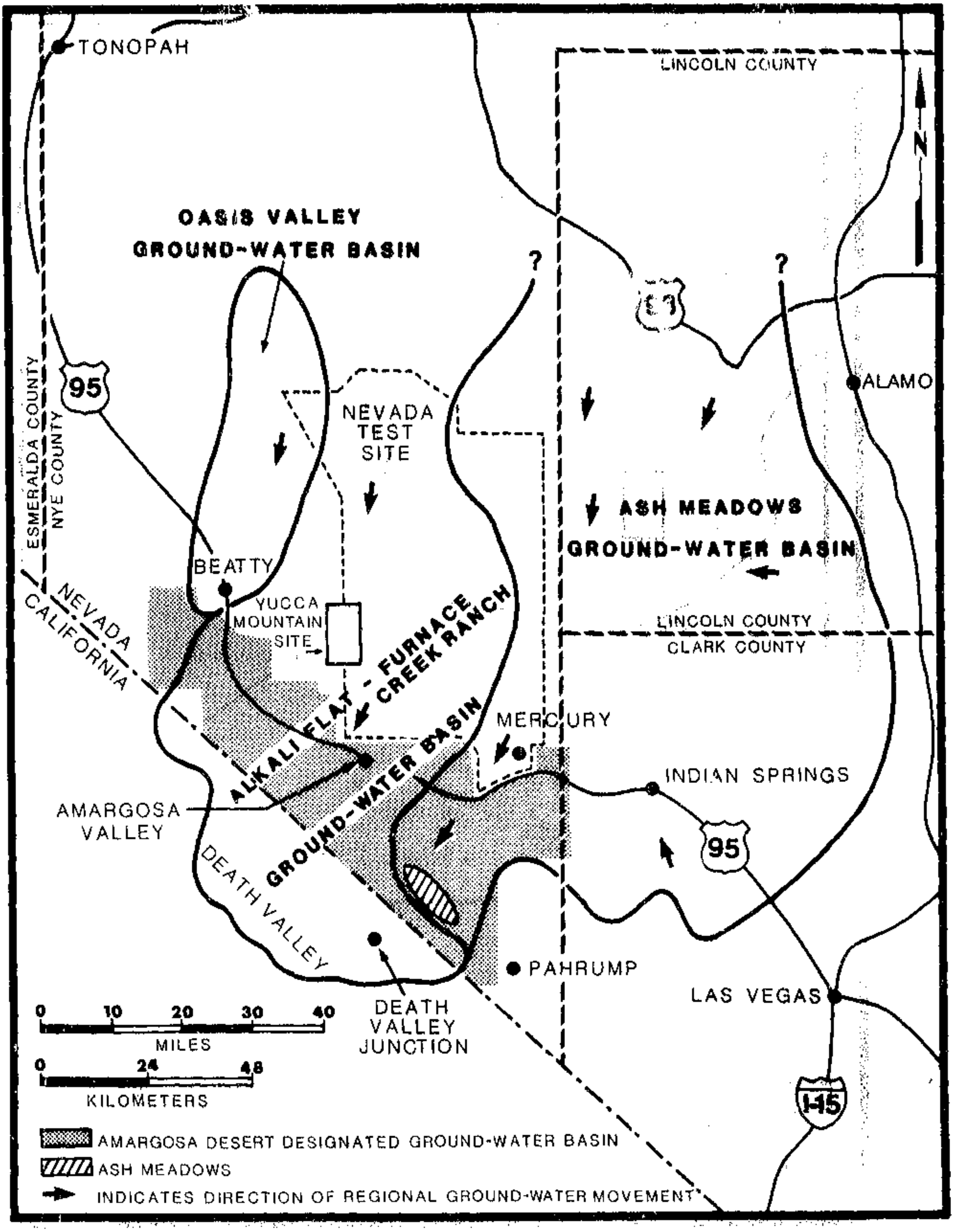

Figure 2-5. Location of Yucca Mountain site with respect to the relevant basins of the Death Valley ground-water system. The Amargosa Desert ground-water basin is a governmentally administrated area designated by the State engineer in order to prevent over appropriation of ground-water resources. Modified from Waddell (1982) and information from the State of Nevada.

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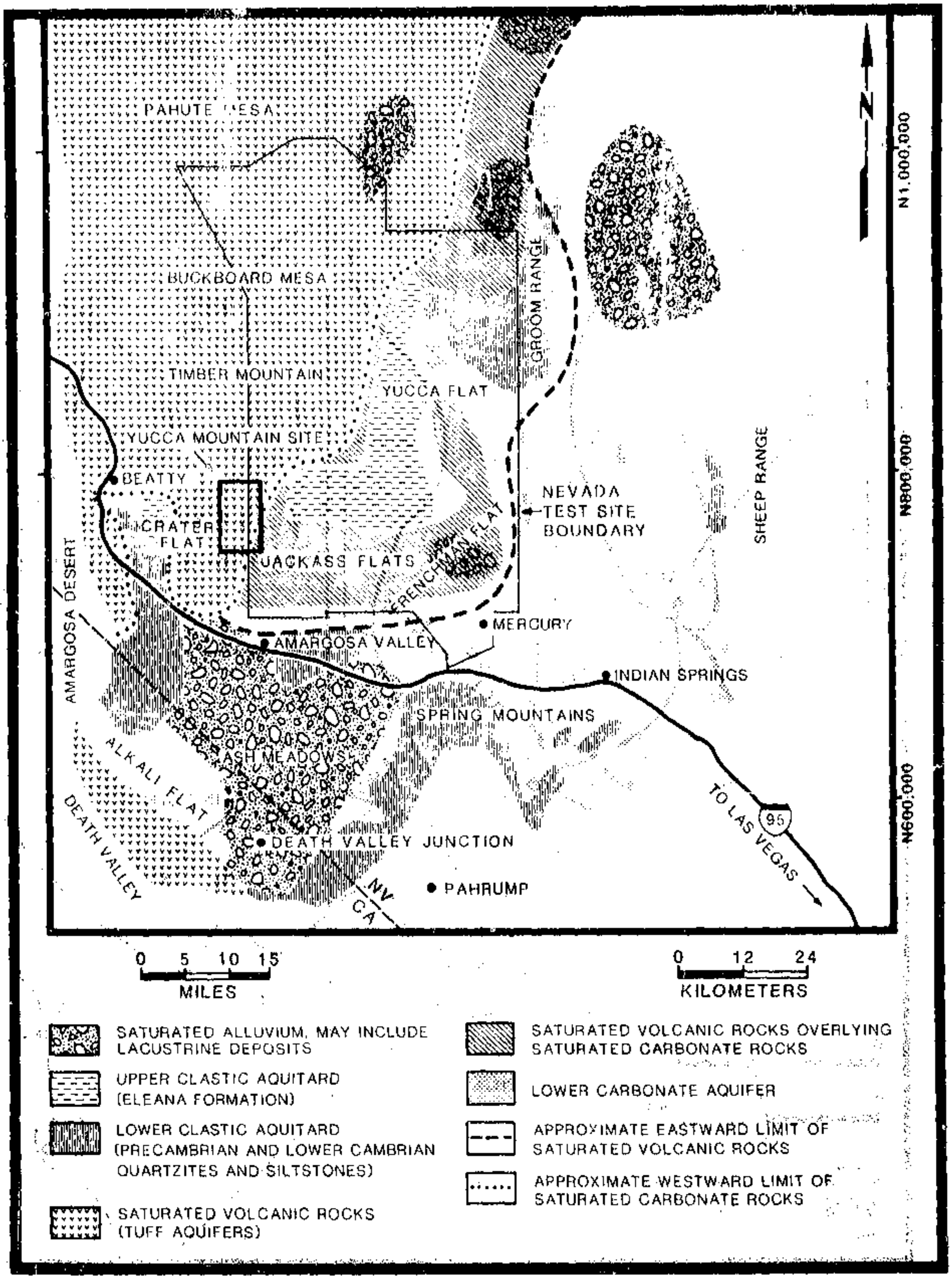

Figure 2-6. General distribution of the major aquifers and aquitards in the southern Great Basin near Yucca Mountain. Compiled from Waddell et al. (1984).

conditions, and a hydrologic system that includes closed ground-water basins and a thick unsaturated zone. This section provides only the most general perspective on the overall setting from which Yucca Mountain was chosen from among other alternatives as discussed in Section 2.2. Detailed descriptions of the geology and hydrology of Yucca Mountain and the surrounding region are provided in chapters 3 and 6.

2.2 IDENTIFICATION OF YUCCA MOUNTAIN AS A POTENTIALLY ACCEPTABLE SITE

This section briefly summarizes the five-step process by which Yucca Mountain and the host rock were selected for detailed study. The five steps discussed in the following subsections are (1) selection of the Nevada Test Site (NTS) (Section 2.2.1), (2) restriction of exploration to an area in and around the southwest NTS (Section 2.2.2), (3) selection of Yucca Mountain as the primary location for exploration (Section 2.2.3), (4) confirmation of site selection by a formal system study (Section 2.2.4), and (5) selection of the host rock for further study (Section 2.2.5).

All steps in the screening process were completed before the Nuclear Waste Policy Act of 1982 (NWPA, 1983) was signed into law in January 1983 and before the U.S. Department of Energy (DOE) general siting guidelines (10 CFR Part 960) were issued in December 1984. The systematic screening studies of steps 4 and 5 used objectives very similar to those specified in the guidelines. The identification of Yucca Mountain as a potentially acceptable site was consistent with the siting criteria formulated for the DOE National Waste Terminal Storage Program (DOE, 1981a) and is consistent with 10 CFR Part 960 (1984).

2.2.1 SELECTION OF THE NEVADA TEST SITE AS AN AREA OF INVESTIGATION

The National Waste Terminal Storage (NWTS) Program was established in 1976. During the early NWTS investigations, salt was the prime host rock of interest for a repository. Additional geologic host materials, including crystalline (granite, gneiss) and argillaceous rock (shale), were also considered. The initial approach to site screening was based on particular rock types and came to be known as the host-rock approach (DOE, 1982a). In 1977 the program was expanded to consider prior land use as an alternative basis for initial screening. The prior-land-use approach considered the advantages of locating a repository on land already withdrawn and committed to long-term institutional control. Because the Nevada Test Site (NTS) was already dedicated to nuclear operations, it was a logical area for investigation for potential repository sites, and formal consideration of the NTS for a repository location began at that time. The prior land use at the NTS establishes a firm reason for concluding that the government will continue to provide strict institutional control over future access to the site.

At the same time the NTS was being considered by the U.S. Department of Energy (DOE) on the basis of prior land use, the U.S. Geological Survey (USGS) proposed that the NTS be considered for a number of geotechnical reasons. These geotechnical and other considerations identified later can be summarized as follows:

- Southern Nevada is characterized by closed hydrologic basins. This means that ground water does not discharge into rivers that flow to major bodies of surface water. It also means that water discharge points can be clearly identified.

- The water table is at great depth (as much as 500 meters (1,640 feet) below the surface). This provides the opportunity to build a repository in the unsaturated zone where the rock containing a repository would not generally release water to drillholes or tunnels. This lack of water would minimize the corrosion of the waste canister, the dissolution of the waste, and the transport of radionuclides from the repository.

- Long flow paths are present between potential repository locations and ground-water discharge points. Radionuclides would have to travel great distances before they could affect man and his surface environment.

- Some of the geologic materials occurring on the NTS are highly sorptive. Radionuclides could be chemically or physically adsorbed by rock, making it extremely difficult for them to move in solution.

- The NTS is located in an arid region, with an annual rainfall of less than about 150 millimeters (6 inches). With the very low precipitation, the amount of moving ground water is also low, especially in the unsaturated zone.

By May 1977 the NWTS Program had undertaken evaluations of both the land use and the geologic attributes of the NTS. The Nevada Nuclear Waste Storage Investigations Project was organized to consider the general suitability of the NTS for a repository and to identify locations, if any, on the NTS or adjacent areas that might be suitable for a repository.

2.2.2 RESTRICTION OF EXPLORATION TO THE SOUTHWESTERN PART OF THE NEVADA TEST SITE AND ADJACENT AREAS

The primary function of the Nevada Test Site (NTS) is to provide a testing ground for nuclear weapons. Figure 2-7 shows past, current, and proposed general areas dedicated to weapons testing. When the National Waste Terminal Storage Program expanded its repository exploration activities to include the NTS, a question arose concerning the compatibility of a repository with nuclear-weapons testing. A task group was established to evaluate the conditions under which the weapons testing program could fully function in the presence of a nearby repository. In August 1978 the Acting Assistant Secretary for Defense Programs of the Department of Energy formalized the task group's finding that locating a repository in certain areas of the NTS might hamper weapons testing. However, it was suggested that the southwestern portion of the NTS and adjacent offsite locations were acceptable for further investigation as potential waste repository sites.

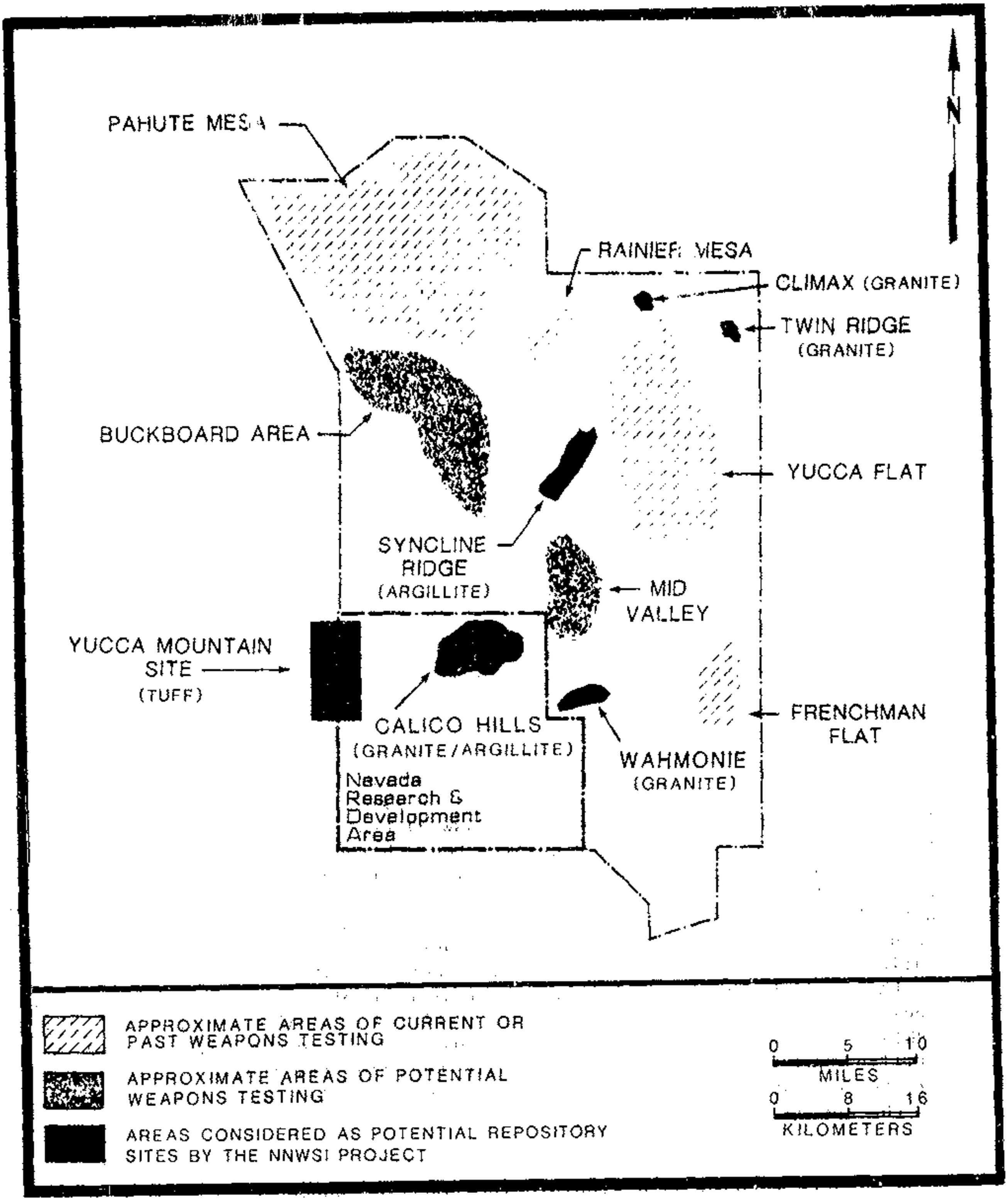

Figure 2-7. Past, current, and potential future weapons testing areas on the Nevada Test Site and areas initially considered for repository siting.

In 1977 the geologic medium of prime interest at the NTS was argillite. Argillite is present in the Eleana Formation, which underlies Syncline Ridge, a topographic feature along the west side of Yucca Flat (Figure 2-7). Geologic investigations there, including exploratory drilling, revealed a complex geologic structure in the center of the area being considered (Hoover and Morrison, 1980; Ponce and Hanna, 1982). It was concluded in April 1978 that the geologic complexity of Syncline Ridge would make characterization difficult, possibly so difficult that it could not be understood to the degree necessary to license a repository (Stephens, 1978). At about the same time, the decision by the Assistant Secretary for Defense Programs included Syncline Ridge in the areas judged unacceptable for repository siting because of nearness to weapons testing. At this juncture, the program refocused on the area in and around the southwestern corner of the NTS. The portion of the redefined exploratory area that occurred on the NTS was subsequently named the Nevada Research and Development Area (NRDA) (Figure 2-7) (Stephens, 1978). The area evaluated included some Bureau of Land Management land west and south of the NRDA and a portion of the Nellis Air Force Range west of the NRDA.

2.2.3 SELECTION OF YUCCA MOUNTAIN AS THE PRIMARY LOCATION FOR EXPLORATION

In August 1978 a preliminary list of potential sites in and near the southwestern part of the Nevada Test Site (NTS) was compiled. Calico Hills, Yucca Mountain, and Wahmonie were considered the most attractive locations in and around the southwest NTS (Figure 2-7) for conducting preliminary borings and geophysical testing.

The Calico Hills location was of particular interest because an aeromagnetic survey showed that granite might occur approximately 500 meters (1,640 feet) below the surface. The first exploratory hole by the Nevada Nuclear Waste Storage Investigations (NNWSI) Project in the southwest NTS was started in 1978 to explore for granite beneath the Calico Hills. At a depth of 772 meters (2,530 feet), drilling was discontinued without reaching granite (Maldonado et al., 1979). A high content of magnetite, discovered in a thick section of Eleana Argillite, was probably responsible for the aeromagnetic anomaly. Reevaluation of the geophysical data indicated that the Calico Hills aeromagnetic anomaly can be entirely attributed to the presence of the magnetite-rich argillite. The existence of an intrusive body in the rocks under Calico Hills could not be confirmed or denied (Snyder and Oliver, 1981). Since granite was not encountered in 772 meters (2,530 feet) of drilling and no unexplained geophysical anomalies remained to indicate its existence, further consideration of the Calico Hills location was suspended in the spring of 1979.

Concurrent with drilling at Calico Hills, geophysical and geologic studies were focused on a granitic rock mass at Wahmonie. These studies indicated that the granitic rock was highly fractured and hydrothermally altered. Additionally, faults with displacements in the alluvium trend into the area from the southwest and a spring deposit associated with the mineralized Hornsilver Fault is present at Wahmonie. In the spring of 1979, the U.S. Geological Survey (Twenhofel, 1979) recommended cessation of exploration of Wahmonie, based on the structural complexity and hydrothermal alteration, indicating that the potential for an acceptable repository host rock at depth was low.

In the summer and fall of 1978, the first exploratory hole was drilled at Yucca Mountain. This hole was drilled to a depth of about 762 meters (2,500 feet) and confirmed the presence of thick tuff beds containing highly sorptive material (Spengler et al., 1979). Preliminary surface mapping indicated the existence of generally undisturbed structural areas possibly large enough for a repository (Christiansen and Lipman, 1965, Lipman and McKay, 1965). Because tuff previously had not been considered as a potential host rock for a repository, a presentation was made to the National Academy of Sciences Committee for Radioactive Waste Management in September 1978 to solicit its views on the potential advantages and disadvantages of tuff as a repository host rock. The concept of investigating tuff as a potential host rock was supported (Gloyna, 1979).

After comparing the results of preliminary exploration at Calico Hills, Wahmonie, and Yucca Mountain, the U.S. Geological Survey recommended (Twenhofel, 1979) that attention be focused on Yucca Mountain and the U.S. Department of Energy (DOE) concurred in that recommendation in April 1979. Immediately thereafter, in April, May, and July 1979, technical peer-review meetings on (1) host-rock investigations, (2) geologic and hydrologic investigations, and (3) tectonic, seismic, and volcanic investigations were held by the NNWSI Project.

These review meetings were attended by nationally known experts as well as prominent experts from Nevada. Before each meeting, the reviewers were provided with background information on specific NNWSI Project activities and overall goals. At the meetings, NNWSI Project participants made detailed presentations and answered questions posed by the reviewers. After each meeting, the review panel summarized its overall assessments and recommendations. The general consensus of the reviewers supported the DOE decision to concentrate its Nevada exploration efforts on the tuffs of Yucca Mountain (DOE/NVO, 1980).

2.2.4 CONFIRMATION OF SITE SELECTION BY A FORMAL SYSTEM STUDY

The foregoing process of selecting Yucca Mountain for early exploration was informal. A more thorough, formal analysis was begun in 1980 to evaluate whether Yucca Mountain was indeed appropriate for further exploration. This analysis was conducted in a manner compatible with the area-to-location phase of site screening described in the National Siting Plan (DOE, 1982a), which was used by the U.S. Department of Energy (DOE) before the Nuclear Waste Policy Act of 1982 (NWPA, 1983) and ensuing siting guidelines (10 CFR Part 960, 1984) were adopted.

The Nevada Nuclear Waste Storage Investigations Project screening activity is documented in five publications, each providing details about a separate element of the activity. The first (Sinnock et al., 1981) summarizes a method for screening the Nevada Test Site (NTS) and contiguous areas for repository locations, documenting the proposed method before its application. The second (Sinnock and Fernandez, 1982) presents a summary description of the parameters used in the screening calculations and provides a detailed discussion of the screening results. The last three provide detailed background material about the performance objectives (Sinnock and Fernandez, 1984), physical attributes and associated quantitative criteria (Sinnock et al., 1984), and computer programs (Sharp, 1984) for rating alternative locations.

Many assumptions were quantified during the screening study, and the validity of the results and conclusions clearly depended and continues to depend on the reasonableness of these assumptions. The information in the referenced screening reports allows each assumption or set of assumptions to be traced to its effects on the results and conclusions. The remainder of this section contains an overview of the data and analyses contained in these reports.

The formal screening analysis (Sinnock and Fernandez, 1982) was applied to an area on and near the southwestern portion of the NTS (Figure 2-8). The analysis consisted of four basic elements.

1. Weighted performance objectives that identified ideal, or at least desired, site conditions.

2. Physical attributes of the screening area that distinguished the physical conditions of alternative locations and host rocks.

3. Favorability estimates that rated, on a relative scale of zero to ten, how well the physical conditions represented by each attribute satisfied each of the relevant objectives for assessing site performance (performance objectives).

4. Calculations of summary rating scores for alternative locations and host rocks based on how well the combined favorabilities of the attributes satisfied the performance objectives.

The performance objectives were organized into a three-level hierarchical tree (Table 2-1), which allowed site-specific objectives of the lowest level of the tree to be clearly tied to the broad goals of waste management (DOE, 1980) represented by the uppermost level of the tree (Sinnock and Fernandez, 1984). Each objective was correlated with existing criteria of the DOE and the Nuclear Regulatory Commission to ensure that no relevant siting factors were overlooked. Table 2-2 shows this correlation and also shows the correlation with the DOE siting guidelines (10 CFR Part 960, 1984), which did not exist at the time of screening. A weight, or percentage describing relative importance, was assigned to each objective at each level of the tree to account for priorities within each level (see figures 2-9a and 2-9b). The weights were obtained from a poll of technical experts (Sinnock and Fernandez, 1984).

The physical attributes that form the second basic element of the formal screening analysis are shown in Table 2-3. Each of the 31 attributes represents a physical condition that both (1) varies throughout the screening area and (2) might influence repository behavior (Sinnock et al., 1984). As Table 2-3 indicates, the attributes fall into two general categories, geographical (attributes 1 through 23) and host rock (attributes 24 through 31).

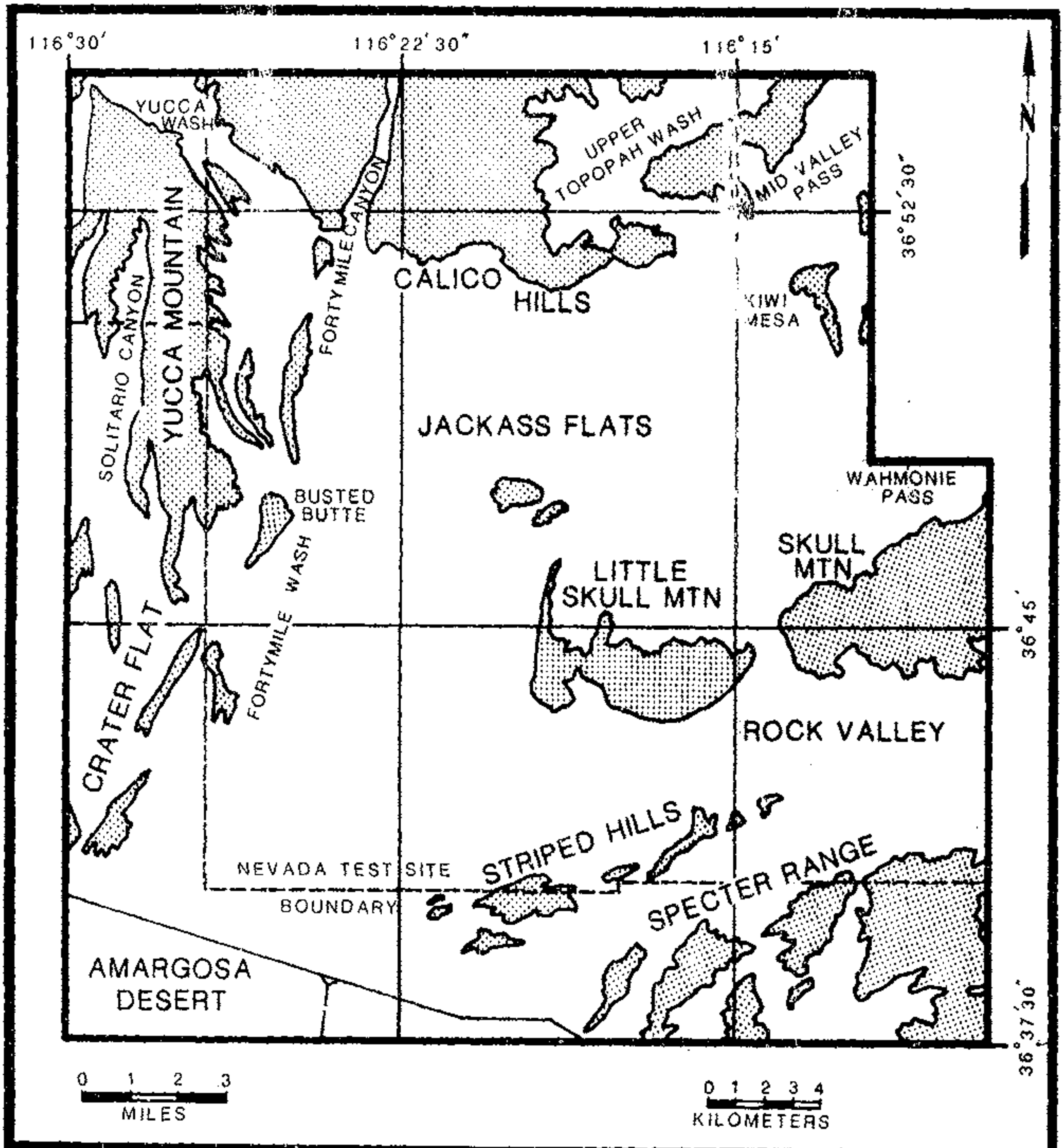

Figure 2-8. Map of the area on and adjacent to the Nevada Test Site within which screening for repository locations was conducted. Figures 2-11a and 2-12 show the results of screening analyses displayed on this base map. Modified from Sinnock and Fernandez (1982).

Table 2-1. Three-tiered hierarchical arrangement of objectives used in site screening by the Nevada Nuclear Waste Storage Investigations Project[a]

- 1.0 Identify locations that permit adequate radionuclide containment in a sealed repository
  - 1.1 Screen for natural systems with maximum potential to resist waste-package disruption processes
    - 1.1.1 Minimize potential for chemically induced release
    - 1.1.2 Minimize potential for mechanically induced release
  - 1.2 Screen for natural systems with minimum potential for waste-package disruption processes
    - 1.2.1 Minimize the potential for seismic hazards to containment in a sealed repository
    - 1.2.2 Minimize the potential for erosional disruption of waste packages
    - 1.2.3 Minimize the potential for volcanic disruption of waste packages
    - 1.2.4 Minimize the potential for inadvertent human intrusion into a sealed repository
    - 1.2.5 Minimize the potential for events that might disrupt containment

- 2.0 Identify locations that permit adequate isolation of radioactive waste from the biosphere
  - 2.1 Screen for natural systems that will retard migration of radionuclides
    - 2.1.1 Maximize ground-water flow time to the accessible environment
    - 2.1.2 Maximize retardation of radionuclides along flow paths
    - 2.1.3 Maximize extent of relatively homogeneous host rock
    - 2.1.4 Maximize migration times of volatile radionuclides
  - 2.2 Screen for natural systems with minimum potential for adverse changes to existing radionuclide migration and retardation processes
    - 2.2.1 Minimize the potential for adverse impacts due to tectonic changes
    - 2.2.2 Minimize the potential for adverse impacts due to climatic changes
    - 2.2.3 Minimize the potential for adverse impacts due to geomorphic changes
    - 2.2.4 Minimize the potential for adverse impacts due to human activities
    - 2.2.5 Minimize the potential for miscellaneous events that might disrupt isolation

- 3.0 Identify locations where safe repository construction, operation, and decommissioning can be cost-effectively implemented
  - 3.1 Screen for locations compatible with surface facility construction and safe operation
    - 3.1.1 Minimize seismic hazards to surface facilities
    - 3.1.2 Minimize cost of surface monitoring system
    - 3.1.3 Minimize adverse foundation conditions
    - 3.1.4 Minimize wind loading on surface structures
    - 3.1.5 Minimize flooding hazards to surface facilities
    - 3.1.6 Ensure availability of resources to construct and operate the repository

Table 2-1. Three-tiered hierarchical arrangement of objectives used in site screening by the Nevada Nuclear Waste Storage Investigations Project[a] (continued)

- 3.2 Screen for locations suitable for subsurface facility construction and safe operation
  - 3.2.1 Minimize seismic hazards to subsurface facilities
  - 3.2.2 Minimize flooding hazards to subsurface facilities
  - 3.2.3 Minimize adverse mining conditions
  - 3.2.4 Optimize the geometry (thickness and lateral extent) of the host rock
  - 3.2.5 Optimize host-rock homogeneity
  - 3.2.6 Maximize compatibility of the host rock with standardized waste package
- 3.3 Screen for locations with characteristics compatible with safe radioactive-waste transportation to a repository
  - 3.3.1 Minimize adverse terrain along potential waste-transportation routes
  - 3.3.2 Optimize distance from existing transportation corridors

4.0 Identify locations for which environmental impacts can be mitigated to the extent reasonably achievable

- 4.1 Minimize or avoid adverse impacts on or from sensitive biotic systems
- 4.2 Minimize impacts on abiotic systems
  - 4.2.1 Minimize impacts on surface geology
  - 4.2.2 Minimize impacts on water quality and availability
  - 4.2.3 Minimize impacts on air quality
- 4.3 Minimize adverse impacts on the existing socioeconomic status of individuals in the affected area
  - 4.3.1 Minimize adverse impacts on local economies
  - 4.3.2 Minimize adverse impacts on life styles
  - 4.3.3 Minimize conflicts with private land use
- 4.4 Reduce impacts on institutional issues
  - 4.4.1 Cooperate with State and local officials
  - 4.4.2 Carefully implement Federal regulations
- 4.5 Minimize adverse impacts on significant historical and prehistoric cultural resources

[a]Source: Sinnock and Fernandez (1982).

Table 2-2. Objectives used for site screening by the Nevada Nuclear Waste Storage Investigations (NNWSI) Project compared to relevant U.S. Department of Energy (DOE) and Nuclear Regulatory Commission (NRC) criteria[a]

NNWSI screening objectives	Comparable national criteria at time of screening			Current national criteria
Number and title	NWTS 33(1) (DOE, 1982b)	NWTS 33(2) (DOE, 1981a)	10 CFR Part 60 (July 1981 NRC proposed rule)	10 CFR Part 960 (1984)
1.0 CONTAINMENT	3.1.2, 3.2.2(1), 4.2	3.2(par. 1), 3.3(par. 1), 3.4(par. 1)	60.111(b)(2)(i), 60.111(b)(2)(ii)(A), 60.111(b)(3)(i)	960.4-1(a)
1.1 Processes		3.4(2)		
1.1.1 Chemical release		3.3(1), 3.4(2), 3.2(1), 3.2(4)	60.123(b)(5), 60.123(b)(13-14)	960.4-2-2(a), 960.4-2-2(b)(4), 960.4-2-2(c)(1,3)
1.1.2 Mechanical release		3.4(2)	60.123(b)(15), 60.132(k)(1)	960.4-2-3(a), 960.4-2-3(b)(1,2)
1.2 Events		3.5(par. 1), 3.5(1)	60.123(a)(7), 60.123(b)(6,7,10)	
1.2.1 Seismic		3.5(2), 3.5(5)	60.112(a), 60.123(a)(5), 60.123(b)(9)	960.4-2-7(a), 960.4-2-7(c)(1-4)
1.2.2 Erosion		3.5(4)	60.112(b), 60.122(i), 60.123(b)(4)	960.4-2-5(a), 960.4-2-5(b)(1,3), 960.4-2-5(c)(1), 960.4-2-5(d)
1.2.3 Volcanic		3.5(3)	60.112(a), 60.123(b)(11)	960.4-2-7(a), 960.4-2-7(b)(1), 960.4-2-7(c)(1)
1.2.4 Human intrusion	3.2.2(3), 3.3.2(4)	3.6(par. 1), 3.6(2)	60.123(b)(1-3)	960.4-2-8(a), 960.4-2-8(b)(1,2), 960.4-2-8(c)(1-4), 960.4-2-8(d)(1,2)
1.2.5 Miscellaneous	2.3		60.122(j)	960.4-2-6(a), 960.4-2-6(b)(1)

Table 2-2. Objectives used for site screening by the Nevada Nuclear Waste Storage Investigations (NNWSI) Project compared to relevant U.S. Department of Energy (DOE) and Nuclear Regulatory Commission (NRC) criteria[a] (continued)

NNWSI screening objectives	Comparable national criteria at time of screening			Current national criteria
Number and title	NWTS 33(1) (DOE, 1982b)	NWTS 33(2) (DOE, 1981a)	10 CFR Part 60 (July 1981 NRC proposed rule)	10 CFR Part 960 (1984)
2.0 ISOLATION	2.1, 3.1.2, 3.2.2(2), 4.2	3.4(par. 1), 3.1(par. 1) 3.2(par. 1), 3.3(par. 1)	60.111(b)(1), 60.111(b)(3)(ii)	960.4-1(a)
2.1 Nuclide migration				
2.1.1 Ground-water flow time		3.2(1), 3.2(2)	60.112(c), 60.122(c), 60.122(f)(1-4)	960.4-2-1(a), 960.4-2-1(b)(1,2), 960.4-2-1(b)(4,5), 960.4-2-1(c)(1), 960.4-2-2(d)
2.1.2 Nuclide retardation	3.3(1)		60.122(d), 60.122(g)(1-3), 60.122(h), 60.123(b)(13-15)	960.4-2-2(a), 960.4-2-2(b)(1,3), 960.4-2-2(b)(5), 960.4-2-2(c)(2)
2.1.3 Host-rock homogeneity				960.4-2-3(b)(1)
2.1.4 Volatile migration				
2.2 Changes to existing systems		3.5(par. 1), 3.5(1),	60.123(a)(7), 60.123(b)(7,12)	
2.2.1 Tectonic		3.5(2-5)	60.112(a), 60.122(a,b), 60.123(a)(5), 60.123(b)(6,8,10,11)	960.4-2-7(a), 960.4-2-7(b)(1), 960.4-2-7(c)(1-5), 960.4-2-7(d)

Table 2-2. Objectives used for site screening by the Nevada Nuclear Waste Storage Investigations (NNWSI) Project compared to relevant U.S. Department of Energy (DOE) and Nuclear Regulatory Commission (NRC) criteria[a] (continued)

NNWSI screening objectives	Comparable national criteria at time of screening			Current national criteria
Number and title	NWTS 33(1) (DOE, 1982b)	NWTS 33(2) (DOE, 1981a)	10 CFR Part 60 (July 1981 NRC proposed rule)	10 CFR Part 960 (1984)
2.2.2 Climatic		3.2(1)	60.112(b), 60.123(a)(8)	960.4-2-1(b)(2), 960.4-2-4(a), 960.4-2-4(b)(1,2), 960.4-2-4(c)(1,2)
2.2.3 Geomorphic		3.1(1), 3.5(4)	60.112(b), 60.122(e,i), 60.123(b)(4)	960.4-2-5(a), 960.4-2-5(b)(2,3), 960.4-2-7(c)(5)
2.2.4 Human activities	3.3.2(4)	3.6(par. 1), 3.6(2)	60.123(a)(3), 60.123(b)(1-3), 60.133(a)	960.4-2-1(c)(2), 960.4-2-8-1(a), 960.4-2-8-1(b)(1), 960.4-2-8-1(b)(2), 960.4-2-8-1(c)(1), 960.4-2-8-1(c)(2), 960.4-2-8-1(c)(3), 960.4-2-8-1(c)(4), 960.4-2-8-1(c)(5), 960.4-2-8-1(d), 960.4-2-8-2(a)
2.2.5 Miscellaneous		3.4(1)	60.122(j)	960.4-2-1(b)(3), 960.4-2-1(c)(3,5), 960.4-2-3(c)(1)
3.0 CONSTRUCTION	3.1.1, 3.3.1, 4.1		60.111(a)(1,2), 60.130(b)(1), 60.130(b)(2)(ii), 60.131(e)	

Table 2-2. Objectives used for site screening by the Nevada Nuclear Waste Storage Investigations (NNWSI) Project compared to relevant U.S. Department of Energy (DOE) and Nuclear Regulatory Commission (NRC) criteria[a] (continued)

NNWSI screening objectives Number and title	Comparable national criteria at time of screening NWTS 33(1) (DOE, 1982b)	NWTS 33(2) (DOE, 1981a)	10 CFR Part 60 (July 1981 NRC proposed rule)	Current national criteria 10 CFR Part 960 (1984)
3.1 <u>Surface facilities</u>	3.2.1	3.7(par. 1)	60.123(a)(6), 60.131(a), 60.131(c)(1)	
3.1.1 Seismic hazards		3.5(5)	60.123(a)(4), 60.123(b)(9,10)	960.5-2-11(a), 960.5-2-11(b)(1), 960.5-2-11(c)(1), 960.5-2-11(c)(2), 960.5-2-11(c)(3), 960.5-2-11(d)
3.1.2 Monitoring and characterization costs	3.3.2(3)	3.7(2)	60.130(9), 60.131(c)(2)	960.5-2-3(a), 960.5-2-3(b)(1), 960.5-2-3(c)(1,2), 960.5-2-4(a), 960.5-2-4(b)(1), 960.5-2-4(c)(1,2), 960.5-2-4(d)
3.1.3 Foundation conditions		3.7(2)		960.5-2-8(a), 960.5-2-8(b)(1,2)
3.1.4 Wind loads		3.7(3)		960.5-2-3(c)(2)
3.1.5 Flooding		3.7(1)	60.123(a)(1)	960.5-2-3(c)(2), 960.5-2-8(b)(2)
3.1.6 Net resource availability	2.6	3.7(4), 3.10(2)		960.5-2-8(c)(1)
3.2 <u>Subsurface facilities</u>	3.1.2, 3.3.2(2)	3.4(3)	60.123(b)(16), 60.130(10), 60.132(a)(1,4), 60.133(b)(4,5)	

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Table 2-2. Objectives used for site screening by the Nevada Nuclear Waste Storage Investigations (NNWSI) Project compared to relevant U.S. Department of Energy (DOE) and Nuclear Regulatory Commission (NRC) criteria[a] (continued)

NNWSI screening objectives	Comparable national criteria at time of screening: NWTS 33(1) (DOE, 1982b)	NWTS 33(2) (DOE, 1981a)	10 CFR Part 60 (July 1981 NRC proposed rule)	Current national criteria 10 CFR Part 960 (1984)
3.2.1 Seismic hazard		3.5(5)	60.123(a)(4), 60.123(b)(9,10)	960.5-2-11(a), 960.5-2-11(b)(1), 960.5-2-11(c)(1), 960.5-2-11(c)(2), 960.5-2-11(c)(3), 960.5-2-11(d)
3.2.2 Flooding		3.2(3)	60.122(f)(3), 60.132(a)(2), 60.132(i)(1), 60.132(g)(1,5)	960.5-2-8(c), 960.5-2-10(a), 960.5-2-10(b)(1), 960.5-2-10(b)(2), 960.5-2-10(c)(1), 960.5-2-10(d)
3.2.3 Mining conditions		3.4(3)	60.123(b)(15,17), 60.132(a)(2), 60.132(e)(1,3), 60.132(f)	960.5-2-9(a)(2), 960.5-2-9(b)(2), 960.5-2-9(c)(2-4), 960.5-2-9(d)
3.2.4 Host-rock geometry		3.1(par. 1), 3.1(2)	60.122(i), 60.132(a)(3)	960.5-2-9(a)(1), 960.5-2-9(b)(1), 960.5-2-9(c)(1)
3.2.5 Host-rock homogeneity		3.4(3)		960.5-2-9(c)(5)
3.2.6 Waste-package compatibility	3.4.1, 3.4.2 3.3.2(1,2)		60.132(a)(1,3), 60.132(i)(2), 60.135(a)(1,2), 60.135(c)(3)	

Table 2-2. Objectives used for site screening by the Nevada Nuclear Waste Storage Investigations (NNWSI) Project compared to relevant U.S. Department of Energy (DOE) and Nuclear Regulatory Commission (NRC) criteria[a] (continued)

NNWSI screening objectives Number and title	Comparable national criteria at time of screening NWTS 33(1) (DOE, 1982b)	NWTS 33(2) (DOE, 1981a)	10 CFR Part 60 (July 1981 NRC proposed rule)	Current national criteria 10 CFR Part 960 (1984)
3.3 Transportation				
3.3.1 Terrain		3.8(2)		960.5-2-7(a),
960.5-2-7(b)(1)(iii),				
960.5-2-7(b)(1)(iv),				960.5-2-7(c)(1,2)
3.3.2 Distance		3.7(2)		960.5-2-7(b)(1)(i),
960.5-2-7(b)(1)(ii),				960.5-2-7(b)(2-4), 960.5-2-7(c)(3)
4.0 ENVIRONMENT	4.3	3.9(par. 1), 3.9.1, 3.9(2)	60.130(b)(2)(i)	960.5-1(a)(2)
4.1 Sensitive biotic systems				960.5-2-5(c)(6),
4.2 Abiotic systems				
4.2.1 Geologic quality		3.9(1)		960.5-2-5(b)(2), 960.5-2-5(c)(2), 960.5-2-5(d)(1)
4.2.2 Water quality		3.9(1)		960.5-2-5(b)(2), 960.5-2-5(c)(2), 960.5-2-5(d)(1), 960.5-2-10(b)(3), 960.5-2-10(d)

Table 2-2. Objectives used for site screening by the Nevada Nuclear Waste Storage Investigations (NNWSI) Project compared to relevant U.S. Department of Energy (DOE) and Nuclear Regulatory Commission (NRC) criteria[a] (continued)

NNWSI screening objectives	Comparable national criteria at time of screening			Current national criteria
Number and title	NWTS 33(1) (DOE, 1982b)	NWTS 33(2) (DOE, 1981a)	10 CFR Part 60 (July 1981 NRC proposed rule)	10 CFR Part 960 (1984)
4.2.3 Air quality		3.9(1)		960.5-2-5(b)(2), 960.5-2-5(c)(2), 960.5-2-5(d)(1)
4.3 Socioeconomics		3.8(par. 1), 3.10(par. 1)		960.5-2-6(a)
4.3.1 Local economies		3.10(1)		960.5-2-6(b)(1-4), 960.5-2-6(c)(1-4), 960.5-2-6(d)
4.3.2 Life styles 960.5-2-5(c)(3-5),				960.5-2-5(d)(2,3), 960.5-2-6(b)(1); 960.5-2-6(c)(1)
4.3.3 Private land use		3.6(2)	60.121(a)	960.5-2-2(a), 960.5-2-2(b)(1), 960.5-2-2(c)(1)
4.4 Institutional issues	2.2	3.9(2)	60.121(b)	960.5-2-5(a), 960.5-2-6(a)
4.4.1 State issues		3.6(2), 3.9(2)		960.5-2-5(b)(1), 960.5-2-5(c)(5), 960.5-2-7(b)(8)
4.4.2 Federal regulation	4.1.1, 4.1.2	3.9(2)		960.5-2-5(b)(1), 960.5-2-5(c)(1), 960.5-2-7(a), 960.5-2-7(b)(7)

Table 2-2. Objectives used for site screening by the Nevada Nuclear Waste Storage Investigations (NNWSI) Project compared to relevant U.S. Department of Energy (DOE) and Nuclear Regulatory Commission (NRC) criteria[a] (continued)

NNWSI screening objectives	Comparable national criteria at time of screening			Current national criteria
Number and title	NWTS 33(1) (DOE, 1982b)	NWTS 33(2) (DOE, 1981a)	10 CFR Part 60 (July 1981 NRC proposed rule)	10 CFR Part 960 (1984)
4.5 Historic and prehistoric resources		3.9(1)		960.5-2-5(b)(2) 960.5-2-5(c)(4,5), 960.5-2-5(d)(3)

[a]Modified from Sinnock and Fernandez (1982).

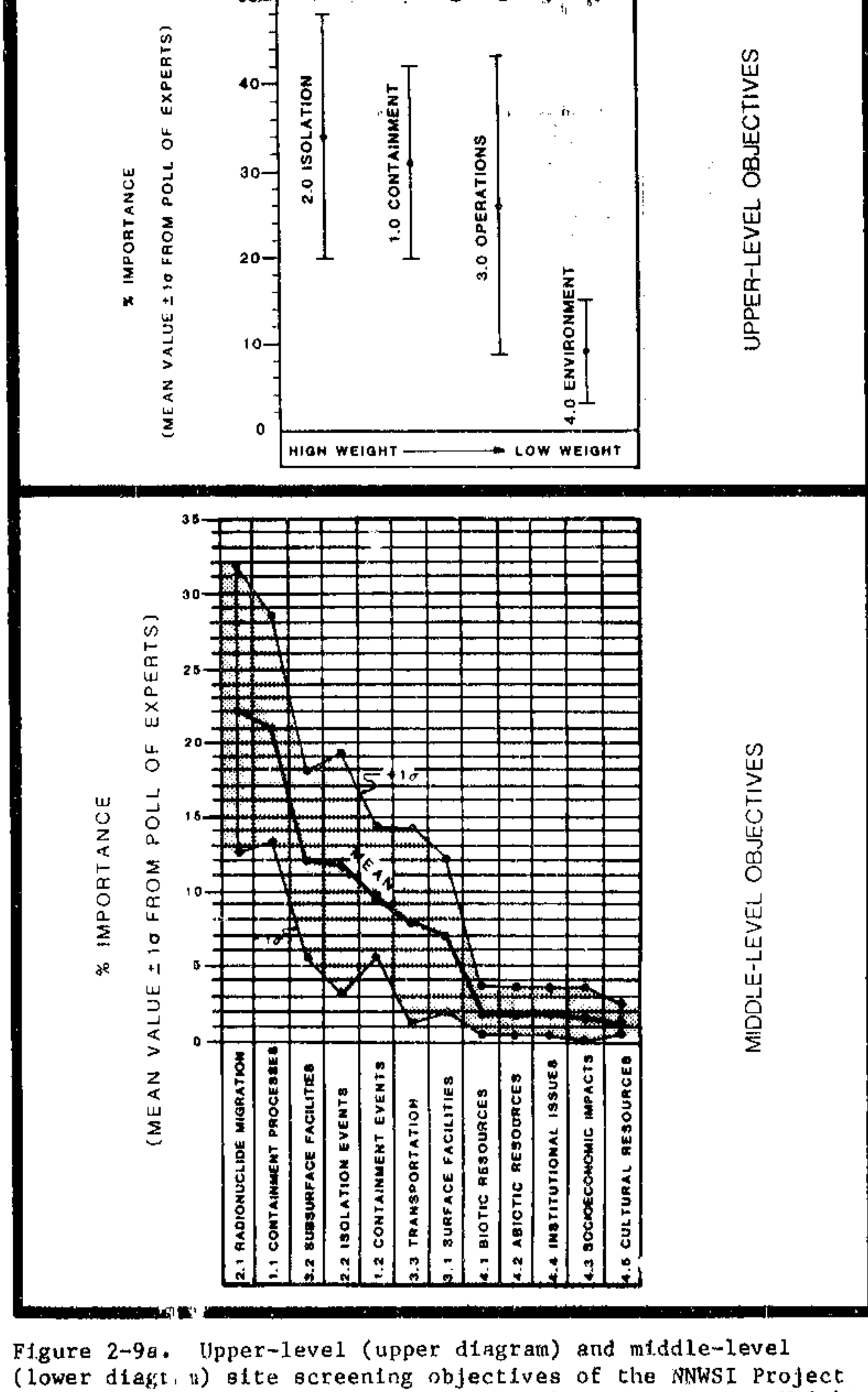


Figure 2-9a. Upper-level (upper diagram) and middle-level (lower diagr m) site screening objectives of the NNWSI Project ranked by weight for each level of the objectives tree. Weights and standard deviations (bracketed, shaded area) were obtained from a poll of experts. Modified from Sinnock and Fernandez (1982).

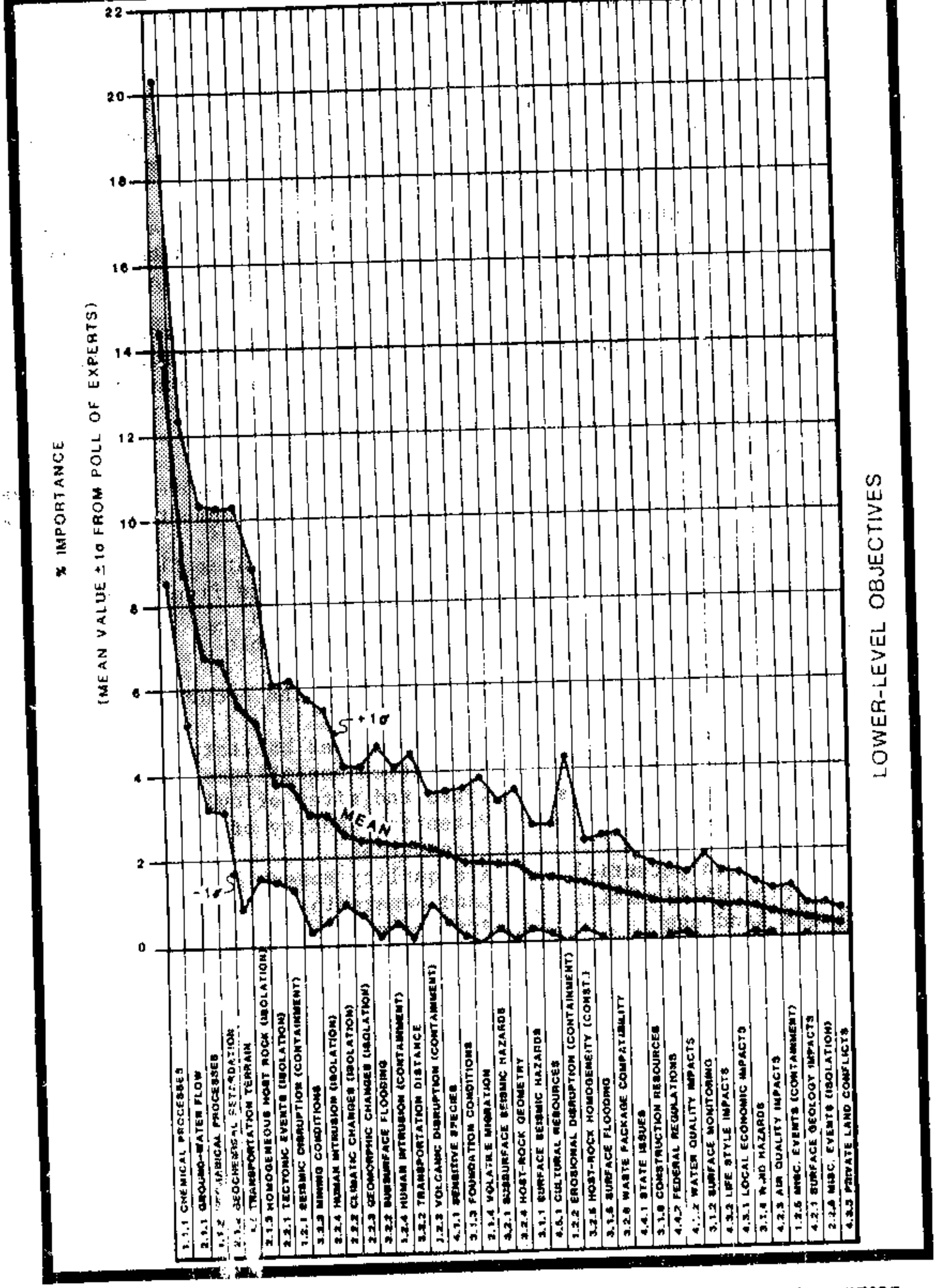


Figure 2-9b. Lower-level site-screening objectives of the NNWSI Project ranked by weight for each level of the objectives tree. Weights and standard deviations (bracketed, shaded area) were obtained from a poll of experts. Modified from Sinnock and Fernandez (1982).

Table 2-3. Physical attributes used to discriminate among alternative locations within the screening area[a]

No.	Attribute	Discriminating conditions
		GEOGRAPHICAL ATTRIBUTES
1	Volcanic potential	Relative potential for basaltic eruptions
2	Fault density	Relative density of faults and fractures
3	Fault trend	Relative potential for fault movement
4	Age of faulting	Fault ages
5	Natural seismic potential	Expected ground acceleration (g)
6	Weapons seismic potential	Expected ground acceleration (g)
7	Bed attitude	Amount of rock dip (degrees)
8	Erosion potential	Projected erosional intensity
9	Flood potential	Flood hazards
10	Terrain ruggedness	Slope steepness (%)
11	Metal resources	Potential for undiscovered metal ores
12	Ground-water resources	Potential for development of ground-water supplies
13	Ground-water flux	Saturated ground-water flux (m^3/s)
14	Ground-water flow direction	Upgradient distance from potential production areas
15	Thickness of unsaturated zone	Depth to water table
16	Sensitive floral species	Potential for the occurrence of sensitive species
17	Sensitive faunal species	Likely species habitats
18	Revegetation potential	Vegetation assemblages
19	Known cultural resources	Types and sites of cultural resources
20	Potential cultural resources	Potential density of undiscovered cultural resources
21	Air pollution potential	Air quality zones
22	Permitting difficulties	Land ownership and control
23	Private land use	Private and nonprivate land
		HOST-ROCK ATTRIBUTES
24	Thermal conductivity	Thermal conductivity (W/m-K)
25	Compressive strength (containment)	Unconfined compressive strength (psi)
26	Compressive strength (construction)	Unconfined compressive strength (psi)
27	Expansion or contraction	Expansion or contraction behavior on heating
28	Mineral stability	Mineral stability on heating
29	Stratigraphic setting	Stratigraphically weighted sorption potential
30	Hydraulic retardation	Potential for radionuclide diffusion into the rock matrix
31	Hydraulic transmissivity	Hydraulic transmissivity (m^2/s)

[a]Data from Sinnock and Fernandez (1982).

A map of the screening area was prepared for each geographical attribute showing the distribution of physical conditions represented by that attribute. A value for appropriate rock properties was assigned to each candidate rock type for each host-rock attribute. The attributes used to evaluate locations with respect to each of the lower-level objectives were weighted to allow the relative importance of various types of physical conditions to be distinguished (Table 2-4).

To supply the third basic element, favorability estimates for the various physical conditions represented by each of the attributes were compiled as graphs (Figure 2-10). These graphs constituted quantitative screening criteria by which the relevant physical attributes of the screening area were compared with the objectives.

The objectives, attributes, favorability graphs, weights, and a base map of the screening area were digitized on a computer graphics system. Computer software was developed to calculate the relative favorability for each of 1,514 half-mile square grid cells of the base map and for each of nine candidate rock types (Sharp, 1984). In these calculations, the favorability value of each attribute for each grid cell or host rock, as appropriate, was first multiplied by the weight of the attribute (Table 2-4 shows the weights assigned to each attribute). The resulting numbers were then multiplied successively by the weights of (a) the appropriate lower-level objectives (Table 2-5), (b) the corresponding middle-level objectives (Table 2-4), and (c) the corresponding upper-level objectives (Table 2-4). These fully weighted numbers were then added together for a total rating score for each of the 1,514 grid cells and for each rock type. Finally, the total scores were scaled to a maximum of 100,000.

Results of the calculations were displayed as maps showing ratings of all 1,514 grid cells (Figure 2-11a) based on geographical attributes (attributes 1 through 23 as shown on Table 2-4) and as lists showing host-rock ratings for both saturated and unsaturated conditions (Figure 2-11b, bottom) (Sinnock and Fernandez, 1982). Grid cell ratings shown on the maps were grouped into high, intermediate, and low favorability categories. These categories generally correspond, respectively, to scores of greater than one standard deviation above the average, within one standard deviation of the average, and greater than one standard deviation below the average. The histogram at the top of Figure 2-11b shows the range of scores for geographic attributes from which the average and standard deviation were calculated. Figure 2-12 shows the ratings obtained by adding the score of the highest rated rock type (scores shown on Figure 2-11b, bottom) occurring beneath the surface at each grid cell to the scores of the grid cells represented on the map of Figure 2-11a. Since some localities within the screening area are not underlain by any of the nine rock types evaluated, their score for rock type was zero and hence the total scores of these grid cells were relatively low.

Figures 2-11a, 2-11b, and 2-12 show the results of only two of many separate analyses that were performed. The others were based on selected subsets of related objectives and attributes and on the confidence that could be assigned to the results drawn from figures 2-11 and 2-12. These analyses, discussed by Sinnock and Fernandez (1982), were used to investigate the factors contributing most to the scores of alternative locations and rock types. Based on groupings of similarly rated grid cells for most or all the

Table 2-4. Matrix of attributes and objectives showing the weights assigned to attributes[a,b]

	ATTRIBUTES	1.1.1	1.1.2	1.2.1	1.2.2	1.2.3	1.2.4	1.2.5	2.1.1	2.1.2	2.1.3	2.1.4	2.2.1	2.2.2	2.2.3	2.2.4	2.2.5
	LEVEL 1	1.0 PROVIDE CONTAINMENT (31%)							2.0 PROVIDE ISOLATION (34%)								
	LEVEL 2	1.1 DISRUPTIVE PROCESSES (68%)		1.2 DISRUPTIVE EVENTS (32%)					2.1 RADIONUCLIDE MIGRATION (65%)				2.2 DISRUPTIVE EVENTS (35%)				
	LEVEL 3	CHEMICAL	MECHANICAL	SEISMIC	EROSIONAL	VOLCANIC	HUMAN INTRUSION	MISCELLANEOUS	GROUND-WATER FLUX	NUCLIDE RETARDATION	HOST-ROCK THICKNESS	VOLATILE MIGRATION	TECTONIC	CLIMATIC	GEOMORPHIC	HUMAN INDUCED	MISC. & COMPLEXITY
GEOGRAPHICAL	1. VOLCANIC POTENTIAL			5		100							40				
	2. FAULT DENSITY	5							5			10					50
	3. FAULT TREND			5									10				
	4. AGE OF FAULTING			30									10				
	5. NATURAL SEISMIC POTENTIAL			60									40				
	6. WEAPONS SEISMIC POTENTIAL							100								10	
	7. BED ATTITUDE (ROCK DIP)																30
	8. EROSION POTENTIAL				100										60		
	9. FLOOD POTENTIAL														10		
	10. TERRAIN RUGGEDNESS														10		20
	11. BASE & PRECIOUS METAL RESOURCE POTENTIAL						50									45	
	12. GROUND-WATER RESOURCE POTENTIAL						50									45	
	13. GROUND-WATER FLUX	5							10	10							
	14. GROUND-WATER FLOW DIRECTION								30								
	15. THICKNESS OF UNSATURATED ZONE								5					100			
	16. SENSITIVE FLORAL SPECIES																
	17. SENSITIVE FAUNAL SPECIES																
	18. REVEGETATION POTENTIAL																
	19. KNOWN CULTURAL RESOURCES																
	20. POTENTIAL CULTURAL RESOURCES																
	21. AIR POLLUTION POTENTIAL																
	22. PERMITTING DIFFICULTIES																
	23. PRIVATE LAND USE																
HOST ROCK	24. THERMAL CONDUCTIVITY	20	30														
	25. COMPRESSIVE STRENGTH (CONTAINMENT)		40								20						
	26. COMPRESSIVE STRENGTH (CONSTRUCTION)																
	27. EXPANSION-CONTRACTION		20														
	28. MINERAL STABILITY	10	10							10		5					
	29. STRATIGRAPHIC SETTING									70	80	20					
	30. HYDRAULIC RETARDATION								10	10		15					
	31. HYDRAULIC TRANSMISSIVITY	60							40			40					

Table 2-4. Matrix of attributes and objectives showing the weights assigned to attributes[a,b] (continued)

LEVEL 1: 3.0 PROVIDE SAFE, COST EFFECTIVE CONSTRUCTION & OPERATIONS (26%)

LEVEL 2		3.1 SURFACE FACILITIES (27%)						3.2 SUBSURFACE FACILITIES (43%)						3.3 TRANSPORTATION SYS. (30%)	
LEVEL 3		3.1.1 SEISMICITY	3.1.2 MONITORING RQMT'S	3.1.3 FOUNDATION COND.	3.1.4 WIND LOADS	3.1.5 FLOODING	3.1.6 AVAIL. NAT. RES.	3.2.1 SEISMICITY	3.2.2 FLOODING	3.2.3 MINING CONDITIONS	3.2.4 HOST-ROCK GEOMETRY	3.2.5 HOST-ROCK HOMOG.	3.2.6 WASTE-PKG. ACCEPT.	3.3.1 TERRAIN	3.3.2 EXISTING CORRIDOR
	ATTRIBUTES														
GEOGRAPHICAL	1. VOLCANIC POTENTIAL														
	2. FAULT DENSITY							10	10	20		50			
	3. FAULT TREND														
	4. AGE OF FAULTING														
	5. NATURAL SEISMIC POTENTIAL	90						85							
	6. WEAPONS SEISMIC POTENTIAL	10						5							
	7. BED ATTITUDE (ROCK DIP)										100	40			
	8. EROSION POTENTIAL			10											
	9. FLOOD POTENTIAL			20		100			5					30	
	10. TERRAIN RUGGEDNESS		70	70										70	
	11. BASE & PRECIOUS METAL RESOURCE POTENTIAL											10			
	12. GROUND-WATER RESOURCE POTENTIAL														
	13. GROUND-WATER FLUX								15						
	14. GROUND-WATER FLOW DIRECTION								10	10					
	15. THICKNESS OF UNSATURATED ZONE														
	16. SENSITIVE FLORAL SPECIES		3												
	17. SENSITIVE FAUNAL SPECIES		7												
	18. REVEGETATION POTENTIAL														
	19. KNOWN CULTURAL RESOURCES		5												
	20. POTENTIAL CULTURAL RESOURCES		15												
	21. AIR POLLUTION POTENTIAL														
	22. PERMITTING DIFFICULTIES														
	23. PRIVATE LAND USE														
HOST ROCK	24. THERMAL CONDUCTIVITY									10			20		
	25. COMPRESSIVE STRENGTH (CONTAINMENT)														
	26. COMPRESSIVE STRENGTH (CONSTRUCTION)									40					
	27. EXPANSION-CONTRACTION												40		
	28. MINERAL STABILITY									10			40		
	29. STRATIGRAPHIC SETTING														
	30. HYDRAULIC RETARDATION														
	31. HYDRAULIC TRANSMISSIVITY								60	10					

assigned to attributes[a,b] (continued)

ATTRIBUTES	4.1.1 SENSITIVE SYS.	4.2.1 SURFACE GEOLOGY	4.2.2 WATER QUALITY	4.2.3 AIR QUALITY	4.3.1 LOCAL ECONOMICS	4.3.2 LIFE STYLES	4.3.3 LAND USE	4.4.1 STATE ISSUES	4.4.2 FEDERAL REGS.	4.5.1 ARCH. & HIST. SITES
LEVEL 1: 4.0 PROVIDE ACCEPTABLE ENVIRONMENTAL IMPACTS (9%)										
LEVEL 2	4.1 BIOTIC SYS. (22%)	4.2 ABIOTIC SYS. (21%)			4.3 SOCIO-ECONOMIC IMPACTS (20%)			4.4 INSTITUTIONAL IMPACTS (21%)		4.5 CULT. RES. (16%)
GEOGRAPHICAL										
1. VOLCANIC POTENTIAL										
2. FAULT DENSITY										
3. FAULT TREND										
4. AGE OF FAULTING										
5. NATURAL SEISMIC POTENTIAL										
6. WEAPONS SEISMIC POTENTIAL										
7. BED ATTITUDE (ROCK DIP)										
8. EROSION POTENTIAL										
9. FLOOD POTENTIAL		50								
10. TERRAIN RUGGEDNESS		60								
11. BASE & PRECIOUS METAL RESOURCE POTENTIAL										
12. GROUND-WATER RESOURCE POTENTIAL			100							
13. GROUND-WATER FLUX										
14. GROUND-WATER FLOW DIRECTION										
15. THICKNESS OF UNSATURATED ZONE										
16. SENSITIVE FLORAL SPECIES	40									
17. SENSITIVE FAUNAL SPECIES	50									
18. REVEGETATION POTENTIAL	10									
19. KNOWN CULTURAL RESOURCES										30
20. POTENTIAL CULTURAL RESOURCES										70
21. AIR POLLUTION POTENTIAL				100						
22. PERMITTING DIFFICULTIES									100	
23. PRIVATE LAND USE							100			

[a]Data from Sinnock and Fernandez (1982).

[b]Weights assigned to each geographic and host-rock attribute for evaluating site conditions with respect to each lower-level objective. The three-level hierarchy is given in Table 2-1; percentage importance for upper (1), middle (2), and lower (3) level objectives is given in Figures 2-9a and 2-9b; and discriminating conditions for geographic and host-rock attributes are presented in Table 2-3.

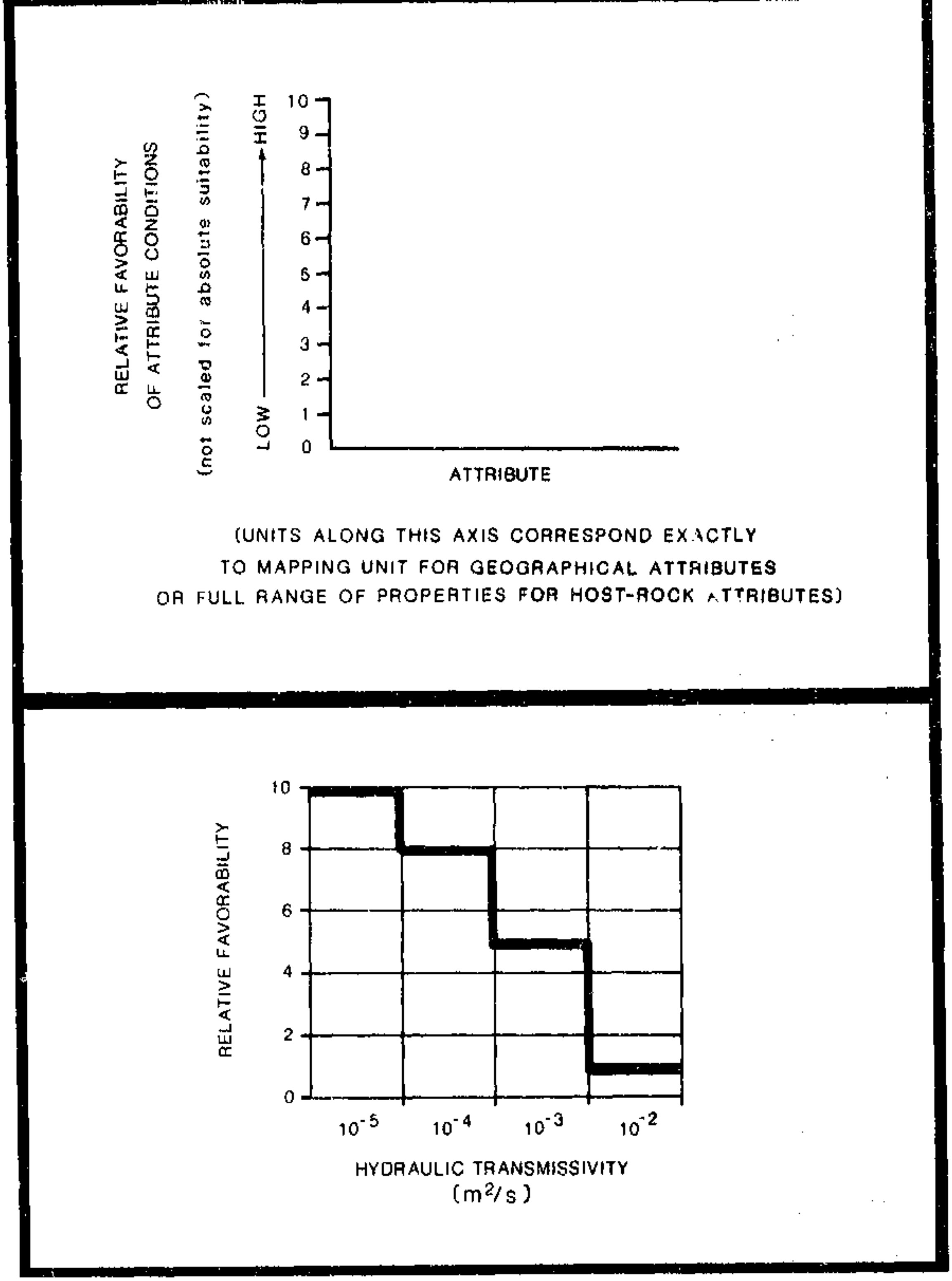
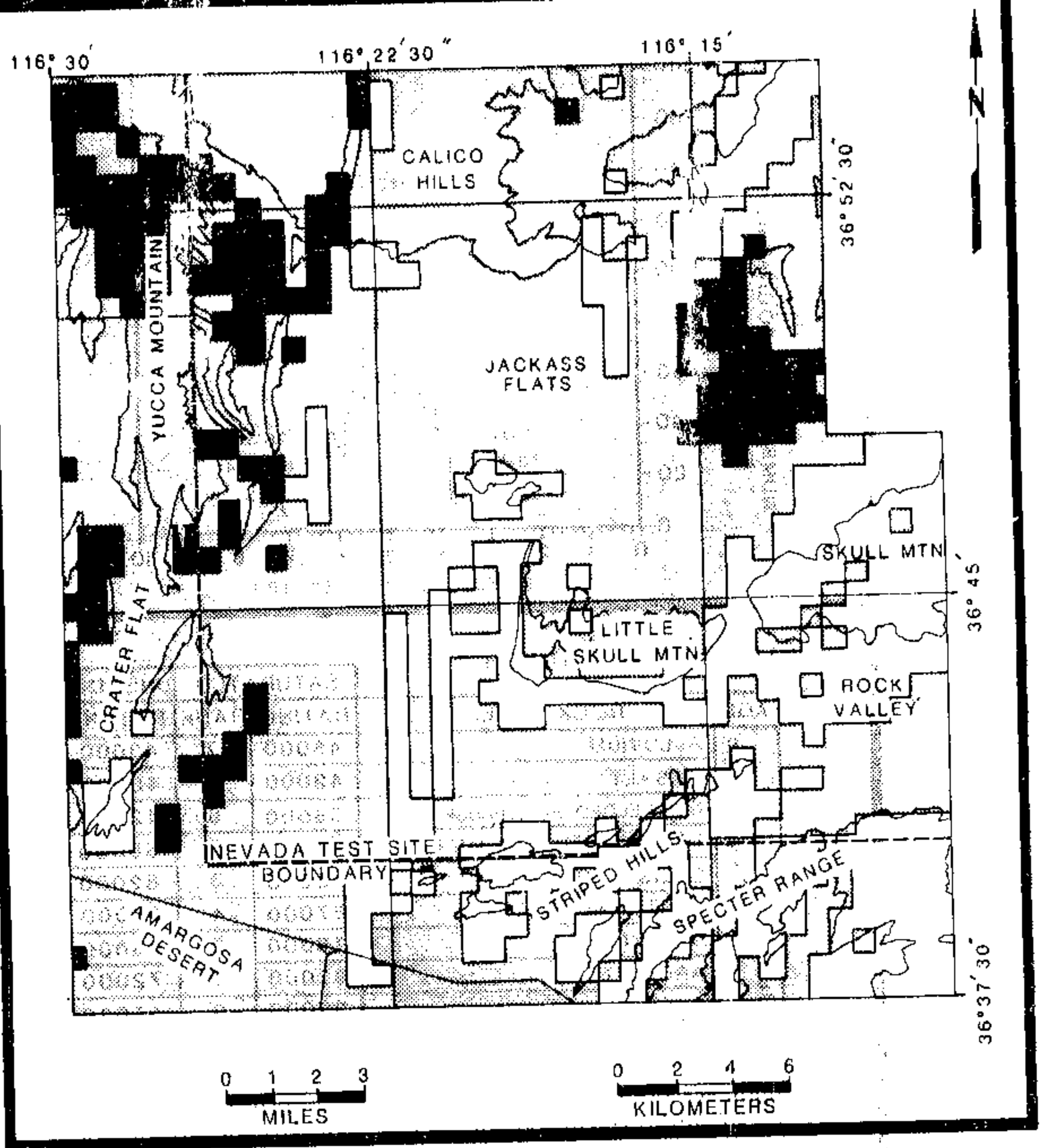


Figure 2-10. General form (upper diagram) of graphs for plotting the favorability estimates used to link the attributes to objectives. A specific example for attribute 31, hydraulic transmissivity, is shown on the lower diagram. Modified from Sinnock and Fernandez (1982).

Table 2-5. Weights assigned to the lower-level objectives (level 3) shown in Table 2-4[a]

	Objective[b]	Weight (%)[c]
1.1.1	Chemical	68
1.1.2	Mechanical	32
1.2.1	Seismic	37
1.2.2	Erosional	14
1.2.3	Volcanic	21
1.2.4	Human intrusion	23
1.2.5	Miscellaneous	5
2.1.1	Ground-water flow	39
2.1.2	Nuclide retardation	30
2.1.3	Host-rock thickness	23
2.1.4	Migration of volatiles	8
2.2.1	Tectonics	31
2.2.2	Climate	21
2.2.3	Geomorphic effects	20
2.2.4	Human effects on isolation system	25
2.2.5	Miscellaneous and complexity	3
3.1.1	Seismicity	21
3.1.2	Monitoring requirements	12
3.1.3	Foundation conditions	26
3.1.4	Wind loads	10
3.1.5	Flooding	18
3.1.6	Available natural resources	13
3.2.1	Seismicity	15
3.2.2	Flooding	21
3.2.3	Mining conditions	27
3.2.4	Host-rock geometry	15
3.2.5	Host-rock homogeneity	12
3.2.6	Waste-package acceptability	10
3.3.1	Terrain	71
3.3.2	Transportation distance	29
4.1.1	Sensitive systems	100
4.2.1	Surface geology	22
4.2.2	Water quality	46
4.2.3	Air quality	32
4.3.1	Local economies	41
4.3.2	Life styles	42
4.3.3	Private land use	17
4.4.1	State issues	53
4.4.2	Federal regulations	47
4.5.1	Archaeological and historic sites	100

[a] Modified from Sinnock and Fernandez (1982).
[b] Only general designations; see Table 2-1 for a complete statement of objectives.
[c] Weights for each group of lower-level objectives sum to 100%.



LEGEND FOR LOCATION RATINGS

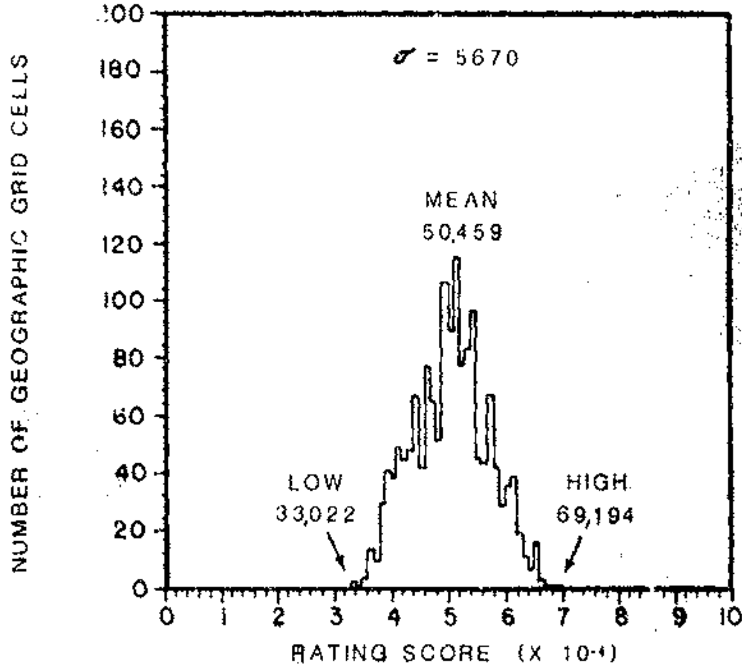
<45,000 (LOW FAVORABILITY)

45,000-60,000 (MEDIUM FAVORABILITY)

>60,000 (HIGH FAVORABILITY)

(BASED ON ATTRIBUTES 1-23 ONLY)

Figure 2-11a. Examples of results of screening analyses based on geographical attributes. Ratings of the 1,514 grid cells that make up the base map are grouped into three categories (see legend). Modified from Sinnock and Fernandez (1982).



HOST-ROCK RATINGS

AGE	ROCK TYPE	SATURATED RATING	SATURATED RANK	UNSATURATED RATING	UNSATURATED RANK
YOUNGER	ALLUVIUM	45000	7	43000	8
	BASALT	49000	6	48000	7
	NONWELDED PAINTBRUSH TUFF	55000	5	42000	9
	TOPOPAH SPRING TUFF	41000	8	58000	5
	CALICO HILLS TUFF	75000	3	62000	3
	CRATER FLAT TUFF	67000	4	60000	4
	GRANITE	76000	2	63000	2
	ARGILLITE	82000	1	72000	1
OLDER	CARBONATE	39000	9	55000	6

NOTE: Host-rock ratings are based solely on host-rock attributes (numbers 24-31 for saturated list; for unsaturated list, numbers 24-30 only). Ratings do not account for site-dependent rock conditions such as in situ stress, in situ temperature, depth, and local structures. Unsaturated ratings omit hydraulic transmissivity, attribute number 31.

Figure 2-11b. Typical histogram (upper diagram) and host-rock rating scores (lower diagram) used to place individual grid cells into high, medium, and low categories. The histogram distribution was used to obtain the distribution of favorabilities that is shown as the legend on Figure 2-11a. For example, the results from the histogram were added to the host-rock rating scores to obtain the combined location ratings for the map shown on Figure 2-12. Modified from Sinnock and Fernandez (1982).

8 0 0 0 8 0 1 2 5

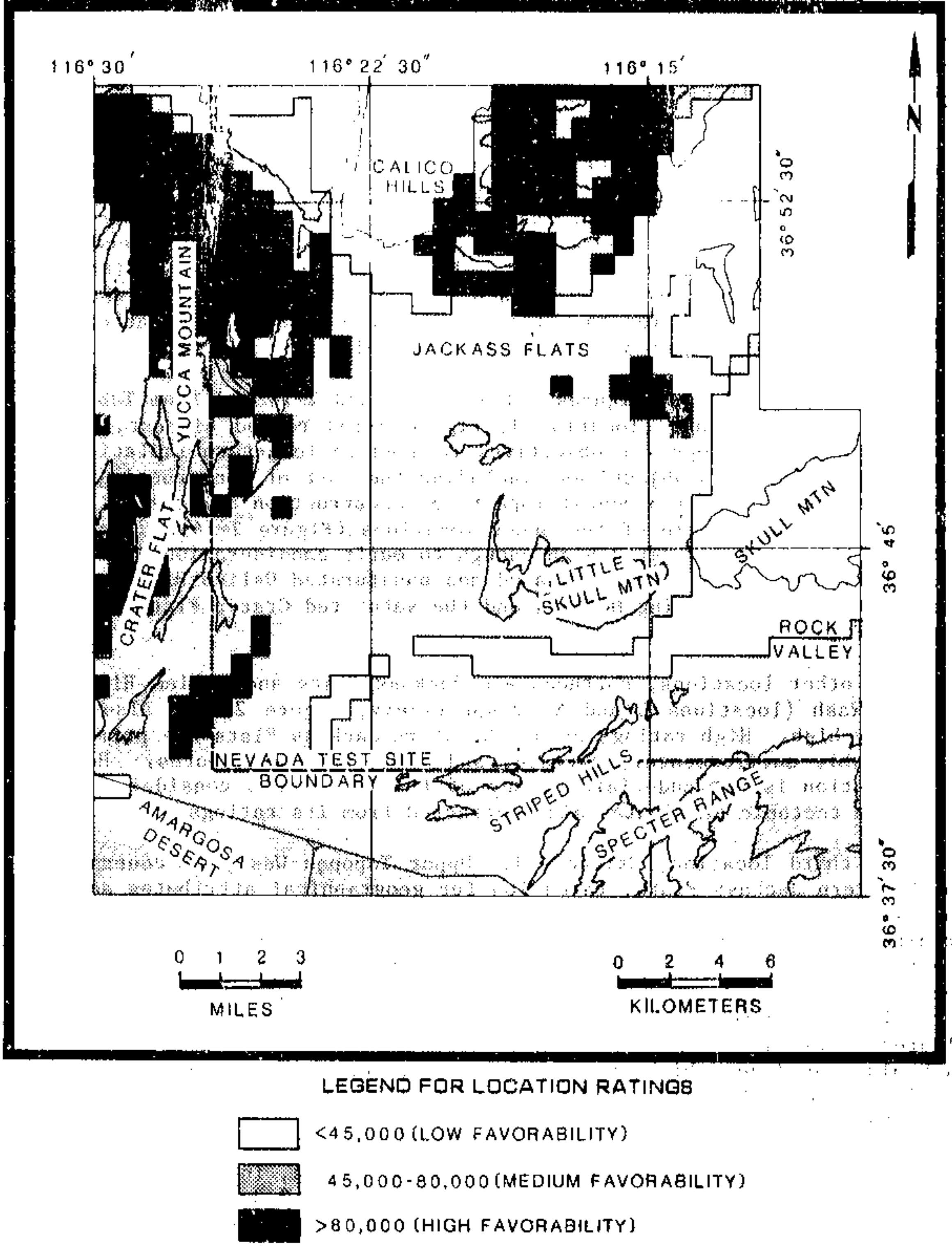


Figure 2-12. Screening analysis results with the value of most highly rated host rock added to the ratings for geographical attributes from Figure 2-11a and the scores scaled to a total score of 100,000. Modified from Sinnock and Fernandez (1982).

separate analyses, 15 relatively distinct locations were identified (Figure 2-13). In this manner alternative locations for a repository were established by the analyses.

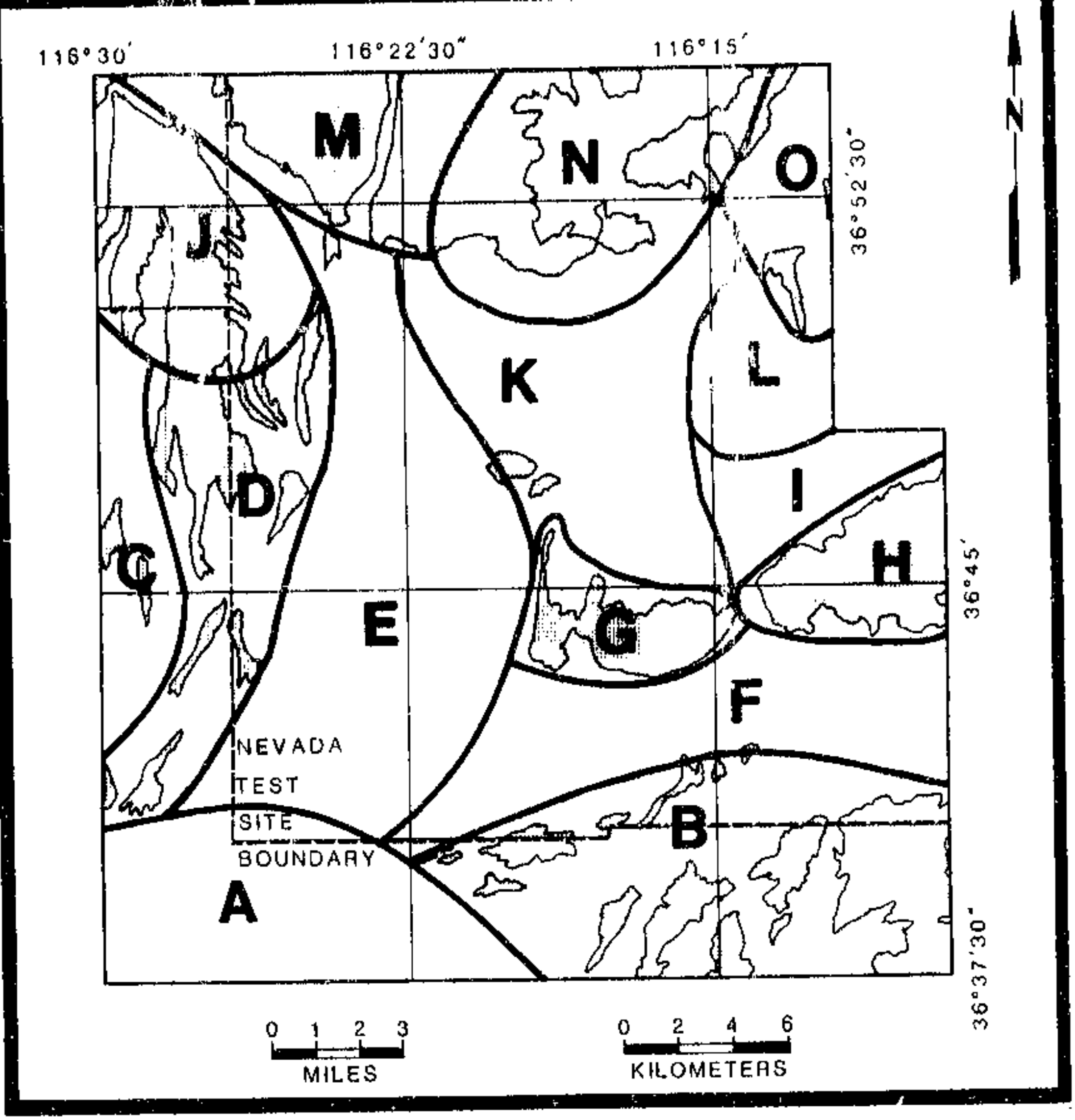
In Figure 2-14 the 15 locations are ranked according to the number of analyses for which all or most of the grid cells within each location rated high, medium, or low. The objective and attribute subsets shown in Figure 2-14 are convenient representations of the most important bases for ranking the potential sites; the figure also shows the relative weights assigned by the experts to each of these subsets. To quantify the basis for the rankings, the weights associated with each of the rating categories shown on Figure 2-14 were summed for each location for the 12 analyses that considered different combinations of objectives (Table 2-6).

As is apparent from figures 2-11a, 2-12, and 2-14 and from Table 2-6, northern Yucca Mountain (location J, Figure 2-13) ranked highest, mainly because of high ratings for objectives related to long-term isolation; its ratings for near-term objectives, including the cost of constructing surface facilities and the environmental impacts of construction and operation, were lower than those of some of the other locations (Figure 2-14). Three rock types at this location rated high enough to merit consideration as potential repository host rocks: the saturated and unsaturated Calico Hills unit, the unsaturated Topopah Spring Member, and the saturated Crater Flat Tuff (lower half of Figure 2-11b).

Two other locations, northeastern Jackass Flats and Calico Hills-Upper Topopah Wash (locations L and N, respectively, Figure 2-13), also rated generally high. High ratings at northeastern Jackass Flats are primarily due to favorable environmental, terrain, and hydrologic attributes. However, this location is not underlain by any of the host rocks considered. Less favorable tectonic attributes also detracted from its ratings.

The third location, Calico Hills-Upper Topopah Wash, in contrast to northeastern Jackass Flats, rated low for geographical attributes and high only when host-rock attributes were considered. Argillite and perhaps granite occur beneath Calico Hills and Upper Topopah Wash, though the granite may be too deep for repository use. Argillite was rated first and granite second for both saturated and unsaturated conditions, and their presence strongly contributed to the high ratings at this location (compare maps from figures 2-11a and 2-12). Hydrologic attributes at Calico Hills-Upper Topopah Wash also rated very high, whereas tectonic, terrain, and human-disturbance attributes generally rated low. The other 12 locations rated significantly lower than those discussed above.

Yucca Mountain emerged from the formal screening, in agreement with the less formal siting activities described in Section 2.2.3, as the location on or near the NTS that offers the most attributes considered to be favorable for a repository site. The screening systematically compared only the relative merits of alternative locations considered in the study. The site-specific data needed for quantitative predictions of site suitability will be collected during site characterization if Yucca Mountain is recommended for characterization.



ALTERNATIVE LOCATIONS

- A AMARGOSA DESERT
- B STRIPED HILLS-SPECTER RANGE
- C EASTERN CRATER FLAT
- D CENTRAL-SOUTHERN YUCCA MOUNTAIN
- E WESTERN JACKASS FLATS
- F ROCK VALLEY
- G LITTLE SKULL MOUNTAIN
- H SKULL MOUNTAIN
- I EASTERN JACKASS FLATS
- J NORTHERN YUCCA MOUNTAIN
- K CENTRAL JACKASS FLATS
- L NORTHEASTERN JACKASS FLATS
- M YUCCA WASH-FORTYMILE CANYON
- N CALICO HILLS-UPPER TOPOPAH WASH
- O KIWI MESA-MID VALLEY PASS

Figure 2-13. Approximate boundaries of 15 alternative locations identified from groupings of similarly rated grid cells for 25 separate analyses. The location identified as northern Yucca Mountain (location J) is larger than, but encompasses, the current site. Modified from Sinnock and Fernandez (1982).

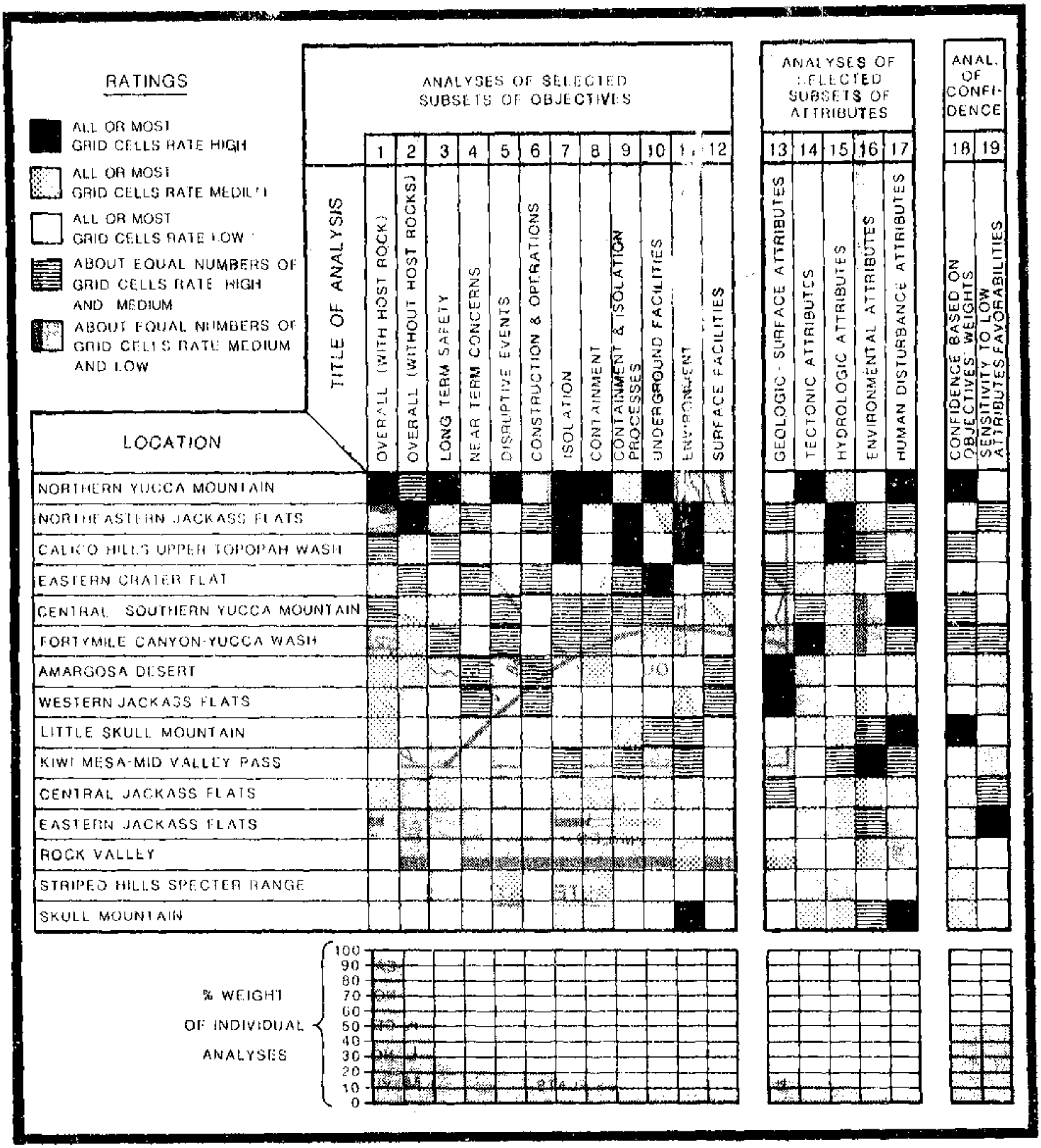


Figure 2-14. Ranking of locations (highest to lowest from top to bottom) based on ratings of all or most grid cells. Separate analyses of (a) objectives (columns 1-12), (b) attributes (column 13-17), and (c) confidence in the ratings (columns 18-19). For each column percentage weights associated with individual analyses were obtained by polling experts and are shown in the histograms at bottom. Modified from Sinnock and Fernandez (1982).

Table 2-6. Ranking of alternative locations (highest to lowest from top to bottom) based on the number and weights of rating categories for the 12 analyses of related objectives[a,b]

Location	Rating category from Figure 2-14									
	High		High and medium		Medium		Medium and low		Low	
	No.	Weight	No.	Weight	No.	Weight	No.	Weight	No.	Weight
Northern Yucca Mountain	6	178.79	1	52.42	2	30.59	3	29.41	0	0
Northeastern Jackass Flats	4	82.56	2	41.51	5	73.48	1	93.66	0	0
Calico Hills-Upper Topopah Wash	3	30.14	2	122.06	1	52.42	1	21.83	5	64.81
Eastern Crater Flat	1	6.55	5	105.91	5	172.24	0	0	1	6.51
Central-Southern Yucca Mountain	0	0	6	156.97	3	86.22	2	30.52	1	17.50
Fortymile Canyon-Yucca Wash	0	0	4	78.58	2	58.97	4	112.15	2	41.51
Amargosa Desert	0	0	3	46.91	3	157.38	4	73.83	2	13.09
Western Jackass Flats	0	0	3	46.91	2	100.17	2	74.25	5	69.88
Little Skull Mountain	0	0	2	13.06	3	117.29	3	63.71	4	97.15
Kiwi Mesa-Mid Valley Pass	0	0	3	30.14	0	0	5	120.50	4	140.57
Central Jackass Flats	0	0	0	0	10	216.96	2	74.25	0	0
Eastern Jackass Flats	0	0	0	0	3	19.64	9	271.57	0	0
Rock Valley	0	0	0	0	1	6.51	9	162.64	2	122.06
Striped Hills-Specter Range	0	0	0	0	2	33.13	3	52.03	7	206.05
Skull Mountain	1	6.51	0	0	2	23.60	2	33.13	7	227.97

[a]Data from Sinnock and Fernandez (1982).
[b]Subsets of objectives listed in Figure 2-14.

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2.2.5 SELECTION OF THE HOST ROCK FOR FURTHER STUDY

Complementing the screening for locations described in Section 2.2.4, a separate screening activity was conducted in 1982 and early 1983 to look in greater detail at the relative merits of alternative rock types at various depths beneath Yucca Mountain. By the end of 1981, four rock units had been identified, in part based on the location screening, as primary candidates for a repository. Two units are in the unsaturated zone: the welded Topopah Spring Member of the Paintbrush Tuff and the nonwelded tuffaceous beds of Calico Hills. The two other units, the welded Bullfrog and Tram members of the Crater Flat Tuff, are located below the water table (Figure 2-15). The objective of the formal evaluation of these four units was to rank them using existing data and analytical methods, supplemented by engineering and scientific judgment. A letter from the U.S. Geological Survey (Robertson et al., 1982) pointed out the "... considerable advantages that might be offered by the unsaturated zone ... One strategy of locating a repository in the unsaturated zone beneath Yucca Mountain would be to place it in units of fractured welded tuff with high fracture conductivity, so that any recharge water that does reach the repository level will move rapidly through it down to the next horizon of low permeability." In July 1982, planning for an exploratory shaft required that a target horizon be chosen. On the basis of the information available at that time, the Topopah Spring Member was designated as the reference unit. The final evaluation of the four rock units (Johnstone et al., 1984), completed seven months later, generally supported this preliminary decision.

Several physical properties of the various rock units were used to compare excavation stability, minability, thermal-loading limits, far-field thermomechanical behavior, and ground-water travel time (Johnstone et al., 1984). The rankings are summarized in Table 2-7. Minability considered specifically the expected ease and cost of the mining process. The Calico Hills unit was a clear choice with respect to this factor because continuous mining machines could be used rather than the more time-consuming and expensive drilling and blasting techniques required for the welded units. Even so, the main result from the minability comparison was that no units were eliminated; all units can be mined successfully with conventional techniques.

Gross thermal loading did not allow significant discrimination among the four units. Loading densities required to keep the floor temperature of emplacement drifts within design limits varied only from 54 to 57 kilowatts per acre. Considering the variability of thermal properties within each rock unit, the four units are nearly identical with respect to emplacement of heat generating wastes. Far-field thermal effects also did not discriminate significantly among the units. All units were predicted to be affected in the far field in virtually the same way. None of the thermal calculations for any of the units suggested any failure mode due to the temperature changes that could affect repository performance. Although the differences among them were very slight, the rock units were still ranked on these two thermal factors (Table 2-7).

The stability of mined tunnels in each unit was evaluated by three different approaches. Near-field computer calculations indicated clear superiority of the three welded units. A subranking among these three units showed that the Topopah Spring Member would be expected to be the most

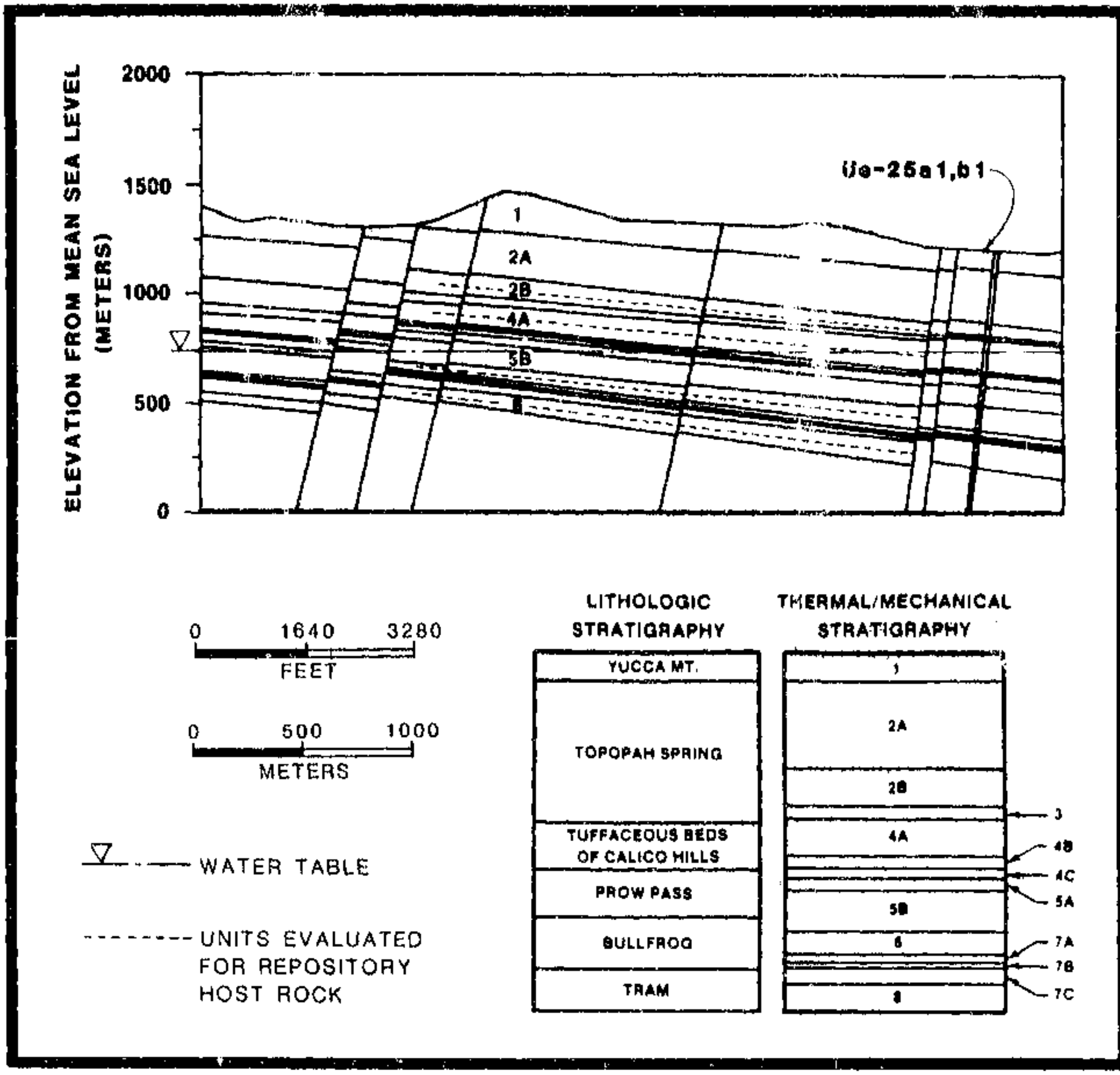

Figure 2-15. East-west cross section (approximate) through repository area at Yucca Mountain showing correlation between lithologic and thermal-mechanical stratigraphy developed for the unit evaluation study. For detail on the thermal-mechanical stratigraphy, see Johnstone et al. (1984). Modified from Johnstone et al. (1984).

Table 2-7. Ranking of four rock units identified as primary candidates for a potential repository host rock[a]

Comparison factors	Relative rank[b]			
	Topopah Spring	Calico Hill	Bullfrog	Tram
Excavation stability				
Calculated near-field thermomechanical response	1	4	2	3
Rock-matrix properties	1	4	4	4
Norges Geotekniske Institute classification[c]	1	4	4	4
Council for Scientific and Industrial Research classification[d]	1	1	2	2
Minability	2	1	3	4
Gross thermal-loading limit	1	1	1	1
Far-field thermomechanical response	1	1	1	1
Ground-water travel time to the water table	1	2	4	3

[a]Data from Johnstone et al. (1984).
[b]Lowest number (1) is highest rank; highest number (4) is lowest rank.
[c]Described by Barton (1976).
[d]Described by Bieniawski (1976).

stable. An evaluation of rock matrix properties provided a more traditional approach to comparing the expected stability among the four units. This method also showed that the Topopah Spring Member was clearly expected to be more stable than the other three units. Two published techniques for classifying the suitability of rock masses for mining, the Norges Geotekniske Institute (NGI) method and the Council for Scientific and Industrial Research (CSIR) method (Barton, 1976; Bieniawski, 1976), were also used to evaluate mine stability. The NGI system showed the Topopah Spring Member to be clearly superior to the other three units. Distinctions based on the CSIR system were less dramatic, but this method also ranked the Topopah Spring unit first. However, none of the units was classified as unsuitable or unusually dangerous with respect to mine stability.

Vertical ground-water travel times from the two unsaturated and two saturated candidate repository horizons to the water table were estimated to be thousands of years. Ground-water travel-time estimates for each rock unit were based on the assumption of porous flow and did not include the effects of heat. Considerable uncertainty existed in the estimates for all the rock units. For rock units in the saturated zone, extreme variability in the assumed hydraulic parameters yielded travel-time estimates that varied by as much as six orders of magnitude. For the two unsaturated units, the Topopah Spring Member ranked highest for travel time because it is farther from the water table than the Calico Hills unit (Figure 2-15).

On the basis of the unit-evaluation study (Johnstone et al., 1984), the first choice for the target repository horizon was the Topopah Spring Member of the Paintbrush Tuff. The second choice was the tuffaceous beds of Calico Hills. The third and fourth choices were the Bullfrog and the Tram members of the Crater Flat Tuff, respectively. If Yucca Mountain is recommended for site characterization, the exact depth and position of a repository in the Topopah Spring Member will be determined during site characterization on the basis of the rock properties that affect performance and mine design. Nothing in the unit-evaluation study suggested that any of the rock units considered would be unsuitable for a repository.

2.3 EVALUATION OF THE YUCCA MOUNTAIN SITE AGAINST THE DISQUALIFYING CONDITIONS OF 10 CFR PART 960

From the nine sites identified as potentially acceptable for the first repository (see Chapter 1), the U.S. Department of Energy (DOE) is required by the Nuclear Waste Policy Act of 1982 (NWPA, 1983) and the DOE general siting guidelines (10 CFR Part 960, 1984) to nominate at least five as suitable for site characterization. The first step in the nomination process, as required by 10 CFR 960.3-2-2-1, is to evaluate each potentially acceptable site against the disqualifying conditions specified in the technical guidelines in accordance with Appendix III of the guidelines.

Altogether, 17 disqualifying conditions are specified in the technical guidelines. They are derived from Section 112 of the Nuclear Waste Policy Act, which requires the guidelines to specify "... factors that qualify or disqualify any site from development as a repository ..." (NWPA, 1983). In particular, the Act specifies factors pertaining to the location of valuable natural resources, hydrology, geophysics, seismic activity, atomic energy defense activities, proximity to water supplies, proximity to populations, the effect upon the rights of users of water, and proximity to components of the National Park System, the National Wildlife Refuge System, the National Wild and Scenic Rivers System, the National Wilderness Preservation System, or National Forest Lands. Each disqualifying condition describes a condition that is considered so adverse as to constitute sufficient evidence, without further consideration, that a site is disqualified. Thus, the presence of a single disqualifying condition is enough to eliminate a site from further consideration. Almost all the 17 disqualifying conditions pertain to conditions whose presence or absence may be estimated without extensive data gathering or complex analysis. The evaluation of the Yucca Mountain site against these disqualifiers is reported in this section by the summary in Table 2-8. A more detailed discussion is presented in Chapter 6.

Because no disqualifying conditions are judged to exist at Yucca Mountain on the basis of the information collected and analyzed to date, the DOE has carried out the remaining steps required by the Nuclear Waste Policy Act Section (112)(b)(1)(E) (NWPA, 1983) and 10 CFR 960.3-2-2-4 (1984) for the nomination of sites as suitable for characterization. These steps and the sections of this document in which they are discussed are listed below.

1. An evaluation of the site as to whether it is suitable for the development of a repository under the guidelines that do not require site characterization for their application (Section 6.2).

2. An evaluation of the site as to whether it is suitable for site characterization under the guidelines that require data from site characterization (Section 6.3).

3. An evaluation of the effects of site characterization activities on public health and safety and on the environment, including alternative site characterization activities that might be taken to avoid such effects (Chapter 4).

4. An evaluation of the regional and local effects of locating a repository at Yucca Mountain (Chapter 5).

5. A comparative evaluation of Yucca Mountain and all other sites considered for nomination for site characterization (Chapter 7).

Summaries of the findings for each of the disqualifying conditions are presented in the remainder of this section. Details of the evaluation of Yucca Mountain against the disqualifying conditions are presented in the cited sections of Chapter 6.

Geohydrology (10 CFR 960.4-2-1(d); Section 6.3.1.1)

Disqualifying condition: A site shall be disqualified if the pre-waste-emplacement ground-water travel time from the disturbed zone to the accessible environment is expected to be less than 1,000 years along any pathway of likely and significant radionuclide travel.

Analysis of existing field and laboratory data indicates that the expected pre-waste-emplacement ground-water travel time along all paths of likely and significant radionuclide travel to the accessible environment would exceed 1,000 years. The flow paths of interest at Yucca Mountain include segments in both the unsaturated and saturated zone. The average travel time from the disturbed zone to the accessible environment is about 43,000 years. The range of travel times is from about 9,000 to 80,000 years.

Flux through the potential host rock is determined by the volume and rate of infiltration and the hydraulic properties of rocks in the unsaturated zone. Upon reaching the water table beneath Yucca Mountain, this water joins other ground water in transit from sources of recharge north and northwest of

Table 2-8. Summary of evaluations of the Yucca Mountain site against the disqualifying conditions

Disqualifying condition and Chapter 6 reference	Synopsis
10 CFR 960.4-2-1(d): GEOHYDROLOGY (6.3.1.1)	
A site shall be disqualified if the pre-waste-emplacement ground-water travel time from the disturbed zone to the accessible environment is expected to be less than 1,000 years along any pathway of likely and significant radionuclide travel.	Not disqualified: On the basis of current estimates of flux, the average travel time to the accessible environment is more than 43,000 years.
10 CFR 960.4-2-5(d): EROSION (6.3.1.5)	
The site shall be disqualified if site conditions do not allow all portions of the underground facility to be situated at least 200 meters below the directly overlying ground surface.	Not disqualified: The shallowest parts of the underground facility are more than 200 meters below the directly overlying ground surface.
10 CFR 960.4-2-6(d): DISSOLUTION (6.3.1.6)	
The site shall be disqualified if it is likely that, during the first 10,000 years after closure, active dissolution, as predicted on the basis of the geologic record, would result in a loss of waste isolation.	Not disqualified: The potential host rock is welded tuff, which is not considered to be soluble.
10 CFR 960.4-2-7(d): TECTONICS (6.3.1.7)	
A site shall be disqualified if, based on the geologic record during the Quaternary Period, the nature and rates of fault movement or other ground motion are expected to be such that a loss of waste isolation is likely to occur.	Not disqualified: Nature and rates of fault movement or other ground motion are not likely to cause loss of waste isolation; low water flux and long ground-water travel times provide additional assurance of waste isolation.

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Table 2-8. Summary of evaluations of the Yucca Mountain site against the disqualifying conditions (continued)

Disqualifying condition and Chapter 6 reference	Synopsis
10 CFR 960.4-2-8-1(d): NATURAL RESOURCES (6.3.1.8)	
A site shall be disqualified if--	
(1) Previous exploration, mining, or extraction activities for resources of commercial importance at the site have created significant pathways between the projected underground facility and the accessible environment; or	Not disqualified: There are no pathways between the underground facility and the accessible environment that were created by previous at-depth exploration, mining, or extraction activities at Yucca Mountain.
(2) Ongoing or likely future activities to recover presently valuable natural mineral resources outside the controlled area would be expected to lead to an inadvertent loss of waste isolation.	Not disqualified: Activities to recover natural mineral resources outside the controlled area would not decrease the waste isolation capability of Yucca Mountain.
10 CFR 960.5-2-1(d): POPULATION DENSITY AND DISTRIBUTION (6.2.1.2)	
A site shall be disqualified if--	
(1) Any surface facility of a repository would be located in a highly populated area; or	Not disqualified: No surface facility at Yucca Mountain would be located in a highly populated area.
(2) Any surface facility of a repository would be located adjacent to an area 1 mile by 1 mile having a population of not less than 1,000 individuals as enumerated by the most recent U.S. census; or	Not disqualified. No surface facility would be adjacent to an area 1 mile by 1 mile with more than 1,000 people.

Table 2-8. Summary of evaluations of the Yucca Mountain site against the disqualifying conditions (continued)

Disqualifying condition and Chapter 6 reference	Synopsis
(3) The DOE could not develop an emergency preparedness program which meets the requirements specified in DOE Order 5500.3 (Reactor and Non-Reactor Facility Emergency Planning, Preparedness, and Response Program for Department of Energy Operations) and related guides or, when issued by the NRC, in 10 CFR 60, Subpart I, "Emergency Planning Criteria."	Not disqualified: An emergency preparedness plan can be developed based on an existing plan for the NTS and the existing State plan and DOE/NV notification procedures.
10 CFR 960.5-2-4(d): OFFSITE INSTALLATIONS AND OPERATIONS (6.2.1.5)	
A site shall be disqualified if atomic energy defense activities in proximity to the site are expected to conflict irreconcilably with repository siting, construction, operation, closure, or decommissioning.	Not disqualified: The engineering design and the coordination of repository schedules with NTS schedules would prevent irreconcilable conflicts caused by atomic energy defense activities in proximity to the site.
10 CFR 960.5-2-5(d): ENVIRONMENTAL QUALITY (6.2.1.6)	
Any of the following conditions shall disqualify a site:	
(1) During repository siting, construction, operation, closure, or decommissioning the quality of the environment in the affected area could not be adequately protected or projected environmental impacts in the affected area could not be mitigated to an acceptable degree, taking into account programmatic, technical, social, economic, and environmental factors.	Not disqualified: No unacceptable adverse environmental impacts have been identified in the affected area or are expected.

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Table 2-8. Summary of evaluations of the Yucca Mountain site against the disqualifying conditions (continued)

Disqualifying condition and Chapter 6 reference	Synopsis
(2) Any part of the restricted area or repository support facilities would be located within the boundaries of a component of the National Park System, the National Wildlife Refuge System, the National Wilderness Preservation System, or the National Wild and Scenic Rivers System.	Not disqualified: No part of the restricted area or repository support facilities would be located within the boundary of any of the specified systems.
(3) The presence of the restricted area or the repository support facilities would conflict irreconcilably with the previously designated resource-preservation use of a component of the National Park System, the National Wildlife Refuge System, the National Wilderness Preservation System, the National Wild and Scenic Rivers System, or National Forest Lands, or any comparably significant State protected resource that was dedicated to resource preservation at the time of the enactment of the Act.	Not disqualified: The presence of the restricted area or repository support facilities will not conflict irreconcilably with the previously designated resource-preservation use of the land.
10 CFR 960.5-2-6(d): SOCIOECONOMICS (6.2.1.7)	
A site shall be disqualified if repository construction, operation, or closure would significantly degrade the quality, or significantly reduce the quantity, of water from major sources of offsite supplies presently suitable for human consumption or crop irrigation and such impacts cannot be compensated for, or mitigated by, reasonable measures.	Not disqualified: Repository water use is not expected to lower the regional ground-water table or reduce water quality.

Table 2-8. Summary of evaluations of the Yucca Mountain site against the disqualifying conditions (continued)

Disqualifying condition and Chapter 6 reference	Synopsis
10 CFR 960.5-2-9(d): ROCK CHARACTERISTICS (6.3.3.2)	
The site shall be disqualified if the rock characteristics are such that the activities associated with repository construction, operation, or closure are predicted to cause significant risk to the health and safety of personnel, taking into account mitigating measures that use reasonably available technology.	Not disqualified: No rock characteristics that could lead to significant health or safety risks have been identified.
10 CFR 960.5-2-10(d): HYDROLOGY (6.3.3.3)	
A site shall be disqualified if, based on expected ground-water conditions, it is likely that engineering measures that are beyond reasonably available technology will be required for exploratory-shaft construction or for repository construction, operation, or closure.	Not disqualified: Significant amounts of ground water are not expected; reasonably available technology is expected to be more than adequate to prevent disruptions due to ground-water conditions.
10 CFR 960.5-2-11(d): TECTONICS (6.3.3.4)	
A site shall be disqualified if, based on the expected nature and rates of fault movement or other ground motion, it is likely that engineering measures that are beyond reasonably available technology will be required for exploratory-shaft construction or for repository construction, operation, or closure.	Not disqualified: Reasonably available seismic design technology is expected to be sufficient to construct an exploratory shaft, and to safely construct, operate, and close a repository; the expected nature and rates of fault movement or other ground motion are not expected to adversely affect the construction of the exploratory shaft or repository construction, operation, and closure.

Yucca Mountain and moves generally horizontally to the accessible environment. Uncertainties in the estimate of travel time at Yucca Mountain include the lack of definition of the extent, and therefore the outer boundary, of the repository disturbed zone, flux estimates, and the potential for lateral flow.

Erosion (10 CFR 960.4-2-5(d); Section 6.3.1.5)

Disqualifying condition: The site shall be disqualified if site conditions do not allow all portions of the underground facility to be situated at least 200 meters below the directly overlying ground surface.

The lower portion of the densely welded tuff of the Topopah Spring Member of the Paintbrush Formation is the potential repository host rock at Yucca Mountain. It has sufficient thickness and depth that all portions of the underground facility would be located more than 200 meters (656 feet) below the directly overlying ground surface. The present repository layout will allow approximately 50 percent of the waste to be emplaced at depths more than 300 meters (1,000 feet).

Dissolution (10 CFR 960.4-2-6(d); Section 6.3.1.6)

Disqualifying condition: The site shall be disqualified if it is likely that, during the first 10,000 years after closure, active dissolution, as predicted on the basis of the geologic record, would result in a loss of waste isolation.

The minerals that compose the rock in and around the Yucca Mountain site are considered insoluble and no dissolution is expected to occur even at the elevated temperatures expected near the waste disposal containers. The host rock for the potential repository horizon at Yucca Mountain consists of the moderately to densely welded, devitrified tuff of the unsaturated Topopah Spring Member. About 98 percent of the host rock consists of alkali feldspars, quartz, and cristobalite, which are minerals that are not prone to aqueous dissolution.

Tectonics (10 CFR 960.4-2-7(d); Section 6.3.1.7)

Disqualifying condition: A site shall be disqualified if, based on the geologic record during the Quaternary Period, the nature and rates of fault movement or other ground motion are expected to be such that a loss of waste isolation is likely to occur.

The nature and rates of expected fault movement are not sufficient to threaten the waste isolation capability of Yucca Mountain. Historical earthquake records show that seven earthquakes were recorded before 1978 within about 10 kilometers (6.2 miles) of the potential repository site; of these, two had Richter magnitudes of 3.6 and 3.4; the remaining five probably had smaller magnitudes, although magnitudes are not available. A new seismic network has recorded three microearthquakes in the same area between August 1978 and the end of 1983; the largest magnitudes were approximately 2.

Geologic evidence available to date indicates that 32 faults within a 1,100 square-kilometer (425 square-mile) area around the site offset or fracture Quaternary deposits.

Earthquake damage to underground facilities is generally less than surface damage. Even if a waste disposal container were damaged, water is required to dissolve radionuclides from the waste form and to transport these radionuclides from the repository to the accessible environment. The expected flux of less than 0.5 millimeter (0.02 inch) per year through the repository has been shown (Section 6.4.2) to be insufficient to transport wastes in quantities that could exceed release limits at the accessible environment, even if some waste material were released from the repository immediately after closure. Travel times of greater than 10,000 years provide additional confidence that radionuclides will not be released to the accessible environment in excess of the limits specified in 40 CFR Part 191 (1985).

Human Interference: Natural Resources (10 CFR 960.4-2-8-1(d); Section 6.3.1.8)

Disqualifying condition: A site shall be disqualified if--

(1) Previous exploration, mining, or extraction activities for resources of commercial importance at the site have created significant pathways between the projected underground facility and the accessible environment; or

(2) Ongoing or likely future activities to recover presently valuable natural mineral resources outside the controlled area would be expected to lead to an inadvertent loss of waste isolation.

Thorough examination of the Yucca Mountain site and comprehensive searches of literature and mining claim files have disclosed no evidence of previous exploration, mining, or extraction activities for resources of commercial importance. The site is within an area of federally controlled lands, most of which were restricted in the early 1950s to prevent public access, and thereby excluded from exploration and development. The U.S. Geological Survey has also mapped the entire area by physical inspection of the ground surface, and it is extremely unlikely that unknown excavations exist at the site. Consequently, no significant pathways have been created between the projected underground facility and the accessible environment.

There are no ongoing or anticipated future activities to recover presently valuable natural mineral resources outside the controlled area that could be expected to lead to an inadvertent loss of waste isolation.

Population Density and Distribution (10 CFR 960.5-2-1(d); Section 6.2.1.2)

Disqualifying conditions: A site shall be disqualified if--

(1) Any surface facility of a repository would be located in a highly populated area; or

(2) Any surface facility of a repository would be located adjacent to an area 1 mile by 1 mile having a population of not less than 1,000 individuals as enumerated by the most recent U.S. census; or

(3) The DOE could not develop an emergency preparedness program which meets the requirements specified in DOE Order 5500.3 (Reactor and Non-Reactor Facility Emergency Planning, Preparedness, and Response Program for Department of Energy Operations) and related guides or, when issued by the NRC, in 10 CFR 60, Subpart I, "Emergency Planning Criteria."

The highly populated area nearest to Yucca Mountain with 1,000 or more persons per square mile is Las Vegas, which is about 137 kilometers (85 miles) away by air. Consequently, surface facilities at Yucca Mountain would not be located within a highly populated area.

The State of Nevada has an existing emergency preparedness plan covering radiological emergencies. This plan identifies the agencies and individuals to be notified in the event of a radiological emergency, provides guidance for participants, and establishes procedures for requesting and providing assistance. Such a plan, meeting the requirements of DOE Order 5500.3 (DOE, 1981b), can be developed for the operation of a repository at Yucca Mountain.

Offsite Installations and Operations (10 CFR 960.5-2-4(d); Section 6.2.1.5)

Disqualifying condition: A site shall be disqualified if atomic energy defense activities in proximity to the site are expected to conflict irreconcilably with repository siting, construction, operation, closure, or decommissioning.

The Yucca Mountain site is over 40 kilometers (25 miles) from the nearest area presently used for underground nuclear detonations, and no area under consideration for future testing is closer to Yucca Mountain than approximately 23 kilometers (14 miles). The potential repository site is not within an area where individuals are normally removed during underground testing activities elsewhere on the Nevada Test Site. However, depending on the size and nature of a particular test, workers may be removed from underground areas within about 80 kilometers (50 miles) of underground tests as a matter of policy and as a precautionary measure. This practice could have a minor effect on the siting, construction, operation, and decommissioning phases of the repository. Temporary suspension of certain activities at the repository site can be planned as a standard operating procedure. These occurrences would be infrequent and of short duration, and would not have significant adverse impacts on any phase of siting or repository activities. Current radiation containment and safety measures for underground nuclear tests at the Nevada Test Site are very stringent, and the possibility of substantial releases of radioactivity to the atmosphere in the future is considered very small. All potential impacts from atomic energy defense activities occurring elsewhere on the Nevada Test Site can be addressed through facility design and construction, and through coordination of scheduling of repository operations and nuclear weapons testing activities.

Environmental Quality (10 CFR 960.5-2-5(d); Section 6.2.[illegible].6)

Disqualifying conditions: Any of the following conditions shall disqualify a site:

(1) During repository siting, construction, operation, closure, or decommissioning the quality of the environment in the affected area could not be adequately protected or projected environmental impacts in the affected area could not be mitigated to an acceptable degree, taking into account programmatic, technical, social, economic, and environmental factors.

(2) Any part of the restricted area or repository support facilities would be located within the boundaries of a component of the National Park System, the National Wildlife Refuge System, the National Wilderness Preservation System, or the National Wild and Scenic Rivers System.

(3) The presence of the restricted area or the repository support facilities would conflict irreconcilably with the previously designated resource-preservation use of a component of the National Park System, the National Wildlife Refuge System, the National Wilderness Preservation System, the National Wild and Scenic Rivers System, or National Forest Lands, or any comparably significant State protected resource that was dedicated to resource preservation at the time of the enactment of the Act.

Recognized environmental impacts associated with the siting, construction, operation, closure, and decommissioning of a repository at Yucca Mountain include (1) disruption of approximately 680 hectares (1,680 acres) of desert habitat, (2) fugitive dust emissions, (3) vehicle emissions, (4) natural radioactivity releases from the excavation of volcanic rock for the repository, and (5) radioactivity releases during the operation of the repository, under both normal and accident conditions. The repository would be designed and operated in compliance with all applicable State and Federal health, safety, and environmental protection regulations.

If a repository is located at Yucca Mountain, the evidence indicates that its siting, construction, operation, closure, and decommissioning would not result in any unacceptable adverse environmental impacts that would threaten the quality of the environment. Neither the restricted area, nor the supporting facilities for a repository at Yucca Mountain, would be located within the boundaries of or irreconcilably conflict with the previously designated use of the National Park System, the National Wildlife Refuge System, the National Wilderness Preservation System, the National Wild and Scenic Rivers System, or National Forest Lands or any comparably significant State protected resource dedicated to resource preservation.

Disqualifying condition: A site shall be disqualified if repository construction, operation, or closure would significantly degrade the quality, or significantly reduce the quantity, of water from major sources of offsite supplies presently suitable for human consumption or crop irrigation and such impacts cannot be compensated for, or mitigated by, reasonable measures.

Repository construction, operation, and closure could increase water consumption by onsite use at the repository facility and would increase offsite use due to the population increase associated with the repository. Because the climate is arid and the water table is deep (more than 500 meters or 1,640 feet below the land surface), it is extremely unlikely that repository activities could degrade the quality of ground water in the Yucca Mountain region. Ground water would be the source of water for the repository. Should the Federal Government develop a repository at Yucca Mountain, a permanent land withdrawal will be necessary, in accordance with the Federal Land Policy and Management Act of 1976, and reservation of water rights would be explicit in the withdrawal.

Estimates of water requirements for the construction, operation, closure, and decommissioning of the repository have been based on preliminary concepts of a two-stage repository. For the first 32 years of repository activities an average of 432,000 cubic meters (350 acre-feet) per year of water will be used. Water use is expected to decrease substantially after this initial period (Morales, 1985). The regional effects of withdrawing this volume of ground water are expected to be negligible. The water level in Well J-13 has remained essentially constant after long periods of constant pumping between 1962 and 1980, which suggests that the aquifers beneath Yucca Mountain can produce large quantities of ground water, and this ground water can be withdrawn for long periods of time without lowering the regional ground-water table.

According to current information, the incremental increase in water supply requirements due to project-related population growth in the region may shorten slightly the time remaining during which present sources are adequate. The maximum 1-year average project-related population increase is not likely to significantly aggravate the water supply situation for any county or community in the bicounty area. Proper planning is needed to ensure that the expansion of facilities occurs in a timely manner. The Nuclear Waste Policy Act of 1982 provides for financial assistance, which will enable local communities to prepare for increased growth (NWPA, 1983).

Rock Characteristics (10 CFR 960.5-2-9(d); Section 6.3.3.2)

Disqualifying condition: The site shall be disqualified if the rock characteristics are such that the activities associated with repository construction, operation, or closure are predicted to cause significant risk to the health and safety of personnel, taking into account mitigating measures that use reasonably available technology.

The laboratory and field data collected and analyzed to date for Yucca Mountain and observations and experience in similar excavations at similar depths indicate that activities associated with repository construction, operation, and closure will not cause significant risk to the health and safety of personnel. Tunnels in similar rock types at the Nevada Test Site are generally supported with only rock bolts and wire mesh. Even when exposed to the ground motion induced by nearby underground nuclear explosions, this support provides stable, safe openings. The stability of openings in the potential host rock has been evaluated using thermomechanical stress analyses, rock-mass classifications, and linear calculations for mine design and pillar sizing. These evaluations show that existing mining technology is sufficient to construct and maintain underground openings in the Topopah Spring Member that will allow repository operations to be carried out safely from construction through closure.

Hydrology (10 CFR 960.5-2-10(d); Section 6.3.3.3)

Disqualifying condition: A site shall be disqualified if, based on expected ground-water conditions, it is likely that engineering measures that are beyond reasonably available technology will be required for exploratory-shaft construction or for repository construction, operation, or closure.

A repository at Yucca Mountain would be located 200 to 400 meters (650 to 1,300 feet) above the water table. No significant quantities of perched water are expected during exploratory shaft or repository construction. Current engineering and technology are more than adequate to handle the hydrologic conditions that are likely to be encountered during exploratory shaft construction or during repository construction, operation, and closure. The sealing of shafts and boreholes is also not expected to require special technology or to pose any significant problems.

Tectonics (10 CFR 960.5-2-11(d); Section 6.3.3.4)

Disqualifying condition: A site shall be disqualified if, based on the expected nature and rates of fault movement or other ground motion, it is likely that engineering measures that are beyond reasonably available technology will be required for exploratory-shaft construction or for repository construction, operation, or closure.

Previously published earthquake recurrence intervals for the region are available. Recurrence intervals for the Nevada Test Site region are reported to be on the order of 25,000 years for $M \geq 7$, 2,500 years for $M \geq 6$, and 250 years for $M \geq 5$. Seismic monitoring of Yucca Mountain from 1978 to 1983 has recorded three small (Richter magnitude less than 2.0) micro-earthquakes within 10 kilometers (6.2 miles) of the site boundary. In addition, historical records show that before 1978, seven earthquakes were recorded in the same approxi-mate area; two had magnitudes of 3.6 and 3.4, and the remaining five probably had smaller magnitudes, although magnitudes are not available.

Because of the sparse historical data, predictions of seismic risk during exploratory shaft construction or during repository construction, operation, and closure at Yucca Mountain are based on empirical relationships between earthquake magnitude and fault rupture length, and between probable earthquake magnitude and expected ground motion at sites away from the earthquake. The exact ground motion at the site would depend on the nature of faulting, the distance of the epicenter from the site, and the extent of attenuation of the seismic energy before it reached the surface facilities site. Evidence indicates that available earthquake-resistant designs and technology should be sufficient to allow safe construction, operation, and closure of a repository at Yucca Mountain.

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Chapter 3

THE SITE

This chapter describes the existing environment of Yucca Mountain and the surrounding region. The data provide a baseline for assessing potential impacts of proposed site characterization activities (Chapter 4) and possible future development as a repository (Chapter 5). Additionally, some data in this chapter are used for evaluating the suitability of the Yucca Mountain site for site characterization (Chapter 6). Yucca Mountain has been identified by the U.S. Department of Energy (DOE) as a potentially acceptable site for a mined geologic repository (Hodel, 1983). The Yucca Mountain site is shown on Figure 3-1 and in other figures in Chapter 3. The site is on limited-access Federal land administered by the Department of the Air Force, the Bureau of Land Management, and the DOE.

In describing the Yucca Mountain environment, this chapter summarizes information from a wide variety of sources. Information describing the Nevada Test Site (NTS) has been accumulating for decades. The area immediately around Yucca Mountain, however, received comparatively little study until about eight years ago when the southwestern part of the NTS began to receive consideration as a possible repository site (Section 2.2.3). Since then, site-specific studies have been carried out, and this chapter draws from them--particularly from recent studies on geologic, hydrologic, biological, and archaeological topics. The description of the region draws heavily from studies of the NTS and of the southern Nevada region. Data for the transportation and socioeconomics sections of this chapter are generally available from regional sources, but much of the information in those sections has been compiled specifically for the Nevada Nuclear Waste Storage Investigations Project.

3.1 LOCATION, GENERAL APPEARANCE AND TERRAIN, AND PRESENT USE

The Yucca Mountain site, shown on Figure 3-1, is located on and immediately adjacent to the southwestern portion of the Nevada Test Site, which is in Nye County, Nevada, about 105 kilometers (65 miles) northwest of Las Vegas. The Yucca Mountain site is about 137 kilometers (85 miles) by air and 161 kilometers (100 miles) by road from Las Vegas.

The Yucca Mountain site lies within the Basin and Range physiographic province, a broad region of generally linear mountain ranges and intervening valleys. The site is in the southern part of the Great Basin, a subdivision of the Basin and Range Province. Figure 3-2 shows the physiographic features in the region. The elevation of northern Yucca Mountain is approximately 1,500 meters (5,000 feet), which is more than 370 meters (1,200 feet) above the western edge of Jackass Flats to the east and more than 300 meters (1,000 feet) higher than the eastern edge of Crater Flat.

Yucca Mountain is a prominent group of north-trending, fault-block ridges that extend southward from Beatty Wash on the northwest to U.S.

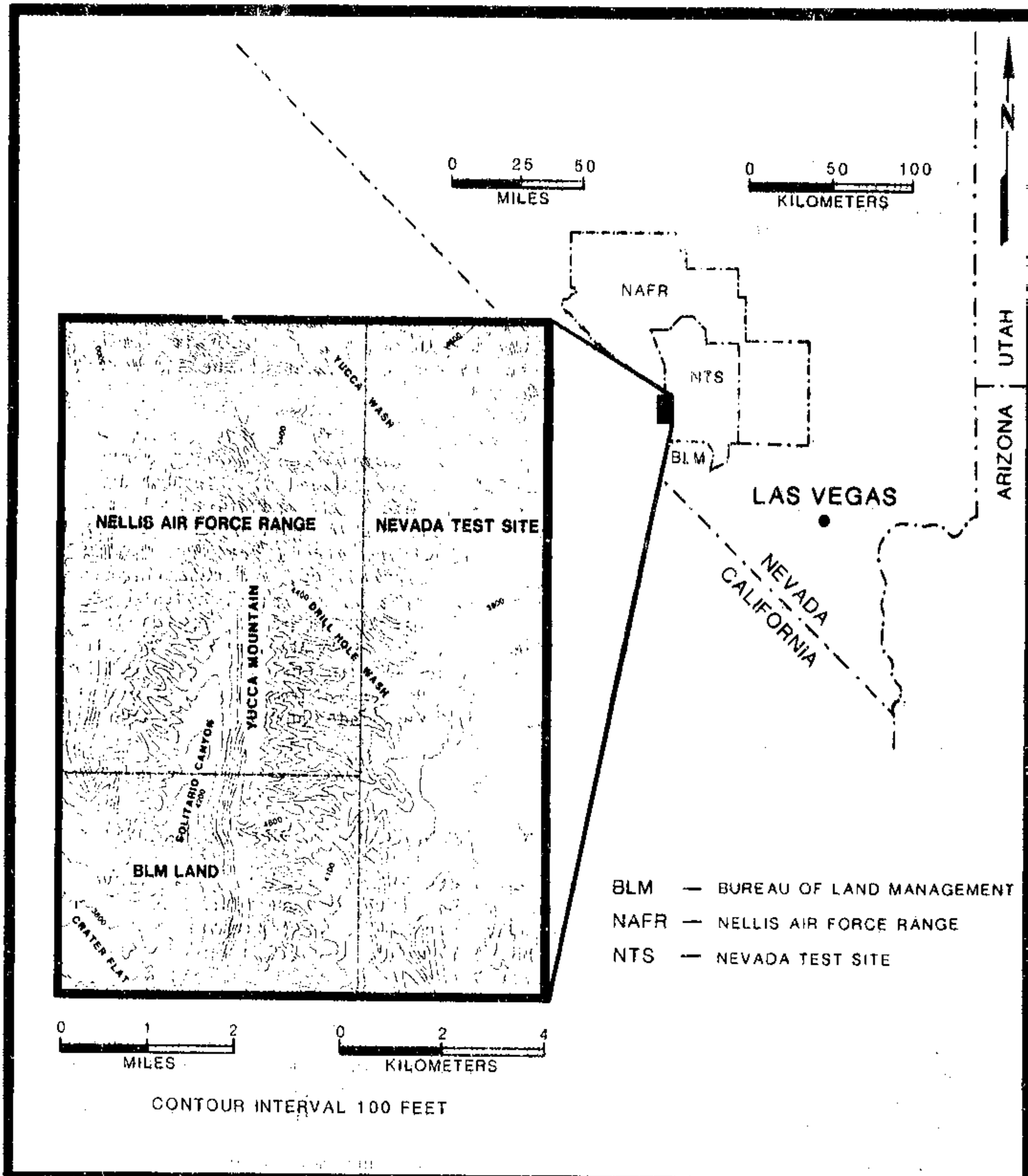

Figure 3-1. Location of Yucca Mountain site in southern Nevada. Proposed repository and surface facilities would be located within the outline shown above. Modified from USGS (1984).

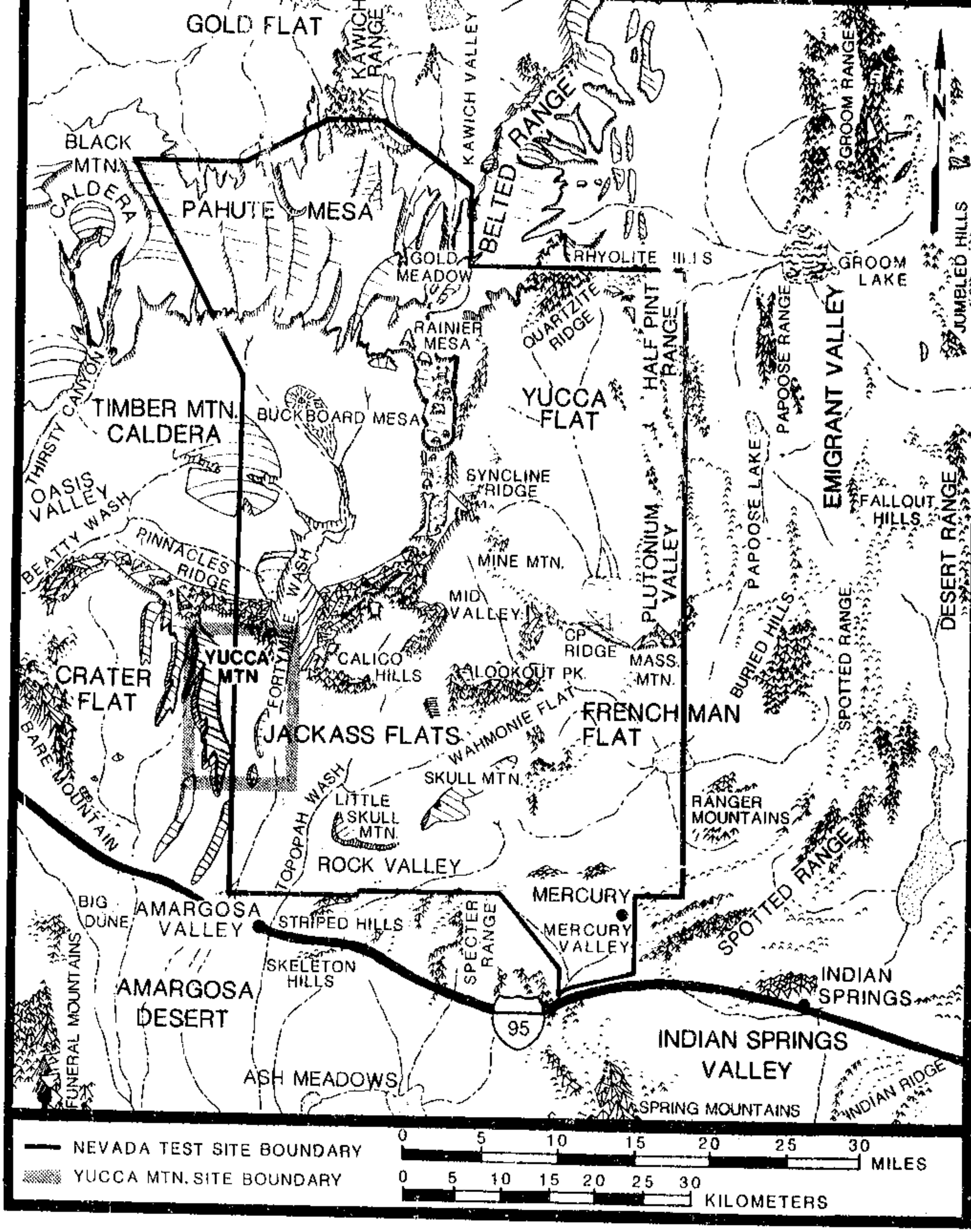

Figure 3-2. Physiographic features of Yucca Mountain and surrounding region. Modified from Sinnock (1982).

Highway 95 in the Amargosa Desert. The terrain at the site is controlled by high-angle normal faults and eastward-tilted volcanic rocks. Slopes are locally steep (15 to 30°) on the west-facing side of Yucca Mountain and along some of the valleys that cut into the more gently sloping (5 to 10°) east side of Yucca Mountain. The valley floors are covered by alluvium. Sandy fans extend down from the lower slopes of the ridges. Fortymile Wash is cut from 13 to 26 meters (40 to 85 feet) into the surface of Jackass Flats. North of Yucca Mountain is the high, rugged volcanic terrain of Pinnacles Ridge. To the west of Yucca Mountain, along the west side of Crater Flat, steep alluvial fans extend from deep valleys that have been cut into Bare Mountain. Basalt cones and small lava flows are present on the surface of the southern half of Crater Flat.

The Yucca Mountain site is located exclusively within lands controlled by the Federal Government. The land parcel under consideration, which includes the underground facilities, the surface facilities, and the controlled area for the repository, is divided as follows: (1) the U.S. Department of Energy (DOE) controls the eastern portion through the withdrawn land of the Nevada Test Site; (2) the Department of the Air Force controls the northwestern portion through the land-use permit for the Nellis Air Force Range (NAFR); and (3) the Bureau of Land Management (BLM) holds the southwestern portion in public trust (Figure 3-1). These lands are currently free and clear of encumbrances, such as rights arising under general mining laws, easements for rights-of-way, and other rights arising under lease, right of entry, deed, patent, mortgage, appropriation, prescription, or other such potential encumbrances (Lutsey and Nichols, 1972).

The preliminary site investigations conducted by the Nevada Nuclear Waste Storage Investigations Project on the BLM portion of the Yucca Mountain site are governed by a BLM/DOE Cooperative Agreement (BLM/DOE, 1983). Preliminary site investigations on the Nellis Air Force Range portion of the Yucca Mountain site were governed by an Air Force Permit (Department of the Air Force, 1983). Because Congress has not yet acted on a Department of the Air Force request for a renewal of the withdrawal for the NAFR, administrative control of the land has reverted to the BLM. Therefore, the BLM/DOE Cooperative Agreement (BLM/DOE, 1982) provides authority for the DOE to conduct preliminary site investigations on the NAFR land. Preliminary site investigations on the portion of Yucca Mountain on the Nevada Test Site (NTS) are covered by the environmental impact statement for the NTS (ERDA, 1977).

There are no competing land-use activities at the Yucca Mountain site. The Department of the Air Force portion of the site is used exclusively for overflight and contains no facilities. The BLM-administered portion of the land has no grazing permits or mineral claims and is not used for recreational purposes (Bell and Larson, 1982). The BLM/DOE cooperative agreements and the Department of the Air Force permit were each accompanied by an environmental assessment of the effects of the activities proposed. Those environmental assessments resulted in findings of no significant impact, and each agreement requires mitigation activities and the restoration of disturbed areas.

3.2 GEOLOGIC CONDITIONS

This section describes the stratigraphy, structure, seismicity, and mineral-resource potential of the Yucca Mountain site and nearby areas. Unless otherwise referenced, the general descriptions of stratigraphy and structure are from Lipman et al. (1966), several articles in Eckel (1968), Byers et al. (1976), Christiansen et al. (1977), Stewart (1980), Sinnock (1982), and Maldonado and Koether (1983). Additional information on the geologic development of southern Nevada is contained in these reports and the many references therein. More detailed descriptions of the structure and seismicity are given in the tectonic section of Chapter 6; detailed stratigraphy and rock properties are discussed in the rock characteristics sections; and geochemistry and mineral and ground-water resource potential are discussed in the geochemistry, human interference, and hydrology sections in Chapter 6.

An understanding of the geology of the Nevada Test Site and surrounding areas has been developed through several decades of surface, subsurface, and geophysical investigations in support of the weapons-testing program. Geologic maps of the Yucca Mountain area were published in the mid-1960s (Christiansen and Lipman, 1965; Lipman and McKay, 1965). As described in Chapter 2, detailed geologic investigations of Yucca Mountain as a potential site for a repository began in 1978 when the first exploratory hole was drilled. Since that time, geologic studies at Yucca Mountain have emphasized stratigraphy, structure, geochemistry, mechanical properties, volcanic history, and seismicity. Many of these studies are still in preliminary stages.

3.2.1 STRATIGRAPHY AND VOLCANIC HISTORY OF THE YUCCA MOUNTAIN AREA

The regional stratigraphic setting of Yucca Mountain is characterized by the four major rock groups discussed in Chapter 2. The first and oldest of these groups, the Precambrian crystalline rocks, are not exposed in the vicinity of Yucca Mountain but may occur at great depths beneath portions of the site. The second group, Upper Precambrian and Paleozoic sedimentary rocks, is present at the surface about 15 kilometers (10 miles) east of Yucca Mountain at Calico Hills, where it is composed of Devonian and Mississippian argillite and carbonates. This group is also observed 30 to 40 kilometers (19 to 25 miles) southeast of Yucca Mountain in the Specter Range and Skeleton Hills, where predominantly Cambrian and Ordovician carbonates and some quartzite are exposed. Carbonates and quartzite of similar age are also present in Bare Mountain about 14 kilometers (9 miles) west of Yucca Mountain. Silurian carbonates have been encountered at a depth of about 1,250 meters (4,100 feet) in drill hole UE-25p#1 (Figure 6-2) about 2.5 kilometers (1.5 miles) east of the Yucca Mountain area.

The third major group, Tertiary volcanic rocks, occurs at Yucca Mountain and comprises at least the upper 2,000 meters (6,500 feet) of the total stratigraphic section. These rocks are composed chiefly of rhyolitic ash-flow tuffs, with smaller amounts of dacitic lava flows and flow breccias and minor amounts of tuffaceous sedimentary rocks and air-fall tuffs.

These rocks form the southern end of the southern Nevada volcanic field, a large plateau segmented by contemporaneous faults and built chiefly of rhyolitic ash flows and related volcanic material. The ash flows that formed this plateau were erupted between about 8 and 16 million years ago from a complex of overlapping, nearly circular volcanic depressions called calderas (Figure 3-3). Collectively, the calderas comprise an area of about 1,800 square kilometers (700 square miles). Outcrops throughout the region indicate that the volcanic rocks extruded from this caldera complex once covered an area of more than 6,500 square kilometers (2,500 square miles).

Quaternary (and uppermost Tertiary) deposits compose the fourth group. This is represented at Yucca Mountain by alluvium and unsorted debris-flow deposits in channels that are cut into the uppermost layers of volcanic rocks and by alluvial-fan deposits that form aprons along the east and west sides of the mountain. Thick alluvium (more than 200 meters or 650 feet) blankets the volcanic rocks beneath Crater Flat to the west and Jackass Flats to the east of Yucca Mountain. Aeolian (windblown) sands, caliche, and soil zones also occur in these thicker Quaternary sections. In Crater Flat, basalt flows and cinder cones of Quaternary age are present at the surface, and flows are also found within the alluvium in the subsurface.

3.2.1.1 Caldera evolution and genesis of ash flows

The voluminous ash-flow sheets that comprise the major thicknesses of volcanic rocks at Yucca Mountain originated from eruptions during the development of calderas. To place the volcanic rock descriptions and terminology in a historical perspective, a brief summary of the evolution of a typical caldera is provided in this section. According to Smith and Bailey (1968), development of a typical caldera is characterized by seven general stages. Some stages overlap, some are repeated several times, and not all take place at every caldera. The Timber Mountain Caldera, the source for the youngest volcanic rocks at Yucca Mountain (Table 3-1), went through all seven stages of evolution (Christiansen et al., 1977). Although volcanic activity at Timber Mountain ceased about 11 million years ago, the caldera is still a well-preserved topographic feature. Its evolution is probably similar to the evolution of the older calderas in the vicinity of Yucca Mountain that produced the older volcanic rocks present beneath the site (Figure 3-3).

The life span of a typical caldera, from stage 1 through stage 7, is generally about 1.5 to 2 million years (Smith and Bailey, 1968). During stage 1, magma is intruded into the crust, causing broad doming of the land surface and crustal extension. Minor eruptions of rhyolitic lavas occur along fissures through the dome and along a major zone of ring fractures, probably tens of kilometers in diameter. Stage 2 is characterized by massive eruptions in rapid succession through the ring fractures, producing massive ash flows that spread over thousands of square kilometers. The volume of material erupted from a single caldera is commonly many hundreds of cubic kilometers. Some of the ash flows produced during stage 2 from calderas in southwestern Nevada are among the most voluminous and widely distributed in the world. Stage 3 generally occurs at the same time as stage 2. As the magma feeds the ash-flow eruptions, the source chamber is drained. The top of the volcano then collapses into the drained magma chamber along the ring

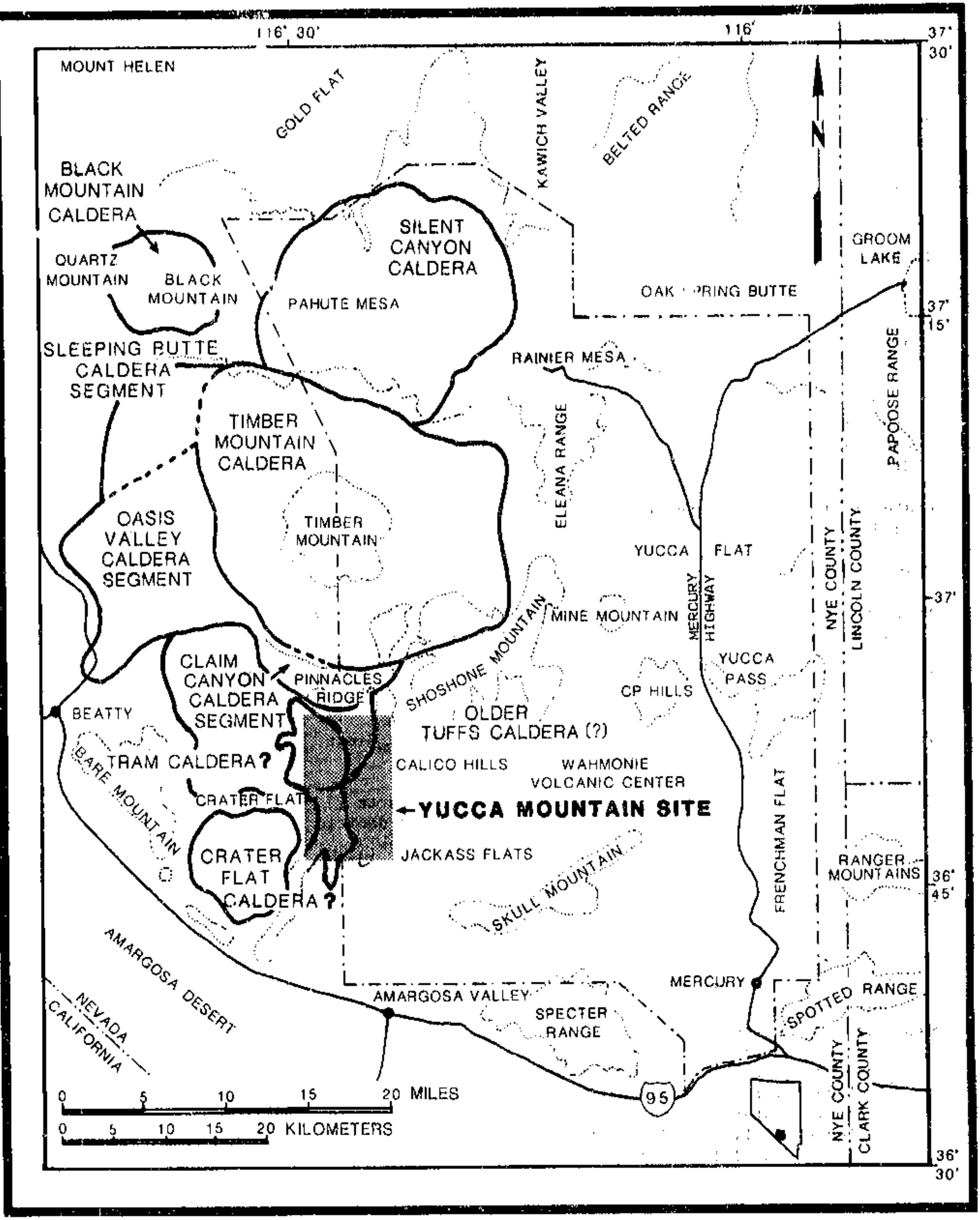

Figure 3-3. Southern end of southern Nevada volcanic field showing possible locations of calderas in the vicinity of Yucca Mountain. Question marks indicate uncertain volcanic centers. Modified from Maldonado and Koether (1983).

Table 3-1. Generalized volcanic stratigraphy for Yucca Mountain showing probable source calderas and ages when calderas were active[a]

Volcanic center	Formation	Unit	Age (millions of years)	Range in thickness[b] (meters)[c]
Timber Mountain Caldera	Timber Mountain Tuff	Rainier Mesa Member	11.3	Not encountered
Claim Canyon and Oasis Valley	Paintbrush Tuff	Tiva Canyon Member	12	0-69
		Yucca Mountain Member	ND[d]	0-36[e]
		Pah Canyon Member	ND	11-83[e]
		Topopah Spring Member	13	287-356
Northwest part of the Calico Hills[f]		Tuffaceous beds of Calico Hills	13.4	95-306[g]
Crater Flat Caldera	Crater Flat Tuff	Prow Pass Member	ND	127-176[g]
		Bullfrog Member	13.5	99-161[e]
Tram Caldera[f]		Tram Member	ND	154-327
Northern Yucca Mountain area		Dacitic lava and flow breccia	ND	0-112[h]
Northeastern Crater Flat[ef]			ND	
Volcanic center uncertain		Tuff of Lithic Ridge	ND	42-311[g]
Northern Yucca Mountain area		Rhyolitic, quartz latitic and dacitic lava and flow breccia	ND	9-323
Northeastern Yucca Mountain		Older ash-flow and bedded tuffs	ND	

[a]Modified from Maldonado and Koether (1983).
[b]Thicknesses on basis of four drill holes at Yucca Mountain, as reported by Maldonado and Koether (1983).
[c]1 meter = 3.28 ft.
[d]ND = no age determination available.
[e]Includes overlying and underlying bedded tuffs.
[f]Volcanic center uncertain.
[g]Includes overlying bedded tuffs.
[h]Includes underlying bedded tuffs.

fractures, forming a circular depression known as a caldera. Vertical displacement along the ring fractures during the collapse of the caldera commonly amounts to many thousands of feet. During stage 4, minor volcanism occurs within the caldera, the unstable outer walls of the caldera undergo rapid erosion, and small lakes commonly form on the caldera floor. Stage 5 is characterized by rhyolitic volcanism and renewed doming within the central part of the caldera. The central dome is generally broken by a complex system of faults as the surface is displaced upward During stage 6, rhyolitic lava flows and small volume ash-flow tuffs erupt along the ring fractures. These late-stage volcanic rocks often are interlayered within and near the caldera with debris flows, gravels, bedded tuffs, and sediments derived from the erupted material. The final stage of caldera evolution (stage 7) is hydrothermal alteration and fumarolic activity. Much of the alteration apparently occurs along fractures.

The ash flows of stage 2 described above generally originate from large-volume gas-charged explosive eruptions. The explosions are caused by the escape of volatiles and the rapid expansion and fragmentation of the ascending rhyolitic lava into clouds of ash-sized particles consisting of hot glass shards and crystals. As the incandescent clouds of gas and superheated ash collapse back to the earth's surface, they flow rapidly down the volcanic slopes and spread across the surrounding terrain. After coming to rest, and depending on the local temperature and overburden pressure, the glass shards and crystals can experience various degrees of compaction and fusion. If the combined effects of heat and pressure are great enough, a rock type known as welded tuff is formed. Commonly the glassy shards develop crystals of feldspar and quartz minerals when hot vapors seep through the semimolten mass during the cooling period. Further crystallization of the glassy shards may also occur through the process of devitrification. If devitrification does not occur, the rocks remain glassy and are referred to as vitric tuffs.

Single ash flows sometimes cool completely before being covered by another hot flow, thereby forming a single cooling unit characterized by densely welded, fractured, central parts surrounded above and below by less-welded parts. Complete cooling of earlier ash flows may not occur if several eruptions are closely spaced, forming volcanic sequences called compound cooling units. A glassy unit, called a vitrophyre, often occurs at the base or top of an ash flow where rapid cooling was caused by contact with the earth or the atmosphere. Lithophysal cavities, formed as gas pockets in the viscous flows, commonly occur in the central parts of thick, densely welded zones. The lithophysae may be circular, elliptical, or flattened depending on the amount of viscous flow and compaction that occurred after they formed. The interior, densely welded parts of the ash flows generally contain closely spaced vertical fractures that developed as the rock cracked during cooling. Fractures with other orientations are developed during sluggish movement of the partially consolidated ash flow or from later tectonic stresses.

Air-fall tuffs commonly occur in association with ash-flow tuffs. They originate from erupted ash that cools in the atmosphere before it settles on the land surface downwind from the source. These lower-volume and lower-temperature ash falls form rock types known as bedded tuffs, which are non-welded, porous, and visibly stratified.

The following sections briefly describe the major Tertiary ash-flow and related stratigraphic units at Yucca Mountain. The general units and calderas are listed in Table 3-1. The rock types and thicknesses described below are based on a report by Maldonado and Koether (1983) and USGS (1984). General descriptions are from the publications listed at the beginning of this section and from a report by Guzowski et al. (1983).

3.2.1.2 Timber Mountain Tuff

The Timber Mountain Tuff is the youngest volcanic unit exposed at Yucca Mountain. It is commonly divided into the Ammonia Tanks Member and the underlying Rainier Mesa Member. Only the Rainier Mesa Member is preserved in the northern part of Yucca Mountain (Lipman and McKay, 1965). The Rainier Mesa Member is an ash-flow unit that was erupted 11.3 million years ago from the Timber Mountain Caldera (Figure 3-3). At Yucca Mountain, it occurs only in low-lying fault blocks (Section 3.2.2), thus indicating the fault blocks had formed by the time the Rainier Mesa Member was erupted. This unit is a moderately welded, devitrified tuff that grades downward into a nonwelded vitric tuff at the base.

3.2.1.3 Paintbrush Tuff

The Paintbrush Tuff at Yucca Mountain consists of four members with thin-bedded, reworked or air-fall tuffs between them. From youngest to oldest, the units are the Tiva Canyon Member, the Yucca Mountain Member, the Pah Canyon Member, and the Topopah Spring Member (Table 3-1). These units were erupted between about 12 and 13.2 million years ago from the Claim Canyon Caldera and perhaps, in part, from the Oasis Valley Caldera (Figure 3-3).

The Tiva Canyon Member forms the caprock at Yucca Mountain and ranges in thickness from zero where it has been eroded away in channels and washes to more than 50 meters (160 feet) on the ridge crests. The member has a moderately to densely welded devitrified central portion, underlain by a less densely welded vitric zone. The member is a compound cooling unit, compositionally zoned from rhyolite in the lower and middle parts to quartz latite near the top. Large xenoliths (fragments of preexisting rocks incorporated in the rising lava) occur at several places within the unit. Flattened lithophysae are common in the middle and upper parts. Bedded air-fall tuff and tuffaceous sediments a few meters thick occur at the base of the member. The total original volume of the Tiva Canyon Member is estimated to be 1,000 cubic kilometers (240 cubic miles), which indicates the massive eruption required to produce it.

The Yucca Mountain Member ranges in thickness from zero to 36 meters (118 feet) and had an estimated original volume of only 17 cubic kilometers (4.1 cubic miles). It is a simple cooling unit with nonwelded to partly welded zones at the base, top, and distal portions. North of the site (drill hole USW G-2), the interior of the member is moderately to densely welded and contains lithophysae. Compositionally, the unit is a rhyolite with little variation from top to bottom.

Bedded tuff and nonwelded ash-flow tuffs occur locally between the Yucca Mountain Member and the underlying Pah Canyon Member. These tuffs range in thickness from zero to 44 meters (144 feet). The matrix is mostly vitric and contains abundant xenoliths of volcanic rocks.

The Pah Canyon Member at Yucca Mountain ranges in thickness from 11 to 83 meters (36 to 272 feet). It is a simple ash-flow cooling unit with nonwelded to partly welded zones at the base and top, and an interior zone of moderate-to-dense welding north of the site. The member is generally vitric, and tuffaceous sediments and air-fall tuff occur at the base.

The Topopah Spring Member contains the horizon being considered as the potential host rock for the repository. The Topopah Spring Member is a compound cooling unit composed of as many as four separate ash-flow sheets and varies in composition from low-silica rhyolite near the top to high-silica rhyolite near the base. At least 275 cubic kilometers (66 cubic miles) of ash-flow material were spread over an area of about 1,800 square kilometers (700 square miles) during eruption of the Topopah Spring Member. At Yucca Mountain, this rock unit is about 350 meters (1,150 feet) thick, but it thins abruptly to the south and is absent near the southwestern corner of the Nevada Test Site. The member also appears to thin to the north where it is only about 290 meters (950 feet) thick (drill hole USW G-2). At Yucca Mountain, the Topopah Spring Member is characterized by four distinct zones, from top to bottom: a nonwelded to densely welded, generally vitric tuff; a moderately to densely welded, devitrified tuff that accounts for most of the total thickness of the member; a basal vitrophyre; and a vitric tuff grading downward from welded to nonwelded. The densely welded devitrified zone, second from the top, is currently being considered as the potential host rock for the repository. The zone contains abundant lithophysae in several intervals, but they are most common in its upper and central portions. In the lower part of the densely welded interval, lithophysae are less abundant, and it is this zone that is preferred as the host rock for the repository. The densely welded portions of the tuff are more intensely fractured than the other portions of the Paintbrush Tuff.

3.2.1.4 Tuffaceous beds of Calico Hills

The tuffaceous beds of Calico Hills is an informal name for tuffaceous rocks that may have originated from a currently obscured volcano near the north end of Calico Hills, east of Yucca Mountain (Figure 3-3). The unit ranges in thickness from 90 to 150 meters (300 to 500 feet) at the site although it thickens to nearly 306 meters (1,000 feet) to the north. It is composed chiefly of nonwelded ash-flow tuffs, numerous thin tuffaceous sedimentary beds, and minor air-fall tuffs. In the northern and eastern part of the site, the unit is typically zeolitized, having undergone a low-temperature, low-pressure alteration to zeolite minerals. In the southern and western part of the site (drill holes USW G-3 and USW H-5), the unit is predominantly vitric and not altered to zeolite minerals.

3.2.1.5 Crater Flat Tuff

Beneath the Calico Hills unit is the Crater Flat Tuff, which consists of three members: the Prow Pass Member at the top, the Bullfrog Member in the middle, and the Tram Member at the base. The Prow Pass Member is about 127 to 176 meters (417 to 577 feet) thick at Yucca Mountain. It contains six partly zeolitized, partly devitrified ash-flow tuffs that probably cooled as a compound unit (drill hole USW G-1). Most of the unit is partially to moderately welded; however, bedded, reworked, and densely welded materials occur in its central part, and zeolitized air-fall tuffs occur at the base. Mudstone fragments, derived perhaps from the Eleana Formation of Devonian-Mississippian age, are abundant in the Prow Pass Member. The Bullfrog Member ranges in thickness from 99 to 161 meters (325 to 530 feet) and consists predominantly of partially to moderately welded ash-flow tuffs with isolated, thin, densely welded layers. The Tram Member is 154 to 328 meters (507 to 1,073 feet) thick and consists of at least four slightly to densely welded ash-flow tuffs, some of which are zeolitized and devitrified. Reworked bedded tuffs also occur in the Tram Member.

3.2.1.6 Older tuffs

In this document, all rocks below the Crater Flat Tuff are referred to as older tuffs. Except for the Lithic Ridge Tuff, no formal stratigraphic units are recognized in the older volcanic rocks. Most of these units have been observed only in drill holes at Yucca Mountain. They generally consist of moderately to densely welded ash flows (interspersed with rhyolitic lava flows, breccia flows, and nonwelded air-fall tuffs) and bedded, reworked tuffs. The total thickness of the older tuffs is unknown. Three drill holes (USW G-1, USW G-2, and USW H-1) have penetrated more than 1,829 meters (6,000 feet) without reaching the base of the volcanic rocks.

3.2.2 STRUCTURE

The structural development of southern Nevada and southeastern California has been long and complex, as briefly discussed in Section 2.1. Crustal extension and associated volcanism, Basin and Range style faulting, and alluvial filling of intervening valleys during Cenozoic time (0 to 65 million years ago) have obscured the relationship of older, regional structural features. In Mesozoic time (65 to 245 million years ago), the Precambrian and Paleozoic sedimentary rocks of southern Nevada were strongly compressed. The folds and thrust faults formed during this interval indicate that compression was directed generally from west to east and that the age of deformation decreases to the east. The regional patterns of exposed pre-Tertiary rocks suggest that several thrust-fault systems and several broad, associated folds trend north to northeast through the area east of Yucca Mountain. The tectonic forces that created these ancient structures have long since been inactive. The absence of pre-Tertiary rocks at the site constrains the discussion of pertinent structures to those produced by Tertiary extensional tectonics. These structures are complex and result from a long and complicated history. Nevertheless, field work conducted during the past few decades and recent studies at Yucca Mountain by the Nevada Nuclear Waste Storage Investigations Project have established a basic understanding of the structural and tectonic framework of this region. (For a detailed discussion of the structural and tectonic framework, see Section 6.3.1.7.)

The site lies in the southern Great Basin. Although topographic expressions of the Basin and Range style structures seem to indicate a relatively simple system of uplifted and down-dropped crustal blocks, the deep structural configuration of some parts of the Basin and Range is complex (Allmendinger et al., 1983; Anderson et al., 1983). The origin of Basin and Range type structures has been attributed, in part, to right-lateral faulting along the western edge of North America during Cenozoic time (Hamilton and Myers, 1966; Atwater, 1970; Christiansen and McKee, 1978). Western North America lies within a broad belt of right-lateral movement caused by differential motion between the North American and the Pacific crustal plates. Some of the right-lateral movement occurs along the San Andreas Fault and similarly oriented faults in California (Figure 3-4). This type of motion may have occurred earlier in southern Nevada and eastern California along the Walker Lane and Las Vegas Valley shear zones, and along the Death Valley and Furnace Creek fault zones. This motion and the related extensional faulting caused fragmentation of the crust into basins and ranges oriented along trends oblique to the right-lateral fault zones. Relatively high seismic activity continues today along the right-lateral Death Valley and Owens Valley fault zones northwest and southwest of Yucca Mountain, thus suggesting that these zones are still active.

Cumulative displacement across the entire zone of inferred right-lateral faulting in the western Great Basin, including fault-slip and large-scale bending, may be in excess of 150 kilometers (95 miles) (Albers, 1967). This estimate includes the bending of structural features along a northeasterly trend due to drag folding along the Walker Lane Shear Zone (Albers, 1967) and the Las Vegas Valley Shear Zone (Longwell, 1960). Maximum displacement along individual fault zones, however, is generally thought to be less than 48 kilometers (30 miles). Several investigators suggest that the right-lateral fault zones became active about 20 to 25 million years ago (Atwater, 1970; Carr, 1974), although other investigators believe the faults were active for a much longer time (Albers, 1967).

Most displacement along the Las Vegas Valley Shear Zone southeast of Yucca Mountain has apparently occurred during the past 17 million years. Fleck (1970) and Carr (1974) conclude that motion along this zone ceased about 10 million years ago. The Las Vegas Valley Shear Zone seems to have been inactive for millions of years; however, seismic activity and surface fault displacements have occurred during this century within the Walker Lane Shear Zone (Figure 3-4).

The caldera complex in southwestern Nevada (described in Section 3.2.1) lies along a northwest trend connecting the Walker Lane and the Las Vegas Valley Shear Zones. Some investigators believe that the caldera complex at Timber Mountain is preferentially located where this northwest-trending zone of right-lateral faulting intersects Basin and Range faults extending southward from the Belted or Kawich ranges, or where the northwest-trending zone intersects the southwest-trending fault zones with components of

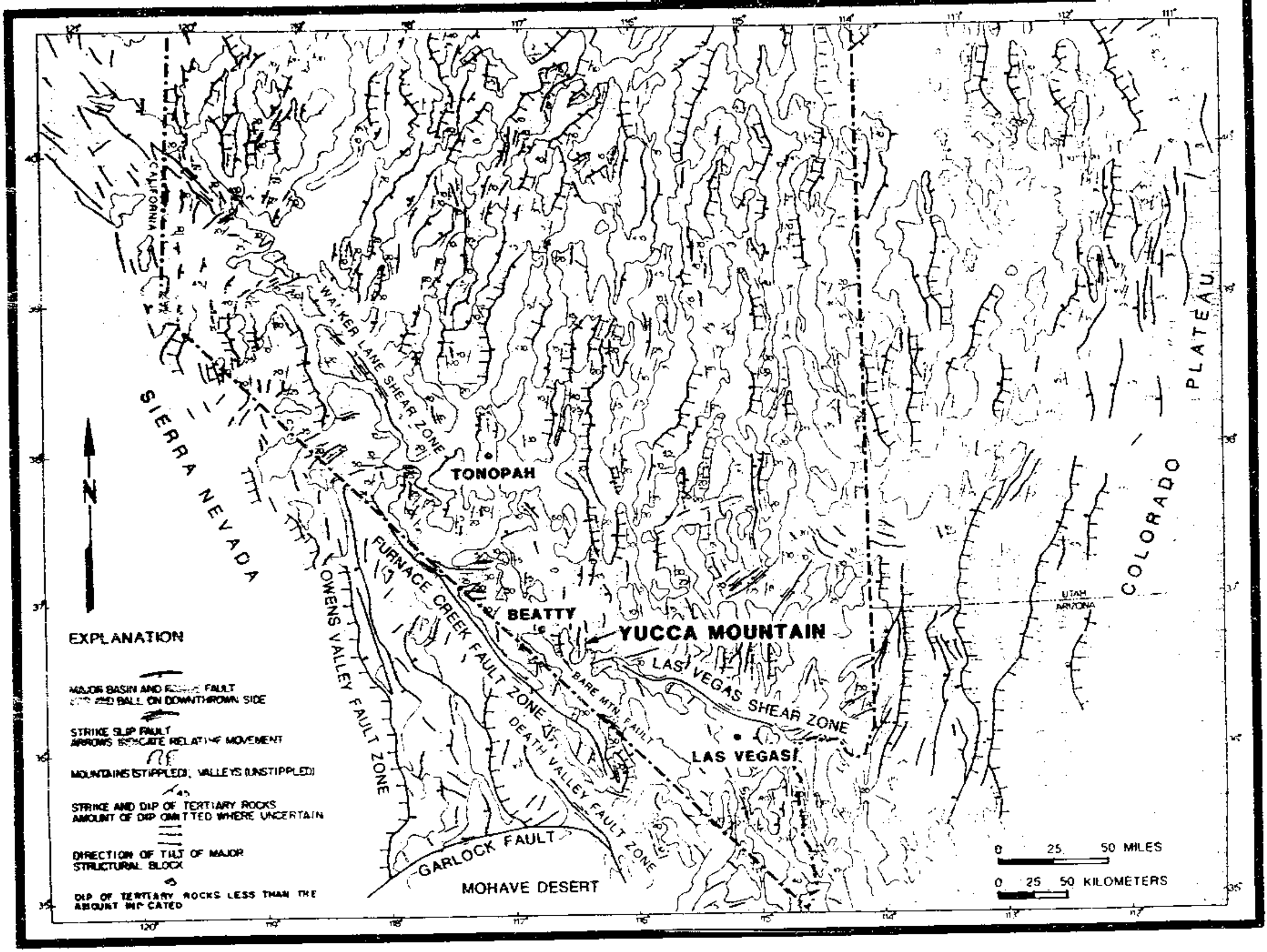

Figure 3-4. Map of the southern Great Basin showing major Basin-Range faults, tilt of major structural blocks, and attitudes of Tertiary rocks. Modified from Stewart (1978).

left-lateral displacement (Carr, 1974) (Figure 3-5). Although no distinct faults can be traced between the two zones, structural, volcanic, and topographic features throughout this region suggest a connection between them (Christiansen et al., 1977).

Structural features at Yucca Mountain include local faults related to caldera collapse and longer faults of the Basin and Range style. The local faults are shown in Figure 3-6 and on hydrogeologic cross sections in Figure 3-7. Hydrogeologic units do not correspond exactly to stratigraphic units. See Table 6-16 and supporting text in Section 6.3.1.1 for descriptions of hydrogeologic units. The hydrogeologic units are gently tilted to the east and are offset by several north-trending high-angle faults, downdropped chiefly to the west, which created several large north-trending structural blocks (Lipman and McKay, 1965; Maldonado and Koether, 1983; Scott et al., 1983; Scott and Bonk, 1984). Other fault systems trend northwest, particularly in the northern and southeastern parts of Yucca Mountain. Detailed mapping of the southern part of the site (Scott and Bonk, 1984) has revealed an area of very closely spaced, small faults that trend northeast. The primary repository area is shown on Figure 3-8 together with possible repository expansion areas. Rock strata in the primary area dip eastward at about 5 to 8°. This area is bounded on the west by a large fault zone along Solitario Canyon. Vertical displacement along the Solitario Canyon Fault diminishes from about 200 meters (700 feet) at the southern end to about 20 meters (70 feet) at the northwestern corner. To the east, the central area is bounded by several smaller, closely spaced faults. The northern edge of the primary area is defined by Drill Hole Wash, an informally named feature. The southern boundary is less well defined. One moderately sized fault, designated the Ghost Dance Fault, occurs within the primary repository area (Scott and Bonk, 1984).

Drill-hole data indicate that some minor high-angle faults may have lateral as well as vertical components of displacement, particularly along northwest-trending faults north of the primary repository area (Maldonado and Koether, 1983.) Displacements along individual faults within the primary repository area are generally less than a few meters, except for the Ghost Dance Fault, shown in Figure 3-7, which dips steeply to the west and has a displacement of about 25 meters (80 feet) (USGS, 1984). Faults that separate major structural blocks may have a hundred or more meters of offset. The density of fractures is generally proportional to the degree of welding of the stratigraphic units. Near the major faults and in some local areas of abundant small-offset faults, fracture density probably increases.

Offsets on the large block-forming faults are greatest in the Tiva Canyon Member of the Paintbrush Tuff and offsets are smaller in the younger Rainier Mesa Member of the Timber Mountain Tuff (Lipman and McKay, 1965; Scott and Bonk, 1984). Thus, most of the offset occurred between the emplacement of the 12.6-million-year-old Tiva Canyon Member and the emplacement of the 11.3-million-year-old Rainier Mesa Member. The remainder of the offset occurred between 11.3 million years ago and the present. Whereas the Tiva Canyon Member was erupted over an area of low relief, indicated by its relatively uniform distribution, the Rainier Mesa Member was erupted on an area disrupted by fault blocks (USGS, 1984).

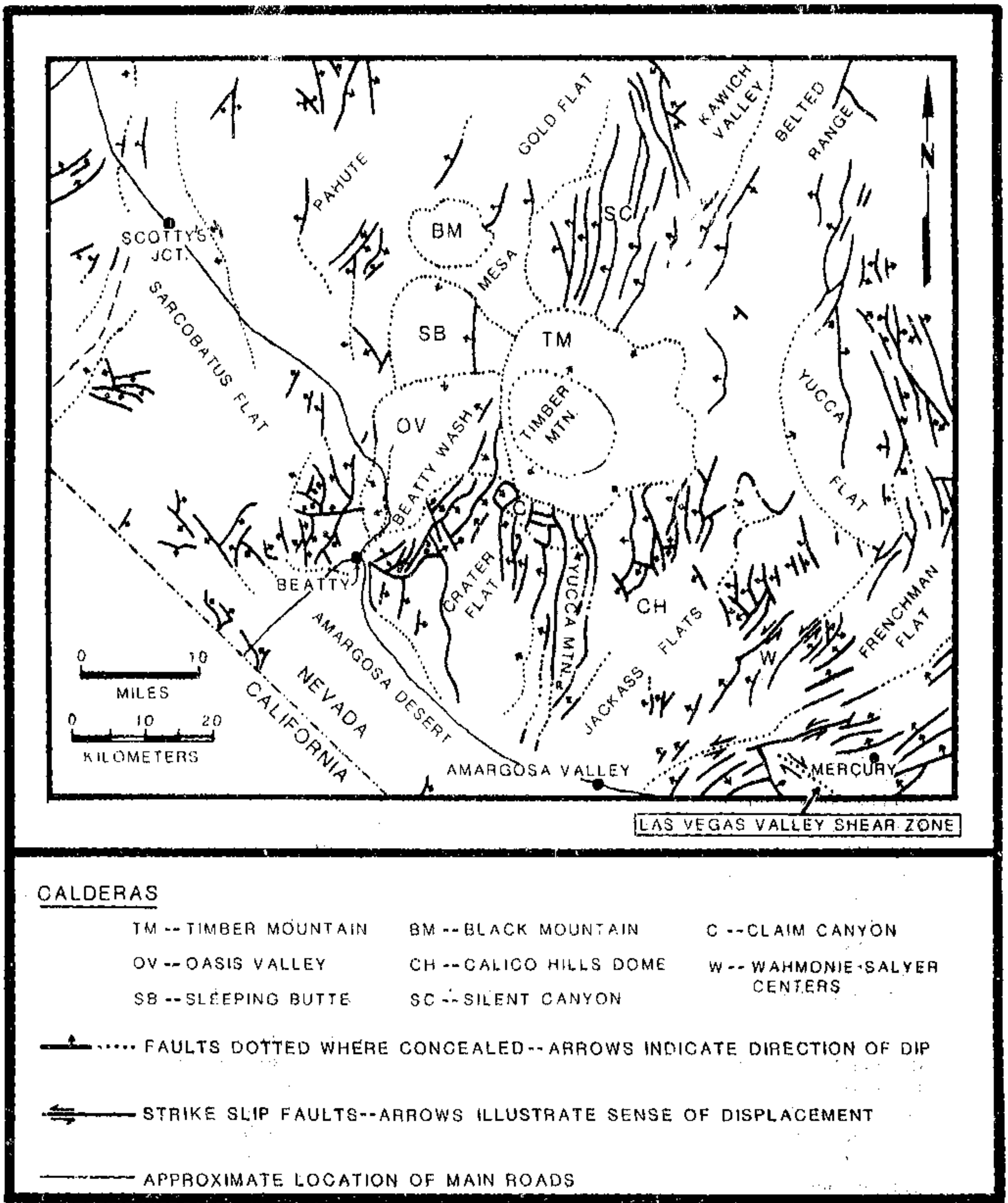

Figure 3-5. Generalized map of Yucca Mountain and vicinity showing calderas and late Cenozoic normal faults and a few strike-slip faults. Modified from Christiansen et al. (1977).

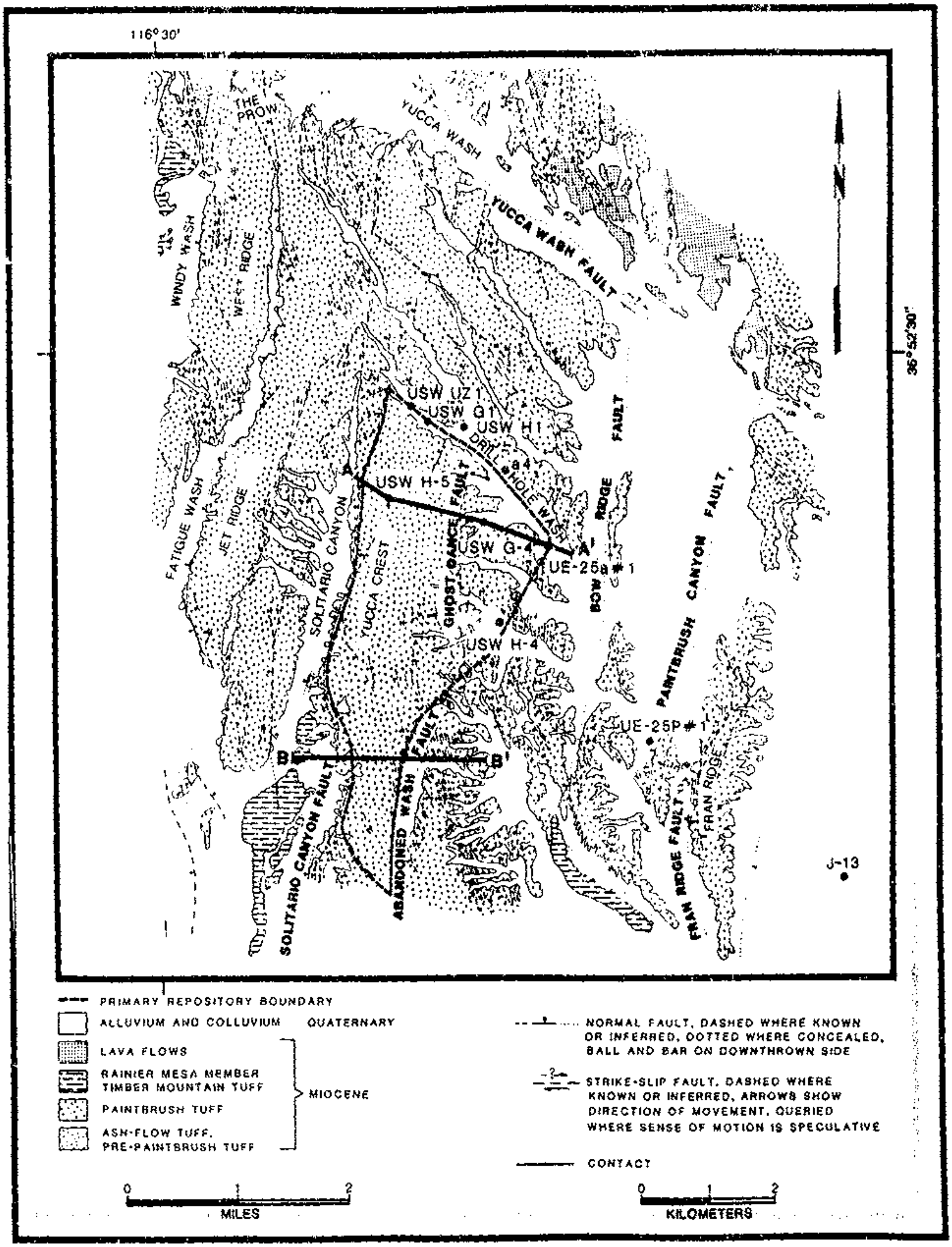

Figure 3-6. Geologic map of Yucca Mountain with approximate outline of primary repository area indicated by dashed line. Cross sections A-A' and B-B' are shown on Figure 3-7. Modified from Scott and Bonk (1984).

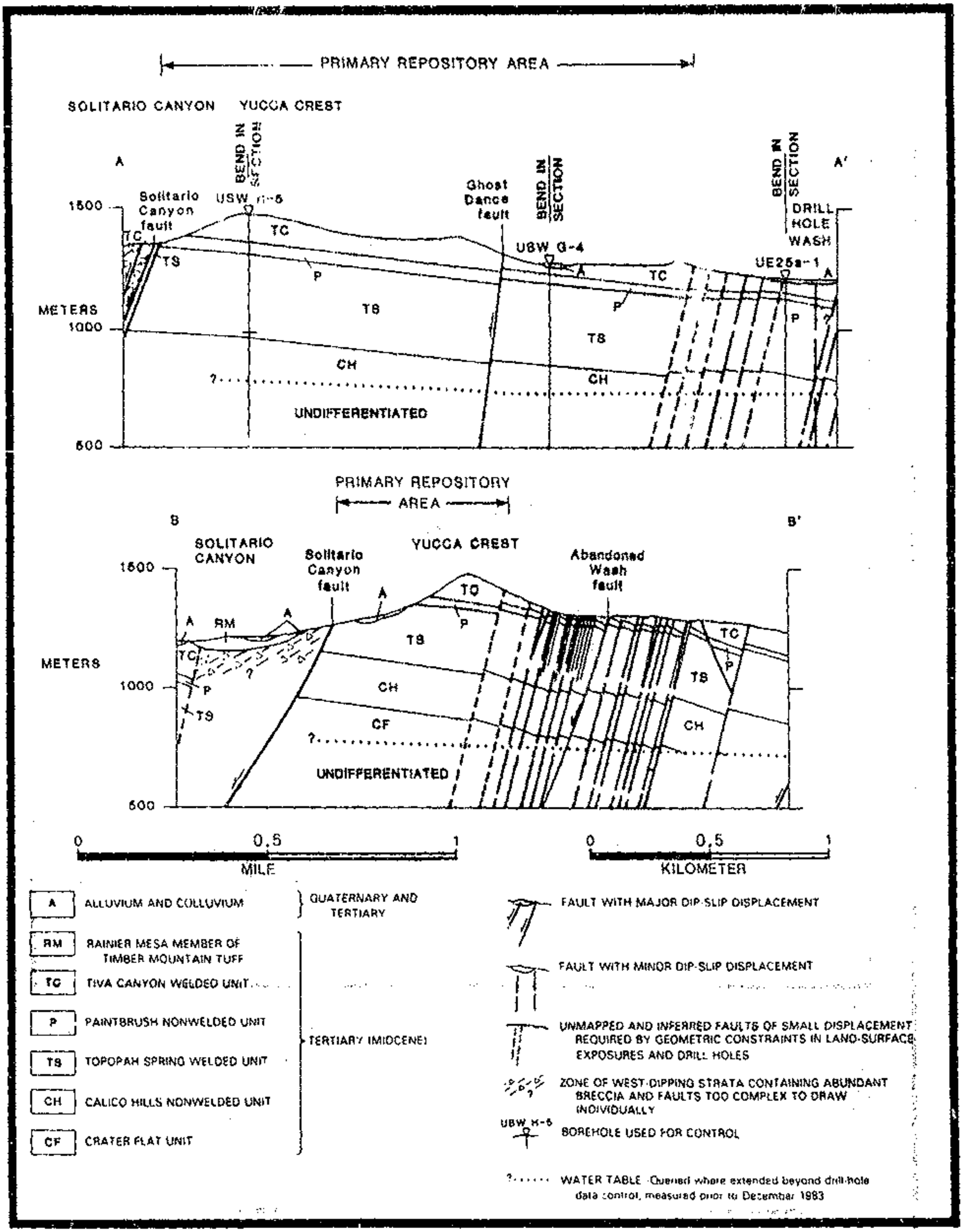

Figure 3-7. Approximately east-west hydrogeologic cross sections modified from Montazer and Wilson (1984) showing faults at and near Yucca Mountain as mapped by Scott and Bonk (1984). See Figure 3-6 for approximate locations of cross sections A-A' and B-B'.

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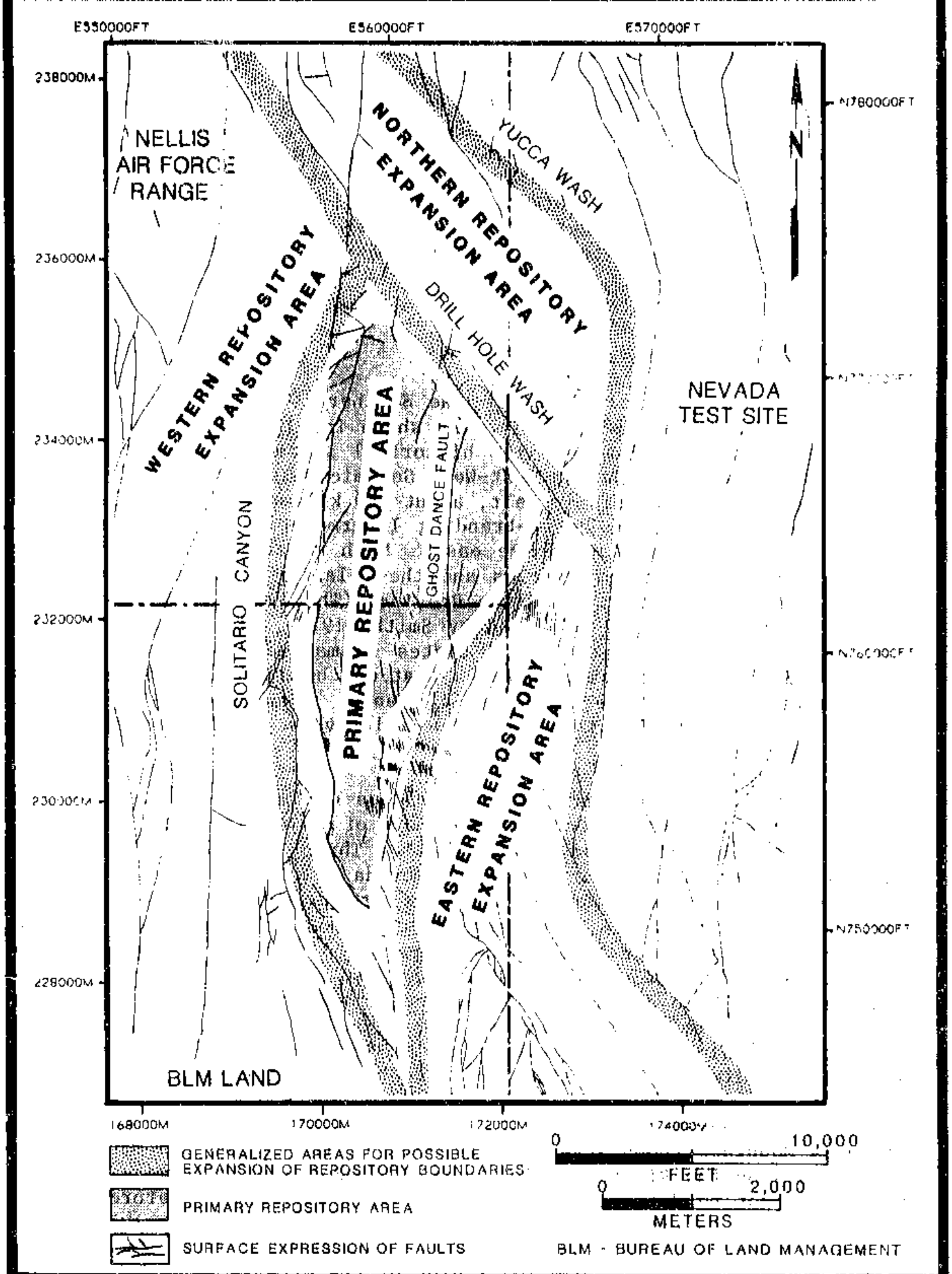

Figure 3-8. Generalized outlines of the primary repository and possible expansion areas. Modified from Mansure and Ortiz (1984).

Thirty-two faults within a 1,100-square-kilometer (425-square-mile) area around the site offset or fracture Quaternary deposits. Five faults are thought to have moved between about 270,000 and 40,000 years ago; four faults moved about 1 million years ago; and 23 faults are thought to have moved between 1 and 2 million years ago (Swadley et al., 1984). At the time of publication of Swadley et al. (1984), no evidence of offset younger than 40,000 years had been confirmed; recently available, but unevaluated thermoluminescence dates may indicate on the order of 1 to 10 centimeters of fault displacement in eastern Crater Flat more recently than 6,000 years ago (Dudley, 1985) (see Section 6.3.1.7.4, potentially adverse condition 1).

3.2.3 SEISMICITY

Catalogs of the seismicity in the Southern Great Basin are available (Rogers et al., 1976, 1981, 1983). As shown in Figure 3-9, Yucca Mountain lies in an area of relatively low historical seismicity, on the southern margin of the southern Nevada East-West Seismic Belt. This belt connects the north-trending Nevada Seismic Belt, about 160 kilometers (100 miles) west of Yucca Mountain, with the north-trending Intermountain Seismic Belt about 240 kilometers (150 miles) to the east. Much remains to be learned about regional and local seismic cycles and the relation between seismicity and fault length in the Basin and Range Province (Thenhaus and Wentworth, 1982). As pointed out by Ryall (1977) and by Smith (1978), the pattern of historic earthquakes in the western United States is marked by relatively brief episodes of intense activity in areas that may have been relatively inactive for hundreds and perhaps thousands of years. Geologic field evidence suggests that Yucca Mountain has been relatively stable for the past 11 million years.

Within a 100-kilometer (62-mile) radius of Yucca Mountain, the most seismically active areas occur in regions of major Tertiary northeast-trending left-lateral shear (USGS, 1984). Three important areas in this category are the Pahranagat, southern Nevada Test Site, and Gold Mountain shear zones. Although some earthquakes are probably occurring on the northeast-trending faults, the larger earthquakes in these areas, for which focal mechanisms are available, have occurred on shorter intervening fault segments with a north strike. Seismicity also occurs in some north-trending fault zones. These earthquakes occur on or near segments of north-trending faults such as the Thirsty Canyon, Yucca, and Pahute Mesa faults (north-northeast trending) or are visible as north-trending epicenter lineations such as at Indian Springs Valley and Sarcobatus Flat (USGS, 1984).

Recorded seismic activity prior to 1978 within 10 kilometers (6 miles) of Yucca Mountain shows seven earthquakes; of these, two had magnitudes of 3.6 and 3.4 on the Richter scale; five had magnitudes that were smaller or that could not be determined due to instrument problems. Before 1979, the standard error in estimates of most earthquake locations was $\pm$ 7 kilometers (4 miles) or more (USGS, 1984). A 47-station seismic network was installed within a 160-kilometer (100-mile) radius of the site in 1978 and 1979, and a 6-station supplemental mini-network was deployed on Yucca Mountain in 1981 (USGS, 1984). No earthquakes with magnitudes greater than 4.3 have been recorded during this monitoring period, and only two micro-earthquakes

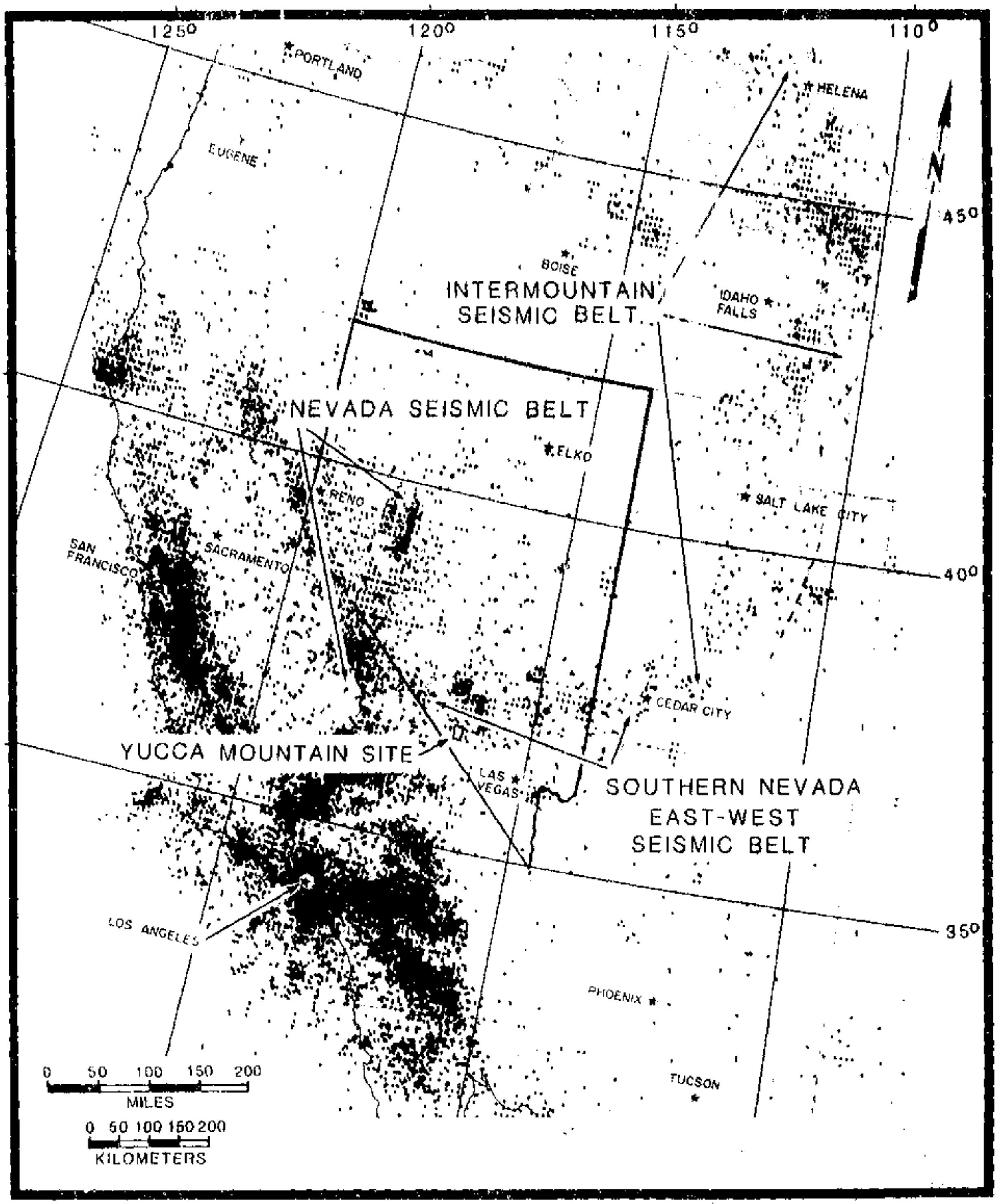

Figure 3-9. Historical seismicity in the western United States showing the Nevada Seismic Belt, the Intermountain Seismic Belt, and the southern Nevada East-West Seismic Belt. It should be noted that some of the seismicity in the western end of the East-West Seismic Belt represents underground explosions at the Nevada Test Site. For California, the minimum-magnitude earthquakes plotted where Richter M ~ 1 and for the rest of the western United States, they were Richter M ~ 3. Modified from Smith (1978).

(M = 1.7 and M = 1.5), at depths of 4 and 9 kilometers (2.4 and 5.6 miles), respectively, have been detected by the network in the vicinity of the site (USGS, 1984). There is some uncertainty in the seismic sources for many signals recorded by the seismic monitoring network in the vicinity of the Nevada Test Site and Yucca Mountain because underground nuclear explosions, surface drilling, and explosions to support geophysical investigations may produce earthquake-like signals. Therefore, the information about earthquake frequencies and magnitudes should be regarded as preliminary.

Surface faulting in response to nuclear tests has been observed at Pahute Mesa and Yucca Flat. The closest historical surface faulting accompanying a natural earthquake occurred in 1872 in Owens Valley, California, about 150 kilometers (95 miles) west of Yucca Mountain; the related earthquake had an estimated magnitude of about eight and one-quarter on the Richter scale (USGS, 1984). Two historical earthquakes with a magnitude of 6 on the Richter scale have been reported; one occurred in 1908 about 110 kilometers (68 miles) southwest of Yucca Mountain, and one occurred in 1966 about 210 kilometers (130 miles) northeast of Yucca Mountain.

Predictions of future seismicity and faulting are complicated by a number of factors. Because the recurrence interval for large earthquakes on a Basin and Range fault may be thousands of years, epicenter maps of historic earthquake or evidence of Holocene faulting alone may not be reliable indicators of future or long-term seismicity (Smith, 1978). Another complication is that when long fault zones in normal fault regimes fail, they may break along segments rather than along the entire length (Swan et al., 1980). Ryall (1977) points out that large (M > 7) earthquakes in the western Great Basin tend to be followed by aftershocks lasting about a century and then seismic activity stabilizes at a low level for centuries or thousands of years. Ryall and VanWormer (1980) applied this concept to seismic zoning in the region and point out that recurrence estimates based on historic or current earthquake distributions are not directly applicable to the problem of identifying the most likely locations of future large earthquakes. From the historical seismicity of the southern Great Basin (two earthquakes of M = 6) and length of active faults, a maximum magnitude of M = 7 to 8 is inferred for earthquakes in the Yucca Mountain region (USGS, 1984). Earthquake depths are less than about 10 kilometers (6.2 miles); very few well-located events are deeper than 10 kilometers (6.2 miles). The wide range of focal depths suggests that faults in the southern Great Basin have large surface areas and extend to considerable depth, which would make them capable of producing large earthquakes. As noted in Section 6.3.1.7.5, estimates of recurrence intervals for major earthquakes in the region ($M \geq 7$) are on the order of 25,000 years; for magnitudes of $M \geq 6$, recurrence intervals are on the order of 2,500 years; and for magnitudes of $M \geq 5$, recurrence intervals are on the order of 250 years. A full evaluation of the possible effects of earthquakes and faulting on postclosure repository performance and preclosure repository operations is given in sections 6.3.1.7 and 6.3.3.4.

3.2.4 ENERGY AND MINERAL RESOURCES

The energy- and mineral-resource potential of Yucca Mountain and surrounding areas has been evaluated by Bell and Larson (1982) and Quade and

Tingley (1983). Boreholes have been drilled in and around Yucca Mountain for the Nevada Nuclear Waste Storage Investigations Project (Maldonado and Koether, 1983; Spengler et al., 1981), and core samples and drill cuttings have been routinely analyzed by geochemical methods. Field exploration and geologic mapping has been conducted by the U.S. Geological Survey (Christiansen and Lipman, 1965; Lipman and McKay, 1965; Scott and Bonk, 1984). From all of the above investigations, it can be concluded that the overall potential for development of mineral or energy resources at Yucca Mountain is low.

3.2.4.1 Energy resources

There is no evidence that Yucca Mountain contains any commercially attractive geothermal, uranium, hydrocarbon, oil shale, or coal resources (Bell and Larson, 1982). None of the drill holes at or near Yucca Mountain have shown evidence of hydrocarbons. The geology of the area suggests that the existence of fossil fuel resources at depth is highly unlikely (Bell and Larson, 1982).

There are no warm springs at Yucca Mountain. The area around Yucca Mountain is well known in terms of heat flow. More than 60 drill holes (some as deep as 1,829 meters (6,000 feet)) have been drilled and analyzed. Surface and subsurface evidence near Yucca Mountain indicates a potential for low to moderate geothermal energy at depths less than 1 kilometer (3,300 feet) (Bell and Larson, 1982). However, the geothermal gradient measured in several drill holes at Yucca Mountain (Sass and Lachenbruch, 1982) indicates that it is unlikely that high-temperature waters could be present at depths that are economically attractive. Water temperatures measured in wells east of Yucca Mountain range from 21 to 65°C (70 to 149°F) (Bell and Larson, 1982). With present technology, this temperature range is insufficient for commercial power generation, which requires temperatures of at least 180°C (350°F) (White, 1973).

Minor amounts of uranium have been reported west of the site at Bare Mountain, but no uranium mines or prospects have been developed. Under current economic conditions, the uranium resources identified in the Bare Mountain area are not attractive targets for development (Bell and Larson, 1982).

3.2.4.2 Metals

Table 3-2 identifies the status, number, and types of exploratory and mining operations for base and precious metals in the Yucca Mountain area, and Figure 3-10 shows the location of these deposits. Historically, Nevada's metallic industry centered around the mining of precious metals in the Comstock district in west-central Nevada and in the Tonopah and Goldfield districts more than 150 kilometers (95 miles) northwest of the site. Although there are numerous small mining districts throughout the southern Great Basin, the only active silver and gold mine in the region is the Stirling-Panama mine near Bare Mountain. Reserves have not been reported by

Table 3-2. Mining operations in the vicinity of Yucca Mountain[a]

Location and resource	Number and status of operations	Type of operations
Bare Mountain (gold, silver, mercury, tungsten, lead)	4 active 10 previously mined 10 unknown status	Prospect pits, open pits, placer, underground tunnels, and shafts
Mine Mountain (silver, lead, mercury)	1 previously mined	Underground tunnels and shafts
Wahmonie (gold, silver, copper)	None active 3 previously mined	Prospect pits, underground shaft
Lee (gold, copper, tungsten)	None active 1 previously mined	Prospect pits, shallow diggings, underground shafts
Northern Yucca Flat Climax District (gold, silver, lead)	None active 1 previously mined	Shallow surface diggings, underground shafts
Amargosa Desert (tungsten, iron)	None active 1 previously mined	Prospect pits

[a]Data from Bell and Larson (1982).

the mine operators of the Stirling-Panama mine, but Bell and Larson (1982) estimate ore reserves in excess of 100,000 tons at a grade of about 0.3 ounce of gold per ton of rock. More recent data from Smith et al. (1983) indicate that the grade of ore at the Stirling-Panama mine ranges from 0.5 to 4.0 ounces of gold per ton.

Lead and copper were also historically important minerals in northern and central Nevada. A mine located northwest of Yucca Mountain has produced a small amount of mercury from cinnabar distributed in seams and spheres in silicified and opalized rhyolite tuff (Cornwall and Kleinhampl, 1961). Base and precious metals have also been prospected and mined east of the site in the Mine Mountain and Wahmonie districts. Information on the mining history in these districts, however, is limited. The land around these districts was withdrawn from public domain more than 30 years ago as part of the Nevada Test Site. The Wahmonie district apparently produced gold and silver sometime between 1905 and 1910 and again in 1928, but the amount was not recorded. Geophysical surveys suggest that the Wahmonie district may contain some precious metal deposits, but the potential amounts remain undetermined (Hoover et al., 1982). The Calico Hills area northwest of the Wahmonie district has been the location of substantial prospecting, but no production has been recorded. Trace amounts of silver and gold occur in the lower Tram

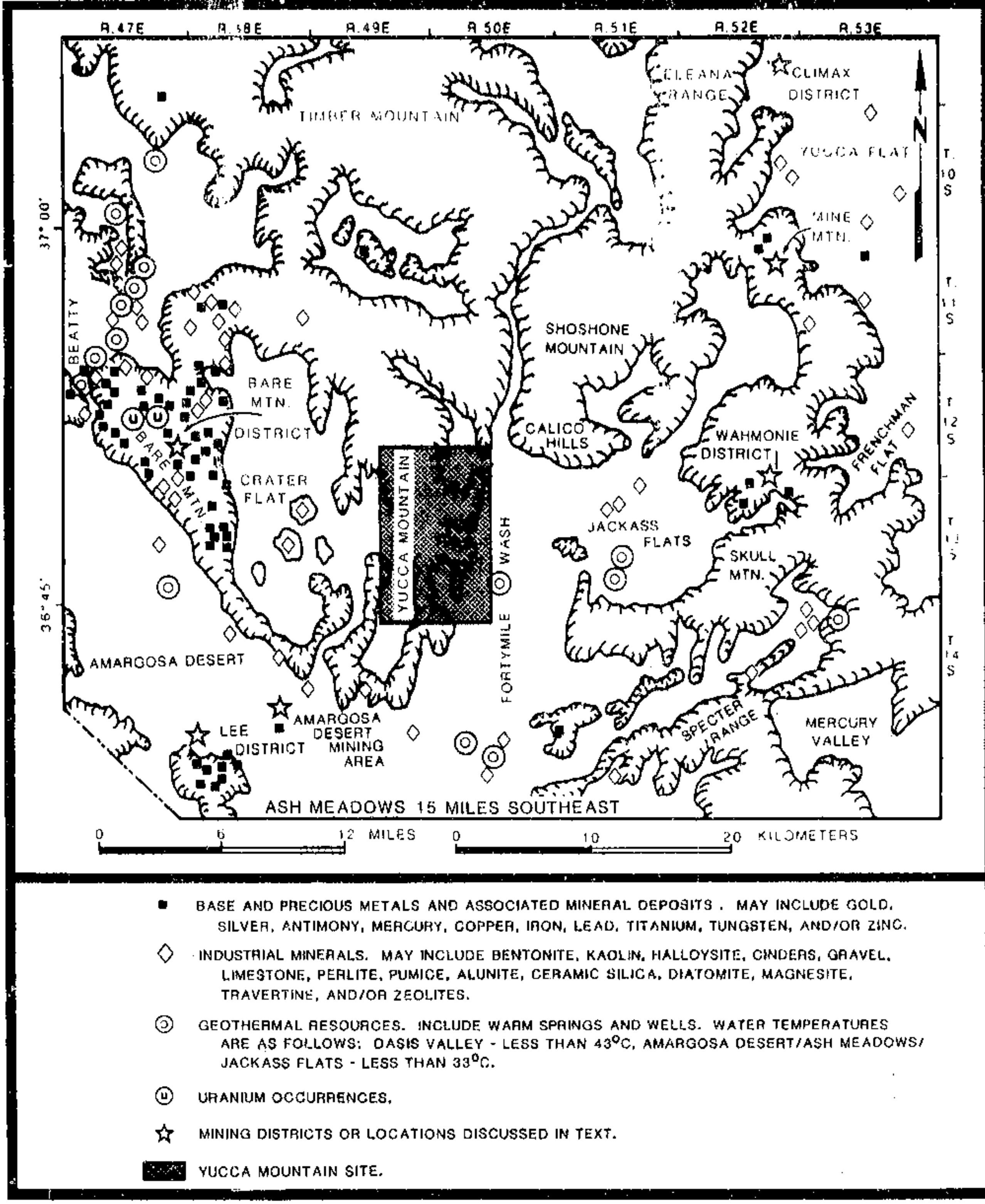

Figure 3-10. Location of metallic ore deposits, industrial materials, thermal waters, and mining districts in the vicinity of Yucca Mountain. Modified from Bell and Larson (1982) and Trexler et al. (1979).

Member at about the 1,070-meter (3,515-foot) depth in drill hole USW G-1 (Spengler et al., 1981). The concentrations, 0.5 part per million (0.016 ounce per ton) for gold and 20 parts per million (0.64 ounce per ton) for silver, are not high enough to be considered of commercial interest, especially at this depth. Although mercury, lead, zinc, and uranium have been identified along fault and fracture zones in volcanic rocks in Nevada, no occurrences of these metals have been reported along fractures of the Yucca Mountain site. On the basis of this preliminary information, Yucca Mountain is not considered to have any potential for the development of metal resources under foreseeable economic conditions and extraction techniques.

3.2.4.3 Nonmetals

A large variety of industrial minerals and rocks are present in the Yucca Mountain region, including clays, ceramic silica, zeolites, alunite, fluorite, sand, gravel, and lightweight construction aggregate (volcanic cinders, perlite, and pumice). Clay resources are predominantly kaolinite, montmorillonite, and halloysite and are extracted from shallow surface pits. Fluorite mineralization, judged to be of local significance, is widespread in Bare Mountain, 16 kilometers (10 miles) west of the site (Bell and Larson, 1982).

Sand and gravel deposits are ubiquitous in the Yucca Mountain area. These materials are extracted from shallow surface pits and are used chiefly for road construction. Volcanic cinder, perlite, and pumice occur in Crater Flat. These materials are mined from surface pits and used for lightweight aggregate, concrete blocks, road base, and decorator stone. Other than sand and gravel, none of these surface resources occur at Yucca Mountain.

3.3 HYDROLOGIC CONDITIONS

This section describes the hydrology of Yucca Mountain and nearby areas. Topics discussed include surface water, ground water, and present and future water use. Much of the descriptive information in this section is summarized from a report by Winograd and Thordarson (1975) and from the discussions presented in Section 6.3.1.1.

Numerous investigations of the geohydrology of Yucca Mountain and nearby areas have been conducted since 1978 (see Section 6.3.1.1 for a list of studies). These studies have resulted in a general understanding of the regional ground-water flow (Waddell, 1982). Detailed studies of water movement, including flow through the unsaturated zone, are in progress or are planned.

3.3.1 SURFACE WATER

No perennial streams occur at or near Yucca Mountain. The only reliable sources of surface water are the springs in Oasis Valley, the Amargosa

Desert, and Death Valley. Because of the extreme aridity of this region, where the annual precipitation averages about 20 percent of the potential evapotranspiration, most of the spring discharge travels only a short distance before evaporating or infiltrating back into the ground.

Rapid runoff during heavy precipitation fills the normally dry washes for brief periods of time. Local flooding can occur where the water exceeds the capacity of the channels. The potential for flooding at Yucca Mountain, and its potential effects on a repository are described in Section 6.3.3.3. In contrast to the washes, the terminal playas may contain standing water for days or weeks after severe storms. Runoff from precipitation at Yucca Mountain drains into Fortymile Wash on the east and Crater Flat on the west, and both areas drain into the normally dry Amargosa River (Figure 3-11). If runoff is very high, water in the Amargosa River flows into the playa in southern Death Valley.

3.3.2 GROUND WATER

Yucca Mountain lies within the Death Valley ground-water system, a large and diverse area in southern Nevada and adjacent parts of California composed of many mountain ranges and topographic basins that are hydraulically connected at depth. In general, ground water within the Death Valley system travels toward Death Valley, although much of it discharges before reaching Death Valley. Ground water in the Death Valley system does not enter neighboring ground-water systems.

The Death Valley ground-water system is divided into several ground-water basins. Information now available indicates that ground water moving beneath Yucca Mountain discharges at Alkali Flat and perhaps at Furnace Creek in Death Valley, but not in Ash Meadows or Oasis Valley. As shown in Figure 2-5, Yucca Mountain is in the Alkali Flat-Furnace Creek Ranch ground-water basin, at a position midway between the Ash Meadows and the Oasis Valley basins (Waddell, 1982).

Geologic formations in southern Nevada have been grouped into broad hydrogeologic units (see Figure 2-4) (Winograd and Thordarson, 1975; Montazer and Wilson, 1984). Several of the units transmit water in sufficient quantities to supply water needs (aquifers), whereas other units have relatively low permeabilities that tend to retard the flow of ground water (aquitards). The geologic and hydrologic properties of the aquifers vary widely. The lower and upper carbonate aquifers and the welded-tuff aquifers store and transmit water chiefly along fractures. In contrast, the valley-fill alluvial aquifers store and transmit water chiefly through interstitial openings. The lower carbonate and valley-fill (alluvial) aquifers are the main sources of ground water in the eastern part of the Nevada Test Site. The stratigraphic and hydrogeologic units that are present at the Yucca Mountain site are shown in Table 3-3. Lithologic characteristics and hydraulic conductivities of the hydrogeologic units are also given in the table. A more detailed discussion of the properties of the hydrogeologic units is given in Section 6.3.1.1.5, and in Montazer and Wilson (1984).

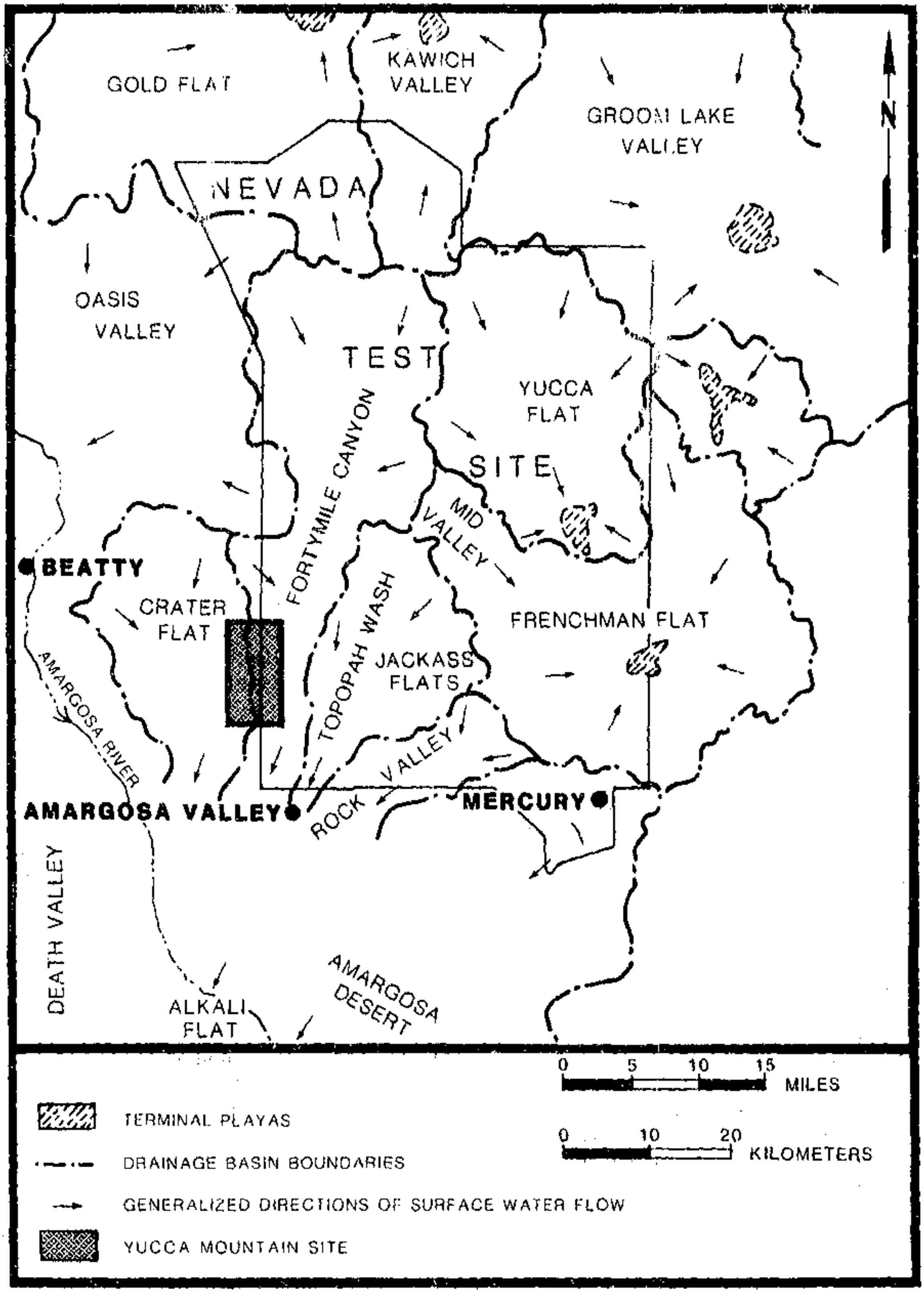

Figure 3-11. Drainage basins in the Yucca Mountain area showing direction of flow of surface water. Modified from ERDA (1977).

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Table 3-3. Dual classification of Tertiary volcanic rocks at Yucca Mountain: stratigraphic units reflect origin and hydrogeologic units reflect hydrologic properties[a]

Stratigraphic unit		Tuff lithology[b]	Hydrogeologic unit[c]	Saturated matrix hydraulic conductivity	Comments
Alluvium		- - -	Alluvium	Generally high	Underlies washes, thin layer on flats
Paintbrush Tuff	Tiva Canyon Member	MD	Tiva Canyon welded unit	1 mm/yr	Caprock that dips 5-10° eastward at Yucca Mountain. High fracture density
Paintbrush Tuff	Yucca Mountain Member	NP, B	Paintbrush nonwelded unit	3300 mm/yr	Vitric, nonwelded, porous, poorly indurated, bedded in part. Low fracture density
Paintbrush Tuff	Pah Canyon Member	NP, B	Paintbrush nonwelded unit	3300 mm/yr	
Paintbrush Tuff	Topopah Spring Member	MD	Topopah Spring welded unit	0.[illegible] mm/yr[d]	Densely to moderately welded, several lithophysal cavity zones, intensely fractured. Central and lower part is potential host rock for repository. Bulk hydraulic conductivity in saturated zone east of the site (at well J-13) about 1.0 m/day
Tuffaceous beds of Calico Hills		NP, B (Vitric / Devitrified (in part zeolitic))	Calico Hills nonwelded unit	Vitric 10[illegible] mm/yr[d]; Zeolitic 0.5 mm/yr[d]	Beneath Yucca Mountain, base of units for unsaturated zone determined by water table. Calico Hills nonwelded unit is vitric in southwest Yucca Mountain, zeolitic in east and north. Zeolitic boundary generally parallels the water table with vitric units above and zeolitic units below a transitional boundary
Crater Flat Tuff	Prow Pass Member	MD	PP_w	88 mm/yr[d]	
Crater Flat Tuff	Prow Pass Member	NP, B	PP_n	22 mm/yr[d]	
Crater Flat Tuff	Bullfrog Member	MD	BF_w	118 mm/yr[d]	
Crater Flat Tuff	Bullfrog Member	NP, B	BF_n / Crater Flat Member	22 mm/yr[d]	
Crater Flat Tuff	Tram Member	NP, B	Crater Flat Member	2[illegible] mm/yr	None
Lava		Undifferentiated	Undifferentiated	Very low	Occurs in northwest part of repository block.
Lithic Ridge Tuff		Undifferentiated	Undifferentiated	Very low	None
Older volcanics		Undifferentiated	Undifferentiated	Very low	In USW H-1 hydraulic head about 50 m higher than water table
Pre-Tertiary Rocks		Undifferentiated	Undifferentiated	Unknown	Occurs 2.5 km east of proposed repository at depth of 1250 m in UE-25p#1 where hydraulic head is about 20 m higher than water table. Bulk hydraulic conductivity high, probably due to high fracture density.

Note: in the diagram, the water table (dashed diagonal line) separates the unsaturated units above from the saturated zone below: "Water Table", "Saturated Zone".

[a]Data from Montazer and Wilson (1984) except as indicated.

[b]NP = nonwelded to partially welded; MD = moderately to densely welded; B = bedded.

[c]Hydrogeologic unit symbols: PP_w = Prow Pass welded unit; PP_n = Prow Pass nonwelded unit; BF_w = Bullfrog welded unit; BF_n = Bullfrog nonwelded unit.

[d]Data from Sandia National Laboratories Tuff Data Base (SNL, 1985).

3.3.2.1 Ground-water movement

The unsaturated zone within the boundary of the primary repository area at Yucca Mountain is about 500 to 750 meters (1,600 to 2,500 feet) thick, but thins to about 200 meters (656 feet) thick 10 kilometers (6.2 miles) away from Yucca Mountain. Within the primary repository area, the local water-table slopes to the southeast, from an elevation of 800 meters (2,600 feet) to as low as 730 meters (2,400 feet) above sea level (see Figure 6-3 for a water-table contour map). The water table is 200 to 400 meters (656 to 1,300 feet) below the horizon proposed for the repository (see Section 6.3.1.1 for a detailed discussion).

Most of the annual precipitation, approximately 150 millimeters (5.9 inches) (Montazer and Wilson, 1984) is returned to the atmosphere by evaporation and plant transpiration. A small part of the precipitation that falls on Yucca Mountain percolates through the matrix of the unsaturated zone. Czarnecki (1985) estimated a recharge rate of about 0.5 millimeter per year (0.02 inch per year) for the precipitation zone that includes Yucca Mountain. Section 6.3.1.1.5 describes the approaches used to estimate flux through the unsaturated zone as well as recharge. The principal source of recharge for the tuff aquifer is probably Pahute Mesa to the north and northwest of Yucca Mountain (Figure 3-2). The general direction of regional ground-water flow is south-southeast toward points of natural discharge at Alkali Flat and perhaps Furnace Creek in Death Valley.

The depth to the carbonate aquifer beneath the primary repository area has not been determined, but it is probably much more than the 1,250 meters (4,100 feet) observed in drill hole UE-25p#1 located 2.5 kilometers (1.5 miles) east of the primary area. At drill hole UE-25p#1, the hydraulic head in the carbonate rocks is 20 meters (66 feet) higher than in the over-lying tuffaceous rocks (Waddell et al., 1984). Because water cannot move in the direction of higher hydraulic head, it is concluded that ground water in the tuff aquifers beneath Yucca Mountain does not enter the carbonate aquifer.

Deep regional movement of ground water south and east of Yucca Mountain occurs chiefly through the lower carbonate aquifer. This aquifer is composed of highly fractured and locally brecciated Middle Cambrian to Late Devonian limestone and dolomites that are moderately to highly transmissive (Winograd and Thordarson, 1975). Because of complex geologic structure, flow paths in the lower carbonate aquifers are complex and are poorly defined. In places the ground-water flow is diverted laterally or vertically because of fault displacements that have juxtaposed the lower carbonate aquifer against less permeable rocks. Where the flow is blocked, such as at Ash Meadows in the southern Amargosa Desert, intersection of the water table with the land surface causes springs (Waddell et al., 1984).

3.3.2.2 Ground-water quality

Schoff and Moore (1964) recognized three types of ground water at the Nevada Test Site and in its vicinity: (1) sodium and potassium bicarbonate, which generally occurs in tuff aquifers and valley-fill aquifers composed chiefly of tuff detritus; (2) calcium and magnesium bicarbonate, which generally occurs in the carbonate aquifers and the valley-fill aquifers composed chiefly of carbonate detritus; and (3) mixed, which is defined as having the chemical characteristics of both type 1 and type 2.

Ground-water chemistry is predominantly controlled by the tuffs and the carbonates. Other rocks present are either considerably less reactive or of such low abundance that they contribute little to the water chemistry. The change in water quality with time in the tuffaceous aquifers was described by Claassen and White (1979) and is summarized as follows:

1. Recharging water obtains carbon dioxide (CO_2) by nonequilibrium processes.

2. Reaction of dissolved CO_2 with vitric tuff occurs by both ion-exchange and ion-diffusion processes.

3. At the same time as number 2 above, chemical precipitation of authigenic phases occurs if suitable surfaces are available for nucleation sites.

The above processes contribute to the excellent quality of water in the tuffaceous aquifers. Recent chemical analyses of ground water from a borehole near the proposed exploratory shaft site (Figure 3-6; borehole USW G-4) are summarized by Bentley (1984). This water, drawn from the tuffaceous aquifer, would be expected to be most similar to ground-water type 1 above. It has 216 milligrams per liter of dissolved solids, a pH of 7.7, and relatively high concentrations of silica (45 milligrams per liter), sodium (57 milligrams per liter), and bicarbonate (143 milligrams per liter). In general, water in the tuffaceous aquifers under Yucca Mountain meets U.S. Environmental Protection Agency secondary standards in major cations and anions and the primary standards for deleterious constituents. The water could be used for all purposes; domestic, stock, municipal supply, irrigation, or industrial uses.

3.3.3 PRESENT AND PROJECTED WATER USE IN THE AREA

Water in southern Nevada (excluding the Las Vegas area) is used chiefly for irrigation and to a lesser extent for livestock, municipal needs, and domestic supplies. Almost all the required water is pumped from the ground, although some springs supply water to establishments in Death Valley and other areas south of Yucca Mountain (Pistrang and Kunkel, 1964; Hunt et al., 1966; Thordarson and Robinson, 1971). Springs in Oasis Valley near Beatty, Nevada, about 30 kilometers (20 miles) northwest of Yucca Mountain, are a significant source of water for public and domestic needs and for irrigation (Thordarson and Robinson, 1971; White, 1979). (See Section 3.6.3 for the amounts of water used annually by towns and communities in the vicinity of Yucca Mountain.) The ground water in the tuff aquifer underlying Yucca Mountain (see figures 2-5 and 2-6) is part of the Alkali Flat-Furnace Creek Ranch ground-water basin, which discharges in Alkali Flat or Death Valley (Waddell, 1982). This aquifer becomes shallower to the south, and the flow is through alluvium rather than tuff. Wells that are located between Yucca

Mountain and Death Valley are likely to be pumping ground water from this same tuff-alluvium aquifer. Total water use during repository siting, construction, operation, and decommissioning is estimated to average 0.4×10^6 cubic meters (350 acre-feet) per year over a 60-year period (Morales, 1985) and is expected to cause only a very localized drawdown of the regional water table. Well J-13 has yielded as much as 1.26×10^6 cubic meters per year in pumping tests, and over 18 years of intermittent pumping, the water level has stayed about the same (Thordarson, 1983).

The principal water users in the area closest to the Yucca Mountain repository site are in the Amargosa Desert in and around the Town of Amargosa Valley and in the Pahrump Valley. In 1979 the State Engineer designated the Amargosa Desert ground-water basin, which encompasses a large part of the Alkali Flat-Furnace Creek Ranch basin and a small part of the Ash Meadows basin (Figure 2-5). According to the Nevada Department of Conservation and Natural Resources (Coache, ca. 1983), 11.23×10^6 cubic meters (9,105 acre-feet) were used for irrigation in the Amargosa Desert ground-water basin in 1983. In considering permit applications, the Nevada State Engineer has assumed consumptive use of 0.0062×10^6 cubic meters (5 acre-feet) per irrigated acre (Morros, 1982). Therefore, about 737 hectares (1,820 acres) were under irrigation in the Amargosa Desert in 1983. This represents a slight decline from the 800 hectares (2,000 acres) reported by the Office of the State Engineer (1974) for 1969. In 1983 industrial, commercial, and quasi-domestic water use in the Amargosa Desert ground-water basin were 1.0×10^6 cubic meters (850 acre-feet), 0.025×10^6 cubic meters (20 acre-feet), and 0.25×10^6 cubic meters (200 acre-feet), respectively (Coache, ca. 1983). As is discussed in Section 3.6.3.3, about 0.5×10^6 cubic meters (400 acre-feet) were used by domestic wells. Total water use in the Amargosa Desert ground-water basin was therefore about 13.0×10^6 cubic meters (10,580 acre-feet). This represents about 44 percent of the total sustained yield of aquifers in the basin (Morros, 1982) (see Section 3.6.3.3).

Certified appropriations and development permits for ground water in the Pahrump Valley totaled 112×10^6 cubic meters (91,000 acre-feet) per year in 1970 although in recent years actual exploitation has averaged about 49×10^6 cubic meters (40,000 acre-feet) per year. In the last ten years, real estate developers have purchased agricultural land (with appurtenant water rights) for constructing homes in subdivisions, and so water use has changed from agricultural to domestic. As is discussed in Section 3.6.3.3, aquifers in the Pahrump Valley could support up to about 16,900 residents with no decline in usable storage, although local effects, such as land subsidence and well interference, could result from sustained development.

From 1967 to 1970, an extensive well field was developed for irrigation in the Ash Meadows area along the east side of the Amargosa Desert. The Desert Pupfish Task Force, consisting of representatives of the National Park Service, and Bureau of Reclamation, the Bureau of Land Management, the Bureau of Sport Fisheries and Wildlife, and the U.S. Geological Survey, requested a study to determine the potential effects of such development on the habitat of the pupfish. A study by the U.S. Geological Survey (Dudley and Larson 1976) concluded that withdrawals of ground water from parts of this well field caused a 0.8-meter (2.5-foot) reduction in the water level in the pool in nearby Devils Hole, thereby threatening the survival of the Devils Hole pupfish (Cyprinodon diabolis). Subsequent law suits and a final ruling by the U.S. Supreme Court in 1976 (Cappaert v. United States, 1976) ordered a restriction in pumping from specific wells in the Devils Hole area.

The mining industry in southern Nevada uses a small amount of water for processing. Water for this purpose is supplied from nearby shallow wells or is trucked in from nearby towns. Many of the mines currently recycle process water, which reduces their consumptive water demand.

3.4 ENVIRONMENTAL SETTING

This section contains a description of existing land use, ecosystems, air quality, noise, aesthetics, archaeological resources, and the radiological background of Yucca Mountain and the surrounding region. The data provide a baseline for assessing potential impacts during site characterization (Chapter 4) and during construction, operation, and decommissioning if Yucca Mountain is selected for a repository (chapters 5 and 6).

3.4.1 LAND USE

Land use in the vicinity of Yucca Mountain includes Federal use, agriculture, mining, recreation, and private and commercial development. These uses are discussed in the following sections. Land-use patterns in southwestern Nevada are shown in Figure 3-12.

3.4.1.1 Federal use

The Yucca Mountain site is on Federal land controlled by three Federal agencies. As shown on Figure 3-12, the Nellis Air Force Range includes 10,670 square kilometers (4,120 square miles) controlled by the U.S. Department of the Air Force, the Nevada Test Site (NTS) includes 3,500 square kilometers (1,350 square miles) controlled by the U.S. Department of Energy, and many thousands of square kilometers are controlled by the Bureau of Land Management (BLM).

The Nellis Air Force Range is used for military weapons testing and personnel training. The portion of the range in the immediate vicinity of Yucca Mountain is reserved for overflights and provides air access to the bombing and gunnery areas located north and west of Yucca Mountain. Land use at the NTS supports nuclear-weapons research and development. The site is dedicated to underground nuclear testing, development and testing of nuclear explosives for peaceful applications, and testing of weapon effects. The BLM applies a multiple use concept in administering the public domain lands and forests. These lands are currently used for recreation, grazing, forest management, and wildlife management.

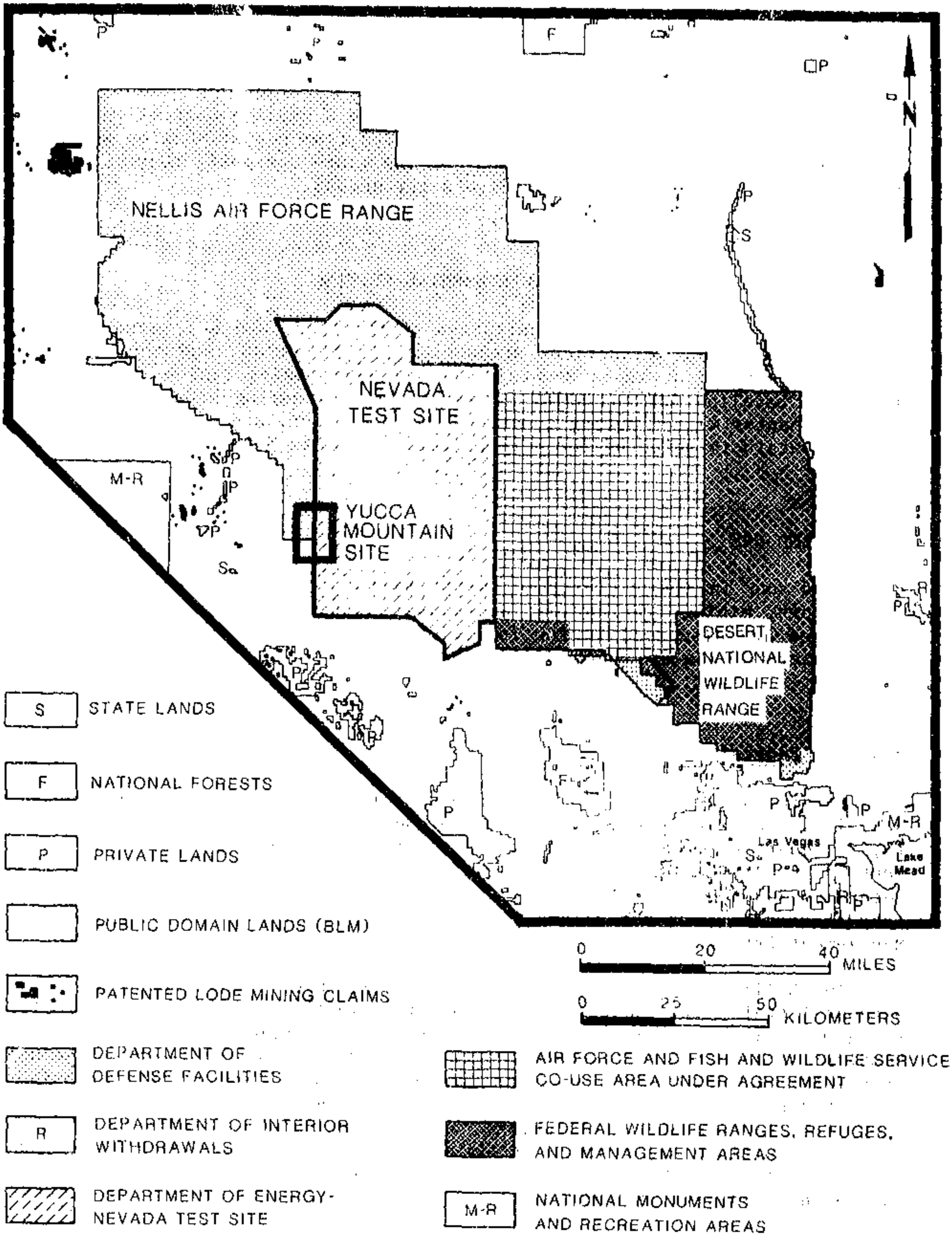

Figure 3-12. Land use in southern Nevada. Modified from Lutsey and Nichols (1972).

3.4.1.2 Agriculture

A limited amount of agriculture is supported in the Oasis Valley, the Amargosa Desert, the Ash Meadows area, and the Pahrump Valley. None of these areas is considered to contain prime agricultural land. A portion of the extensive Bureau of Land Management lands in southern Nye County is used for cattle grazing; these lands are considered the major agricultural resource near the site (Collins et al., 1982).

3.4.1.2.1 Grazing land

The Bureau of Land Management controls large parcels of range land south and west of the site, portions of which are leased for cattle grazing. Five leases exist near the site (Figure 3-13). With two exceptions, no grazing leases have been issued for lands lying north or east of U.S. Highway 95 from Las Vegas to Tonopah. No grazing leases have been issued for Yucca Mountain.

3.4.1.2.2 Cropland

Blocks of private land in the Amargosa Desert, Oasis Valley, Ash Meadows area, and Pahrump Valley contain the only farming and ranching operations in the region. Extensive cultivation is only found in the Amargosa Desert and Pahrump Valley. An informal poll conducted by the Department of Agriculture County Cooperative Extension agent in Pahrump indicates that farms located south of Beatty had a total of 3,850 hectares (9,500 acres) under irrigation in July 1981 distributed as follows: 2,430 hectares (6,000 acres) alfalfa, 810 hectares (2,000 acres) irrigated pasture, 325 hectares (800 acres) cotton, 130 hectares (320 acres) small grains, 97 hectares (240 acres) Sudan grass, 25 hectares (60 acres) turf, 25 hectares (60 acres) orchard, and 8 hectares (20 acres) melons (Collins et al., 1982).

3.4.1.3 Mining

There are 17 active mines and mills in southern Nevada. Most of the mining operations employ fewer than 10 workers per mine, although a few operations employ as many as 250 workers. The mineral resources in the area near Yucca Mountain are described in Section 3.2.4. The mining operations in the vicinity of Yucca Mountain are described in Table 3-2.

3.4.1.4 Recreation

Recreational land uses are abundant in southern Nevada. In general, the camping and fishing sites in the northern part of the region are used during spring, summer, and fall, and those in the southern part are used throughout the year. The Desert National Wildlife Range, approximately 100 kilometers (60 miles) from the Yucca Mountain site by air is a joint-use area by the

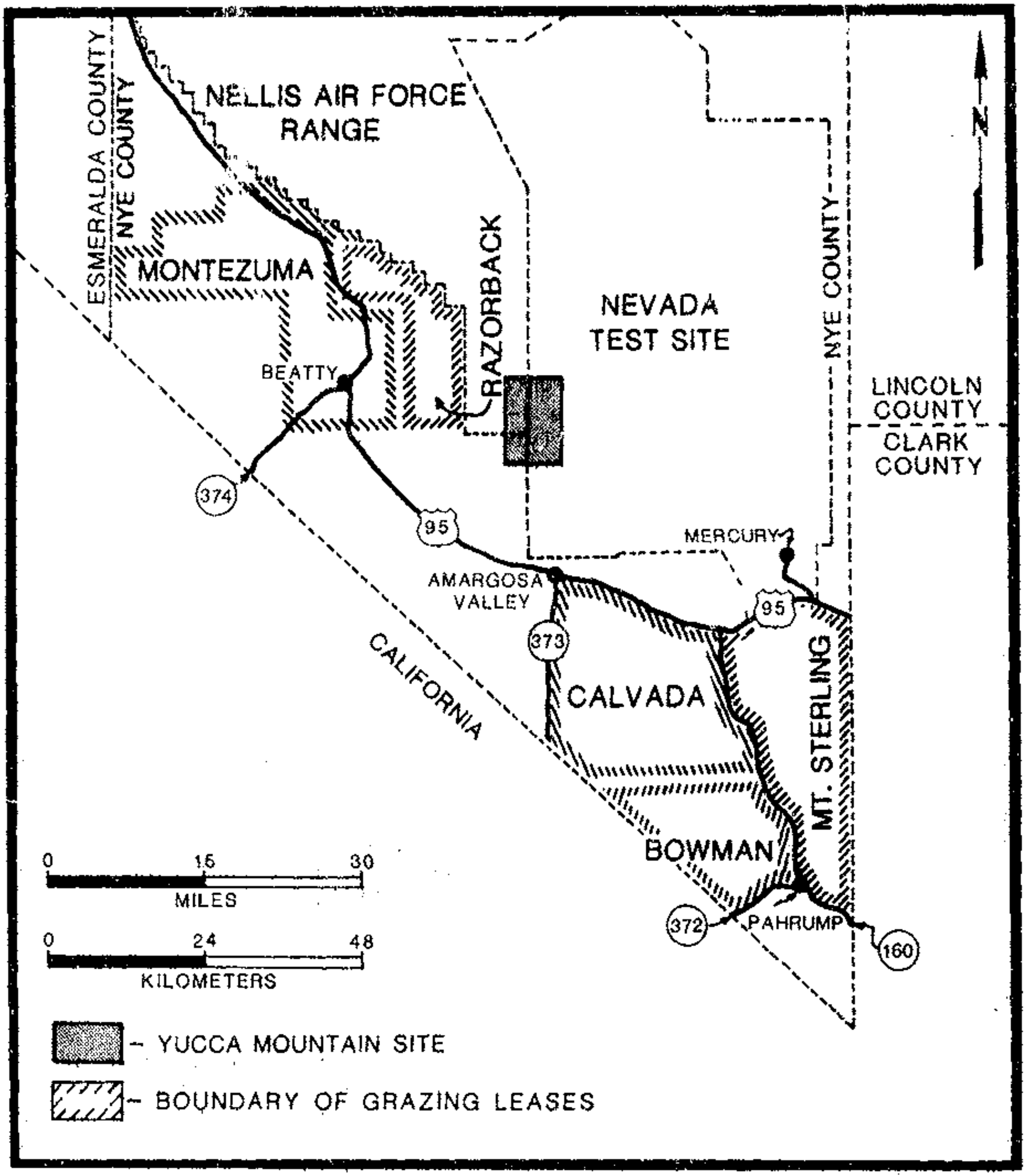

Figure 3-13. BLM grazing leases near the Yucca Mountain site. Modified from Collins et al. (1982).

U.S. Department of the Air Force and the U.S. Fish and Wildlife Service, and provides some recreational opportunities.

The Mojave Desert in California, which includes Death Valley National Monument, extends along the southwestern border of Nevada. The boundary of Death Valley National Monument, which extends into Nevada, lies approximately 30 to 40 kilometers (20 to 25 miles) west and southwest of the Yucca Mountain Site (Figure 3-12). The National Park Service estimates that the population within the Monument boundaries ranges from a minimum of 900 permanent residents during the summer months to as many as 35,000 tourists per day during the major holiday periods in the winter months. Up to 80,000 tourists have visited Death Valley during the Death Valley 49ers Encampment Weekend in November. The Spring Mountains to the southeast of Yucca Mountain (Figure 3-2) are also a major recreational area. Floyd R. Lamb State Park is located about 16 kilometers (10 miles) north and east of Las Vegas, and is about 2 kilometers (1 mile) north of U.S. Highway 95.

3.4.1.5 Private and commercial development

Most private and commercial developments in the region are in the Las Vegas Valley (Figure 3-12). Private lands are scarce in the vicinity of Yucca Mountain and are located in the following areas (figures 3-12 and 3-13):

1. Amargosa Desert - 600 hectares (1,500 acres).

2. Town of Amargosa Valley - acreage at intersection of U.S. Highway 95 and State Route 373 and in the valley stretching southward from this intersection.

3. Beatty - limited acreage along U.S. Highway 95 and State Route 374.

4. Indian Springs - limited acreage along U.S. Highway 95.

5. Pahrump and Pahrump Valley - planned community development in the Pahrump Valley:

   - Johnnie Townsite, about 65 hectares (160 acres) (sec. 36, T. 17 S., R. 52 E., and sec. 1, T. 18 S., R. 52 E.).
   - Forty Bar Estates, planned to be more than 40 hectares (100+ acres) (secs. 7 and 8, T. 17 S., R. 52 E.).

6. Oasis Valley - unknown acreage.

There are no subdivisions planned for the Ash Meadows areas. The U.S. Fish and Wildlife Service recently purchased all the private land in the Ash Meadows areas that was being considered for development.

3.4.2 TERRESTRIAL AND AQUATIC ECOSYSTEMS

An extensive literature review was performed in 1981 to determine the current state of knowledge about the ecological characteristics of the Yucca Mountain area (Collins et al., 1981, 1982). Based upon the review findings, a field study was initiated in 1982 to gather data on the ecological characteristics of the study area outlined in Figure 3-14 (O'Farrell and Collins, 1983, 1984; Collins and O'Farrell, 1985). The findings of the literature review and subsequent field studies are summarized in the following sections.

3.4.2.1 Terrestrial vegetation

The southwestern Nevada Test Site (NTS) encompasses three floristic zones: (1) the Mojave Desert, which is a warm dry desert occurring below an elevation of 1,200 meters (4,000 feet); (2) the Great Basin Desert, which is a relatively cooler and wetter desert occurring at elevations above 1,500 meters (5,000 feet); and (3) the transition zone, often called the Transition Desert, which extends in a broad east-west corridor between the Mojave and Great Basin deserts at elevations of between 1,200 and 1,500 meters (4,000 and 5,000 feet). Literature reviews indicated that the following five major vegetation associations occur in the southwest portion of the NTS within the three floristic regions: Larrea-Ambrosia (creosote bush-bursage), Larrea-Lycium-Grayia (creosote bush-boxthorn-hopsage), Coleogyne (blackbrush), Artemisia (sagebrush), and Artemisia-pinyon-juniper.

During 1983, field studies were conducted to determine the distribution and species composition of the major floral and faunal associations at Yucca Mountain. Associations were named after the shrubs that dominate them on the basis of canopy coverage and numerical density. Four groups of undisturbed vegetation associations were recognized: (1) those in which Larrea tridentata and Ambrosia dumosa were common, (2) those in which Larrea was present but Ambrosia was not, called Larrea-Ephedra or Larrea-Lycium, (3) those in which Coleogyne ramosissima was prevalent, and (4) mixed transition associations in which both Larrea and Coleogyne were absent.

In addition, a grassland-burn association was described that occupies an old burn site. Detailed lists of the species composition can be found in O'Farrell and Collins (1984).

3.4.2.1.1 Larrea-Ambrosia

An association dominated by Larrea tridentata and Ambrosia dumosa exists on bajadas (an area of coalescing alluvial fans) on the southeastern side of the study area (Figure 3-14). The association generally occurs below elevations of 1,100 meters (3,600 feet) (O'Farrell and Collins, 1984) in loose soils either with or without pavements of small rocks. Larrea-Ambrosia is at its upper elevational limit and contains elements of Transition Desert vegetation.

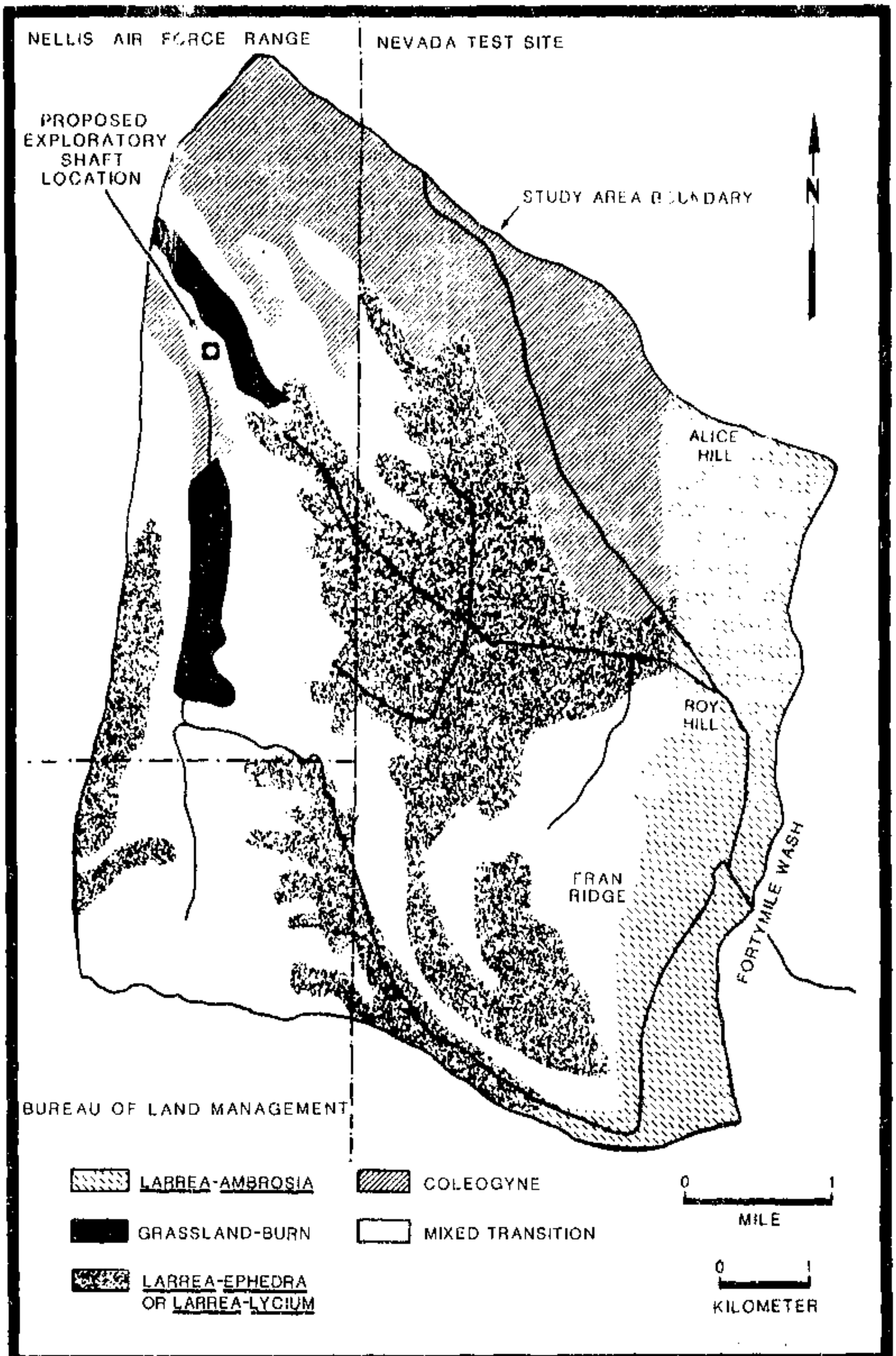

Figure 3-14. Distribution of major vegetation association groups on Yucca Mountain. Modified from O'Farrell and Collins (1984).

3.4.2.1.2 Larrea-Ephedra or Larrea-Lycium

These associations predominate on the eastern bajadas of central Yucca Mountain at elevations ranging from 1,000 to 1,300 meters (3,400 to 4,300 feet). Relief is generally low to moderate, and soils are rocky with an imperfectly developed surface pavement. These associations are absent on upper bajadas and at the bases of high hills or mountains where slopes begin to steepen sharply, but are present along drainages in mountainous areas.

3.4.2.1.3 Coleogyne

Vegetation in which Coleogyne ramosissima predominates occurs in two distinct locations: (1) on the tops of the larger, flatter ridges of the northern portion of the study area, including the northern portion of Yucca Mountain, and (2) on the bajada south of Pinnacles Ridge and east of Prow Pass in the upper Yucca Wash drainage. This association is an indicator of and is restricted to the Transition Desert. Coleogyne favors sites with moderate- to low-slope angles and does not occur on steep, rocky, or boulder-strewn slopes. Coleogyne is absent where relatively level ridge tops give way to steep, rocky slopes. Desert pavements are often well developed on bajadas where Coleogyne occurs. Coleogyne tends to form near monocultures having few associated species. Bromus rubens, an introduced winter annual grass, does not occur in the thick stands that usually characterize Coleogyne in other parts of the Nevada Test Site.

3.4.2.1.4 Mixed transition

This vegetation association is actually a mosaic of local associations dominated by a variable mixture of shrubs including: Ephedra nevadensis, Eriogonum fasciculatum, Grayia spinosa, Haplopappus cooperi, Hymenoclea salsola, Lycium andersonii, and Psorothamnus fremontii (O'Farrell and Collins, 1984). Mixed transition associations occur on upper bajadas and slopes above the Larrea dominated associations. It is the dominant vegetation on slopes and ridge tops throughout the southern and central sections of Yucca Mountain (Figure 3-14). The large variability of the microhabitat associated with this vegetation probably accounts for its heterogeneity.

3.4.2.1.5 Grassland-burn site

A large portion of the ridge top of central Yucca Mountain was burned either shortly before or in 1978. This burn, which extended for 2.3 kilometers (1.4 miles) and occupied 77 hectares (190 acres), is old enough that a community of perennial and annual grasses with only scattered shrubs has had time to develop. Composition of the original vegetation was difficult to determine because dense Coleogyne existed at the northern boundary of the burn, but at the southern boundary a diverse mixed transition community with only scattered Coleogyne predominated. Coleogyne has a higher susceptibility to fire, and it most likely predominated throughout most of the site prior to the burn.

A more recent burn covering 15 hectares (38 acres) occurred on a small ridge northwest of Yucca Ridge. The former vegetation was certainly Coleogyne since this association occurs at the edges and in scattered unburned patches throughout the burn. Charred shrub stumps are still standing, and there is some sprouting from stumps. The vegetation consists mainly of herbaceous species, primarily grasses. These two burns comprise 1.8 percent of the study area.

3.4.2.2 Terrestrial wildlife

3.4.2.2.1 Mammals

Of the 46 mammal species expected to occur within the study area (Collins et al., 1982), 17 were found during actual field studies (O'Farrell and Collins, 1983, 1984). Rodents account for over half of the observed mammal species. Activity patterns, food habits, population dynamics, life spans, and home ranges are well documented for the small mammals of the area (Jorgensen and Hayward, 1965).

A live-trapping program was used in 1982 and 1983 to determine the species composition and relative abundance of small mammals (less than 200 grams) in the major vegetation associations (O'Farrell and Collins, 1983, 1984). Eleven species were trapped. Merriam's kangaroo rat (Dipodomys merriami) and the long-tailed pocket mouse (Perognathus formosus) were the most abundant and widespread species. Merriam's kangaroo rat predominated at lower elevations in bajada habitats. Long-tailed pocket mice, although present in most habitats, were the dominant species only at higher elevations, in canyons, and on ridges, where soils were rocky. Deer mice (Peromyscus maniculatus), little pocket mice (Perognathus longimembris), and canyon mice (Peromyscus crinitus) were the most common associated species. Species diversity was fairly consistent, with six or seven species consistently trapped in all undisturbed vegetation associations.

Black-tailed jackrabbits and desert cottontails were found to be the most conspicuous and wide ranging of the larger mammals. The coyote was the most widely distributed and the most numerous carnivore. Evidence of mule deer was observed at all elevations and in all vegetation associations sampled. However, there were concentrations of sign both in sheltered upper canyons on the eastern slope of Yucca Mountain and along some ridge lines that may represent access routes. Scats were fresh and in various states of decomposition and had been deposited by both adults and fawns. Skeletal material of adults and a fawn were also observed. Sightings and fresh sign of deer decreased in late spring (O'Farrell and Collins, 1983).

Burro tracks and scats of various ages were observed throughout the project area except in the lower elevations of the Larrea-Ambrosia vegetation association. Yucca Mountain ridge and the valley along the southern boundary of the field study area contained significant concentrations of fresh sign. However, the highest concentrations were observed in Solitario Canyon (which is also called Hinge Fault Valley in several publications) where a herd of about 20 burros was observed. No evidence of bighorn sheep was found in the area.

3.4.2.2.2 Birds

The literature describes the avifauna on the Nevada Test Site (NTS) (Hayward et al., 1963). Sixty-six species of birds are recorded as either seasonal or permanent residents in the area. Many other species visit the area briefly during spring and fall migration. There are 27 permanent breeding residents, most of whom inhabit sagebrush-pinyon-juniper vegetation, and a number of more widely distributed spring and summer residents. The NTS is a winter feeding ground for large flocks of migrating passerine birds (sparrows and finches). Several species remain as winter residents because disturbed areas have an abundance of tumbleweed seed, which is an important winter food source. Migratory waterfowl and shore birds frequent the temporary lakes formed by precipitation runoff in Yucca and Frenchman playas.

During the 1982 site-specific investigations (O'Farrell and Collins, 1983), 35 species of birds were recorded. Black-throated sparrows (Amphispiza bilineata) were observed most frequently. Rock wrens (Salpinctus obsoletus) were also observed at all elevations, especially in rocky habitats and along washes. Mourning doves (Zenaida macroura) arrived during the first week in May and bred at the site. Common ravens (Corvus corax) were also conspicuous residents, although they were not present in large flocks.

Six species of raptorial birds were observed, but sightings were infrequent. A red-tailed hawk (Buteo jamaicensis) was nesting in the study area. No waterfowl or suitable habitats for waterfowl were found.

3.4.2.2.3 Reptiles

Eight species of lizards, one tortoise specie (Gopherus agassizii), and four species of snakes have been recorded (O'Farrell and Collins, 1983). The side-blotched lizard (Uta stansburiana) and western whiptails (Cnemidophorus tigris) were the most frequently observed and ubiquitous lizard species; the former was observed ten times more frequently than the latter species. Coachwhips (Masticophis flagellum); speckled rattlesnakes (Crotalus mitcheli); gopher snakes (Pituophis melanoleucus); and western shovel-nosed snakes (Chionactis occipitalis) were the only species of snakes observed, and they were seen infrequently. No amphibians were discovered.

3.4.2.3 Special-interest species

No plant or animal on the Nevada Test Site (NTS) or in the study area (Figure 3-14) is currently listed, nor have any been officially proposed for listing, under the Endangered Species Act of 1973. Therefore, there are no areas designated as critical habitats in the study area. The Mojave fishhook cactus and desert tortoise which occur in the study area are being reviewed for possible addition to the list of Endangered and Threatened Species (USFWS, 1983b; USFWS, 1985a). Both are classified under Category 2, "... taxa for which information now in possession of the Service indicates that proposing to list as endangered or threatened is possibly appropriate, but for which conclusive data on biological vulnerability and threat are not currently available to support proposed rules." Six species of birds including the white-faced ibis (Plegadis chihi), Swainson's hawk (Buteo swainsoni), ferruginous hawk (Buteo regalis), western snowy plover (Charadrius alexandrinus nivosus), mountain plover (Charadrius montanus), and the long-billed curlew (Numenius americanus) have been recorded on the NTS (O'Farrell and Emery, 1976) but were never observed on the study area. They have also been classified as Category 2 species under consideration for possible listing (USFWS, 1985a). The range of the spotted bat (Euderma maculatum), a Category 2 mammal (USFWS, 1985a), includes the NTS but the species has never been observed there. The desert tortoise is a State-protected species, designated as rare.

The Mojave fishhook cactus, Sclerocactus polyancistrus, which was distributed on the rocky ridges of Yucca Mountain (Figure 3-15), was more abundant than published information would suggest. Its areal distribution included the top of Yucca Mountain and the entire western slope to the western boundary of the study area (Figure 3-15). Twenty-two live and a number of dead Sclerocactus individuals were recorded during 40 kilometers (25 miles) of surveys in Solitario Canyon. Most were found in the middle and southern portions of the Canyon. Eleven were recorded in 20 kilometers (13 miles) of transects on Yucca Ridge; 8 of the 11 were found together on the extreme southern portion of Yucca Ridge. The density of Sclerocactus observed on Yucca Ridge was significantly lower than the density in Solitario Canyon. No Sclerocactus were found during 34 kilometers (21 miles) of ridge surveys conducted on the eastern slope of Yucca Mountain; however, an archaeologist reported the presence of a Sclerocactus between Fran Ridge and Roy Hill (Figure 3-15).

The desert tortoise, Gopherus agassizii, ranges from northern Sinaloa, Mexico, into Arizona, California, southern Nevada, and southwestern Utah. Yucca Mountain is close to the northern range of the species. Evidence of the desert tortoise was observed throughout the project area to elevations of 1,600 meters (5,240 feet) (Figure 3-16); however, densities were estimated to be low (less than 20 per square mile) when compared with other parts of its range.

3.4.2.4 Aquatic ecosystems

No permanent or major sources of seasonal free water, and hence no riparian habitats, exist on Yucca Mountain. The larger washes and drainages within the area tend to contain a distinct flora consisting of species found only in washes and species that, although present in the surrounding vegetation, are most common in washes.

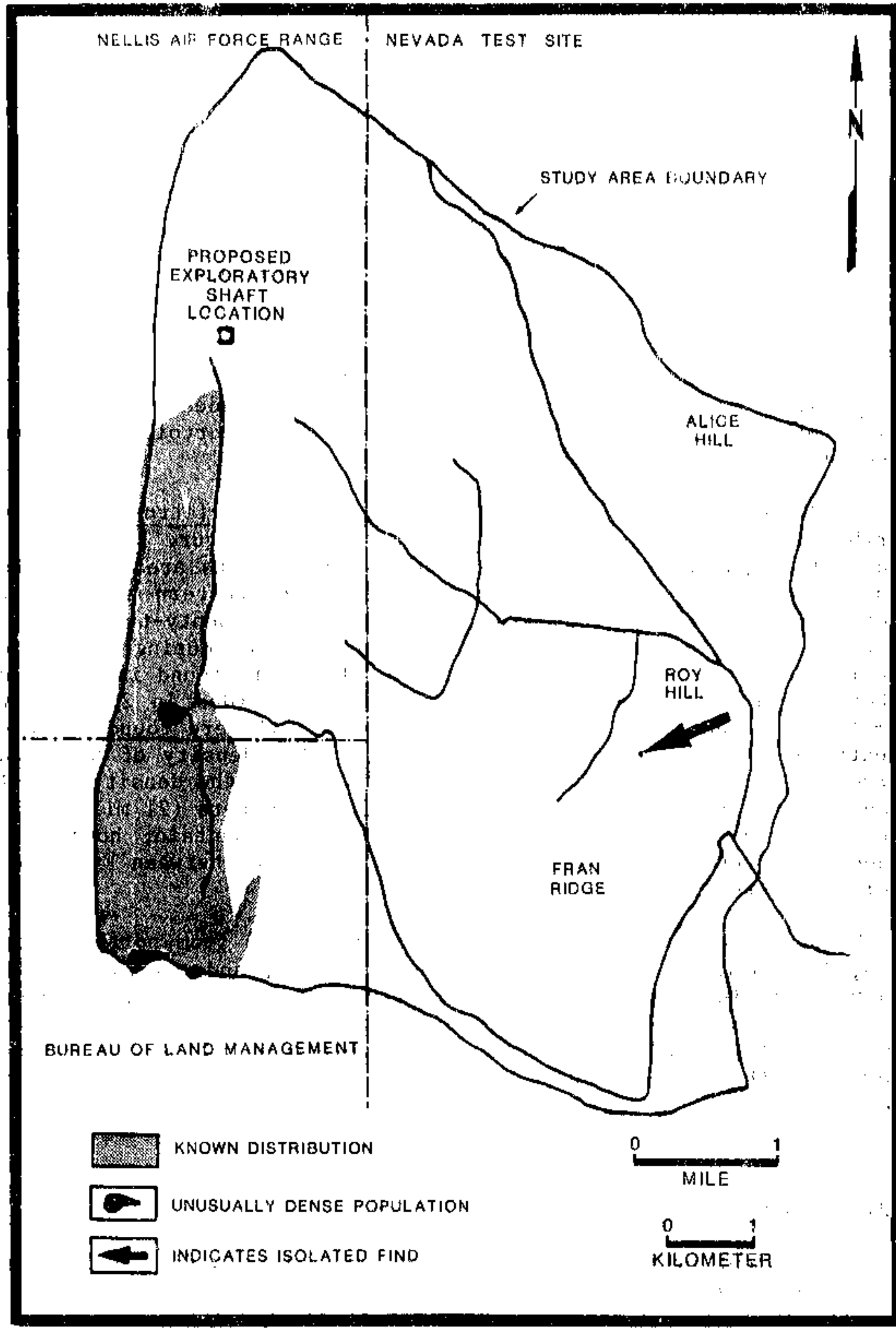

Figure 3-15. Distribution of Mojave fishhook cactus on Yucca Mountain. Modified from O'Farrell and Collins (1983).

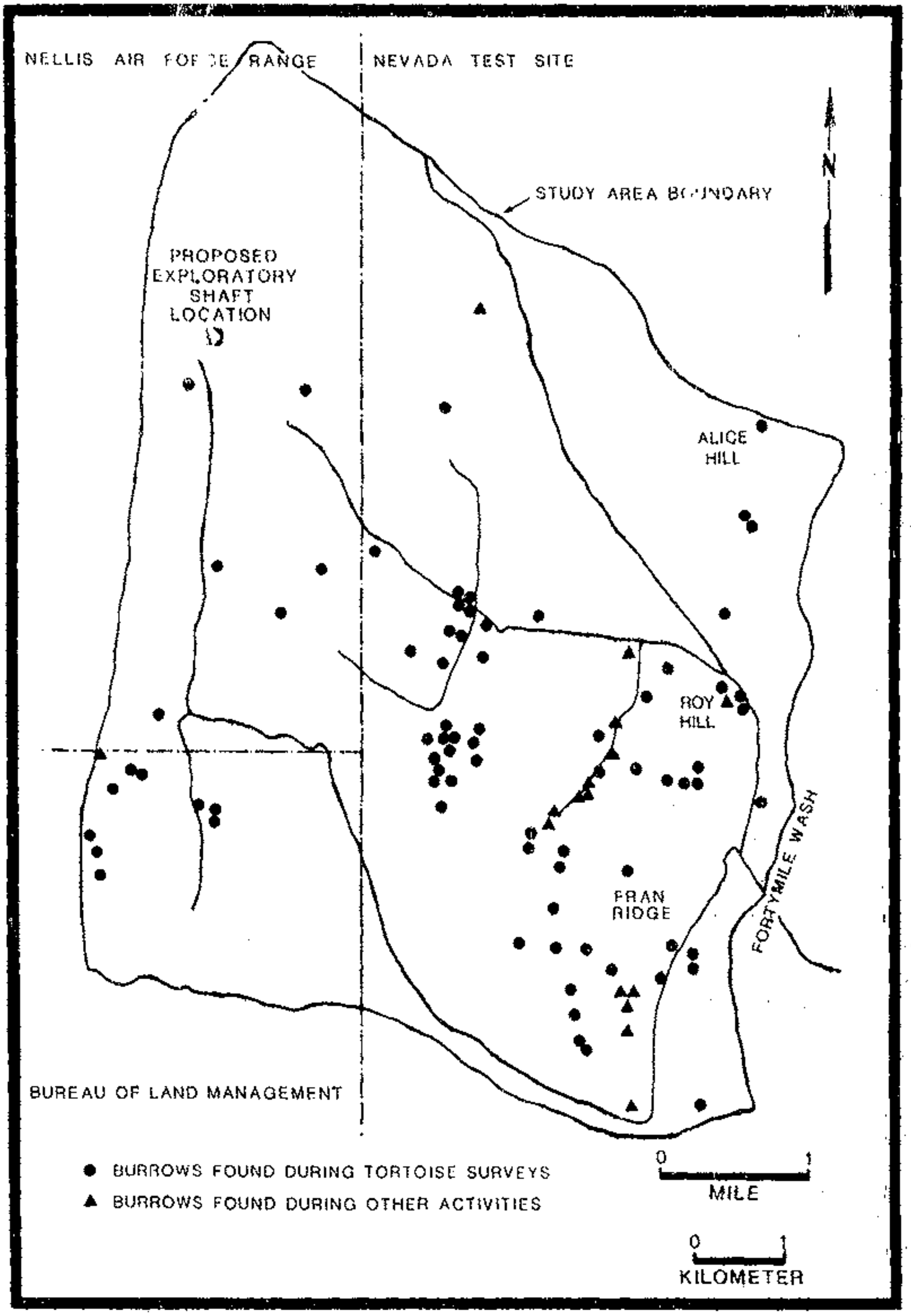

Figure 3-16. Distribution of desert tortoise burrows on Yucca Mountain. Modified from O'Farrell and Collins (1983).

Ash Meadows is about 40 kilometers (25 miles) south of Yucca Mountain and contains approximately 30 springs. These springs are fed by a different ground-water basin than that which underlies Yucca Mountain (Section 6.2.1.6). Relict populations of pupfish and many unusual endemic plants exist in these spring habitats, including four species of fish listed as endangered by the U.S. Fish and Wildlife Service (USFWS): Devils Hole pupfish, Cyprinodon diabolis; Warm Springs pupfish, Cyprinodon nevadensis pectoralis; Ash Meadows Amargosa pupfish, Cyprinodon nevadensis mionectes; and Ash Meadows speckled dace, Rhinichthys osculus nevadensis (USFWS, 1983a); seven endangered plants, Amargosa niterwort, Nitrophila mohavensis; Ash Meadows ivesia, Ivesia eremica; Ash Meadows sunray, Enceliopsis nudicaulis var. corrugata; spring-loving centaury, Centaurium namophilum; Ash Meadows blazing star, Mentzelia leucophylla; Ash Meadows milk vetch, Astragalus phoenix; and Ash Meadows gumplant, Grindelia fraxinopratensis; and an endangered insect, Ash Meadows naucorid, Ambrysus amargosus (DOI, 1984). Twelve species of endemic molluscs are candidates for possible listing as endangered or threatened species in the future (DOI, 1984), and the Ash Meadows vole (Microtus montanus nevadensis) has been classified as a Category 2 mammal which is being reviewed for possible addition to the list (DOI, 1984).

3.4.3 AIR QUALITY AND WEATHER CONDITIONS

The climate of the Yucca Mountain site and the surrounding area is characterized by high solar insolation, limited precipitation, low relative humidity, and large diurnal temperature ranges. The lowest elevations are characterized by hot summers and mild winters, which are typical of other Great Basin desert areas. As elevation increases, precipitation amounts increase and temperatures decrease.

Daily minimum temperatures sometimes deviate from this pattern because minimum temperatures occasionally occur at low elevations in closed topographic basins during calm, cloudless nights. Under these conditions, the ground surface cools quickly, thereby cooling the air near the surface. This cooler, denser air then drains down the terrain to form pools of cold air in closed topographic basins. These conditions generally dissipate quickly after sunrise when the ground surface is heated by the sun. Aside from these locally induced conditions, the overall weather patterns of the region are primarily influenced by continental air masses, which contain only limited amounts of moisture.

Meteorological data have been collected on the Nevada Test Site since 1956 at various locations. A 10-year climatological summary (1962 to 1971) for the weather station that was located at Yucca Flat is given in Table 3-4. Yucca Flat is approximately 40 kilometers (25 miles) northeast of Yucca Mountain. This summary is considered to be typical of conditions throughout the area, but local conditions may differ slightly because of site-specific influences. Because of its higher elevation, Yucca Mountain would be expected to have greater precipitation and lower temperatures than the Yucca Flat station.

Table 3-4. Climate summary for Yucca Flat, 1962-1971[a]

MONTH	TEMPERATURE[b] (°F)							DEGREE DAYS (Base 65°)		PRECIPITATION[b,c] (INCHES)											
	AVERAGES			EXTREMES													SNOW				
	DAILY MAXIMUM	DAILY MINIMUM	MONTHLY	HIGHEST	YEAR	LOWEST	YEAR	HEATING	COOLING	AVERAGE	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	GREATEST DAILY	YEAR	AVERAGE	GREATEST MONTHLY	YEAR	GREATEST DAILY	YEAR
JAN	52.1	20.8	36.5	73	1971	-2	1970	877	0	.53	4.02	1969	T	1971#	1.25	1969	0.9	4.3	1962	4.3	1962
FEB	56.7	25.8	41.3	77	1963	5	1971#	662	0	.84	3.55	1969	T	1967#	1.16	1969	1.9	17.4	1969	6.2	1969
MAR	60.9	27.7	44.3	87	1966	9	1969	634	0	.29	.60	1969	.02	1966	.38	1969	2.0	7.5	1969	4.5	1969
APR	67.8	34.4	51.1	89	1962	13	1966	411	1	.45	2.57	1965	T	1962	1.08	1965	0.7	3.0	1964	3.0	1964
MAY	78.9	43.5	61.2	97	1967	25	1967	147	38	.24	1.62	1971	T	1970#	.86	1971	0	T	1964	T	1964
JUN	87.6	49.9	68.8	107	1970	29	1971#	35	154	.21	1.13	1969	T	1971	.45	1969	0	0		0	
JUL	96.1	57.0	76.6	107	1967	40	1964#	0	366	.52	1.34	1966	0	1963	.77	1969	0	0		0	
AUG	95.0	58.1	76.6	107	1970	39	1968	1	368	.34	1.04	1965	0	1962	.35	1971#	0	0		0	
SEP	86.4	46.7	66.5	105	1971	25	1971	51	103	.68	2.38	1969	0	1968#	2.13	1969	0	0		0	
OCT	76.1	36.9	56.5	94	1964+	12	1971	266	9	.13	.45	1969	0	1967#	.42	1969	0	T	1971	T	1971
NOV	61.8	27.6	44.7	32	1962	13	1966	602	0	.71	3.02	1965	0	1962	1.10	1970	0.5	4.8	1964	2.3	1964
DEC	50.7	19.9	35.3	70	1964	-14	1967	914	0	.79	2.66	1965	T	1969#	1.31	1965	2.3	9.9	1971	7.4	1971
ANN	72.5	37.4	54.9	107	AUG 1970#	-14	DEC 1967	4600	1039	5.73	4.02	JAN 1969	0	SEP 1968#	2.13	SEP 1969	8.3	17.4	FEB 1969	7.4	DEC 1971

Table 3-4. Climate summary for Yucca Flat, 1962-1971[a] (continued)

MONTH	Relative humidity (%), hour (Pacific Standard Time) [illegible]	Relative humidity (%), hour 10	Relative humidity (%), hour 16	Relative humidity (%), hour 22	Wind[b,d] (speeds in mph): Average speed	Wind: Peak speed	Wind: Year	Wind: Resultant (dir/sp) 23-02 PST	Wind: Resultant (dir/sp) 11-14 PST	Station pressure (inches): Averages	Station pressure: Highest	Station pressure: Lowest	(e) Average sky cover sunrise to sunset	Average number of days[f]: Sunrise to sunset: Clear	Sunrise to sunset: Partly cloudy	Sunrise to sunset: Cloudy	Precipitation: .01 inch or more	Precipitation: .10 inch or more	Precipitation: .50 inch or more	Precipitation: 1.00 inch or more	1.0 inch or more of snow	Thunderstorms	Temperature: Maximum: 90° F or more	Temperature: Maximum: 32° F or less	Temperature: Minimum: 32° F or less	Temperature: Minimum: 0° F or less
JAN	67	49	35	60	6.5	58	1965	233/0.7	135/2.6	26.10	26.54	25.42	4.9	13	8	10	2	1	*	*	*	*	0	1	29	*
FEB	67	45	32	56	6.9	52	1967	275/1.1	118/2.7	26.05	26.42	25.56	5.0	11	8	9	3	2	*	*	1	0	0	*	23	0
MAR	58	31	23	44	8.4	55	1971	240/1.8	186/4.5	25.99	26.43	25.43	4.8	12	9	10	3	1	0	0	1	1	0	0	24	0
APR	52	27	21	38	9.1	60+	1970#	250/2.2	198/5.1	25.96	26.39	25.50	4.5	13	9	8	3	1	*	*	*	1	0	0	12	0
MAY	46	22	17	31	8.3	60+	1967	260/1.5	179/7.2	25.94	26.39	25.47	4.3	14	11	6	2	1	*	0	0	1	4	0	2	0
JUN	39	19	14	26	7.9	60+	1967	272/1.9	185/8.2	25.92	26.20	25.56	3.0	19	7	4	2	1	0	0	0	2	14	0	*	0
JUL	40	20	15	28	7.5	55	1971	278/0.9	185/12.0	26.00	26.19	25.68	3.0	19	9	3	3	2	*	0	0	4	29	0	0	0
AUG	44	23	16	30	5.7	60+	1968	222/1.5	182/12.0	26.00	26.22	25.71	3.0	20	8	3	3	1	0	0	0	4	27	0	0	0
SEP	43	21	17	32	7.0	52	1970	281/1.3	163/6.4	26.00	26.36	25.56	2.1	22	6	2	2	1	1	*	0	2	11	0	1	0
OCT	46	24	19	36	6.8	60	1971	286/1.3	138/3.7	26.06	26.40	25.52	2.9	20	7	4	1	1	0	0	0	*	2	0	9	0
NOV	61	[illegible]	31	52	6.1	51	1970	234/1.2	152/4.1	26.08	26.58	25.64	4.8	13	7	10	3	2	*	*	*	*	0	0	23	0
DEC	68	50	41	64	6.6	53	1970	288/1.9	109/1.0	26.07	26.59	25.49	4.6	14	8	9	3	1	1	*	1	*	0	1	29	1
ANN	53	31	23	41	7.4	60+	APR 1970#	—	—	26.01	26.59	25.42	3.9	190	97	78	30	14	3	1	3	14	87	2	152	1

[a]Data from Bowen and Egami (1983).
[b]# = most recent of multiple occurrences.
[c]T = trace (amount too small to measure).
[d]Average and peak speeds are for the period starting with December 1964. The directions of the resultant wind are from a summary covering the period December 1964 through May 1969.
[e]Sky cover is expressed in the range from 0 for no clouds to 10 when the sky is completely covered with clouds. Clear, partly cloudy, and cloudy are defined as average daytime cloudiness of 0-3, 4-7, and 8-10 in tenths, respectively.
[f]* = one or more occurrences during the period of record but average less than one-half day.

Temperature is probably one of the most variable meteorological parameters of the Yucca Mountain area on both a daily and an annual basis. The hottest months are generally July and August, which have average monthly temperatures for the 10-year record at Yucca Flat of 24.8°C (76.6°F), and average daily maximums of 35.6°C (96.1°F) and 35.0°C (95.0°F), respectively. Average daily temperature ranges for these months are nearly 22°C (40°F). The highest temperature recorded at Yucca Flat is 42°C (107°F) and has occurred in June, July, and August. Conversely, December is usually the coldest month of the year, with a monthly average temperature of 1.8°C (35.3°F) and an average daily minimum temperature of [illegible]°C (19.9°F). The extreme low temperature recorded in December was -25°C (-14°F). Minimum temperatures at the site can be affected by the drainage flows described previously and may differ from the temperatures recorded at Yucca Flat.

Precipitation in the region is sparse; it averages only about 145 millimeters (5.7 inches) annually at Yucca Flat. The sparseness of precipitation is due to the land-based air masses that influence the region's weather and the blocking effect of the Sierra Nevada. Pacific air masses that could bring moisture to the region generally drop most of their moisture on the western slopes of the Sierra Nevada; little moisture is left to precipitate on the east side. Precipitation that does reach the area is concentrated in the winter months, but thunderstorms at other times of the year can also be significant sources of moisture for the area. Thunderstorms occur on 16 percent of the days in July and August, but only on 5 percent of the days annually. The greatest monthly precipitation for Yucca Flat is 102 millimeters (4.02 inches), and the greatest daily amount is 54 millimeters (2.13 inches). With an average of only 145 millimeters (5.7 inches) of precipitation annually, these maximums represent significant storm events. The statistical maximum 24-hour precipitations for 10-year and 100-year storm events for Yucca Flat are 38 millimeters and 57 millimeters (1.50 inches and 2.25 inches), respectively (Hershfield, 1961).

Wind speed and direction data have been compiled for the station located at Yucca Flat for the period 1961-1978 (DOC, 1986). Although these data reflect terrain influences specific to Yucca Flat, the setting at Yucca Mountain is similar enough to warrant use of the Yucca Flat data for this analysis. The general north-south alignment of the basin in which the repository would be located will most likely be the major influence on surface wind patterns, as is the case for Yucca Flat. Winds from the south dominate the distribution, occurring 14 percent of the time on an annual basis. Winds from the north are also quite frequent, occurring just over 11 percent of the time, again on an annual basis. Seasonally, southerly winds are most common in the spring and summer months, shifting to a northerly dominance in fall and winter months. Wind speed at the Yucca Flat station, averaged over the entire period of record, was 3.6 meters per second (8.1 miles per hour), with the highest average speeds of around 6.3 meters per second (14 miles per hour) associated with the spring and summer southerly winds.

High winds in the area are usually associated with the passage of winter storm fronts, but they can also accompany thunderstorms. Wind speeds in excess of 100 kilometers per hour (60 miles per hour), with gusts of up to 172 kilometers per hour (107 miles per hour) may be expected to occur on a 100-year return period (Quiring, 1968). Such velocities are not common, however, as is evidenced by the Yucca Flat annual average wind speed of 11.9 kilometers per hour (7.4 miles per hour) (Table 3-4). Monthly average wind speeds do not deviate significantly from this value, with a high of 15 kilometers per hour (9.1 miles per hour) in April and a low of 10 kilometers per hour (6.1 miles per hour) in November.

Other than temperature extremes, severe weather in the region includes occasional thunderstorms, lightning, tornadoes, and sandstorms. Severe thunderstorms may produce high precipitation with durations of approximately one hour, which may create a potential for flash flooding (Bowen and Egami, 1983). Tornadoes have been observed within 80 kilometers (50 miles) of Yucca Flat but are considered infrequent (DOC, 1952; Pautz, 1967).

3.4.3.1 Air quality

Site-specific air-quality data are not available for the study area. Data from similar desert locations, however, suggest that air quality at the site is probably very good. Elevated levels of either ozone or total suspended particulates may occasionally occur because of pollutants transported into the area or because of local sources of fugitive particulates (Bowen and Egami, 1983). Ambient concentrations of other criteria pollutants (sulfur dioxide, nitrogen oxides, and carbon monoxide) are probably low because there are no significant sources of these pollutants nearby. The nearest significant source of pollutants is the Las Vegas area, which is 137 kilometers (85 miles) by air away, and is not expected to measurably affect the air quality in the Yucca Mountain area.

3.4.4 NOISE

Although baseline noise levels have not been measured in the Yucca Mountain area, they can be estimated. There are two types of noise-producing areas in the study area: (1) uninhabited desert and (2) small rural communities. In the uninhabited desert, the major sources of noise are natural physical phenomena such as wind and rain, the activities of wildlife, and an occasional airplane. Annually, wind is the predominant noise. Table 3-4 presents an average annual wind speed at Yucca Flat. For noise assessment purposes, this area would be considered windy. Desert noise levels as a function of wind have been measured at an upper limit of 22 dBA for a still desert and 38 dBA for a windy desert (Brattstrom and Bondello, 1983). For Yucca Mountain, 30 dBA is probably a reasonable estimate; it corresponds with noise levels presented in the environmental impact statement prepared for the MX missile system for areas similar to Yucca Mountain (Henningson, Durham and Richardson Sciences, 1980).

Annual rural-community noise levels have been estimated by the U.S. Environmental Protection Agency at 50 dBA (EPA, 1974). This level would be characteristic of annual noise expected for Indian Springs, Mercury, or the Town of Amargosa Valley.

3.4.5 AESTHETIC RESOURCES

Yucca Mountain is in the southern part of the Great Basin and is characterized by dissected ranges that rise abruptly from moderate slopes of alluvial piedmonts. The terrain is rugged and arid, has scant vegetation, and is not visually unique.

The project area to be disturbed is not visible from major population centers or public recreation areas, but may be visible from public highways and parts of the Amargosa Valley. A viewshed analysis of the project area has not yet been conducted.

3.4.6 ARCHAEOLOGICAL, CULTURAL, AND HISTORICAL RESOURCES

Literature reviews of the archaeological, cultural, and historical resources of Yucca Mountain and the surrounding vicinity were conducted by Pippin and Zerga (1983). Extensive field surveys of areas that were to be sites of field activities, such as drilling, or that were under consideration as a potentially acceptable repository site were subsequently performed. Intensive (100 percent) surveys for cultural resources have preceded and will precede land-disturbing activities. All identified potential adverse impacts have been and will continue to be mitigated. To date, more than 28 square kilometers (11 square miles) have been surveyed on and near Yucca Mountain (Pippin et al., 1982). Although the archaeological resources of this area have been mapped, the locations are considered sensitive and, therefore, do not appear on the figures in this document.

Studies were conducted in consultation with the Nevada State Historic Preservation Officer (SHPO). A Programmatic Memorandum of Agreement is being developed among the U.S Department of Energy, the Advisory Council on Historic Preservation, and the National Conference of State Historic Preservation Officers, including the Nevada SHPO, to ensure continued consultation and to guide future archaeological surveys and data-recovery activities.

Resources that could have been affected by preliminary investigations were identified and marked (Pippin et al., 1982). Limited test excavations were also conducted on a sample of the identified sites. Information regarding the excavation methodology and the significance of the sites is presented in Pippin (1984) and is summarized in Table 3-5. Site significance was evaluated in accordance with research domains outlined in an Archaeological Element for the Nevada Historic Preservation Plan (1982).

An archaeological site is identified as any location of past human activity evidenced by the presence of material items manufactured or altered by man (e.g., stone tools, pottery), architectural structures (e.g., walls, windbreaks), or functionally specific facilities (e.g., hearths, pits, cairns). Thus, a location that contains anything from a single pottery shard to a large campsite would be recorded as an archaeological site.

A total of 178 prehistoric aboriginal sites were identified, which represented use of the Yucca Mountain area by small and highly mobile groups or bands of aboriginal hunter-gatherers. The sites consisted of two basic types: campsites and extractive locations. Campsites are temporary locations

Table 3-5. Listing of all sites eligible for National Register and the recommended preservation procedures for cultural resources in the NNWSI Yucca Mountain Project area[a]

Site number	Subsurface component likely	Surface collection required	Recommended procedure for preservation
26Ny1011[b]	Yes	Yes	Test for subsurface component and mitigate if any construction is scheduled in the area.
26Ny1964	Yes	Yes	Avoid or mitigate by scientific study.
26Ny1967	Yes	Yes	Avoid or mitigate by scientific study.
26Ny1995	Yes	Yes	Avoid or mitigate by scientific study.
26Ny1996	No	Yes	Surface collect if any construction is scheduled in the area.
26Ny2005[b]	Yes	Yes	Test for subsurface component and mitigate if any construction is scheduled in area.
26Ny2960	No	No	Avoid site if at all possible.
26Ny2977	No	Yes	Avoid site or surface collect if any construction is scheduled in this area.
26Ny3004	No	Yes	Avoid site or surface collect if any construction is scheduled in the area.
26Ny3005	Yes	Yes	Avoid or mitigate by scientific study.
26Ny3008	No	Yes	Avoid site or surface collect if any construction is scheduled for the area.
26Ny3009	Yes	No	Avoid or mitigate by scientific study.
36Ny3011	No	Yes	Avoid site or surface collect if any construction is scheduled in the area.
26Ny3016	Yes	Yes	Avoid or mitigate by scientific study.
26Ny3017	No	Yes	Avoid site or surface collect if any construction is scheduled for the area.
26Ny3018	No	Yes	Avoid site or surface collect if any construction is scheduled for the area.

Table 3-5. Listing of all sites eligible for National Register and the recommended preservation procedures for cultural resources in the NNWSI Yucca Mountain Project area[a] (continued)

Site number	Subsurface component likely	Surface collection required	Recommended procedure for preservation
26Ny3020	Yes	Yes	Avoid or mitigate by scientific study.
26Ny3021	Yes	Yes	Avoid or mitigate by scientific study.
26Ny3022	Yes	Yes	Avoid or mitigate by scientific study.
26Ny3027[b]	No	Yes	Avoid site or surface collect if any construction is scheduled in the area.
26Ny3028	Yes	Yes	Avoid or mitigate by scientific study.
26Ny3030[b]	Yes	Yes	Test for subsurface component and mitigate if any construction is scheduled in the area.
26Ny3037	Yes	Yes	Avoid or mitigate by scientific study.
26Ny3038	Yes	Yes	Test for subsurface component and mitigate if any construction is scheduled in the area.
26Ny3039	No	Yes	Avoid or mitigate by scientific study.
26Ny3040	Yes	Partial	Avoid or mitigate by scientific study.
26Ny3041[b]	Yes	Yes	Test for subsurface component and mitigate if any construction is scheduled in the area.
26Ny3042	Yes	Yes	Avoid or mitigate by scientific study.
26Ny3043	Yes	Yes	Avoid or mitigate by scientific study.
26Ny3044	No	Yes	Avoid site or surface collect if any construction is scheduled in the area.
26Ny3047	No	Yes	Avoid site or surface collect if any construction is scheduled in the area.
26Ny3049	No	Yes	Avoid site or surface collect if any construction is scheduled in the area.
26Ny3051	No	Yes	Avoid or mitigate by scientific study.

Table 3-5. Listing of all sites eligible for National Register and the recommended preservation procedures for cultural resources in the NNWSI Yucca Mountain Project area[a] (continued)

Site number	Subsurface component likely	Surface collection required	Recommended procedure for preservation
26Ny3054	Yes	Yes	Avoid or mitigate by scientific study.
26Ny3055	Yes	Yes	Avoid or mitigate by scientific study.
26Ny3056	Yes	Yes	Avoid or mitigate by scientific study.
26Ny3057	Yes	Yes	Avoid or mitigate by scientific study.
26Ny3058	Yes	Yes	Avoid or mitigate by scientific study.
26Ny3062	Yes	Yes	Avoid or mitigate by scientific study.
26Ny3066	Yes	Yes	Avoid or mitigate by scientific study.
26Ny3070	No	Yes	Avoid or mitigate by scientific study.
26Ny3074	No	Yes	Avoid site or surface collect if any construction is scheduled in the area and protect as a water source.
26Ny3075	No	Yes	Avoid site or surface collect if any construction is scheduled in the area.
26Ny3082	No	Yes	Avoid site or surface collect if any construction is scheduled in the area.
26Ny3089	Yes	Yes	Avoid or mitigate by scientific study.
26Ny3090	No	Yes	Avoid site or surface collect if any construction is scheduled in the area.
26Ny3091	No	Yes	Avoid site or surface collect if any construction is scheduled in the area.
26Ny3092	No	Yes	Avoid site or surface collect if any construction is scheduled in the area.
26Ny3093	No	Yes	Avoid site or surface collect if any construction is scheduled in the area.
26Ny3094	Yes	Yes	Avoid or mitigate by scientific study.

Table 3-5. Listing of all sites eligible for National Register and the recommended preservation procedures for cultural resources in the NNWSI Yucca Mountain Project area[a] (continued)

Site number	Subsurface component likely	Surface collection required	Recommended procedure for preservation
26Ny3096	No	Yes	Avoid site or surface collect if any construction is scheduled in the area.
26Ny3098	No	Yes	Avoid site or surface collect if any construction is scheduled in the area.
26Ny3099	Yes	Yes	Avoid or mitigate by scientific study.
26Ny3100	No	Yes	Avoid site or surface collect if any construction is scheduled in the area.
26Ny3107[b]	Yes	Yes	Test for subsurface component and mitigate if any construction is scheduled in the area.
26Ny3108[b]	Yes	Yes	Test for subsurface component and mitigate if any construction is scheduled in the area.
26Ny3110[b]	Yes	Yes	Test for subsurface component and mitigate if any construction is scheduled in the area.
26Ny3111[b]	Yes	Yes	Test for subsurface component and mitigate if any construction is scheduled in the area.
26Ny3112[b]	Yes	Yes	Test for subsurface component and mitigate if any construction is scheduled in the area.
26Ny3113[b]	Yes	Yes	Test for subsurface component and mitigate if any construction is scheduled in the area.
26Ny3114[b]	Yes	Yes	Test for subsurface component and mitigate if any construction is scheduled in the area.
26Ny3116[b]	Yes	Yes	Test for subsurface component and mitigate if any construction is scheduled in the area.

Table 3-5. Listing of all sites eligible for National Register and the recommended preservation procedures for cultural resources in the NNWSI Yucca Mountain Project area[a] (continued)

Site number	Subsurface component likely	Surface collection required	Recommended procedure for preservation
26Ny3117[b]	Yes	Yes	Test for subsurface component and mitigate if any construction is scheduled in the area.
26Ny3118[b]	Yes	Yes	Test for subsurface component and mitigate if any construction is scheduled in the area.
26Ny3119[b]	Yes	Yes	Test for subsurface component and mitigate if any construction is scheduled in the area.
26Ny3162	Yes	Yes	Avoid or mitigate by scientific study.
26Ny3163	Yes	Yes	Avoid or mitigate by scientific study.
26Ny3190	Yes	Yes	Avoid or mitigate by scientific study.
26Ny3191[b]	Yes	Yes	Avoid or mitigate by scientific study.
26Ny3635	No	Yes	Avoid or mitigate by scientific study.
26Ny3636	Yes	Yes	Avoid or mitigate by scientific study.
26Ny3924	No	Yes	Avoid or mitigate by scientific study.
S050184RR06	No	Yes	Avoid or mitigate by scientific study.
S050284RR05	No	Yes	Avoid site or surface collect if any construction is scheduled in the area.

[a]Modified from Pippin et al. (1982).
[b]Site is outside of the area of proposed intensive activity.

where groups varying in size from single-family units to small bands of 20 to 30 individuals lived for days or months while using nearby resources or traveling through the area. Such campsites, 21 of which were identified on Yucca Mountain, are recognized by the presence of artifacts, structures, and facilities related to food preparation and consumption, shelter, and other maintenance activities, such as the manufacture or repair of clothing and tools.

One hundred and forty-one of the prehistoric sites are extractive locations. These are the remains of more limited, task-specific activities associated with hunting, gathering, and processing of wild plants and with procurement of other raw materials used in manufacturing tools and clothing. The survey identified several kinds of extractive locations, and the site types are summarized in Table 3-6. In addition, 16 sites were identified but not classified.

The cultural resources of Yucca Mountain can be categorized according to four general adaptive strategies (Pippin, 1984). The earliest strategy was reflected by a linear pattern of archaeological sites along major ephemeral stream drainages. Although the terrace edges of these drainages continued to be occupied by later populations, there appears to have been a shift in settlement patterns away from these linear sources of water that began about 7,000 years ago. During that time, temporary camps became established in the uplands of Yucca Mountain. About 1,500 years ago, there appeared to be another shift in adaptation. For the first time, the availability of plant resources seemed to have a major influence on site locations. A final adaptation in the area was indicated by numerous cairns, several isolated tin cans, and a prospector's camp.

The first recorded entry of Euro-American travelers into the area now occupied by the Nevada Test Site (NTS) was that of a group of emigrants to California in 1849 (Worman, 1969). This group had broken away from a party led by Captain Jefferson Hunt after hearing rumors of a shorter route to California than that afforded by the Old Spanish Trail. While Hunt headed southward over known territory, the splinter party plunged off into the unknown. A second split was made north of Indian Springs where a group of wagons, known as the Bennett-Arcane Party, decided to take a southerly route. The remaining wagons, the Jayhawkers, followed a westward course to Tippipah Spring, where another split occurred. One group, still called the Jayhawkers, went south between Skull Mountain and Fortymile Canyon. The Jayhawkers crossed Topopah Wash and entered the Amargosa Valley east of the Wash. The other group, the Briers, entered Fortymile Canyon west of Tippipah Spring and went on to the Amargosa Desert. These trails are shown in Figure 3-17.

Later movements into the area involved prospectors, ranchers, wild-horse hunters, and the establishment of relay stations for stage and freight lines. Operating mines were the Horn Silver Mine, the Climax Tungsten Mine at the north end of Yucca Flat, a cinnabar mine and retort on Mine Mountain, and galena deposits at the Groom Mine (Worman, 1969).

Other historic resources located in the region include the Emigrant Trail, Cot Cove (an early 20th-century prospector's camp located immediately west of Prow Pass), ghost towns, mining camps, Mormon settlements, and

Table 3-6. Prehistoric archaeological sites in the Yucca Mountain area[a]

Site type	Activities represented	Typical features, artifacts, and location	Number
Temporary camps	Food preparation and consumption; shelter; maintenance activities	Evidence of fire (hearths, pits, etc.), rock alignments (windbreaks, shelters); stone tools, bone, vessels, grinding implements, etc.; location variable	21
Tinajas (cisterns)	Water collection	Bedrock basins with rock covers to retard evaporation; often near other extractive locations or camps	19
Knapping stations	Stone-tool manufacturing	Stone tools and waste material; locations quite variable	16
Quarries	Collection of toolstone	Large amounts of waste, parent material, stone tools; located on or near sources of material, some very extensive	12
Milling stations	Processing of plant resources (seeds)	Grinding implements (manos); stone tools; locations vary but common in rock shelters	27
Caches	Storage of tools, raw materials	Rock alignments, piles; concentrations of raw materials; tools; common in small rock shelters	8
Isolated artifacts	Hunting and collecting	Isolated stone tools and waste; variable locations	78
Sites of unknown function	Unknown	Diffuse concentrations of stone tools and waste; isolated artifacts with a suspected subsurface component; variable locations but isolated, common in small rock shelters	16

[a]Data from Pippin et al. (1982). Note that some sites were classified under more than one site type.

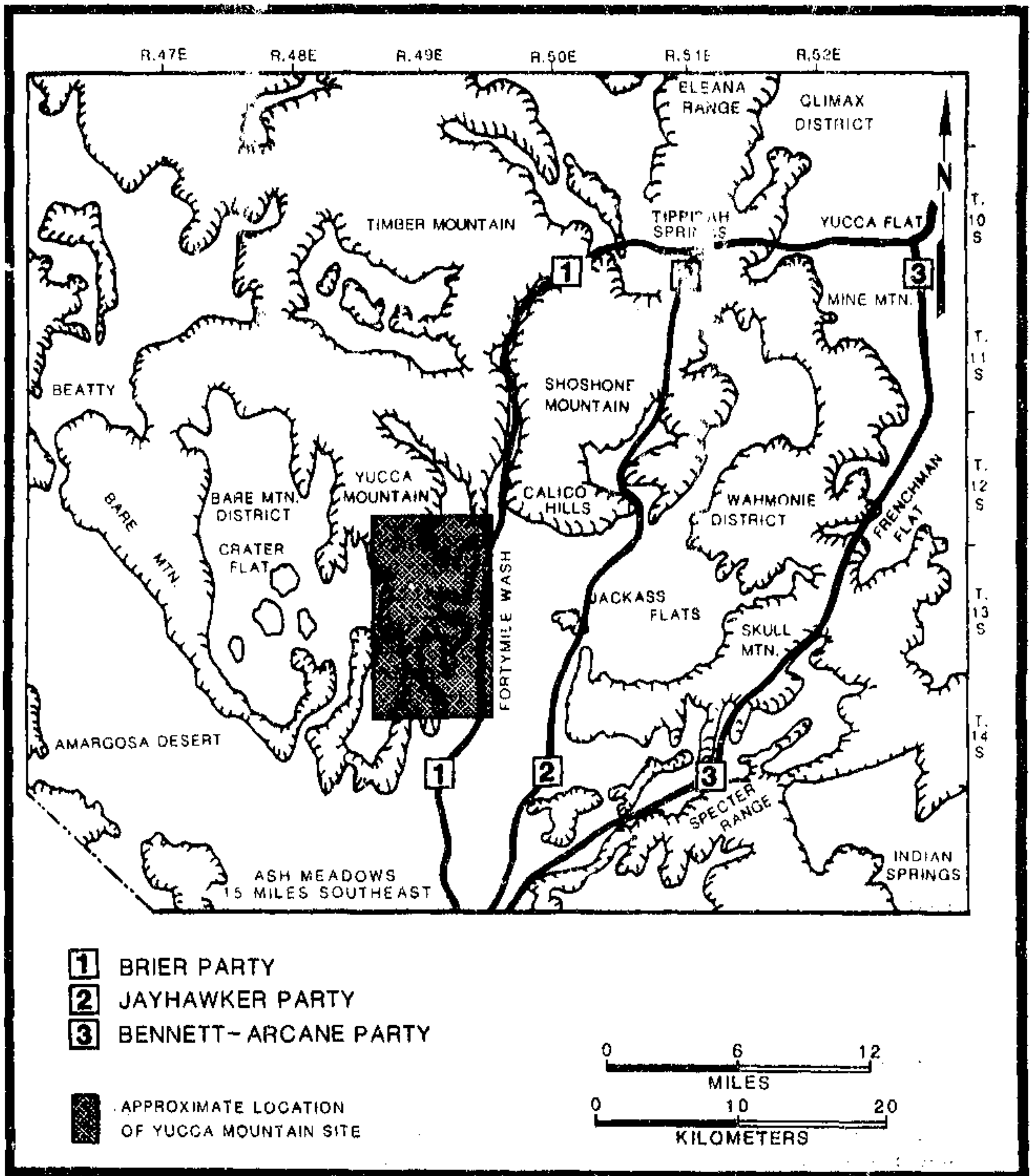

Figure 3-17. Location of historic trails near Yucca Mountain. Modified from Worman (1969).

ranches located in southern Nevada. A U.S. Department of Energy study revealed 145 historic and 5 prehistoric sites located off the NTS but within a 140-kilometer (87-mile) radius of it (Kensler, 1981). The most common sites identified were mining operation sites and ranches.

3.4.7 RADIOLOGICAL BACKGROUND

Environmental background radiation levels from all sources in the general area surrounding the Nevada Test Site (NTS) vary considerably depending mainly on elevation and natural radioactivity content of the soil. In 1983 the environmental radiation dose rate at 86 monitored locations within 300 kilometers (185 miles) of the NTS ranged from 42 to 140 millirems per year, with an average of 87 millirems per year (Patzer et al., 1984). It has been observed that exposures (whole-body radiation) measured at offsite stations nearest to the NTS are decreasing with time (ERDA, 1977). This decrease is believed to result from radioactive decay of fallout deposited mainly during periods of atmospheric testing.

Radiation levels within the NTS boundary increased from 1951 to the mid-1960s as a result of atmospheric weapons testing and other experiments. Radiation levels at specific locations within the test site vary considerably, depending on the history of the location, and may exceed 5 millirems per hour in localized areas (ERDA, 1977). Most of the radioactivity created at the test site by underground tests remains in or near the underground cavity locations. Measurements of radioactivity in the principal NTS groundwater system during the 1983 measuring period showed only minor concentrations of tritium. None of the radionuclide concentrations measured are expected to result in measurable radiation exposures to residents or site workers (Patzer et al., 1984).

Some radioactivity remains on the surface from pre-1962 atmospheric testing of weapons, nuclear-cratering explosions, nuclear-propulsion-systems tests, and radioactive wastes generated by other NTS activities. The locations of these wastes on the NTS are shown in Figure 3-18 (ERDA, 1977). Almost all of the sites are located in the northeastern quadrant of the NTS.

3.4.7.1 Monitoring program

The U.S. Department of Energy (DOE) is responsible for providing radiological safety services on the Nevada Test Site (NTS) and maintaining an environmental surveillance program designed to control, minimize, and document exposures to the NTS working population. Air and potable-water samples are collected at specific areas where personnel spend significant amounts of time. Additional air-sampling stations are located throughout the NTS in support of the testing program and the radioactive-waste-management program. Water from supply wells, open reservoirs, natural springs, contaminated ponds, and sewage ponds is also sampled and analyzed to evaluate the possibility of any movement of radioactive contaminants in the NTS water system. Thermoluminescent dosimeters (TLDs) are used to measure the ambient NTS external gamma-radiation levels.

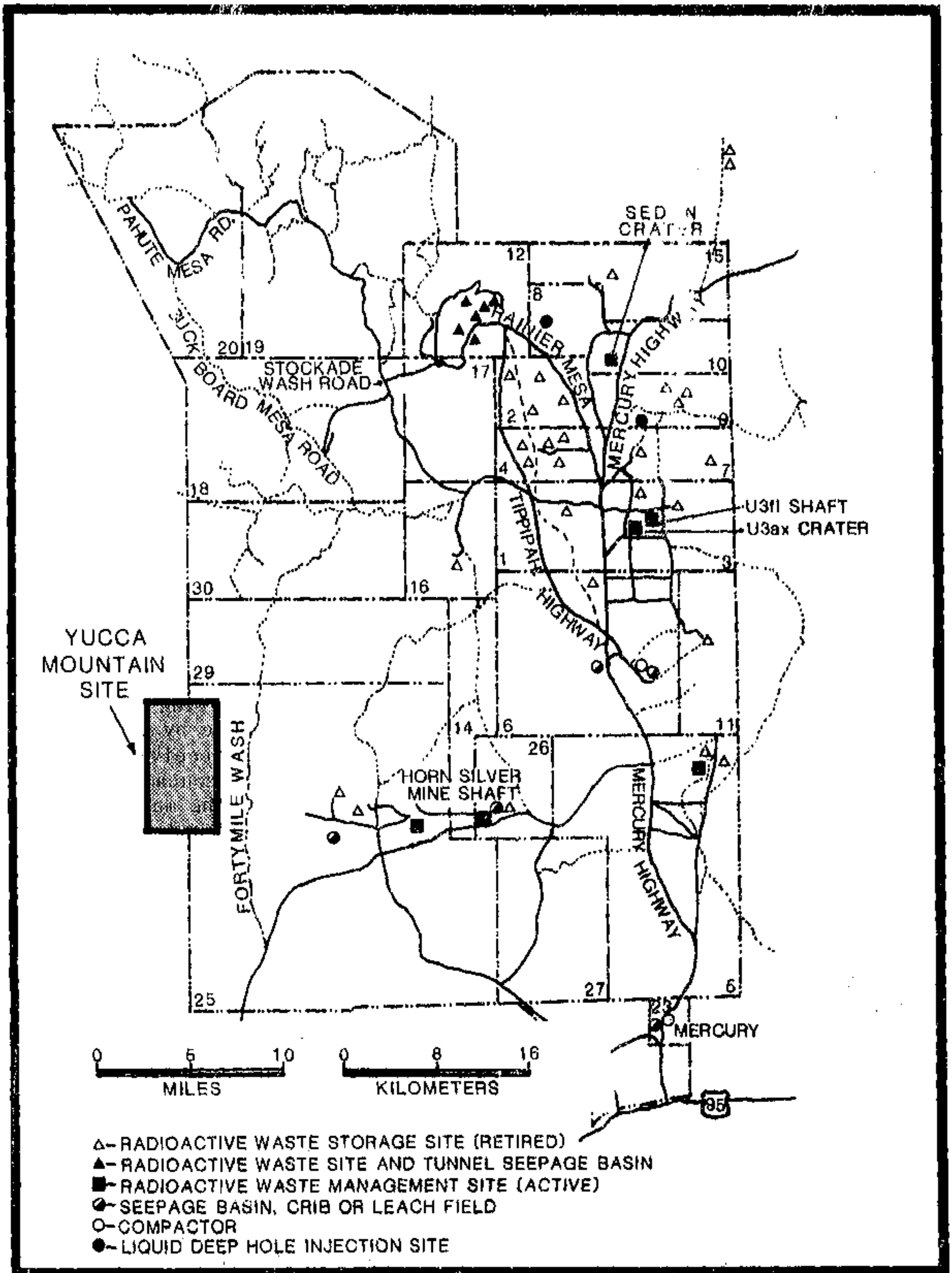

Figure 3-18. Locations of radioactive waste areas at Nevada Test Site. Modified from ERDA (1977).

The U.S. Environmental Protection Agency (EPA), through its Environmental Monitoring Systems Laboratory in Las Vegas, has performed radiological monitoring in the NTS offsite area. Since 1958 continuous monitoring has been performed to determine the levels of radiation and radioactivity present. Samples of air, water, and milk are routinely collected and analyzed and external radiation exposures are measured. Radioactivity attributable to the resuspension of dust particles in the air from contaminated areas on the NTS has never been detected in offsite samples. No contained underground tests have resulted in exposure to offsite residents that exceeded the radiation protection guidelines applicable to underground nuclear testing (ERDA, 1977). It is predicted that future containment will be as good or better (ERDA, 1977). No radioactivity released from activities at the NTS in four of the last five years was measured off the site by any of the monitoring networks (Patzer et al., 1984).

A recent major innovation in this long-term monitoring program has been the establishment of a network of community monitoring stations in 15 offsite communities (Douglas, 1983) (Figure 3-19). This network differs from other networks in the offsite radiation monitoring and public safety program in that it incorporates Federal, State, and local government participation. The DOE Nevada Operations Office and the EPA Environmental Monitoring Systems Laboratory provide technical guidance for the program.

3.4.7.2 Dose assessment

Using the measured quantities of radioactivity in various environmental media, the maximum dose to a hypothetical individual living at the Nevada Test Site (NTS) boundary may be estimated. This was done by calculating the 50-year committed dose equivalent for the individual receiving a 1-year intake of air and water conservatively assumed to be contaminated with radionuclides at concentrations measured on the site. The maximum calculated doses to the total body, bone, and lung were 0.18, 2.0, and 0.24 millirems, respectively. These doses to the hypothetical individual at the NTS boundary represent increases of less than 0.5 percent over natural background for total body and lung, and less than 1.5 percent over natural background for bone (Scoggins, 1983).

Airborne radionuclides detected off the site from NTS activities for 1974 through 1983 are listed in Table 3-7. Although no radioactivity released in four of the last five years was detected off the site, the theoretically possible dose to the offsite population from releases on the NTS can be calculated by using annual average meteorological data and atmospheric dispersion equations. Based on the 1983 radioactivity releases (Patzer et al., 1984), the estimated annual population dose from NTS activities to the 4,600 people residing within 80 kilometers (50 miles) of a central point on the NTS was 0.00005 man-rem (5×10^{-5} man-rem) (Patzer et al., 1984). For comparison, the annual population dose to this same population from natural background radiation is approximately 400 man-rem. Shifting the center point for the 80-kilometer (50-mile) radius from a central point on the NTS to a central point on Yucca Mountain results in including about 15,300 additional people in the annual population dose calculation. The annual background population dose to the 19,908 people

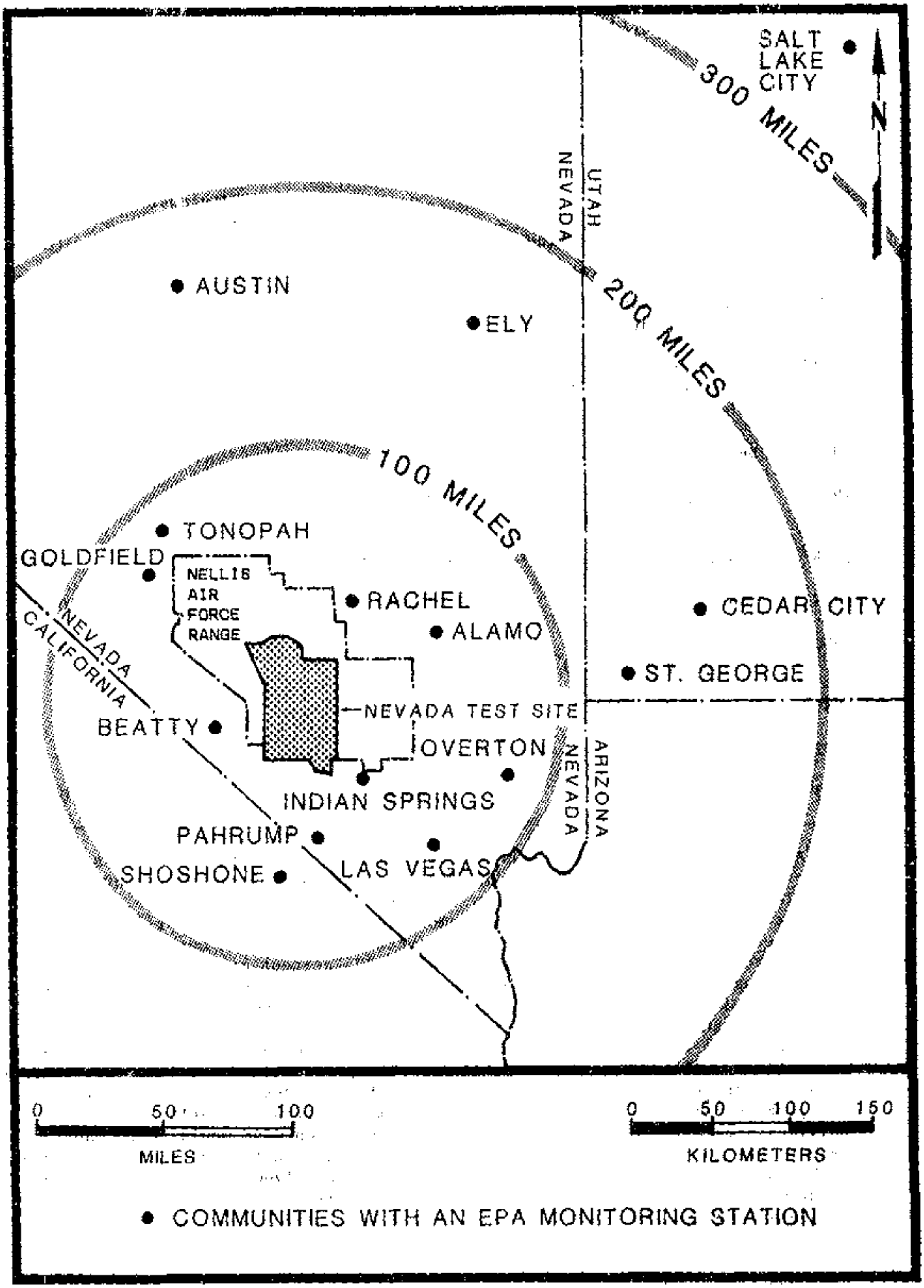

Figure 3-19. Community monitoring stations around the Nevada Test Site. Modified from Douglas (1983).

8 0 0 0 8 0 2 1 5

Table 3-7. Airborne radionuclides from the Nevada Test Site detected off the site, 1974 through 1983

Year	Station detecting radionuclides[a]	Radionuclides detected	Highest calculated individual whole-body dose[b] (microrem)	Population dose[c] (man-rem)
1974[d]	Beatty,* Diablo, Indian Springs*	Xe-133	[illegible]	0.003
1975[e]	Beatty,* Diablo, Hiko, Indian Springs,* Las Vegas	Xe-133, Kr-85, H-3	2.1	0.00065
1976[f]	Death Valley Junction*	H-3	1.3	0.00078
1977[g]	Beatty,* Diablo, Hiko, Las Vegas, Tonopah	Xe-133	2.5	0.0013
1978[h]	Diablo, Indian Springs*	Xe-133, H-3	6.2	0.0087
1979[i]	None	None	0	0
1980[j]	Lathrop Wells* (Amargosa Valley)	Xe-133, Xe-135	11	0.00072
1981[k]	None	None	0	0
1982[l]	None	None	0	0
1983[m]	None	None	0	0

[a]All communities are in Nevada except Death Valley Junction, which is in California. Those communities marked with an asterisk (*) are within 80 kilometers (50 miles) of the proposed repository surface facilities complex.

[b]Dose calculated from the largest amount detected (not necessarily within the 80-kilometers (50-mile) radius. For perspective, the largest dose listed (11.0 microrems or 11.0×10^{-6} rem) is only 0.005 percent of the average annual dose an individual in this area receives from naturally occurring internal and external radiation and 0.001 percent of the Nuclear Regulatory Commission radiation protection standard of 0.5 rem per year (10 CFR Part 20, 1984).

[c]Population dose calculated using the radionuclide detected and the population within the 80-kilometers (50-mile) circle. The population dose, sometimes referred to as collective dose, is simply a summation of the doses received by individuals in an exposed population. For example, if each member of a population of 100 individuals received a dose of 0.1 rem, the population dose would be 10 man-rem. These population doses are extremely small compared with the annual population dose of 400 man-rem from naturally occurring radiation received by the 4,600 people living within the area analyzed (Patzer et al., 1984).

[d]Data from EPA (1975).

[e]Data from EPA (1976).

[f]Data from EPA (1977).

[g]Data from Grossman (1978).

[h]Data from Grossman (1979).

[i]Data from Potter et al. (1980).

[j]Data from Smith et al. (1981).

[k]Data from Black et al. (1982).

[l]Data from Black et al. (1983).

[m]Data from Patzer et al. (1984).

conservatively estimated to reside within 80 kilometers (50 miles) of a central point at Yucca Mountain is about 1,790 man-rem (Jackson et al., 1984). The population within 80 kilometers (50 miles) of the repository was conservatively estimated by identifying the counties within an 80-kilometer (50-mile) radius of the proposed repository and dividing the 1980 county population by the county area to obtain population density. Once county population densities were determined, the county area within the 80-kilometer (50-mile) radius was multiplied by that county's density to estimate population. The results were then summed for each county. If population centers (i.e., cities or unincorporated places) outside the 80-kilometer (50-mile) radius are accounted for, the population within 80 kilometers (50 miles) of the proposed repository is estimated to be 11,674 (Morales, 1985).

The highest calculated dose was 1.8×10^{-8} millirems per year to an individual living in Rachel, with lesser amounts to individuals in the towns of Amargosa Valley, Beatty, and Indian Springs, Nevada (Patzer et al., 1984). Natural radioactivity in the body causes individual annual internal doses ranging from 26 to 36 millirems per year, and environmental background averages 87 millirems per year. Therefore, the maximum theoretical dose estimate of 1.8×10^{-8} millirems per year from airborne radionuclide emissions during 1983 on the NTS is a very small fraction of the natural internal and external radiation background.

3.5 TRANSPORTATION

This section describes the existing and projected transportation network in the vicinity of the Yucca Mountain site. This information will be used in chapters 4, 5, and 6 to evaluate the potential impact of transporting people, materials, and radioactive waste.

3.5.1 HIGHWAY INFRASTRUCTURE AND CURRENT USE

Figure 3-20 shows the existing highway network near the site. U.S. Highway 95, a four-lane road between Las Vegas and the Mercury turnoff, is the major artery over which construction material and people would be transported. At Mercury, U.S. Highway 95 becomes a two-lane road. Access to the site would be via a proposed 26-kilometer (16-mile) access road from U.S. Highway 95 just west of Amargosa Valley. This access road would only be used by site-related traffic.

Table 3-8 presents traffic counts along U.S. Highway 95 for 1982. Annual average daily traffic represents the average number of vehicles passing over a road segment for any day of the year. The average annual weekday traffic represents the average number of vehicles passing over the same road segment for any given 24-hour weekday of the year. When the annual average weekday traffic count exceeds the average annual daily traffic, weekday traffic dominates weekend traffic. Therefore, Table 3-8 indicates that weekday use of U.S. Highway 95 dominates traffic flow between Las Vegas and Mercury. However, from Mercury west toward Beatty, weekend traffic

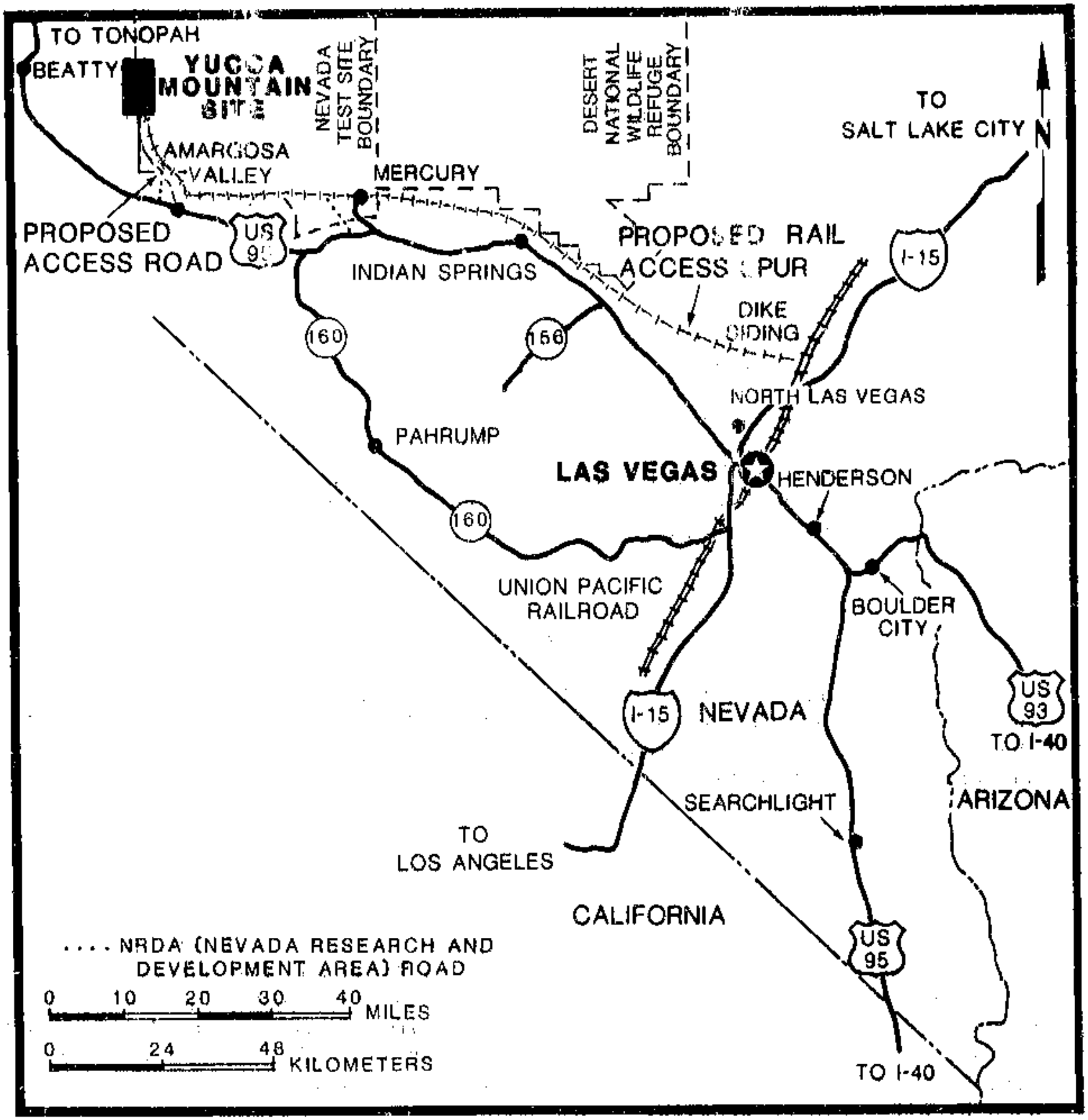

Figure 3-20. Regional transportation network and proposed road and rail access to the Yucca Mountain site.

Table 3-8. Traffic patterns on U.S. Highway 95, 1982[a]

Highway segment[c,d]	Distance[b] (km)	Traffic volume (number of vehicles): Average annual daily traffic	Average annual weekday traffic	Peak-hour traffic as a percentage of annual average weekday traffic: Morning (6-7 a.m.)	Evening (5-6 p.m.)
Town of Amargosa Valley to Beatty	47	1450	1433	2.5[f]	6.0[f]
S.R. 160 to Town of Amargosa Valley	27	1685	1665	2.5[f]	6.0[f]
NRDA[e] Road to S.R. 160	8	1785	1764	2.5[f]	6.0[f]
Mercury Intersection to NRDA Road	5	1960	1937	2.5[f]	6.0[f]
Indian Springs to Mercury intersection	29	2820	2883	7.49	9.3
S.R. 156 to Indian Springs	21	3030	3098	7.49	9.3
Northern limits of Las Vegas metropolitan area to S.R. 156	22	3500	3579	7.49	9.3

[a] Information supplied by Pradere (1983).
[b] 1 kilometer (km) = 0.621 mile.
[c] See Figure 3-20 for the location of highway segments.
[d] S.R. = State Route.
[e] NRDA = Nevada Research and Development Area.
[f] Estimated.

dominates the use. This use pattern reflects worker traffic between Las Vegas and the Nevada Test Site (NTS).

Worker traffic between the NTS and Las Vegas is characterized by morning and early-evening peaks. The evening peak dominates as shown in Table 3-8. Of critical importance is the ability of the roadway to handle the traffic volume or density during this peak period. This ability can be assessed by noting the level of service realized during the peak period. The level of service describes the flow of traffic and the propensity for traffic accidents at different traffic volumes. Table 3-9 presents a description of the level of service at different traffic volumes. Table 3-10 compares actual evening peak-hour traffic volumes and level of service for each road segment. Note that the actual number of cars along the entire length of U.S. Highway 95 from Las Vegas to Beatty is less than the maximum service volume designated as level B.

Traffic levels through metropolitan Las Vegas are high, and certain sections of U.S. Highway 95, south of the northern city limits, and of Interstate 15 are congested. Congested streets include the following: Fremont Street (U.S. Highway 95) from Charleston Boulevard to Bruce Street; Interstate 15 northbound from Sahara Avenue to Charleston Boulevard; and Interstate 15 southbound from U.S. Highway 95 to Charleston Boulevard (Clark County Transportation Study Policy Committee, 1980). The following ramps for Interstate 15 and U.S. Highway 95 interchange are also congested: Interstate 15 South to U.S. Highway 95 West; U.S. Highway 95 West to Interstate 15 South; and U.S. Highway 95 East to Interstate 15 South (Clark County Transportation Study Policy Committee, 1980).

3.5.2 RAILROAD INFRASTRUCTURE AND CURRENT USE

As shown in Figure 3-20, the closest rail line to the site is the Union Pacific line, which passes through Las Vegas. This line connects Salt Lake City with Los Angeles. To access the site, a spur line of approximately 161 kilometers (100 miles) has been proposed from Dike Siding, which is 18 kilometers (11 miles) northeast of Las Vegas, as shown in Figure 3-20.

The Union Pacific line passing through Las Vegas is designated as a class A mainline. A class A mainline meets at least one of the following three tests (DOT, 1977):

1. High Freight Density Test, which involves carrying at least 20 million gross tons per year.

2. Service to Major Markets Test.

3. National Defense Test, which requires a rail route of the highest physical category in corridors designated as essential in the Strategic Rail Corridor Network for national defense.

Table 3-9. Traffic service levels and characteristics[a]

Level	Characteristics
A[b]	Highest level of service Free flow, with little or no restriction on speed or maneuverability by presence of other vehicles Lane density is approximately 10 vehicles per mile
B	Zone of stable flow Operating speed is beginning to be restricted, but restrictions on maneuverability by other vehicles is still negligible Typical design criteria for rural highways Lane density is approximately 20 vehicles per mile
C	Still a zone of stable flow Speed and maneuverability are becoming constrained Typical design criteria for urban highways Lane density is approximately 30-35 vehicles per mile
D	Approaching unstable flow Tolerable average speeds can be maintained but are subject to considerable and sudden variation Probability of accidents has increased Most drivers would consider these conditions undesirable Lane density is 40-50 vehicles per mile
E	Unstable flow Wide fluctuation in flow Little independence in speed selection and maneuverability Lane density is 70-75 vehicles per mile
F	Forced-flow operations Speed may drop to zero for short periods Lane density continues to increase, reaching "jam density" at approximately 150 vehicles/mile

[a]Data from Carter et al. (1982).
[b]Level A is currently illegal because, to obtain the lane density, vehicle speeds must exceed 88 kilometers per hour (55 miles per hour).

Table 3-10. Evening-peak-hour (5-6 p.m.) traffic patterns on U.S. Highway 95, 1982[a]

Highway segment[b,c,d]	Distance[e,f] (km)	Actual traffic volume[f] (cars)	Maximum service volume (passenger cars per hour) Service level A	Service level B	Service level C
Amargosa Valley to Beatty	47	86	285	822	1104
5 miles east of Amargosa Valley to Amargosa Valley	8	100	304	810	1134
S.R. 160 to 5 miles east of Amargosa Valley	19	100	228	684	1053
NRDA Road to S.R. 160	8	106	61	427	875
Mercury Intersection to NRDA Road	5	116	66	442	929
Indian Springs to Mercury Intersection	29	268	996	1660	2490
S.R. 156 to Indian Springs	21	288	996	1660	2490
Northern limits of Las Vegas metropolitan area to S.R. 156	22	333	996	1660	2490

[a]Traffic data for the highway section between Las Vegas and Mercury represent actual counts. Data for the section beyond Mercury have been estimated from average annual daily traffic data.

[b]See Figure 3-20 for the location of highway segments.

[c]For brevity, the Town of Amargosa Valley is referred to here as "Amargosa Valley."

[d]S.R. = State Route; NRDA = Nevada Research and Development Area.

[e]1 kilometer = 0.621 mile.

[f]Information supplied by Pradere (1983).

Class A mainline routes carry most of the nation's rail traffic. Furthermore, they typically show the best economic performance in terms of unit cost for maintenance and operation and of return on investment.

The line is primarily single track with frequent sidings (i.e., areas at which trains can pull off the main track to the "side"). There are 88 sidings in the 721-kilometer (448-mile) section between Salt Lake City and Barstow, California, which is an average of approximately one every 8 kilometers (5 miles). Train operations are controlled by a Centralized Traffic Control system in Salt Lake City. The majority of the line is continuously welded rail (Nunn, 1983). A number of safety devices are included throughout the mainline route: hot boxes, wide-load detectors, dragging-equipment detectors, high-water detectors, slide-fence detectors, and a microwave communication system (WESTPO, 1981).

A hot box is used to detect overheated conditions. Wide- and high-load detectors are used to ensure that loads are within design limits for the track. High-water detectors are placed in areas that are prone to flooding. Slide-fence detectors are used to detect breaches in fencing used to constrain mud and rock slides. Dragging-equipment detectors are used to ensure that equipment (e.g., brake rods and air hoses) dragging along the track is identified. Dragging-equipment detectors lower the possibility of derailment caused by equipment lodging between wheels and rails. These detectors also lower the possibility of damage to turnout equipment at sidings (WESTPO, 1981).

The average number of trains per day passing along the mainline section through Las Vegas from 1978 to 1983 is given in Table 3-11. Table 3-11 also lists the average number of cars per train and the average number of tons per freight train. An analysis of the capacity of principal mainlines, prepared under the auspices of the Western Governors' Policy Office (WESTPO, 1981), estimated that single tracks with centralized traffic-controlled lines (such as the Union Pacific line) could accommodate between 25 and 54 trains daily. Because of its centralized traffic-control system, good maintenance, and frequent sidings, the Salt Lake City to Barstow section of the Union Pacific line should be at the high end of this range.

Table 3-11. Recent railroad-traffic patterns[a]

Year	Average number of trains per day[b]	Average number of cars per train		Average number of tons per train	
		Eastbound	Westbound	Eastbound	Westbound
1978	16.4	68	65	3,077	5,599
1979	17.4	70	65	3,000	6,138
1980	16.7	73	65	3,040	6,279
1981	19.2	68	64	3,042	6,500
1982	13.3	NA[c]	NA	3,206	5,799
1983	13.9	70	61	3,168	5,908

[a]Information supplied by Nunn (1983).
[b]Only freight trains listed. The number of passenger trains for all years listed was two per day (one eastbound and one westbound). The given numbers of freight trains are equally distributed between eastbound and westbound traffic.
[c]NA = not available.

3.6 SOCIOECONOMIC CONDITIONS

This section describes recent and expected future baseline social and economic conditions in the bicounty area surrounding the Yucca Mountain site. These conditions provide the basis for the evaluations in chapters 4, 5, and 6.

If a repository were located at Yucca Mountain, social and economic impacts would occur in areas where repository-related expenditures would be made and where the inmigrating repository-related work force would reside. To the extent that resources are available at competitive prices, it is expected that the majority of repository-related expenditures would be made in Nye County, where the site is located, and in neighboring Clark County, the major metropolitan area in southern Nevada. The Nevada Test Site (NTS), adjacent to the Yucca Mountain site in Nye County, employs U.S. Department of Energy (DOE) and contractor personnel with skills similar to the construction and mining skills that would be required by the repository work force. Historical settlement patterns of workers at the NTS provide a reasonable indication of where repository workers and their families would settle. Recent settlement patterns of these NTS workers were analyzed using their ZIP codes. These data, summarized in Table 5-26, indicate that most (96 percent) of the NTS workers reported ZIP codes in Nye and Clark counties in 1984. The socioeconomic baseline conditions presented in this chapter focus on this bicounty area, where almost all the Yucca Mountain work force would be expected to reside, shown within the shaded boundary in Figure 3-21. However, since the data summarized in Table 5-26 also indicate that about 1.5 percent of the recent NTS workers reported ZIP codes in other Nevada counties (Douglas, Lander, Lincoln, Lyon, and White Pine, and Carson City, a

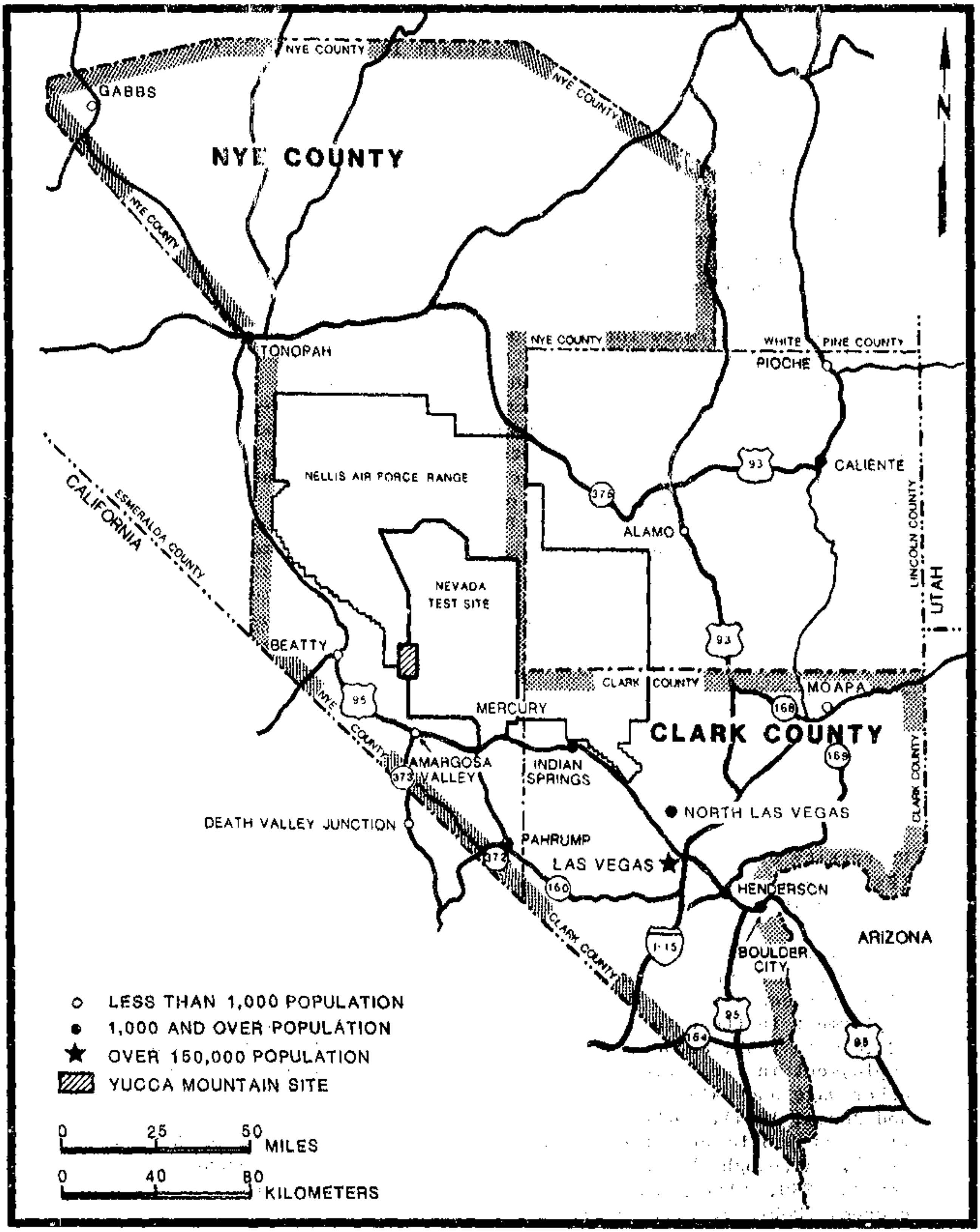

Figure 3-21. Bicounty area surrounding the Yucca Mountain site.

consolidated municipality), the DOE intends to consider a larger geographic area in future studies, if Yucca Mountain is approved for site characterization.

3.6.1 ECONOMIC CONDITIONS

Two sources of employment data are used in this section. Where the text presents totals or the percentage distribution in selected industries for 1980 and 1983, wage and salary employment data developed by the Nevada Employment Security Department (ESD) are used. These data are readily available on an annual basis for both counties. The most recent year for which ESD data are available for both counties is 1983. Since ESD does not produce long-term employment projections, OBERS data published by the U.S. Department of Commerce, Bureau of Economic Analysis, were used to develop the employment projections appearing in this section. These data are only available for 1978, the base year for the 1980 OBERS projections, and for selected subsequent years. To differentiate between these two sources of employment data, ESD values are referred to as wage and salary employment and OBERS values are referred to simply as employment or persons employed. ESD data are derived from a U.S. Department of Labor, Bureau of Labor Statistics, survey of private nonagricultural and civilian government establishments and are a measure of the number of persons reported to be on the establishments' payrolls. The survey excludes proprietors, the self-employed, unpaid volunteer or family workers, farm workers, domestic workers, and military personnel (DOL, 1985). The OBERS projections are based on a more comprehensive definition of employment that includes self-employed, agricultural production and agricultural service workers, and military personnel as well as wage and salary employment (DOC, 1981b). Employment data from these two sources are thus based on different data bases and definitions. The more comprehensive OBERS employment values will exceed those of the ESD in any historical year. All employment data are by place (i.e., county) of work.

Population data are based on population forecasts prepared by the University of Nevada, Reno (UNR), for the State Office of Community Services (Ryan, 1984a,b). These population forecasts are referred to hereafter as the UNR population forecasts.

Since World War II, Nevada's economy has expanded rapidly, especially the hotel and gaming industry, for which revenue increased more than 100 times between 1945 and 1983 (including inflation). Direct wage and salary employment in the hotel, gaming, and recreation industry in Nevada was about 120,000 in 1983, accounting for about 30 percent of the total wage and salary employment in the State. Some estimates indicate that the same percentage of other wage and salary employment depends indirectly on this industry (McBrien and Jones, 1984). Other major employers include other services; transportation and public utilities; trade; and government (State of Nevada, ESD, 1984). Although the smallest employer in the State in recent years (State of Nevada, ESD, 1984), mining has played a significant role in the State's economy (Dobra et al., 1983).

The Nevada economy is expected to continue to expand well into the future. The hotel, gaming, and recreation industry will continue to expand, although this sector's share of total income is expected to decline slightly over the forecast period (McBrien and Jones, 1984). Nevada real personal income is expected to more than double between 1983 and 2000, growing at an average annual rate of 4.6 percent. Since local income forecasts are not available, this analysis is based on multiplying the UNR population forecasts by the per capita personal income from the OBERS projections of the U.S. Department of Commerce, Bureau of Economic Analysis (DOC, 1985).

3.6.1.1 Nye County

Approximately 2 percent of Nevada's wage and salary employment in 1980 was in Nye County. In 1980, total wage and salary employment in Nye County was about 6,700 (State of Nevada, OCS, 1984). In 1983, 89 percent of the total wage and salary employment of 8,630 in Nye County was in the mining industry, the service industry, and civilian government (State of Nevada, OCS, 1985b).

As in most of the United States, the service industry is the largest employer in Nye County, but the character of the area is better defined by its other large employers: mining and government. Although construction is a considerably smaller sector, it is also important in an analysis of employment impacts associated with a repository at Yucca Mountain.

The mining industry has played a major historical role in the economy of Nye County. Tonopah, the largest community in the county as reported by the 1980 census, was founded as a silver mining center, and the community and the county have experienced boom and bust periods fluctuating with mineral demand. Wage and salary employment in the mining industry increased 198 percent (an average of nearly 20 percent per year) between 1975 and 1981, from 520 to 1,550 (McBrien and Jones, 1984; State of Nevada, OCS, 1985b).

In 1983, 9 percent of the Nye County wage and salary employment was in the government sector (State of Nevada, OCS, 1985b). The primary Federal Government activities in Nye County are located at the Nevada Test Site (NTS) and the Nellis Air Force Range. However, most workers at the NTS are employed by firms in the private sector that contract with the U.S. Department of Energy. Most employees of these facilities reside in Clark County and commute to their jobs; only thirteen percent of the NTS workers reported ZIP codes in Nye County in 1984 (Table 5-26). Nye County also has more than 500 county and State government employees providing education, police and fire protection, and other government services (McBrien and Jones, 1984).

While not among the largest sectors in the county, agriculture is an important activity in the Pahrump and Amargosa valleys. Primary agricultural products of the Pahrump Valley include alfalfa, cotton, hay, and dairy products. In 1980 about 6,000 hectares (14,000 acres) of hay and alfalfa were under cultivation and about 28,000 head of cattle were raised in Nye County (McBrien and Jones, 1984).

Baseline employment projections for the mining, construction, government, and services sectors are shown in Table 3-12. Table entries are based on OBERS projections, adjusted to make them consistent with more recent UNR population forecasts (Ryan, 1984a,b). The employment projections in Table 3-12 indicate that, in the absence of the proposed repository project, mining employment is expected to increase by about 3.0 percent per year while construction is expected to grow at an average annual rate of about 3.5 percent between 1985 and 2000. The 1985 value was determined by linear interpolation between 1983 and 1990.

Table 3-12. Employment in selected industries in Nye County, 1978-2000[a]

Employment category and growth[b]	1978[c]	1983	1985	1990	2000
	Year				
Mining					
Number of persons employed	735	1,010	1,140	1,470	1,770
Average annual growth (%)	NA[d]	6.6	6.2	5.2	1.9
Construction					
Number of persons employed	467	384	435	564	729
Average annual growth (%)	NA	-3.8	6.4	5.3	2.6
Government					
Number of persons employed	785	897	941	1,050	1,260
Average annual growth (%)	NA	2.7	2.4	2.2	1.8
Services					
Number of persons employed	3,742	4,630	5,114	6,323	8,609
Average annual growth (%)	NA	4.4	5.1	4.3	3.1

[a] Entries are based on 1985 OBERS regional employment projections (DOC, 1985), applied to historical Nye County employment estimates from McBrien and Jones (1984), and adjusted by the ratio of recent UNR State population forecasts (Ryan, 1984a,b) to OBERS population projections. See Section 3.6.1.3.

[b] Growth rate applies during time interval starting from year indicated in column to the immediate left.

[c] Data from McBrien and Jones (1984).

[d] NA = not applicable.

3.6.1.2 Clark County

More than half of Nevada's wage and salary employment in 1980 was in Clark County (State of Nevada, OCS, 1984). About one-third of Clark County's wage and salary employment, or more than 70,000, was in the hotel, gaming, and recreation industry (State of Nevada, ESD, 1981). Major employers in Clark County in 1983 were the service industries, which include hotels, gaming, and recreation (49 percent); trade industries (20 percent); government (12 percent); transportation and public utilities (6 percent); and construction (5 percent). The mining sector in Clark County is relatively small, with about 0.1 percent of the 1983 wage and salary employment (State of Nevada, ESD, 1984). The retail trade industry, a primary component of the wholesale and retail trade industry in the Las Vegas area, depends heavily on the hotel and gaming industry to bring buyers into the region. Wage and salary employment in the mining industry was 500 in 1980 and 300 in 1983 (State of Nevada, OCS, 1984; State of Nevada, ESD, 1984).

As shown in Table 3-13, employment in the service sector, which includes the hotel, gaming, and recreation industry, is projected to more than double between 1978 and 2000. Table 3-13 shows projected growth in the construction and services industries through the year 2000. OBERS projections for the small mining industry in Clark County are not available. Entries in Table 3-13 are based on OBERS projections, adjusted to make them consistent with more recent University of Nevada, Reno, population forecasts for the county (see Section 3.6.1.3). Baseline construction employment is expected to show very modest growth of 1.6 percent per year between 1985 and 2000.

Table 3-13. Employment in selected industries in Clark County, 1978-2000[a]

Employment category and growth[b]	Year 1978	1985	1990	2000
Construction				
Number of persons employed	14,909	19,300	20,820	24,610
Average annual growth (%)	NA[c]	3.8	1.5	1.7
Services				
Number of persons employed	89,886	131,200	155,000	200,000
Average annual growth (%)	NA	5.6	3.4	2.6

[a]Estimates from 1980 OBERS regional projections, adjusted for the more recent 1985 OBERS State employment projections and the difference between 1980 OBERS and UNR population forecasts (DOC, 1981c, 1985; Ryan, 1984b). See Section 3.6.1.3.

[b]Growth rate applies during time interval starting from year indicated in column to the immediate left.

[c]NA = not applicable.

3.6.1.3 Methodology

The employment projections appearing in tables 3-12 and 3-13 incorporate information obtained from recent projections of economic growth for the State and Nye and Clark counties. The purpose of the projection method is to make effective use of the most recently available economic forecast data and to produce employment projections whose underlying assumptions are consistent with those of the population forecasts appearing in Section 3.6.2. This section describes data sources and methods.

No employment projection is directly available for Nye County. The employment projections that appear in Table 3-12 are based on the 1985 OBERS projection of Nevada employment published by the U.S. Department of Commerce, Bureau of Economic Analysis (DOC, 1985), and on historical Nye County employment estimates that appear in McBrien and Jones (1984). To project Nye County employment, State employment growth rates were obtained from the 1985 OBERS projection for each industry that appears in Table 3-12. These rates were applied to historical (1978) estimates of employment in each sector to project future county employment levels whose underlying assumptions are consistent with those of the 1985 OBERS projection for the State.

Clark County employment projections are directly available. The 1980 OBERS regional projections publication contains projections of Clark County employment for selected years through the year 2000 for each industry represented in Table 3-13. The more up-to-date 1985 OBERS publication does not contain a Clark County employment projection. To take into account the more up-to-date economic growth assumptions implicit in the 1985 OBERS projections, the 1980 OBERS Clark County employment projection in each year was scaled downward by the ratio of the 1985 OBERS projection of total State employment to the 1980 OBERS projection of total State employment. One of the major differences in the population data for the two projections is that the 1985 OBERS projections are based on 1980 census counts, while the 1980 OBERS projections are not.

An additional adjustment was made to the Clark and Nye county employment projections described above to improve their consistency with the University of Nevada, Reno (UNR) population forecasts appearing in Section 3.6.2. The reason for this adjustment is that some of the economic growth assumptions implicit in the 1985 OBERS projections may be inconsistent with those implicit in the UNR population forecasts that appear in Section 3.6.2. The UNR forecasting project did not produce employment forecasts. Thus, the OBERS-derived employment projections for each year for each industry were scaled upward by the ratio of the UNR State population forecast to the 1985 OBERS State population projection. Projections for 1985 are not present in the 1985 OBERS publication. These were obtained by linear interpolation. Note that the terms "forecast" and "projection" are used here as used by the developers of these data.

3.6.2 POPULATION DENSITY AND DISTRIBUTION

This section presents data on recent and forecast baseline population in Nevada and in Nye and Clark counties.

The prediction of future growth of Nevada's State and county populations, like any prediction, is subject to increasing uncertainty as the forecast period increases. The forecasts shown rely implicitly and explicitly on many assumptions about future economic, demographic, and social conditions. Populatio forecasts presented in this section were prepared by the Bureau of Business and Economic Research, University of Nevada, Reno (UNR), for the State of Nevada Office of Community Services (Ryan, 1984b). Although the UNR forecast does not extend beyond the year 2000 and has not yet been published in final form, it is the most recent forecast available for the two counties. Thus, it was used as the basis for estimates presented in chapters 4, 5, and 6.

Recent population data for communities in southern and central Nye County and central and western Clark County are also presented in this section. Population forecasts for these communities are not available. Approximate distances to the proposed location of the surface facilities at the Yucca Mountain site from these communities are also shown in this section. As discussed in Chapter 5, the proposed access road to the surface facilities is expected to be about 26 kilometers (16 miles) in length, and intersect U.S. Highway 95 approximately 0.8 kilometer (0.5 mile) northwest of the existing intersection of U.S. Highway 95 and State Route 373. All other distances are measured along existing roads as shown in the Nevada Map Atlas, fifth edition (State of Nevada, Department of Transportation, ca. 1984).

3.6.2.1 Population of the State of Nevada

This section presents data on recent and forecast baseline population of the State of Nevada. In 1984, Nevada had an estimated population of 947,395 (Ryan, 1984b). Nevada's recent historical population growth has been the greatest of any of the 50 states: 63.8 percent, or an average annual increase of 5.1 percent between 1970 and 1980. About eighty-four percent of this growth came from net migration (State of Nevada, OCS, 1984). In 1980, 14.7 percent of the State's population was clasified as rural. Nevada had a 1980 population of 800,493 with a density of 7.3 persons per square mile (DOC, 1981a).

Historical and forecast Nevada population appear in Table 3-14. According to these forecasts by UNR, the State population is expected to grow at an average annual rate of 3.5 percent from 1985 to 1990, with the growth rate declining to an average annual rate of 2.6 percent between 1990 and 2000.

Table 3-14. Population of the State of Nevada, 1970-2000[a]

State of Nevada population and growth	Year 1970	1980	1985	1990	2000
Population	488,738[b]	800,493[b]	980,597	1,164,480	1,498,234
Average annual growth (%)	NA[c]	5.1	4.1	3.5	2.6

[a]Unless otherwise noted, the entries in this table are based on Ryan, (1984b).

[b]Data from Clark County Department of Comprehensive Planning (1983b).

[c]NA = not applicable.

3.6.2.2 Population of Nye County

This section presents data on recent and forecast baseline population in Nye County, and data on the recent population in communities nearest to Yucca Mountain, and their approximate distances from the proposed location of the surface facilities.

Nye County had an estimated 1984 population of 17,750 (Ryan, 1984b). Population growth in Nye County paralleled that of the State until 1980, when it increased significantly, and the Nye County share of the State population rose from 1.1 percent in 1980 to 1.9 percent by 1984 (calculated from data in Ryan, 1984b). In 1980, all of Nye County's population was classified as rural. The 1980 population was 9,048 with a density of 0.5 person per square mile (DOC, 1981a).

The UNR forecast shows that the Nye County population is expected to increase to 3.0 percent of the State population by 1990 and decline slightly to 2.8 percent by the year 2000. This baseline population forecast appears in Table 3-15 and shows extremely rapid average annual population growth rates between 1980 and 1990, followed by a sharp decline in growth rates between 1990 and 2000.

For communities in southern and central Nye County, 1980 census population data are available only for Tonopah, a census designated place and also the county seat. The 1980 population of the Tonopah census designated place was 1,952 (DOC, 1981a). Recent estimates of the population in communities in Nye County indicate a 1984 population of 2,500 for Tonopah (Smith and Coogan, 1984). However, since the geographic boundaries associated with this estimate are not known, it may not be strictly comparable with the Tonopah census designated place. Three unincorporated towns in southern Nye County that are located closest to the proposed site are Amargosa Valley, Beatty, and Pahrump. The community formerly called Lathrop Wells, and now also called Amargosa Valley, is only one of several locations where residents of the unincorporated Town of Amargosa Valley are clustered. This settlement is the closest residential population to the proposed location of the surface facilities at Yucca Mountain; two other population concentrations of the Town of Amargosa Valley (referred to as the Amargosa Farm area and the American Borate housing complex) are located farther to the south as described in Section 3.6.4.1.1. The three concentrations have estimated populations of 45, 1,500, and 280, respectively (Smith and Coogan, 1984). However, the population of Amargosa Valley is highly variable and dependent upon several economic factors such as the base price of minerals (Black, 1985). A single value for total population of the unincorporated town is not available. The unincorporated town of Beatty had an estimated 1984 population of 800. The unincorporated town of Pahrump had an estimated 1984 population of 5,500 (Smith and Coogan, 1984). Approximate distances from the proposed location of the surface facilities at Yucca Mountain to the communities listed above are: Amargosa Valley (at the nearest population concentration), 27 kilometers (17 miles); Beatty, 72 kilometers (45 miles); Pahrump, 97 kilometers (60 miles); and Tonopah, 222 kilometers (138 miles).

Table 3-15. Population of Nye County, 1970-2000[a]

Nye County population and growth	Year				
	1970	1980	1985	1990	2000
Population	5,599[b]	9,048[b]	20,190	34,790	42,408
Average annual growth (%)	NA[c]	4.9	17.4	11.5	2.0

[a]Unless otherwise noted, the entries in this table are based on Ryan (1984b).
[b]Data from Clark County Department of Comprehensive Planning (1983b).
[c]NA = not applicable.

3.6.2.3 Population of Clark County

This section presents data on recent and forecast baseline population in Clark County, data on the 1980 population in Clark County communities nearest to Yucca Mountain, and the approximate distances of these communities from the proposed location of the surface facilities.

The 1984 population of Clark County was about 549,800 (Ryan, 1984b). Clark County population grew 69.5 percent between 1970 and 1980 (or an average annual rate of 5.4 percent) making it the second fastest growing metropolitan area in the nation for that decade. As the County population has grown, its rate of growth has declined over the past 30 years, from 163.0 percent between 1950 and 1960 (10.2 percent annual average growth) to 115.2 percent between 1960 and 1970 (8.0 percent annual average), and to the 69.5 percent figure cited above between 1970 and 1980. This pattern of declining growth rates follows that of the nation (Clark County Department of Comprehensive Planning, 1983b). As was the case for the State as a whole, net migration accounted for 84 percent of county population growth in the 1970s (State of Nevada, OCS, 1984). Although about 96 percent of Clark County's 1980 population resided in the Las Vegas Valley, the county rural population of 9,767 (2.1 percent of the total population) (Clark County Department of Comprehensive Planning, 1983b) exceeded the total Nye County population for that year. The 1980 Clark County population was 463,087 with a density of 58.8 persons per square mile (DOC, 1981a).

Baseline forecasts of Clark County's population are given in Table 3-16 and show declining average annual growth rates through the year 2000. As shown in Table 3-17, these forecasts lie within the range of other population forecasts developed for Clark County in recent years.

Table 3-16. Population of Clark County, 1970-2000[a]

Clark County population and growth	Year 1970	1980	1985	1990	2000
Population	273,288[b]	463,087[b]	567,150	661,700	889,269
Annual average growth (%)	NA[c]	5.4	4.1	3.1	3.0

[a]Unless otherwise noted, the entries in this table are based on Ryan (1984b).
[b]Data from Clark County Department of Comprehensive Planning (1983b).
[c]NA = not applicable.

The Las Vegas Valley, consisting of a number of incorporated cities and unincorporated towns, had a 1980 population of 443,730 with a density of 585 persons per square mile (Clark County Department of Comprehensive Planning, 1983b). The communities in the Las Vegas Valley are listed below, with their 1980 populations in parentheses. Incorporated cities in the Las Vegas Valley include Las Vegas (164,674), North Las Vegas (42,739), and Henderson (24,363). Unincorporated towns and communities in the Las Vegas Valley are East Las Vegas, Enterprise, Grandview, Lone Mountain, Paradise, Spring Valley, Sunrise Manor, and Winchester (combined 1980 population of 207,710). An additional 4,244 persons lived in other areas of the Las Vegas Valley. The remainder of Clark County, which makes up about 90 percent of its geographic area, had a 1980 population density of 2.7 persons per square mile.

Table 3-17. Comparison of population forecasts (in thousands) for Clark County, 1980-2000

Year	UNR[a]	OBERS[b]	Bureau of Economic Analysis[c]	Clark County Regional Planning Council[c]			State Water Plan[c]			McDonald & Grefe[c]	State Planning Coordinator's Office[c]
				Low	Medium	High	Low	Medium	High		
1980	463	463	403	420	435	460	473	483	500	461	411
1985	567	547	ND	495	520	555	568	601	635	550	527
1990	662	634	524	560	600	650	662	715	770	664	660
1995	775	ND[d]	ND	535	680	755	739	810	885	766	757
2000	889	823	628	700	750	850	816	894	1000	891	867

[a]Data from Ryan (1984b), except 1995 which was calculated by linear interpolation between 1990 and 2000.

[b]Data from McBrien and Jones (1984).

[c]Data from Table 1-4 in Clark County Department of Comprehensive Planning (1983a).

[d]ND = no data.

Boulder City (1980 population of 9,590) and the unincorporated town of Indian Springs (1980 population of 1,446) are located outside of the Las Vegas Valley. The remainder of the Clark County population outside of the Las Vegas Valley was 8,321 in 1980 (Clark County Department of Comprehensive Planning, 1983b).

Indian Springs, located along U.S. Highway 95 in northwestern Clark County is the nearest Clark County community to the site. The distance from the proposed location of the surface facilities to Indian Springs is about 95 kilometers (59 miles). The distance from the proposed location of the surface facilities to the Las Vegas Valley (measured from the U.S. Highway 95 and Interstate 15 interchange) is about 161 kilometers (100 miles).

3.6.3 COMMUNITY SERVICES

The purpose of this section is to present a description of community services in Clark and Nye counties, and to provide a preliminary analysis of their current adequacy. The U.S. Department of Energy conducted a coarse screening so that detailed studies would not be performed on sites which ultimately would not be chosen for site characterization (see also Section 6.2.1.7.4). The extensive primary research which would be necessary for a thorough evaluation of existing services and projection of future service needs was therefore not conducted; instead, published information was used, whenever possible, to gain insights into the adequacy of the existing services and to provide background information on individual communities in Clark and Nye counties which might experience impacts from project-induced population growth. Because recent settlement patterns of the Nevada Test Site workers indicate that only a small proportion of repository workers and dependents are expected to settle outside of southern Nye County, Indian Springs, and the Las Vegas urban area (Table 5-26), extensive background information on community services in other parts of southern Nevada was not considered necessary for this preliminary analysis.

The services described in this section include housing, education, water supply, waste-water treatment, solid waste, energy utilities, public safety (police and fire services), medical and social services, library facilities, and parks and recreation. Future community services requirements were projected assuming that present ratios of services to population (e.g., police officers per 1,000 persons) would be valid in future years (see Section 5.4.3). Current community services are described in the following sections.

The incorporated cities in the bicounty area provide a variety of community services within their boundaries. Services in the unincorporated towns near the repository site, however, are generally not provided by the town governments. Instead, they are provided by the Nye and Clark county commissions, county-wide agencies, local special-purpose districts, voluntary organizations, and private firms under contract to the counties.

3.6.3.1 Housing

Table 3-18 summarizes 1980 housing characteristics for Clark and Nye counties. While the number of persons per unit is almost equal for the two counties, other characteristics differ significantly. Nye County had a higher percentage of mobile homes (44 compared to 11 percent), while Clark County had a higher percentage of multiple family units (29 compared to 9 percent). The vacancy rate in 1980 was 8.4 percent in Clark County and 17.9 percent in Nye County.

3.6.3.2 Education

Statistics on public and private schools in Clark and Nye counties are summarized in Table 3-19. In Nye County, two of the elementary schools, a junior high school, and one of the high schools are located in Tonopah. Other communities having secondary schools are Beatty, Gabbs, and Pahrump. A one-room, seven-student contract school is operated at the Fallini Ranch for grades 1-8 (Research and Educational Planning Center, 1984). There are no private schools in the county. As seen in Table 3-19, ratios of schools per 1,000 residents are much larger in Nye County than in Clark County because of the relatively small size of the schools in Nye County (McBrien and Jones, 1984). The educational personnel-to-student ratio is slightly higher in Nye County.

Of the Clark County schools, 66 elementary, 17 junior high, 10 senior high, and 2 special education schools are located in the greater Las Vegas area. Indian Springs, the Clark County community nearest the Yucca Mountain site, has one elementary school and one combined junior and senior high school (Clark County Department of Comprehensive Planning, 1980). The student-to-teacher ratio in Clark County is about 20 to 1. Specific data on the number of private schools or their operating costs are not available. However, enrollment estimates are included in Table 3-19. Also located in Clark County are the University of Nevada, Las Vegas (UNLV), and Clark County Community College (a two-year college) (McBrien and Jones, 1984) with a combined 1980-1981 enrollment of 18,972.

3.6.3.3 Water supply

In Nye County centralized water supply services are available only in Beatty, Tonopah, Mercury, and Gabbs (State of Nevada, OCS, 1982b), and within parts of Pahrump. These utilities served about 64 percent of the county population in 1980. Table 3-20 summarizes available information on water supply sources and amounts in those areas of Clark and Nye counties near the Nevada Test Site (NTS). Examination of Amargosa Desert basin well log data maintained by the Nevada Department of Conservation and Natural Resources identified 207 domestic water wells in the Amargosa Valley area. More wells may exist than are accounted for in these data. Assuming one well per household, 2.61 persons per housing unit (Table 3-18), and a use of 6.8 cubic meters per day (1,800 gallons per day) per well (the maximum allowable

Table 3-18. Housing characteristics in Clark and Nye counties, 1980

Characteristic	Clark County[a]	Nye County[b]
Composition and housing types		
Total housing units	190,6[illegible]7	4,292
Occupied units	173,8[illegible]1	3,434
Vacant units	15,969	768
Seasonal and second homes	747	90
Units within urban areas	178,686	0
Units within rural areas	7,896	4,292
Owner-occupied units	102,555	2,291
Renter-occupied units	71,336	1,143
Year-round housing types		
Single-family units	114,315	1,916
Multiple-family units	54,815	393
Mobile homes	20,730	1,893
Persons per unit	2.64	2.61
Housing values and rents		
Median value for single-family and mobile homes	$ 67,800	$35,600
Median monthly cash rent	$ 264	$ 155
Median value for condominiums	$ 73,000	0
Government-assisted housing[c]		
Units receiving construction, operation, or rental payment assistance[d]	12,732	56
Units receiving home construction or purchase assistance or both (not including Federal Housing Administration loans)	4,700	7

[a]Data from the State of Nevada, OCS (1982a).
[b]Data from the State of Nevada, OCS (1982b).
[c]Federal or State assistance during 1981.
[d]Some units may be counted more than once.

Table 3-19. Elementary and secondary school facilities and enrollment in Clark and Nye counties[a]

Characteristic	Clark County (1982-1983) Number	Clark County (1982-1983) Number per 1,000 residents[b]	Nye County (1983) Number	Nye County (1983) Number per 1,000 residents[b]
	PUBLIC SCHOOLS			
Number of public schools				
Elementary	78	0.151	11[c]	0.710
Junior high	18	0.035	4[d]	0.258
Senior high	15[d]	0.029		
Contract schools (K-8)	0	0	1	0.065
TOTAL	111	0.215	16	1.033
Enrollment				
Elementary	44,100	85.6	1,653	106.7
Junior high	19,600	38.1	922[c]	59.5
Senior high	19,200	37.3		
Special education	6,800	13.2	130	8.4
Contract schools (K-8)	0	0	7	0.5
TOTAL	89,700	174.2	2,712	175.1
Average daily attendance	86,500	168.0	ND[e]	ND
Educational personnel				
Administrative staff	174	0.338	10	0.646
Elementary school teachers	2,007	3.897		
Secondary school teachers	1,945	3.777	148[f]	9.555
Special education teachers	609	1.182	ND	ND
TOTAL	4,735	9.194	158	10.200
	PRIVATE SCHOOLS[g]			
Enrollment				
Kindergarten	548	1.064	0	0
Elementary	2,312	4.489	0	0
High school	1,852	3.596	0	0
Multiple grade	129	0.250	0	0
TOTAL	4,841	9.399	0	0

[a]Clark County data for public schools estimated by McBrien and Jones (1984) from the 1982-1983 Clark County School District Budget, except where otherwise noted. Nye County data from State of Nevada, OCS (1982b), Research and Educational Planning Center (1984), and M. Johnson (1984).

[b]Population data from Ryan (1984a); 1982 population used for Clark County, 1983 population used for Nye County.

[c]Includes some middle schools.

[d]Includes some combined junior and senior high schools.

[e]ND = no data.

[f]Includes elementary and secondary school teachers.

[g]Data from State of Nevada, OCS (1985a).

Table 3-20. Current (1980-1984) water supply accounted for in areas of Clark and Nye counties near the Nevada Test Site[a]

Community	Estimated population accounted for[b]	Water source	Estimated water use[c] acre-ft/yr	mgd
Amargosa Valley[d]	540	Domestic wells	418	0.373
Beatty[e]	1200-1500	Four municipal wells	165	0.147
Crystal	42[f]	Domestic wells 160 ft deep	30	0.03
Indian Springs	912	Municipal well capable of supplying 0.8 mgd to 53 customers, plus approximately 80 domestic wells with unknown capacity	700	0.6
Indian Springs Air Force Base	500	Two wells supplying 0.2 mgd potable water	300	0.3
Johnnie	2[g]	No data	1	0.001
Mercury	300	Three municipal wells coupled with a distribution system	237	0.212
Nevada Test Site	ND[h]	Six wells supplying 1.2 mgd	1300	1.2
Pahrump[i]	1260	Wells in valley-fill aquifer	1700	1.5
TOTAL			4851	4.363

[a]Data from the MITRE Corporation (1984, tables 2-11 and 2-12), unless otherwise noted.

[b]Population in this table is not total community population as discussed in sections 3.6.2.2, 3.6.2.3, and 3.6.4.1.1. Instead, it is the population for which water use data were available, as cited in the references to this table.

[c]1 acre-foot = 1,234 cubic meters; mgd = million gallons per day, 1 mgd = 1,120.55 acre-feet per year. Values for acre-feet are rounded to the same number of significant digits as in the mgd data.

[d]Alkali Flat-Furnace Creek ground-water basin area. An additional 220 acre feet per year are used for commercial and quasi-municipal purposes (Coache, ca. 1983), but corresponding population data are unavailable.

[e]Data from the Beatty Water and Sanitation District (Walker, 1984). An undetermined amount of water is used by persons not served by the district.

[f]Twenty families.

[g]One family.

[h]ND = no data.

[i]Data for the Central Nevada Utilities service area only (Rogozen, 1985). Total domestic water use in Pahrump is unknown.

without a permit) yields the estimates of Amargosa Valley water use and population served shown in Table 3-20.

A total of 8,436 cubic meters per day (2.263 million gallons per day), which does not include use at the NTS, was used by the 3,494 southern Nye County residents for whom water data are available. Thus, the water demand is estimated to be 2,455 cubic meters per day (0.648 million gallons per day) per 1,000 persons.

Fluoride concentrations in three of the four wells operated by the Beatty Water and Sanitation District exceed the U.S. Environmental Protection Agency's maximum contaminant levels for drinking water (40 CFR 141, 1982). The fourth well produces water of acceptable quality, but the District has recently been unable to obtain sufficiently high flows from it (Walker, 1984). The Nye County Commission was recently awarded $6,000 in U.S. Housing and Urban Development block grant funds from the Nevada Office of Community Services for an engineering and hydrological study to determine the future water supply for the Beatty Water and Sanitation District (Walker, 1985).

The main areas of existing and potential future agricultural water use are in the Amargosa and Pahrump valleys south of the proposed repository site in Nye County. The total sustained yield of aquifers in the Amargosa Desert ground-water basin has been estimated to be 30×10^6 cubic meters (24,000 acre-feet) per year (Morros, 1982). Certified appropriations for agricultural use in this basin totaled 32×10^6 cubic meters (26,320 acre-feet) in 1983; however, actual agricultural water use (with or without certificated permits) in that year was 11.2×10^6 cubic meters (9,105 acre-feet) (Coache, ca. 1983). Certificated appropriations and development permits for ground water in the Pahrump valley totaled 112×10^6 cubic meters (91,000 acre-feet) per year in 1970, although in recent years actual exploitation has averaged about 49×10^6 cubic meters (40,000 acre-feet) per year. In the last ten years, real estate developers have purchased agricultural land (with appurtenant water rights) for constructing homes in subdivisions, and water use has transferred from agricultural to domestic. An overdraft (i.e., long-term withdrawal exceeding replenishment) has existed, and the State Engineer has opposed certification of new permits for irrigation. However, agricultural use is declining rapidly as land is developed for residential use.

According to Harrill (1982), the maximum amount of water that can be withdrawn and consumed annually and indefinitely without creating a continuing overdraft on ground-water storage (safe yield) in the Pahrump Valley is 23×10^6 cubic meters (19,000 acre-feet). (Note that this is a net consumptive use.) About 70 percent of the withdrawals for domestic use and 50 percent of the withdrawals for public water supply systems and commercial use are returned to the valley-fill aquifer. Assuming that the present ratio between domestic and commercial withdrawals (2 to 5) continues, and using a method presented by Harrill (1982), it may be shown that a sustainable pumping rate of 53×10^6 cubic meters (42,900 acre-feet) per year may be achieved if all agricultural uses are converted to domestic and commercial. Using the per capita consumption rate of 2.445 cubic meters per day (2,445 per 1,000 persons) (648 gallons per day), it may be shown that the Pahrump Valley aquifer may support up to about 16,900 residents with no decline in usable storage. However, as noted by Harrill (1982), local effects, such as land subsidence and well interference, could result from sustained development.

Table 3-21 shows sources and suppliers of water in metropolitan areas of Clark County. Lake Mead on the Colorado River supplies 60 percent and wells supply 40 percent of the municipal and industrial water for the county (Nevada Development Authority, 1984). Metropolitan areas are served by 7 water systems managed by 22 distribution companies (State of Nevada, OCS, 1982a), while rural users rely upon private wells. The cities of Boulder City, Henderson, and North Las Vegas manage their individual distribution systems. The Las Vegas Valley Water District is the distributor for the City of Las Vegas and unincorporated Clark County (State of Nevada, NDCNR, 1982). The aggregate capacity of the metropolitan water systems is about 2.12×10^6

Table 3-21. Water supply in metropolitan areas of Clark County[a]

Community	Supplier[b]	Source	Maximum capacity (mgd)[c]	Peak demand (mgd)
Boulder City	Colorado River Commission/Las Vegas Valley Water District	Lake Mead	14.8	7.8
Henderson	Colorado River Commission/Las Vegas Valley Water District, BMI	Lake Mead	19.3	13.6
Las Vegas[d]	Colorado River Commission/Las Vegas Valley Water District	Lake Mead (60%) Wells (40%)	479.0	195.1
North Las Vegas	Colorado River Commission/Las Vegas Valley Water District	Lake Mead (60%) Wells (40%)	45.9	25.3
TOTAL			559.0	241.8

[a]Data from Nevada Development Authority (1984).
[b]Data from State of Nevada, NDCNR, (1982).
[c]mgd = million gallons per day; 1 gallon = 0.003785 cubic meters.
[d]Includes unincorporated areas of Clark County.

cubic meters (559 million gallons) per day. Peak demand in 1982 was 1,780 cubic meters (0.469 million gallons) per day per 1,000 persons. Thus, peak demand represents about 43 percent of capacity.

Available rights to surface water (from Lake Mead) in the Las Vegas metropolitan area are currently about 321 x 10^6 cubic meters (84.8 billion gallons) per year or an average of about 878 x 10^3 cubic meters (232 million gallons) per day (State of Nevada, NDCNR, 1982). The present use of ground water in Las Vegas Valley is about 88 x 10^6 cubic meters per year (64 million gallons per day), but the State Engineer has adopted a goal to reduce this to 62 x 10^6 cubic meters per year (45 million gallons per day) (State of Nevada, NDCNR, 1982). Present delivery systems are adequate for current needs. However, supply may not be sufficient for the baseline demand projected for the Las Vegas Valley in 2020 and later years (see Section 5.4.3.3).

3.6.3.4 Waste-water treatment

Waste-water treatment facilities in Nye County operate in Beatty, Gabbs, and Tonopah; the remainder of the county uses private waste-water treatment systems (e.g., septic tanks) (State of Nevada, OCS, 1982b). The Beatty Water and Sanitation District's oxidation pond system is presently at capacity (Walker, 1985). Central Nevada Utilities operates two aerobic treatment plants for the Calvada housing subdivision in Pahrump. In Clark County, approximately one third of the water consumed enters the county sewage system (McBrien and Jones, 1984). This waste water is treated in 11 facilities operated in Boulder City, Henderson, Las Vegas, Overton, and other sites throughout the county (State of Nevada, OCS, 1982a). Table 3-22 summarizes waste-water treatment in Clark County and southern Nye County.

3.6.3.5 Solid waste

Trash collection in Nye County is handled by private contractors. County-owned, privately operated landfills are located outside the Town of Amargosa Valley, Beatty, Pahrump, Tonopah, and Gabbs. Refuse in Las Vegas, North Las Vegas, Henderson, and the unincorporated areas of Clark County is collected by Clark Sanitation Company, Silver State Disposal, and Automated Transfer Services, which form one private collection service. Fees are collected from residents by these companies, which pay a percentage of the fees collected to the county and to the cities. The major landfill in the bicounty area, Sunrise, is owned by the Bureau of Land Management, leased by Clark County, and operated and maintained by Clark Sanitation Company. The landfill's 130 hectares (320 acres) are adequate for current needs. Other major landfills are located at Boulder City and Nellis Air Force Base.

3.6.3.6 Energy utilities

Electrical power in Nye County is distributed by the Sierra Pacific Power Company, Mount Wheeler Power, and the Valley Electric Association. In Nye County, propane is supplied by four distributors and heating oil by three

Table 3-22. Waste-water treatment facilities in Clark and Nye counties[a]

Community	Type of facility	Maximum capacity (mgd)[b]	Peak load (mgd)
Amargosa Valley	Septic tanks	ND[c]	ND
Beatty[d]	Oxidation ponds	0.05	ND
Boulder City	Facultative (aerobic-anaerobic) ponds	[illegible].8[e]	1.0
Clark County unincorporated	Advanced secondary treatment (trickling filter)	9[illegible].0[f,g]	38.0
Henderson[h,i]	Secondary treatment (aerated lagoon system); rapid infiltration; re-use facilities under construction	6.2	2.5
Indian Springs	Evaporation ponds	ND	ND
Indian Springs Air Force Base	Primary treatment (Imhoff tanks); sludge disposal in pits	ND	ND
Las Vegas	Secondary treatment (trickling filters), chemical treatment for phosphorus removal	37.5	30.0
Mercury	Oxidation ponds	ND	ND
Nevada Test Site	No information	ND	ND
North Las Vegas	Uses City of Las Vegas plant	NA[j]	NA
Pahrump[k]	Aerobic package plants for Calvada development, septic tanks for rest	0.06	ND

[a]Data from the MITRE Corporation (1984) and the Nevada Development Authority (1984), except where otherwise noted.
[b]mgd = million gallons per day; 1 gallon = 0.003785 cubic meters.
[c]ND = no data.
[d]Data from Walker (1984).
[e]Data from Henry (1985).
[f]Data from Brown and Caldwell and Culp/Wesner/Culp (1980).
[g]Data from Bechtel (1985).
[h]Data from URS Company (1979)
[i]Data from Billingsley (1985).
[j]NA = not applicable.
[k]Data from Rogozen (1985).

distributors. The main sources of electrical power for Clark County are the hydroelectric plant at Hoover Dam, Nevada Power Company's fossil-fuel Clark Generating Station (near Las Vegas), and Reid Gardner Generating Station (near Moapa). Distributors in Clark County include the Boulder City Electrical Department, the Nevada Power Company, and the Overton Power District. Piped natural gas is available only in Clark County. Table 3-23 summarizes electrical and natural gas supply services in the two counties.

3.6.3.7 Public safety services

The Nye County Sheriff's Office provides police protection for the entire county except for the incorporated city of Gabbs. The Sheriff's Office employs 44 deputies and 14 dispatchers to cover 5 million hectares (12 million acres) of the county; Gabbs employs an additional three deputies (State of Nevada, OCS, 1982b). Thus, there were about 3.53 commissioned police officers for every 1,000 people in the county in 1982. This relatively high ratio is explained in part by the large area of the county and the long distances between towns (McBrien and Jones, 1984).

Nye County has 12 fire departments, which operate 14 fire stations, staffed by 128 firefighters (all but 14 are volunteers). The largest stations are the Amargosa Volunteer Fire Department and the Tonopah Fire Department, which each have 25 firefighters. The Tonopah Fire Department has four paid employees. The 12 fire departments own a total of 36 major pieces of equipment (State of Nevada, OCS, 1982b). As with police protection, the number of firefighters (9.61 per 1,000 people in 1982) is relatively high. This may be attributed in part, to the nature of the volunteer fire departments and the regional geographic characteristics (McBrien and Jones, 1984).

The Las Vegas Metropolitan Police Department, which is responsible for the City of Las Vegas and unincorporated areas of Clark County, employs 738 police officers, including 27 in its airport section (LVMPD, 1984). There are also 17 officers in Boulder City (McBrien and Jones, 1984), 41 in Henderson (McBrien and Jones, 1984), and 97 in North Las Vegas (Fay, 1984). Thus, the county had 893 police officers for a total 1983 population of 535,150 (Ryan, 1984a), or about 1.67 commissioned officers per 1,000 residents. The four police departments operated about 430 vehicles in 1983 (McBrien and Jones, 1984). According to a recent study by the Las Vegas Metropolitan Police Department, sheriff stations and detention facilities in many of the Clark County rural communities are inadequate, especially in those areas with a rapid growth in tourism (LVMPD, 1983).

Clark County is served by 24 fire departments through 41 fire stations. Five of these fire departments are located on government facilities and at private industrial complexes. All but four of the remaining fire departments are staffed by volunteers. There are 218 volunteer firefighters in the 15 Clark County community volunteer fire departments and 525 paid firefighters at the 9 private and public stations. Thus, the county had 0.423 volunteer and 1.019 paid firefighters for every 1,000 people in the county in 1982. Fire departments in Clark County use 105 major equipment pieces, including pumpers, tankers, security and emergency items, and squad cars. Most departments own one or two pieces of equipment, although the Clark County

Table 3-23. Energy distributors in Nye and Clark counties[a]

Utility	Service area	Supplier	Capacity: Total	Capacity: Maximum daily use
Boulder City Electrical Department	Boulder City	DOE and Colorado River Commission	[illegible].3 MW[b]	27.2 MW
C.P. National	Henderson	El Paso Natural Gas Company	[illegible] MMSCFD[c]	ND[d]
Mount Wheeler Power[e]	Northwest Nye County	Not Known	ND	ND
Nevada Power Company	Henderson, Las Vegas, N. Las Vegas, unincorporated areas of Clark County	Nevada Power Company	1792 MW	1528 MW
Overton Power District	Bunkerville, Logandale, Mesquite, Overton	Colorado River Commission[g]	ND	13.735 MW[f]
Sierra Pacific Power Company[e]	Northwest and central Nye County	Not known	ND	ND
Southwest Gas Company	Boulder City, Las Vegas, N. Las Vegas, unincorporated areas of Clark County	El Paso Natural Gas Company	160.0 MMSCFD	150.4 MMSCFD
Valley Electric Association	Beatty, Amargosa Valley, Pahrump, Scotty's Junction	Colorado River Commission[g]	ND	ND

[a]Data from Nevada Development Authority (1984), except where otherwise noted.
[b]MW = megawatt.
[c]MMSCFD = million standard cubic feet per day (natural gas).
[d]ND = no data.
[e]Data from the State of Nevada, OCS (1985b)
[f]Summer peak (combined capacities of Parker Dam and Colorado River Storage Project).
[g]Data from the Clark County Comprehensive Energy Plan (Clark County Department of Comprehensive Planning, 1982a).

Fire Department has 33 major pieces of equipment and Nellis Air Force Base has 10 (State of Nevada, OCS, 1982a).

3.6.3.8 Medical and social services

In 1982 there were 6 physicians in Nye County, or .450 per 1,000 residents, and 676 in Clark County, or 1.31 per 1,000 residents. At the end of 1982, Clark County had 215 dentists, or 0.417 per 1,000 residents. All Nye County has been ranked as a priority 1 health-manpower-shortage area by the U.S. Public Health service; i.e. it has the highest priority for allocating health manpower recruited by the Health Service Corps (State of Nevada, NSHCC, 1983). Health care services in the three communities nearest the proposed waste repository site are limited. Amargosa Valley has no resident doctors or dentists. Its clinic is staffed by a full-time physician's assistant provided by the Central Nevada Rural Health Consortium (Longhurst, 1984). The Beatty medical clinic is staffed by a part-time physician's assistant and visited by a dentist periodically; there is no doctor in the town (Thayer, 1984). Pahrump has a county-owned-and-maintained medical clinic staffed by a full-time physician's assistant. A doctor visits the clinic once a week from Las Vegas, and another doctor is in private practice in the town. All three communities have volunteer ambulance services and access to the "Flight for Life" helicopter service operated by Valley Hospital in Las Vegas.

Areas of Clark County having a health manpower priority of 1 include Searchlight-Davis Dam-Southpoint, Indian Springs, Virgin Valley, Moapa Valley, Lake Mead, Jean-Goodsprings, Sandy Valley, Blue Diamond-Lee Canyon, Mount Charleston, and Central and North Central Las Vegas. The Paiute Indian colonies in the Las Vegas Valley and the Moapa Valley have a priority rating of 4. Priority 4 means that the area does not have as great a health manpower shortage as priority 1 (State of Nevada, NSHCC, 1983).

Acute care facilities in the two counties are listed in Table 3-24, along with the average number of beds in various service classes in 1982. In addition, Clark County has 11 long-term care facilities having a total of 1,047 beds (State of Nevada, NSHCC, 1983). Thus, at the end of 1982, Clark County civilian hospitals had 3,012 beds, or 5.85 per 1,000 residents. Nye County had 22 acute care hospital beds and 24 long-term care beds (all at Nye General Hospital), for a total of 3.45 per 1,000 residents. The Nye General Hospital in Tonopah has been operating at a deficit (Pahrump Valley Times-Star, 1983). In an effort to improve the situation, the Nye County Commission formed a special assessment district in March 1984 (Pahrump Valley Times-Star, 1984a). Since the towns of Amargosa Valley and Pahrump had voted overwhelmingly to oppose a "health tax" for the hospital, they were not included within the new district. According to the town councils of Beatty and Amargosa Valley (Thayer, 1984; Boyd, 1984), very few people in these communities use Nye General.

An important factor in evaluating health care systems in the area is the impact of the large visitor population on health services. In 1980 the Las Vegas area had nearly 12 million visitors who stayed an average of 4.3 nights (Las Vegas Review-Journal et al., 1985). Therefore, an average of

Table 3-24. Hospital facilitites in Nye and Clark counties, 1982: average number of allocated hospital beds per classification[a]

Facility	Total beds[c]	Class[b] 1	2	3	4	5	6	7	8	9	10	11
					COMMUNITY HOSPITALS							
Boulder City	38	31.0	5.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
St. Rose de Lima	78	59.1	14.9	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Desert Springs	222	179.5	0.0	0.0	18.8	22.8	0.0	0.0	0.0	0.0	0.0	0.0
Southern Nevada Memorial	356	152.4	26.8	33.0	35.9	22.0	0.0	0.0	30.0	30.0	11.6	8.0
Sunrise	670	459.4	56.0	42.0	72.0	0.0	5.0	35.0	0.0	0.0	0.0	0.0
Valley	298	210.0	0.0	12.0	20.0	25.0	0.0	0.0	31.0	0.0	0.0	0.0
Women's	61	40.0	21.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
North Las Vegas	168	115.0	0.0	6.0	16.0	0.0	0.0	0.0	0.0	31.0	0.0	0.0
Nye General	22	17.4	2.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	1,913	1263.8	125.7	93.0	170.7	69.8	5.0	35.0	61.0	61.0	11.6	8.0
					SPECIAL HOSPITALS							
Raleigh Hills	34	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.5	0.0
Las Vegas Mental Health Center	40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40.0	0.0	0.0	0.0
Subtotal	74	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40.0	0.0	33.5	0.0
					FEDERAL HOSPITALS							
Nellis Air Force Base	35	32.5	0.5	2.5	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0
TOTAL	2,022	1296.3	126.2	95.5	170.7	69.8	5.0	35.0	103.0	61.0	45.1	8.0

[a] Data from State of Nevada, OHPR (1983).

[b] Bed classes are as follows: 1 = medical/surgical, 2 = obstetrical, 3 = pediatric, 4 = intensive care unit/cardiac care unit, 5 = intermediate care, 6 = pediatric intensive care unit, 7 = neonatal intensive care unit, 8 = psychiatric, 9 = rehabilitation/physical medicine, 10 = alcohol treatment, 11 = jail (security).

[c] This column shows total licensed beds as of December 31, 1982. The sum of the average number of allocated beds in each bed class may differ from the total licensed beds for a given hospital because more or fewer beds may have been available during the year.

141,000 visitors per day (more than 25 percent of the resident population) may require some type of health care, primarily emergency services. In 1982 about 130 acute-care hospital beds were allocated for use by out-of-area patients (McBrien and Jones, 1984). The hospital admission rate for visitors to Clark County has been estimated at 0.5 per 1,000 visitors. According to the Nevada State Health Coordinating Council (State of Nevada, NSHCC, 1983), 6.9 percent of the admissions to Clark County hospitals are out-of-state residents.

Social services in southern Nevada are provided by a variety of State and local agencies. The Nevada Department of Human Resources administers programs dealing with adoption, child abuse, emergency shelter, family counseling, mental health, mental retardation, public health screening and education, senior citizens, vocational training and rehabilitation, and welfare. The Nevada Equal Rights Commission handles complaints of discrimination in housing and employment. The Nevada Industrial Insurance System administers workers compensation programs (Clark County Department of Comprehensive Planning, 1982b).

In southern Nye County, the Nye County Commission administers an emergency shelter program, while the Southern Nevada Mental Health Unit, a State agency, provides mental-health counseling. The County and the State jointly maintain a senior citizens center in Pahrump.

Local public social service agencies in Clark County include the 8th Judicial District Court, the Clark County Health District, Clark County Social Services, the Economic Opportunity Board of Clark County, and the City of Las Vegas' Senior Citizens Law Project. Types of services provided include alcohol and drug abuse counseling, burials, care of child-abuse victims, emergency shelters, low-income energy assistance, family counseling, homemaker assistance, public-health screening, protective services, legal aid, and a variety of programs for senior citizens (Clark County Department of Comprehensive Planning, 1982b).

3.6.3.9 Library facilities

Nye County does not have a county-wide library system. Individual libraries are located in Beatty, Gabbs, Amargosa Valley, Manhattan, Pahrump, Round Mountain, and Tonopah. The new library in the Town of Amargosa Valley is staffed by a full-time librarian and an assistant and is funded by the town and the Nye County School District. The Beatty library, which is also new, has 12,000 books and a full-time librarian. About one-third of the support for the library comes from the Nye County School District, and the remainder from local tax revenues (Thayer, 1984). A library assessment district was recently formed in Pahrump (Pahrump Valley Times-Star, 1984b).

Library services are provided by four library districts in Clark County. Boulder City, Henderson, and North Las Vegas maintain municipal systems, while the Clark County Library District is responsible for the City of Las Vegas and unincorporated areas of the county. Branches are located in the Las Vegas metropolitan area and in Blue Diamond, Bunkerville, Goodsprings, Indian Springs, Mesquite, Mount Charleston, Overton, and Searchlight. The four districts have a total of 565,909 books and employ the equivalent of 102 full-time staff members, including professional librarians and administrative staff (State of Nevada, NSL, 1984).

3.6.3.10 Parks and Recreation

Table 3-25 summarizes the major types of public park and recreational facilities in Nye and Clark counties. Not included in the table are a variety of other facilities owned and operated by local governmental agencies and special-purpose districts, such as exercise courses, jogging trails, volleyball courts, gymkhana arenas, picnic areas, and campgrounds.

In southern Nye County, most of the public recreational facilities are maintained by local special-purpose districts. In Pahrump these facilities are provided by the town board. The Amargosa Valley Improvement Association owns a 16-hectare (40-acre) park, with facilities including a softball field, a gymkhana arena, and a drag track. Parks and recreation facilities in Beatty are considered by the Beatty General Improvement District to be adequate for the present population except that additional baseball/softball fields are needed (Crowell, 1985). The District is currently developing a ten-year recreation plan. According to the Pahrump Town Board, park and recreational facility development in that community is not keeping pace with population growth (Moore, 1985).

According to an analysis by the Clark County Parks and Recreation Department, demand for facilities for most recreational activities exceeds the supply (Clark County Department of Comprehensive Planning, 1984).

The Las Vegas Department of Recreation and Leisure Activities manages 55 parks, having a combined developed area of about 262 hectares (647 acres) (Clark County Department of Comprehensive Planning, 1982b). Of these, 18 are at schools and are operated through joint-use agreements with the Clark County School District. Another 170 hectares (419 acres), most of which are associated with Angel Park, are held in reserve for future expansion.

North Las Vegas has 76 hectares (187 acres) of neighborhood and community parks, playgrounds, and sports fields (including a golf course). In addition, a 421-hectare (1,040-acre), largely undeveloped regional park is located in the city. Besides serving local residents, the parks are used by residents of Las Vegas and unincorporated Clark County, as well as by personnel from Nellis Air Force Base. According to the Superintendent of Parks, existing personnel and facilities are inadequate for the present population (F.M. Johnson, 1984).

Table 3-25. Public parks and recreational facilities in Nye and Clark counties

Service provider	Number of parks	Total area in hectares (acres)	Baseball fields	Football/soccer fields	Pools	Equipped playgrounds	Recreation centers	Tennis courts	Basketball courts	Golf courses
				NYE COUNTY						
Amargosa Valley Improvement Association[a]	1	16.2 (40)	3	0	ND[b]	ND	ND	2	2	ND
Beatty General Improvement District[c]	1	2.0 (5)	1	1	1	1	1	1	1	0
Town of Pahrump and Pahrump Swimming Pool District[d]	1	No Data	2	0	1	1	0	1	1	0
				CLARK COUNTY						
Clark County Commission[e]	40	1325 (3275)	38	16	11	25	8	28	3	0
City of Boulder City[f]	7	6.6 (16.4)	8	0	1	0	1	11	0	1
City of Henderson[g]	12	33.1 (81.7)	4	ND	2[f]	3	1	4	5	0
City of Las Vegas[h]	55	261.8[i] (646.9)	36[j]	ND	7[j]	2	10	ND	ND	1
City of North Las Vegas[k]	16	75.7 (187)	0[l]	6[l]	3[l]	6	1	11[l]	3[l]	1

[a] Data from Rogosen (1985).
[b] ND = No data.
[c] Data from Crowell (1985).
[d] Data from Moore (1985).
[e] Data from Clark County Department of Parks and Recreation (1984).
[f] Data from Nevada Development Authority (1984).
[g] Data from Lucas (1984).
[h] Data from Clark County Department of Comprehensive Planning (1982b).
[i] Another 169.7 hectares (419 acres) are held in reserve for future expansion.
[j] Data from BMHL (1982).
[k] Data from F.H. Johnson (1984).
[l] Data from Dabney (1984).

The Henderson Parks and Recreation Department manages 12 parks having a combined area of about 33 hectares (82 acres). According to the Department, these facilities are "understaffed and underdeveloped" (Lucas, 1984).

3.6.4 SOCIAL CONDITIONS

This section contains a preliminary description, based on available data, of existing sociocultural characteristics of southern Nevada. Because actual transportation routes have not yet been identified, communities through which high-level radioactive waste would be transported have not yet been identified. The focus of this section is on those communities in the bicounty area that could be affected by inmigrating repository workers. The data provide the basis for the preliminary assessment of sociocultural impacts described in chapters 4, 5, and 6. This type of description is sometimes classified as describing the quality of life in the affected area and involves measuring both objective and subjective components of community social life. A single index of the quality of life has not been determined for all residents in the study area because southern Nevada, which has experienced rapid and dynamic change, has a wide diversity of cultures and social organization. The following sections describe (1) social organization and structure, (2) culture and lifestyle, (3) community attributes, and (4) a preliminary assessment of citizen concerns about the repository.

3.6.4.1 Existing social organization and social structure

The terms social organization and social structure, as used in the following sections, refer to the major social groupings and the network of social relationships that exist among residents in a given location.

In contrast to the social impacts documented in the traditional boomtown literature (Cortese and Jones, 1977; Murdock and Leistritz, 1979; see, however, Wilkinson et al., 1982, and Murdock et al., 1985, for a more recent discussion of this literature), the bicounty area of southern Nevada comprises two distinct social settings: (1) a rural component, which includes all of Nye County and the nonurban sections of Clark County, and (2) an urban component, which includes about 96 percent of the Clark County population. Table 3-26 presents selected social characteristics of Nye and Clark counties, the State of Nevada, Mountain States, Western States, and the U.S.

3.6.4.1.1 Rural social organization and structure

As indicated in Table 3-26, Nye County exhibits a high rate of population growth and inmigration, as compared with the national average. In 1980 only 25 percent of Nye County residents were born in the State (Table 3-26). Historically, a high rate of inmigration and population turnover associated with boom and bust mining activities has occurred both in the State and in Nye County (Elliott, 1973; Paher, 1970). These data suggest the absence of community cohesion, defined as social forces that draw and keep persons

Table 3-26. Selected social characteristics[a]

Characteristic	U.S.	Western States	Mountain States	State of Nevada	Nye County	Clark County
Number of persons per square mile	64.0	24.6	13.3	7.3	0.5	58.8
Urban (%)	73.7	83.9	76.4	85.3	0.0	95.5
Racial composition (%)						
White	83.4	81.5	88.1	87.3	92.2	84.8
Black	11.7	5.2	2.4	6.4	0.3	10.0
American Indian, Eskimo, Aleut	0.7	1.8	3.3	1.8	4.7	0.8
Other	4.2	11.5	6.2	4.0	2.8	4.4
Spanish origin (%)	6.5	14.5	12.7	6.8	5.5	7.6
Males per 100 females	94.5	98.0	98.7	102.4	115.7	101.7
Age 65 and over (%)	11.3	10.0	9.3	8.2	9.0	7.6
Population increase 1970-80 (%)	11.4	23.9	37.2	63.8	61.6	69.5
Born in-state (%)	63.9	45.3	44.1	21.4	24.9	18.5
Owner-occupied homes (%)	64.4	60.3	67.2	59.6	66.7	59.0
One-person households (%)	22.7	23.6	21.6	24.6	26.6	24.3
Marriage rate[b]	10.4	24.1	29.6	148.9	11.7	116.0
Divorce rate[b]	5.2	7.6	8.0	16.0	7.7	16.4
Suicide rate[b]	12.8	17.2	17.8	27.8	14.6	22.8
Homicide rate[b]	9.7	8.6	8.7	17.0	27.2	19.4
Crime rate[c]	5396.5	6923.2	6383.5	8485.1	2980.2	9075.3

[a]Except where otherwise indicated, data were obtained from DOC (1983a).

[b]All values were calculated from data in Giovacchini (1983). Values for marriage and divorce were calculated from data on page 160 and pages 4-7. Values for suicide and homicide for the United States, Western and Mountain states and the State of Nevada were calculated from data on pages 165-172. Yearly rates for each state were averaged over the four years 1977-1980 (inclusive) to arrive at an overall average rate for the Mountain or Western states. Data for Hawaii and Alaska are not included in the Western states' averages. Values for suicide and homicide for Nye and Clark counties were calculated from population estimates shown on page 2, suicide data presented on pages 100-103, and homicide data presented on pages 110-113. Yearly rates were averaged for the four years 1977-1980 (inclusive). Marriage and divorce rates are expressed as a rate per 1,000 inhabitants; suicide and homicide rates are expressed as a rate per 100,000 inhabitants.

[c]Values for the U.S., Western and Mountain states and Nevada were calculated from data in U.S. Department of Justice (1978-1980, 1982). Values for Nye and Clark counties were calculated from data in State of Nevada, Department of Law Enforcement Assistance (1980) and county population estimates on page 3 of Giovacchini (1983). Data are expressed as a rate per 100,000 inhabitants, and represent an average of the respective yearly rates.

together (Schacter, 1968). Based on data in Table 3-26, other indicators point to a greater degree of social cohesion in Nye than in Clark County, although these data should be interpreted with caution in view of the small numbers and small population base. In Nye County, the percentage of owner-occupied homes was higher than in Clark County; divorce rates and crime rates were lower. The population was fairly homogeneous in rural and racial composition (although the census data also show that in 1980 Native Americans constituted almost 5 percent of the total Nye County population). Approximately 40 percent of these Native Americans lived on reservations. Nye County had a relatively high ratio of males to females in 1980.

The most striking feature of the area surrounding the Yucca Mountain site is the sparseness of population. As shown in Table -26, the 1980 Nye County population density was only 0.5 person per square mile. The Yucca Mountain site is bounded entirely on one side by the Nevada Test Site (NTS); on the remaining sides, the population is dispersed over a wide geographic area, which is predominantly undeveloped desert or mountainous land. Forms of social organization include several farming communities, isolated ranches and mining settlements, and a few villages which serve as trade centers (Smith and Coogan, 1984). In addition, there is a company housing complex for workers at the American Borate Company and temporary housing at Mercury for workers and visitors at the NTS.

Data on settlement patterns of recent U.S. Department of Energy and contractor employees at the NTS indicate that some rural communities may be affected by inmigrating repository workers (Table 5-26). Four communities closest to the proposed repository site are Amargosa Valley, Beatty, and Pahrump in Nye County and Indian Springs in Clark County. The distinctive features of these communities are described in the following paragraphs, including distances from the proposed location of the surface facilities at Yucca Mountain. All distances presented below are road miles as shown in the Nevada Map Atlas (State of Nevada, Department of Transportation, ca. 1984), plus the length of the proposed access road to U.S. Highway 95, which is expected to be 26 kilometers (16 miles) long (see Section 3.6.2).

Amargosa Valley is the nearest population center to the repository site. The population of the town is spread unevenly throughout approximately 1,036 square kilometers (400 square miles) (Hansen, ca. 1984) and is highly variable (see Section 3.6.2.2). Approximately 45 people (Smith and Coogan, 1984) were concentrated along U.S. Highway 95 in the community formerly called Lathrop Wells, which is about 27 kilometers (17 miles) from the proposed surface facilitites at Yucca Mountain. There are two other locations where the town's population is concentrated: the Amargosa Farm area, which is approximately 18 kilometers (11 miles) south of U.S. Highway 95 and west of State Route 373, and the American Borate housing complex on Nevada State Route 373, close to the California border. Population in these locations was estimated to be 1,500 persons and 280 persons, respectively (Smith and Coogan, 1984). The valley has witnessed growth in recent years. The Research and Educational Planning Center (1984) estimates that there is a large Hispanic population (approximately 50 percent) and a transient population of from 20 to 25 percent. Both mining and ranching are important in the area (Research and Educational Planning Center, 1984). Much of the land can be classified as "agriculturally marginal." Under irrigation, the