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Draft Environmental Assessment for Characterization of the Hanford Site Pursuant to the Nuclear Waste Policy Act of 1982 (Public Law 97-425)

Hanford Site
Richland, Benton County, Washington

February 1983

U.S. Department of Energy
Washington D.C. 20585

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DRAFT ENVIRONMENTAL ASSESSMENT
FOR
CHARACTERIZATION OF THE HANFORD SITE
PURSUANT TO THE
NUCLEAR WASTE POLICY ACT OF 1982
(PUBLIC LAW 97-425)

HANFORD SITE
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FOREWORD

On January 7, 1983, President Reagan signed into law the Nuclear Waste Policy Act of 1982 (Public Law 97-425). This Act establishes a step-by-step process by which the President, Congress, affected individual states and Indian tribes, U.S. Department of Energy (DOE), and other Federal agencies can work together in the siting, construction, and operation of a high-level nuclear waste repository.

The DOE is required by Section 116(a) of the Act to identify states having potentially acceptable sites for a waste repository. A potentially acceptable site is defined by the Act as "...any site at which, after geologic studies and field mapping but before detailed geologic data gathering, the Department undertakes preliminary drilling and geophysical testing for the definition of the site location." By letter dated February 2, 1983, the Secretary of the DOE notified the Governor and Legislature of the State of Washington that the Hanford Site, near Richland, Washington, contains a potentially acceptable repository site.

Pursuant to Section 112 of the Act, the DOE issued Proposed General Guidelines for Recommendation of Sites for Nuclear Waste Repositories on February 7, 1983 in the Federal Register.

The next step under the Act is the DOE's nomination of five locations for site characterization, based on a consideration of the siting guidelines and the environmental assessments to be prepared for each of the five nominated sites, followed by a recommendation of three candidate sites to the President for his approval. The DOE intends to complete these actions in the summer of 1983 in order to permit the conduct of a sufficiently thorough site characterization program at each site to support the Presidential recommendation of a site for the first repository by March 31, 1987, as required by the Act.

Site characterization work at Hanford has been ongoing since 1976. The principal borehole at Hanford was approved in May 1982, and the Exploratory Shaft was begun in November 1982. An environmental assessment for Basalt Waste Isolation Project Exploratory Shaft construction was prepared by the DOE and issued in September of 1982 to meet the requirements of the National Environmental Policy Act of 1969. A finding of no significant impact (FONSI) was published in the Federal Register on September 16, 1982. The Nuclear Waste Policy Act of 1982 establishes a new requirement that an environmental assessment evaluating specific issues contained in the Act be prepared. This document is a draft of the environmental assessment required by the Act. Under the terms of the Act, site characterization work may continue at this site while certain requirements of the Act are being implemented. The final environmental assessment will accompany the nomination of the Hanford Site for site characterization, pursuant to Section 112 of the Act. Pursuant to Section 112(f) of the Act, ongoing site characterization work has been continued during the preparation of this environmental assessment.

Chapter 1.0 of the environmental assessment discusses the basis for recommending the Hanford Site for site characterization. Chapter 2.0 contains a series of background summaries of topics that are relevant to the information presented in the remainder of the environmental assessment. The material necessary to meet the requirements of Section 112(b)(1)(E) of the Act is presented in Chapter 3.0.

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FIGURES:

TABLES:

1.0 BASIS FOR NOMINATION OF THE HANFORD SITE

The Hanford Site, and more specifically the reference repository location, is evaluated in detail in Chapter 3.0 of this draft environmental assessment. The results of this evaluation are the basis for nominating the Hanford Site for site characterization leading to selection of the first repository site. The major conclusions from Chapter 3.0 are presented in this chapter. Based on currently available information, there do not appear to be any factors pertaining to the Hanford Site that preclude it from being nominated by the U.S. Department of Energy (DOE) as a candidate site. Several years of effort have not revealed any features that would disqualify Hanford as a potential repository site. Detailed site characterization studies are under way and an Exploratory Shaft will be completed to provide manned access to the three candidate horizons: the Cohassett flow, the McCoy Canyon flow, and the Umtanum flow of the Grande Ronde Basalt. Information obtained during these studies is necessary to determine whether the Hanford Site should ultimately be recommended as a site for development of a repository.

1.1 SITE CHARACTERIZATION SUITABILITY

The proposed siting guidelines (DOE, 1983) have been individually evaluated and the preliminary conclusions indicate that site characterization work should continue. However, full compliance with the system guidelines, program guidelines, and technical guidelines require completion of detailed site characterization studies. An evaluation of each guideline, and the preliminary conclusions resulting from the evaluation, are presented in Section 3.1.

1.2 REPOSITORY DEVELOPMENT SUITABILITY

The Act requires that each guideline be used in evaluating the suitability of the site for characterization, but that in evaluating the suitability of the site for development as a repository, only those guidelines that do not require characterization need be used. Only five of the eighteen proposed siting guidelines were determined to not require site characterization prior to assessing site suitability for development as a repository. These five technical guidelines dealt with human intrusion, surface characteristics, population density and distribution, environmental protection, and socioeconomic impacts. The candidate site, when evaluated against each of the five guidelines, did not reveal any disqualifying factors applicable to the Hanford Site (see Section 3.2). The preliminary conclusions drawn after evaluating each of the five guidelines are presented in Section 3.1.

1.3 SITE CHARACTERIZATION IMPACTS

Impacts of site characterization activities were described in a prior environmental assessment (DOE, 1982a) and were determined to pose no significant impact (DOE, 1982b) to the public health and safety and the environment. A detailed discussion of expected minor impacts is presented in Section 3.3 and in the prior environmental assessment (DOE, 1982a).

1.4 COMPARATIVE EVALUATION

A comparative evaluation of other sites and locations being considered by the DOE as potential repository sites is presented in Section 3.4. The sites and locations that have been compared are:

- Yucca Mountain on the Nevada Test Site in tuff (Nevada)
- Gibson Dome Area in bedded salts of the Paradox Basin (Utah)
- Bedded salts in the Permian Basin (Texas)
- Vacherie Salt Dome (Louisiana)
- Richton Salt Dome (Mississippi)
- Cypress Creek Salt Dome (Mississippi).

Site-specific information for some of these locations is limited, and each geologic medium has a blend of positive and negative characteristics.

1.5 DECISION PROCESS

The decision process used to select the reference repository location on the Hanford Site has taken 6 years to complete. Each step of the process evaluated the available information to select successively smaller areas for evaluation as a repository site. The reference repository location in the Cold Creek syncline on the Hanford Site was selected by the DOE in 1982. The basic steps of this siting process are discussed in Section 3.5 and the decisions made at each step are discussed in detail in the Site Characterization Report (DOE, 1982c).

1.6 REPOSITORY IMPACTS

The regional and local impacts that would be associated with a repository, if located at the Hanford Site, are expected to be minimal. An infusion of construction and operating monies over the next several decades would bolster the economy of the area. High-level waste and spent fuel will be shipped in high-integrity shielded casks that are designed to contain the wastes even in the event of an accident. Therefore, transportation impacts are expected to be minimal. Preliminary analyses of the waste isolation capability of basalts at Hanford are favorable with groundwater traveltimes to the accessible environment in excess of 10,000 years.

2.0 BACKGROUND SUMMARIES

2.1 NATIONAL WASTE TERMINAL STORAGE PROGRAM

The DOE is assigned responsibility for developing the necessary programs for the treatment, management, storage, and disposal of nuclear wastes primarily through the Atomic Energy Act of 1954, the Energy Reorganization Act of 1974, the Department of Energy Organization Act of 1977, and the Nuclear Waste Policy Act of 1982.

The DOE's commercial waste management program, the National Waste Terminal Storage (NWTS) Program, complies with the Federal laws by developing the technology and facilities to permanently dispose of commercial high-level radioactive wastes. The overall objective of the NWTS Program is to plan, develop, and implement the technology and provide the facilities for the terminal isolation of commercial high-level and transuranic radioactive waste in a manner to demonstrate waste disposal capability, to assure the public and occupational health and safety, and to protect the environment. To meet this overall objective, the NWTS Program will site, design, construct, and operate mined geologic repositories consistent with the legislated schedules. Approximately 70,000 metric tons (77,000 tons) of spent fuel will have been discharged from commercial nuclear powerplants by the year 2000. The NWTS Program is planning to have the first repository available with the capacity to dispose of that quantity of waste by 1998.

To achieve these objectives, the DOE will isolate nuclear wastes in deep, mined geologic repositories with a number of natural and man-made barriers between the wastes and the uppermost strata of the Earth's surface (the biosphere). These barriers include the waste form itself, the waste packaging, the backfills and seals of the repository, the host rock immediately surrounding the wastes, the geologic and hydrologic regime surrounding the host rock, and institutional barriers.

The NWTS Program has three field projects centered on investigating various rock types: the basalts beneath the Hanford Site (Basalt Waste Isolation Project (BWIP)), the tuffaceous rocks at the Nevada Test Site (Nevada Nuclear Waste Storage Investigation), and various salt regions throughout the United States (Office of Nuclear Waste Isolation). In addition, the DOE is studying crystalline rocks (intrusive igneous and high-grade metamorphic rocks such as granite) as a potential medium for geologic disposal. The regions presently under consideration are shown in Figure 2-1.

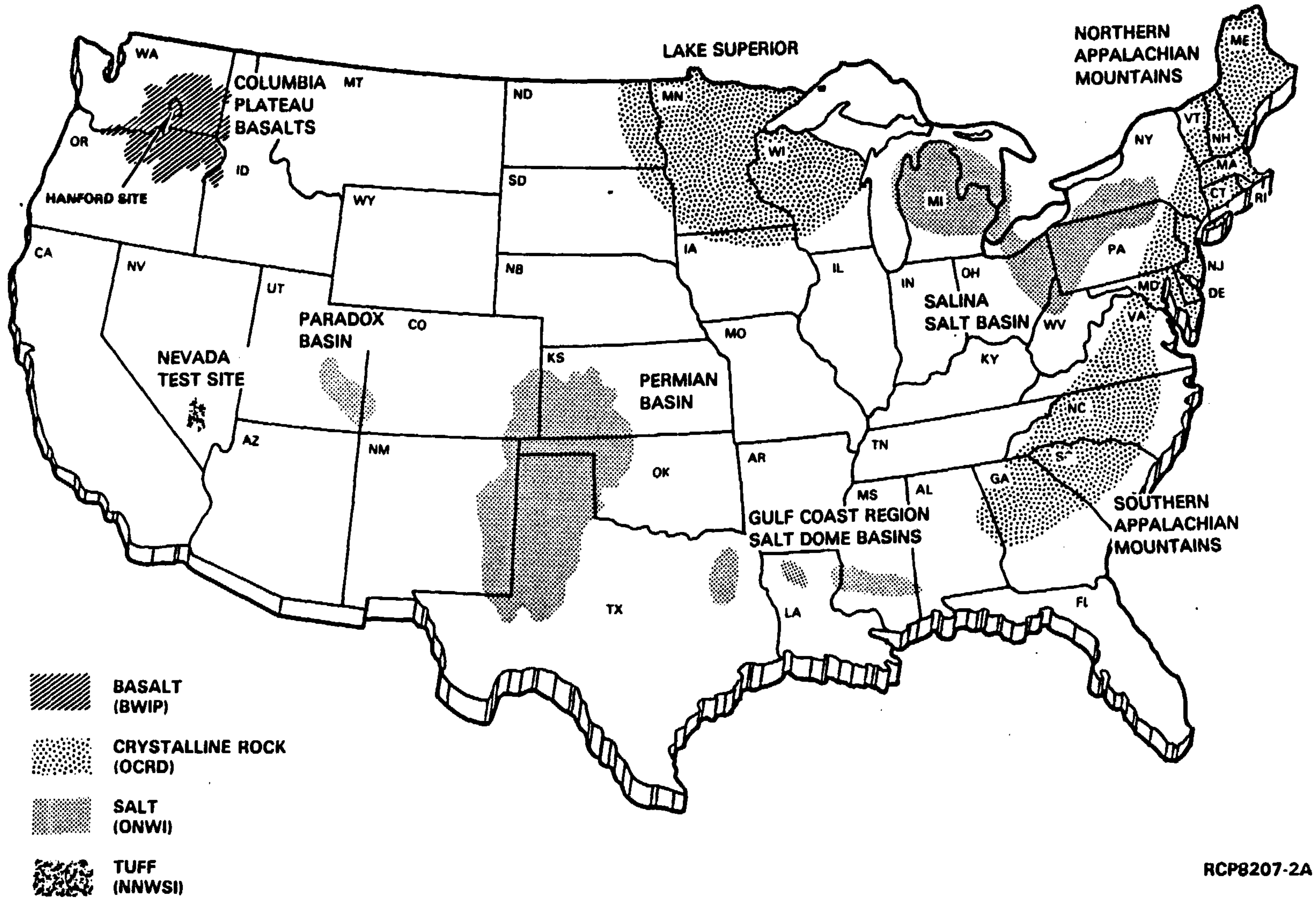

FIGURE 2-1. Regions That are Being Considered for Geologic Disposal of Radioactive Waste.

2.2 THE NATIONAL WASTE TERMINAL STORAGE SITING PROCESS

The NWTS Program siting investigations have been following a formal three-step siting process that begins with national screening and culminates in detailed site characterization of candidate sites for a nuclear waste repository. This siting process is described in the Public Draft, National Plan for Siting High-Level Radioactive Waste Repositories and Environmental Assessment (DOE, 1982d). The first phase of the siting process is site screening, which covers the activities planned to find sites favorable for waste isolation. A number of approaches have been used to initiate screening studies, with each approach eventually using common steps to arrive at and to evaluate specific sites.

The DOE has used three approaches to identify starting points for screening studies:

1. A host rock approach was initiated by identifying regions containing potentially suitable host rock types. Early in the NWTS Program, rock salt was so identified, and regions in the conterminous United States containing salt domes and bedded salt formations were delineated as starting points for site screening. The DOE has screened the United States for regions containing crystalline rocks such as granite.

2. In addition, the DOE has initiated siting studies at federally owned land tracts in Nevada and Washington (known as the Nevada Test Site and the Hanford Site), which have been committed to nuclear activities and which may contain suitable host rocks at appropriate depths for a repository.

3. Another approach, province screening, is based on scrutiny of successively smaller subdivisions of broad provinces where geohydrologic conditions include multiple natural barriers to radionuclide migration. This approach is being implemented by the U.S. Geological Survey on an experimental basis in one of eleven geohydrologic provinces of the United States. A province working group, composed of earth scientists from the states in that province and the U.S. Geological Survey, is initiating the prototypical studies.

The locations currently under study were identified using the host rock and land use approaches. The province screening, and possibly other approaches, may identify additional locations. Future NWTS Program activities will be carried out in accordance with the Nuclear Waste Policy Act of 1982.

2.3 BASALT WASTE ISOLATION PROJECT SITING PROCESS

In the DOE-NWTS Program national site screening plan, early consideration was given to the Hanford Site in Washington State because of its prior long-standing use and commitment to nuclear activities and existing Government ownership. Although the Hanford Site was selected as the study area, initial screening encompassed the Pasco Basin, which is the smallest physiographic unit with geologic and hydrologic characteristics that would influence the conditions of a repository beneath the Hanford Site.

A methodology was used to systematically and rapidly focus on areas that had a high likelihood of containing a potential repository site. A description of the methodology used during the site screening process is presented in Section 3.5 of this document. Initial screening reduced the area from about 4,145 square kilometers (1,600 square miles) to an area of about 1,800 square kilometers (700 square miles). Successive screening steps led to the identification of ten candidate sites in the central part of the Hanford Site known as the Cold Creek syncline, an area of about 180 square kilometers (70 square miles). Preliminary evaluation of the ten candidate sites made it clear that the sites were too closely matched to be differentiated between by routine ranking; therefore, a method of dominance analysis was used for this purpose. The dominance analysis showed that two of the ten candidate sites, located in the western portion of the Cold Creek syncline and designated sites A and H, had about the same dominance numerical value, a value which was significantly greater than the values for other sites. These two sites overlapped each other in area, and the combination was selected as the reference repository location. The reference repository location is shown in Figure 2-2.

Three candidate repository horizons within the reference repository location have been identified for further study: the Umtanum flow, McCoy Canyon flow, and the Cohassett flow in the Grande Ronde Basalt.

The reference repository location is an area of about 48 square kilometers (18 square miles) with nearly flat-lying terrain. An optimization study was made, using selected environmental engineering and design criteria, to identify the specific location for a principal borehole and Exploratory Shaft within the reference repository location. The location identified was in the west-central part of the reference repository location as shown in Figure 2-2.

2.4 BASALT WASTE ISOLATION PROJECT STATUS

The Hanford Site is situated in the Pasco Basin, a lowland area on the Columbia Plateau. The Columbia Plateau was formed by more than 100 basalt flows that literally flooded the region lying between the Cascade Range to the west, the Rocky Mountains to the east, the Okanagan Mountains to the north, and the Blue Mountains to the south. The reference repository location is situated in a relatively flat terrain within the Pasco Basin.

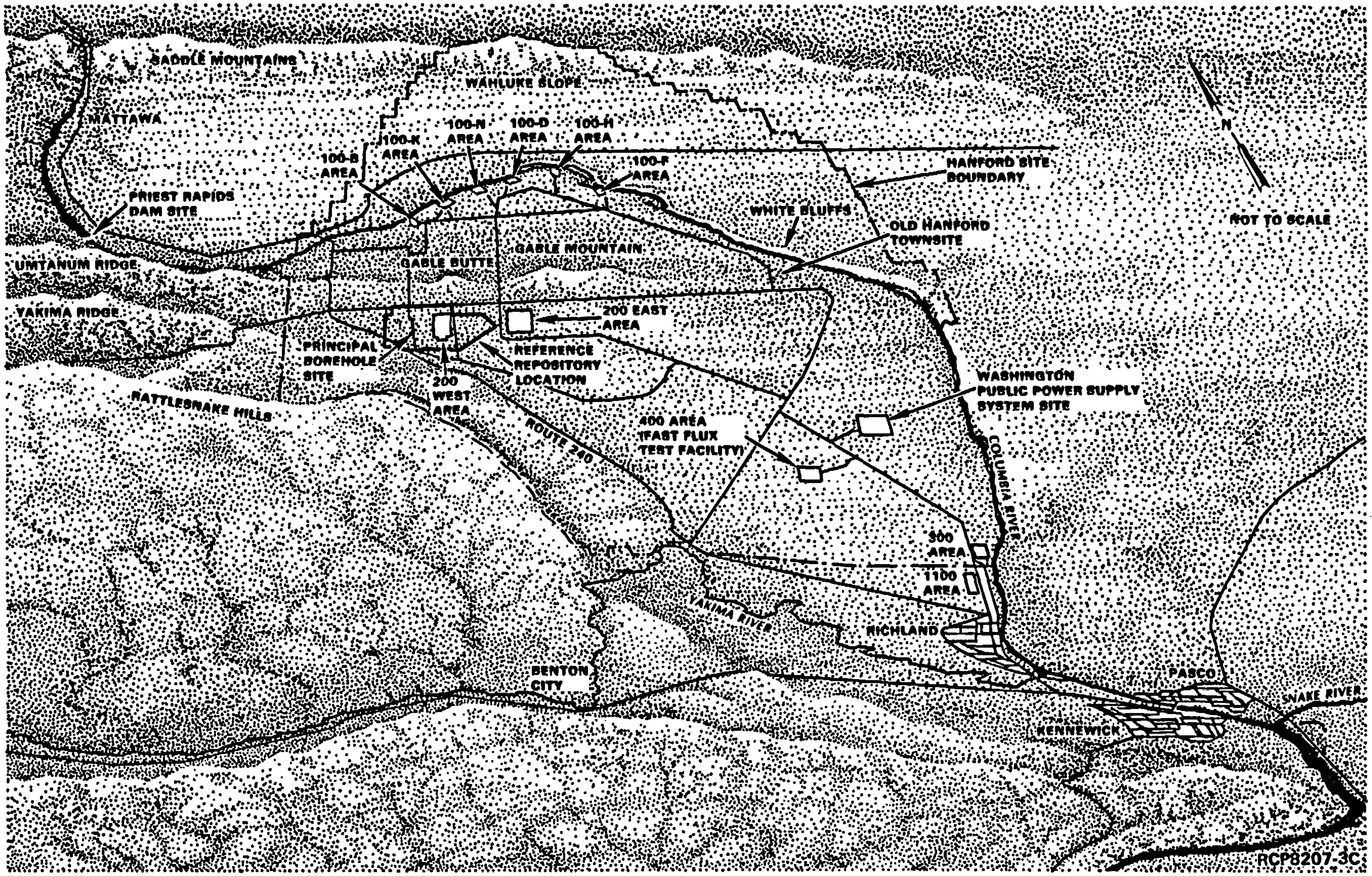

FIGURE 2-2. The Hanford Site and the Reference Repository Location.

2.4.1 Geologic Description of Candidate Area and Site

In the central portion of the Columbia Plateau where the Hanford Site is located, no pre-basalt basement rocks are exposed. The basalt flows of the Columbia River Basalt Group have been drilled to a depth of more than 3,250 meters (10,655 feet) in the Pasco Basin and a number of the flows encountered in drilling are more than 100 meters (328 feet) thick and laterally continuous. The internal structures that develop within a flow during the emplacement of the flow over the ground surface and subsequent cooling of the molten lava are termed intraflow structures. Intraflow structures are not uniform from one flow to another or even within a given flow. Intraflow structure may vary in thickness, be absent entirely from any given flow, or occur repeatedly within a single flow. However, the intraflow structure of some of the thicker flows (greater than 30 meters (100 feet)) does show considerable continuity and uniformity within the Pasco Basin.

Although basalt is a fractured and jointed rock, data from rock core samples show that the great majority of fractures within the flow interiors are filled with multiple generations of secondary minerals, such as clays. The results of laboratory and field testing indicate that the volume of unfilled fractures is small, as attested by the low total fracture porosity and permeability.

Folding and faulting of the Columbia River basalt appear to have developed at about the same time during the past 16 million years. On the basis of existing data, such as fault plane solutions and hydrofacturing tests, the principal direction of the existing stress field for the Pasco Basin is generally indicated by north-south compression. The average rate of uplift of the mountains that form the north and south boundaries of the Pasco Basin is less than 1 meter (3.28 feet) in 10,000 years and appears to have been rather uniform throughout this time period. The basalt stratigraphy, or sequence of basalt flows within the Pasco Basin, is well understood (see Fig. 2-3).

Current mineral industry operations within 100 kilometers (62 miles) of the reference repository location are limited to surface mining of diatomaceous earth, sand and gravel, and clay and stone. A small, depleted, low-pressure natural gas field was in production from 1929 to 1941 at the southern edge of the Hanford Site, and a few small gold placers have also been worked along the Columbia River. Exploration for hydrocarbons is continuing north and west of the Hanford Site. Groundwater is used for domestic, agricultural, and industrial purposes. The production of groundwater is primarily from wells less than 300 meters (984 feet) in depth. The poor quality of groundwater in the Grande Ronde Basalts restricts its use for these purposes.

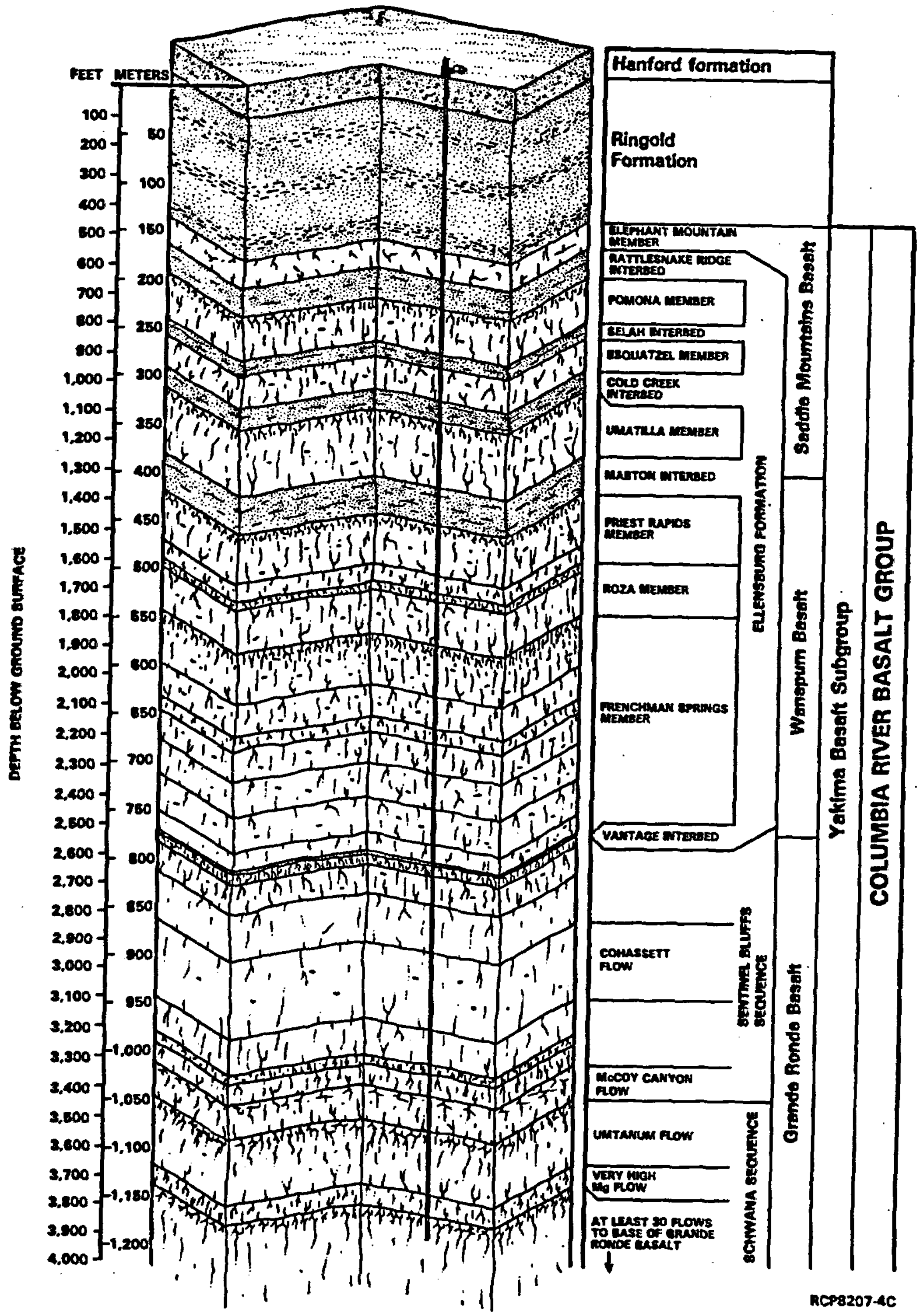

FIGURE 2-3. Stratigraphy of the Columbia River Basalt Group, Yakima Basalt Subgroup, and Intercalated and Suprabasalt Sediments Within the Pasco Basin.

Present plans in the area of site geology during detailed site characterization are to complete the determination of the geologic, mineralogic, and petrographic characteristics of the candidate repository horizon(s) and surrounding strata within the reference repository location. Work will also be continued on determining the nature and rates of past, present, and projected structural and tectonic processes within the geologic setting and reference repository location.

The reference location for a repository in basalt for the terminal storage of nuclear wastes on the Hanford Site and the candidate horizons within this reference repository location have been identified and the preliminary characterization work in support of the site screening process has been completed. Technical questions regarding the qualification of the site were identified to be addressed during the detailed site characterization phase of the DOE-NWTS Program site selection process. Resolution of these questions will be provided in the final site characterization progress report, currently planned to be issued in 1987, and in the safety analysis report to be submitted with the license application. The additional information needed to resolve these questions and the plans for obtaining the information have been identified in the Site Characterization Report that was submitted to the U.S. Nuclear Regulatory Commission (NRC) pursuant to 10 CFR 60 on November 12, 1982.

On the basis of the geotechnical data now available, the following can be concluded for the basalts underlying the Hanford Site:

- Basalt flows located more than 610 meters (2,000 feet) below the ground surface are not subject to significant erosion, and several flows appear to have thick enough flow interiors and sufficient lateral continuity to accommodate the construction of a nuclear waste repository.

- The present calculated rate of deformation poses no threat to the long-term integrity of a repository in basalt at the Hanford Site.

- The basalt stratigraphy, or sequence of basalt flows, beneath the Hanford Site is well understood and the depth to the flows can be predicted with reasonable accuracy.

- The low permeability measured in boreholes for the basalt-flow interiors indicate these portions of the flows will provide the isolation necessary to prevent the radionuclides reaching the accessible environment in concentrations above established guidelines.

- Preliminary tests indicate that the basalt rock, groundwater, and materials to be placed in terminal storage are compatible under both ambient and expected thermal stress conditions, in that they favor long-term stability.

- There is an extremely low probability of any adverse climatic impact on a repository in basalt at the Hanford Site.

- No faults have been identified on the Hanford Site that would have an adverse impact on a repository constructed at the reference repository location.

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

- There are no economic resources mined from the basalt in the vicinity of the Hanford Site at the present time, other than groundwater pumped from shallow aquifers. The Hanford Site is relatively unattractive to future subsurface mineral exploration and development within the Columbia River Basalt Group compared with other areas of the Columbia Plateau.

- The reference repository location is situated in a favorable position with respect to available transportation modes, support and service facilities, remoteness from population centers, and smoothness of the terrain.

- There is no land conflict with currently planned or existing facilities on the Hanford Site.

Fifteen issues or technical questions have been identified that need to be resolved during detailed site characterization. These issues are in the form of questions that require answers to satisfy regulatory and technical criteria. Three of these issues are designated "key issues." Key issues are those technical questions where engineers cannot substantially and economically alter a negative finding. The three key issues are as follows:

- What is the total amount (activity) of radionuclides potentially releasable to the accessible environment in a 10,000-year period, and is this amount in compliance with applicable U.S. Environmental Protection Agency (EPA) regulations?

- Can stability and isolation capability of the repository be maintained in the presence of coupled in situ, excavation-induced, and thermal-induced stresses?

- Can repository shafts, tunnels, and exploratory boreholes be constructed and sealed without causing preferential pathways for groundwater or increasing the potential for radionuclide migration from a nuclear waste repository such that compliance with applicable EPA regulations is not possible?

The additional work needed to resolve the criteria requirements has been identified (DOE, 1982c) and the methods, plans, and schedules to support this work have been outlined. All of the data needed to satisfy the criteria would be obtained during the detailed site characterization phase. Where positive resolution of the criteria requirements cannot be satisfied by technical data, performance-assessment modeling will be conducted.

2.4.2 Hydrogeology

Groundwater beneath the Hanford Site from both confined and unconfined aquifers discharges to the Columbia River. The recharge areas are the highlands adjacent to and beyond the Hanford Site to the west. The sediments overlying the basalt and those intercalated with the basalts are hydraulically the most permeable. There are some zones between flows that also transmit large quantities of water; such zones are found primarily in the upper basalt section within the Wanapum and Saddle Mountains Basalts. The flow tops and dense flow interiors of the Grande Ronde Basalt are overall hydraulically tighter than the shallower basalts and produce less groundwater than shallow basalts.

The groundwater movement is generally in an east to southeast direction within the Cold Creek syncline beneath the Hanford Site. Data on hydrologic properties, hydraulic heads, and groundwater chemistry indicate that lateral groundwater flow takes place primarily through permeable flow tops and sedimentary interbeds. Vertical groundwater flow or mixing between these different permeable layers may occur along geologic structures such as the Umtanum Ridge-Gable Mountain anticline. Some vertical leakage between high-permeability zones may also take place across the low-permeability interiors of individual basalt flows, although the quantity of such leakage is considered quite low compared to the volume of groundwater moving laterally.

Modeling of the near-field groundwater flow system around a repository indicates that the groundwater flow paths are primarily controlled by the more permeable flow tops between successive flows. Results of modeling also indicate that the minimum groundwater travel-times from the repository site to the accessible environment, a distance defined by the EPA in its proposed regulations (EPA, 1982) as 10 kilometers (6.2 miles), appear to be greater than 10,000 years. The very small quantities of radionuclides, which do ultimately travel to the accessible environment, appear to remain small and well below the EPA-proposed regulations.

Over the past several years, a number of far-field hydrologic modeling studies have been conducted by independent organizations. Each study had limiting assumptions and used the most recent data available at the time of the study. Traveltimes were estimated for groundwater movement between the repository and a discharge point at the Columbia River, a distance of 8 to 60 kilometers (5 to 35 miles) depending on the assumed flow path. Traveltimes estimated exceeded 13,000 years. Regardless of the different assumptions used, these estimated pre-waste-emplacement traveltimes are significantly longer than the NRC-proposed technical criterion (NRC, 1981a) of a 1,000-year minimum traveltime between the repository and the accessible environment.

Detailed site characterization studies in the area of hydrology are planned to verify that the pre-emplacement groundwater traveltimes near the repository are sufficiently long to meet proposed regulatory criteria. Further plans include the determination by characterization studies and laboratory tests and modeling of the total amount (activity) of radionuclides that are potentially releasable from a nuclear waste repository in basalt to the accessible environment.

2.4.3 Geochemistry

A preliminary assessment of the environmental conditions within the basalts beneath the reference repository location has been made. The parameters measured were temperature, pressure, groundwater composition, basalt mineralogy, Eh, and pH. The results of these studies have established the prevailing geochemical conditions for the candidate repository horizons of the Grande Ronde Basalt. Based on the current knowledge of these environmental conditions, matrix dissolution and leaching (ion exchange) represent the major degradation mechanisms for the waste form. General corrosion is the mechanism that will probably dominate canister degradation. At the end of the waste containment period, precipitation of new, less soluble, mineral phases from saturated solutions is the process that will likely control radionuclide concentrations in the groundwater flow system for all meaningful time periods relative to release criteria.

Plans for detailed site characterization studies in the area of geochemistry are to verify (by testing, characterization, and modeling) that the geochemical and hydrologic properties of the geologic setting (in conjunction with the waste form) will meet release requirements from the repository subsystem to the site and from the site to the accessible environment. This work includes the determination of a site-specific data base on the solubility and sorption characteristics of the nuclides contained in the waste. Work will be continued on determining the characteristics of the host rock environment (Eh, ph, groundwater composition, etc.) in support of waste package design activities and performance modeling of the waste isolation system.

2.4.4 Geoengineering

Geoengineering data on the state of in situ stress show that the ratio of the maximum horizontal stress to the vertical stress is approximately 2, and that the direction of maximum horizontal stress is consistent with the geologic evidence of north-south compression.

Determinations of strength and deformability of basalt, measured both in the laboratory and in situ, indicate that the behavior of a large rock mass measured in situ is generally different from that measured on a small specimen in the laboratory. It was found that for closely jointed rock like basalt, it is necessary to measure the thermal and mechanical properties on a large enough block to include a representative number of fractures and joints.

A large basalt block has been isolated in the Near-Surface Test Facility (a test facility located in Gable Mountain) to determine the thermal and mechanical behavior of the basalt in situ. This block measures 2 meters (6.6 feet) on a side and is cut 4.5 meters (14.8 feet) into the sidewall of the tunnel. The data from this test will be unique in that this isolated block of basalt represents the largest block of intact basalt rock ever isolated in this manner for in situ determinations.

Preliminary results from two in situ heater tests, which simulate the heat from a nuclear waste package, suggest that basalt responds to thermal loading in a predictable fashion and the walls of the storage borehole for the waste package maintain their structural integrity up to the maximum temperature measured (450°C (842°F)). Vertical deformation was more predictable than the horizontal deformation due to the large number of vertical joints in the basalt tested.

2.4.5 Near-Surface Test Facility

The Near-Surface Test Facility (Fig. 2-4) is a full-scale demonstration facility to examine how basalt, a geologic formation, is affected by heat and possibly radiation-induced stresses from the emplacement of commercial high-level nuclear waste. Electric heaters have been used in the past test programs. The Near-Surface Test Facility is located at Gable Mountain on the Hanford Site (Fig. 2-2).

Development work at the Near-Surface Test Facility will provide data for large masses of rock, necessary for determining the suitability of basalt for a commercial high-level waste repository. Additional tests planned at the Near-Surface Test Facility are to develop small-scale geomechanics instrumentation, for the purpose of measuring the disturbed rock zone around tunnel openings during excavation, determine/detect anomalies or changed conditions in advance of mining activities, determine the position of tunnel excavation with respect to overlying/underlying strata.

Tests are also being conducted in the area of excavation technology development. The purpose of these tests are to develop and/or confirm equipment and techniques to be used for the construction of at-depth facilities, and support repository design and construction. The capabilities and economies associated with a tunnel-boring machine in basalt as opposed to conventional mining techniques are to be assessed. Additional tests to develop waste emplacement/retrieval equipment are also being planned. Test objectives are to develop the technology required to construct long horizontal emplacement holes, develop techniques and demonstrate remote emplacement and retrieval of prototype waste packages for the horizontal placement configuration using prototypical handling equipment, develop techniques and procedures for emplacing backfill, and demonstrate (as a worst case situation) the retrieval of waste canisters from a horizontal emplacement hole with backfill in place.

Additional tests to demonstrate the performance of waste package backfill are also being evaluated by the BWIP.

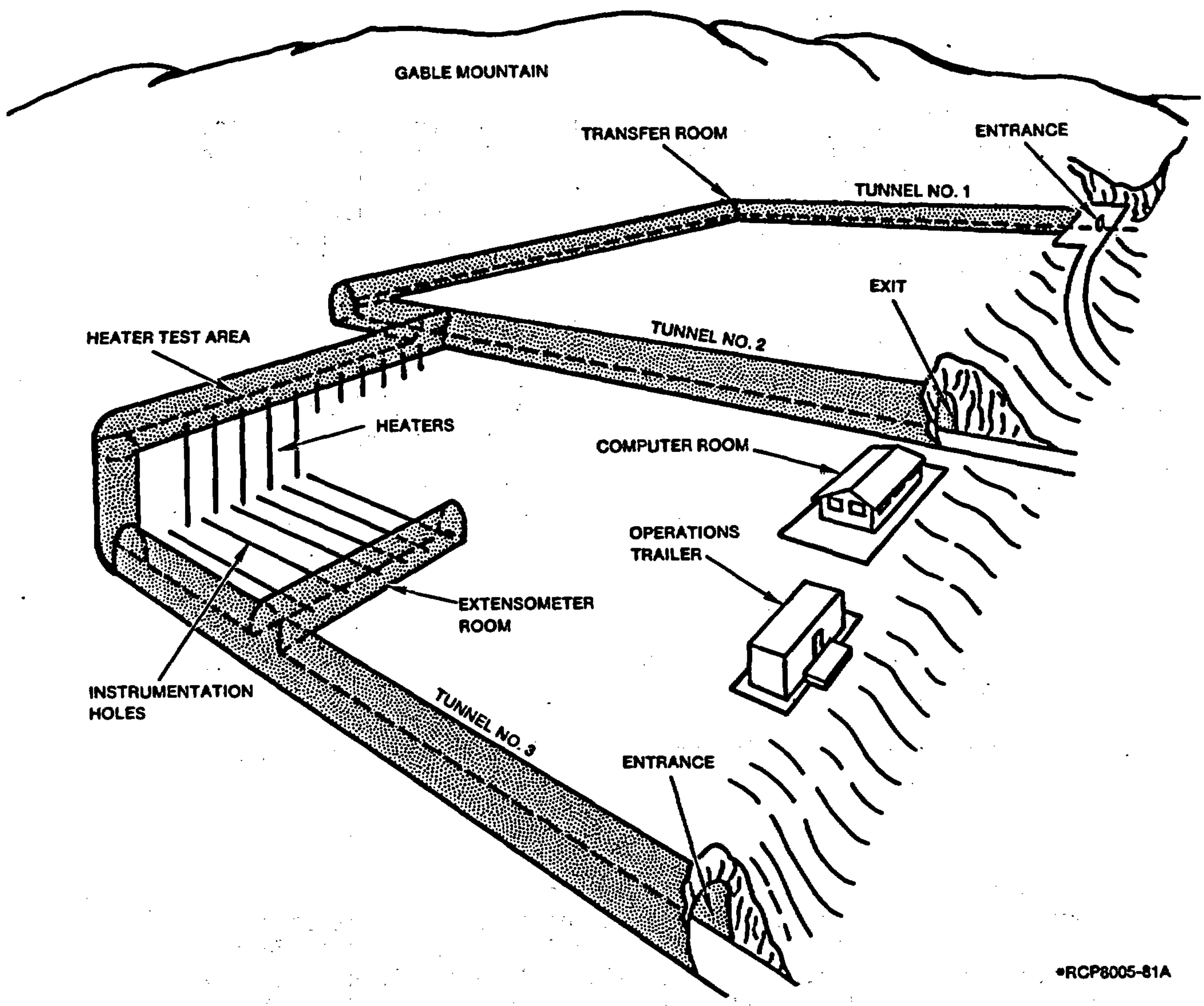

FIGURE 2-4. Conceptual Sketch, Near-Surface Test Facility.

Detailed site characterization studies in the area of geomechanics are planned to determine that the stability and isolation capability of the repository can be maintained in the presence of coupled in situ, excavation induced, and thermally induced strain. Development work will also be carried out to determine that satisfactory representative measurements or estimates of rock mass strength can be obtained and that current methods of in situ stress measurement are reliable enough to use as a basis of repository design.

2.4.6 Exploratory Shaft

The detailed characterization of a site at Hanford, which consists primarily of the selection of a site, design and design verification testing of a repository and waste package, and the construction of an Exploratory Shaft, will provide information to the DOE that is needed to aid in the determination of the suitability of a site at Hanford for use as a repository.

With a proposed site and a continuing conceptual design in preparation, the next major program phase, as noted in the Public Draft, National Plan for Siting High-Level Radioactive Waste Repositories and Environmental Assessment (DOE, 1982d), will be the detailed in situ characterization at depth. The objectives of this action are the following:

- Evaluate the effectiveness of the shaft construction method.
- Confirm the ability to seal off underground aquifers from work areas.
- Examine the effects of shaft construction on the surrounding rock.
- Measure the hydraulic properties of groundwater at the proposed repository depth.
- Characterize the rock mass of the host medium.

Assuming tests conducted in a chamber cut into the rock in Grande Ronde Basalt confirm current information about rock properties at this depth, a series of short tunnels will be driven to facilitate further detailed characterization. These tunnels will be constructed employing hard-rock mining techniques and will total approximately 305 meters (1,000 feet) in length.

The construction of an Exploratory Shaft and associated characterization activities are necessary to evaluate the adequacy of the basalt underlying the Hanford Site for use as a repository and are in keeping with 10 CFR 60 (NRC, 1981a) and the Nuclear Waste Policy Act of 1982.

2.4.7 Waste Package Development

The conceptual waste package design for commercial high-level waste forms consists of the waste form sealed in a low-carbon steel canister and surrounded by a tailored backfill composed of 75 percent crushed basalt and 25 percent bentonite clay. The repository conceptual design calls for waste to be emplaced horizontally in long boreholes. Present plans call for delayed backfilling to allow the waste canister to cool and to readily facilitate the possibility of retrieval as required by the NRC-proposed technical criteria (NRC, 1981a). Borosilicate glass is the assumed commercial high-level waste form, with spent fuel being an alternate waste form.

The waste package is being designed to provide safe handling of the waste during shipment and emplacement (as well as retrieval), to provide containment of the waste during the peak thermal period in which heat from fission product decay dominates (300 to 600 years), and, finally, to ensure the controlled and slow release of radionuclides during the period of geologic control to meet NRC-proposed release criteria (NRC, 1981a). During the thermal period (the first 1,000 years after closure), the metallic canister provides a primary function of preventing release of the waste to the general environment or to the repository and site subsystems. During the thermal period, the backfill acts also as a secondary barrier by preventing water from reaching the canister and by buffering the water near the canister, thus inhibiting corrosion.

During the period of geologic control, the primary barriers to radionuclide migration are the waste form and the backfill. The waste form functions to limit release of radionuclides and the backfill functions to retard radionuclide migration by sorption or chemical alteration to insoluble nuclide-containing secondary minerals, as well as retarding the rate of groundwater flow in the immediate vicinity of the waste form. The backfill also serves as a redundant barrier in the event that some containment is lost during the first 1,000 years after closure. There are no waste package containment requirements beyond 1,000 years, but it is expected that waste packages designed to prevent release during the period of highest heat output will provide some containment beyond the thermal period.

It was found that the iron oxide in the basalt is only partially oxidized and the equilibrium condition that now exists between the iron oxides in the basalt and the available oxygen present in the groundwater is one of low oxidation potential (Eh). Under these conditions, essentially all of the available oxygen in the environment of the emplacement hole will be consumed by reaction with the iron oxide existing in the basalt. Under these reducing conditions, many of the radionuclides are extremely insoluble and thus immobile. Corrosion of metals is also significantly reduced in an oxygen-poor environment.

Plans for detailed site characterization studies in the area of waste package development include an experimental determination of whether the very near-field interaction between the waste package and its components, the underground facility, and the geologic setting compromise the performance of either the waste package or repository. These studies will address both the radionuclide containment capability of the repository and performance of the waste package system. Further efforts are planned to upgrade the present waste package conceptual design and to perform design verification tests in support of final design and performance-assessment efforts. The role of a unique waste package borehole backfill will also be determined to ensure the operational redundance of barriers around the waste.

2.4.8 Repository Design

A conceptual repository design is being prepared for a nuclear waste repository in basalt that can handle and isolate high-level waste, spent fuel (if declared as waste), and transuranic waste. A repository cutaway that represents the present conceptual design (currently in review) including surface facilities, five access shafts, a central shaft pillar, and underground waste storage areas is shown in Figure 2-5.

The conceptual repository design, which was discussed in the Site Characterization Report (DOE, 1982c), is based on the capability to store 27,900 waste packages containing a total of 47,400 metric tons (52,140 tons) of heavy metal equivalent of reprocessed high-level waste and spent fuel declared as waste, and 32,000 packages of solidified transuranic waste. These waste forms will be isolated within the Grande Ronde Formation below the ground surface.

The present repository conceptual design includes surface waste receiving and inspection facilities, surface decontamination and packaging facilities, a shaft pillar containing five shafts connecting the surface and the underground workings, underground storage panels, transport facilities, and ancillary service systems including two separate ventilation systems.

The function of the repository is to provide long-term containment and isolation. After the storage rooms have been filled with waste packages, the storage rooms are expected to be filled with engineered backfill intended to act as a barrier against radionuclide migration. At the time of decommissioning of the repository, multiple seals will be placed in accesses between the panel areas and in the shaft pillar, and in the shafts above the repository level.

The isolation of nuclear wastes in deep, mined repositories will require the sealing of all penetrations, such as shafts, tunnels, repository rooms, or boreholes, into and nearby the repository. A research and development program is being conducted during detailed site characterization to develop and demonstrate required technology for sealing penetrations related to a repository excavated in basalt.

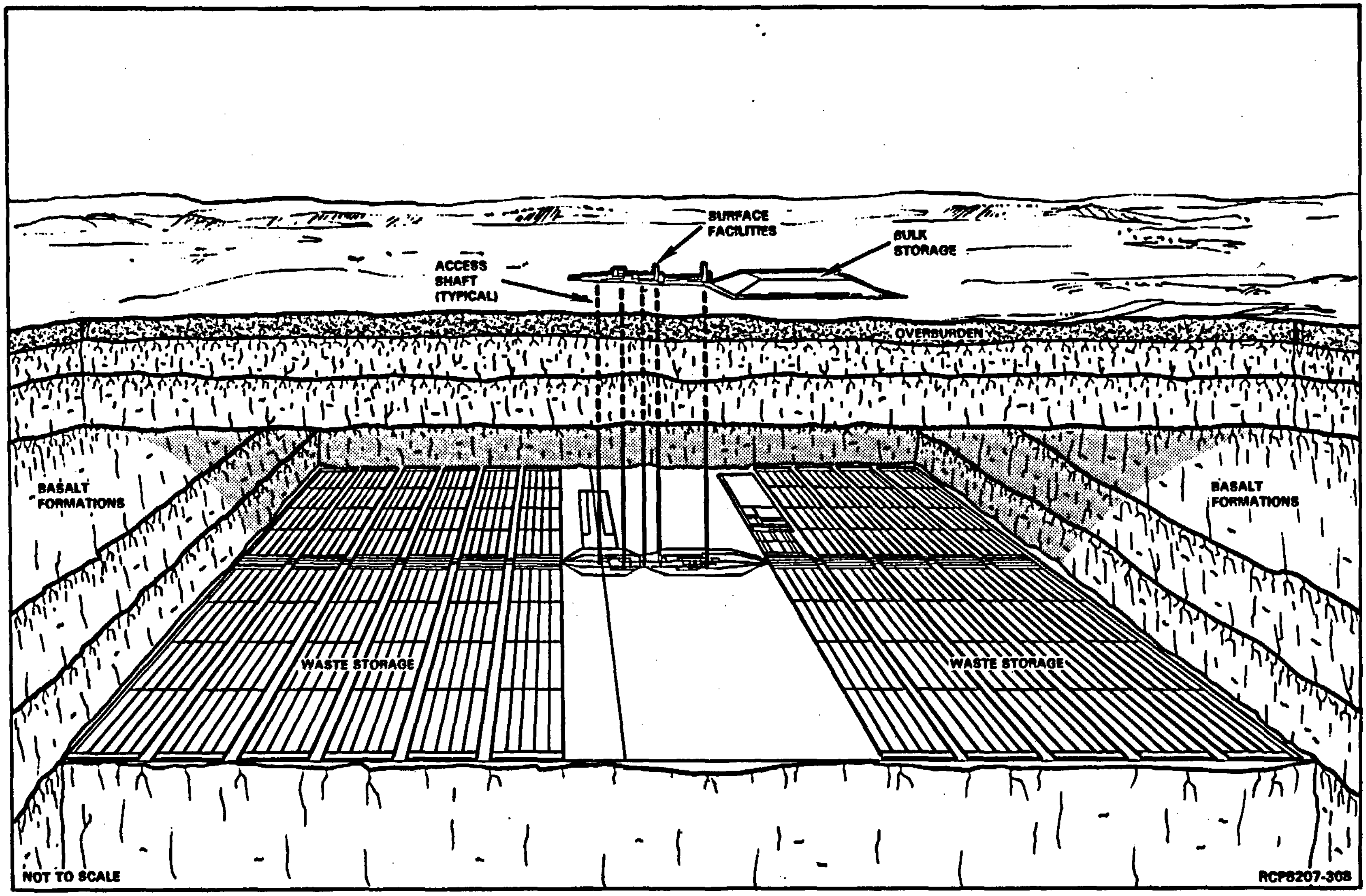

FIGURE 2-5. Conceptual Repository Cutaway.

2.5 HANFORD ENVIRONMENT

2.5.1 Hanford Site Location

The Hanford Site (Fig. 2-6 and 2-7) occupies approximately 1,500 square kilometers (570 square miles) of a semiarid region in the southeastern part of the State of Washington. The nearest population center, Richland, Washington, 1980 population 33,578 (BOC, 1981), is approximately 5 kilometers (3 miles) south of the southernmost boundary of the Hanford Site. The 1980 population within an 80-kilometer (50-mile) radius was estimated to be 417,000 (Sommer et al., 1981). This is an estimate from the actual 1980 U.S. Census data.

2.5.2 Geology-Topography

The Hanford Site is located in southeastern Washington State in the Pasco Basin (a portion of the Columbia Plateau), which is composed of large quantities of basalt overlain by thick layers of sedimentary material. The Hanford Site overlies the structural low point of the Pasco Basin and is bounded to the southwest, west, and north by large ridges that trend eastward and southeasterly from the Cascade Range, enter the Pasco Basin and die out within its confines. The Hanford Site is bounded to the east by the Columbia River and the steep White Bluffs of the Ringold Formation. To the southeast the Site is bounded by the confluence of the Yakima and Columbia Rivers and by the city of Richland.

Detailed stratigraphic and geologic data are available to characterize the Hanford Site environment (Tallman et al., 1979; ARHCO, 1976; Myers/Price et al., 1979) and have allowed subdivision of the basalts into a number of formations, members, and flows. The stratigraphic sequence beneath the Hanford Site is shown in Figure 2-3. For more detail on this topic, see Section 2.4.1.

2.5.3 Seismicity

Hanford is located in an area of historically low seismic activity (Algermissen, 1969; Algermissen and Perkins, 1976). The U.S. Geological Survey and the University of Washington have monitored earthquake activity in this region since 1969. Earthquakes recorded generally have magnitudes less than 4 on the Richter scale (Wallace et al., 1980).

The largest instrumentally recorded earthquake in the central Columbia Plateau is a magnitude 4.4 event on the Royal Slope about 85 kilometers (50 miles) north of the Hanford Site. Several earthquakes measuring modified Mercalli intensity VII to VIII have occurred in the surrounding region, but the magnitude had decreased to less than modified Mercalli intensity IV by the time the Hanford Site was reached. The largest event to occur within the Columbia Basin, the 1936 Milton-Freewater earthquake, had a modified Mercalli intensity of VII.

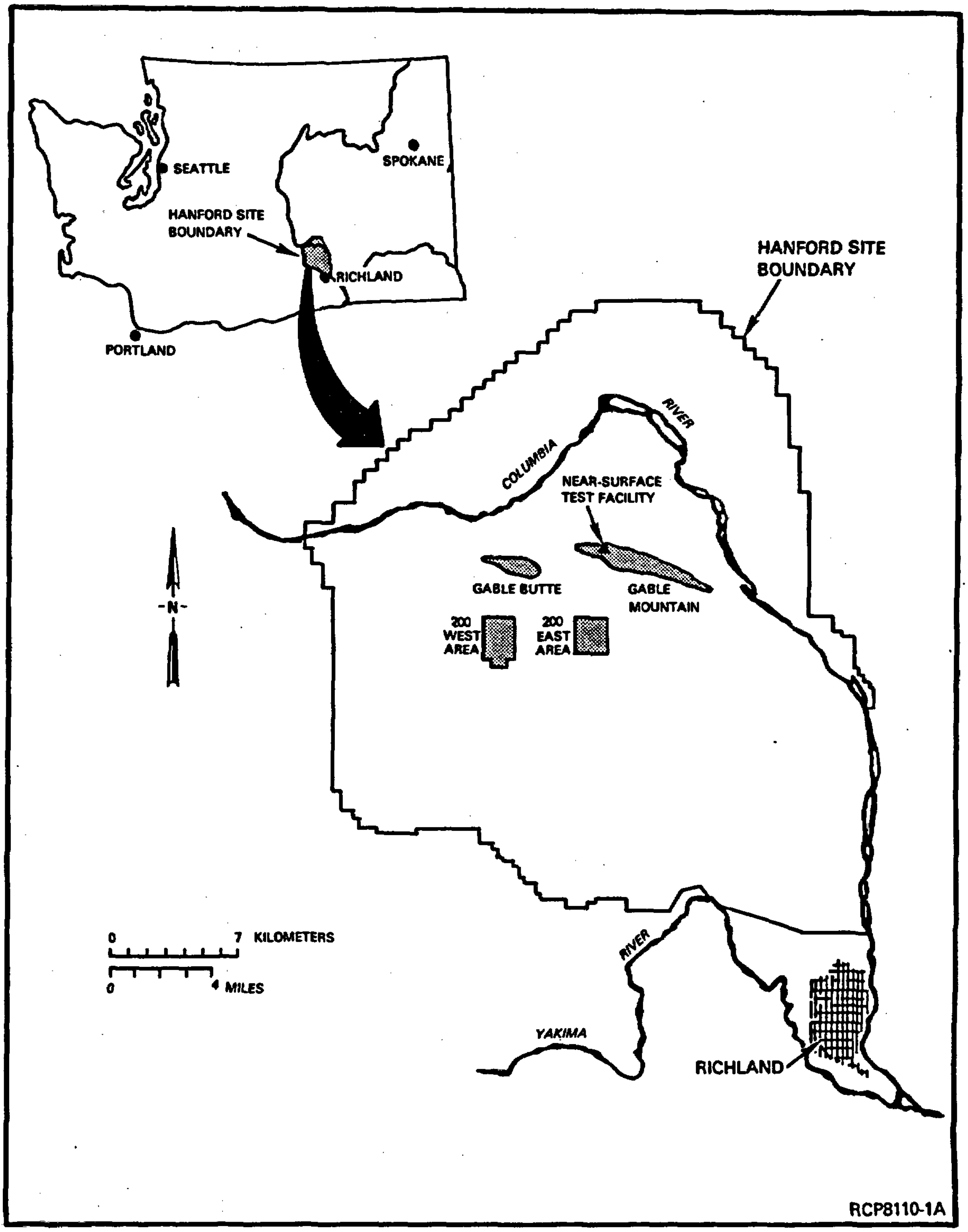

FIGURE 2-6. Location of the Hanford Site.

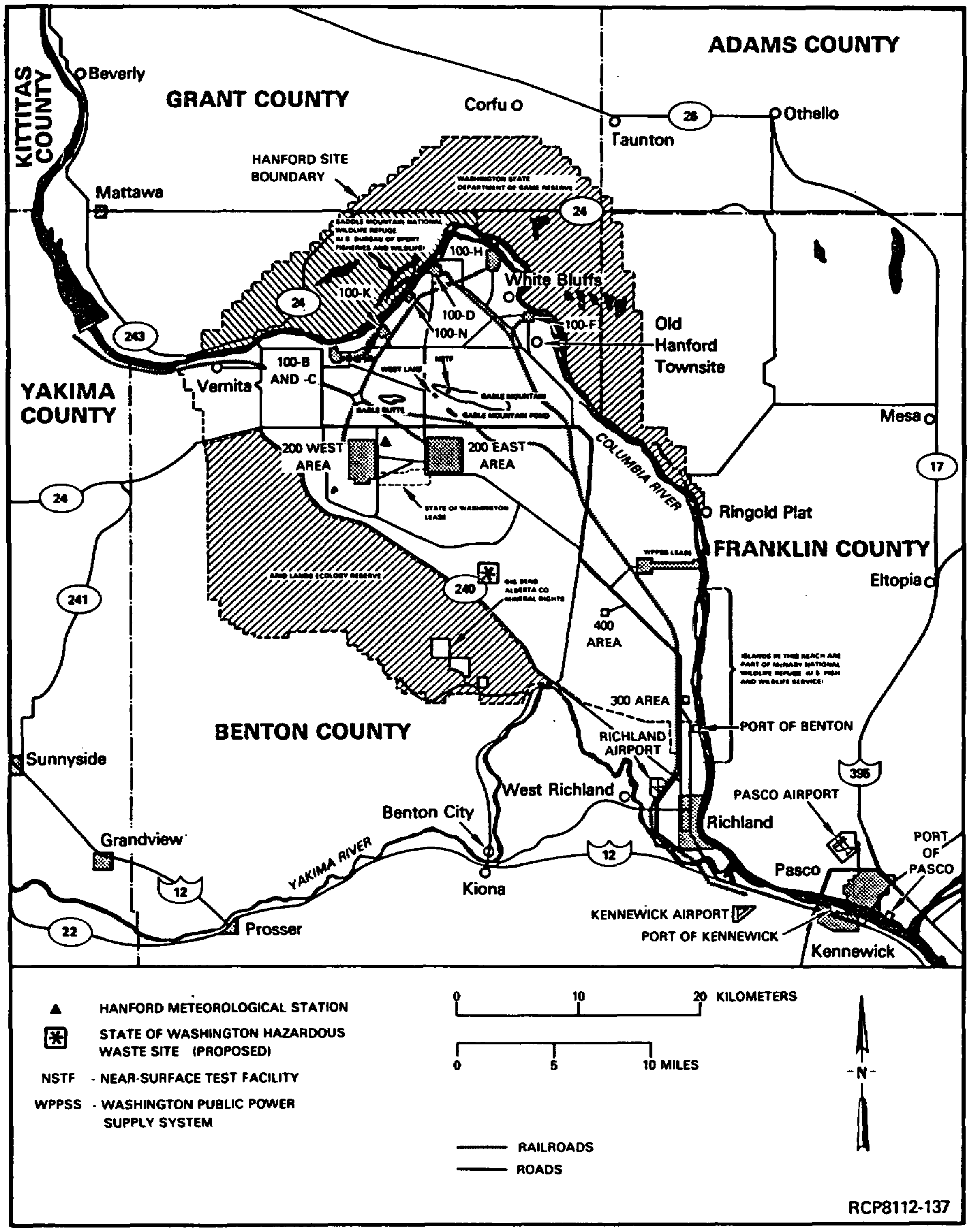

FIGURE 2-7. Location of Existing Nuclear Facilities on the Hanford Site.

Because this earthquake cannot definitely be linked to a geologic structure, it is assumed that a similar event could occur again anywhere in the Columbia Basin. This event has been designated the Hanford regional historical earthquake. The largest potential fault near Hanford is the postulated Rattlesnake-Wallula lineament, which is located at the southeast end of the Rattlesnake Hills.

2.5.4 Climatology

For general climatological purposes, meteorological data from the Hanford Meteorological Station are representative of the Hanford Site. The Hanford Meteorological Station tower is located between the 200 East and 200 West Areas and has continuously gathered data since 1944. Detailed climatological data are found in Stone et al. (1972). The Cascade Range to the west (see Fig. 2-6) greatly affects the climate of the Hanford area and forms a barrier to eastward-moving Pacific Ocean storm fronts. The mountains form a rain shadow producing mild temperatures and arid climatic conditions throughout the Pasco Basin region.

Average maximum and minimum temperatures recorded at Hanford for the month of January (the coldest month) are 3°C (37°F) and -6°C (22°F), and those for July (the warmest month of the year) are 33°C (92°F) and 16°C (61°F). Average annual precipitation is 16 centimeters (6.3 inches). The estimated average annual evaporation rate is 134 centimeters (53 inches), which essentially eliminates deep infiltration in the soil. Projections from available precipitation data indicate that a maximum accumulated annual rainfall of approximately 46 centimeters (18 inches) can be expected to have a recurrence interval of 1,000 years (ERDA, 1977) with a maximum soil penetration of 4 meters (13 feet).

Tornadoes rarely occur in the Hanford region, tend to be small, and produce little damage. Only one tornado has been observed on the Hanford Site in the last 29 years of observation. Existing data indicate that the probability of a tornado hitting a particular structure on site during any one year is an estimated six chances in a million (ERDA, 1975).

2.5.5 Hydrology

The Columbia River is the dominating factor in the Hanford Site hydrology and flows through the northern part and along the eastern boundary. The Yakima River is situated along part of the southern boundary. Groundwater exists beneath the Hanford Site in an unconfined aquifer and in confined aquifers composed of interbeds and interflow zones within the underlying basalt flows.

The Columbia River is normally about 75 to 90 meters (250 to 300 feet) below the plateau where the reference repository location is located. Under maximum probable flood conditions for the Columbia River Basin, the U.S. Army Corps of Engineers has estimated that the reference repository location would still be 60 to 75 meters (200 to 250 feet) above the highest probable water elevation (COE, 1969). Submersion of the Columbia River wetlands as a result of such flood conditions would have no direct effects on the facilities. Studies of a hypothetical 50 percent breach of the upstream Grand Coulee Dam, which would result in the devastation of downstream cities including Pasco, Richland, Kennewick, and Portland, show a flood elevation at 45 to 60 meters (150 to 200 feet) below the Exploratory Shaft site.

The water table, representing the upper limit of the unconfined aquifer, ranges from 46 to 100 meters (150 to 328 feet) beneath the ground surface and slopes toward the river. Near the Columbia River the water table fluctuates in response to river level changes and, in general, is within a few meters of the ground surface. Studies at Hanford indicate that precipitation does not directly reach the water table from the flat desert plains surrounding the reference repository location (ERDA, 1975, p. II.3-D-22).

The unconfined aquifer occurs within the sedimentary deposits referred to as the Hanford and Ringold Formations. The aquifer receives natural recharge from the Cold Creek and Dry Creek Valleys west of the Hanford Site and from runoff along the Rattlesnake Hills. Artificial recharge enters the aquifer from two groundwater mounds created by waste processing and disposal activities in the 200 East and 200 West Areas. Groundwater flows in a general west to east direction from the recharge areas and discharges into the Columbia River (ERDA, 1975, pp. II-3-D-22-27).

Groundwater also exists in the interflow zones of the basalt flows and in sedimenary interbeds referred to as the Rattlesnake Ridge, Selah, Cold Creek, and Mabton zones of the Saddle Mountains and Wanapum Basalts. Recharge to these upper confined flow systems results from precipitation and stream flow in the mountains west of Hanford. Hydrologic data acquired from wells penetrating these aquifers indicate the same general west to east groundwater movement toward the Columbia River.

2.5.6 Ecology

The Hanford Site contains large relatively undisturbed expanses that contain numerous plant and animal species suited to the semiarid environment of the region. The Columbia River also provides a habitat for aquatic species. The major facilities and activities occupy only about 6 percent of the total available land area and the surrounding wildlife is little affected by these facilities. A very extensive discussion of the Hanford Site ecology, including detailed descriptions of the aquatic ecology, Columbia River biota, terrestrial ecology, plant species, animal species, insects, and rare or endangered species is presented in ERDA (1975, pp. II.3-F-3, II.4-G-1) and DOE (1982d). A brief summary of this information is presented below.

2.5.6.1 Vegetation. The Hanford Site is within the boundaries of the sagebrush vegetation zone as it occurs in the State of Washington (Daubenmire, 1970). Approximately 40 percent of the ground area is occupied by plants at the peak of the spring growing season. Some of the Hanford Site vegetation is not indigenous. For example, cheatgrass and Russian thistle (tumbleweed), both dominant plant species, were introduced with the advent of agriculture.

Sagebrush/cheatgrass vegetation is the prevalent vegetation type in the 200 Area plateau. Typically, cheatgrass provides half of the total plant cover. Sagebrush is conspicuous because of the plant's relatively large size, with its combined plant canopies covering an estimated 18 percent of the ground (Cline et al., 1977). Tumbleweeds are of interest because they are an early invader of any cleared surface areas and continue in abundance until competition from other plans reduces their number.

Over 100 species of plants have been collected and identified for the 200 Area plateau (ERDA, 1975, p. II.3-G-39,44). Mosses and lichens appear abundantly on the soil surface; lichens commonly grow on shrub stems.

Since there are no grazing livestock on the Hanford Site, the amount of vegetation eaten by animals is small. Jackrabbits, pocket mice, and birds probably consume less than the insect species. The decomposer organisms, bacteria and fungi, consume most of the primary production after the plant parts die.

2.5.6.2 Mammals. Over 30 mammal species have been observed on the Hanford Site. Most of these are small and nocturnal (ERDA, 1975, p. II.3-G-15,49).

The mule deer is the only big game mammal present in significant numbers and, while not abundant, it uses some of the pond areas for watering and feeding. Deer tagged near the Columbia River have been observed as far as 48 kilometers (30 miles) from the Site (Fitzner and Price, 1973).

The cottontail rabbit is scattered throughout the Hanford Site. The jackrabbit is also widely distributed and is an important food item for coyotes and birds of prey. Ponds and ditches support muskrat and beaver; porcupine and raccoon are also observed while badgers occur in low numbers. The dominant small mammal is the Great Basin pocket mouse.

Coyotes are the most important mammalian predator and roam over large areas, consuming a variety of prey.

2.5.6.3 Birds. Over 125 species of birds have been observed at the Hanford Site (ERDA, 1975, p. II.3-G-17,46). The chukar partridge is the most important upland game bird and is concentrated primarily in the Arid Lands Ecology Reserve portions of the Hanford Site and the Rattlesnake Hills. Local populations exist in the Gable Mountain and White Bluffs area.

The Canada goose is probably the most important of the nesting waterfowl. Its nesting habitat is confined to the islands in the Columbia River. The river also provides a resting sanctuary for migratory ducks and geese (Fitzner and Price, 1973).

Birds associated with ponds on the 200 Area plateau have been studied (Fitzner and Price, 1973; Fitzner and Rickard, 1975). Small perching birds and others are attracted to the ponds with tree-shrub communities. Shore birds frequent all ponds and the major migrating birds stop at the ponds for rest and forage.

Birds of prey use the Hanford Site as a refuge from human intrusions, and the golden eagle and bald eagle are both winter visitors (Fitzner and Rickard, 1975).

2.5.6.4 Insects. Amost 300 species of insects have been identified at the Hanford Site (ERDA, 1975, p. II.3-G-21,51). Of the insects, the darkling ground beetle and the grasshopper are probably the most important and prevalent. Dramatic natural fluctuation of these species has been noted over the observation years.

2.5.6.5 Reptiles and Amphibians. Approximately 16 species of amphibians and reptiles have been observed at the Hanford Site (ERDA, 1975, p. II.3-G-20,46). When compared with the southwestern United States desert areas, the occurrence of these species is infrequent. Among reptiles, the side-blotched lizard is the most abundant and can be found throughout the Hanford Site. Horned and sagebrush lizards are also found but not commonly seen. The most common snake is the gopher snake; the yellow-bellied racer and the Pacific rattlesnake are also common. Striped whipsnakes and desert night snakes appear occasionally and are an important food item for birds of prey. Some toads and frogs are observed near the 200 Area ponds and ditches.

2.5.6.6 Aquatic Ecology. The Columbia River supports the dominant aquatic ecosystem and presents a very complex set of trophic relationships, which are discussed extensively in ERDA-1538 (1975, p. II.3-F-3). Several small ponds result from effluent discharge on the 200 Area plateau. The largest of these, Gable Mountain Pond, supports a simple food web based mainly on sedimented organic matter. This pond and U Pond both support introduced populations of goldfish.

2.5.6.7 Threatened or Endangered Species. No species of plant or animal registered as rare, threatened, or endangered is known to exist or depend on the habitats unique to the 200 Area plateau. However, the presence of open water on the Hanford Site attracts and supports many species of plants and animals normally rare or unknown in the general plateau area.

2.5.7 Land and Water Use

Land uses in the surrounding area include urban and industrial development, and irrigated and dryland farming. Of the irrigated crops, alfalfa hay uses 34 percent of the total area, wheat 15 percent, and potatoes about 20 percent. And in recent years grapes have also gained in importance. Fruit and hop growing is also important in the Yakima region. Water removal, from the Columbia River other than Hanford's, amounts to about 2.5×10^8 cubic meters per year (200,000 acre-feet per year) within 80 kilometers (50 miles) of the N Reactor, from an annual average river flow of about 3.4×10^3 cubic meters per second (120,000 cubic feet per second) or about 1.07×10^{11} cubic meters per year (87 million acre-feet per year).

2.5.8 Historical Sites and National Landmarks

The U.S. Department of the Interior (DOI, 1982) lists 20 historic sites for Benton, Grant, and Franklin Counties. Among these, the Ryegrass Archeological District is listed as being in the "Hanford Works Reservation" (since 1978 designated as the "Hanford Site") along the Columbia River. Other historic sites listed are: Paris Archeological Site, Hanford Island Archeological Site, Hanford North Archeological District, Locke Island Archeological District, Rattlesnake Springs Sites, Snively Canyon Archeological District, Wooded Island Archeological District, and Savage Island Archeological District. A number of archeological sites within the Hanford Site boundaries have been identified (Rice, 1968a, 1968b) and are described in detail in ERDA (1975, p. II.3-A-14).

2.6 RELATED ENVIRONMENTAL DOCUMENTATION

The Final Environmental Impact Statement: Management of Commercially Generated Radioactive Waste (DOE, 1980) presented an analysis of environmental impacts that could occur if various technologies for management and disposal of certain classes of commercially generated radioactive wastes (namely high-level and transuranic) were to be developed and implemented.

The DOE proposed a program strategy emphasizing development of conventionally mined waste repositories, deep in the Earth's geologic formations, as a means of disposing of commercially generated high-level and transuranic wastes. Based on this environmental impact statement, the DOE adopted the proposed program strategy (DOE, 1981). Included in the Final Environmental Impact Statement (DOE, 1980) are descriptions of the characteristics of nuclear waste, the alternative disposal methods under consideration, and potential environmental impacts and costs of implementing these methods.

Generic environmental impacts related to repository construction, operation, and decommissioning are analyzed in the Final Environmental Impact Statement (DOE, 1980), as are the impacts of predisposal waste treatment, storage, and transportation to the extent that they might affect the selection of a disposal option.

An Environmental Assessment for the Basalt Waste Isolation Project Exploratory Shaft Construction (DOE, 1982a) was prepared in the summer of 1982. The assessment discussed the proposed action of constructing an Exploratory Shaft at Hanford and presented five basic alternatives. The alternatives included the use of alternate site characterization methods, selection of an alternate site, delay of the proposed action, a "no action" alternative, and a "limited no action" alternative. The major environmental impact noted in the environmental assessment was the selective clearing and grading of 8 hectares (29 acres) of land. Over half of the plants in this area were destroyed and all the animals were displaced. Biological monitoring has shown that no threatened or endangered species were resident on the site. Other impacts include blowing dust due to wind erosion of disturbed soil; wet suppression of dust during construction of roadways and parking lots will be followed by surfacing with gravel. Another effect that will result from the accumulation of drill cuttings and mined rock are spoil piles. Possible mechanisms by which spoil piles can cause environmental damage are by dust emissions, chemical leaching, and mechanical slip or collapse. Existing dust-suppression techniques, which have proven effective, will be used to keep emissions from the spoil piles within applicable limits. Measures are also planned to mitigate the effects of chemical leaching and mechanical slip of collapse.

A finding of no significant impact (FONSI) for the construction of the Exploratory Shaft and associated detailed site characterization studies was published in the Federal Register on September 16, 1982 by the DOE (1982b) in compliance with the National Environmental Policy Act of 1969. Subsequent to the issuance of the FONSI, drilling operations for the Exploratory Shaft were started in November 1982.

3.0 EVALUATION OF STATUTORY REQUIREMENTS

Section 112(b)(1)(E) of the Nuclear Waste Policy Act of 1982 requires that the environmental assessment accompanying the nomination of a site for characterization as a candidate repository site include a detailed statement of the basis for such recommendation and of the probable impacts of the site and a discussion of alternative activities relating to site characterization that may be undertaken to avoid such impacts. Such an environmental assessment shall include:

i) An evaluation by the Secretary as to whether such site is suitable for site characterization under the guidelines established under subsection (a) of the Act

ii) An evaluation by the Secretary as to whether such site is suitable for development as a repository under each such guideline that does not require site characterization as a prerequisite for application of such guideline

iii) An evaluation by the Secretary of the effects of the site characterization activities at such site on the public health and safety and the environment

iv) A reasonable comparative evaluation by the Secretary of such site with other sites and locations that have been considered

v) A description of the decision process by which such site was recommended

vi) An assessment of the regional and local impacts of locating the proposed repository at such site.

The guidelines referred to above were promulgated as the Proposed General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories by the Secretary of the DOE in the Federal Register (Vol. 48, No. 26, pp. 5670-5682) on February 7, 1983.

Sections 3.1 through 3.6 of this document provide a discussion and evaluation of the six criteria established by Section 112(b)(1)(E)(i) through (vi) of the Nuclear Waste Policy Act of 1982. In Section 3.3 the evaluation of site characterization activities required by Section 112(b)(1)(E)(iii) includes a discussion of alternative site characterization activities relating to site characterization that may be undertaken to avoid such impacts.

3.1 SUITABILITY OF THE HANFORD SITE FOR SITE CHARACTERIZATION

Section 112(b)(1)(E)(i) criteria: Evaluation of whether the Hanford Site is suitable for site characterization under the proposed siting guidelines (DOE, 1983).

The DOE's proposed siting guidelines are presented in three parts: system guidelines, program guidelines, and technical guidelines. The system guidelines address the primary objectives of protecting the health and safety of the public and the environment. They relate the performance of the geologic repository system to standards for allowable releases of radioactive material and provide the basis for developing the technical criteria. The program guidelines define the policy requirements to be followed in implementing the DOE's program for selecting a repository site. The technical guidelines specify factors for the qualification and disqualification of specific sites and the conditions that would be considered favorable or potentially adverse.

When the DOE published the proposed siting guidelines, DOE recognized that it may not be possible to provide a complete evaluation of a site against all of the proposed siting guidelines at the time an environmental assessment is prepared. Where a complete evaluation has not been possible in this assessment, a discussion of the current status of activities relating to the guidelines (currently available information and a brief summary of planned activities) is presented in conjunction with a preliminary conclusion that directly relates to conformance with the proposed siting guidelines.

3.1.1 System Guidelines

A nuclear waste repository must contain and isolate radioactive material in a manner that is safe and environmentally acceptable. The DOE has proposed system guidelines to achieve these objectives and to provide a basis for the program and technical guidelines discussed in the sections that follow.

The system guidelines combine the safety and environmental objectives with applicable standards and regulations to define general requirements for system performance: (1) the period that precedes the permanent closure of the repository and (2) the period that follows closure. This division is consistent with the proposed EPA regulation, "Environmental Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes," 40 CFR 191 (EPA, 1982), which specify different numerical performance requirements for these periods.

3.1.1.1 Peformance Before Permanent Closure. System Guideline 960.3-1 (Performance Before Permanent Closure) (DOE, 1983) states that:

The repository operations area shall be sited and designed to comply with the limits established by the Nuclear Regulatory Commission in 10 CFR 20 and by the Environmental Protection Agency in the proposed 40 CFR 191, Subpart A, Environmental Standards for Management and Storage. A site shall be disqualified if during site investigation it becomes clear that the site, together with state-of-the-art engineered systems and controls, will preclude a repository at that site from complying with 10 CFR 20 and the proposed 40 CFR 191, Subpart A.

(a) Favorable Conditions

(1) A combination of meteorological conditions and low population densities such that few, if any, members of the general public would be exposed to radiation due to emissions during repository operation.

(2) Absence of contributing radioactive releases from other nuclear facilities governed by 40 CFR 190 or the proposed 40 CFR 191 that would require consideration in accordance with 40 CFR 191.03.

(b) Potentially Adverse Conditions

(1) Presence of other nuclear facilities governed by the proposed 40 CFR 191 with actual or projected releases at or near the maximum value permissible under those standards.

(2) Proximity to populated areas that could be routinely affected by repository effluents considering prevailing meteorological conditions.

3.1.1.1.1 Summary of Available Information. Because current repository design concepts are based on the handling of prepackaged nuclear waste, routine releases of radioactive effluents to the atmosphere are not anticipated. Atmospheric dispersion may be of importance, however, in the evaluation of accidental releases, even though the magnitude of releases under hypothetical accident conditions would be very low. Data from the Hanford Meterological Station, approximately 5.8 kilometers (3 miles) east of the Exploratory Shaft site, provide a good approximation of the dispersion conditions at the reference repository location.

The stability frequency for all windspeeds currently used for Hanford dispersion calculations are shown below:

Very stable - 24 percent
Moderately stable - 32 percent
Neutral - 14 percent
Unstable - 30 percent

These data show that stability class data are skewed to both poor and good dispersion conditions, with a relatively high frequency of poor dispersion conditions. Some differences between atmospheric conditions measured at the Hanford Meteorological Station and the reference repository location are expected based on localized topographic conditions. Atmospheric dispersion models can account for some of the localized topographic influences on meteorological conditions at the reference repository location although monitoring at the site may be needed to verify the atmospheric models.

Prevailing wind directions at the Hanford Site are out of the northwest as shown in Figure 3-1. Under stable atmospheric conditions, there is also a significant frequency of winds from the west and southwest. Because access to the Hanford Site is controlled by the DOE, there are no population centers within 20 kilometers (12.5 miles) of the reference repository location (Fig. 3-2). The city of Richland, with a 1980 population of 33,578, is approximately 40 kilometers (25 miles) southeast of the reference repository location and is the closest principal downwind population center.

Atmospheric dispersion modeling has not been conducted for potential radiological accident conditions at a repository, although such calculations will be performed during preparation of the Site Recommendation Report. However, it can be qualitatively stated that the potential for a significant atmospheric release of radioactive material is minimal, considering the low probability and consequences of an accident involving solidified and containerized high-level waste. Any such releases would also be dispersed over the 40-kilometer (25-mile) longitudinal distance, ignoring the other components of dispersion.

The Hanford Site is managed by the DOE in support of commercial and defense nuclear programs. Commercial nuclear fuel cycle facilities in operation at the Hanford Site that are governed by 40 CFR 190 (EPA, 1977) or proposed regulations 40 CFR 191.03 (EPA, 1982) include nuclear fuel fabrication facilities, nuclear powerplants in various stages of construction, and a low-level waste site. Combined releases from these facilities and projected releases from a repository are expected to be well below the limits in the proposed EPA regulations (EPA, 1982). An assessment of the combined doses from commercial nuclear facilities will be included in the Site Recommendation Report (if Hanford is chosen as a repository site).

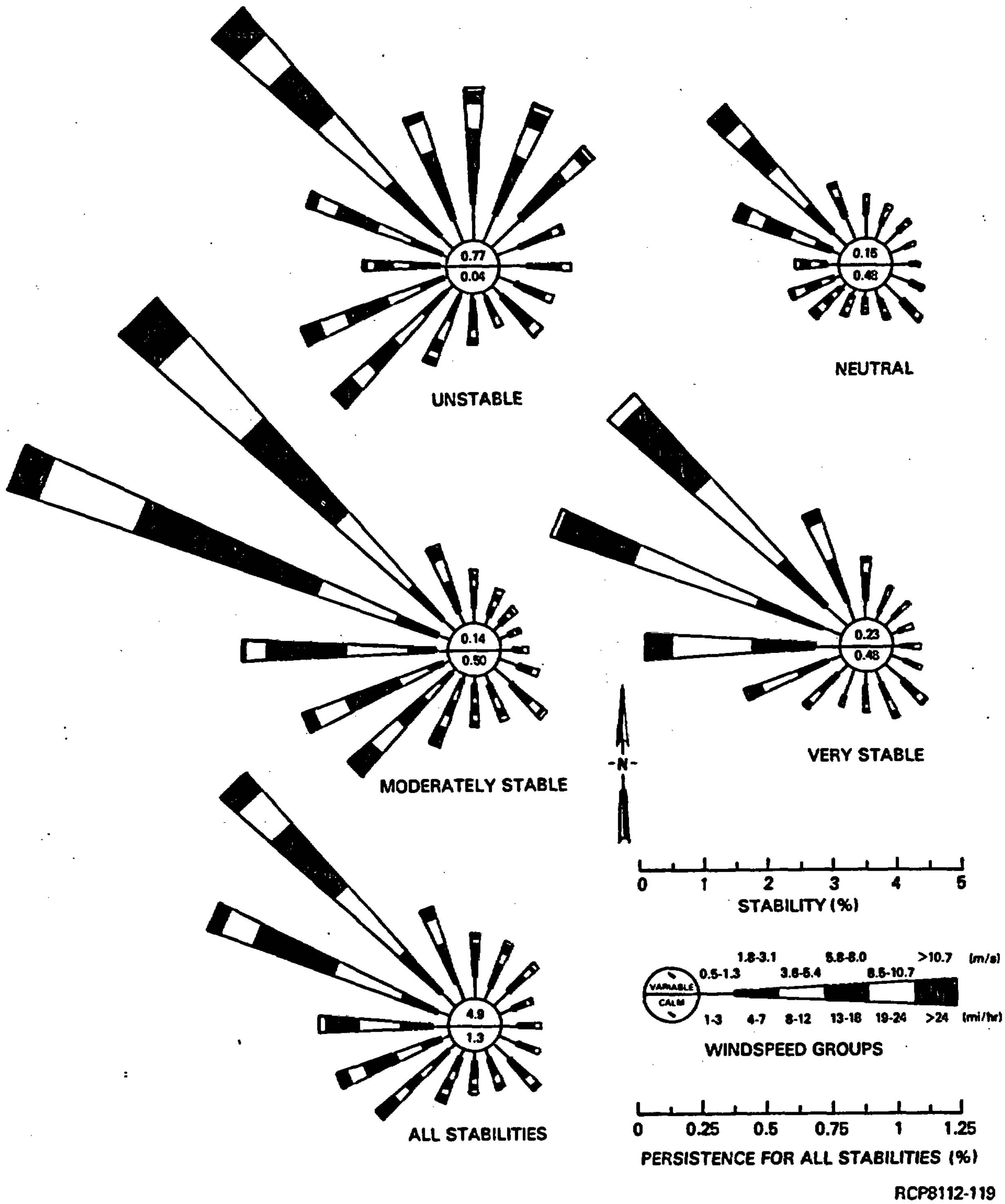

FIGURE 3-1. Wind Roses as a Function of Stability and for All Stabilities of the Hanford Meteorological Station, Based on Winds at 60 Meters (197 feet) and Air Temperature Stabilities Between 1 and 60 Meters (3 to 197 feet) for the Period 1955 through 1970. (The points of the rose represent the directions from which the winds come.)

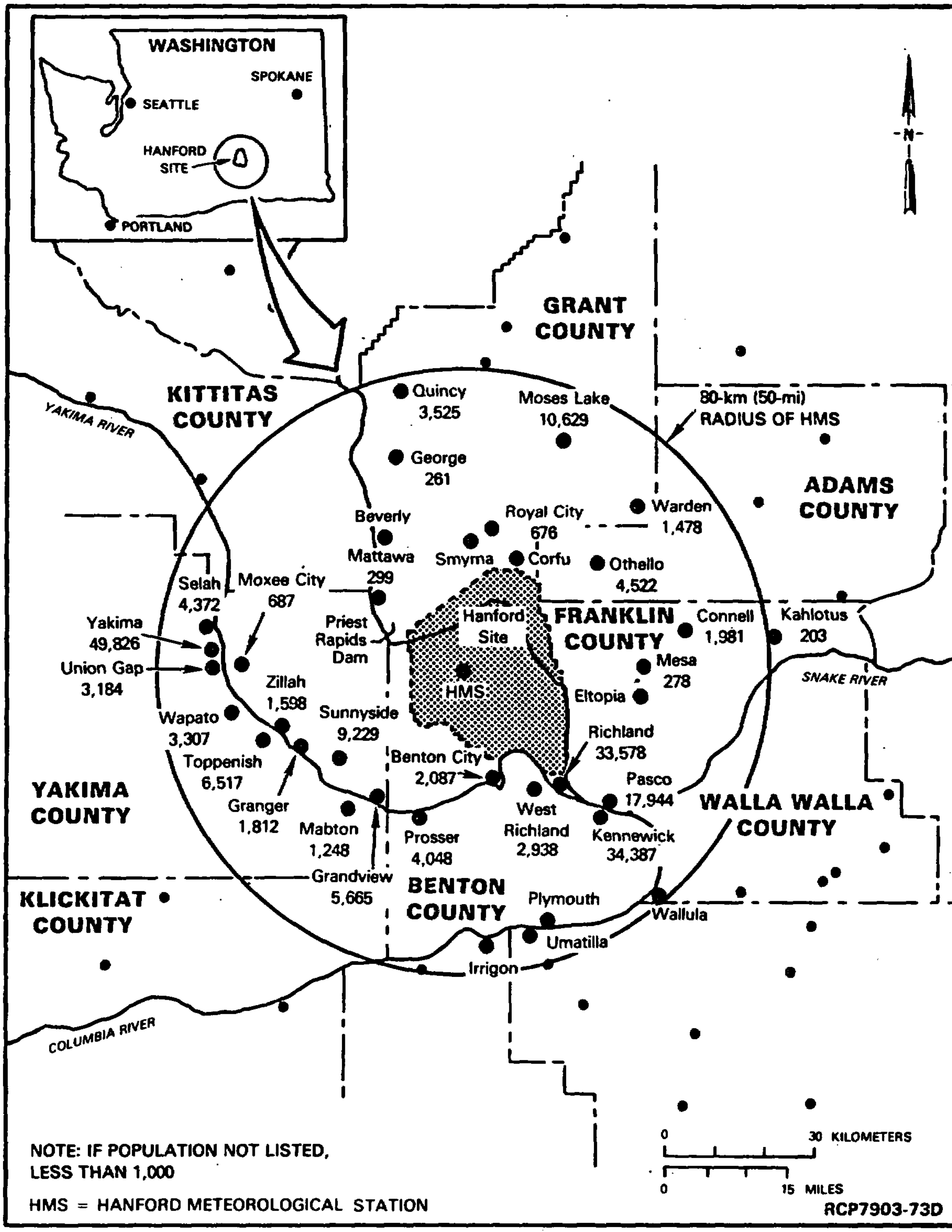

FIGURE 3-2. U.S. Census Populations for 1980 of Cities Within an 80-Kilometer (50-mile) Radius of the Hanford Meteorological Station.

3.1.1.1.2 Preliminary Conclusions. The proposed repository site possesses a number of favorable conditions that are expected to allow repository operations to comply with the limits established by the NRC in 10 CFR 20 (NRC, 1982a) and by the EPA in proposed 40 CFR 191, Subpart A (EPA, 1982). Due to the low population density of the surrounding area and the distance from the proposed repository site to population centers, routine repository operations would not be expected to result in radiation exposure to members of the general public. Repository emissions, under routine operating conditions, are not expected to contain radioactivity above natural background levels. In the final environmental impact statement (DOE, 1980), it was calculated that even for the most severe operational accident postulated for a repository (dropping a canister down the repository mine shaft) the maximum individual would receive a 70-year whole body radiation dose of 3.5 x 10^{-5} rem. The repository design will incorporate filtration/adsorption systems to limit radioactive emissions below the levels allowed by the NRC and EPA. Data on releases from other nuclear facilities at Hanford and specific information on expected operational releases from a repository will be gathered in order to fully evaluate this guideline in the Site Recommendation Report.

Contributing radioactive releases from other facilities at Hanford that are governed by 40 CFR 190 (EPA, 1977) or the proposed 40 CFR 191 (EPA, 1982) will require a careful evaluation to determine that the combined releases from all facilities do not exceed the limits contained in the proposed 40 CFR 191.03. Preliminary information indicates that the repository can be designed to meet the requirements of proposed 40 CFR 191.03.

3.1.1.2 Performance After Permanent Closure. System Guideline 960.3-2 (Performance After Permanent Closure) (DOE, 1983) states that:

The site and engineered systems shall provide reasonable assurance that, after the permanent closure of the repository, credible postulated releases of radioactive materials to the accessible environment will not exceed the quantities of radioactive materials that may enter the environment as specified in the proposed 40 CFR 191, Subpart B, Environmental Standards for Disposal. A site shall be disqualified if the characteristics that influence radionuclide transport are too complex to allow reasonable confidence of compliance with the proposed 40 CFR 191.13 when considered in conjunction with state-of-the-art engineered systems, including those required under 10 CFR 60.113.

(a) Favorable Conditions

(1) Ground-water travel times to the accessible environment of more than 10,000 years.

(2) Geochemical conditions or ground-water volumetric flow limits that limit radionuclide releases.

(3) A geologic setting that is easily characterized or modeled with existing performance-assessment techniques.

(b) Potentially Adverse Conditions

Geologic setting, site geometries and characteristics, and radionuclide-transport characteristics that are extremely difficult to characterize and model.

3.1.1.2.1 Summary of Available Information. The site for a potential repository in basalt is at depth from ground surface greater than 900 meters (2,952 feet) and more than 700 meters (2,296 feet) from the top of the basalt sequence. The groundwater movement from a potential repository to the Columbia River has been modeled by several different organizations (DOE, 1982c). The traveltimes exceeded 13,000 years. With the accessible environment at 10 kilometers (6.3 miles) from the edge of the repository, the traveltimes would exceed at least 10,000 years and could be greater than 30,000 years. The geochemical conditions in the deep basalts limit the solubility of many radionuclides. Also, chemical interactions between the basalt and most radionuclides in the waste would retard the movement of such radionuclides relative to groundwater flow (DOE, 1982c). In addition, the layered nature of the basalt system tends to encourage horizontal movement through the basalt flow tops rather than through the more impermeable dense interiors of the basalt flows. Low-measured vertical and horizontal hydraulic gradients in the Cold Creek syncline surrounding the reference repository location increase calculated traveltimes from earlier modeling studies.

3.1.1.2.2 Preliminary Conclusions. The characteristics of the basalts are in some cases rather straight-forward and simple. In other cases, characterization and, hence, a proper understanding and modeling are more difficult and challenging. Site characterization and modeling activities are on schedule in providing an adequate understanding of the site in terms of NRC regulatory guides. The Site Characterization Report (DOE, 1982c) presents detailed data that were used to develop these preliminary conclusions. As can be seen by the information presented in Section 3.1.1.2.1, preliminary traveltimes exceed the favorable condition of 10,000 years to the accessible environment. At this time it appears that site and engineered systems will be able to control releases of radioactive materials to the accessible environment below the limits proposed in 40 CFR 191, Subpart B (EPA, 1982).

3.1.2 Program Guidelines

In discharging its responsibilities for the safe disposal of radioactive wastes, the DOE must recognize and follow national policies concerning radioactive waste disposal. Extending beyond the technical considerations of siting a safe, permanent repository, they include environmental, socioeconomic, and political considerations. These policies have been developed over the last 25 years in the course of meetings, discussions, studies, and debates between Federal, State, and local governments and participation by members of the public in meetings and hearings.

3.1.2.1 Conduct of Site Investigation. Program Guideline 960.4-1 (Conduct of Site Investigations) (DOE, 1983) states that:

> *Studies to identify potential repository sites will consider several geologic media, different hydrogeologic settings, and lands already dedicated to the nuclear activities of the Federal Government. To the extent practicable, sites recommended for detailed characterization shall be in different geologic media.*

3.1.2.1.1 Summary of Available Information. The formal three-step siting process described in Section 2.2 of this document was used by the NWTS Program to determine that the Hanford Site appears to be a suitable site. The host rock approach had previously identified rock salt as being a suitable host rock type. Consequently, areas in the conterminous United States that contain salt domes and bedded salt formations are undergoing site screening studies. This approach was not used to select the Hanford Site for siting studies.

Another approach used by the NWTS Program was to initiate siting studies on federally owned tracts of land in Nevada and Washington that are presently committed to nuclear activities and that may contain host rocks at appropriate depths for a repository. This approach was used to initiate siting studies at the Hanford Site in southeastern Washington State. The Hanford Site has been dedicated to nuclear activities since 1943 and is underlain by many layers of basaltic rock. The combined geologic, geochemical, hydrologic, and geomechanical properties of basalt are currently considered suitable for a potential repository at Hanford. Further site characterization studies are planned throughout the next few years to enable a final decision to be made as to the suitability of the Hanford Site.

The third approach, province screening, is being implemented by the U.S. Geological Survey on an experimental basis in one of eleven geohydrological provinces of the United States. The province screening approach was developed after the Hanford Site was selected for siting studies. Consequently, this approach could not be used to select the Hanford Site for initial siting studies.

3.1.2.1.2 Preliminary Conclusions. The Hanford Site is the first site recommended by the DOE for detailed site characterization. It is expected that other sites recommended for detailed site characterization will be in geologic media other than basalt. Current studies being conducted in bedded salt, domed salt, and tuff support this conclusion.

3.1.2.2 Consultation With States and Affected Indian Tribes. Program Guideline 960.4-2 (Consultation With States and Affected Indian Tribes) (DOE, 1983) states that:

> *The DOE shall provide to State officials and to the governing bodies of any affected Indian tribe timely and complete information regarding both plans and results concerning all phases of site evaluation, investigation, and characterization and the development of a geologic repository. Written responses to written requests for information from officials of affected states or Indian tribes will be provided within no more than 30 days. In performing any aspect of the geologic repository program, the DOE shall consult and cooperate with the governor and the legislature of an affected State and the governing body of an affected Indian tribe in an effort the resolve concerns regarding public health and safety, environmental, and economic impacts of any proposed repository. If requested, or after notifying states or Indian tribes that potentially acceptable sites have been identified within a State or tribal land, the DOE shall seek to enter into binding written agreements to specify procedures for consultation and cooperation with the affected State or Indian tribe.*

3.1.2.2.1 Summary of Available Information. The activities of the BWIP have been conducted under an open information policy that allows members of the general public, State and local government representatives, members of Indian tribes, the NRC, and members of the technical community to discuss the current status of the BWIP at any time. This policy will continue during detailed site characterization and all subsequent phases of the BWIP. A summary of meetings conducted with parties that have shown interest in BWIP activities is presented in Table 3-1. This table lists the major meetings that have taken place prior to the submittal of the Site Characterization Report (DOE, 1982c) to the NRC.

In the spring of 1979, the Intergovernmental BWIP Working Group was formed by Governor Dixy Lee Ray to keep the State of Washington informed on the status of the BWIP and its relationship to the NWTS Program. In August of 1982, Governor John Spellman established the State of Washington High-Level Nuclear Waste Management Task Force, a Citizens Advisory Council, and a Technical Advisory Group. A series of five meetings with representatives from the State of Washington have been held (see Table 3-1).

TABLE 3-1. Summary of Outside Meetings Conducted by the Basalt Waste Isolation Project.

Transmittal of Site Characterization Report to NRC (and meeting with the State of Washington)	11/12/82
Meeting and tour for the Washington State High-Level Nuclear Waste Task Force[a]	10/22/82
Public hearing conducted by the Washington State Legislative Subcommittee on Radioactive Waste	10/21/82
Briefing and tour for the Pasco City Council	10/16/82
Briefing and tour for Tri-City local governments	5/20/82
Fourth meeting with the Intergovernmental BWIP Working Group[b]	4/22/82
Third meeting with the Intergovernmental BWIP Working Group	10/2/81
Third BWIP Technical Information Meeting	12/2-4/80
Yakima Indian Nation briefing and tour	8/25/80
Second meeting with the Intergovernmental BWIP Working Group	1/7/80
Second BWIP Technical Information Meeting	12/5-6/79
Washington State Legislative Workshop on nuclear waste disposal	10/12/79
Public Information Meeting, Portland, Oregon	8/9/79
Public Information Meeting, Seattle, Washington	8/8/79
Public Information Meeting, Richland, Washington	8/6/79
First meeting with the Intergovernmental BWIP Working Group	7/31/79
First BWIP Technical Information Meeting	11/17/78

[a]Established by Governor John Spellman.

[b]Established by Governor Dixy Lee Ray.

On February 2, 1983, pursuant to Section 116 of the Act, the Secretary of the DOE notified the Governor of the State of Washington that Hanford contains a potentially acceptable site for a nuclear waste repository.

3.1.2.2.2 Preliminary Conclusions. The DOE's program for characterization of the Hanford Site basalts has been conducted under an open-door policy in the past, and future activities will be carried out in accordance with this guideline. The Secretary of the DOE in his February 2, 1983 letter to the Governor of the State of Washington offered to begin the formal process of consultation and cooperation required by the Nuclear Waste Policy Act of 1982. To date, no affected Indian tribes have been designated by the Secretary of the Department of Interior. (The Yakima Indian Reservation is the nearest Indian Reservation to the Hanford Site, approximately 50 kilometers (30 miles) from the reference repository location.) The process of consultation and cooperation will follow the requirements of the Act and this guideline.

3.1.2.3 Environmental Impact Considerations. Program Guideline 960.4-3 (Environmental Impact Considerations) (DOE, 1983) states that:

> *Environmental impacts shall be given due consideration throughout the site-characterization and site-selection processes. The environmental assessments that accompany the nomination of sites shall include the following items as specified by Section 112 of the Act:*
>
> *(a) An evaluation as to whether the site under consideration is suitable for site characterization under these siting guidelines;*
>
> *(b) A preliminary evaluation as to whether the site under consideration would be suitable for a repository by comparison to those siting guidelines that can be invoked without the results of site characterization;*
>
> *(c) An evaluation of the effects of site characterization activities on the public health and safety and the environment;*
>
> *(d) A reasonable comparative evaluation of the site under consideration with other sites and locations that have been considered;*
>
> *(e) A description of the decision process which led to the site being recommended;*
>
> *(f) An assessment of the regional and local impacts of locating a geologic repository at the site being recommended.*

A final environmental impact statement will be submitted in support of a decision to recommend a site to the President as suitable for the construction of a geologic repository. Written in accordance with Section 114(f) of the Act, this statement will be based on the requirements of the National Environmental Policy Act and will be the vehicle for evaluating the environmental acceptability of the recommended site in comparison to the available alternatives.

3.1.2.3.1 Summary of Available Information. The NWTS Program has followed the requirements of the National Environmental Policy Act of 1969 in its various activities. Two of the more important programmatic environmental documents are:

- Final Environmental Impact Statement: Management of Commercially Generated Radioactive Waste (DOE, 1980)
- Public Draft, National Plan for Siting High-Level Radioactive Waste Repositories and Environmental Assessment (DOE, 1982d).

During the performance of the BWIP activities, important environmental documents have been prepared for certain characterization activities. Several of these documents are listed below:

- Environmental Assessment for Exploratory Borehole Drilling Activity: Wells ARH-DC-4, -5, -6, -7, and -8, Hanford Reservation, Benton County, Washington (DOE, 1978a)
- Environmental Assessment for the Near-Surface Test Facility, Hanford Reservation, Richland, Washington (DOE, 1978b)
- Environmental Assessment for the Basalt Waste Isolation Project Exploratory Shaft Construction (DOE, 1982a).

3.1.2.3.2 Preliminary Conclusions. Environmental impacts will continue to be given due consideration during the site characterization and site selection processes. This draft environmental assessment addresses the six items listed in Program Guideline 960.4-3. The Nuclear Waste Policy Act of 1982 requires that a final environmental impact statement be prepared to support the site recommendation report. These actions are in full compliance with the purpose and intent of this program guideline. Prior to construction and operation of a nuclear waste repository, the NWTS Program will issue an environmental report that meets the requirements of 10 CFR 51, as part of the construction license application to the NRC.

3.1.2.4 Regional Distribution. Program Guideline 960.4-4 (Regional Distribution) (DOE, 1983) states that:

> *After the selection of the first repository site, a major consideration in siting additional repositories shall be regional distribution. The DOE shall consider the advantages of regional distribution in the siting of repositories to the extent that technical, policy, and budgetary considerations permit.*

3.1.2.4.1 Summary of Available Information. The NWTS Program is committed to developing a regional repository system to take advantage of suitable host rock sites in different parts of the United States. Regional repositories will allow for a more equitable distribution of impacts and/or benefits than an approach that places the burden of nuclear waste disposal on a single area. Cooperation among states in a particular region would be enhanced by this approach and common problems associated with nuclear waste could be resolved.

3.1.2.4.2 Preliminary Conclusions. Siting studies being conducted by the DOE cover various regions of the United States (see Fig. 2-1). After the first repository site is selected, the DOE will carefully consider the advantages of a regional distribution when selecting subsequent repository sites.

3.1.2.5 Schedule for the First Repository. Program Guideline 960.4-5 (Schedule for the First Repository) (DOE, 1983) states that:

> *The DOE shall nominate at least five sites determined suitable for site characterization and subsequently recommend to the President at least three of these nominated sites for detailed characterization as candidate sites. Not later than March 31, 1987, the President shall submit to the Congress a recommendation of one site from the three sites initially characterized that the President considers qualified for application for a construction authorization for a repository.*

3.1.2.5.1 Summary of Available Information. Following the issuance of siting guidelines and consultation with the Governors of affected states, at least five sites will be nominated as suitable for characterization as candidate sites. Three of these five sites will be recommended to the President not later than January 1, 1985, for selection of the first repository site as required by the Nuclear Waste Policy Act of 1982.

3.1.2.5.2 Preliminary Conclusions. This guideline states a specific procedural requirement from the Nuclear Waste Policy Act of 1982. Currently the DOE plans, budgets, and schedules are being developed to ensure compliance with this guideline.

3.1.2.6 Schedule for the Second Repository. Program Guideline 960.4-6 (Schedule for the Second Repository) (DOE, 1983) states that:

> *The DOE shall nominate at least five sites determined suitable for site characterization and subsequently recommend to the President at least three of these nominated sites for characterization as candidate sites. Not later than March 31, 1990, the President shall submit to the Congress a recommendation of a second site from any sites already characterized that the President considers qualified for a construction authorization for a second repository.*

3.1.2.6.1 Summary of Available Information. Five sites, including three additional sites not nominated to meet Section 960.4-5 of the proposed siting guidelines (DOE, 1983), will be nominated for characterization and possible selection of the second repository site. These five sites cannot include either of the two sites that were not recommended to the President by Section 960.4-5 of the proposed siting guidelines (DOE, 1983). Subsequent to this nomination, three of these five sites will be recommended to the President as suitable for site characterization not later than July 1, 1989. This action will comply with the requirements and provisions of the Nuclear Waste Policy Act of 1982.

3.1.2.6.2 Preliminary Conclusions. This guideline also states a specific procedural requirement from the Nuclear Waste Policy Act of 1982. Plans, budgets, and schedules of the DOE are being developed to meet this guideline.

3.1.3 Technical Guidelines

In selecting a site for a nuclear waste repository that is safe and environmentally acceptable, it is necessary to consider a variety of geotechnical and environmental factors. The site must provide natural barriers for waste containment and isolation. These barriers should keep radionuclides from reaching people in unacceptable quantities by (1) maintaining the waste in its emplaced location for a given period of time (providing waste containment), (2) limiting radionuclide mobility through the geohydrologic environment to the accessible environment (providing isolation), and (3) making human intrusion difficult. The technical guidelines evaluated below were prepared to define the physical, chemical, and institutional constraints required to isolate radioactive wastes. Most of the technical guidelines include favorable and potentially adverse conditions that can be evaluated to aid in determining compliance with the guideline. These conditions were taken from the final draft of the NRC's technical criteria to be issued as 10 CFR 60, Subpart E (NRC, 1982b). The summary of available information and the analysis used to make the preliminary conclusions for each guideline are contained in DOE (1982c).

3.1.3.1 Site Geometry. Technical Guideline 960.5-1 (Site Geometry) (DOE, 1983) states that:

The geologic repository shall be located in a geologic setting that physically separates the radioactive wastes from the accessible environment and has a volume of rock adequate for placement of the underground facility.

This guideline deals with the depth, thickness, and lateral extent of the basaltic host rock. The stratigraphy of the reference repository location consists of a thick sequence of laterally extensive basalt flows overlain by approximately 180 meters (590 feet) of sediments. Over 50 basalt flows are present in the Pasco Basin (Fig. 3-3) down to a depth of at least 3.2 kilometers (1.9 miles). At least three candidate repository horizons, the Umtanum, Cohassett, and McCoy Canyon flows, appear to meet the thickness, lateral extent, and depth requirements needed for construction of an underground facility and for assurance that the projected releases of radionuclides would be less than those specified in Section 960.3-2 of the proposed siting guidelines (DOE, 1983).

3.1.3.1.1 Depth of Underground Facilities. Technical Subguideline 960.5-1-1 (Depth of Underground Facilities) states that:

The site shall allow the underground facility to be placed at a minimum depth such that reasonably foreseeable human activities and natural processes acting at the surface will not lead to a projection of radionuclide releases greater than those discussed in Section 960.3-2. The site shall be disqualified if site conditions do not allow all portions of the underground facility except the shafts to be at least 200 meters from the directly overlying ground surface.

(a) Favorable Conditions

(1) Site conditions permitting the emplacement of waste at a minimum depth of 300 meters from the ground surface (10 CFR 60.122(b)(6)).

(2) A geologic setting where the nature and rates of the geomorphic processes that have been operating during the past million years would, if continued in the future, not affect or would favorably affect the ability of the geologic repository to isolate the waste (10 CFR 60.122(b)(1)).

(b) Potentially Adverse Conditions

A geologic setting that shows evidence of extreme erosion during the past million years (10 CFR 60.122(c)(17)).

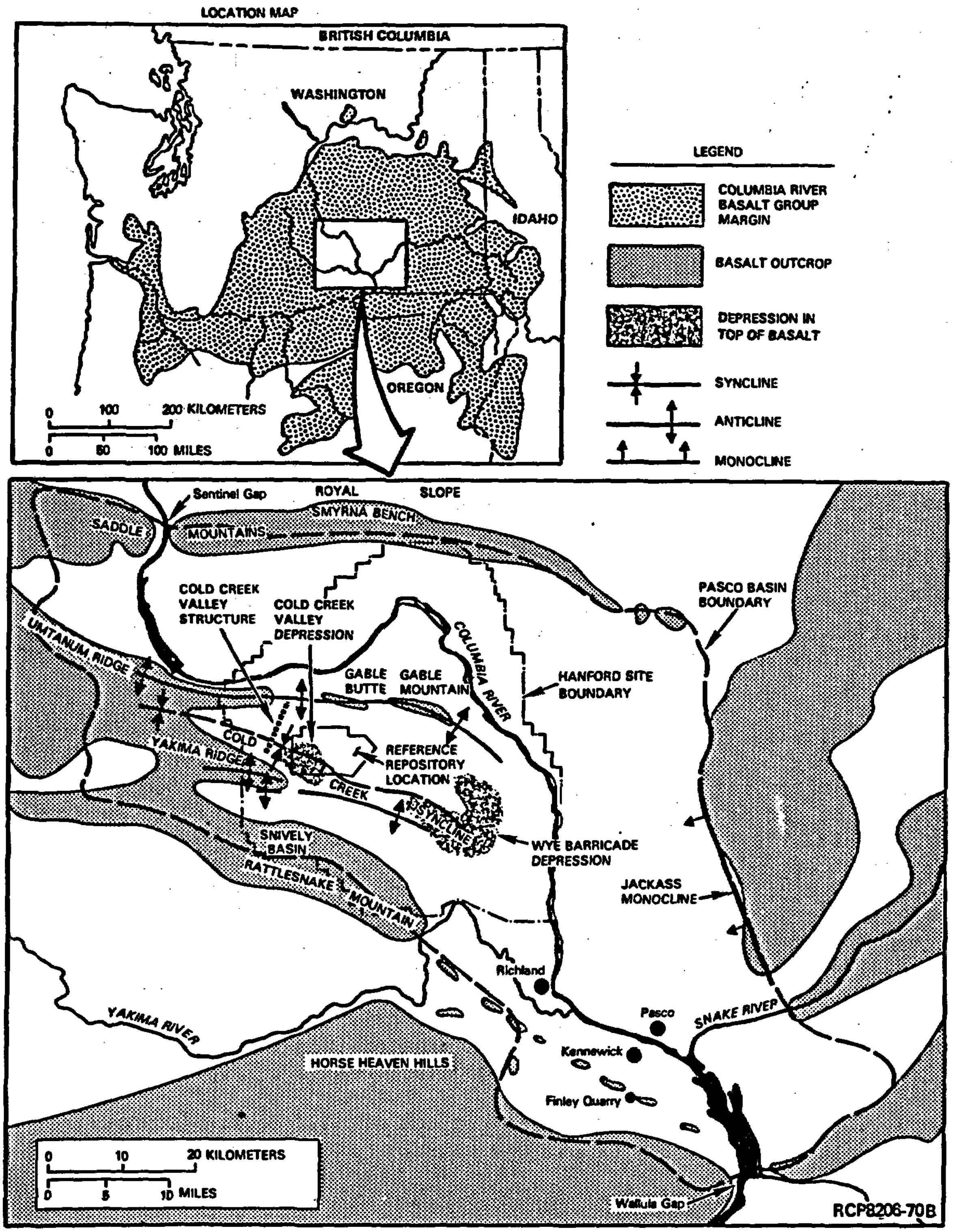

FIGURE 3-3. Extent of the Columbia River Basalt Group, Pasco Basin, and Reference Repository Location.

3.1.3.1.1.1 Summary of Available Information. Based on data from five deep boreholes within the site, the top of the uppermost candidate horizon (Cohassett flow) lies at 869 to 942 meters (2,850 to 3,092 feet) below ground surface (-646 to -746 meters (-2,118 to -2,448 feet) below sea level). The top of the McCoy Canyon flow lies 1,026 to 1,090 meters (3,365 to 3,576 feet) below ground surface (-803 to -894 meters (-2,633 to -2,932 feet) below sea level). The top of the Umtanum flow lies 1,059 to 1,135 meters (3,475 to 3,723 feet) below ground surface (-836 to -936 meters (-2,743 to -3,071 feet) below sea level). Studies show that the area of the site has, over the past 15 million years, been undergoing subsidence, and this is expected to continue into the foreseeable future (Reidel and Fecht, 1982).

Within the Pasco Basin geomorphic processes have been dominated by degradational processes on basalt ridges. Although degradation and aggradation processes were briefly accelerated during periods of catastrophic floods during the past million years, overall rates of degradation and aggradation have been relatively low. These rates are interpreted to reflect the dry climate and low rates of uplift and subsidence (WCC, 1980). The maximum credible depth of erosion is mean sea level or about 190 meters (620 feet) beneath the present surface at the site.

Geomorphic processes within the site have principally resulted in aggradation over the past million years, although degradation has occurred locally. This trend is expected to continue over the next million years.

3.1.3.1.1.2 Preliminary Conclusions. Penetration of the repository by human activity is considered very unlikely due to the proposed depth of the repository and the lack of known economically valuable recoverable resources in the reference repository location (see Sections 960.5-2-2 and 960.5-6-1 of the proposed siting guidelines (DOE, 1983)). Based on current data, the three candidate horizons at the site exceed the minimum requirement of 200 meters (656 feet) below ground surface of the underground facility. Past and current geomorphic processes are not expected to change in the foreseeable future, and the site is not expected to change from an area of subsidence to one of uplift. Therefore, the possibility of the repository being exhumed by erosion is very small. If a repository were placed in any one of the three candidate horizons, reasonably foreseeable human activities and natural processes would not be expected to cause radionuclide releases greater than those discussed in Section 960.3-2 of the proposed siting guidelines (DOE, 1983).

3.1.3.1.2 Thickness and Lateral Extent of Host Rock. Technical Subguideline 960.5-1-2 (Thickness and Lateral Extent of Host Rock) states that:

> *The thickness and lateral extent of the host rock shall accommodate the underground facility and ensure that impacts induced by the construction of the repository and by waste emplacement will not lead to a projection of radionuclide releases greater than those discussed in Section 960.3-2.*

(a) Favorable Conditions

The host rock is of sufficient extent to allow significant latitude in terms of depth, configuration, or location of the underground facility.

(b) Potentially Adverse Conditions

A volume of rock with physical properties adequate for the underground facility but laterally restricted to a small portion of the site.

3.1.3.1.2.1 Summary of Available Information. Available borehole data (five boreholes) indicate that throughout the reference repository location, the Cohassett flow is 73 to 81 meters (239 to 266 feet) thick, the McCoy Canyon flow is 34 to 45 meters (110 to 147.5 feet) thick, and the Umtanum flow is 60 to 71 meters (197 to 232 feet) thick. All three candidate repository horizons appear to be laterally continuous throughout the reference repository location and the northern Pasco Basin (see Fig. 3-3). The candidate repository horizons are known to occur at least 27.8 kilometers (16.7 miles) north, 26.4 kilometers (15.8 miles) east, 13.6 kilometers (8.2 miles) south, and 21.4 kilometers (12.8 miles) west of the center of the reference repository location.

3.1.3.1.2.2 Preliminary Conclusions. The three candidate repository horizons are both thick and laterally continuous beyond the boundaries of the reference repository location and are expected to adequately accommodate the underground facility. Potential radionuclide releases from the three candidate horizons, due to construction activities and waste emplacement, should be less than those established in Section 960.3-2 of the proposed siting guidelines (DOE, 1983). The study of field exposures of the candidate repository horizons will be continued to determine typical, short-range variations in flow thickness. New borehole data will also be used to improve the predictive accuracy of flow thickness.

3.1.3.2 Geohydrology. Technical Guideline 960.5-2 (Geohydrology) (DOE, 1983) states that:

The geohydrologic regime in which the site is located shall be compatible with waste containment, isolation, and retrieval.

Input addressing Technical Guideline 960.5-2 (DOE, 1983) centers on the hydrologic and geologic characteristics of a potential repository site. Based on data for basalt, numerical models are being developed to address questions regarding groundwater traveltimes and radionuclide concentration releases to the accessible environment under both undisturbed and reasonable scenario conditions.

The geohydrologic regime in basalt beneath the Hanford Site has characteristics favorable to waste containment and isolation. These include a tectonic setting undergoing a very low rate of deformation, rock layers of low permeability, plus groundwater traveltimes and potential radionuclide release rates well within recommended Federal guidelines. A summary discussion of present and future hydrologic conditions, hydrologic modeling, shaft construction, and dissolution features follows.

3.1.3.2.1 Present and Future Hydrologic Conditions. Technical Subguideline 960.5-2-1 (Present and Future Hydrologic Conditions) states that:

> *The present and probable future geohydrologic regime of the site shall be capable of preventing radionuclide transport for the repository to the accessible environment in amounts greater than those discussed in Section 960.3-2. The site shall be disqualified if the average pre-waste-emplacement ground-water travel time along the path of likely radionuclide travel from the disturbed zone to the accessible environment is less than 1,000 years.*
>
> *(a) Favorable Conditions*
>
> *(1) The nature and rates of hydrologic processes operating within the geologic setting during the past million years would, if continued in the future, not affect or would favorably affect the ability of the geologic repository to isolate the waste (10 CFR 60.122(b)(1)).*
>
> *(2) For disposal in the saturated zone, hydrologic conditions that provide a host rock with a low horizontal and vertical permeability; a downward or predominantly horizontal hydraulic gradient in the host rock; and a low vertical permeability and low hydraulic potential between the host rock and the surrounding hydrogeologic units; or a pre-waste-emplacement ground-water travel time along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment that substantially exceeds 1,000 years (10 CFR 60.122(b)(2)).*
>
> *(3) For disposal in the unsaturated zone, hydrogeologic conditions that provide a low and nearly constant moisture content in the host rock and the surrounding hydrogeologic units; or a water table sufficiently below the underground facility such that the capillary fringe does not encounter the host rock; or a laterally extensive low-permeability hydrogeologic unit above the host rock that would divert the downward infiltration of water beyond the limits of the underground facility; or a host rock with a high saturated permeability and an effective porosity that provides for free drainage; or a climatic regime in which precipitation is a small percentage of the potential evapotranspiration (10 CFR 60.122(b)(3)).*

(b) Potentially Adverse Conditions

None specified.

3.1.3.2.1.1 Summary of Available Information. There exists no direct method to evaluate the past groundwater environment other than through inferences using the structural/tectonic setting, groundwater chemistry, and numerical models.

By understanding the structural and tectonic stability of an area, one can infer the likelihood of generating new groundwater flow paths. Available geologic, geophysical, geodetic, and seismologic data suggest that the Pasco Basin was deforming at a low rate of strain in the Miocene and this rate has continued to the present (Rasmussen, 1967; WPPSS, 1974; UWGP, 1979; Savage et al., 1981; PSPL, 1982; Reidel and Fecht, 1982). This slow rate of deformation along known geologic structures is also expected to continue for a projected minimum 10,000-year period (see Sections 960.5-5-1 and 960.5-5-3 of the proposed siting guidelines (DOE, 1983)). Thus, groundwater flow paths as now characterized have probably extended into the past and are projected into the reasonable future.

Groundwater chemistry provides direct long-term evidence of the water's history. Present data have identified distinct groundwater chemistries in the shallow versus deep basalts, each with distinguishable isotopic signatures. The areal continuity of these chemical types and groundwater ages suggest these waters have undergone uniform geochemical processes since their infiltration. Geochemical modeling is planned to more fully understand the rock-water interactions required to produce the chemistries found (see discussion under Technical Guideline 960.5-3). These results will be coupled with the latest conceptual and numerical models to produce a reasonable projection of both past and future hydrologic processes and rates that may affect radionuclide transport.

The proposed disposal of nuclear waste in Columbia River basalt would occur within the saturated zone. Therefore, the favorable conditions quoted earlier that pertained to waste disposal in the unsaturated zone do not apply to basalt.

Groundwater within basalt moves laterally through zones of high hydraulic conductivity (within portions of interbeds and flow tops) and vertically through fractured basalt interiors (the degree of vertical movement depends on the flow's vertical transmissivity). In nonstructurally deformed areas, minimal groundwater quantities are thought to move across flow interiors separating more permeable zones. Thus, flow interiors are interpreted to act as low conductivity aquitards. Because of the greater-than-normal occurrence and length of fracturing in structurally disturbed areas (e.g., Umtanum Ridge-Gable Mountain anticline) (see Fig. 3-3), water is considered to seep vertically through such structures to a larger extent than in nondisturbed areas. As opposed to anticlines, synclines are broad, open features having undergone little structural disturbance. Thus synclinal areas, such as the location of the reference repository location, should contain less secondary fracturing and less vertical groundwater leakage compared to anticlinal areas.

Overall, groundwater moves from areas of recharge to discharge. Local reacharge areas for shallow basalts are the basalt outcrops surrounding the Pasco Basin. Regional recharge of deeper basalts is thought to be from interbasin groundwater movement. Discharge is to the major rivers (see Fig. 3-3), but the exact discharge location(s) is unknown. Along these groundwater flow paths, water is under artesian conditions. Areas of flowing artesian wells exist within the Cold Creek Valley (west of the reference repository location) and along the Columbia River where low land elevations exists.

Within the Saddle Mountains Basalt, most equivalent horizontal hydraulic conductivities for flow tops and sedimentary interbeds range between 10^{-4} and 10^{-6} meters per second (10^{1} to 10^{-1} feet per day), with a mean value of 10^{-5} meters per second (10^{0} feet per day). The majority of hydraulic conductivity values for flow tops in the Wanapum Basalt range between 10^{-4} and 10^{-7} meters per second (10^{1} to 10^{-2} feet per day), with a mean value of 10^{-5} meters per second (10^{0} feet per day). Hydraulic conductivities for flow tops within the Grande Ronde Basalt generally range from 10^{-5} to 10^{-9} meters per second (10^{0} to 10^{-4} feet per day), with a mean value of about 10^{-7} meters per second (10^{-3} feet per day).

Results of hydrologic tests across dense interior (colonnade and entablature) sections of basalt flows give horizontal hydraulic conductivities of 10^{-12} to 10^{-13} meters per second (10^{-7} to 10^{-8} feet per day). These values are thought typical of dense flow interiors. Those portions of flow tops that do not consist of interconnected vesicles and fractures are considered to have hydraulic conductivities between the lowest values reported for flow tops and those typical of flow interiors.

The variability in hydraulic conductivity for a particular stratigraphic unit probably results from areal changes in fracture/vesicular frequency and interconnections, plus differences in secondary mineral infilling. These features relate to the cooling and emplacement history of a flow in addition to any post-emplacement disturbance.

The only reported estimates of vertical conductivity for Columbia River basalt are from numerical model studies of Tanaka et al. (1974) for the Walla Walla River Basin Irrigation Project and from MacNish and Barker (1976) for the Walla Walla River Basin. Tanaka et al. (1974) estimated the vertical hydraulic conductivity for the basalt sequence to be between 10^{-12} and 10^{-10} meters per second (10^{-7} and 10^{-5} feet per day). MacNish and Barker (1976) stated that it may be as low as 10^{-8} meters per second (10^{-3} feet per day) within their area of study. These estimates were iteratively derived from a model that simulated an observed head distribution.

Numerical model simulations for the BWIP studies use the conservative value of 10^{-10} meters per second (10^{-5} feet per day) as the vertical hydraulic conductivity across basalt flows (DOE, 1982c). This is about 2 orders of magnitude larger than the mean horizontal conductivity for the columnar sections of a basalt flow as determined from downhole hydrologic testing. Vertical hydraulic conductivity field testing was initiated by the BWIP during fiscal year 1983.

Hydraulic head data collected from within the reference repository location are being integrated with Hanford-wide information to develop a more complete understanding of the groundwater system. Within the Saddle Mountains Basalt beneath the reference repository location, head elevations decrease with depth from 137 to 127 meters (449 to 417 feet). Lower heads with depth are characteristic of groundwater recharge areas such as found in the shallow basalts along the western Hanford Site. Head elevations are rather uniform within the Wanapum and Grande Ronde Basalts in the reference repository location, averaging 123 $\pm$ 1.5 meters (403 $\pm$ 5 feet) above mean sea level. These generally uniform head distributions are common in the Cold Creek syncline and are interpreted as indicating an area of lateral groundwater movement--that portion of the groundwater system not undergoing major recharge or discharge. The average areal head gradient in the deep basalts is a low 10^{-4} meter/meter (foot/foot). Groundwater from the reference repository location appears to move southeasterly.

Based on available data, hydraulic head changes in the deep basalts beneath the Hanford Site appear to be slow and of small magnitude. This is concluded upon examining long-term head monitoring records from boreholes DC-1 and DDH-3, plus several shallower monitoring wells.

An examination of hydraulic heads from piezometers placed in the Grande Ronde Basalt in borehole DC-1 indicates small head changes ($\pm$1 meter ($\pm$3 feet)) over the past decade in most piezometers following hole equilibration.

Borehole DDH-3 has a single piezometer open across two flow contacts in the Frenchman Springs Member of the Wanapum Basalt. Heads have been periodically monitored in DDH-3 since 1970. These measurements give head elevations of approximately 117 to 118 meters (384 to 387 feet) above mean sea level. Such small changes monitored over a 12-year period suggest that the overall head elevation has changed little in that portion of the Wanapum Basalt.

An active borehole monitoring program (borehole locations are shown in Fig. 3-4) is also maintained in a series of shallow boreholes completed in either the lower Saddle Mountains or upper Wanapum Basalts. These holes are located adjacent to the Columbia River, within the Cold Creek syncline, and in the Cold Creek Valley where heavy groundwater withdrawals are taking place. A summary of these data indicates that over the period for which monitoring records are available (approximately 4 years), heads in boreholes DB-1 and DB-2, sited near the Columbia River, have undergone a slow, cyclic response with a maximum head variation of $\pm$1 meter ($\pm$3 feet) having a periodicity of greater than 1 year. Very minor head variations ($\pm$0.2 meter ($\pm$0.6 feet)) have taken place in borehole DB-4, located centrally within the Cold Creek syncline and in DB-7 ($\pm$0.4 meter ($\pm$1.3 feet)), located in the southern Cold Creek syncline. In the Cold

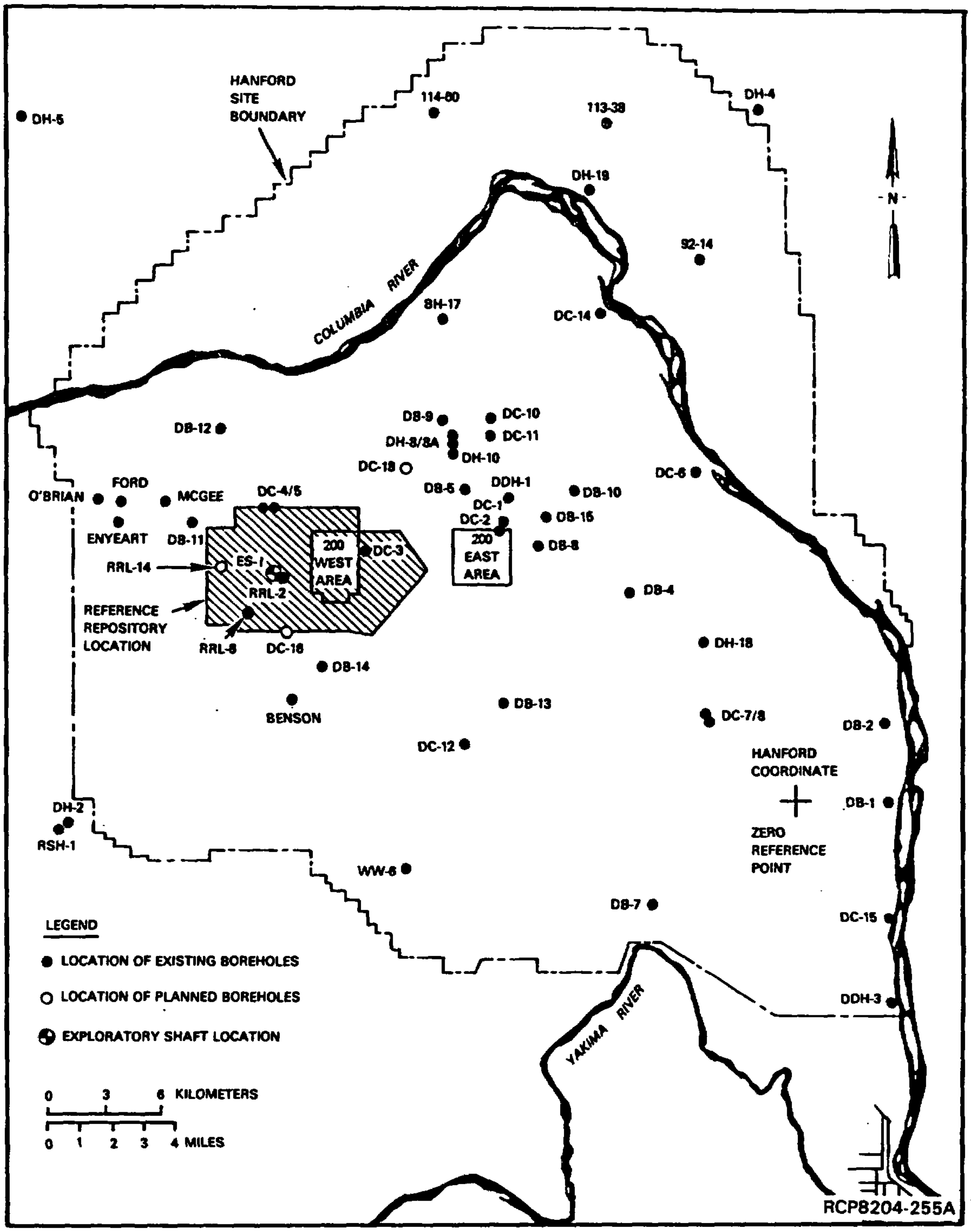

FIGURE 3-4. Location of Existing and Planned Boreholes at the Hanford Site.

Creek Valley west of the Cold Creek structural barrier mentioned earlier, water levels in DB-11 have declined 7.5 meters (24.5 feet) since 1978. This change resulted from nearby agricultural water withdrawals.

The above monitoring data indicated that hydraulic heads in the deep basalts beneath Hanford change slowly and by small amounts. Heads in shallow basalts, east of the Cold Creek structural barrier, vary by slightly larger amounts.

Distinct groundwater chemical types exist in the Columbia River basalts. Changes from one type to another occur rapidly over short stratigraphic distances. Overall, Saddle Mountains, Wanapum, and Grande Ronde groundwaters are of sodium bicarbonate, sodium chloride-bicarbonate and sodium chloride chemical types, respectively. The specific stratigraphic boundaries separating these chemical types vary by small amounts depending upon areal location. Major isotopic shifts between shallow and deep basalts also take place. Such hydrochemical and isotopic shifts (coupled with small vertical hydraulic head gradients) are believed to delineate flow system boundaries and suggest the lack of significant vertical mixing of groundwaters in structurally nondeformed areas. Studies are under way to examine the possibility of groundwater mixing along the Umtanum Ridge-Gable Mountain anticline and the Cold Creek Valley structure (see Fig. 3-3). Future geochemical modeling is also directed toward evaluating these concepts.

Modeling of the near-field groundwater flow system around a repository indicates that the groundwater flow paths are primarily controlled by the more permeable flow tops between successive flows. Results of modeling also indicate that the minimum groundwater traveltimes from the repository site to the accessible enviroment, a distance defined by the EPA in its proposed regulations (EPA, 1982) as 10 kilometers (6.2 miles) appear to be greater than 10,000 years. The very small quantities of radionuclides, which do ultimately travel to the accessible environment, appear to remain small and well below the EPA-proposed regulations.

Over the past several years, a number of far-field hydrologic modeling studies have been conducted by independent organizations. Each study had limiting assumptions and used the most recent data available at the time of the study. Traveltimes were estimated for groundwater movement between the repository and a discharge point at the Columbia River, a distance of 8 to 60 kilometers (5 to 35 miles) depending on the assumed flow path. Traveltimes estimated exceeded 20,000 years. Regardless of the different assumptions used, these estimated pre-waste-emplacement traveltimes are significantly longer than the NRC-proposed technical criterion (NRC, 1981a) of a 1,000-year minimum traveltime between the repository and the accessible environment.

A preliminary analysis of post-waste-emplacement flow paths and traveltimes has also been performed. The analysis of groundwater flow patterns for the post-closure period indicates that the thermal environment (i.e., temperature field in the vicinity of the repository) will significantly influence the natural groundwater flow paths and traveltimes. Flow paths within the thermally influenced zone are predominantly upward where buoyancy driving forces are strong; whereas, outside this zone the flow direction is controlled by the regional hydraulic gradient. The net effect is that the post-waste-emplacement traveltimes appear to be longer than those for pre-waste-emplacement conditions. This is because groundwater is being driven vertically through several additional basalt flows of low interior permeability compared to pre-waste-emplacement flow paths.

3.1.3.2.1.2 Preliminary Conclusions. Available data indicate that the local structural/tectonic setting has been undergoing a slow rate of deformation of several million years and most of this deformation occurs along existing geologic structures. Thus, new groundwater pathways are not expected to be generated in the foreseeable future and the nature and rate of hydrologic process should remain relatively constant. The horizontal hydraulic conductivities of basalt flow interiors are very low with groundwater production from the basalts restricted to limited zones within given flow tops and sedimentary interbeds. This groundwater movement is predominantly horizontal and occurs under a low hydraulic potential. Pre-emplacement groundwater traveltimes to the accessible environment substantially exceed 1,000 years. These factors lead to the preliminary conclusion that radionuclide releases will meet the limits of Section 960.3-2 of the proposed siting guidelines.

3.1.3.2.2 Hydrologic Modeling. Technical Subguideline 960.5-2-2 (Hydrologic Modeling) states that:

The geohydrologic regime shall be capable of being characterized with sufficient certainty to permit modeling to show that present and probable future conditions would lead to a projection of radionuclide releases less than those discussed in Section 960.3-2.

(a) Favorable Conditions

Sites that have simple stratigraphic and hydrogeologic sequences and a lack of structural, tectonic, or cross-cutting igneous features such that the geohydrology can be readily characterized and modeled with reasonable certainty.

(b) Potentially Adverse Conditions

(1) Potential for foreseeable human activities to adversely affect the ground-water flow system, such as ground-water withdrawal, extensive irrigation, the subsurface injection of fluids, underground pumped storage, military activities, or the construction of large-scale surface-water impoundments (10 CFR 60.122(c)(2)).

(2) *Potential for natural phenomena like landslides, subsidence, or volcanic activity of such a magnitude that they could create large-scale surface-water impoundments that could change the regional ground-water flow system (10 CFR 60.122(c)(3)).*

(3) *Potential for the water table to rise sufficiently to cause the saturation of waste-emplacement areas in the unsaturated zone (10 CFR 60.122(c)(4)).*

(4) *Potential for structural deformation--such as uplift, subsidence, folding, or faulting--that may adversely affect the regional ground-water flow system (10 CFR 60.122(c)(5)).*

(5) *Potential for changes in hydrogeologic conditions that would increase the transport of radionuclides to the accessible environment, such as changes in the hydraulic gradient, average interstitial velocity, storage coefficient, hydraulic conductivity, natural recharge, potentiometric levels, and discharge points (10 CFR 60.122(c)(6)).*

(6) *Potential for adverse changes in hydrologic conditions resulting from reasonably foreseeable climatic changes (10 CFR 60.122(c)(7)).*

3.1.3.2.2.1 Summary of Available Information. Geohydrologic studies are providing data defining the occurrence, distribution, supply, and history of basalt groundwaters. The tectonic and structural features important to understanding the long-term waste isolation potential of basalt are being defined and integrated into conceptual and numerical models. As demonstrated in the Site Characterization Report (DOE, 1982c) the local geologic and hydrologic setting can be characterized and modeled. Uncertainty in understanding the geohydrologic regime is a function of basic data input, the conceptual model, the numerical models, and how uncertainty propagates from each of these model levels to the next higher one. The degree of approximation or error in the numerical codes will be checked in the process of code verification and benchmarking.

Performance-assessment methodology is based on the conjuctive use of a set of numerical models. These models are designed to describe the coupled processes of rock stress-strain, heat transfer, groundwater flow, and radionuclide transport. The set of models are grouped into three categories: very near field (canister to room scale), near field (repository scale), and far field (groundwater basin scale). The very near-field models use a representation that considers both the fractured and porous features of the basalt medium. The near-field and far-field models use the concept of an "equivalent porous continuum" to represent the major basalt flows and confined aquifers.

For the very near-field zone, the performance models are used to compute the fractional radionuclide release rates at the boundary of the engineered barriers and candidate repository horizon. Output from near-field predictions are the concentrations of key radionuclides in the groundwater and the time-integrated activity crossing the 10-kilometer (6.2-mile) controlled zone boundary. Flow paths and traveltimes in the far-field zone (i.e., from the control zone boundary to points in the accessible environment) are determined as functions of the recharge/discharge characteristics, hydrologic properties and boundary conditions, and major structural features of the geologic system.

Very near-field analyses indicate that the fractional release rates for key radionuclides are a function of the release rate at the waste package, hydraulic properties of the emplacement horizon, and the magnitude of the thermally induced driving forces. For radionuclides with even a nominal amount of sorption (i.e., kd greater than 5.0 milliliters per gram), the retardation effects are sufficient to reduce the release rates from the repository horizon to levels well below the 10^{-5} per year proposed regulatory criterion, during the first 10,000 years (Baca et al., 1982). The very low solubility properties of major radionuclides (technetium, uranium, plutonium, americium) in the reducing (anoxic) environment of the deep basalt plays an even greater role than sorption in maintaining release rates below the proposed release criterion.

Near-field simulation results for the candidate repository horizons indicate that relatively few radionuclides are of concern within a 10,000-year waste isolation period. Most actinide elements and long-lived fission products are of little importance because of their retardation characteristics and apparently very low solubilities. The radionuclide ^{14}C appears to be a key radionuclide in the spent fuel inventory because of its mobility (i.e., nonsorbing characteristic and relatively long half-life). For the flow paths predicted from the candidate repository horizons, since average traveltimes are greater than 10,000 years to the accessible environment, the radionuclide fluxes are zero at the 10-kilometer (6.2-mile) boundary during the first 10,000 years. The radionuclide fluxes reaching the accessible environment are below the conservative maximum permissible concentration levels at the control zone boundary for all future times.

As noted in Section 3.1.3.2.1.1, far-field hydrologic modeling has been performed by several independent organizations. Each study concluded that under pre-waste-emplacement conditions, groundwater traveltimes from the repository to the accessible environment substantially exceeded the 1,000-year proposed criteria.

Several non-site-specific credible scenarios for disruptive event occurrence have been proposed in the technical literature (Arnett et al., 1980). These generic scenarios have been screened and evaluated on the basis of credibility, consistency with site-specific geologic and hydrologic knowledge, event likelihood, and release potential to preliminarily define scenarios relevant to disruption of a repository in

Columbia River basalt. Scenarios initially considered applicable consisted of the following natural, man-induced, and repository-induced events for the first 10,000 years following repository decommissioning:

- Fault zone directly or indirectly connecting the repository with the biosphere
- Shaft seal degradation or failure
- Intrusion by borehole
- Loss of integrity due to microearthquake swarm zone
- Intrusion by basaltic dike.

Dike intrusion was eliminated from consideration based on a close examination of the nature and conditions of historic basaltic extrusions. Preliminary analysis of the consequences of a microearthquake event centered at the repository indicates no significant effects over the 10,000-year period of interest. No definitive evidence was found that either magmatic intrusion by basaltic dike or a microearthquake event would have significant hydrologic effects.

Currently, with the exception of volcanism (Johnpeer et al., 1981) (see discussion under Technical Guideline 960.5-5), no attempt has been made to estimate the probabilities of occurrence of such events within the Pasco Basin. Instead, consequence analyses have been undertaken to determine their potential for disruption of a repository in basalt. In many instances, the consequences of a particular event are sufficiently small to cause the issue of probability of occurrence to be of limited or no interest; i.e., even if the probability of occurrence of an event is one, the radionuclides would be contained in the deep basalt away from the accessible environment.

The current list of plausible scenarios will be expanded to include other postulated events: (1) repository-induced phenomena, (2) man-induced phenomena, and (3) effects of climatic variation. If it is determined that an event or process has a potentially significant consequence, the overall risk will be calculated from the consequence and the probability of occurrence.

3.1.3.2.2.2 Preliminary Conclusions. The basalt geohydrologic environment can be characterized and appears to be a suitable setting for the long-term isolation of radionuclides under nondisruptive and reasonable disruptive scenario conditions. Studies are under way or planned to examine the effects from additional disruptive scenarios associated with man-induced or natural phenomena. These modeling efforts are necessary to make a final determination that radionuclide releases are less than those specified in Section 960.3-2 of the proposed siting guidelines (DOE, 1983)

3.1.3.2.3 Shaft Construction. Technical Subguideline 960.5-2-3 (Shaft Construction) states that:

The geohydrologic regime of the site shall allow the construction of repository shafts and maintenance of the integrity of shaft liners and seals.

(a) Favorable Conditions

Absence of large highly transmissive aquifers between the host rock and the land surface.

(b) Potentially Adverse Conditions

Rock or ground-water conditions that would require complex engineering measures in the design and construction of the underground facility or in the sealing of boreholes and shafts (10 CFR 60.122(c)(21)).

3.1.3.2.3.1 Summary of Available Information. Approximately 15 water-bearing horizons having hydraulic conductivities of greater than or equal to 10^{-5} meters per second (1 foot per day) have been identified beneath the reference repository location. These horizons could produce water inflows of several tens to several thousand liters (gallons) per minute. Potential high-production horizons include sedimentary interbeds within the Saddle Mountains Basalt, flow tops in the Priest Rapids, Roza, and Frenchman Springs members of the Wanapum Basalt plus selected flow tops in the Grande Ronde Basalt.

Groundwater inflows can be controlled in a shaft sunk by blind hole drilling through the use of drilling muds and additives. If a shaft is sunk by conventional mining techniques (blasting and mucking), water inflow is controlled by freezing or grouting. The Exploratory Shaft will be completed by blind hole drilling.

The blind hole drilling technique will seal aquifers by floating a circular steel liner into the shaft hole and then filling the annulus between liner and rock with grout. Grout will be pumped into the annulus in stages from the bottom up such that the fluid that maintains the hydrostatic pressure is gradually displaced. After the grout has set, the steel liner and grout can be removed in zones of competent rock. This is necessary to allow access to the candidate repository horizons or to install impermeable barriers for decommissioning of the repository.

The drilling, blasting, and mucking shaft-sinking technique requires that control of aquifers be accomplished before the shaft is emplaced. Control is achieved by either pressure grouting or freezing. Both techniques require holes to be bored into the aquifer before blasting the shaft. Grout is pumped into the aquifer from small holes radiating from the shaft and then allowed to set before blasting continues. The freezing technique uses a circle of boreholes drilled from the surface to conduct freezing liquids to the aquifers. The water is frozen in the aquifer prior to blasting. With either technique, the blasted shaft is lined with reinforced concrete to provide a more complete and permanent seal. In zones where water inflow is small enough to be controlled by pumps, freezing or grouting would not be necessary. Sealing the shaft for decommissioning would be similar to that planned for the blind hole drilling technique.

3.1.3.2.3.2 Preliminary Conclusions. The water-bearing horizons that could pose a potential inflow concern during shaft construction have been identified. Water inflow rates have been calculated based on measured heads and equivalent hydraulic conductivities. The construction of the Exploratory Shaft at Hanford will show that large-diameter shafts can be blind bored to repository depth, and intersected aquifers can be sealed off from the shaft.

3.1.3.2.4 Dissolution Features. Technical Subguideline 960.5-2-4 (Dissolution Features) states that:

The site shall be such that any subsurface rock dissolution that may be occurring or is likely to occur would not lead to a projection of radionuclide releases greater than those discussed in Section 960.3-2. The site shall be disqualified if it is shown that active dissolution fronts would cause significant interconnection of the underground facility to the site hydrogeologic system during the first 10,000 years.

(a) Favorable Conditions

No evidence that the host rock within the operations area was subject to dissolution during the past million years.

(b) Potentially Adverse Conditions

Evidence of dissolution such as breccia pipes or dissolution cavities (10 CFR 60 122(c)(11)).

3.1.3.2.4.1 Summary and Conclusions. This guideline does not apply to hard rocks such as basalt. No further evaluation of this guideline is necessary.

3.1.3.3 Geochemistry. Technical Guideline 960.5-3 (Geochemistry) (DOE, 1983) states that:

The site shall have geochemical characteristics compatible with waste containment, isolation, and retrieval. The site shall be such that the chemical interactions among radionuclides, rock, ground water, and engineered components would not lead to a projection of radionuclide releases greater than those discussed in Section 960.3-2.

(a) <u>*Favorable Conditions*</u>

(1) *The nature and rates of the geochemical processes operating within the geologic setting during the past million years would, if continued in the future, not affect or would favorably affect the ability of the geologic repository to isolate the waste (10 CFR 60.122(b)(1)).*

(2) *Geochemical conditions that promote the precipitation or sorption of radionuclides; inhibit the formation of particulates, colloids, and inorganic and organic complexes that increase the mobility of radionuclides; or inhibit the transport of radionuclides by particulates, colloids, and complexes (10 CFR 60.122(b)(4)).*

(3) *Mineral assemblages that, when subjected to the expected thermal loading, will remain unaltered or will be altered to mineral assemblages with equal or increased capability to inhibit radionuclide transport (10 CFR 60.122(b)(5)).*

(b) <u>*Potentially Adverse Conditions*</u>

(1) *Ground-water conditions in the host rock--including chemical composition, high ionic strength, or oxidizing or reducing conditions and pH--that could increase the solubility or chemical reactivity of the engineered barrier systems (10 CFR 60.122(c)(8)).*

(2) *Geochemical processes that would reduce the sorption of radionuclides, result in the degradation of the rock strength, or adversely affect the performance of the engineered barrier systems (10 CFR 60.122(c)(9)).*

(3) *For disposal in the saturated zone, ground-water conditions in the host rock that are not chemically reducing (10 CFR 60.122(c)(10)).*

3.1.3.3.1 <u>Summary of Available Information</u>. Demonstration of the compatibility of a nuclear waste repository in basalt with this guideline requires an assessment of the nature and rates of long-term (past 1 million years) geochemical processes operating within the basaltic geologic setting. In addition, the geochemical conditions that affect the stability of the basalt and engineered barriers system, and the solubility and transportation of radionuclides must be addressed.

Determination of actual geochemical conditions during the last 1 million years can be determined indirectly by using groundwater age data and by interpreting secondary-mineral assemblages. Secondary-mineral assemblages are present within the basalt that have wide stability ranges whose ages of deposition are not known precisely. However, the ages of the oldest secondary minerals are almost certainly greater than 1 million years.

The geochemistry of the groundwater in the reference repository location and surrounding area tends to be buffered by reaction with basalts that constitute the bulk of the rocks at depth. Because of the relatively high rock-to-water ratios and because the rock and groundwater compositions do not change appreciably with time and the thermal gradient remains constant, changes in groundwater chemistries would most likely result from an influx of oxygenated surface waters. Such an influx is likely to be very slow; both theoretical considerations and experimental results indicate that such water would react with basalt and become strongly reducing. Thus, oxidization conditions are not expected to persist.

The current understanding of the prevailing geochemical conditions in the candidate repository horizons in the reference repository location is summarized in Table 3-2.

TABLE 3-2. Environmental Conditions in the Candidate Repository Horizons.

Parameter	Flow		
	Cohassett	McCoy Canyon	Umtanum
Depth range* (m)	912.3 - 992.1	1,059.2 - 1,099.4	1,099.4 - 1,170.1
Mean temperature (^{o}C)	51.2	56.0	58.2
Mean hydrostatic pressure (MPa)	9.2	10.4	11.0
pH	9.5 ± 0.05	9.5 ± 0.05	9.5 ± 0.05
Eh (V)	-0.45 ± 0.07	-0.45 ± 0.07	-0.45 ± 0.07

*Below surface (top of flow to bottom of flow).

Work to develop a more complete understanding of the nature of the groundwater chemistry and Eh-pH controlling mechanisms is under way. Based on the current data set, Jacobs and Apted (1981) have suggested that dissolution of basalt glass and the precipitation of secondary minerals may be responsible at both ambient and elevated temperatures. Indirect Eh measurements (oxygen depletion) from preliminary 200°C (392°F) basalt-groundwater hydrothermal experiments support the proposed mechanism and suggest control to be very rapid (within several hundred hours). Additionally, steady-state solution compositions from these experiments are very similar to the composition of in situ groundwaters. These preliminary results suggest that the mechanism(s) controlling solution chemistry, pH and Eh, are similar at both ambient and elevated temperatures. Further refinement and confirmation of these concepts will result from carefully designed basalt hydrothermal experiments and detailed in situ analyses of the basalt-groundwater system.

Thermal loading of the groundwater-saturated repository will result in hydrothermal interactions in the waste/barrier/basalt system. The dominant process will be gradual dissolution of coexisting primary solid phases. Dissolution will be accompanied by precipitation and growth of an assemblage of secondary alteration phases that are more stable under the given repository conditions (Helgeson, 1968). Primary phases include silicates and oxides in basalt, backfill, and waste form components, and metals or alloys for canister components.

The various dissolution and growth mechanisms for each solid are qualitatively similar, yet can be meaningfully divided along the functional requirements of each component of the waste package. Canister materials should be selected to be relatively inert to groundwater. Groundwaters with Eh and pH conditions similar to those in the candidate repository horizons generally lead to low corrosion rates for proposed canister materials (e.g., carbon steel).

The dissolution of basalt (and, by extension, backfill and buffer components) and attendant growth of secondary alteration phases will control (buffer) the geochemical parameters within the repository. This is because basalt, especially the glassy portion, is volumetrically the dominant reactive solid phase. Also, the alteration phases formed, such as clays and zeolites, will significantly absorb radionuclides and retard their migration to the accessible environment.

The basalt geochemical environment can affect radionuclide transport by controlling radionuclide solubility and sorption behavior--the two dominant retardation mechanisms in the basalt geohydrologic system. Available data suggest that both solubility and sorption controls are important factors in limiting radionuclide releases to the accessible environment.

The solubility amd mobility of a radionuclide is dependent on the environmental conditions (Eh, pH, temperature, stable complexes, etc.) of the geohydrologic system. Theoretical solubility estimates of a variety of important actinide and fission products are available for conditions anticipated in the Grande Ronde basalt geochemical environment (Early et al., 1982). In addition, some experimental data has been collected by the BWIP. These theoretical and experimental studies generally confirm that the strongly reducing and alkaline groundwaters encountered in a nuclear waste repository in basalt result in lowered solubilities for many key radionuclides. Specifically, reducing conditions led to the formation of low oxidation states for many radionuclides that inhibit production of stable complex species. In addition, it appears that the high pH promotes the precipitation of most actinides in the form of oxides and hydroxides. Insufficient solubility data are available for other important radionuclides. Static and dynamic (flow-through) experiments that will address this question are in progress.

Investigation of the specific dissolved radionuclide species in Grande Ronde Basalt groundwater has been approached theoretically (Early et al., 1982), but experimental confirmation is lacking. The possibility that formation of organic complexes and/or colloids might occur has been considered and specific studies to resolve these issues are either planned or in progress.

Radionuclide distribution coefficient values have been determined for the sorption of the majority of the key radionuclides on representative geologic materials under conditions applicable to geohydrology for the basalt system (Salter et al., 1981a, 1981b; Ames, 1980; Ames and McGarrah, 1980a, 1980b, 1980c). These distribution coefficient values are used currently in radionuclide transport models to evaluate the radionuclide retardation capabilities of the basalt geohydrologic system (Wood, 1980; Arnett et al., 1981). However, this method has two basic limitations: (1) it assumes equilibrium (i.e., a reversible system) and (2) it assumes that sorption is linearly dependent on radionuclide concentration. In addition, the measured distribution coefficient values do not distinguish between precipitation and sorption reactions. The assumptions, implicit in the use of simple distribution coefficient based models, are not valid for all radionuclides; sorption isotherms are often nonlinear, and some sorption reactions can be controlled kinetically and/or can be irreversible.

To improve the evaluation of radionuclide retardation for use in transport modeling, radionuclide sorption-desorption isotherms are currently being determined for the basalt geohydrologic system (Salter et al., 1981a, 1981b). These isotherm "equations" describe sorption as a function of radionuclide concentration and will replace the distribution coefficient values in the retardation equation. Sample radionuclide distribution coefficient values, however, can be used to qualitatively evaluate the retardation capabilities of the geohydrologic system and to establish reasonable experimental parameters for more advanced sorption experiments (kinetic and flow-through sorption). Kinetics and reversibility of the radionuclide sorption reactions in the basalt geohydrologic system are also being determined. Kinetic sorption equations, where applicable, can be used in place of equilibrium sorption isotherms to determine radionuclide retardation. Present investigations of both equilibrium and kinetic sorption behavior, over the range of repository conditions, and the development of mathematical functions (sorption isotherms, etc.) to describe this behavior will permit a more accurate assessment of radionuclide retardation.

Available groundwater chemistry data, results from basalt solids characterization studies and sorption isotherm experiments, suggest that the suite of observed secondary minerals and hydrothermal alteration products in the host basalt and backfill material strongly sorb many key radionuclides under anticipated environmental conditions. Sorption-desorption and kinetics studies are continuing and will help provide additional refinement in sorption systematics for input to radionuclide transport modeling efforts.

3.1.3.3.2 Preliminary Conclusions. Present Eh-pH, chemical, and secondary mineralogical conditions in the basalt geochemical system seem to be the result of rock-water interaction processes that have been operative at least during the Quaternary. The basalt mineralogy and the high rock-water ratio seem to effectively buffer the groundwater composition against significant change.

Available geochemical data indicate that the candidate repository horizons at the Hanford Site provide effective containment and isolation for many radionuclides present in high-level nuclear waste. Groundwaters from these basalt flows are strongly reducing (Eh = -0.45 ± 0.07 volt) and alkaline (pH = 9.5 ± 0.5). These factors tend to enhance the stability of metallic components of the waste package and lead to decreased solubilities and increased sorption of many radionuclides. The role of colloid formation in the basalt geochemical system currently is being addressed experimentally. Hydrothermal alteration of the backfill/basalt system results in formation of a variety of stable mineral assemblages such as clays and zeolites, which have superior sorptive capabilities. These geochemical characteristics lead to the preliminary conclusion that projected releases of radionuclides will not exceed the limits in Section 960.3-2 of the proposed siting guidelines (DOE, 1983).

3.1.3.4 Rock Characteristics. Technical Guideline 960.5-4 (Rock Characteristics) (DOE, 1983) states that:

The site shall have geologic characteristics compatible with waste containment, isolation, and retrieval.

Input addressing Technical Guideline 960.5-4 (DOE, 1983) centers on data regarding the effect of geomechanical, chemical, thermal, and radiation-induced stresses on basalt and the ability to develop, operate, and close a repository without undue hazard to repository personnel. Discussions in this section are based primarily on conceptual repository and waste package design considerations (KE/PB, 1982) and on information obtained through field and laboratory tests, including the BWIP Near-Surface Test Facility at Gable Mountain (see Fig. 3-3).

3.1.3.4.1 Physical Properties. Technical Subguideline 960.5-4-1 (Physical Properties) states that:

The site shall provide a geologic system that is capable of accommodating the geomechanical, chemical, thermal, and radiation-induced stresses that are expected to be caused by interactions between the waste and the host rock.

(a) Favorable Conditions

None specified.

(b) <u>Potentially Adverse Conditions</u>

Potential for such phenomena as thermally induced fractures, hydration and dehydration of mineral components, brine migration, or other physical, chemical, or radiological phenomena that could lead to projections of radionuclide releases greater than those discussed in Section 960.3-2.

3.1.3.4.1.1 <u>Summary of Available Information</u>. Field data on thermal spalling and slabbing of the candidate repository horizons have not yet been obtained; however, information for the Pomona flow has been generated during tests at the Near-Surface Test Facility. Full-Scale Heater Test #2, which was conducted for 2 years, subjected the Pomona basalt to temperatures up to 490°C (914°F) at the borehole wall. It has been estimated that the temperature at the borehole wall within the repository host rock will be subjected to temperatures up to approximately 300°C (572°F) (DOE, 1982c). No spalling or slabbing was observed in the before-heating and after-heating photographs. However, several minor instances of opening of existing small fractures and creation of new small fractures were observed. Analysis of the probable cause and extent of these features is ongoing. Although this information is of a somewhat qualitative nature with regard to predicting the response of the basalt under actual repository conditions where some openings will be larger and stresses higher, the indication is that basalt has a stronger resistance to thermal degradation than do most other rock types. A summary of basalt characteristics including porosity, density, thermal conductivity, Young's modulus, Poisson's ratio, and tensile strength are presented in Section 3.4.

Hydrous mineral phases such as clays, which are present in the host basalt and will be a major component of the waste package backfill, are susceptible to dehydration reactions during heating. These reactions are accompanied by loss of volume. Studies on smectite clay by Koster van Groos (1981) show that the temperature of loss of interlayer water is pressure dependent and occurs at 130°C (266°F) under atmospheric conditions and 430°C (806°F) at a pressure of 30 megapascals. During the early period of the repository, the ambient pressure will be nearly atmospheric and thermal modeling of the very near-field environment suggest that temperatures will be high enough to cause dehydration of backfill and basalt clays. Eventually, resaturation will occur and the clay minerals will reversibly rehydrate and swell. Studies show that shrinking/swelling processes accompanying dehydration/rehydration reactions have no deleterious effects on the waste package or the surrounding host basalt. Further testing to confirm this conclusion is nearing completion.

As noted in the discussion of Technical Guideline 960.5-3 (DOE, 1983), the geochemical environment of the groundwater in the candidate repository horizons tends to be buffered by its interaction with basalt and will tend to remain constant as long as the temperature does not change. Basalt-water hydrothermal studies at 150°C (302°F) and 300°C (572°F) (Apted and Myers, 1982) indicate that while the specific rock-water reactions, which occur under these conditions, may differ from those at lower temperatures in this system, groundwater compositions still are effectively buffered and large chemical perturbations are avoided. Hydrothermal studies at 100°C (212°F) to complement those already completed are in progress.

At the low neutron flux levels associated with nuclear waste, measurable neutron-induced radiation effects on barrier materials are not expected to occur during the period of isolation in the repository. Hence, the major concern in evaluating candidate barrier materials, including the host rock, is the effect of the gamma radiation. Incidental radiation can affect the stability of barrier materials by affecting changes in (1) bulk physical structure, (2) any protective layer, and/or (3) chemistry of the intruding groundwater. During the containment period, alpha and beta radiation will not penetrate the canister (to the surrounding media). The effects of alpha radiation on groundwater will be evaluated under the assumption that the containment is lost. Researchers have concluded that gamma radiation principally affects the groundwater and does so by producing chemical changes (radiolysis) through excitation and ionization processes (Stobbs and Swallow, 1962; Byalobzheskii, 1970; Wu, 1978). The primary radiolysis process in aqueous solutions is the decomposition of water to form short-lived radicals (e^-_{aq}, H^+, OH^-, HO_2) and the longer-lived molecular products, H_2 and H_2O_2. If, in some manner, the radiolytic hydrogen is continuously removed from the system, the oxidation potential (Eh) of the solution could increase and remain high. This increase in Eh would be generally deleterious to the stability of canister materials and could also lead to an increase in solution concentrations (and, hence, release rates) of multivalent radionuclides.

Conversely, it can be hypothesized that, in a sealed and decommissioned repository constructed in basalt, where highly reducing conditions (e.g., low Eh) are expected to be imposed by the host rock (Jacobs and Apted, 1981), a high-hydrogen fugacity will tend to suppress the deleterious effects of radiolysis reaction on Eh. Thus, the corrosiveness and solution properties of any intruding groundwater may be unaffected or minimally affected by radiation.

Currently available data indicate radiation effects on candidate backfill materials should not affect the important functional characteristics (e.g., a chemical/physical barrier to water and radionuclide transport) (Friedlander et al., 1964). This, however, will be verified through testing in a high-intensity gamma field. In addition, tests to evaluate the effect of high-intensity gamma field on canister corrosion may be conducted.

3.1.3.4.1.2 Preliminary Conclusions. Currently available data suggest that the site is capable of accommodating the geomechanical, chemical, thermal, and radiation-induced stresses that are expected to be caused by interactions between the waste and the host rock without fracturing. Indication is that basalt has a stronger resistance to thermal degradation than do most other rock types. In addition, shrinking/swelling processes accompanying dehydration/rehydration reactions indicate no deleterious effects on the waste package or the surrounding host basalt. Basalt-water hydrothermal studies at 150°C (302°F) and 300°C (572°F) (Apted and Myers, 1982) indicate that while specific rock-water reactions, which occur under these conditions, may differ from those at lower temperatures in this system, groundwater compositions still are effectively buffered and large chemical pertubations are avoided. Currently available data also indicate radiation effects on candidate backfill material should not affect the important functional characteristics. However, this will be verified through testing in a high-intensity gamma field. In addition, tests to evaluate the effect of high-intensity gamma field on canister corrosion and to confirm the effect of dehydration/rehydration reactions will be conducted.

3.1.3.4.2 Operational Safety. Technical Subguideline 960.5-4-2 (Operational Safety) states that:

The site shall be such that the construction, operation, and closure of underground areas will not cause undue hazard to repository personnel. The site shall be disqualified if the applicable safety requirements of the DOE and NRC could not be met.

(a) Favorable Conditions

None specified.

(b) Potentially Adverse Conditions

(1) Rock conditions that would require complex engineering measures in the design and construction of the underground facility or in the sealing of boreholes and shafts (10 CFR 60.122(c)(21)).

(2) Geomechanical properties that would not permit underground openings to remain stable until permanent closure (10 CFR 60.122(c)(22)).

3.1.3.4.2.1 Summary of Available Information. The stability of repository openings is directly influenced by the properties of the host rock and by the state of stress around the openings. If stresses resulting from the natural setting and from thermal loading cannot be adequately accommodated by the rock mass, the possibility for failure of the rock and for creation of pathways for radionuclide migration is introduced. In order to ensure safe conditions for repository operation and to preserve the isolation capability of the host rock, the stability of the openings must be maintained throughout the life of the repository. Therefore, an adequate understanding of in situ stress conditions and rock mass properties is of significant importance.

There are inherent difficulties associated with assessing mine stability in the absence of direct access to candidate horizons from a shaft or tunnel. Measurement of in situ stress from the surface still involves uncertainties, and rock mass properties can only be roughly estimated using laboratory data. However, empirical knowledge accumulated over the past few decades indicates that laboratory-measured rock properties from core samples, along with measurements of in situ stress and observations of geologic structure made from exploratory boreholes, are of significant value for a preliminary assessment of opening stability.

Hydraulic fracturing stress measurements conducted in five basalt flows on the Hanford Site have generally shown a trend of increasing maximum principal stress with depth. The maximum principal stresses were measured in the horizontal plane and average orientations were found to be in a range from N. 16° E. to N. 25° E. for all deep flows tested.

In borehole RRL-2, the in situ stress ratio in the Cohassett flow was found to be approximately 20 percent lower than for the Umtanum flow (approximately 2:1). While no measurements have been made in the McCoy Canyon flow, one test series conducted approximately 35 meters (115.5 feet) above it in Grande Ronde Basalt Flow 7 showed in situ stress levels comparable to the Umtanum flow. Regardless of depth, the ratio of maximum principal stress to vertical stress is in the 2.0:1 to 2.5:1 range.

A very preliminary estimate is that average maximum principal stress magnitudes greater than 80 megapascals or average stress ratios (greater than 3.0) (maximum horizontal to vertical) are the upper limits beyond which construction of a repository could be economically unattractive. Future numerical modeling and design analysis efforts will attempt to confirm this estimate.

In general, the uniaxial compressive strength and deformation modulus of the entablature and colonnade of the candidate horizons are similar, while the flow top is much weaker and more deformable. Uniaxial compressive strengths for flow-top and breccia zones are typically less than 25 percent of those for interior zones in the flow. Vesicular zones tend to be somewhat stronger, but still have strengths only 35 to 65 percent of the dense interior zones. The uniaxial compressive strength of the Cohassett flow interior, which includes the entablature and colonnade, is 62 percent of that for the Umtanum flow and 73 percent of that for the McCoy Canyon flow; however, all three can be considered high-strength rocks. There appears to be no substantial differences in deformation modulus values between the candidate horizons, except for an anomalously low value for the McCoy Canyon colonnade.

Thermal and thermomechanical properties measured for samples from the Cohassett and Umtanum flows in RRL-2 were very similar. Values for the specific heat and the thermal expansion coefficient differed by less than 3 percent for the two flows. Values for thermal conductivity for the Umtanum flow were approximately 85 percent of those for the Cohassett. These differences are not of major significance from a design standpoint.

Using Bieniawski's (1979) geomechanics classification system, the rock mass rating values for all three candidate flows are in reasonable agreement. Only one of the six parameters in the system (specifically the rock quality designation) differs for the flows. With all three flows in the "good rock" category, estimated rock mass strength and roof support requirements would be the same.

Use of the Q system classification method (Barton et al., 1974) also results in the conclusion that all three candidate flows fall in the "good rock" category. However, Q system estimates of deformation modulus and support requirements differ between flows more than do estimates using the geomechanics classification system. The differences arise from the fact that the Q system incorporates the in situ stress level into the calculation using the stress reduction factor. This factor is a function of the ratio of the uniaxial compressive strength to the maximum principal stress for the flow in question. Since the Cohassett flow samples have shown the lowest compressive strength values, a corresponding low strength-to-stress ratio results in a reduced modulus estimate and a somewhat increased support requirement.

3.1.3.4.2.2 <u>Preliminary Conclusions</u>. As a result of a review of in situ stress information, results of laboratory and field tests to determine physical, mechanical, thermal, and thermomechanical properties of basalt, and estimates of rock mass characteristics based on the geomechanics classification systems, some conclusions regarding the operational safety of the repository can be made. The stress conditions at all the candidate horizons should permit construction of a repository. Tunnels can be constructed using either tunnel boring machines or the drill and blast method. The classification of the candidate horizons as "good rock" by both Bieniawski's (1979) method or the Q method (Barton et al., 1974) indicates that tunnels will usually require only light support. The strength and deformation modulus of the basalt during normal operations and at limited temperatures indicates that the basalt is not expected to deform significantly during operation of the repository. Therefore, placing of tunnel seals should require no complex engineering methods. Construction of the Exploratory Shaft will yield valuable information relating to shaft construction and, consequently, repository construction techniques that will not result in undue hazards to repository personnel.

Analysis of the known geologic and hydrologic conditions, as summarized in this draft environmental assessment and detailed in the Site Characterization Report (DOE, 1982c), indicates that compliance with applicable safety regulations can be achieved.

3.1.3.5 Tectonic Environment. Technical Guideline 960.5-5 (Tectonic Environment) (DOE, 1983) states that:

> *The site shall be located in a geologic setting where the effects of current or reasonably foreseeable tectonic phenomena will not lead to a projection of radionuclide releases greater than those discussed in Section 960.3-2.*

Input addressing Technical Guideline 960.5-5 (DOE, 1983) centers on an evaluation of faulting and seismicity, igneous activity, and uplift, subsidence, and folding within and in the vicinity of the reference repository location. Available data regarding these conditions indicate that the reference repository location is in an area of relatively low seismicity compared to adjacent seismo-tectonic provinces. No seismic events have been related to specific structure within the Pasco Basin. Most faults are associated with anticlinal ridges and are interpreted to be contemporaneous with folding. The reference repository location is in the broad flat-lying Cold Creek syncline, interpreted to be relatively undeformed. Long-term uplift and subsidence rates have been determined to be low and appear to have continued from at least 14 thousand years ago to present. The last Columbia River basalt flow was erupted 6 million years before present and only very minor tephra deposits have occurred from Cascade volcanics in the last 6 million years. Preliminary assessment of the tectonic setting of the reference repository location indicate that the tectonic effects will not lead to a projection of releases of radionuclides greater than those specified in Section 960.3-2 of the proposed siting guidelines (DOE, 1983).

3.1.3.5.1 Faulting and Seismicity. Technical Subguideline 960.5-5-1 (Faulting and Seismicity) states that:

> *The site shall be located in a geologic setting where faults that might affect waste isolation, if any, can be identified and shown to have hydrologic properties and seismic potentials that will not lead to a projection of radionuclide releases greater than those discussed in Section 960.3-2.*
>
> *(a) Favorable Conditions*
>
> *(1) The nature and rates of faulting, if any, operating within the geologic setting during the past million years would, if continued in the future, not affect or would favorably affect the ability of the geologic repository to isolate the waste (10 CFR 60.122(b)(1)).*
>
> *(2) The nature and rates of faulting, if any, operating within the geologic setting during the past million years would, if continued into the future, have less than one chance in 10,000 over the next 10,000 years of leading to releases of radioactive waste to the accessible environment (proposed 40 CFR 191.13).*

(b) *Potentially Adverse Conditions*

(1) *Faults in the geologic setting that may adversely affect the regional ground-water flow system (10 CFR 60.122(c)(5)).*

(2) *Evidence of active faulting within the geologic setting during the past million years (10 CFR 60.122(c)(12)).*

(3) *Historical earthquakes that, if repeated, could affect the site significantly (10 CFR 60.122(c)(13)).*

(4) *Indications, based on correlations of earthquakes with tectonic processes and features (e.g., faults), that either the frequency of occurrence or the magnitude of earthquakes may increase (10 CFR 60.122(c)(14)).*

(5) *More frequent occurrences of earthquakes or earthquakes of higher magnitude than are typical of the region in which the geologic setting is located (10 CFR 60.122(c)(15)).*

3.1.3.5.1.1 Summary of Available Information. The site is located in the Cold Creek syncline, a part of the Yakima Fold Belt that is characterized by long narrow anticlines and broad synclines. Most faults within the fold belt are associated with anticlinal fold axes, are thrust or reverse (although normal faults are also present), and are interpreted to be contemporaneous with folding. Deformation of the fold belt appears to have continued on existing structures, and stress appears localized in steeply dipping strata and on existing structures. Faults of major displacement are not anticipated in the shallow-dipping synclinal strata on the basis that only a few tectonic features that have been found in the thousands of meters of core drilled within the Pasco Basin synclines and on the basis of mechanical analysis studies conducted by Price (1982).

Strain on the anticlinal fold areas has resulted in faults which, in places, have cut strata as young as Quaternary in age. Faults cut Quaternary sediments on anticlines in the central Gable Mountain area (about 8 kilometers (4.5 miles) northeast of the reference repository location) and at Finley Quarry in the Horse Heaven Hills (see Fig. 3-3). Long-term displacement rates on the Gable Mountain fault based on the offset of Quaternary sediments are calculated to be very low (less than 5.00×10^{-6} meters per year (16.0×10^{-6} feet per year)) (PSPL, 1982). The low displacement rate on this fault is consistent with other geologic and "contemporary" data sources that suggest deformation has been proceeding at an average low rate of strain over at least the last 14 million years.

Historical and instrument data indicate that the Pasco Basin and the reference repository location are areas of relatively low seismicity compared to adjacent seismo-tectonic provinces in eastern Washington. Seismicity in the central Columbia Plateau is confined to a thin 28-kilometer (17.5-mile) crust and is characterized by temporally and spatially limited swarms of low magnitude (less than 3.5) shallow earthquakes that may be characteristic of brittle deformation in basalt. Deep earthquakes (greater than 6 kilometers (3.8 miles)) responding to the same stress regime, occur as single events or mainshock-aftershock sequences, appear more diffuse in spatial distribution, and do not generally appear to be related to shallow events. Differences in recurrence (b value) and pattern activity suggest the basalt may behave in a more brittle manner than rocks beneath the basalt in which some aseismic deformation may be occurring.

Focal mechanism solutions in the central Columbia Plateau from ongoing seismic monitoring indicate that a nearly north-south, nearly horizontal compression with a nearly vertical axis of least compression exists today. This stress regime is supported by geodolite observations (Savage et al., 1981; USGS and PAG, 1981) and appears to be the same regime that resulted in the nearly east-west folds on subparallel thrust and reverse faults and steeply dipping northwest and northeast-trending faults in the Yakima Fold Belt that bounds the Pasco Basin. This stress regime apparently has been unchanged for more than 14 million years.

Historic earthquakes have been felt in only a few areas and have been small, except for two moderate-sized events near Umatilla (modified Mercalli intensity III) in 1893 and the Milton-Freewater area (modified Mercalli intensity VII) in 1936. The largest events recorded during 12 years of instrumental monitoring in the central Columbia Plateau are concentrated near the Saddle Mountains and Frenchman Hills north of the Hanford Site. The largest instrumentally recorded earthquake in the central Columbia Plateau is a magnitude 4.4 event on Royal Slope about 85 kilometers (50 miles) north of the Hanford Site. The surface facilities will be designed for a ground acceleration of 0.25 g, which corresponds to a magnitude greater than 4.4 event. No events have been recorded in the reference repository location.

Earthquakes in the central Columbia Plateau are not presently associated with mapped geologic faults, nor do hypocenters align in a manner that suggest the presence of unmapped faults. Swarms have occurred in the flanks of the Saddle Mountains structure (see Fig. 3-3), which is faulted, but the events do not correspond with mapped faults. Swarms have also occurred elsewhere where there are no mapped geologic structures.

3.1.3.5.1.2 Preliminary Conclusions. Completed studies suggest faulting and seismicity in the geologic setting of the reference repository location do not appear to present significant problems regarding Section 960.5-5-1 of the proposed siting guidelines (DOE, 1983). The reference repository location in the Cold Creek syncline contains relatively undeformed strata in an environment where bordering anticlines apparently have been deforming slowly at low average rates of strain. The patterns and rates of deformation have apparently been continuously in operation for at least 14 million years and can be assured to continue over the next few thousand to tens of thousands of years. Major structures have been identified, and it is assumed that future strain will be localized on these structures; however, the more detailed mechanics of the deformation process remain to be assessed. The low rate of strain is also apparent in the relatively low seismicity of the central Columbia Plateau and Hanford Site. The seismicity and stress field of the central Columbia Plateau will continue to be monitored as part of detailed site characterization.

Uncertainties regarding the location of folds or faults, geologic (long-term) and contemporary rate of deformation, geologic structures, and seismicity of the geologic setting with respect to the site will be addressed during detailed site characterization. These specific studies to resolve uncertainties are necessary to make a final conclusion that seismic factors will not lead to a projection of radionuclide releases greater than those discussed in Section 960.3-2 of the proposed siting guidelines (DOE, 1983).

3.1.3.5.2 Igneous Activity. Technical Subguideline 960.5-5-2 (Igneous Activity) states that:

The site shall be located in a geologic setting where centers of igneous activity during the past million years, if any, can be identified and shown to have no effects that will lead to a projection of radionuclide releases greater than those discussed in Section 960.3-2.

(a) Favorable Conditions

(1) The nature and rates of igneous processes within the geologic setting during the past million years would, if continued into the future, not affect or would favorably affect the ability of the geologic repository to isolate the waste (10 CFR 60.122(b)(1)).

(2) The nature and rates of igneous activity, if any, in the geologic setting during the past million years would, if continued into the future, have less than one chance in 10,000 over the next 10,000 years of leading to releases of radioactive material to the accessible environment (proposed 40 CFR 191.13).

(b) Potentially Adverse Conditions

(1) The presence in the geologic setting of intrusive dikes, sills, or stocks that may adversely affect the regional ground-water flow system (10 CFR 60.122(c)(5)).

(2) Evidence of igneous activity within the geologic setting during the past million years (10 CFR 60.122(c)(16)).

3.1.3.5.2.1 Summary of Available Information. The distribution and age of volcanic rock within the reference repository location and Columbia Plateau are known with a high degree of confidence from surface mapping and boreholes that penetrate the basalt. Detailed studies of the Columbia River Basalt Group have provided extensive information for utilization or analysis of the nature and origin of lava; these data indicate the last eruption of Columbia River basalt occurred over 6 million years before present, with vent areas located east of the Hanford Site. There has been no igneous activity within the reference repository location during the past million years.

Cascade volcanism has periodically produced ash falls recorded in and around the reference repository location in the sedimentary record since about 15 million years before present. The distance of the site from these volcanoes, however, has resulted in only minor (maximum of several centimeters) ash accumulations.

Terrestrial heat flow measurements provide data related to the potential for renewed igneous activity. Present knowledge of the Columbia Plateau is from published data (Blackwell, 1978; Korosec and Schuster, 1980) and thermal measurements made in conjunction with hydrologic testing of the Hanford Site wells. All available data indicate low heat flow, not indicative of likely future volcanic activity.

The volcanic history of the area, terrestrial heat flow measurements, and the volcanic history of the Cascades provide data for an assessment of future igneous activity (Johnpeer et al., 1981; Murphy and Johnpeer, 1981). This assessment has shown that the probability for assessment induced events from igneous activity disturbing the integrity of a repository is exceedingly low.

3.1.3.5.2.2 Preliminary Conclusions. The reference repository location is within an area where the probability for renewed igneous activity has been assessed to be a less than one chance in 10,000 over the next 10,000 years (Johnpeer et al., 1981; Murphy and Johnpeer, 1981). Minor airfall tephra from the Cascade Range is likely to be deposited on the site in the next 10,000 years, but would not affect repository performance.

3.1.3.5.3 Uplift, Subsidence, and Folding. Technical Subguideline 960.5-5-3 (Uplift, Subsidence, and Folding) states that:

The site shall be located in a geologic setting where significant uplift, subsidence, or folding, if any, that has occurred during the past million years can be identified and shown to have hydrologic, seismic, and erosional implications that will not lead to a projection of radionuclide releases greater than those discussed in Section 960.3-2.

(a) *Favorable Considerations*

(1) *The nature and rates of uplift, subsidence, and folding within the geologic setting during the past million years would, if continued into the future, not affect or would favorably affect the ability of the geologic repository to isolate the waste (10 CFR 60.122(b)(1)).*

(2) *The nature and rates of tectonic deformation in the geologic setting during the past million years would, if continued into the future, have less than one chance in 10,000 over the next 10,000 years of leading to releases of radioactive material to the accessible environment (proposed 40 CFR 191.13).*

(b) *Potentially Adverse Considerations*

(1) *The occurrence in the geologic setting of folds that may adversely affect the regional ground-water flow system (10 CFR 60.122(c)(5)).*

(2) *Evidence of active uplift, subsidence, or folding within the geologic setting during the past million years (10 CFR 60.122(c)(12)).*

3.1.3.5.3.1 Summary of Available Information. Areas of subsidence and uplift and the rate at which this deformation has occurred have been determined for the time period from 15 to 10.5 million years before present and estimated from 10.5 million years before present to the present. The development of structurally controlled topography since at least the Miocene indicates that the reference repository location is in a portion of the Pasco Basin that has been subsiding for the last 15 million years. Simultaneously, uplift was occurring on the ridges that bound the basin. Rates of subsidence and rates of uplift were relatively low with calculations suggesting that they ranged between 40 and 70 meters (131 to 230 feet) per million years from 15 to 10.5 million years before present. Continuing subsidence in the basin and uplift on the ridges is suggested by sediment-filled basins and the fact that the present structural relief can be explained by extrapolating the Miocene growth rates to the present (Reidel and Fecht, 1982).

Estimates of faulting due to folding also suggest slow continued growth of the folds to the present time. Measurements of faulting (PSPL, 1982) suggest decreasing displacement with decreasing age; slip rates are calculated to be in the order of less than 10 meters (33 feet) per million years.

Geodolite observations of the Hanford net and the pattern of seismicity are used to determine the contemporary rate of deformation. Geodolite surveys (Savage et al., 1981; USGS and PAG, 1981) suggest that nonuniform compression is continuing at a rate of about 0.04 to 0.02 millimeter (0.0016 to 0.0008 inch) per year.

Taken together, the "geologic" and "contemporary" data suggest that the reference repository location is in a slowly subsiding syncline surrounded by anticlinal ridges that are growing at a very slow rate. The continued pattern of folding since the Miocene also indicates that deformation is, and has been, concentrated along anticlinal ridges and future deformation can be expected to occur along these trends.

3.1.3.5.3.2 Preliminary Conclusions. The reference repository location is in a slowly subsiding syncline (1 centimeter (0.39 inch)) in next 10,000 years) surrounded by anticlines growing at a slow rate. Deformation is concentrated in the anticlines and minimal deformation occurs in the syncline. Currently available projections of subsidence in the site at slow rates are not anticipated to change the groundwater flow systems, seismicity, or erosion at the site. Release rates of radionuclides greater than those specified in Section 960.3-2 of the proposed siting guidelines (DOE, 1983) as a result of deformation are not expected. Further site characterization will be focused on assessing whether deformation has been continuous from about 14.5 million years before present or has occurred in periodic pulses. Work will also include an assessment of whether such deformation has been basinwide or localized on specific structures and will include continued seismic monitoring and periodic geodetic surveillance.

3.1.3.5.4 Human Intrusion. Technical Guideline 960.5-6 (Human Intrusion) (DOE, 1983) states that:

> *The site shall be located to reduce the likelihood that past, present, or future human activities would cause unacceptable impacts on meeting the isolation guidelines discussed in Section 960.3-2.*

Input addressing Technical Guideline 960.5-6 centers on a discussion of the potential for natural resources at the site and on land ownership and control as it pertains to human intrusion. As the reference repository location is currently on DOE-controlled land and resource potential is considered to be low, human intrusion related to resource exploration is not likely to be of concern during the operational and early post-closure phases of the repository. However, as previously discussed under Technical Subguideline 960.5-2-2, intrusion by borehole (possible due to exploration activities) has been determined to be a disruptive event warranting evaluation. Studies evaluating this scenario will be carried out as part of the hydrologic and performance-assessment modeling work currently under way.

3.1.3.5.4.1 Natural Resources. Technical Subguideline 960.5-6-1 (Natural Resources) states that:

> *The site shall be such that the exploration history or relevant past use of the site or adjacent areas can be determined and can be shown to have no unacceptable impact on meeting the isolation guidelines discussed in Section 960.3-2. The site features shall make human intrusion unlikely or, in combination with engineered systems, mitigate the consequences of intrusion to within the limits discussed in Section 960.3-2.*
>
> *(a) Favorable Conditions*
>
> *Natural-resource concentrations that are not significantly greater than the average condition for the region.*
>
> *(b) Potentially Adverse Conditions*
>
> *(1) The presence of naturally occurring materials, whether identified or undiscovered, within the site in such form that (i) economic extraction is currently feasible or potentially feasible during the foreseeable future or (ii) such materials have greater gross value or net value than the average for other areas of similar size that are representative of, and located in, the geologic setting (10 CFR 60.122(c)(18)).*
>
> *(2) Evidence of subsurface mining for resources within the site (10 CFR 60.122(c)(19)).*
>
> *(3) Evidence of drilling within the site for any purpose other than repository-site characterization (10 CFR 60.122(c)(20)).*

3.1.3.5.4.1.1 Summary of Available Information. An inventory and economic assessment (GG/GLA, 1981) of known minerals or fossil fuel resources within a 100-kilometer (60-mile) radius of the proposed site have shown that no known economic resource would preclude the siting of a repository at Hanford. Current exploratory drilling by Shell Oil Company has not found any economical quantities of natural gas but exploratory drilling is continuing.

Groundwater resources development within the vicinity of the reference repository location has been administratively controlled by the DOE and its predecessor agencies. Groundwater production within the Saddle Mountains Basalt is 3.8 to 386 liters (1 to 10^2 gallons) per minute and 3.8 to 386 liters (1 to 10^2 gallons) per minute within the Wanapum Basalt. Although certain zones within the Grande Ronde Basalt yield water at rates up to about 38 liters (10 gallons) per minute, these zones are presently not economically exploitable, due to water treatment requirements and high drilling costs.

No mining has occurred within the reference repository location, and all drilling activity has been documented. No drilling has occurred within the reference repository location to potential repository depths except that completed for preliminary characterization.

3.1.3.5.4.1.2 Preliminary Conclusions. The quantity and value of potential natural resources within the reference repository location does not make it more attractive to resource exploration or development than the surrounding areas in the geologic setting (GG/GLA, 1981). Existing boreholes are known and documented and no mining activity has occurred within the reference repository location. Continued exploratory drilling around the Pasco Basin for natural gas has not proven any economical quantities. A brief discussion of a modeling analysis of borehole intrusion is contained in the discussion of Technical Guideline 960.5-2-2.

3.1.3.5.4.2 Site Ownership and Control. Technical Subguideline 960.5-6-2 (Site Ownership and Control) states that:

The site shall be located on land for which the Federal Government can obtain ownership, control access, and obtain all surface and subsurface rights required under 10 CFR 60.121 to ensure that surface and subsurface activities at the site will not lead to a projection of radionuclide releases greater than those discussed in Section 960.3-2.

(a) Favorable Conditions

Present ownership and control of land and rights as required by 10 CFR 60.121.

(b) Potentially Adverse Conditions

Land-use conflicts involving land dedicated by the Federal Government for potentially incompatible purposes.

3.1.3.5.4.2.1 Summary of Available Information. Lands within the reference repository location and the remainder of the Hanford Site have been under the jurisdiction of the Federal Government since 1943-1944. The Hanford Site is presently managed by the DOE. The lands designated for the repository consist of acquired lands plus Section 10 and part of Section 4, Township 12 North, Range 25 East of the Willamette Meridian, which is public domain. Sections 10 and 4 have been withdrawn from all forms of appropriation under the public land laws including the mining and mineral leasing laws and have been reserved for use by the U.S. Atomic Energy Commission in connection with its Hanford Operations. The pertinent part of the applicable Public Land Order 1273 reads as follows:

"Subject to valid existing rights, the following-described public lands in Washington are hereby withdrawn from all forms of appropriation under the public-land laws, including the mining and the mineral-leasing laws, and reserved for use of the Atomic Energy Commission in connection with its Hanford Operations."

All functions of the U.S. Atomic Energy Commission with respect to the Hanford Site and certain other locations have been transferred to the Secretary of Energy. As a result, Sections 10 and 4, Township 12 North, Range 25 East of Willamette Meridian, are under the jurisdiction of the DOE, which holds that land pursuant to the above-described provisions of Public Land Order 1273.

Most of the Hanford Site south of the Columbia River is fenced and/or posted to prohibit access by unauthorized personnel.

3.1.3.5.4.2.2 Preliminary Conclusions. The Hanford lands were placed under Federal jurisdiction in 1943-1944. Since Federal jurisdiction predates local, regional, and state planning for the area, Hanford lands are designated as an existing special use area in all land use plans. Compatibility of the repository with other DOE land use plans at the Hanford Site is assured by the integration of the project into overall Hanford land use planning activities. Access to the reference repository location can only be gained by passing through one of the several security check points. The Federal Government's ownership of the Hanford Site results in compliance with Technical Subguideline 960.5-6-2 (DOE, 1983).

3.1.3.5.5 Surface Characteristics. Technical Guideline 960.5-7 (Surface Characteristics) (DOE, 1983) states that:

> *The site and its surrounding area shall be such that surface characteristics or conditions can be accommodated by engineering measures and can be shown to have no unacceptable effects on repository operation and waste isolation as discussed in Sections 960.3-1 and 960.3-2.*

This section includes a discussion of surface water, terrain, meteorology, and offsite hazards.

Shallow flash flooding of the reference repository location may result from a 100-year flood in the Cold Creek. Catastrophic flooding may result from future continental glaciation. Engineering measures will accommodate Cold Creek flooding and studies will be done to assess the effect of a catastrophic flood on groundwater recharge.

The terrain of the reference repository location is, in general, flat lying and no major engineered measures are required. Occassional high wind and associated duststorms may require some additional safety precautions. The reference repository location is on DOE land committed to nuclear activities.

3.1.3.5.5.1 Surface-Water Systems. Technical Subguideline 960.5-7-1 (Surface-Water Systems) states that:

The site shall be such that the surficial hydrologic system, both during expected climatic cycles and during extreme natural phenomena, will not cause unacceptable impacts on repository operation or waste isolation as discussed in Sections 960.3-1 and 960.3-2.

(a) Favorable Conditions

None specified.

(b) Potentially Adverse Conditions

(1) Potential for foreseeable human activities to adversely affect the ground-water flow system, such as extensive irrigation or the construction of large-scale surface-water impoundments (10 CFR 60.122(c)(1)).

(2) Potential for flooding the underground facility, whether through the occupancy and modification of floodplains or through the failure of existing or planned man-made surface-water impoundments (10 CFR 60.122(c)(2)).

3.1.3.5.5.1.1 Summary of Available Information. A number of dam failure scenarios have been evaluated by the U.S. Army Corps of Engineers (COE, 1951) including failure of Grand Coulee Dam. These scenarios account for flow augmentation due to failure of earthen portions of dams downstream from Grand Coulee Dam and consequent releases of their respective storage volumes. The most extreme scenario evaluated (and considered as the worst case) was that of a 50-percent breach of Grand Coulee Dam. The flood resulting from this release does not reach the reference repository location.

The only remaining site for a potential dam on the Columbia River in the United States is approximately at river kilometer 560 (mile 336) (proposed Ben Franklin Dam). Harty (1979) has provided a detailed analysis of the possible effects of the proposed Ben Franklin Dam and reservoir on the Hanford Site activities. In particular, this study addressed transient adjustments of the shallow groundwater system. No analysis was made of the potential impact on groundwater systems deeper than the unconfined system.

The reference repository location is situated outside and above the limits of the Columbia River floodplain. However, it is possible that the location could be subjected to shallow flash flooding from the ephemeral Cold Creek stream during the anticipated 100-year-long preclosure phase of a repository. The inundation at the reference repository location that would be associated with a 100-year flash flood event would be of limited areal extent. Further studies including topographic surveys and analyses will be undertaken to quantify the exact extent and depth of such an event. These studies will be performed with topographic resolution that is detailed enough to support engineering decisions with respect to mitigation measures, should they be determined to be appropriate.

Within the range of climatic conditions probable at the reference repository location within the next 10,000 years, catastrophic flooding (as was associated with the last period of continental glaciation) represents the most significant potential impact. Geologic field data indicate that the maximum flood level achieved within the Pasco Basin from Pleistocene flooding was on the order of 370 meters (1,215 feet). The duration and number of floods is not known, but each probably consisted of short-lived crests. Floodwaters within the basin are believed to have subsided over a period of weeks. The net residual effect of this event on conditions at the reference repository location was that of sediment deposition.

A number of studies have been conducted to predict future ice ages. One model predicts that glaciation may advance into northern Washington within 10,000 years (Foley et al., 1981), while another estimates that the probability of ice cover at Hanford in the next million years is 50 percent (Bull, 1979, 1980). The maximum advance of continental glaciation in the Pleistocene was about 130 kilometers (80 miles) north of the Hanford Site.

The potential for vertical movement of groundwater resulting from standing floodwaters within the Pasco Basin will be assessed using numerical simulation. The sensitivity of regional groundwater flow models to adjustment of recharge parameters will also be evaluated in future studies.

Information that can be used to evaluate growth trends in irrigated agriculture has been gathered by Stephan et al. (1979), Wukelic et al. (1981), Pacific Northwest River Basins Commission (1980), and Johnson et al. (1981). These reports involve inventorying and assessing regional land use trends using various survey methods and/or remote sensing. Additionally, Leaming (1981) provided an assessment of water resource economics within the Pasco Basin. This report addressed the economic likelihood of various scenarios of surface groundwater use.

3.1.3.5.5.1.2 Preliminary Conclusions. The reference repository location is sited above the floodplain of the major rivers flowing into the Pasco Basin. Flooding resulting from dam break scenarios also does not reach the proposed repository site. Shallow water inundation of the surface facilities that could occur during a 100-year flash flood event of the Cold Creek ephemeral stream will be mitigated by engineering measures. Studies are planned to evaluate the impact on waste isolation resulting from human activities and floodwater from catastrophic flooding resulting from potential future glaciation.

Irrigation utilizing groundwater resources, or the construction of surface-water impoundments, near the Hanford Site, is not expected to adversely affect the groundwater flow system. It is not expected that the surficial hydrologic system will cause unacceptable impacts on repository operation or waste isolation as discussed in Sections 960.3-1 and 960.3-2 of the proposed siting guidelines (DOE, 1983).

3.1.3.5.5.2 Terrain. Technical Subguideline 960.5-7-2 (Terrain) states that:

The site shall be located in an area where the surface terrain features do not unacceptably affect repository operation.

(a) Favorable Conditions

Generally flat terrain.

(b) Potentially Adverse Conditions

Road and rail access routes that encounter steep grades, sharp switchbacks, slope instability, or other potential sources of hazard to incoming waste shipments.

3.1.3.5.5.2.1 Summary of Available Information. The reference repository location is located in the basin and valley terrain in the western Pasco Basin. The terrain consists of the low-sediment-filled portion of the basin. The reference repository location is generally flat and featureless with a gentle southerly slope (less than 5 percent) except for the Umtanum Ridge bar in the northern portion of the site. Relief on this bar is about 30 meters (98 feet) and it has a southerly slope of about 15 percent. The slope on the bar has been stable since the bar was formed during the Pleistocene.

3.1.3.5.5.2.2 Preliminary Conclusions. The terrain in the site is essentially flat and featureless, except for the south slope of the Umtanum Ridge bar in the northern part of the site. The slope of the bar and the generally flat and featureless terrain of the site present no access or slope stability problems or other hazards with respect to meeting the intent of Section 960.5-7-2 of the proposed siting guidelines (DOE, 1983).

3.1.3.5.5.3 Meteorology. Technical Subguideline 960.5-7-3 (Meteorology) states that:

The site shall be located where anticipated meteorological conditions would not result in the projection of unacceptable effects on repository operations.

(a) Favorable Conditions

None specified.

(b) Potentially Adverse Conditions

None specified.

3.1.3.5.5.3.1 Summary of Available Information. For general climatological purposes, meteorological data collected at Hanford by the U.S. Weather Bureau from 1912 to 1945 and by the Hanford Meteorological Station from 1945 to present are representative of the Hanford Site. These data were combined into a single set of data for the period 1912 to 1970 by Stone et al. (1972).

Tornadoes rarely occur in the Hanford region and are generally of short duration, with short narrow paths. Tornadoes and funnel clouds have only been observed three times on the Hanford Site since 1916.

Duststorms are relatively common in the Hanford area and occur most frequently in the March through May period and during September. On the average, there are 8.3 duststorms per year (Orgill et al., 1974). Duststorms are recorded in the meteorological record when visibility becomes restricted to 10 kilometers (6.3 miles) or less. Major contributors to airborne dust or sand in the Hanford region are local construction activities, the surface soil itself, and surrounding agricultural land activities.

Stagnation occurs when low windspeeds and restricted mixing coexist, permitting an abnormal buildup of pollutants from sources within the region. A stagnation lasting 20 days can be expected one season in 20; a 10-day stagnation period can be expected every other season. Only one season in three will fail to produce a stagnation period of at least 8 days.

3.1.3.5.5.3.2 Preliminary Conclusions. None of these meteorological conditions are believed to have unacceptable effects on repository operation. Onsite meteorological parameters will be monitored in the future. Severe and extreme meteorologic phenomena that will be considered for design and operating bases of the repository have been identified and include, among others, high winds, extreme temperatures, severe duststorms, and lightning (DOE, 1982c). These conditions can be accommodated by engineering measures such that there will be no unacceptable effects on repository operation.

3.1.3.5.5.4 Offsite Hazards. Technical Subguideline 960.5-7-4 (Offsite Hazards) states that:

> *The site shall be such that present and projected effects from nearby industrial, transportation, and military installations and operations including atomic energy defense activities, can be accommodated by engineering measures and can be shown to have no unacceptable impacts on repository operation.*

(a) *Favorable Conditions*

Siting on lands already committed for DOE nuclear reservations.

(b) *Potentially Adverse Conditions*

(1) The presence of nearby potentially hazardous facilities.

(2) Siting close enough to an atomic energy defense facility to compromise or interfere with the use of that facility for defense purposes.

3.1.3.5.5.4.1 Summary of Available Information. Nearby hazards were considered as part of the reference repository site identification process. In relation to nearby potential hazards of the Hanford Site, the three major areas of concern used in site screening procedures were:

- Proximity of repository to transportation routes
- Industrial/military installations and operations
- Gas or petroleum pipelines/storage areas.

Surface site screening performed by Woodward-Clyde Consultants (WCC, 1980, 1981) required any candidate site locations to be at least 1 kilometer (0.6 mile) from areas with a potential for explosion, generating missiles, noxious vapors, highways, interstate highways, railroads, and navigable waterways rendered. The DOE Hanford Site is already committed to several nuclear activities. No adverse affects on other nuclear activities carried out on the Hanford Site are expected.

3.1.3.5.5.4.2 Preliminary Conclusions. The reference repository location is near the center of the Hanford Site, which is already committed to nuclear activities. It was selected so that effects from present and projected industrial, transportation, and military installations have no unacceptable impacts on repository operation. Therefore, the reference repository location is expected to comply with this subguideline.

3.1.3.5.6 Population Density and Distribution. Technical Guideline 960.5-8 (Population Density and Distribution) (DOE, 1983) states that:

The site shall be located to limit the potential risk to the population. The site shall be so located that risk to the population from repository operation does not exceed system-performance guidelines. A site shall be disqualified if it would fail to comply with EPA's standard for radiation doses received by members of the public as a result of the management and storage of these wastes (proposed 40 CFR 191, Subpart A).

3.1.3.5.6.1 Population Near The Site. Technical Subguideline 960.5-8-1 (Population Near the Site) states that:

The site shall be located away from population concentrations and urban areas. A site shall be disqualfied if any surface facility of a repository would need to be located in a highly populated area or adjacent to an area one mile by one mile having a population of not less than 1,000 individuals.

(a) Favorable Conditions

Remoteness from population centers (10 CFR 60.122(a)(7)).

(b) Potentially Adverse Conditions

A population density and distribution such that projected releases could result in the exposure of many people.

3.1.3.5.6.1.1 Summary of Available Information. Information pertaining to the proximity of the Hanford Site to population centers can be obtained from the 1980 census. The nearest population center to the Hanford Site is Richland, Washington, which had a population of 33,578 in 1980 (BOC, 1981). Intensive farming is carried out along the Yakima River Valley to the south of Rattlesnake Hills and to the east. West of the Hanford Site is the U.S. Army's Yakima Firing Center, which has restricted access. There are approximately 11,700 workers associated with the Hanford Site.

Understanding demographic patterns in the vicinity of a proposed repository site at the Hanford Site is an important part of socioeconomic impact analyses. The 1980 census data on the population of incorporated cities and counties within 80 kilometers (50 miles) of the Hanford Meteorological Station are shown in Figure 3-2. Current and projected population statistics for Benton and Franklin Counties and the primary socioeconomic impact area are given in Section 3.6 of this document. Cities and towns outside the impact area have absorbed only a small amount of growth from the larger area. Unincorporated portions of the bicounty area, however, received a significant percentage (41.7 percent) of the growth between 1970 and 1980. Since the rate of a city's population growth tends to decrease as it matures, the distributional pattern of growth in the bicounty and primary impact areas will almost certainly be different than in the past. Growth patterns will also be affected by future construction of bridges across the Columbia River and the growth or decline of various economic sectors.

As can be seen in Table 3-3, most of the growth during the past decade in Benton County can be attributed to the large number of people (78.3 percent) moving into the area (migration) rather than to natural increase (birthrate). In Franklin County less than half of the growth in population can be attributed to migration.

TABLE 3-3. Components of Population Change by County and State.

Area	Population size[a]		Population change 1970-1980		Change (%) 1970-1979[b] due to:	
	1970	1980	Number	Percent	Natural increase	Net migration
Benton County	67,540	109,444	41,904	62.0	21.7	78.3
Franklin County	25,816	35,025	9,209	35.7	59.3	40.7
Washington State	3,413,244	4,130,163	716,919	21.0	42.3	57.7

[a]BOC (1981).

[b]State of Washington (1979), Table 14. Comparable data were not yet available for 1980.

High levels of net in-migration tend to be selective of the age group between 20 and 65. This is illustrated by the data presented in Table 3-4. The bicounty area is forecasted to have increasingly higher proportions of its population concentrated in this age group.

3.1.3.5.6.1.2 Preliminary Conclusions. The Hanford Site is located in an area of low population density and away from population areas and urban concentrations. There appears to be no significant problems with respect to meeting System Guideline 960.3-1 (DOE, 1983).

TABLE 3-4. Population Distribution by Age and Sex.*

Area	Age category	1970		1980		1990	
		Population distribution (%)					
		Male	Female	Male	Female	Male	Female
Benton County	0-19	42.9	40.7	36.4	34.2	33.4	32.0
	20-64	51.0	52.5	57.0	58.1	59.8	59.9
	65+	6.1	6.8	6.6	7.7	6.8	8.1
Franklin County	0-19	43.1	41.4	36.8	35.4	34.1	32.8
	20-64	51.0	51.3	56.8	56.5	59.4	58.6
	65+	5.8	7.3	6.3	8.1	6.6	8.6
Washington State	0-19	38.9	36.7	32.4	30.8	30.2	28.9
	20-64	53.0	52.7	58.9	57.6	60.8	58.7
	65+	8.2	10.6	8.7	11.6	9.0	12.4

*State of Washington (1981).

3.1.3.5.6.2 Transportation. Technical Subguideline 960.5-8-2 (Transportation) states that:

The cost and other impacts of transporting radioactive waste to a repository shall be considered in selecting the repository sites. Consideration shall be given to the proximity of locations where radioactive waste is currently generated or temporarily stored and the transportation and safety factors involved in moving such waste to a repository.

(a) Favorable Conditions

Ability to select transportation routes that minimize risk to the general population.

(b) Potentially Adverse Conditions

Site locations requiring the concentration of transportation routes through highly populated areas.

3.1.3.5.6.2.1 Summary of Available Information. Transportation costs and other impacts were considered in nominating the Hanford Site for site characterization. The Hanford Site is not located near a concentration of commercial nuclear powerplants. This will require relatively long transportation routes to the Hanford Site from various parts of the United States. Current estimates are that approximately 90 percent of waste shipped to a potential repository at Hanford will be by rail and the remaining 10 percent by truck.

3.1.3.5.6.2.2 Preliminary Conclusions. The establishement of transportation routes to the Hanford Site are necessary to evaluate potential risks to the general population. These DOE studies are currently under way and will be one of the many factors that will be considered in selecting a repository site. A detailed evaluation of transportation factors associated with a repository at Hanford would be presented in an environmental impact statement prepared to support the Site Recommendation Report if Hanford is recommended by DOE as a repository site. Section 3.6 of this document contains an analysis of transportation factors related to siting a nuclear waste repository at Hanford. It is expected that the requirements of this guideline can be met.

3.1.3.5.7 Environmental Protection. Technical Guideline 960.5-9 (Environmental Protection) (DOE, 1983) states that:

The site shall be such that a repository can be constructed and operated in a manner that provides reasonable assurance that the environment will be adequately protected, for this and future generations. The site shall be located so as to reduce the likelihood and consequences of potential environmental impacts, and these impacts shall be mitigated to the extent reasonably achievable. A site shall be disqualified if a repository would result in an unsatisfactory adverse environmental impact that threatens the health or welfare of the public or the quality of the environment and cannot be mitigated. A site shall be disqualified if it is located within the boundaries of a significant nationally protected natural resource, such as a National Park, National Wildlife Refuge, or Wilderness Area, and its presence conflicts irreconcilably with the previously designated use of the site.

(a) Favorable Conditions

(1) Ability to meet all procedural and substantive environmental requirements applicable to the site, at the Federal, State, and local level, with assurance and within time constraints.

(2) Adverse environmental impacts, to present and future generations, can be avoided or reduced to an insignificant level through the application of reasonable mitigating measures.

(b) *Potential Adverse Conditions*

(1) *Probable conflict with applicable Federal, State, or local environmental requirements.*

(2) *Significant adverse environmental impacts that cannot be avoided or minimized.*

(3) *Proximity to, or direct adverse environmental impacts of the repository or its support systems on, a component of the National Park System, the National Wildlife Refuge System, the Wild and Scenic River System, the National Wilderness Preservation System, or National Forest Land.*

3.1.3.5.7.1 Summary of Available Information. The reference repository location is situated on DOE's 1,500-square-kilometer (570-square-mile) Hanford Site, which has been dedicated to nuclear activities since 1943. Environmental analyses conducted for the DOE's existing nuclear activities suggest that compliance with environmental laws and regulatory requirements would not be a problem if a repository is located at Hanford. The Hanford Site is not located within the boundaries of a significant nationally protected natural resource. Construction and operation of a repository would not be inconsistent with existing land use plans. No adverse environmental effects that threaten the health or welfare of the public or the quality of the environment, which cannot be mitigated, have been found.

3.1.3.5.7.2 Preliminary Conclusions. Information currently available leads the DOE to believe that a repository can be constructed and operated at Hanford in the manner that assures that the environment will be adequately protected in compliance with this guideline. A final conclusion will be reached after additional environmental studies are conducted. Design of a repository would mitigate any resulting environmental impacts to the extent reasonably achievable. Detailed documentation of this site's acceptability under this guideline would be included in the environmental impact statement accompanying the Site Recommendation Report if the Hanford Site is ultimately selected by the DOE for recommendation to the President as a repository site.

3.1.3.5.8 Socioeconomic Impacts. Technical Guideline 960.5-10 (Socioeconomic Impacts) (DOE, 1983) states that:

The location of the site shall be such that any significant adverse social and/or economic impacts on communities and regions resulting from repository construction, operation, and decommissioning or the transportation of radioactive waste to the site can be accommodated by reasonable mitigation or compensation.

(a) *Favorable Considerations*

(1) *Locally available labor.*

(2) *Potential for repository-related increases in local employment, increases in business sales, increases in government revenues, or improvements in community services.*

(b) *Potentially Adverse Conditions*

(1) *The existence of, or the potential for, a lack of the necessary labor force or a lack of local suppliers.*

(2) *A projected substantial decrease in community services due to repository development.*

(3) *Conditions where the development, construction, operation, or decommissioning of a repository may require any purchase or acquisition of water rights that will have a significant adverse effect on the present or future development of the area.*

3.1.3.5.8.1 Summary of Available Information. The available information on socioeconomic impacts is reviewed in Section 3.6 of this report.

3.1.3.5.8.2 Preliminary Conclusions. Preliminary analysis indicates that there will be no significant adverse social and/or economic impacts on nearby communities and regions resulting from repository construction, operation, and decommissioning, or the transportation of radioactive wastes. A technically qualified labor force (except for the hard-rock miners) is located nearby in the Tri-Cities and the surrounding areas. This area has a history of providing for the needs of large construction projects on the Hanford Site.

3.2 SUITABILITY OF THE HANFORD SITE FOR REPOSITORY DEVELOPMENT

Section 112(b)(1)(E)(ii) criteria: Evaluation of whether the site is suitable for development as a repository under each guideline that does not require site characterization as a prerequisite for application of the guideline.

In order to evaluate this guideline, it is necessary to define "site characterization" for the BWIP as those "activities, whether in the laboratory or in the field, undertaken to establish the geologic condition and the ranges of parameters of a candidate site relevant to the location of a repository, including borings, surface excavations, excavations of exploratory shafts, limited subsurface lateral excavations and borings, and in situ testing needed to evaluate the suitability of a candidate site for the location of a repository, but not including preliminary borings and geophysical testing needed to assess whether site characterization should be undertaken" (Nuclear Waste Policy Act of 1982).

It has been determined that for the purposes of this draft environmental assessment, only the last five technical guidelines can be applied without conducting site characterization activities. These guidelines are:

- 960.5-6 Human Intrusion
- 960.5-7 Surface Characteristics
- 960.5-8 Population Density and Distribution
- 960.5-9 Environmental Protection
- 960.5-10 Socioeconomic Impacts.

Some of these guidelines specifically include disqualifying factors that would cause a candidate site to be eliminated from further consideration for a nuclear waste repository. Based upon available information, none of these disqualifying factors contained in Technical Guidelines 960.5-6 through 960.5-10 are known to exist at or near the reference repository location.

The guideline on "Human Intrusion," and its subguidelines dealing with "Natural Resources" and "Site Ownership and Control" were evaluated in Section 3.1. The preliminary conclusions indicate that the reference repository location is considered suitable for repository development under the requirements of Technical Guideline 960.5-6, "Human Intrusion." No disqualifying factors are associated with this guideline.

The "Surface Characteristics" guideline, and its attendant subguidelines, were evaluated in Section 3.1 and the reference repository location was found to be in compliance with the stated requirements. The preliminary conclusions drawn earlier indicate that the candidate site is considered suitable for repository development in accordance with Technical Guideline 960.5-7, "Site Characteristics." This guideline also does not contain disqualifying factors.

The guideline dealing with "Population Density and Distribution," and its associated subguidelines, were evaluated in Section 3.1 of this draft environmental assessment. The preliminary conclusions indicate that the candidate site is considered suitable for repository development under the requirements of Technical Guideline 960.5-8.

Two disqualifying factors are integral components of the guideline. The disqualifying factor dealing with radiation doses that might be received by members of the general public as a result of a nuclear waste repository must be considered in the design of the repository and waste packages, the selection of backfill material, as well as the specific characteristics possessed by the candidate site. No geologic or hydrologic information gathered to date indicates that a repository at the candidate site might endanger the health and safety of the public. The second disqualifying factor deals with population density concerns near the candidate site. These population density factors do not exist at or near the candidate site.

An evaluation of the "Environmental Protection" guideline is presented in Section 3.1. To date, no site characteristics have been identified which would indicate that this disqualifying factor dealing with unsatisfactory adverse environmental impacts would apply to the candidate site. The other disqualifying factor deals with the location of a candidate site within the boundaries of a significant nationally protected natural resource (i.e., National Park, Wilderness Area, etc). The candidate site at Hanford is not within a nationally protected natural resource area.

The guideline concerned with "Socioeconomic Impacts," was evaluated in Section 3.1 and is examined in more detail in Section 3.6 of this draft environmental assessment. The preliminary conclusions reached in Section 3.1 indicate that the candidate site meets the requirements of Technical Guideline 960.5-10 and may be considered suitable for repository development under this guideline. There are no disqualifying factors associated with this guideline.

3.3 SITE CHARACTERIZATION IMPACTS AND ALTERNATIVES

Section 112(b)(E)(iii) criteria and alternatives: Evaluation of the effect of site characterization activities at the Hanford Site on public health and safety and the environment. Also included in this section is an analysis of alternative site characterization activities that may be undertaken to avoid such impacts.

3.3.1 Screening Process Potential Impacts

The screening process, per se, has no physical interaction with the environment. The process itself uses existing information, or information gathered for collateral purposes, in the compilation of map overlays. These overlays provide a topographic representation of various characteristics of the areas depicted (e.g., proximity to population zones of given densities, presence of known geologic anomalies, etc.). Each overlay represents land areas considered unusable or less than desirable for one particular reason. Taken in the aggregate, the overlays depict all land areas within the boundaries of the Hanford Site that currently available information shows to be less than optimum for a high-level nuclear waste repository (WCC, 1981).

3.3.2 Survey and Characterization Potential Impacts

A wide variety of geologic and hydrologic techniques have been employed to survey and characterize areas of the Hanford Site as the BWIP selected the Exploratory Shaft site. Most processes, such as aerial and satellite photography and magnetometer surveys, have no discernible environmental effect and, accordingly, did not require environmental documentation.

Borehole drilling has sufficient potential impact to require a brief environmental evaluation of each proposed drill site. Since the beginning of the screening process in 1978, the BWIP has drilled, reentered and deepened, or conducted tests in approximately 36 boreholes on the Hanford Site. Twenty of these were shallow holes to investigate unconfined aquifers and did not penetrate into the basalt for any appreciable distance, if at all.

Borehole locations were selected to acquire necessary data while minimizing environmental impact. It was recognized that, in the shrub-steppe ecology of the Hanford Site, land-surface disturbance would constitute the greatest potential for adverse environmental impact, due to the potential of increased wind- and water-driven erosion and loss of wildlife habitat. Each potential drill site was examined to ensure that: (1) it was located as close as possible to existing roads, (2) it was not within a wetland, (3) it was not within a known archaeological site, and (4) site activities would not adversely impact any threatened or endangered plant or animal species.

Land surface disturbance at the typical drill site was limited to selective clearing and grading of a 0.4-hectare (1.0-acre) site, construction of about 300 meters (1,000 feet) of single-lane dirt road, digging and lining of a 6- by 9- by 1.2-meter (20- by 30- by 4-foot) mud pit, and laying of a 45- by 90-meter (150- by 300-foot) compacted gravel drilling-support pad. This activity, and subsequent drilling, resulted in the production of some airborne dust and regulated air pollutants (particulates, sulfur oxides, carbon monoxide, hydrocarbons, photochemical oxidants, and nitrogen oxides). Dust emissions were controlled with wet-suppression techniques in compliance with General Regulation 80-7 of the Benton-Franklin-Walla Walla Counties Air Pollution Authority (APCA, 1980). Regulated pollutant emissions averaged less than 570 kilograms (1,250 pounds) per month per site, well below the EPA's limit of 45 metric tons (50 tons) per year for a major stationary source (EPA, 1980).

The borehole resulting from such an operation was typically 15.25 centimeters (6 inches) in diameter and up to 1,260 meters (4,200 feet) deep. Current plans call for all such holes to be permanently plugged at the conclusion of testing. The mud pit will be refilled, and the drilling sites will be returned, as closely as practicable, to their natural states.

Additional boreholes are planned to be drilled during the next few years of site characterization activities. The main purpose for the new boreholes will be to provide hydrologic data necessary to more fully define the hydrologic system beneath and beyond the Hanford Site. The DOE does not believe that such data are available from other sources. Knowledge of the hydrologic system is an important component of performance-assessment models used to predict nuclide migration away from a potential repository. For each new borehole, an environmental evaluation will be prepared to ensure that impacts are minimized.

3.3.3 Exploratory Shaft Impacts

The impacts of the Exploratory Shaft construction operation and decommissioning were addressed in the environmental assessment (DOE, 1982a). The following information is summarized from that earlier environmental assessment. No new information has been developed that would alter that analysis.

3.3.3.1 Construction Impacts. The major construction impact is the selective clearing and grading of 8 hectares (20 acres) of shrub-steppe terrain. More than half the plants within this area will be destroyed and all the animals will be displaced. Ongoing biological monitoring continues to show no threatened or endangered species resident upon the proposed Exploratory Shaft site.

The Exploratory Shaft site is in an area subjected to high winds, with monthly gusts in excess of 65.0 kilometers (40.4 miles) per hour. Under such conditions, wind erosion of disturbed soil can become a problem. The DOE is using approved soil-stabilization techniques, including wet suppression of dust during construction of roadways and parking lots, followed by surfacing with gravel.

The paucity of rainfall at Hanford, coupled with the high relative porosity of the surface soil at the shaft site (Gephart et al., 1979), make a storm drain system unnecessary. These same characteristics allow the effective disposal of site sewage by means of a septic tank/drain field complex. Structural materials of such a system are virtually inert, and the contemplated system will be very small, compared to similar active systems for the 200 West Area and deactivated systems associated with abandoned military cantonments nearby. No significant environmental effects are anticipated.

Site buildings will be either trailers or prefabricated steel buildings assembled at the site on pre-poured concrete slabs. Normal occupancy of the surface structures will average about 30 persons, most of whom will remain indoors throughout their shifts. This combination of low personnel density, prefabricated construction, and little personnel outdoor movement during working hours will combine to minimize long-term impacts on wildlife.

The most significant environmental effects directly related to shaft construction will be those resulting from digging mud pits and from accumulating drill cuttings and mined rock, called "muck," in spoil piles. The mud pit complex will cover approximately 0.4 hectare (1.0 acre) with a series of shallow pits, subdivided by baffles and dikes and surrounded by low berms approximately 2 meters (6.6 feet) high. The pits will be covered and lined to prevent evaporation and seepage. The majority of mud pit impact will result from soil disturbance and unavoidable fugitive dust emissions during construction. Appropriate suppression techniques will be employed to keep dust emissions within applicable limits.

The actual volume of material to be removed from the shaft and test chamber is approximately 7,700 cubic meters (272,000 cubic feet). The volume of this material will increase to approximately 17,000 cubic meters (600,000 cubic feet) upon removal, due to fragmentation and loose packing in a spoil pile. In addition, up to 12,000 cubic meters (424,00 cubic feet) of fragmented basalt mined from the tunnels will constitute an adjacent spoil pile. The possible mechanisms by which spoil piles can cause environmental damage are by dust emissions, chemical leaching, and mechanical slip or collapse. Existing dust suppression techniques, which have proven effective, will be used to keep emissions from the spoil pile within applicable limits of General Regulation 80-7 of the Benton-Franklin-Walla Walla Counties Air Pollution Authority (APCA, 1980). The miniscule size of this pile, compared to piles produced by commercial mining activities at other locations, will greatly simplify this effort.

Detailed chemical analysis will be made to determine the composition of the rock that will constitute the pile. (Samples will be obtained in advance from a nearby borehole to the proposed shaft depth.) On the basis of this analysis, appropriate chemical effluent monitoring plans and physical barriers, such as dikes, berms, and liquid collection sumps, will be established, if necessary, to prevent rain from leaching chemicals from the spoil pile into the site surface.

Conservative mining practice will be followed in establishing the slope of the spoil pile sides, taking into consideration the changes in angle of repose that may be caused by saturation by heavy rainfall. This will preclude impacts due to landslip or collapse of the spoil pile, which will be located well away from areas frequented by personnel to enhance personnel safety.

With the exception of sewage, which will be disposed of through the site leach field, all construction wastes and refuse will be collected and trucked from the site for disposal in the existing Hanford Site landfill facility.

The Hanford Site is within the "South-Central Washington Intra-State Air Quality Control Region" as defined by the EPA (Golden et al., 1979). This entire region is classified by the EPA as a Category II air quality region. Airborne emissions from diesel equipment used during construction are not expected to present any significant impact, due to the limited amount of such equipment to be used, the scarcity of other activities, and the generally good atmospheric mixing in the area of the site. The use of central station-generated electrical power, wherever possible, further reduces potential impacts from fossil fuel exhaust emissions. Emissions of regulated air pollutants (particulates, sulfur oxides, carbon monoxide, hydrocarbons, photochemical oxidants, and nitrogen oxides) from the site are expected to be de minimus. Consequently, the project will not be a major stationary source under EPA regulations and, therefore, will not be subject to Prevention of Significant Deterioration (PSD) (EPA, 1980) permitting review.

The remoteness of the site from human habitation and from occupied Hanford facilities mitigates the effects of any high drilling-noise levels. Drilling activities will generate noise levels that could reach 110 decibels immediately adjacent to the noise sources. Effective muffler systems will be used on heavy equipment during construction to minimize adverse environmental impacts. Impacts on members of the general public will meet the requirements of the Noise Pollution Control Act of 1972, which requires that "noise levels do not exceed 70 decibels at the nearest habitation."

While visible from Route 240, the aesthetic impact of the site will be minimal. About 2.3 kilometers (1.4 miles) of existing gravel road will be upgraded by adding gravel. A new gate and guard station was added at the outside fence. The most prominent feature, the drill rig, will not be near or on a line of sight to any scenic view or outlook and, in any case, will be in place only a short time. The site buildings will be small and will be similar to numerous structures in the area.

Laying of the site waterline from the 200 West Area did require clearing of a 6.2-meter (20-foot) wide strip of ground 4.8 kilometers (3 miles) long. Construction of the overhead powerline caused partial disturbance to a 4.6-meter by 10.4-kilometer (15-foot by 6.5-mile) area. No streams, rivers, or wetlands were crossed or impacted. Natural vegetation will be allowed to reestablish itself along both rights-of-way.

Since these construction impacts are confined to the Hanford Site, no public health or safety impacts are expected. Access to the Hanford Site by members of the general public is prohibited, except for specific highways.

3.3.3.2 Operational Impacts. Following construction of the surface support facilities and the completion of the shaft and test chamber, a few years of testing will ensue, followed by construction of a series of tunnels. Once the tunneling activity is completed, the Exploratory Shaft and its associated support facilities will enter a period of extensive testing. The potential environmental impacts associated with this operational phase will be minor compared to the potential impacts of construction. The most significant source of dust, noise, and effluent production will be the commuter vehicles used by site personnel at the beginning and ending of each shift. Assuming the limiting case of no car pooling and two 35-person shifts, a maximum of 70 motor vehicles would be moving in the Exploratory Shaft vicinity for approximately 10 minutes at shift change. For comparison, shift change at nearby nuclear powerplants under construction involves the movement of several thousands of motor vehicles.

Due to elevated temperatures encountered at depth, shaft ventilating air will also be cooled to maintain an acceptable environment for personnel working in the test chamber. Air will be compressed to about 3.75 atmospheres (55 pounds per square inch) by high-pressure blowers, routed through a series of coolers, dryers, and chillers, and then carried to the subsurface through two 15-centimeter (6-inch) embedded shaft service lines. This air will circulate and return to the surface through the shaft. The overall rate of release of heat at the surface will be less than 500 kilowatts. This is approximately 0.1 percent of the rate of release of heat from the Fast Flux Test Facility, a nearby nuclear test reactor that releases all energy produced as heat.

It should be reemphasized that the basic purpose of the test activities to be carried out in the shaft, shaft station, and tunnels is the detailed characterization of the basalt at the proposed storage horizon with respect to its potential ability to contain a high-level nuclear waste repository. If test results or a change in program direction make the site inappropriate for further characterization, test activity will cease and the shaft will be decommissioned.

3.3.3.3 Potential Accident Impacts. The most environmentally severe potential site accidents involve fires in site facilities and the possibility of a magazine explosion.

The Exploratory Shaft site is within the area served by the Hanford Fire Department. Site design was predicated on any single building involved in a fire becoming a total loss, as the expected fire department-response time will be approximately 20 minutes. Separation between buildings and the metal exterior of the buildings provide reasonable assurance that fire will not spread from building to building, while cleared areas around buildings and the cleared strip surrounding the site fence are designed as firebreaks to prevent facility fires from spreading to the surrounding vegetation. The Hanford Fire Department has off-road fire-fighting vehicles and extensive training and experience in their use to limit and suppress brushfires.

These considerations, coupled with the lack of sources of ignition found in industrial facilities (welding, flammable vapors, etc.), indicate that the Exploratory Shaft facilities will not contribute significantly to fire-related environmental impact at Hanford.

Inside the revetment, separate structures will contain a maximum of 910 kilograms (2,000 pounds) of 60 percent gel Class B explosive, or equivalent, and 400 detonators. In the extremely unlikely event of accidental detonation, the structures and revetments are designed to prevent the resulting blast-and-fragmentation effects from damaging the facilities or surrounding habitat.

None of the impacts of potential accidents are expected to be felt away from the Hanford Site. Thus, no public health or safety impacts are anticipated.

3.3.3.4 Decommissioning Impacts. Upon completion of Exploratory Shaft construction and testing activities, a decision will be made from among four options: (1) development of the site for use as a high-level radioactive waste facility, (2) use of the facility for generic research and development activities such as a Test and Evaluation Facility (such a decision would have to be supported, however, by a separate environmental document), (3) holding the site for consideration at a future date for use as a radioactive waste repository, or (4) immediate decommissioning. A decommissioning process at this stage of development would not have to consider any nuclear-related effects, since no nuclear material would have entered the shaft. The primary area of concern would, therefore, become the minimization of further disturbance of the site surface.

The effects of the decommissioning process would be very similar in type and magnitude to the effects of site preparation, with the major exception that wildlife disruption would be relatively minor, since the site will have been inhabited by personnel continuously until decommissioning.

The most significant potential impacts of this process will be emissions of dust and exhaust fumes, consumption of petroleum, generation of noise, and possible leaching of acidic or caustic chemicals from the spoil pile. The dust emission potential will be greatly reduced by wet suppression techniques from a spray system that will be used later to assist in area revegetation, while the vehicle exhaust will make a negligible contribution to the overall Hanford output. Approximately 37,900 liters (10,000 gallons) of diesel fuel will be consumed by heavy machinery, and considerable noise will be generated in the immediate area. The intensity and pitch of this noise will be very similar to those of grading operations in a residential subdivision, and in any event will be conducted in such a remote area as to be far less than 70 decibels at the nearest human habitation. By the time the shaft will have been completed, the chemistry of the rock removed from the various strata will be well known, and approved mitigative measures associated with leaching will be taken, if necessary.

In the event that the Exploratory Shaft becomes a part of a nuclear waste repository in basalt, the shaft would be decommissioned using the same practices and procedures planned for the rest of the repository. These procedures will be described in detail in the environmental documentation that will be written for the repository.

3.3.4 Potential Environmental Impacts of Alternatives

In the course of developing the proposed action (i.e., detailed site studies through the construction of an Exploratory Shaft) several alternative actions were considered. These alternatives are:

- "No action"
- Limited "no action"
- Delayed action
- Alternate Exploratory Shaft site
- Alternate Exploratory Shaft design.

The following is a summary of the alternative actions and the potential environmental impacts of these alternatives.

3.3.4.1 "No Action" Impacts. In the broad sense, the "no action" alternative for this activity was defined as the cessation of all actions relating to site characterization. Included would have been all survey and characterization activities, such as drilling and seismograph emplacement, any remaining screening actions and reviews, and all siting, designing, and construction activities related to an Exploratory Shaft. Information collected to date would be transferred to archives, fieldwork teams would be disbanded, and support contracts terminated. All dedicated equipment would be stored, issued to other Hanford projects, or sold as excess. Following these actions, all project personnel would cease all efforts related to shaft location selection, shaft design, and shaft construction. (It should be mentioned that this case was treated to provide a baseline for consideration; such an action conflicts with the current version of 10 CFR 60.10 (NRC, 1981b), which is the "site characterization" section of the rule concerning high-level nuclear waste repositories.)

The immediate direct physical impact of this course of action would have been the avoidance of all the effects discussed in Section 3.3.3 that relate to shaft area preparation, shaft facilities construction, shaft boring, testing, and decommissioning. Most impacts associated with area screening and test drilling had already occurred, since these programs had been conducted for several years.

The most severe and most immediate effect of such an action would have been socioeconomic in nature. Termination of the effort would have resulted in loss of employment of 200 workers, supporting 500 dependents and providing 600 support positions for the local economy. A more severe impact, although one difficult to quantify, would have been the markedly increased ratio of costs to benefits that early termination of the program would cause. The selection/characterization effort was initiated to acquire detailed geophysical knowledge of the properties of Columbia River basalts as they relate to high-level nuclear waste disposal. To have stopped short of adequate characterization would have reaped no benefit for much of the impact and expenditure, as the information to be gained from the shaft is synergistically coupled to the information in hand and is necessary to determine the viability of the Columbia River basalt as a potential disposal medium.

The consideration of indirect (DOE, 1982a) impacts resulting from adoption of the "no action" alternative required a realization that large quantities of high-level commercial nuclear waste currently exist. This situation makes inevitable some form of disposal, a circumstance recognized by the DOE in its acceptance of the responsiblity to develop technologies for management and disposal of commercially generated high-level nuclear wastes (DOE, 1980). The process selected by the DOE to discharge this responsibility includes the detailed characterization of several potential sites representing the potentially suitable geologic medium. Adoption of the broad "no action" alternative for the BWIP Exploratory Shaft would have terminated characterization of basalt in general, as well as the basalt at Hanford in particular. This would have left the question of suitability for waste disposal of the stable rock underlying large areas of the country unanaswered, a situation that would have left the volume of high-level commercial nuclear waste unchanged, while reducing the potential sites and areas available for its disposal.

3.3.4.2 Limited "No Action" Alternative Site Characterization Impacts. Under a narrower definition of "no action," an Exploratory Shaft would not be constructed, nor would surface support facilities be erected. However, ongoing BWIP characterization activities, including drilling of small-diameter boreholes, field surveying, and data analysis, would continue, with the interim objective of acquiring increasingly more detailed geoscientific information.

The direct effect of the adoption of this course of action would have been the prevention of all effects described in Section 3.3.3 that directly related to the shaft and its surface support area. This part of the program, with its increased personnel needs and requirements for clearing and grading a limited land area, would have disappeared. However, effects of other forms of data gathering would have accumulated indefinitely. Assuming the need for some finite level of data to support a repository site recommendation report, and further assuming that an Exploratory Shaft would not have been constructed, extensive drilling activities would have continued in an attempt to supply the needed information. The accumulated effect of clearing the land, grading sites, and excavating mud pits at more that 20 borehole sites would have equalled or exceeded the effects on the environment for construction of the shaft, and the sheer number of small-diameter holes would have tended to degrade the integrity of the potential site. In short, at this stage, Exploratory Shaft construction is considered to be a more environmentally efficient data-gathering process than small-diameter hole drilling and allied processes.

3.3.4.3 Delayed Action Impacts. Adoption of a delayed action alternative would have required cessation of site characterization activities for some finite period of time, after which the proposed course of action would have been continued. There would have been no difference in direct environmental impact between this alternative and the present proposed action, beyond the obvious change in time of occurrence.

A negative, secondary impact would result, however, inasmuch as some program costs would have continued during the period of inactivity, and in all probability, several of the more highly skilled technical persons necessary to efficient Exploratory Shaft construction would have left the project. Resumption of characterization activities would have then required some combination of key personnel acquisition and on-the-job training. The result of this course of action, as compared to drilling the Exploratory Shaft at this time, would have been the generation of the same direct environmental impacts at substantially greater costs to acquire the same data.

3.3.4.4 Alternate Site Impacts. The DOE is implementing various approaches to screen land areas and select sites suitable for detailed characterization to determine their potential as sites for deep geologic nuclear waste repositories. One of the approaches being implemented defined current land use as a basis for identifying areas where site exploration would be conducted. The Hanford Site has been committed to nuclear activities for nearly 40 years and may contain suitable host rocks at appropriate depths for a repository. Consequently, the DOE has requested the BWIP to screen and characterize areas, as appropriate, within the boundaries of the Hanford Site and in the Pasco Basin.

The entire Hanford Site is underlain by basalt flows, and many specific locations could have been selected on the basis of existing data that would have met minimum criteria for construction of an Exploratory Shaft. A number of reasonable sites may exist on the Hanford Site; however, the Exploratory Shaft site was determined to be the optimal site based on the site screening process (WCC, 1981). The extensive surveying and geosciences data-gathering activities performed to date have led to the conclusion that no better site can be selected now for detailed characterization (WCC, 1981). Few, if any, other locations are as well characterized as the currently designated Exploratory Shaft site, since characterization activity has been concentrated there since its selection. This would have implied additional environmental impact in direct proportion to the number of boreholes deemed necessary to characterize the alternate location to the same level of detail as existed for the reference location and would have resulted in unnecessary costs and delays.

Selection of the Exploratory Shaft location included an iterative design process, inasmuch as the shaft and repository designs are site specific. The selection process was primarily dominated by environmental considerations. For these two reasons, selecting an alternate Exploratory

Shaft site at Hanford would have required the expenditure of additional resources in resurvey and redesign activities and would not have necessarily resulted in a site that is in any way superior to the present proposed site.

3.3.4.5 Alternative Exploratory Shaft Design Potential Impacts. Alternatives to the proposed shaft design included alternate methods of shaft construction, varying the number of shafts, and varying the size, number, and location of underground test chambers. Some variations of the design of surface support facilities were also possible as a function of the shaft design. The environmental effects of such variations would have been minimal, relating mostly to small differences in sizing of the surface support area and its facilities.

A somewhat more significant difference in effect would have resulted from a change in shaft construction methodology. The only other current method of sinking a shaft is that of drilling shot holes, blasting, and mechanically removing the fragmented overburden. (This is the principal conventional mining technique of the mineral industry.) Employing this method for the penetration of aquifers requires the use of auxiliary techniques to prevent flooding in the shaft. Depending on the volumetric flow rates of the aquifers encountered, these techniques involve some combination of shaft pumping, drilling through blowout preventers near the bottom of the shaft, and injecting high-pressure grout in an annulus ahead of the advancing shaft, or drilling a series of wells around the prospective shaft location and injecting highly chilled brine to freeze the groundwater around the shaft location until the shaft can be excavated and cased.

Due to the volumetric flow rates of the aquifers the Exploratory Shaft must penetrate, probably all three of these techniques would have been required in conjunction with a conventional drill-and-blast shaft. Compared to the proposed support facilities for a bored shaft, the necessary brine chilling plant would have been large, costly and energy intensive.

Considering the primary purpose of the Exploratory Shaft is that of rock characterization, conventional drill-and-blast methods, used in conjunction with aquifer freezing, would have altered the subterranean environment for some distance from the shaft axis. Fracturing from the blasting process would have extended into the surrounding rock, and the drilling process, to be successful, would have markedly altered shaft area thermodynamics. All of these effects would have reduced the credibility of data gathered from the test areas due to the pertubations caused by shaft construction. In summary, use of this method would have increased the environmental cost/benefit ratio, causing increased expenditures of resources and increased surface environmental impact to acquire a given amount of data.

3.4 COMPARATIVE EVALUATION WITH OTHER SITES

3.4.1 Introduction

The Nuclear Waste Policy Act of 1982 requires, in Section 112(b)(1)(E)(iv), that the environmental assessment prepared to accompany each site nomination include:

> "...a reasonable comparative evaluation by the Secretary of such site with other sites and locations that have been considered."

Section 3.4 of this document was prepared to address this requirement.

The comparative evaluation includes the other sites and locations currently under consideration, as specified in the Nuclear Waste Policy Act of 1982. One site currently under consideration is Yucca Mountain, on the Nevada Test Site, in a rock type known as tuff (Fig. 3-5). Another potential site is in the vicinity of Gibson Dome near Davis Canyon in the Paradox Basin, which is a bedded salt formation underlying Utah. Other bedded salt locations within the Permian Basin are being studied with possible sites in Deaf Smith and Swisher Counties, Texas. And finally, three salt domes (Vacherie, Richton, and Cypress Creek) are being studied as potential sites for a repository in Louisiana and Mississippi. Thus, the Hanford candidate site will be compared with the following:

1. Yucca Mountain on the Nevada Test Site in tuff (Nevada)
2. Gibson Dome Area in bedded salts of the Paradox Basin (Utah)
3. Bedded salts in the Permian Basin (Texas)
4. Vacherie Salt Dome (Louisiana)
5. Richton Salt Dome (Mississippi)
6. Cypress Creek Salt Dome (Mississippi).

At least five of these seven sites will be nominated for site characterization and subsequently at least three will be recommended to the President for detailed characterization. Once detailed site characterization is complete, one site from the three will be selected for the first repository site.

3.4.2 Factors Used to Evaluate Sites

The principal documents used to develop this comparison of rock types include the previous chapter of this draft environmental assessment, Doctor et al. (1982), Nelson et al. (1982), NWTS (1982), and ONWI (1981, 1982).

Because the various sites have widely different data bases, it is difficult to compare them. Each candidate site has some favorable and some less favorable characteristics against which decision makers must develop a technical consensus concerning the medium's isolation capability. This isolation results from both inherent favorable rock properties plus engineering components to enhance isolation.

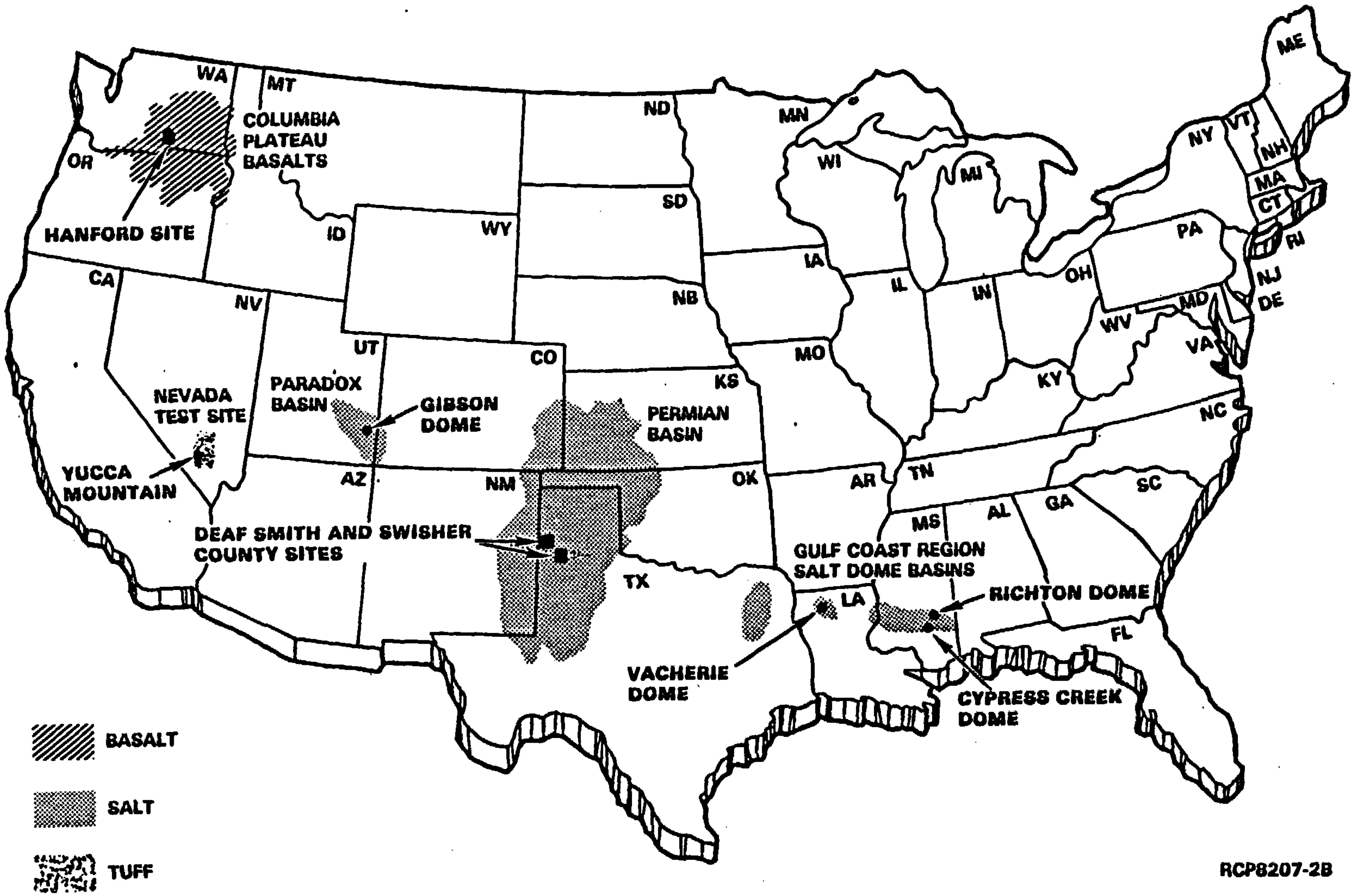

FIGURE 3-5. Specific Geologic Sites Under Active Consideration for the Disposal of Radioactive Waste.

It should be noted that the environment assessments accompanying other nominations may contain additional information or analysis relative to the factors contained in this section. Updated information or analysis will appear in the final environmental assessment nominating the Hanford Site.

3.4.3 Site Geometry

Though site geometries in the various geologic media differ, each appears to have sufficient depth, thickness, and lateral extent to meet proposed siting guidelines.

3.4.3.1 Depth of Underground Facilities. If a repository were constructed in basalt at the Hanford Site, it would be located in one of three candidate basalt flows in Grande Ronde Basalt. These are the Cohassett, McCoy Canyon, or Umtanum flows, which lie 869 to 942 meters (2,850 to 3,092 feet), 1,026 to 1,090 meters (3,365 to 3,576 feet), and 1,059 to 1,135 meters (3,475 to 3,723 feet) below ground surface, respectively.

If constructed in tuff at the Nevada Test Site, the repository would probably be in the Topopah Spring Member about 365 meters (1,200 feet) below ground surface. This formation is in the unsaturated zone (i.e., above the water table).

At the Gibson Dome in Utah, a repository would probably be constructed in the Paradox Formation. The top of this horizon is about 823 meters (2,700 feet) below ground surface.

If constructed in bedded salt of the Permian Basin, the repository would be constructed in the Lower San Andres Formation. In the areas of interest (Deaf Smith and Swisher Counties, Texas) these salt beds range in depth from about 610 meters (2,000 feet) to 792 meters (2,600 feet) below ground surface.

If a repository were constructed at either the Vacherie, Richton or Cypress Creek Domes, it would be placed at depths of 792 meters (2,600 feet), 660 meters (2,150 feet), and 732 meters (2,400 feet), respectively.

3.4.3.2 Thickness and Lateral Extent of Host Rock. For the proposed Hanford site, three laterally continuous basalt flows with thick, dense interiors are under consideration: the Cohassett, McCoy Canyon, and Umtanum. In the reference repository location, the Cohassett flow is 73 to 81 meters (239 to 266 feet) thick, the McCoy Canyon flow is 34 to 45 meters (110 to 148 feet) thick, and the Umtanum flow is 60 to 71 meters (197 to 232 feet) thick. These flows are found throughout the Pasco Basin, a region several tens of kilometers across in any direction.

The thickness of the Topopah Springs tuff under consideration at the Nevada Test Site is about 73 meters (240 feet). These formations extend for several kilometers in all directions from the proposed repository site.

The salt formation considered in the Paradox Basin is about 73 meters (240 feet) thick and extends for tens of kilometers in any direction.

Two salt formations studied in the Permian Basin are each over 38 meters (125 feet) thick and extend for tens of kilometers in any direction.

At the Vacherie Salt Dome, the usable salt thickness extends from about 236 meters (775 feet) to 914 meters (3,000 feet) in depth. The net area available for repository construction covers approximately 7 square kilometers (1,760 acres).

The usable salt dome thickness at the Richton Dome, extends from about 221 meters (725 feet) to 914 meters (3,000 feet) in depth. The net area available for repository construction covers about 15 square kilometers (3,760 acres).

The usable salt dome thickness at the Cypress Creek Dome extends from about 387 meters (1,270 feet) to 914 meters (3,000 feet) in depth. The net area available for repository construction is about 8.6 square kilometers (2,130 acres).

3.4.4 Geohydrology

With the exception of tuff, each candidate geologic medium possesses rocks of low permeability overlain by aquifers of various production rates. (Tuff has low permeability and the proposed repository level lies above the water table.) Groundwater traveltimes and radionuclide transport rates predicted through preliminary modeling for basalt appear very favorable for waste isolation. Modeling studies are under way for tuffs at the Nevada Test Site and for the salt sites.

3.4.4.1 Present and Future Hydrologic Conditions. Groundwater within the basalts at the Hanford Site moves laterally through limited zones of high permeability existing within some sedimentary interbeds and flow tops. These zones are separated by aquitards of low hydraulic conductivity comprised of basalt flow interiors and the hydraulically tight portions of flow tops. The three basalt candidate horizons are located in basalt flows having interior hydraulic conductivities of about 10^{-11} to 10^{-13} meters per second (10^{-6} to 10^{-8} feet per day).

Available geologic data suggest that the Pasco Basin was deforming at a low rate of strain in the Miocene and this rate has continued to the present. This slow deformation along known geologic structures is expected to continue into the foreseeable future. Therefore, groundwater flow paths, as now characterized, have probably extended into the past and are projected to continue into the reasonable future.

The proposed repository location in tuff on the Nevada Test Site is in the unsaturated zone. Here the water table lies approximately 500 meters (1,640 feet) below ground level. The amount and rate of moisture movement through the unsaturated zone is estimated to be small, although data are few. The regional groundwater flow direction is east and south from Yucca Mountain under a variable head gradient. This variability probably results from structurally controlled flow paths. Vertical head gradients appear to vary little to a depth of 1,100 meters (3,600 feet). Between 1,100 and 1,806 meters (3,700 to 5,920 feet) an upward head gradient is suggested. Transmissivities in the saturated zone are as high as several hundred square meters per day depending on the degree of fracturing. Hydraulic conductivities can vary several orders of magnitude within given stratigraphic units. The largest hydraulic conductivities typically occur within 100 meters (328 feet) of the water table.

The hydrostratigraphy of the Paradox Basin area consists of an upper unit of relatively low water yield receiving recharge from surface sources, a very low permeability middle unit in which a repository might be located, and a deep brine aquifer unit recharged at discrete locations. The generalized groundwater flow directions are to the south and west.

The hydrostratigraphy in the Permain Basin consists of an upper fresh water aquifer unit, a middle relatively impervious unit in which the repository would be located, and a deep, brine aquifer unit. The regional flow is downward to the deep aquifer, and at very low flow rates.

The Vacherie Dome is overlain by 163 meters (535 feet) of alternating silts, clays, and sand of variable hydraulic conductivities. The finer sediments, clays, and calcareous zones appear to be aquitards. Sandy lenses have hydraulic conductivies of approximately 10^{-5} meters per second (approximately 1 foot per day). Eighty meters (265 feet) of gypsum, brecciated limestone, and anhydrite caprock having unmeasured hydrologic properties overlie the salt dome. Groundwater flow in the caprock is primarily through fractures, joints, and solution channels. The salt itself probably has a low hydraulic conductivity.

The Richton Dome is overlain by 158 meters (520 feet) of interbedded sand and clay with some mudstone, siltstone, and lignite. The hydraulic conductivity of these sediments average approximately 10^{-5} meters per second (approximately 1 foot per day). This overlies 64 meters (210 feet) of caprock composed of gypsum and anhydrite having a hydraulic conductivity of approximately 10^{-5} meters per second (approximately 1 foot per day) The hydraulic conductivity of the caprock and caprock-salt interface are similar. The hydraulic conductivity of the salt dome itself has not been measured, although it is expected to be very low. The regional groundwater flow near the dome appears to be southward.

The Cypress Creek Dome is overlain by 360 meters (1,180 feet) of interbedded sand and clay with an overall hydraulic conductivity of about 10^{-4} meters per second (about 10 feet per day). These sediments overlie 62 meters (203 feet) of caprock composed of anhydrite, gypsum, and sandstone. The hydraulic conductivity of this caprock is about 10^{-5} meters per second (1 foot per day). The hydraulic conductivity of the caprock-salt interface is about 2 orders of magnitude less than the caprock itself. The hydraulic conductivity of the salt dome has not been measured though it is probably very low. The regional groundwater flow direction near the dome appears to be south.

Site-specific measurements of salt's hydraulic conductivity at each of the bedded and dome sites are planned.

3.4.4.2 Hydrologic Modeling. Very near-field (canister to room scale) modeling in the Hanford Site basalts indicates that for those radionuclides with even a nominal amount of sorption (i.e., kd greater than 0.5 milliliter per gram), the retardation effects are sufficient to reduce release rates from the repository horizons to levels well below the 10^{-5} per year proposed regulatory criterion during the first 10,000 years. The very low-solubility properties of major radionuclides (technetium, uranium, plutonium, americium) in basalt's reducing environment plays an even greater role than sorption in maintaining release rates below the proposed release criteria (EPA, 1982).

Near-field (repository-scale) simulation results in basalt indicate that relatively few radionuclides are of concern within a 10,000-year waste simulation period. Most actinide elements and long-lived fission products are of little importance because of their retardation characteristics and very low solubilities. Far-field simulation results in basalt indicate that groundwater traveltimes to the accessible environment (10-kilometer (6.2-mile) distance from repository boundary) exceed 30,000 years; the total traveltime to the Columbia River southeast of the repository is predicted to be in excess of 100,000 years.

Preliminary modeling of the Nevada Test Site (including the Yucca Mountain portion) is under way. Estimates of groundwater traveltimes and radionuclide transport rates to the accessible environment are not available.

Detailed site characterization of the salt sites are not available. However, regional hydrologic models are available. Therefore, hydrologic modeling of groundwater flow and radionuclide transport are based on expected regional conditions. These studies suggest that groundwater traveltimes are long and that radionuclides would not reach the accessible environment for well over 10,000 years.

3.4.4.3 Shaft Construction. For the repository located in basalt, a choice of conventional drilling and blasting, blind boring, or a combination of these methods may be used for sinking shafts. Grouting or freezing in advance of shaft sinking would be necessary to control groundwater if the conventional drill and blast method is chosen.

Groundwater present in strata overlying the candidate repository horizons can be controlled by engineering techniques and will not preclude construction of shafts.

In the unsaturated tuff at the Nevada Test Site, it is anticipated that the amount of water draining into the shaft constructed by drilling and blasting or blind boring will be small and easily handled. No special construction or maintenance techniques are anticipated. There is much construction experience in similar nearby formations stemming from weapons testing.

Groundwater present in strata overlying the Paradox and Permian Basin sites and the Vacherie, Richton, and Cypress Creek Salt Domes can be controlled by standard engineering techniques and will not preclude shaft construction.

3.4.4.4 Dissolution Features. Basalt is impervious to dissolution. There are no dissolution features in the basalt flows considered for the Hanford repository.

Rocks considered for repository construction at the Nevada Test Site are not soluble. No conceivable future changes in the geohydrologic system could cause dissolution of the tuffs at Yucca Mountain.

Dissolution features are possible in salt deposits. No dissolution features have been identified near the Gibson Dome area in the Paradox Basin. Some dissolution has been reported in the upper salts at the Permian Basin sites and is suspected in the salt-caprock interface of the Vacherie, Richton, and Cypress Salt Domes. Dissolution of salt in the lower portions of these domes has not been determined.

3.4.5 Geochemistry

The basalt geochemical environment at Hanford is favorable for isolating waste because of a high sorption capacity, low waste solubility, and no rock dissolution potential. These basic characteristics appear shared with tuff at the Nevada Test Site. Salt possesses low solute sorption, low waste solubility, and the possibility of rock dissolution.

3.4.5.1 Site Geochemistry. Hydrochemical data from the Hanford Site characterize the shallow basalt groundwaters as sodium bicarbonate chemical types, with low total dissolved solids (300 to 500 milligrams per liter) overlying a deep sodium chloride system having higher total dissolved solids (600 to 1,200 milligrams per liter).

Present Eh-pH, chemical, and secondary mineralogical conditions in the basalt geochemical system seem to be the result of rock-water interaction processes that have been operative at least during the Quaternary. The basalt mineralogy and the rock-water ratio appear to effectively buffer the groundwater composition against significant change.

Available geochemical data indicate that the candidate repository horizons at Hanford provide effective containment and isolation for many radionuclides present in high-level nuclear waste. Groundwaters from these basalt flows are strongly reducing (Eh = -0.45 $\pm$ 0.07 volt) and alkaline (pH = 9.5 $\pm$ 0.5). These factors enhance the stability of metallic components of the waste package and lead to decreased solubilities and increased sorption of many radionuclides. Hydrothermal alteration of the backfill/basalt system results in formation of a variety of stable phases such as clays and zeolites, which have superior sorptive capabilities.

Groundwater beneath Yucca Mountain at the Nevada Test Site is a sodium bicarbonate chemical type with total dissolved solids ranging from 175 to 900 milligrams per liter. Water near the water table does contain some oxygen. This is generally undesirable for the multivalent waste elements that normally show the lowest solubilities for the lower oxidation state species found in the absence of oxygen. Water in the unsaturated zone is also presumed to be oxidizing. The groundwater's pH is neutral (approximately 7.2), a condition tending to minimize solubility of waste elements. Concentrations of ionic species that might act as complexing agents (and, thus, possibly enhance radionuclide mobility) are low.

The mineralogy of tuff is generally favorable for sorption. Clays and zeolites, which inhibit the movement of radionuclides, are common throughout the stratigraphic units that underlie the Yucca Mountain site. The Calico Hills unit, which lies directly below the unsaturated Topopah Spring Member, is largely made up of zeolites. Matrix diffusion, a bulk process which may involve adsorption and diffusion of waste elements into the rock matrix, is also thought to be an important retardation mechanism at the Yucca Mountain site.

Few data are available concerning the site-specific geochemical environment at each of the salt sites. However, groundwater chemistry should change with depth at each site. The sequence of change would probably be that of a fresh water calcium bicarbonate groundwater overlying more saline sodium chloride waters. With depth, pH would also increase. A salt environment should be slightly reducing, thus contributing to low solubilities for actinides. However, the sorptive capacity of salt itself is very low, so the sorptive surfaces for radionuclide retardation would be from mineral and/or sedimentary lenses (clay, silt, etc.) inclusions.

3.4.6 Rock Characteristics

Technology exists for the design and construction of a repository in each candidate geologic medium as well as the sealing of exploratory boreholes. All facilities will meet appropriate safety requirements. The geomechanical-, chemical-, thermal-, and radiation-induced stresses expected in each host rock from waste emplacement are under study.

3.4.6.1 Geomechanical Parameters. Parameters used for the conceptual design of the Hanford repository are shown below. These values are based on a large number of tests and are representative of properties expected in basalt flows at the repository location. Preliminary average geomechanical parameters for the Topopah Spring Member at the Nevada Test Site are also shown.

Site	Porosity (%)	Density (g/cm^3)	Thermal conductivity (W/m^{o}C)	Young's modulus (GPa)	Poisson's ratio	Tensile strength (MPa)
Hanford Site (basalt)						
(Apparent)	2.8					
(Total)	7.3	2.8	1.16	67.6	0.25	14.8
Nevada Test Site (tuff)	12	2.2	1.7	28	0.28	3.5
Generic Salt Sites*	1.0	2.2	6.6	36	0.25	--

3.4.6.2 Constructibility. Shaft construction at the Hanford Site presents a challenge because of the depth, diameter, and possible groundwater inflows. The Exploratory Shaft Program will serve to assess the effectiveness of blind boring through basalt to the required depth. Experience gained by successfully completing large-diameter (2.3- to 3.0-meter (7.5- to 10-foot)) shafts to over 1,500-meter (5,000-foot) depths in basaltic rock at Amchitka Island, Alaska will be used by the BWIP. Groundwater inflow will be controlled by engineering measures.

The Yucca Mountain site in Nevada presents no significant problems in construction of either shafts or the repository. There is much construction experience in similar geologic materials from the underground weapons testing program.

Construction in salt is easier than hard rocks because it is softer and easier to drill and mine. The Gibson Dome in the Paradox Basin has low rainfall and a mesa and valley topography. These conditions may necessitate transport of water to the site.

*Site-specific geomechanical parameters are being determined. Parameters are dependent on temperature, confining pressure, and the specific formation.

The Permian Basin site has flat topography and abundant groundwater supplies. Groundwater control measures will need to be undertaken as the shaft penetrates the upper aquifers.

Shaft drilling at the Vacherie, Richton, and Cypress Creek Domes require penetrating 200 to 400 meters (600 to 1,400 feet) of overlying sediments and caprock before reaching the salt stock.

3.4.7 Tectonic Environment

One Quaternary age fault is identified on the Hanford Site outside of the reference repository location. Quaternary faulting exists in the Nevada Test Site near Yucca Mountain and in the Paradox Basin. Faulting in the Permian Basin and salt dome sites appears to be pre-Quaternary. Each geologic medium lies in a zone of low seismicity. The probability of igneous activity at any site is very low.

3.4.7.1 Faulting and Seismicity. Faulting in the Hanford Site is associated with anticlinal ridges and appears contemporaneous with folding. Strain on anticlinal folds has resulted in faults that, in places, have cut Quaternary strata. Faults of major displacement are not anticipated in the shallow dipping strata of synclinal areas, such as the Cold Creek syncline where the repository site is proposed. Historical and instrument data indicate that the Pasco Basin is an area of low seismicity. The largest event recorded during 12 years of instrument monitoring of the central Columbia Plateau is a magnitude 4.4 event on Royal Slope, north of Pasco Basin and about 50 kilometers (80 miles) north of the repository site. No earthquake has been recorded in the repository site.

Faulting of Quaternary age at the Nevada Test Site is localized in the basins. No known faults of Quaternary age occur on Yucca Mountain (the faults that are present are older than 2 million years). Faults located near Yucca Mountain whose latest movement is of Quaternary age are the Rock Valley fault (27 kilometers (17 miles) distant) and a fault in Crater Flat (8 kilometers (5 miles) distant). The peak acceleration of ground motion that would occur at Yucca Mountain (assuming that nearby faults were to become active and produce a maximum magnitude earthquake of 7 or 8) is about 0.4 g based on historical records of earthquakes within a radius of about 96 kilometers (60 miles) of Yucca Mountain. Studies of ground motion from underground weapons tests at the Nevada Test Site indicate that peak accelerations at Yucca Mountain from this source would not exceed 0.3 g.

Quaternary faults in the vicinity (at least 16 kilometers (10 miles) distant) of the Gibson Dome, Paradox Basin, include: the Lockhart Fault and associated faults, the Needles Fault Zone, Shay Graben, and Bridger Jack Graben. Both the Shay Graben and Needles Fault Zones exhibit evidence of Quaternary movement. This is an area of low seismicity.

Quaternary age faults of tectonic origin have not been identified in the siting area of the Permian Basin. This is an area of low seismicity.

Strata surrounding the Vacherie Dome show increases in dip typical of those around salt diapirs. Over the central portion of the dome, several faults have been inferred in profile and mapped on the surface. These faults are believed to be pre-Quaternary in age because of the undeformed nature of the overlying sediments and stream terraces. The Vacherie Dome, as well as the Richton and Cypress Creek Domes, are in areas of low seismicity.

Some faulting is indicated in the region immediately surrounding the Richton Dome but no faulting is suggested over the dome itself. These deeper faults are considered to be pre-Quaternary in age. The dome has been considered to be stable over the past several million years, but no site-specific evidence is available.

Strata surrounding the Cypress Creek Dome are essentially flat lying except for upturning along the dome's margin. No site-specific data are available concerning local faulting or the dome's stability.

3.4.7.2 Igneous Activity. Lava flows underlying the Hanford Site erupted 6 to 16.5 million years ago from fissures in the eastern and southern portions of the Columbia Plateau. The basalt flows in the Pasco Basin have a thickness of over 3,000 meters (9,840 feet). Since 6 million years before present, there has been no igneous activity within the vicinity of the Hanford Site. The annual probability of renewed igneous activity has been estimated to be less than 10^{-8}.

Igneous activity, principally volcanism, has been a major feature of the Nevada region around Yucca Mountain during the geologic past. Yucca Mountain itself is a thick volcanic sequence that was formed 12 to 15 million years ago. Since then, volcanic activity has waned. The last major period of volcanism ended about 8 million years ago; small basalt outpourings occurred 1.1 to 0.3 million years ago in Crater Flat. The nearest of these basaltic eruptions is 6.4 to 8 kilometers (4 to 5 miles) southwest of Yucca Mountain. Based on studies of the occurrence of volcanism in Nevada and adjacent parts of California, the annual probability of disruption of a repository at Yucca Mountain by basaltic volcanism is calculated to be in the range of 10^{-8} to 10^{-10}.

There is no known Quaternary igneous activity in the vicinity of the salt sites.

3.4.8 Human Intrusion

The basalts at Hanford and tuffs at Nevada have low resource values, while moderate resource values are associated with the salt sites. The Hanford Site and the Nevada Test Site are Government-owned properties. The potential development of a repository is consistent with current land use at either of these sites. The salt sites are located on either public or private lands.

3.4.8.1 Natural Resources. An inventory and economic assessment of known mineral or fossil fuel resources within a 100-kilometer (60-mile) radius of the proposed repository site at Hanford has shown that no known economic resource would preclude the siting of a repository at Hanford. Based on current data, the quantity, gross and net value, and commercial potential of such resources appear to be less than or equal to the remainder of the Columbia Plateau and the western United States. Groundwater resources within the vicinity of the three candidate basalt flows are presently not considered economically exploitable due to low quantities, required water treatment, and drilling costs. Shallow groundwater resources do exist at the Hanford Site.

There are apparently no geothermal, fuel, or mineral resources that would be attractive to future generations near the Yucca Mountain site in Nevada. Groundwater does exist beneath Yucca Mountain; however, it seems unlikely that this resource would prove attractive because of the great depth (500 meters (1,650 feet)) to water, rugged topography, and the fact that equivalent groundwater resources exist nearby at shallower depths in more accessible basins.

The Gibson Dome in the Paradox Basin lies outside known areas of occurrence of coal. Several uranium and vanadium prospects exist, but they are not currently operational. No hydrocarbon deposits of economic significance have been encountered near the site. The Gibson Dome is not associated with any natural resources. There is no evidence of subsurface mining or drilling within locations considered for repository development. The salt in the Paradox Formation is not of a quality useful for commercial or culinary purposes. Shallow groundwater resources do exist.

There are no known mineral deposits in the proposed siting areas of the Permian Basin. Any human intrusion would likely result from the exploration for oil and gas. Exploration interest has increased recently. There are no natural resource concentrations in the Permian Basin that are significantly greater than the average condition for the region that warrants economic extraction. Although there is historical evidence of drilling activities for oil and gas within Deaf Smith and Swisher Counties, the locations under consideration are not associated with hydrocarbon production or other resource recovery operations. The salt in the Permian Basin is not of a quality that would be used for commercial or culinary purposes. There is no evidence of subsurface mining at the locations considered. Shallow groundwater resources exist in the Permian Basin.

There are no known mineral deposits, other than the salt, in the vicinity of Vacherie Dome; however, lignite deposits might be commercially mined 9.6 to 16 kilometers (6 to 10 miles) from the dome. Potential mineral resources at Vacherie Dome include sand, groundwater, gravel, salt, gypsum, anhydrite, lignite, oil, and gas. However, the availability of more abundant, shallower, and more profitable mineral resources elsewhere in the Gulf Coast region might preclude major developments at the Vacherie Dome. All but the northwest flank of the dome have been drilled for oil or gas exploration. No production zones were found. The probability of finding substantial quantities of oil or gas is considered low. Shallow fresh water groundwater resources exist above the dome as well as the Richton and Cypress Creek Domes.

There is no known mineral deposits in the vicinity of Richton Dome other than salt. Sulfur and oil explorations have not resulted in production of these commodities. Exploration for sulfur has occurred in the caprock of the dome; however, mining for sulfur did not follow. There has been petroleum exploration adjacent to the dome. None of these resources presently have encouraging economic potential.

There is a producing oil field adjacent to Cypress Creek Dome, though production has declined during the past 10 years. A small oil and gas field is also located on the flanks of the dome. Although the dome is situated along the extension of a productive trend, indications are that the near-dome area has a poor-to-fair potential for future hydrocarbon production. Other mineral resources are not considered to have a commercial potential in today's economics and markets.

3.4.8.2 <u>Site Ownership and Control</u>. The Hanford Site is owned and controlled by the Government and has been dedicated to nuclear activities for 40 years.

The Yucca Mountain site in Nevada and adjacent areas is under Federal Government control. The northern portion of the site is on the Nellis Air Force Bombing Range, the southern portion is on land administered by the Bureau of Land Management, and a small portion on the Nevada Test Site is administered by the DOE. At present, the Bureau of Land Management land is not closed to entry, but the U.S. Air Force and DOE lands are. The U.S. Air Force land under exploration has no surface facilities and is used only for aircraft overflights. The Bureau of Land Management portion has never been used for any purpose except in the current exploration for a repository site. The land would have to be withdrawn for repository use.

Land near Gibson Dome in the Paradox Basin is privately owned. The site is bounded by Canyonlands National Park. This proposed repository site is on public land under the jurisdiction of the Bureau of Land Management. The land would have to be withdrawn for repository use.

Potential repository sites in the Permian Basin are privately owned farmland. The Federal Government would have to obtain ownership, control access, and obtain surface and subsurface rights to this land if dedicated for repository use.

The land above the Vacherie and Richton Domes is privately owned. The entire Cypress Creek Dome is within the boundaries of DeSoto National Forest. A portion of Cypress Creek Dome land is also owned and managed by the U.S. Forest Service. The U.S. Forest Service, in turn, has granted use of the land to the Mississippi National Guard. Some parcels of Cypress Creek Dome are also owned by the State of Mississippi and are managed for the benefit of Mississippi schools. The land above all three dome sites would have to be acquired before repository use.

3.4.9 Surface Characteristics

Appropriate engineering designs can be undertaken at each proposed repository site to mitigate the effects of potential flash floods or inclement weather conditions. The only possible impact from adjacent installation at any of the sites is ground motion from weapons testing at the Nevada Test Site.

3.4.9.1 Surface Water Systems. The primary surface water features adjacent to the Hanford Site are the Columbia and Yakima Rivers. Runoff into these rivers is extremely low because of small annual precipitation. West Lake is the only natural pond on the Hanford Site. It is about 1 meter (3 feet) deep, covers about 40,000 square meters (9.6 acres), and is 5 kilometers (3 miles) northeast of the reference repository location.

A number of flooding scenarios have been examined by the BWIP including probable maximum flood, dam failures, and river blockage due to landslides. The most extreme scenario evaluated was a 50 percent breach of Grand Coulee Dam. The floods resulting from these releases do not reach the reference repository location. There is a 60 percent probability that the extreme southwest corner of the repository location could be subject to shallow flash flooding from the ephemeral Cold Creek during the 100-year-long postclosure phase of a repository. This flooding potential would not affect an underground repository and engineering measures would be sufficient to keep any floodwaters from existing surface facilities.

There are no perennial streams or lakes near the Yucca Mountain site. The flooding potential of ephemeral Fortymile Wash and its tributaries, as it might impact the Yucca Mountain site, has been analyzed. The maximum potential floods are estimated to have a rise of 7.6 meters (25 feet) and will stay within the confines of present channel of Fortymile Wash. However, maximum potential floods in the tributaries feeding Fortymile Wash may exceed channel capacities and inundate some areas. Therefore, the potential for flooding must be a design consideration for both access routes and surface facilities. This flooding potential can be mitigated through a combination of proper selection of building sites and diversion measures.

The Davis Canyon site near Gibson Dome in the Paradox Basin does not include areas covered by major rivers, lakes, or streams. The canyon is drained by intermittent streams that flow into Indian Creek which drains into the Colorado River. Surface facilities can be constructed outside the probable maximum flood boundaries.

The Deaf Smith and Swisher County locations in the Permian Basin do not include areas covered by major rivers, lakes, or streams. The surface facilities can be constructed outside the probable maximum flood boundaries.

Vacherie Dome is drained mostly by Bashaway Creek to the east and by intermittent tributaries of Palmer's Creek to the west. Based upon the dome and floodplain boundaries, about 15 percent of the surface above Vacherie Dome would be flooded in the event of a 500-year flood. Earthen flood protection is recommended and drainage diversion plus nominal fill may be required.

Richton Dome is in the Leaf River watershed and is drained by several creeks radiating from the dome. Based on 500-year floodplain maps, approximately 20 percent of Richton Dome could be subject to flooding. However, the remaining 17 square kilometers (6.6 square miles) are located outside the floodplain. This is an adequate area to site the repository.

The major creek draining the Cypress Creek Dome is Cypress Creek. It is part of the Black Creek drainage to the south. Intermittent streams originating north and east of the dome flow into the Leaf River drainage basin. Approximately 52 percent of the dome would be inundated by the 500-year floodplain. About 4.9 square kilometers (1.9 square miles) of the dome are outside the floodplain and would be usable as a repository site. Nevertheless, earthwork would be recommended for flood protection. This effort may require the draining and filling of swamps.

3.4.9.2 Terrain. Terrain around the proposed repository site at Hanford is nearly flat and should pose no problems for construction of surface facilities.

The Yucca Mountain site in Nevada is somewhat rugged having a maximum topographic relief of about 335 meters (1,100 feet). However, there are some relatively flat areas in selected mountain drainages and along the edges of the mountain. Access routes need not cross rugged terrain. Although there are some constraints on the design of surface facilities and access routes, these can be minimized by prudent site selection for facilities and through proper engineering.

The Gibson Dome area in the Paradox Basin is characterized by mesa and valley "badlands" topography. The candidate site occupies a low broad valley surrounded by high mesas. There are no topographic constraints in locating a repository. However, major access routes to the proposed repository site would have to be constructed.

The surface topography of the Permian Basin is essentially flat and would not restrict construction of surface facilities. Site locations have little topographic relief broken by numerous shallow playa lakes and a few intermittent creek beds. No terrain constraints have been identified precluding a repository in this area.

The Vacherie Dome is characterized by low hills drained by a small stream. The surface topography is essentially flat and would not restrict the construction of surface facilities.

The Richton Dome is characterized by moderate topographic relief and some stream dissection. The surface topography is nearly flat and would not restrict the construction of surface facilities.

The Cypress Creek Dome is characterized by rolling hills and a low area drained by a small stream. Low relief exists near the site, and there are no slope-related hazards present.

3.4.9.3 Meteorology. The Hanford Site is classified as a mid-latitude semiarid desert with cool, wet winters and warm, dry summers. This area is in the rain shadow of the Cascade Range, which accounts for the relatively low annual rainfall of 15 to 18 centimeters (6 to 7 inches), variation of wind patterns, and some moderation of temperature. In winter, a chinook (warm and dry) wind from the southwest can result in a sudden large temperature rise (11°C (20°F) per hour), rapid melting of snow (if present), and strong gusty winds. Occasionally, an incursion of cold arctic air results in relatively low temperatures (less than -18°C (0°F). The mean monthly temperatures for January and July, the coldest and warmest months of the year, are -1.4°C (29.5°F) and 24.7°C (76.5°F) respectively. Anticipated meteorological conditions at the reference repository location would not impact repository operations.

The climate of Yucca Mountains on the Nevada Test Site is arid with hot summers and dry winters. Temperatures exceeding 37.8°C (100°F) are common during the summer. Temperatures below 0°C (32°F) occur on occasion during much of the year. More than half the precipitation is snow. High precipitation rates have occurred from local convective storms. These storms can cause surface flooding. High winds are associated with winter storms and thunderstorms. Winds have been estimated as high as 160 kilometers (100 miles) per hour. Lightning is most frequent during July and August. Yucca Mountain is prone to lightning strikes, because of high elevation compared to surrounding basins.

The Paradox Basin exists in a semiarid mid-latitude climate. In the Permian Basin, dispersion conditions are generally favorable in this semiarid mid-latitude climate. The Vacherie, Richton, and Cypress Creek Domes are all in Class II air-quality control regions in a humid subtropical climate. Severe weather (i.e., hurricanes and tornadoes) does occur in these areas. This does not preclude the construction of a repository, but specific design criteria would have to be met by the repository structures to ensure that adverse weather conditions do not impact repository operations.

3.4.9.4 Impact From Adjacent Installations. The Hanford Site occupies approximately 1,460 square kilometers (570 square miles). Existing facilities and operational areas on the Hanford Site are identified by area numbers (see Fig. 2-4). Each area is a controlled or limited access area enclosed by a fence. Operation and maintenance of the above Hanford Site facilities would have no impact on the proposed repository.

At the Nevada Test Site, all industrial and transportation facilities are many kilometers (miles) from the Yucca Mountain site and should have no impact on repository operations. The only effect existing facility operations would have is that of ground motion from underground nuclear tests and unusual noise levels from overflights of military aircraft.

There are no industrial, transportation, or military installations in the vicinity of the Gibson Dome, Paradox Basin. A nearby abandoned air strip should have no impact on repository operations.

In the vicinity of Vacherie Dome, several small airports, low-altitude training routes, and industrial facilities exist. An operating repository should not be impacted by these industrial areas.

There are no nuclear or industrial facilities in the Richton Dome area. The Richton airport is nearby. This should not impact an operating repository.

Nuclear or industrial facilities do not exist near the Cypress Creek Dome. It lies entirely within the boundary of the DeSoto National Forest. Under a special use permit from the U.S. Forest Service, the area is used as a bomb-firing range and tank field as part of the Camp Shelby Military Reservation. An agreement with the area's present users would be necessary to avoid impacting repository operations.

3.4.10 Demography

All sites are located in low population areas. Waste transport and repository operation risk studies are not completed at any proposed repository site.

3.4.10.1 Population. The Hanford Site lands are within the Federal Government's jurisdiction. Adjoining lands are privately owned, with the exception of those areas controlled by the State of Washington, county, and city governments. The closest Indian Reservation is owned by the Yakima Nation, and is located approximately 26 kilometers (16 miles) west of the Hanford Site, 50 kilometers (30 miles) from the proposed repository location. The three towns nearest the proposed repository site are Richland (35 kilometers (22 miles)), Kennewick (45 kilometers (28 miles)), and Pasco (45 kilometers (28 miles)). Their 1980 populations were 33,578; 34,397; and 17,944 respectively.

There are no people living within a radius of 20 kilometers (12 miles) of the Yucca Mountain site in Nevada. The nearest community is the town of Lathrop Wells (65 people), located 22 kilometers (14 miles) to the south. Beatty (900 people) is about 264 kilometers (165 miles) west. Las Vegas, population 500,000, is approximately 160 kilometers (100 miles) from Yucca Mountain.

At all five salt sites there are fewer than 1,000 individuals located in a 2.6-square-kilometer (1-square-mile) area adjacent to the potential surface facility site. The population density of these areas is low, averaging less than 1 person per square kilometer (1.5 persons per square mile) near the Gibson Dome site, 5 persons per square kilometer (14 persons per square mile) in the siting area of the Permian Basin, 6 persons per square kilometer (15 persons per square mile) near the

Richton Dome site, 8 persons per square kilometer (20 persons per square mile) at the Vacharie Dome site, 6 persons per square kilometer (15 persons per square mile) in the area of the Cypress Creek Dome. None of these dome sites are in a standard metropolitan statistical area.

3.4.10.2 Risk From Transportation and Operation. Evaluation of specific highway and rail routes for transporting radioactive waste to specific proposed repository sites has not been completed. Detailed studies are under way and results will be discussed in the Site Recommendation Report. Transportation risk comparisons among all proposed repository sites can be made qualitatively, since such risks are directly related to transportation distance. Although the geographic locations of future waste sources are uncertain, current sources are predominantly located in the eastern United States. Transportation risks associated with western repository sites (e.g., Washington and Nevada) therefore, would be expected to exceed those for more centrally located sites, such as the Gulf Coast Salt domes. However, since previous environmental impact studies of nuclear waste transportation have shown the transportation risks to be small in comparison to other commonly accepted risks.

3.4.11 Environmental Protection

None of the potential repository sites compared here is located in a significant nationally protected natural resource. The acceptability of the environmental impacts of a repository at each of the recommended sites will be evaluated in more detail in the environmental impact statement prepared to support the Site Recommendation Report.

3.4.11.1 Air Quality. Air-quality control regions are designated as Class I, Class II, or Class III. Class I regions have very stringent air-pollution control requirements; Class II and Class III regions have progressively less stringent requirements. All of the potential repository sites compared here are within Class II regions. However, Canyonlands National Park, which is a Class I region, is within 2.4 kilometers (1.5 miles) of the proposed Gibson Dome site in the Paradox Basin. Airborne particulate emissions are a potential problem at this site and may require special mitigation measures to prevent deterioration of air quality.

3.4.11.2 Water Quality. No surface water is available on or near the Yucca Mountain site and the nearest private use of groundwater is about 22 kilometers (14 miles) away. Groundwater quality in these private wells is generally good. The well that would support detailed site characterization supplies potable water. The reference repository location at the Hanford Site does not contain any potable surface water resources. The upper unconfined aquifer beneath the reference repository location supplies high quality potable water to private wells off of the Hanford Site. Water to be used to support detailed site characterization studies, however, would be provided by the Hanford water supply system which withdraws water from the Columbia River. The Gibson Dome contains no potable surface or groundwater resources. No fresh-water aquifers are located at either of the sites in the Permian Basin or the salt domes.

3.4.11.3 Ecology/Wildlife Protection. The Hanford, Nevada, Gibson Dome, and Permian sites contain no threatened or endangered flora or fauna. The salt domes may have threatened or endangered species. The desert tortoise and Mohave fishhook cactus are given special consideration where they occur near the Yucca Mountain site.

3.4.11.4 Cultural Resources. Cultural resources include those resources that have significant scientific, educational, historical, archaeological, architectural, or recreational value. Although the Department of the Interior lists a number of historic sites (DOI, 1982) on or near the Hanford Site, none of these are near the reference repository location. At the Yucca Mountain site, there are 72 archaeological sites that are considered potentially eligible for listing; one trail eligible for listing is adjacent to Yucca Mountain. The Gibson Dome contains several historical sites and contains isolated artifacts. Historical sites are located in towns in the Permian Basin. There are no known prehistoric or historic sites on or near the salt domes.

3.4.11.5 Noise. The remoteness of both the Nevada and the Hanford sites from human habitation and from occupied facilities ensures that noise pollution requirements will be met. Construction activities will generate increased noise levels for short periods of time at all sites. Noise levels, if unmitigated, might present a problem at the Gibson Dome Site; noise levels are not expected to be a problem at the other salt sites. Mitigation measures, such as mufflers for engines and line-of-sight noise barriers, could be used at any site if needed to reduce noise to allowable limits.

3.4.11.6 Solid Waste Disposal. The major solid waste will be mine spoils. The area occupied by the spoils will be about 8 hectares (20 acres) at all potential sites compared here. Without mitigation measures, fugitive dust depositions and rainwater runoff from the spoil piles may be a problem at all the salt sites because of the effects of salt on vegetation and crops. Mitigation measures at the Permian Basin site might include a thick earthen cover over the spoil piles. A possible mitigation meausure at the Gibson Dome is to transport the material offsite for disposal in nearby abandoned mines. Material from the three salt domes might be deposited in the Gulf of Mexico. Fugitive dust depositions and rainwater runoff from spoil piles at Nevada and Hanford are not expected to be a problem because of the more benign nature of the excavated material and the more arid climates. Small amounts of other solid wastes would be generated by construction and operation of repository facilities at all sites.

3.4.11.7 Aesthetics. The Nevada Test Site is not visible from publicly accessible locations. Construction facilities would have limited visibility from the Canyonlands National Park near the Gibson Dome and in the Permian Basin. Facilities would be largely concealed by wooded areas at the salt dome sites. While the reference repository location at Hanford is visible from Route 240, the aesthetic impact of the site will be minimal. Surface facilities for the construction and operation of a repository would be similar to numerous structures on the Hanford Site.

3.4.12 Socioeconomic Impacts

No adverse socioeconomic impacts are expected at either the Hanford Site or the Nevada Test Site. Some adverse impacts may occur at the salt sites.

3.4.12.1 Site Impacts. The available information on socioeconomic impacts at the Hanford Site is reviewed in Section 3.6.2 of this draft environmental assessment. Preliminary analysis indicates that there will be no adverse social and/or economic impacts on nearby communities or regions resulting from construction of a repository at the Hanford Site.

The Yucca Mountain site in Nevada is devoted to nuclear activities, principally the testing of nuclear weapons. A large work force of craftsmen, professionals, and scientists already work at the Nevada Test Site. The additional work force needed to construct and operate a repository would be a small percentage increment to the present work force. There would be no significant impact on existing community and governmental facilities and services. Additional road and railroad construction to the proposed repository site would pose no engineering problems.

The socioeconomic conditions at all five salt sites would be affected by increased employment, increased business and government revenue, and increased demands on community services. The available labor force and supplies in these areas are limited; therefore, the additional work force needed to construct and operate a repository would be a large percentage increment to the present work force. However, adverse impacts could be easily mitigated.

Two locations, the Gibson Dome in the Paradox Basin and the Permian Basin, may require acquisition of water rights. Also, the Cypress Creek Dome location is part of the DeSoto National Forest, which is used as a revenue source by local and state governments and is used by the United States military for training.

3.5 DESCRIPTION OF THE DECISION PROCESS

Section 112(b)(1)(E)(v) criteria: Description of decision process by which the reference repository site was recommended.

The NWTS Program siting investigations have been following a formal three-step process that begins with national screening and culminates in detailed site characterization of candidate sites for a nuclear waste repository. This siting process is described in the Public Draft, National Plan for Siting High-Level Radioactive Waste Repositories and Environmental Assessment (DOE, 1982d). (See Section 2.2 for more detail on the siting process.) In 1978, the DOE established the BWIP and initiated a site-screening study to identify locations within the Hanford Site where a repository for nuclear waste could be sited. This section summarizes the site-screening study conducted at Hanford. This study consisted of a series of screening steps, based on geotechnical, safety, socioeconomic, and statutory guidelines, that progressively reduced the size of the land area to that which would be subject to detailed characterization. The site-screening study was limited to the Hanford Site (Fig. 3-6) by virtue of its long-standing use and commitment to nuclear activities (DOE, 1982d) and its existing government ownership. However, to provide a broader scope from which to study processes that might affect the Hanford Site, initial screening encompassed the Pasco Basin (Fig. 3-6). The Pasco Basin is the smallest physiographic unit that includes the Hanford Site and that may reasonably form the boundaries of the geologic and hydrologic subprovinces that influence conditions at Hanford. This screening would also determine whether there are any apparent, obviously superior site localities in a natural region (i.e., the Pasco Basin, outside of the Hanford Site) (WCC, 1980, Vol. I).

In October 1978, the BWIP awarded a contract to Woodward-Clyde Consultants, San Francisco, California, to conduct the Hanford Site screening. This study would lead to the identification of site localities, areas of about 26 to 130 square kilometers (10 to 50 square miles), having a high likelihood of containing suitable sites for locating a repository for nuclear wastes. The methodology used for screening site localities consisted of the following items:

- Identification of objectives and development of guidelines for application to the study area
- A multistep screening process that permits the application of guidelines to smaller and smaller areas until the site localities have been identified
- Development of a data base of appropriate scope and detail that could be utilized for defining the conditions within the areas defined in each substep of the screening process.

3.5.1 Identification of Objectives and Development of Basalt Waste Isolation Project Siting Guidelines

There were seven key assumptions guiding the site locality identification study (WCC, 1980, Vol. I) that were important in establishing the objectives and developing guidelines. Restated, these are the following:

- The repository will require licensing involving the NRC, other Federal agencies, and possibly State and local entities.
- The design and operation of most surface facilities will be governed by existing safety and environmental licensing requirements.

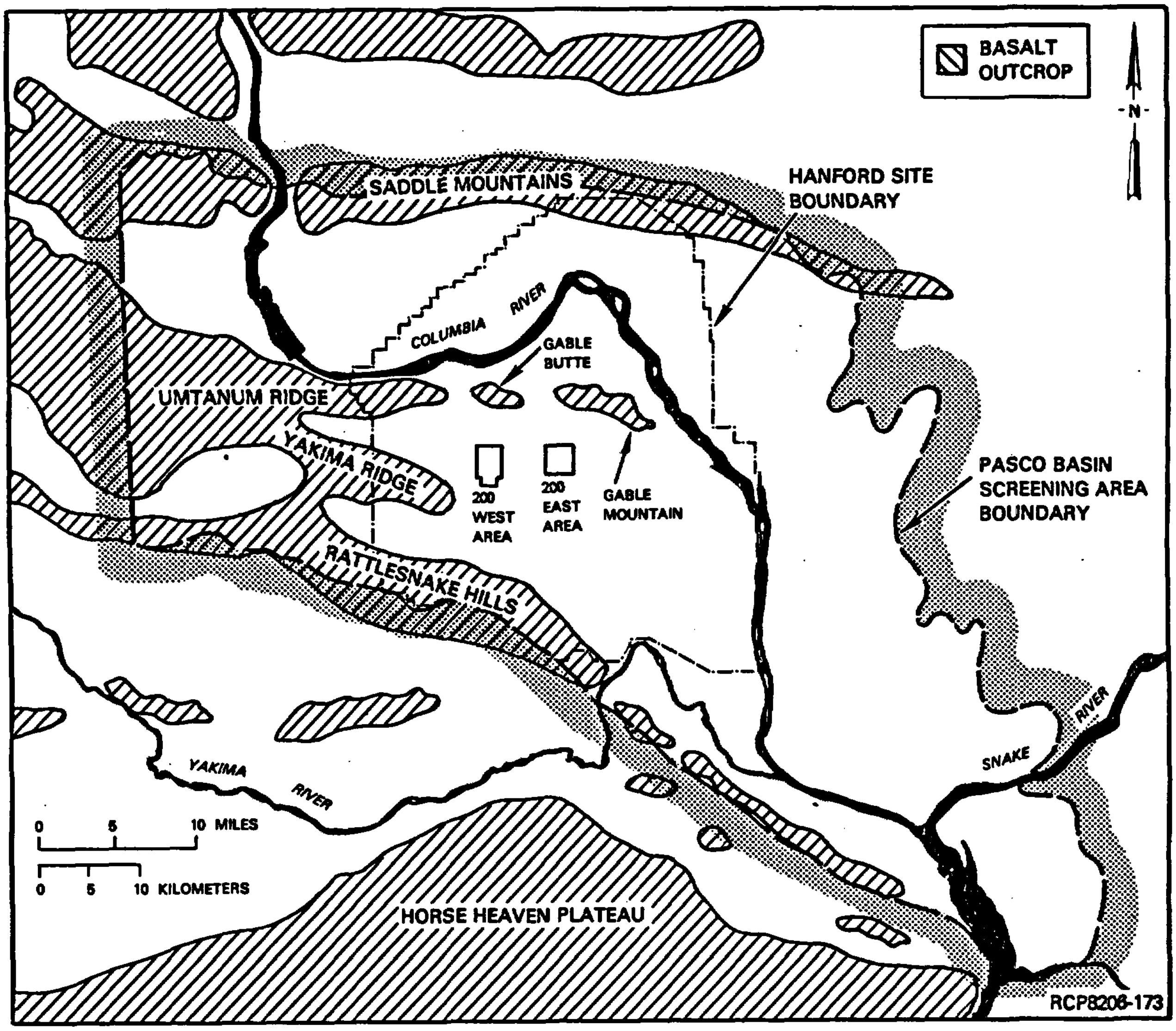

FIGURE 3-6. Pasco Basin Screening Area and Hanford Site Boundaries.

- Nominal design and performance characteristics for the repository have been estimated.

- The long-term safety-related characteristics of the host rock system can be estimated and can be used in the selection guidelines.

- The repository will be designed for two time frames: relatively short emplacement and retrieval phase and a much longer isolation phase.

- The site locality identification study will be based on available data; siting guidelines will be based on currently available technology.

- The repository licensing requirements will be written in the style of other nuclear fuel cycle facilities.

On the basis of these assumptions, several objectives were established to reflect specific characteristics of the repository facilities, as well as conditions and concerns with the study area. The hierarchy of objectives provide the framework for choosing and applying guidelines to identifying site localities. It was deduced from a proposed general statement of policy for licensing requirements for a repository (NRC, 1978) that to be accepted as suitable the site must meet the following objectives:

- Maximize public health and safety

- Minimize adverse environmental and socioeconomic impact

- Minimize cost necessary to attain the requisite levels of safety, as well as costs of mitigation.

The objectives were then expanded and restated to bear on conditions or events that could be associated with an underground repository. The safety objective was particularized to state: maximize public health and safety in relation to natural hazards, man-made hazards and events, and repository-induced events. The environmental objective was particularized as: minimize adverse environmental and socioeconomic impact related to construction, operation, and closure and surveillance. The cost objective was particularized by stage of repository development: minimize system costs related to construction and impact mitigation, operation and maintenance, closure, decommissioning, and surveillance (WCC, 1980, Vol. I).

For each of the objectives established, one or more "consideration" or technical matter of concern was identified to describe the subject matter that must be addressed in order to orient the siting study toward achievement of the objectives. These considerations reflect characteristics, conditions, or processes in the study area. For each consideration defined, a measure was selected or developed to allow differentiation between areas or localities in terms of the consideration.

For some considerations, a specific level of achievement was required or implied by statute, regulation, technological limitations, or gross economic considerations. In these cases, a limit was established for the appropriate measure. The value of the measure at which the limit was set was an "inclusionary" guideline. For those considerations where no specific level of achievement was required, the measure itself was the guideline and was used to characterize or classify areas and localities with similar characteristics. These were called "classifying" guidelines.

The considerations, measures, and guidelines used for the site locality identification study are found in WCC (1980, Vol. I, Table III-3). A detailed discussion of background and rationale for selecting the various measures and guidelines is presented in WCC (1980, Vol. I, Appendix A).

3.5.2 Screening for Site Localities

The first step in screening the Pasco Basin was to define candidate areas (Fig. 3-7). Screening involved the use of inclusionary guidelines which represent a total of nine considerations under the work objectives of maximizing public health and safety, minimizing adverse environmental impacts, and minimizing system costs. A relisting of the considerations, measures, and guidelines used at this step is found in WCC (1980, Vol. I, Table IV-2). The candidate area defined by the composite overlay is shown in Figure 3-7.

The second step in the screening of the Pasco Basin was to delineate subareas. Seven inclusionary considerations and guidelines were used in this screening step and are found in WCC (1980, Vol. I, Table IV-3). When the overlays depicted these seven guidelines (fault rupture, flooding, ground failure, erosion denudation, hazardous facilities, induced seismicity, and site-preparation costs) were compiled, the resulting subareas, shown in Figure 3-8, were identified. These subareas were then carried into the next step in screening to identify site localities.

Site localities were identified first through an evaluation of the subareas based on the classifying guidelines presented in WCC (1980, Vol. I, Table III-3). A detailed discussion of each of these classifying guidelines is given in the Appendix of WCC (1980, Vol. I). Included in the information provided in the said Appendix is a statement on the relevance to siting and the approach used for employing the guideline. The evaluation of subareas was conducted in two steps:

- Evaluation of subareas within the Pasco Basin screening area outside of the Hanford Site
- Evaluation of the subareas within the Hanford Site.

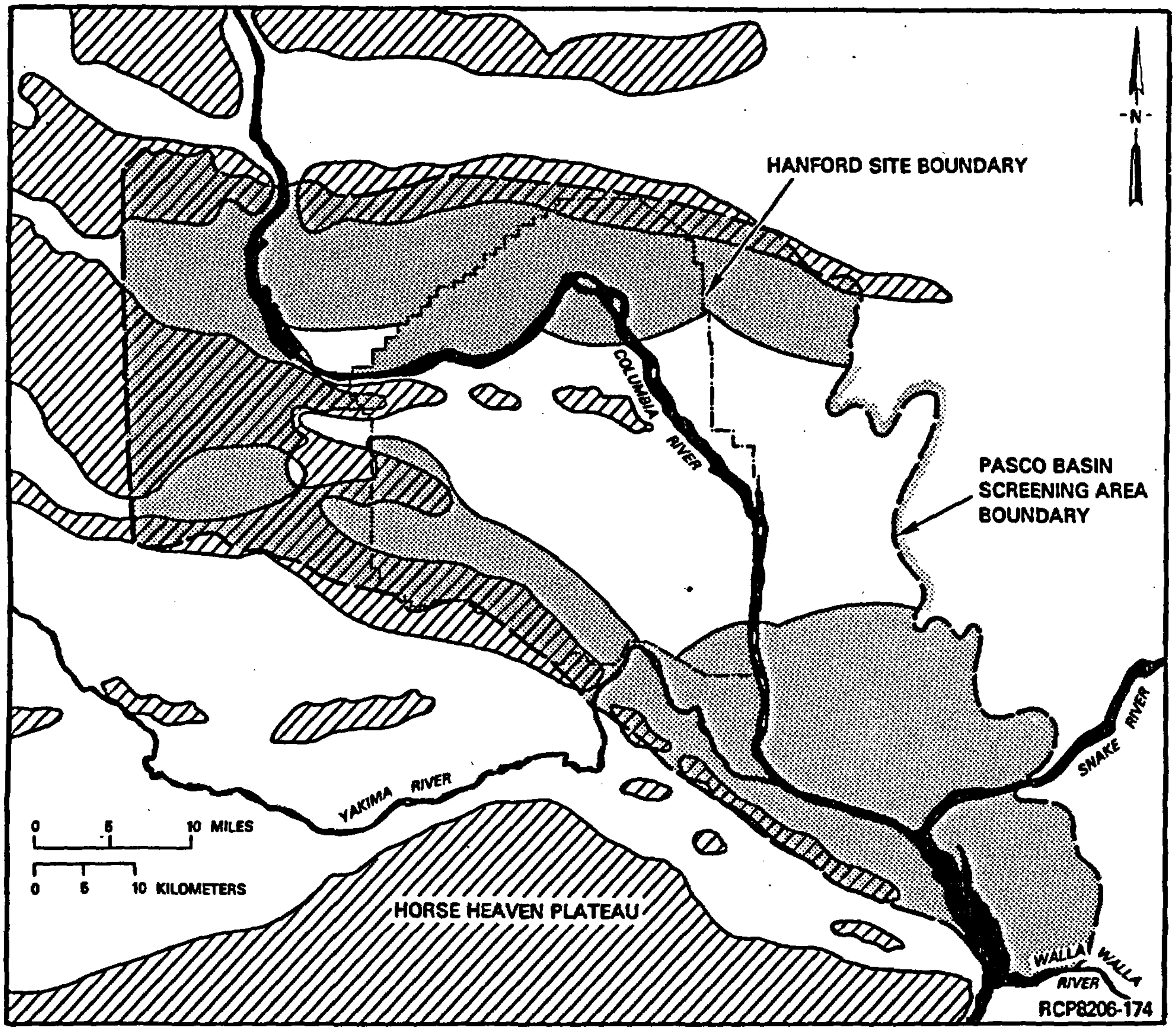

FIGURE 3-7. Candidate Area (outlined with shaded area).

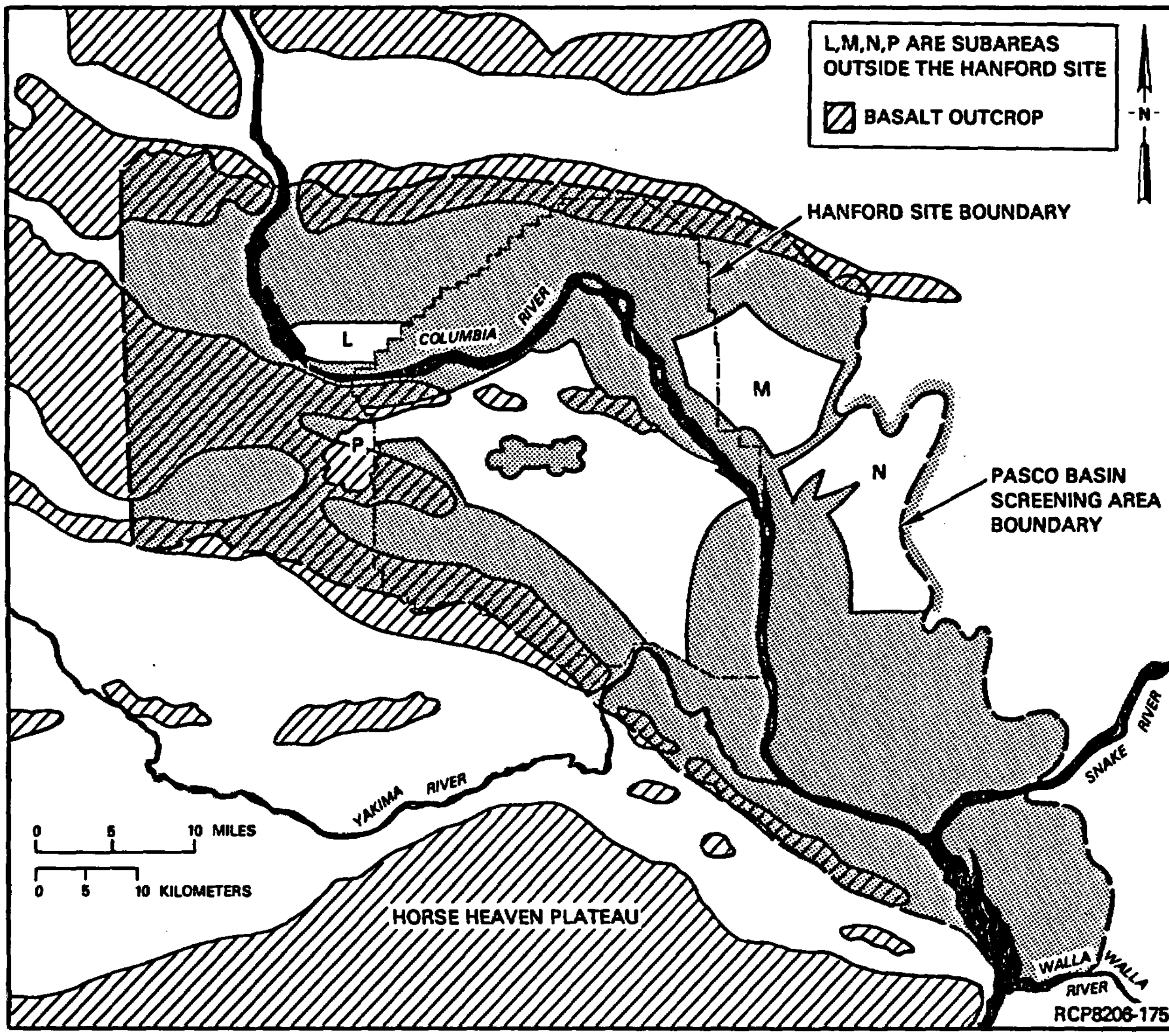

FIGURE 3-8. Subareas (unshaded).

The first step was designed to determine whether any apparent, obviously superior site localities occur in the subareas outside the Hanford Site. The results of this evaluation indicated that three of the four subareas that were outside the Hanford Site (L, M, and N, Fig. 3-8) were used for irrigated farming and were also in close proximity to the Columbia River. The fourth subarea (designated by the letter P in Fig. 3-8), in addition to being used for irrigated farming, was an area where the bedrock dip was greater than 5 degrees; one of the baseline conditions for the repository host rock was a flow dip of less than 5 degrees (WCC, 1980, Vol. I). On the basis of land use, hydrology, and bedrock dip, these sites were not obviously superior to those found within the Hanford Site and, therefore, no further consideration was given to these subareas (WCC, 1980, Vol. I).

The second step in the evaluation of subareas within the Hanford Site and prior to the identification of site localities was to study the available surface and subsurface areas separately and to evaluate the impact of the surface versus the subsurface screens. In all circumstances the subsurface considerations took precedence over the surface considerations. If the subsurface screening showed obvious superiority, the surface screen was downgraded. An overlay was made of the Hanford Site showing both inclusionary and classifying guidelines that affected the subsurface (bedrock dip, microseismicity, and hydrology). The results of this screening are shown in Figure 3-9. A second composite overlay was made using those guidelines that affect the surface (aircraft impact, transportation, protected ecological areas, terrain ruggedness, flooding, landslides, erosion, denudation, and hazardous facilities). The results of this screening are shown in Figure 3-10. The area resulting by combining the surface and subsurface screens was believed to be more suitable and has a higher likelihood of containing suitable waste repository sites. In addition, the area delineated by these combined screens continued to provide sufficient area and adequate geotechnical conditions for the identification of several site localities. The combined area resulting from the application of surface and subsurface screens was then examined to identify site localities.

The general size of a site locality is less than 130 square kilometers (50 square miles) and more than 26 square kilometers (10 square miles), and five site localities were identified. The location of these five site localities designated H-1 through H-5 is shown in Figure 3-11. One site was north of Gable Mountain, west of the Columbia River (H-1); one site was north of Gable Mountain, east of the Columbia River (H-2); and three sites were south of Gable Mountain (H-3, -4, and -5). The three site localities south of Gable Mountain were defined somewhat arbitrarily to maintain equal size. A small subarea west of site locality H-3 (Fig. 3-10) was not considered further due to its small size, which would preclude a repository based on a subsurface area of 26 square kilometers (10 square miles) (including a buffer zone).

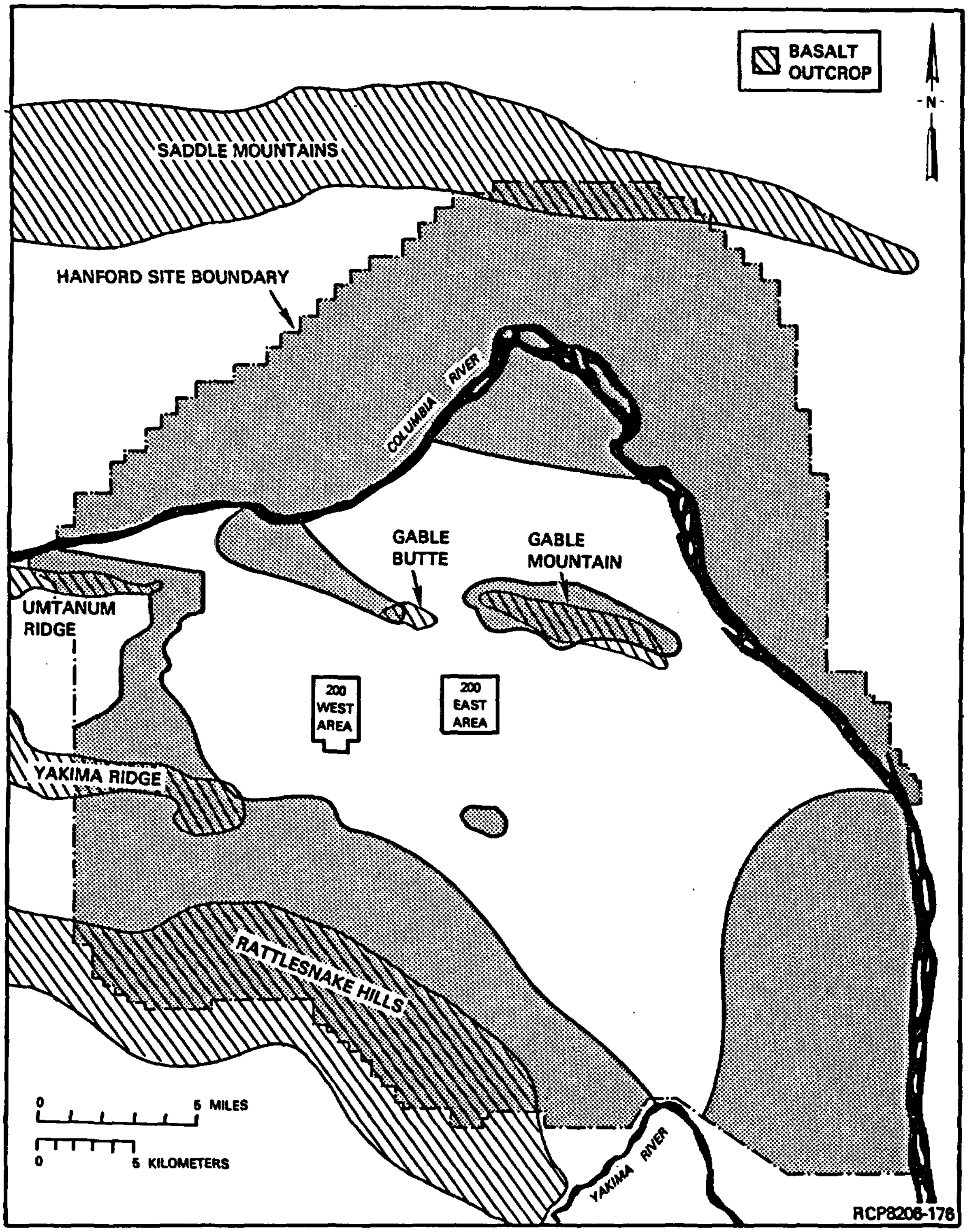

FIGURE 3-9. Available Subsurface Areas on the Hanford Site (unshaded).

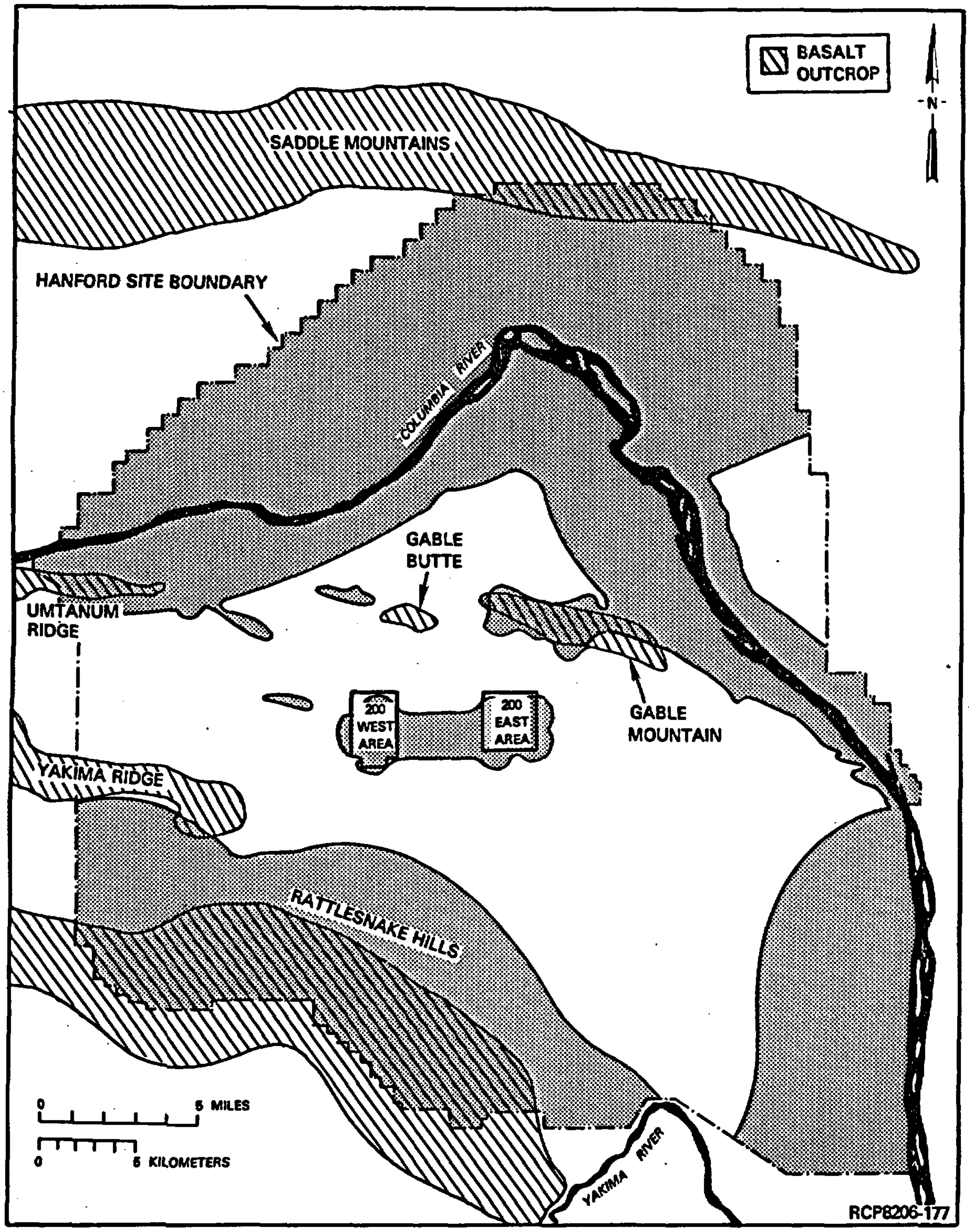

FIGURE 3-10. Available Surface Areas on the Hanford Site (unshaded).

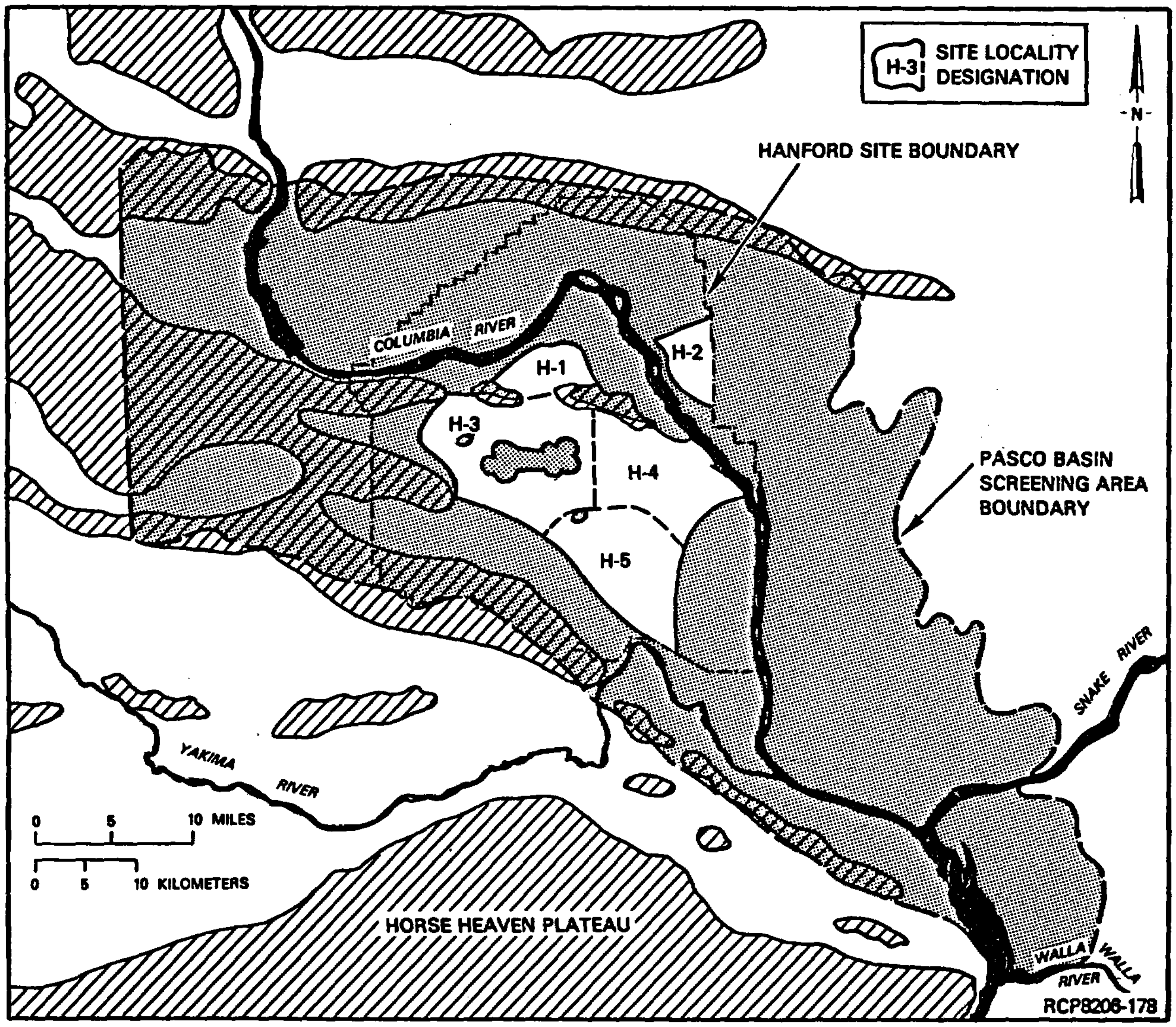

FIGURE 3-11. Site Localities.

To characterize the existing conditions within each site locality and to provide a basis for evaluating the site localities with respect to identifying candidate sites in the next steps of the siting process, 23 descriptive parameters were selected representing geology, hydrology, seismology, land use, ecology, and man-made hazards. Estimated ranges of the existing conditions in each of the five site localities are given in WCC (1980, Vol. I, Table IV-4).

Figure 3-12 is a schematic representation of the screening methodology leading to the identification of site localities on the Hanford Site.

The documentation of the site locality identification study is found in WCC (1980, Vol. I and II). Volume I describes the methodology, guidelines, and screening process. Volume II describes the data compilation and cataloging. The major sources of site-specific characterization data were three integration reports published by the BWIP: RHO-BWI-ST-4 (Myers/Price et al., 1979); RHO-BWI-ST-5 (Gephart et al., 1979); and RHO-BWI-ST-7 (Smith et al., 1980).

3.5.3 Identification of Reference Repository Location

In October 1979, the contract with Woodward-Clyde Consultants was renewed to continue the site-screening study through the identification of a reference repository location. The initial step was identifying candidate sites within the five site localities. The size of a candidate site was determined from the repository baseline conditions (WCC, 1980, Vol. I, Table III-1). An area of about 26 square kilometers (10 square miles) was selected which would include surface and subsurface facilities and an exclusion area buffer zone. Screening guidelines assured that each locality would support at least one candidate site (BWIP, 1980).

The identification of candidate sites was based on a selective and successive examination and evaluation of the range of conditions for the 23 parameters described in WCC (1980, Vol. I, Table IV-42). These parameters were selected to reflect the concerns of the objectives of the siting study. Other considerations were also given to established NRC reactor siting criteria, the Office of Nuclear Waste Isolation draft site-qualification criteria (ONWI, 1979), NRC draft repository criteria, National Academy of Sciences guidelines, and Rockwell Hanford Operations technical requirements. The relationship of the Office of Nuclear Waste Isolation (ONWI, 1979) generic repository criteria and the site-specific consideration used for candidate site identification is given in BWIP (1980) and in BWIP (1981a).

BASALT WASTE ISOLATION PROJECT
GUIDELINE DEVELOPMENT

OBJECTIVES:	NUMBER OF SPECIFIC CONSIDERATIONS	NUMBER OF MEASURES	SCREENING GUIDELINES INCLUSIONARY	SCREENING GUIDELINES CLASSIFYING
• MAXIMIZE PUBLIC HEALTH AND SAFETY	19	26	23	22
• MINIMIZE ADVERSE ENVIRONMENTAL IMPACT	6	7	5	2
• MINIMIZE COST	2	3	0	3

SCREENING PROCESS

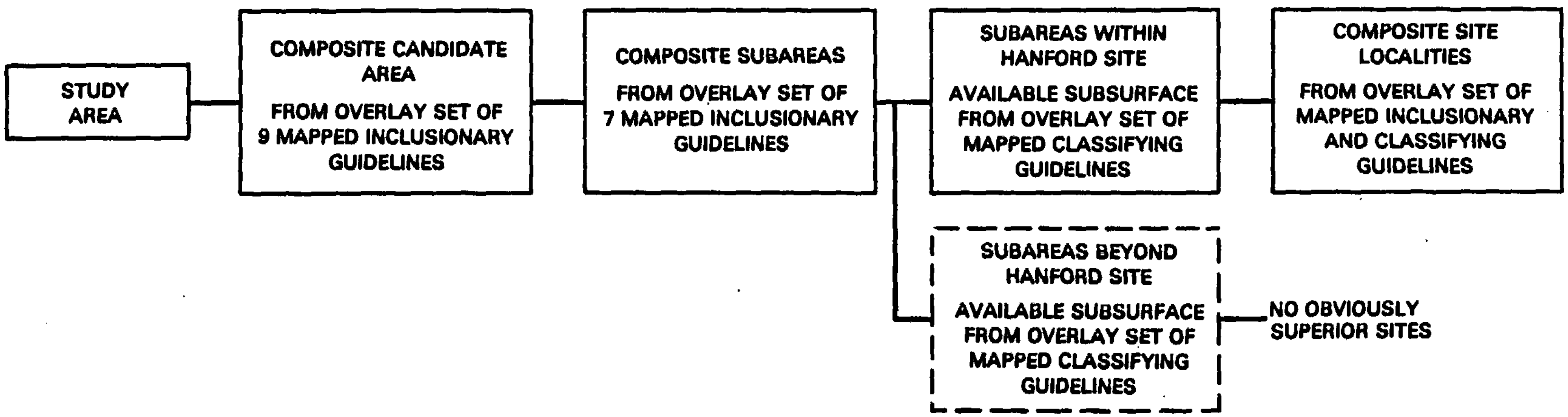

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FIGURE 3-12. Schematic Representation of the Screening Methodology.

To identify candidate sites, screening overlays representing the range of conditions and area affected by each parameter under consideration were superimposed. The results of this overlay process were used to identify the portion within each locality which tended to maximize the desirable characteristics with regard to the parameters. Nine candidate sites were thus identified within the site localities, lettered R through Z in Figure 3-13. Seven of the nine candidate sites (R through X) lie in a group, within the Cold Creek syncline, a major structural feature of the Pasco Basin. Two other candidate sites (Y and Z) lie just outside this structure (WCC, 1981).

Once the candidate sites were identified, the emphasis of the siting process shifted from one of narrowing the area within the Pasco Basin under consideration to the identification of a reference repository location and an alternate repository location from among the candidate sites. The process used is not an overlay of maps, but a formal comparison of the available data through a ranking process, known as decision analysis. Decision analysis is a systematic process that helps decision makers in comparing alternative courses of action. The approach to this process consists of four steps (WCC, 1981):

- Structuring the problem in terms of criteria and developing measures by which alternatives can be quantitatively compared
- Describing the consequences of each alternative in terms of the measures
- Determining preferences for different consequences
- Synthesizing the information to logically rank order the alternatives and performing sensitivity analyses.

The procedure stresses flexibility for ease of implementation, yet incorporates consistency checks for ensuring accuracy and defensibility of the analyses.

Preliminary ranking was performed to identify a subset of candidate sites from the nine sites originally identified. Five attributes (indicated in WCC, 1981, Table V-3), for which data were available to compare the sites, were applied following the dominance analysis process. The results of the application are as follows:

Ranks first	U
Ranks second	V
Could rank third	R, T, W
Could rank fifth	S
Could rank sixth	X, Y, Z.

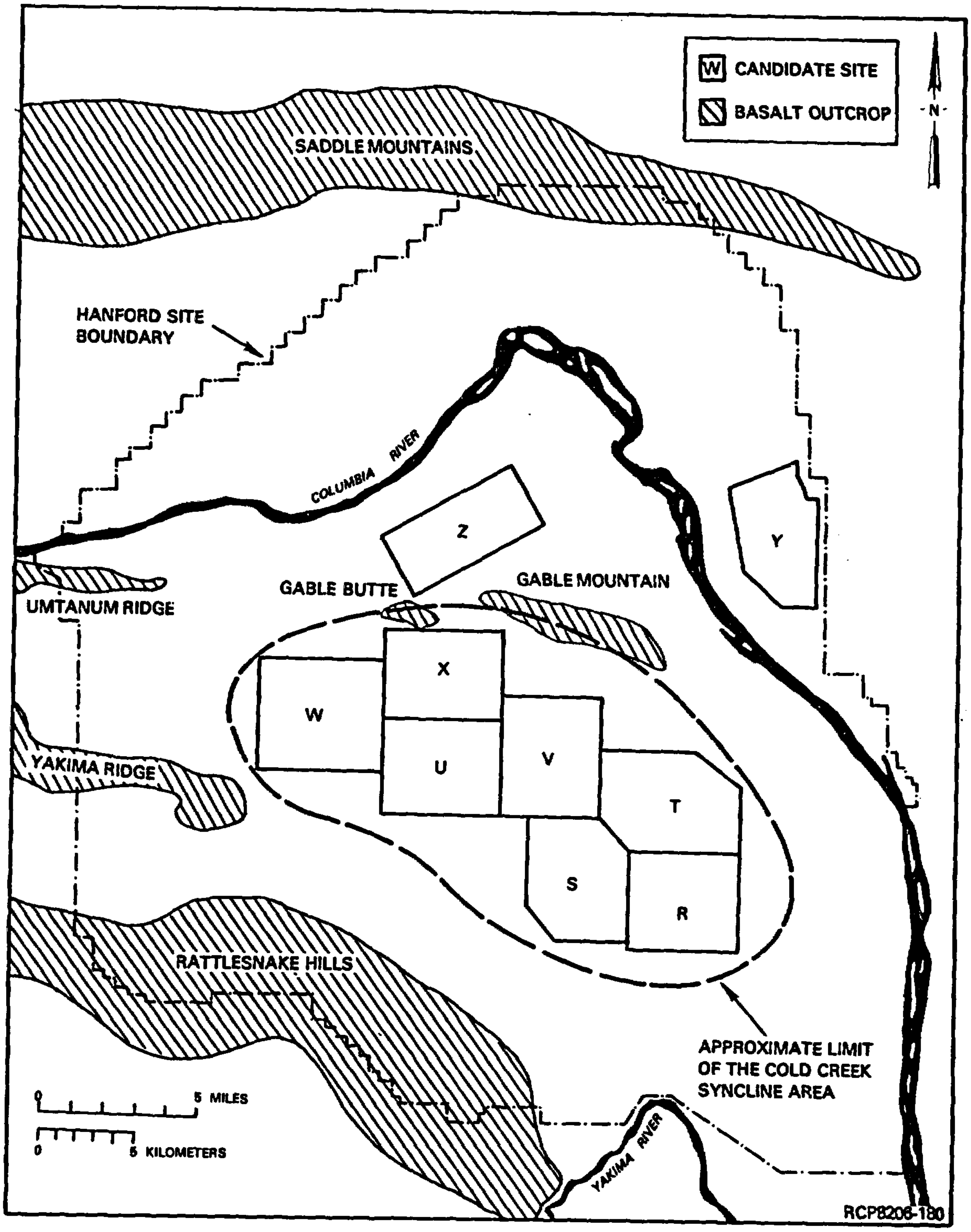

FIGURE 3-13. Candidate Sites on the Hanford Site.

Meetings between geotechnical specialists from Rockwell Hanford Operations and Woodward-Clyde Consultants confirmed that the attributes were appropriate to use and that their relative importance was also appropriate (WCC, 1981).

Candidate sites U and V, which ranked first and second, respectively, clearly were favorable for further studies. The choice for a third candidate site from among R, W, and T was not clearly defined. A review of site conditions showed that candidate sites Y and Z, near the Columbia River, were not technically superior to those in the Cold Creek syncline and were too close to the potential discharge zone (the Columbia River) as well as distant from transportation, safety, and support facilities. For these reasons the two candidate sites, Y and Z, were removed from further study (WCC, 1981).

The remaining seven contiguous candidate sites in the Cold Creek syncline displayed geologic and physical similarities throughout the siting process. These sites were renamed A through G (Fig. 3-14) and were then considered for further evaluation to identify a reference repository location. However, because the seven contiguous sites appeared to be so closely matched, further evaluation of the Cold Creek syncline was based on a more detailed study in the siting area (WCC, 1981). Results of the geologic fieldwork were subsequently summarized in Myers and Price (1981).

Because of the linear trends resulting from the geophysical studies in the Cold Creek syncline (Myers and Price, 1981, Appendix B), it was considered necessary to reevaluate the boundaries of the seven candidate sites (A through G). For ease of comparison with previous work, the original candidate site boundaries (A through G) were maintained and three additional candidate site boundaries were superimposed on portions of the original seven sites, but outside of the influence of the more prominent geophysical lineaments. These additional sites were designated H, J, and K (see Fig. 3-15).

Preliminary evaluation of the ten candidate sites (A through H, J, and K) makes it clear that the sites were too closely matched to be differentiated between by routine ranking. A more rigorous application of the decision analysis process was required. Procedures differ primarily in the detail of data available. To this end, an enlarged data base was compiled, referred to as a criteria matrix. The text of the criteria matrix is an exhaustive description of physical, socioeconomic, and biological conditions at the candidate sites using information available as of a cutoff date of May 16, 1980. That text as well as a description of the procedure followed to complete each descriptor, rationale for inclusion in the criteria matrix, and additional supportive data is included in WCC (1981, Appendix A).

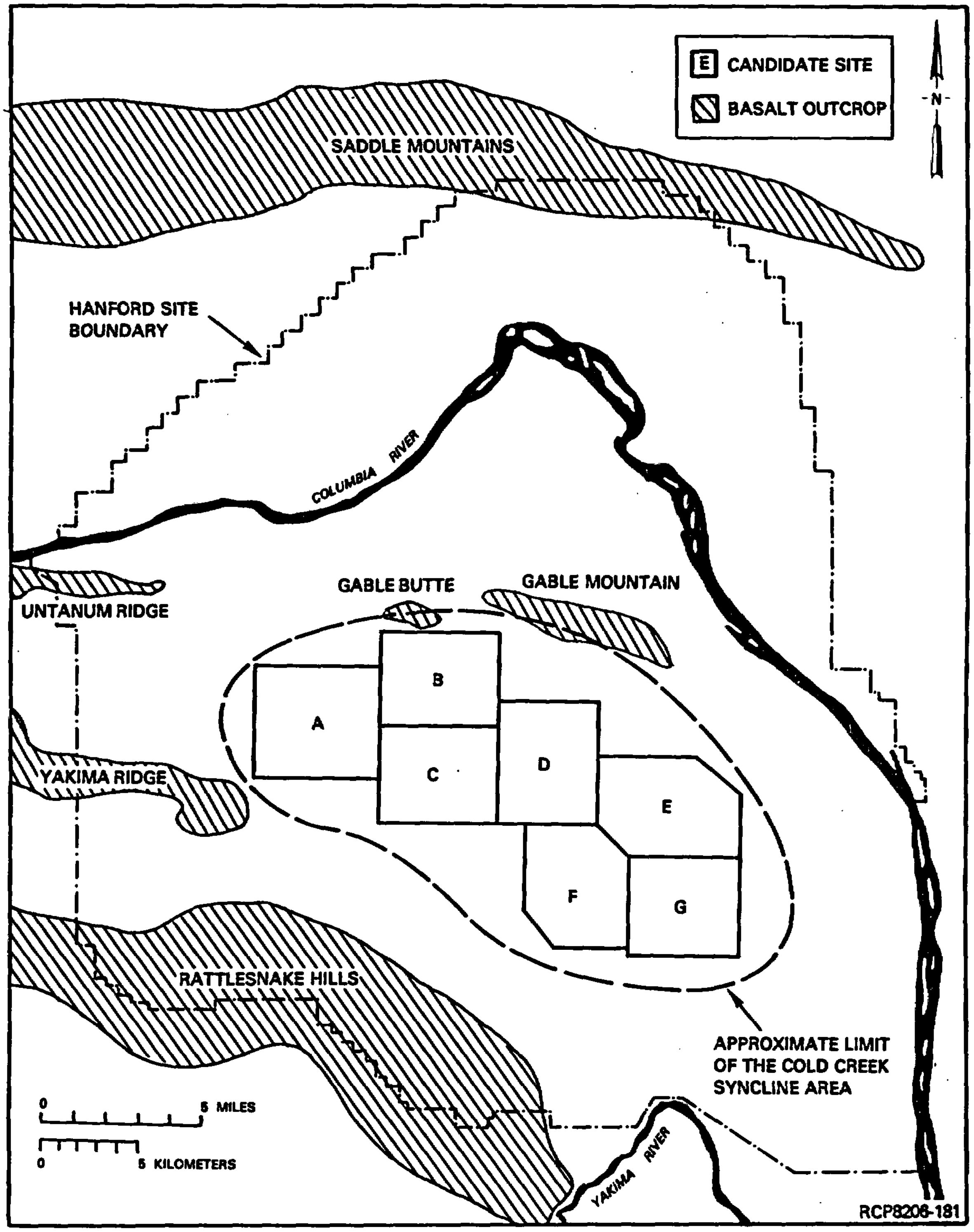

FIGURE 3-14. Initial Candidate Sites in the Cold Creek Syncline Area.

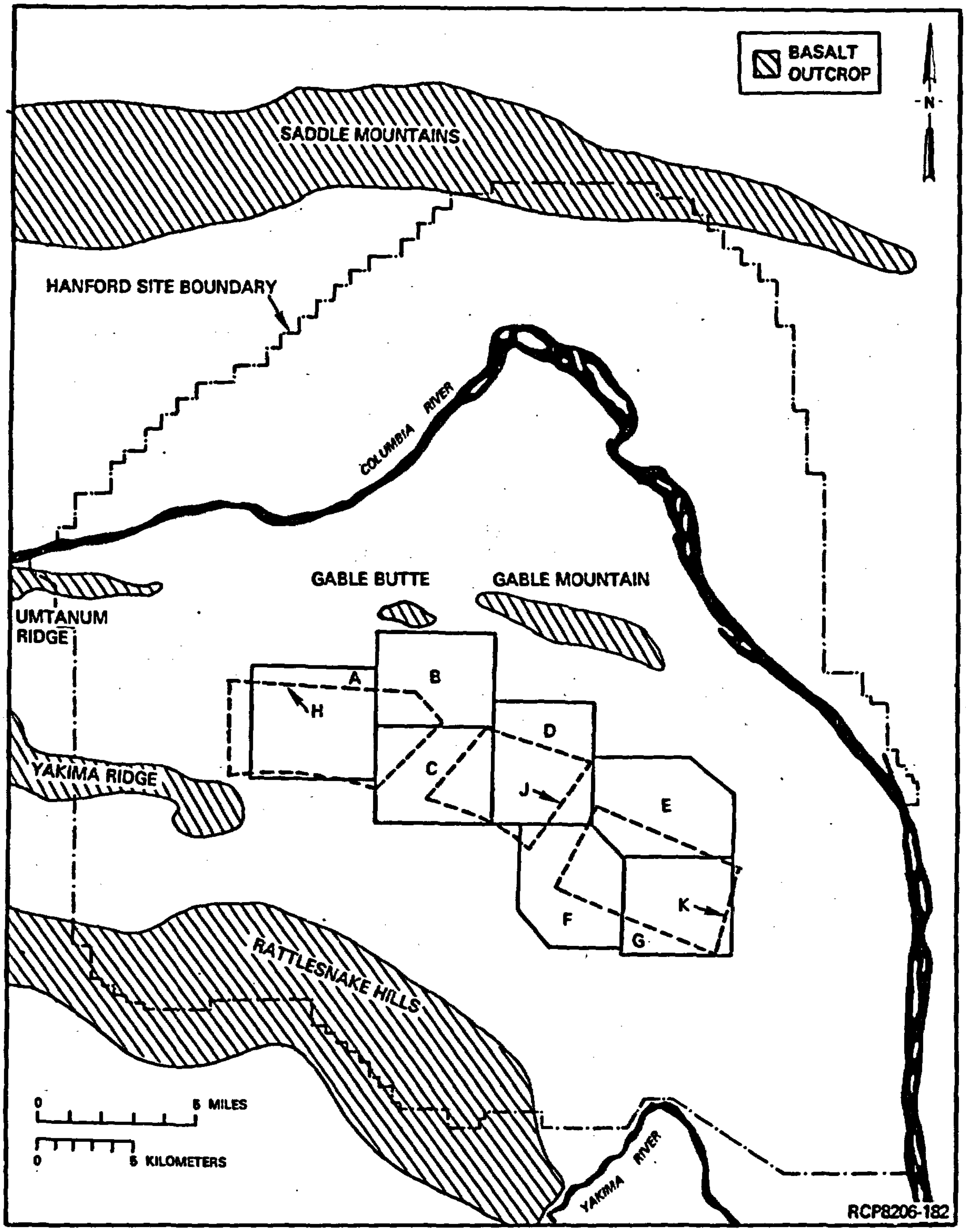

FIGURE 3-15. Ten Candidate Sites. The three superimposed candidate sites (H, J, and K) avoid prominent geophysical lineaments.

From a detailed evaluation of criteria and data comprising the criteria matrix, criteria were selected that could be used to differentiate between the candidate sites. The ten ranking criteria selected were: bedrock fractures and faults, lineaments, potential earthquake sources, groundwater traveltimes, contaminated soil/contaminated groundwater/surface facilities, host flow interior, tiers, vegetative natural communities, unique microhabitats, and special species (WCC, 1981).

As mentioned above, the site ranking was done using the method of dominance analysis. This was carried out by a siting committee formed of technical representatives from Woodward-Clyde Consultants and Rockwell Hanford Operations. Once the ranking criteria were defined, they were applied to each candidate site. The siting committee judged each site utilizing available published and unpublished data as outlined by the criteria matrix and their own professional judgment. The favorable or unfavorable consequence of each site in terms of the measures for each ranking criteria was then established (WCC, 1981).

The next step of dominance analysis was the determination of preference for a series of consequences. This became necessary because there were a number of criteria and alternative variations, and a simple dominance analysis was too difficult to perform. Ordinal dominance analysis was used to proceed with ranking (WCC, 1981).

Ordinal dominance analysis allows the assessment of tradeoffs to determine the relative importance of the measures used in differentiating among candidate sites. Tradeoffs were assessed by the siting committee. They were examined in two ways: First, given a hypothetical site with all the criteria at the most desirable levels and given that one criterion had to be changed to its least desirable level, which one would be changed? The criterion selected for this question had the least weight. The question was then repeated progressively until all criteria were ranked.

The second way of assessing tradeoffs required the determination of how much one was willing to give up from one criterion to enhance a second criterion. This rank ordering should agree with the first method (WCC, 1981). The results of the weighting procedure pointed up two features:

- In the site-ranking process, the siting committee had a strong consensus that environmental impact and man's activities criteria were useful only to differentiate among otherwise identical sites (no weight was placed on these criteria).

- The siting committee could not agree on the relative importance of the internal structures of the basalt flows (tiers versus thickness of flow interiors).

The final step was synthesizing the information for ranking. This step merely involved the siting committee's discussion and evaluation of all sites with respect to the ranking criteria, site characteristics, and analysis method.

The results of the ordinal dominance analysis are shown in Table 3-5. In this table, it is shown that six criteria formed the basis of ranking. The relative values assigned to each criterion were determined by means of scale or distance or a simple numerical scale based on level of acceptability. The additive numerical functions were determined based on the site-ranking-value terms indicated in Table 3-5. The results of the ranking show that site H is dominant over all other sites. Site A, which is almost totally included within Site H, has about the same dominance numerical value (4.68 and 4.66, respectively). These two sites were combined to form the reference repository location (Fig. 3-16).

Site J (see Fig. 3-15), another of the new sites designated to avoid the aeromagnetic anomalies in the Cold Creek syncline, was classified as the alternate site. The numerical dominance value of the J site was 3.70 (see Table 3-5). Table 3-5 shows that for the three most important criteria (considered by the siting committee), lineaments, host flow thickness, and tiering, candidate sites A and H rated numerically higher than all other sites with candidate site J ranked third. The reference repository location and the alternate repository location are shown in Figure 3-17.

The reference repository location consists of about 47 square kilometers (18 square miles) of nearly flat-lying terrain. The basalt formations underlying the reference repository location are buried by as much as 198 meters (650 feet) of sediments and are relatively flat lying.

The Columbia River Basalt Group within the Cold Creek syncline has been sampled at three locations to a depth of about 1,220 meters (4,000 feet), but only limited work has been conducted on the reference repository location. The field data indicate that the top of the basalts can be used to reasonably reflect the geologic structure of the underlying basalt flows.

Documentation of the study to identify a reference repository location on the Hanford Site is contained in WCC (1981, Vol. I and II).

3.5.4 Identification of Principal Borehole Site

With the identification of the A-H site as the reference repository location, the BWIP in conjunction with Kaiser Engineers, Inc. and Parsons Brinckerhoff Quade & Douglas, Inc., the architect-engineer for the BWIP, met to locate a proposed site for a principal borehole for an exploratory shaft. Two tentative locations for a repository shaft pillar within the reference repository location were proposed. These were situated about 1.6 kilometers (1 mile) apart west of the 200 West Area. The principal borehole and the Exploratory Shaft were considered directly relatable structurally and functionally to the shaft pillar area for the repository.

TABLE 3-5. Ordinal Dominance Analysis of Candidate Sites.

Candidate Site Relative Value Matrix

Candidate site	Lineaments (l')	Host flow (h)	Tiers (t)	Potential earthquake (p)	Groundwater travel (g')	Bedrock fractures (b)
A	0.92	0.67	1.00	0.75	0.25	0.54
B	0.25	1.00	0.67	0.63	0.50	0.19
C	0.50	0.58	0.67	0.47	0.50	1.00
D	0.33	0.75	0.33	0.88	1.00	0.32
E	0.33	0.67	0.00	1.00	1.00	0.24
F	0.00	0.00	0.33	0.00	0.25	0.92
G	0.42	0.00	0.00	0.41	0.00	0.00
H	1.00	0.67	1.00	0.69	0.25	0.38
J	0.58	0.67	0.33	0.63	1.00	0.81
K	0.58	0.17	0.00	0.38	0.25	0.00

Ordinal Dominance Analysis Table

Site-ranking value	l'	l'+h	l'+t	l'+h+t	l'+h+t +p	l'+h+t +p+g'	l'+h+t +p+g'+b	Site dominated by
A(0.834)	1.84	2.51	2.84	3.51	4.26	4.39	4.66	H
B(0.496)	0.50	1.50	1.17	2.17	2.79	3.05	3.15	A,H,J
C(0.550)	1.00	1.58	1.67	2.25	2.72	2.97	3.47	A,H
D(0.495)	0.66	1.41	0.99	1.74	2.62	3.12	3.28	A,H,J
E(0.442)	0.66	1.33	0.66	1.33	2.33	2.83	2.95	A,C,D,H,J
F(0.088)	0	0	0.33	0.33	0.33	0.46	0.92	All
G(0.255)	0.84	0.84	0.84	0.84	1.25	1.25	1.25	A,C,H,J,K
H(0.860)	2.00	2.67	3.00	3.67	4.36	4.49	4.68	--
J(0.584)	1.16	1.83	1.49	2.17	2.79	3.28	3.70	A,H
K(0.366)	1.16	1.33	1.16	1.33	1.71	1.84	1.84	A,H,J

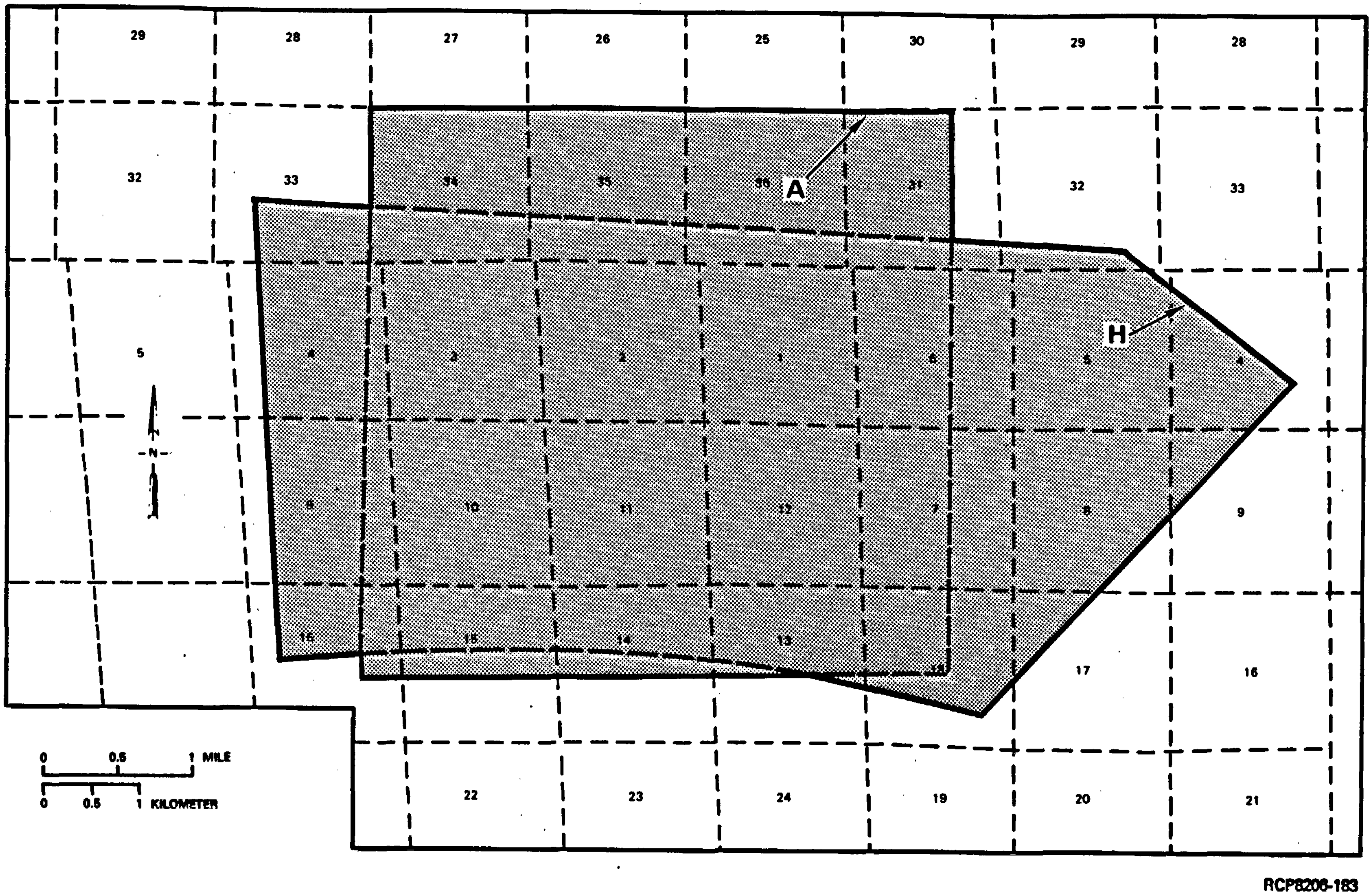

FIGURE 3-16. Reference Repository Location (A-H site).

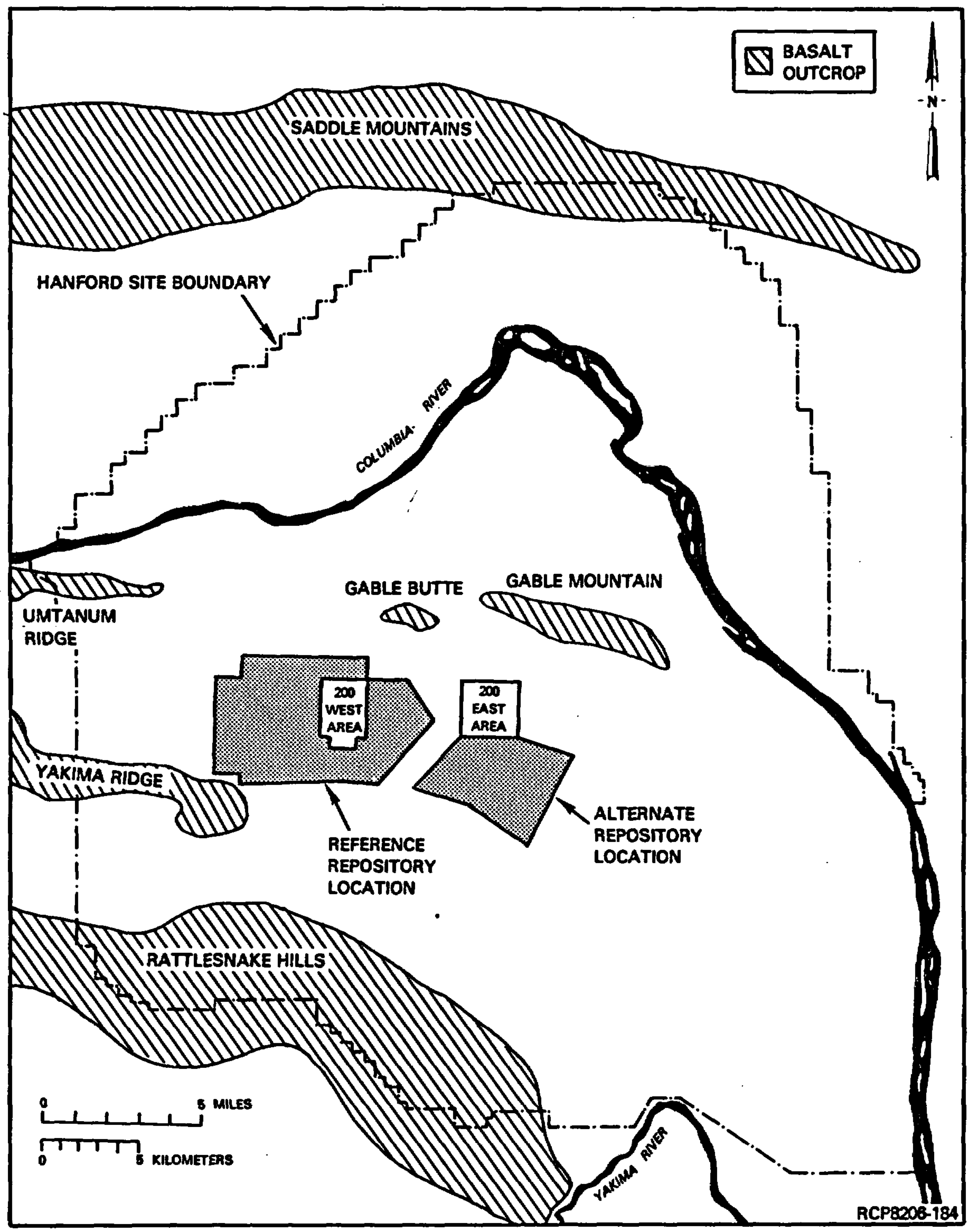

FIGURE 3-17. Location of the Reference Repository Location and Alternate Repository Location.

The limited site characterization information available from the reference repository location required that several shallow boreholes be drilled to the top of basalt to confirm the overall dip of the basalt units. Two of these boreholes were drilled to a depth of 456 meters (1,500 feet) to elevate structural continuity of the flow units. The results confirmed an overall dip of less than 1 degree across the reference repository location. The axis of the Cold Creek syncline was also determined more precisely. Figure 3-18 is a contour map of the top of basalt beneath the reference repository location and shows the location of boreholes drilled for characterization.

To enable selection of a specific location for construction of the principal borehole for the Exploratory Shaft, exclusion-area criteria were developed to aid in the selection of a specific location (BWIP, 1981b). These criteria are land use, surface contamination, groundwater contamination, Exploratory Shaft, and repository orientation.

A composite overlay of the reference repository location is shown in Figure 3-19, which is the result of screening of land use considerations, surface contamination, groundwater contamination, and Exploratory Shaft set-back requirements. This composite shows that the area remaining for consideration is in Sections 2, 3, 10, and 11 in the western half of the reference repository location. Within this area, adequate space exists for location of the Exploratory Shaft and repository area (WCC, 1980, Vol. I).

Other desirable features were also utilized to pick the specific location for a principal borehole for the Exploratory Shaft. Regarding the feature of minimum surface grade, the entire surface area in Sections 2, 3, 10, and 11 is nearly level, which means that the surface facilities could be located at any spot in this area with minimal surface grading. As a means of minimizing power and water costs, consideration was given toward locating the principal borehole close to the separations area where services are available. Since the engineering design of the repository will not be completed until information is obtained from depth, it is desirable to reserve as much room as possible for the repository location. To ensure flexibility, it would be desirable to locate it near the intersection of Sections 2, 3, 10, and 11, thereby providing the most area for movement of the repository. The location of the principal borehole should also be near the intersection of Sections 2, 3, 10, and 11. This is the location of an existing borehole, RRL-2, which has been cored to a depth of about 1,211 meters (3,973 feet).

On the basis of the site characterization work and the engineering studies, the DOE determined in May 1982 that the optimal area for siting a principal borehole for the Exploratory Shaft was near the intersection of Sections 2, 3, 10, and 11.

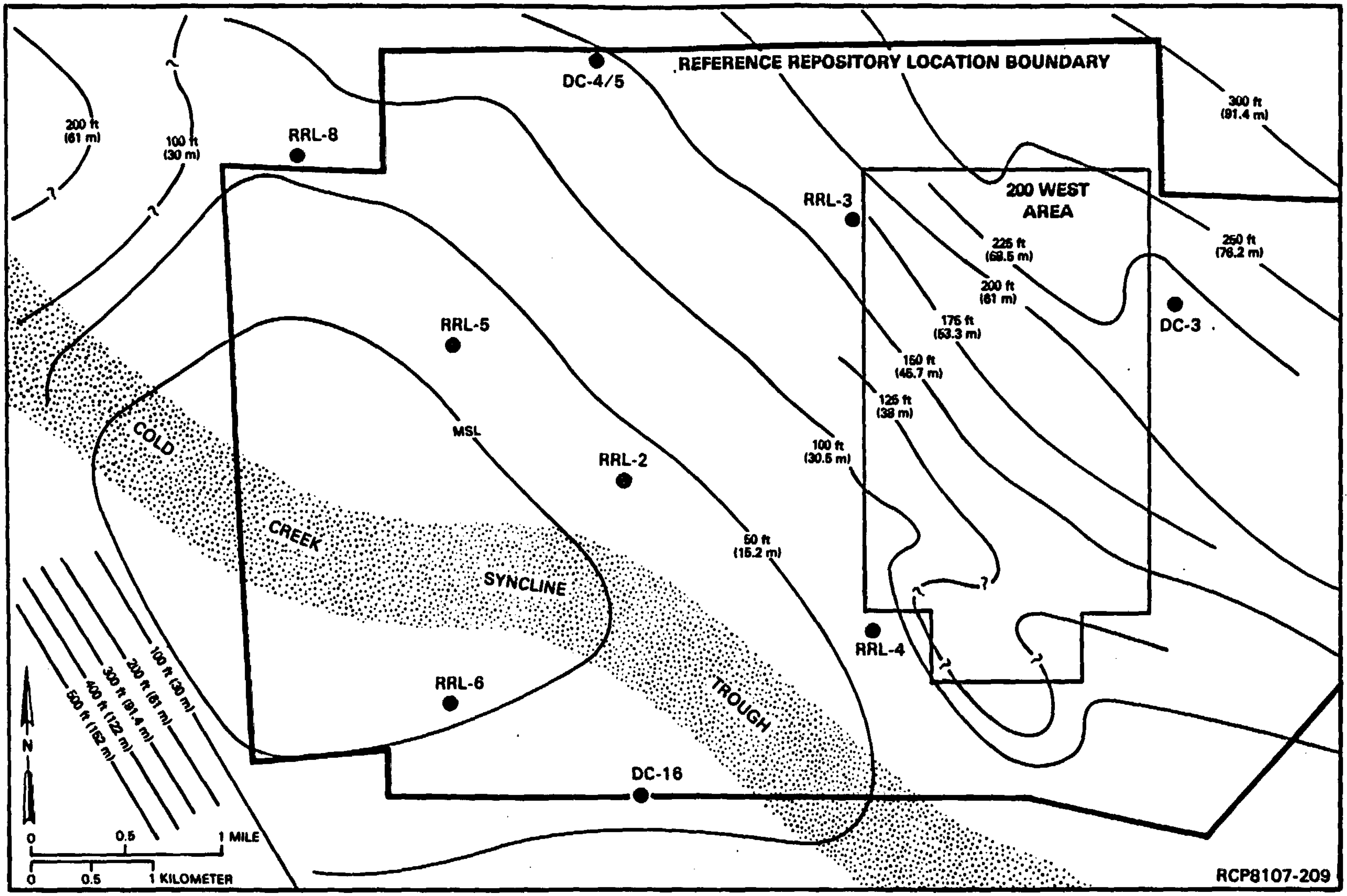

FIGURE 3-18. Top-of-Basalt Contours in the Reference Repository Location.

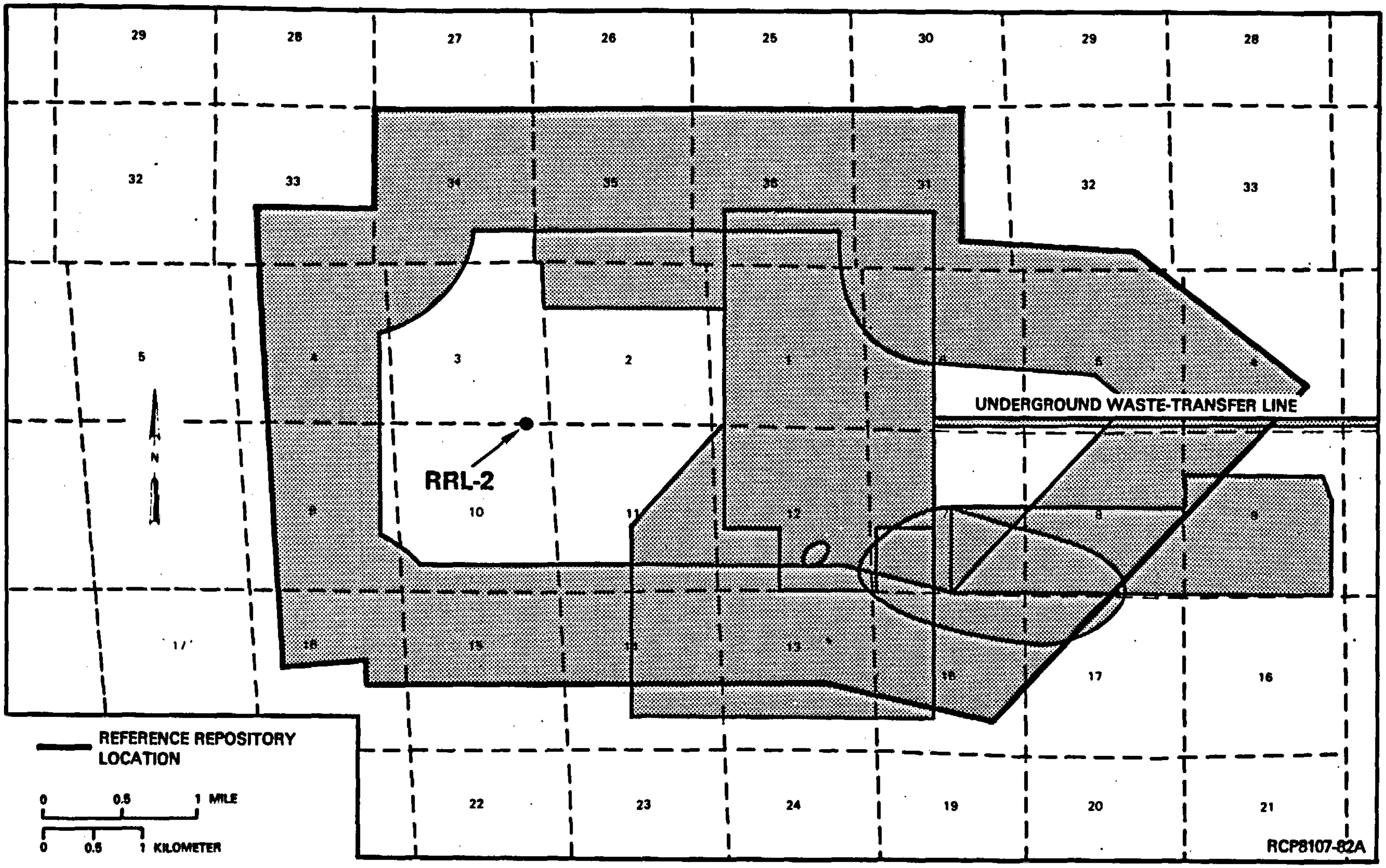

FIGURE 3-19. Composite Overlay Showing Suitable Areas for Siting Within the Reference Repository Location (unshaded areas within the A-H site).

3.6 REGIONAL AND LOCAL IMPACT ASSESSMENT OF A PROPOSED REPOSITORY

Section 112(b)(1)(E)(vi) of the Act requires an assessment of the regional and local impacts of locating a proposed repository at the site nominated for site characterization. Regional and local impacts of locating a nuclear waste repository at the Hanford Site include construction impacts, socioeconomic impacts associated with construction and operation, and transportation impacts associated with operation. Regional and local impacts are divided between those impacts that affect areas outside the Hanford Site (i.e., regional) and those impacts limited to the Hanford Site (i.e., local).

The Final Environmental Impact Statement: Management of Commercially Generated Radioactive Waste (DOE, 1980) presents an analysis of environmental impacts that could occur if various technologies for the disposal of radioactive waste were to be developed and implemented. The Final Environmental Impact Statement (DOE, 1980) is based on generic information rather than specific data. The impact assessment presented here is specific for a nuclear waste repository at Hanford, but is based on preliminary design information and must be considered as a predecessor of more detailed analyses to be prepared as more information becomes available. Such detailed analyses will be included in the environmental impact statement accompanying the Site Recommendation Report, if the reference repository location at Hanford is ultimately selected by the DOE for recommendation to the President as a repository site.

3.6.1 Construction Impacts of a Proposed Repository

Construction impacts associated with building a repository on the Hanford Site are mainly local impacts; i.e., impacts are limited to the Hanford Site. Major construction impacts are associated with surface facilities including development away from the repository site and development at the repository site.

3.6.1.1 Development Away From the Repository Site. Development away from the repository site consists of transportation facilities, utilities, and the visitors' center.

Transportation to the repository site will be provided by connections to the existing Hanford Site road and railroad networks. Rail traffic, originating at the Burlington Northern Railroad yard in Pasco will be transferred at the Hanford Site boundary to Hanford locomotives. A helicopter landing pad will also be provided at the repository site.

Incoming utilities consist of water, electric power, and telephone. Raw water will be supplied from the Columbia River by an existing river pump station, which will be modified by the addition of new pumps and other facilities. A new buried pipeline will connect these new pumps to the repository site. Two new 138-kilovolt transmission lines, routed over separate parallel rights-of-way, will connect the repository to the Hanford Site power system. A new overhead telephone line will connect the repository to the Hanford Site telephone network.

A visitors' center will be located at the intersection of the repository access road and an existing Hanford Site road.

By making connections with existing Hanford Site facilities, environmental impacts away from the repository site will be minimized. Also, prior to decisions regarding construction, environmental evaluations will be conducted and used as input to the final decisions. Construction practices to minimize impacts will be employed including dust suppression, soil stabilization, and allowing natural vegetation to reestablish along rights-of-way.

3.6.1.2 Development at the Repository Site. The repository site will consist of a 80-hectare (200-acre) central process area located over and contained within the surface projection of the 588-hectare (1,455-acre) subsurface facility. Surrounding the projection of the subsurface facility to the surface is a 2-kilometer (6,560-foot) control zone with an area of approximately 3,840 hectares (9,000 acres). The total area enclosed by the outside boundary of the control zone is approximately 4,247 hectares (10,500 acres). The entire central process area will be surrounded by a double security fence.

The major construction impacts at the repository site will be the selective clearing and grading of over 80 hectares (200 acres) of shrub-steppe terrain (i.e., all of the central process area plus an area outside the central process area for a parking lot, helicopter landing pad, and a mine water percolation pond). Any topsoil stripped at this time will be stockpiled for future replacement and planting. All of the plants within this area will be destroyed and all of the animals will be displaced. Ongoing environmental monitoring, however, continues to show no threatened or endangered species residing within the proposed repository site.

Following clearing and grading, the culverts, drainage structures, and the lower, large-diameter storm sewers will be installed. Excavations and embankments will be formed; storm drainage ditches and structures will be constructed. Dust and erosion control measures will continue during the entire construction phase until final paving, erosion control, and planting are provided.

The remoteness of the site from human habitation and from occupied Hanford facilities mitigates the effects of any high construction noise levels. Effective muffler systems will be used on heavy equipment during construction to minimize adverse environmental impacts. Impacts on members of the general public will meet the requirements of the Noise Pollution Control Act of 1972, which requires that "...noise levels do not exceed 70 decibels at the nearest habitation."

3.6.2 Socioeconomic Impacts of a Proposed Repository

The preliminary socioeconomic analysis in this section will focus on the anticipated cause and effect relationship between the construction and operation activities of a nuclear waste repository at Hanford and the demographic, economic, public service and social characteristics of the region containing the proposed repository located in basalt. The primary concern will be the identification of the size and distribution within the region of the demographic and economic impacts and their effect on community infrastructure. The analysis will also acknowledge the distinction between objectively measured changes in the socioeconomic conditions that are likely to occur in the study area and the subjective evaluations of those changes by the people who stand to be affected.

This is a prospective analysis of construction and operation activities that are not expected to begin until 1990. In addition, those activities are currently projected to last about 80 years before all activities are terminated. The current repository conceptual design is preliminary and subject to refinement and change. In addition, the study region has a history of volatility with respect to rapid change in socioeconomic conditions. Uncertainty in the scope of BWIP activities coupled with uncertainty in projecting baseline socioeconomic conditions far into the future dictate that this analysis will be general in focus and tentative in drawing conclusions about likely socioeconomic impacts.

Financial and technical assistance to a state in which a repository is sited is provided for in Section 116 of the Nuclear Waste Policy Act of 1982. Federal assistance would be designed to mitigate the impact on such state of the development of a repository. Specific details of this program have not been developed at this time.

3.6.2.1 Study Region. The study region is defined for the purposes of this analysis as the area surrounding the local project site (Hanford Site) that is expected to experience the major share of demographic, economic and infrastructure impacts from a potential repository. Prior analyses of project development activities on the Hanford Site by the Washington Public Power Supply System (WCC, 1975) have shown that the majority of in-migrant workers live in one of the Tri-Cities (Richland, Pasco, or Kennewick) or nearby Benton City or West Richland. With the recent Washington Public Power Supply System work force cutbacks and generally depressed economic conditions, claims for unemployment insurance by former Washington Public Power Supply System employees indicate that some of the Hanford work force live in Yakima County as well as many of the smaller outlying communities. Although these communities will continue to grow along with future growth in employment opportunity in and around the Tri-Cities, the study region as defined here will receive most of these new workers as residents and, therefore, will be faced with most of the potential socioeconomic impacts (both beneficial and adverse) of the project. Economic impacts will likely be even more concentrated in the study region than demographic impacts, given past patterns of the purchases of goods and services and the distribution of revenues associated with Hanford activities.

The judgment of the significance of any socioeconomic impacts due to a repository, especially those impacts that can be quantified, will largely be made relative to the projected baseline condition. In the following section, the expected repository work force will be examined in a general way and compared, in subsequent sections, with socioeconomic attributes of the study region such as housing availability, schooling, and local transportation systems. Given the uncertainty regarding future labor force conditions in the region, the analysis of project work force will provide a crude estimate of the demographic growth that could be caused by the project and will specify the assumptions on which this estimate is based.

3.6.2.2 Project Work Force. The entire project is assumed to proceed through four distinct stages beginning in 1990 and lasting a total of 82 years. Each of these stages involves a different set of activities and requires a specialized labor force to conduct these activities. The attributes of the potential repository that constitute important determinants of socioeconomic impacts are the size of the work force, the required skills of the work force, and the timing of the work activities over each of the four project stages. The discussion of the project work force in this report reflects the most current information available based on ongoing conceptual design efforts. However, this information is acknowledged to be preliminary and subject to changes in technical design considerations and in the scheduling of the proposed project activities.

The first component of the construction phase covers a 7-year period from 1990 to 1996. This phase involves the construction of surface facilities (service and storage), several access shafts, and subsurface facilities. A significant component of the construction work force will involve mining activities. This is an important consideration for the assessment of socioeconomic impacts because workers with the requisite mining skills are not likely to be found in the region's labor force. If workers with skills not readily available in the local area must in-migrate from outside areas, the implied growth in the area could cause socioeconomic impacts if the number of immigrants exceeds the ability of the community to absorb these impacts.

The second component is the operational phase. This phase is expected to last 24 years (from 1997 to 2020). It is the period of maximum activity, involving the mining of panels, drilling of storage holes and the receipt, packaging and emplacement of waste materials. The third component is the caretaker phase, lasting 31 years (from 2021 to 2051) and involving a greatly reduced level of manpower activity needed to meet the 50-year retrievability requirement. The final component is the backfilling phase, lasting 20 years (from 2052 to 2071).

An estimate of the total primary work force requirement is presented in Table 3-6. Since the mining component represents skills so specialized that most of this labor force component can be expected to in-migrate, the mine work force is estimated separately. When the nuclear waste repository in basalt conceptual design is developed in greater detail, the socioeconomic analysis will be able to estimate work force requirements and local availability more precisely.

TABLE 3-6. Estimated Basalt Waste Isolation Project Work Force Requirements[a] by Project Phase and Estimated In-Migration Caused by Project.

Project phase	Project period	Number of years	Mine work force	Other work force	Total average annual work force[b]	Estimated number of in-migrants[c]
I. Construction	1990 - 1996	7	300	300	600	1,600
II. Operation	1997 - 2020	24	200	750	950	2,500
III. Caretaker	2021 - 2051	31	--	130	130	300
IV. Backfill	2052 - 2071	20	--	210	210	500

[a]Work force data are preliminary estimates and are subject to further revision.

[b]Average annual work force figures are intended to reflect the number of workers that would be required on the job each day during the indicated project phase. Not enough scheduling information is available at this time to allow for an estimate of the variability of work force requirements within each phase (e.g., peak requirements). Average annual work force estimates were developed from preliminary estimates of total man-hours or man-days in each phase, assuming 2,000 hours or 250 days per man-year.

[c]Total number of in-migrants includes estimated in-migrating primary workers, secondary workers and the dependents of both primary and secondary workers. In-migrating primary workers are crudely estimated here by assuming that 95 percent of the mine work force and 50 percent of all other workers will in-migrate. Assuming a secondary employment multiplier of 1.9, new jobs in the secondary support section are estimated and it is further assumed that 50 percent of these secondary jobs will be filled by new in-migrants. Finally, each in-migrant worker is assumed to be accompanied by 1.5 dependents. These assumptions regarding propensity to in-migrate depend in turn on uncertain future levels of unemployment in the region and on concurrent construction activity, both of which help determine local labor availability. The calculated number of in-migrants has been rounded to two significant digits.

The need for a large number of workers having hard-rock mining skills is a characteristic of this project that is unique in comparison with other Hanford projects. Unless local workers can be trained in the required mining skills, almost all the miners needed during the construction and operation phases of the nuclear waste repository in basalt will have to in-migrate to the area.

Whether the level of primary work force in-migration is signficantly larger than that implied by the need for miners depends on several factors. First, the craft skills needed for repository construction and operation must be compared with the availability of local workers possessing these skills. Second, the craft unions play an important role in the assignment of available workers to available jobs. Third, any wage differential between BWIP jobs and comparable jobs at other projects will influence the propensity for employed workers to switch jobs. Fourth, and perhaps most important, the timing of BWIP activities relative to the timing of other industrial activities planned during this period of time can either reduce or increase the need for additional outside workers. The ability of the project to employ local workers would have a positive economic and psychological impact for the area, but it is new people coming in who can cause change to occur. Depending on its magnitude and perceived severity, such change could cause negative socioeconomic impacts.

As shown in Table 3-6, the total population impact caused by a major development project is typically larger than the number of primary workers needed on that project. However, in an area such as the Tri-Cities that has experienced several cycles of rapid population change, the secondary employment response to changing opportunity may significantly lag fluctuations in primary employment demand. For example, secondary business may not leave the area as soon as the primary activity is reduced. Secondary employment has stronger ties to the area compared with transient construction employment.

Different but simultaneous activities that draw from a common labor pool essentially compete for scarce labor resources. To the extent that the supply of workers having the needed skills is less than the demand, workers will either in-migrate or commute from long distances. This could become a burden upon the community if these workers need housing, schooling and other services that may be in short supply. The main determinant of socioeconomic impacts can be traced to the match between the pressures a project places upon a community (demographic, fiscal, services and social) and the ability of the community to meet those pressures in a planned, orderly, cost-effective way. In the case of the BWIP, the projected work force requirements and estimated project in-migration is small relative to recent Hanford Site activities and these effects can be expected to be spread across several large communities in Benton, Franklin, and Yakima Counties. However, actual work force requirements and patterns of in-migration will have to be monitored closely after the project is initiated because experience at other large development sites indicates that engineering conceptual designs tend to underestimate actual peak work force experience, largely due to scheduling problems that occur during the construction phase.

3.6.2.3 Demography. This study region has experienced dynamic swings in population, including sustained growth and sudden declines. The demographic fortunes of this region have been primarily driven by employment opportunities associated with Hanford Site developments, though more recently the manufacturing and agriculture sectors have exerted an increasingly influential and stabilizing effect on the region. Data on population size and distribution for Benton and Franklin Counties and the five major municipalities that constitute the study region are provided in Table 3-7. In addition, data are provided on population forecasts for the years 1985 and 1990. The 1990 forecasts made in 1982 are on the order of 20 percent lower than those prepared only one year earlier, a net difference of more than 37,000 persons expected in the bicounty area over the next 8 years. The current expectation, therefore, is for the bicounty area and the study region to grow in size by only about 4 percent over the 1980 to 1990 decade. This is compared with a growth of 54.8 percent over the prior decade, 1970 to 1980, an unusually rapid rate of growth.

Most of this growth can be attributed to net in-migration of population to the area in response to the rapid expansion of employment opportunity during the 1970-1980 decade. Net in-migration in this period accounted for 80 percent of Benton County's growth and almost 36 percent of Franklin County's growth. The balance of total growth is due to natural increase, the excess of births over deaths. Pinpointing the components of growth in each of the municipalities that constitute the study region is more difficult, however, because these cities have also grown due to annexation of adjacent unincorporated areas. According to a recent analysis, "...from 1970 to 1980, the cities of Richland, Pasco, Kennewick, and West Richland had expanded their municipal boundaries by 51 percent" (State of Washington, 1982c).

Population forecasts for this region are quite uncertain at best, even when looking only a few years into the future. Population forecasts covering the 80-year lifespan of the BWIP activities would be very difficult. There is no way to accurately anticipate developments in the economy of this area over such a long time frame. Several useful observations can be made, however. First, the economy of the region is becoming increasingly diversified and hence is likely to show greater stability in the future than in the past. Second, the sheer numbers of people living and working in the study region are now and can reasonably be expected to remain large relative to the potential additional population influx that this proposed repository might cause. Based on the very rough numbers provided in Table 3-6, the BWIP in-migration, when dispersed residentially over the municipalities both within and outside of the defined study region, is not likely to amount to even 2 percent of the baseline population. This effect is small compared with the population and employment dynamics experienced in the study region in recent years. Notwithstanding the painful effects of the recent Washington Public Power Supply System employment cutbacks, population in the area is expected to grow between 1980 and 1990 but at a rate far below the explosive growth experienced during the prior decade.

TABLE 3-7. Population Size and Distribution Based on Census, Current Estimates, and Forecasts for Benton and Franklin Counties and Municipalities in the Basalt Waste Isolation Project Study Region--1970-2000.

Municipality by county	Census and current estimates			Actual change (%) 1970-1980	Forecasts[d]		Forecast change (%) 1980-1990
	1970[a,b]	1980[a,c]	1981[c]		1985	1990	
Benton	67,540	109,444	111,700	62.0	103,994	112,475	2.8
*Benton City	1,070	2,087	1,970	95.0			
*Kennewick	15,212	34,397	35,350	126.1			
*Richland	26,290	33,578	33,550	27.7			
*West Richland	1,107	2,938	3,934[a]	165.4			
Balance of County	23,861	36,444	36,896	52.7			
Franklin	25,816	35,025	36,200	35.7	33,500	37,591	7.3
*Pasco	13,920	18,425	19,050	32.4			
Balance of County	11,896	16,600	17,150	39.5			
Bicounty Total	93,356	144,469	147,900	54.8	137,494	150,066	3.9
NWRB Study Region[e]	57,599	90,837	93,854	57.7	86,600[f]	94,500[f]	4.0
State Total	3,413,244	4,132,180	4,264,000	21.1	4,339,000	4,603,000	11.4

NOTE: NWRB = nuclear waste repository in basalt.

[a]Actual census count.

[b]State of Washington, 1979.

[c]State of Washington, 1982a.

[d]State of Washington, 1982b.

[e]The five incorporated cities listed above (denoted by *) comprise the study region for this analysis. Although this area includes some people living in unincorporated areas, that component cannot be accurately measured with currently available data.

[f]Forecasts for the study region are based on a projected 63 percent share of the respective bicounty forecasts.

3.6.2.4 Economy. Up until mid-1981, the economy in the Tri-Cities metropolitan area had been one of the most rapidly growing in the nation. The economic base in the Tri-Cities in 1981 was distributed into four major sectors: Hanford construction activities (primarily Washington Public Power Supply System facilities) accounted for 36 percent; research and development (including DOE activities) accounted for 39 percent; agriculture and related agro-business accounted for 20 percent, and other manufacturing accounted for the remaining 5 percent. The most significant decline in employment during 1982 has been due to the loss of Washington Public Power Supply System jobs. Employment losses are expected to increase through the end of fiscal year 1983. Total unemployment in the Tri-Cities has increased from about 7,300 persons in 1981 to 12,200 by November 1982 or from 8.9 percent to 15.4 percent of the resident civilian labor force (State of Washington, 1982c, 1982d). Nonagricultural wage and salary employment in the Tri-Cities for fiscal year 1981 and projected for fiscal year 1983 is shown in Table 3-8. Significant losses in jobs for the area over this period are principally due to lost construction jobs and smaller associated lost employment in the secondary support sectors of the local economy. The manufacturing and agriculture sectors can anticipate small gains over this time, however.

As with population forecasts, it is exceedingly difficult to anticipate the BWIP impacts on the region's economy years into the future. Current conceptual design estimates suggest that about $33 million in wages may be expended annually for construction labor and another $113 million a year for other direct construction costs. By way of comparison, the Hanford Site payroll exceeded $400 million in 1978. Annual direct operating costs are currently estimated to be under $60 million per year. The fiscal impact that these figures represent for the study region will depend upon economic conditions at the time the construction and operation phases are undertaken. Although the amounts involved are not large compared with the massive capital projects experienced at the Hanford Site in recent years, they will likely be welcomed for the stabilizing effect they would exert on the economy.

3.6.2.5 Housing. Housing impacts are directly related to the growth or decline of population and the health of the economy in the study region. The demand for housing created by development activity such as the BWIP depends not only on the number of new in-migrating workers expected in the study region but also on their family size, income level, and preference for housing type. Housing impacts are less likely if currently available housing stock can absorb the influx of new people than if new construction is required. However, since vacancy rates vary by type and quality of housing, some in-migrants may experience difficulty obtaining the housing of their choice and means.

TABLE 3-8. Nonagricultural Wage and Salary Employment in the Richland-Kennewick-Pasco Standard Metropolitan Statistical Area, Fiscal Year Averages, 1981 and Projected 1983 (State of Washington, 1982c).

Type of employment	Fiscal year average employment			
	1981		1983	
	Number	Percent	Number	Percent
Total	62,380	100.0	54,600	100.0
Total manufacturing	9,080	14.6	9,810	18.0
Food and kindred products	2,140	3.4	2,410	4.4
Printing and publishing	330	0.5	330	0.6
Chemicals	5,620	9.0	6,080	11.1
Primary and fabricated metals	350	0.6	350	0.6
Other manufacturing	640	1.0	640	1.2
Mining	40	0.1	40	0.1
Construction	12,180	19.5	6,630	12.1
Transportation, communications, and utilities	2,410	3.9	2,350	4.3
Wholesale and retail trade	11,450	18.4	10,550	19.3
Finance, insurance and real estate	1,590	2.5	1,510	2.8
Services	15,590	25.0	14,110	25.8
Government	10,040	16.1	9,600	17.6

According to a recent housing study for the Tri-Cities Standard Metropolitan Statistical Area (T-CRERC, 1982), the study region's housing sector is experiencing "...a virtual depression." Due primarily to the Washington Public Power Supply System employment cutbacks, high interest rates and a sluggish economy, the region's housing construction activity has declined over 90 percent during 1982, vacancies have increased dramatically, particularly for apartment units (over 22 percent according to one survey), and prices for rental units have begun to drop. Nevertheless, financing is difficult to find at a reasonable rate, and new single family units are in the high price range.

The potential for housing impacts due to the BWIP can be roughly estimated by comparing a projection of housing demand due to project-induced in-migration with project housing availability. Housing demand is estimated on the basis of 1.1 primary or secondary in-migrant job holders per household. This assumption recognizes that the spouses of some primary or secondary workers will themselves hold a primary or secondary job. In addition, some unrelated workers will likely share housing. Based on the projected number of in-migrant primary and secondary workers to the study region during the operations phase of the BWIP, a need for about 900 housing units is estimated. Conservatively assuming that the ratio of housing units to total population that existed around 1980 will be obtained during the operations phase (0.35 to 1) and a comparable vacancy rate of about 2 percent (below current levels but more reasonable over the long run), and a baseline population of around 100,000 people in the study region, then perhaps 700 housing units would be available in the study region itself and several hundred more in other portions of the Standard Metropolitan Statistical Area. Since some of the projected in-migrants can be expected to seek housing outside this area, existing vacant units may be able to accommodate the remaining new families.

While it is possible that housing could be affected by the BWIP, the overall anticipated demographic and economic effect of the BWIP is likely to be less than for projects that the region's housing market has been able to accommodate without serious impact in the past. The housing construction industry has been very responsive to rapidly changing housing needs in the region.

3.6.2.6 <u>Local Transportation</u>. Local traffic congestion has been recognized as one of the major socioeconomic impacts of rapid growth in the study region in the past. Heavy rush-hour traffic flows have been experienced in the Tri-Cities, particularly during the period of very rapid population growth and high Hanford Site employment in the recent past. Since the employment declines and subsequent net out-migration from the area due to the Washington Public Power Supply System cutbacks, traffic congestion has noticeably abated. However, future growth in the region could cause the traffic problem to recur. The major municipalities are arranged geographically in a linear pattern with respect to the Hanford Site that tends to create transportation bottlenecks during periods of heavy use. Recognizing this problem, transportation planning has received special attention in the region, and a number of recent and prospective developments suggest that future problems in this regard are much less likely than in the past. For example, several bridges are under construction or under consideration that would provide more direct access for Franklin County residents to the Richland area and the Hanford Site. A public transportation system went into service in May 1982 and the DOE operates a shuttle bus system from Richland to the Hanford Site.

Forecasts of possible transportation impacts due to the BWIP are difficult to make given uncertainty in both the project configuration and the local economy. Based on the work force information presented in Section 3.6.2.2, an estimate of the number of cars to be added to the daily commuter traffic during the operations phase would be on the order of 700 vehicles per day during the operations phase. This represents approximately 400 vehicles commuting to the Hanford Site and approximately 300 vehicles added to the general commuter traffic that is generated by secondary workers. This estimate is based on an assumed 1.4 persons per vehicle on average. This is also a maximum estimate because it assumes no use of mass transit. Given that these commuters are residentially dispersed within the region, this implied addition to local traffic flow is quite small and adverse impacts are unlikely.

3.6.2.7 Public Services. Socioeconomic impacts associated with public services are not expected to be significant. The size of the direct project effects are small relative to the fluctuations, both up and down, that have been experienced in the study region over the last decade. This large variation in demand for public services has sometimes exceeded service system capacity but generally services have been adequately provided. The study region has planned for and accommodated itself well to the rapid growth it has experienced. The recent economic declines and loss of activity has been experienced as more painful than rapid growth. Therefore, it seems likely that BWIP-related growth will be viewed as positive. If it makes up for slack demand for services during a periodic economic down time, that would be viewed as a beneficial impact. If the project activity adds to concurrent future growth, the study region should be able to assimilate that as well.

Given the small demographic impact of the BWIP relative to the projected baseline, the impacts on public services are expected to be insignificant. For example, the level of fire and police protection is not likely to be affected. Education impacts can be estimated roughly by assuming that 25 percent of the new in-migrant population is school-age (5 to 19). On this basis, the BWIP might bring in 600 new students during the operation phase or about 2 percent of the current Tri-Cities school enrollment. Given that these students would be distributed over several school districts and assuming expected growth in the school systems over the next 10 to 80 years commensurate with projected population growth, the school system should be able to absorb the new growth with no adverse impact.

Little increase in demand for health care facilities and personnel is expected due to the project. Projected new in-migration would require less than three beds and one physician at the prevailing ratio of beds and physicians to population. Currently, health care facilities within the study region are implementing expansion plans, and the BWIP is not expected to have any adverse health care impacts.

Finally, the projected population in-migration due to BWIP is not likely to cause any direct impacts on available park land nor cause recreational facilities to be overused.

3.6.2.8 Utilities. Utilities are comprised of the power and communications systems, water and sewer systems, and the solid waste services. Impacts from BWIP activities are not expected to be significant; however, the effect of population increase in the Tri-Cities needs to be carefully assessed by utility planners. Of the utilities, water and sewer systems are particularly sensitive to population increases. Several of the systems within the Tri-Cities were approaching capacity before the recent economic decline. Sewer treatment facilities that are currently being upgraded in the city of Richland are designed to handle the needs of a population of 68,500. The level of growth implied by the BWIP is not expected to adversely impact the utilities.

3.6.2.9 Long-Term Socioeconomic Impacts. Potential long-term impacts that could be caused by the BWIP include economic, political, aesthetic and cultural effects. Impacts of this sort tend to be evaluated subjectively and are difficult to measure. Long-term economic impacts include the potential impacts that implementation of a nuclear waste repository at the Hanford Site could have on public perceptions of the suitability of the study region for diversified industrial development.

Aesthetic impacts are expected to be small primarily because the repository site is remotely located with respect to population settlement. Therefore, visual and noise impacts will be minimal. Regarding the potential for cultural impacts, care will be taken to ensure that repository construction does not disrupt any known or potential historical or archeological sites that may be located on the Hanford Site.

3.6.3 Transportation

The repository will be designed to receive spent fuel, high-level waste, and transuranic waste; the repository may receive high-level waste from defense-related nuclear activities, subject to future policy decisions. Shipments by both truck and rail will be accommodated.

Shipments of nuclear waste to the repository will be in accordance with applicable Federal regulations. Currently, the NRC and the U.S. Department of Transportation regulate the transportation of radioactive materials. Transportation and packaging criteria and standards are outlined in the Code of Federal Regulations (NRC, 1982c; DOT, 1981). The environmental impacts of transportation activities are addressed in Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes (NRC, 1977).

The normal radiological impacts of nuclear waste transportation are small in comparison to naturally occurring ambient radiation levels. The potential radiological consequences of transportation accidents are controlled primarily by the highly damage-resistant shipping containers required under current Federal regulations. Although these radiological impacts are of less significance, they are directly related to transportation distance. The localized environmental impacts due to transportation will be determined in part by the availability and capacity of existing highway and rail routes and the existence of heavily populated areas along these routes. If selected as a repository, the environmental impact statement that will be prepared to support the Site Recommendation Report will provide detailed information on the environmental impacts of waste transportation.

Both spent fuel and high-level waste will be shipped in specially designed casks. Spent fuel has been shipped in the United States for many years. Massive, heavily shielded shipping casks are available for both truck and rail transport of spent fuel from current-generation nuclear power reactors. Most spent fuel casks will accept either pressurized-water-reactor or boiling-water-reactor spent fuel by using different fuel baskets. These casks are designed to contain the spent fuel even in the event of an accident. More detailed information on existing spent fuel shipping casks is presented in Technology for Commercial Radioactive Waste Management (DOE, 1979). The existing spent fuel shipping casks were designed to transport short-cooled (6 months or less) irradiated fuel; however, most spent fuel transport will involve fuel that has been cooled for at least several years. Consequently, there appears to be considerable incentive to build a fleet of casks specifically designed for this long-cooled fuel because its lower thermal and radiation output would permit an increase in cask capacity and a reduction in handling costs.

Solidified high-level waste will be shipped in casks similar to those for spent fuel. Prior to shipment, the waste will be packaged in cylindrical steel canisters, currently assumed to be 0.3 meter (1 foot) in diameter by 3 meters (10 feet) long. The configuration differences between spent fuel and high-level waste shipping cask designs are dictated by the differences in waste form/package dimensions, thermal power, and radiation levels; high-level waste is a more concentrated waste form than the spent fuel from which it is produced.

The split between rail and truck shipments cannot be forecast with certainty, due to numerous economic and logistics considerations. Rail shipments are generally favored over truck shipments due to their significantly larger payloads. However, since some nuclear power reactors do not currently have rail spurs at their sites, it is assumed that about 10 percent of spent fuel shipments will be by truck and 90 percent by rail. It is assumed that all commercial high-level waste shipments will be by rail.

The shipping cask capacities assumed in estimating numbers of shipments to the repository are as follows:

	Truck cask	Rail cask
Spent fuel assemblies--pressurized water reactor	2	12
Spent fuel assemblies--boiling water reactor	5	32
High-level waste canisters (0.3 meter (1 foot) diameter x 3 meters (10 feet) long)	Not applicable	12

The current repository design basis specifies a total of approximately 70,000 metric tons (77,000 tons) of spent fuel or its equivalent quantity of commercial high-level waste to be shipped to the repository during the initial 24 years of operation. This design basis includes the assumption that one-half of this total will be in the form of spent fuel and the other half will be in the form of reprocessing plant high-level waste. On these bases, the average annual shipments to the repository will consist of 168 truck shipments of spent fuel, 246 rail shipments of spent fuel, and 55 rail shipments of commercial high-level waste. These annual average shipments total to 469, or between 1 and 2 shipments per day.

3.6.4 Summary Conclusions

The regional and local impacts that might be associated with a proposed repository located at the Hanford Site are expected to be minimal. An infusion of construction and operating monies over the next several decades would bolster the economy of the area without deleteriously affecting the environment. Preliminary analyses of the waste isolation capability of basalts at Hanford are favorable and final analyses will have to be approved by the NRC prior to operation of a repository at the Hanford Site.

4.0 GLOSSARY

accessible environment -- the atmosphere, the land surface, surface waters, oceans, and the parts of the lithosphere that are more than 10 kilometers (6.2 miles) in any direction from the original location of any of the radioactive waste in a disposal system.

aquifer -- a zone of rock below the surface of the earth that readily transmits water and is capable of producing water as from a well.

capillary fringe -- a zone in which the pressure is less than atmospheric, overlying the zone of saturation and containing capillary interstices.

containment -- confinement of the radioactive wastes within prescribed boundaries (e.g., within a waste package).

disqualifying conditions -- a condition that, if present at a candidate site, would eliminate that site from further consideration; a single disqualifying condition is sufficient.

disturbed zone -- that portion of the controlled area whose physical or chemical properties have changed as a result of underground facility construction or heat generated by the emplaced radioactive waste such that the resultant change in properties may have a significant effect on the performance of the geologic repository.

Eh -- a measure of the oxidation reduction potential (volts); the difference in potential measured in a cell having both oxidized and reduced form of an element (measured) and the standard hydrogen electrode potential.

engineered barrier -- man-made components of a disposal system designed to prevent the release of radionuclides into the geologic medium involved; such term includes the high-level radioactive waste form, high-level radioactive waste canisters, and other materials placed over and around such canisters.

fault -- a fracture in the earth's crust along which movement parallel to the fracture plane has displaced one side of the fracture relative to the other side.

faulting -- the tectonic process that results in displacement along a fault.

favorable condition -- a condition that, if present, will not necessarily qualify a site relative to a specific criterion but will enhance confidence that subsequent analysis will show that the criterion can be met.

fugacity -- the escaping tendency of a substance in a heterogeneous mixture, by which a chemical equilibrium responds to altered conditions.

geologic repository -- any system licensed by the NRC that is intended to be used for, or may be used for, the permanent deep geologic disposal of high-level radioactive waste and spent nuclear fuel, whether or not such system is designed to permit the recovery, for a limited period during initial operation, of any materials placed in such system. Such term includes both surface and subsurface areas at which high-level radioactive waste and spent nuclear fuel handling activities are conducted.

geologic setting -- the tectonic, geologic, hydrologic, and geochemical systems of a region in which a site is or may be located.

highly populated area -- the population center associated with a Standard Metropolitan Statistical Area.

host rock -- rock within which radioactive waste is emplaced for disposal.

hydrologic properties -- those properties of rocks and water, including their chemistry, that influence the flow of groundwater.

igneous activity -- emplacement (intrusion) of molten rock material into solid rocks in the earth's crust or expulsion (extrusion) of such material onto the earth's surface or into its atmosphere or water bodies.

isolation -- inhibiting the transport of radioactive material in the subsurface so that the amounts and concentrations of this material entering the accessible environment will be kept within prescribed limits.

models -- conceptual definitions and associated mathematical representations that simulate the response of a repository system under natural or perturbed conditions. An example is a hydrologic model to predict groundwater travel or radionuclide transport from the waste-emplacement area to the accessible environment.

permanent closure -- final backfilling of the underground facility and the sealing of shafts and boreholes.

potentially adverse condition -- a condition that, if present, will not disqualify a site relative to a specific criterion but will require additional analysis, specific site characterization, or identification of compensating or mitigating factors before qualifying the site.

pre-waste-emplacement -- under conditions that exist before repository development.

qualifying condition -- a condition that, if met, indicates that a site is acceptable with respect to a specific criterion.

Quaternary (Period) -- the youngest of the periods of the Cenozoic Era, extending from approximately 1.8 million years ago to the present.

radioactive waste -- high-level radioactive waste and spent nuclear fuel.

repository -- geologic repository.

saturated zone -- that part of the Earth's crust beneath the deepest water table in which all voids, large and small, are ideally filled with water under pressure greater than atmospheric.

site -- a surface location and the underlying rocks, including the underground facility and extending through a control zone from which incompatible activities will be restricted after permanent closure.

system performance -- the total, integrated result of all acting processes and events caused by or affecting a repository.

tectonic -- of, pertaining to, or designating the rock structure and external forms resulting from deformation of the earth's crust.

underground facility -- the underground structure, including mined openings and backfill material, but excluding shafts, boreholes, and their seals.

unsaturated zone -- the zone between the land surface and the deepest water table; it includes the capillary fringe. Generally, water in this zone is under less than atmospheric pressure, and some of the voids may contain air or other gases at atmospheric pressure. Beneath flooded areas or in perched water bodies the water pressure locally may be greater than atmospheric.

5.0 REFERENCES

Algermissen, S. T., 1969, "Seismic Risk Studies in the United States," in Proceedings of the Fourth World Conference on Earthquake Engineering, Santiago, Chile, January 1969.

Algermissen, S. T. and Perkins, D. M., 1976, A Probabilistic Estimate of Maximum Acceleration in Rock in the Contiguous United States, Open-File Report 74-416, U.S. Geological Survey, Denver, Colorado.

Ames, L. L., 1980, Hanford Basalt Flow Mineralogy, PNL-2847, Pacific Northwest Laboratory, Richland, Washington.

Ames, L. L. and McGarrah, J. E., 1980a, Basalt Radionuclide Distribution Coefficient Determinations FY 1979 Annual Report, PNL-3146, Pacific Northwest Laboratory, Richland, Washington.

Ames, L. L. and McGarrah, J. E., 1980b, Investigation of Basalt-Radionuclide Distribution Coefficients: Fiscal Year 1980 Annual Report, RHO-BWI-C-108/PNL-3462, Pacific Northwest Laboratory for Rockwell Hanford Operations, Richland, Washington, December 1980.

Ames, L. L. and McGarrah, J. E., 1980c, High-Temperature Determination of Radionuclide Distribution Coefficients for Columbia River Basalts, RHO-BWI-C-111/PNL-3250, Pacific Northwest Laboratory for Rockwell Hanford Operations, Richland, Washington, December 1980.

APCA, 1980, General Regulation 80-7 of the Benton-Franklin-Walla Walla Counties Air Pollution Control Authority, Board of Directors of the Benton-Franklin-Walla Walla Counties Air Pollution Control Authority, Richland, Washington, published May 6, 1980, effective July 1, 1980.

Apted, M. J. and Myers, J., 1982, Comparison of the Hydrothermal Stability of Simulated Spent Fuel and Borosilicate Glass in a Basaltic Environment, RHO-BW-ST-38 P, Rockwell Hanford Operations, Richland, Washington, July 1982.

ARHCO, 1976, Preliminary Feasibility Study on Storage of Radioactive Wastes in Columbia River Basalts, ARH-ST-137, Atlantic Richfield Hanford Company, Richland, Washington.

Arnett, R. C., Baca, R. G., Caggiano, J. A., Price, S. M., Gephart, R. E., and Logan, S. E., 1980, Preliminary Hydrologic Release Scenarios for a Candidate Repository Site in the Columbia River Basalts, RHO-BWI-ST-12, Rockwell Hanford Operations, Richland, Washington, November 1980.

Arnett, R. C., Mudd, R. D., Baca, R. G., Martin, M. D., Norton, W. R., and McLaughlin, D. B., 1981, Pasco Basin Hydrologic Modeling and Far-Field Radionuclide Migration Potential, RHO-BWI-LD-44, Rockwell Hanford Operations, Richland, Washington, June 1981.

Atomic Energy Act of 1954, Public Law 83-703

Baca, R. G., Wilde, R. T., Arnett, R. C., and Deju, R. A., 1982, Performance Assessment for a Repository in Basalt: A Summary of Preliminary Results, RHO-BW-SA-248 P, Rockwell Hanford Operations, Richland, Washington, September 1982.

Barton, N., Lein, R., and Lunde, T., 1974, "Engineering Classification of Rock Masses for the Design of Tunnel Support," Rock Mechanics, Vol. 6, pp. 189-236.

Bieniawski, Z. T., 1979, "The Geomechanics Classification in Rock Engineering Applications," in Proceedings of the 4th International Society of Rock Mechanics, Montreaux, Switzerland.

Blackwell, D. D., 1978, "Heat Flow and Energy Loss in the Western United States," in Cenozoic Tectonics and Regional Geophysics of the Western Cordillera, Smith, R. B. and Eaton, G. P., eds., Memoir 152, Geological Society of America.

BOC, 1981, 1980 Census of Population and Housing, Washington, PHC80-V-49, Advance Reports, Bureau of the Census, U.S. Department of Commerce, Washington, D.C., March 1981.

Bull, C., 1979, "Glaciological Parameters of Disruptive Event Analysis," in A Summary of FY-1978 Consultant Input for Scenario Methodology Development, Scott, B. L., Benson, G. L., Craig, R. A., and Harwell, M. A., eds., PNL-2851, Pacific Northwest Laboratory, Richland, Washington.

Bull, C., 1980, Glaciological Parameters of Disruptive Event Analysis, PNL-2863, Pacific Northwest Laboratory, Richland, Washington.

BWIP, 1980, Identification of Candidate Sites Suitable for a Geologic Repository in Basalt Within Hanford, RHO-BWI-LD-24, Rockwell Hanford Operations, Richland, Washington.

BWIP, 1981a, Comparison of NWTS-33(2) Criteria and BWIP Screening Considerations, RHO-BW-EV-1 P, Rockwell Hanford Operations, Richland, Washington.

BWIP, 1981b, The Identification of a Preferred Site for the Exploratory Shaft Within the Reference Repository Location (RRL): Hanford Site, RHO-BWI-ST-16, Rockwell Hanford Operations, Richland, Washington.

Byalobzheskii, A. V., 1970, Radiation Corrosion, AEC-TR-7096, U.S. Atomic Energy Commission, Washington, D.C.

Cline, J. F., Vresh, D. W., and Rickard, W. H., 1977, "Plants and Soil on a Sagebrush Community on the Hanford Reservation," Northwest Science, Vol. 51, No. 6, p. 70.

COE, 1951, Artificial Flood Possibilities on the Columbia River, U.S. Army Corps of Engineers, Washington District, Washington, D.C.

COE, 1969, Lower Columbia River Standard Project Flood and Probable Maximum Flood, U.S. Army Corps of Engineers, North Pacific Division, Portland, Oregon.

Daubenmire, R., 1970, Steppe Vegetation of Washington, Technical Bulletin 62, Experimental Station, Washington State University, Pullman, Washington.

Department of Energy Organization Act of 1977, Public Law 95-91.

Doctor, P. G., Oberlander, P. L., Rice, W. A., Devary, J. L., Nelson, R. W., and Tucker, P. E., 1982, A Technology Demonstration: Geostatistical and Hydrologic Analysis of Salt Areas, PNL-4129, Pacific Northwest Laboratory, Richland, Washington, September 1982.

DOE, 1978a, Environmental Assessment for the Exploratory Borehole Drilling Activity: Wells ARH-DC-4, -5, -6, -7, and -8, Hanford Reservation, Benton County, Washington, DOE/EA-0048, U.S. Department of Energy, Washington, D.C., June 1978.

DOE, 1978b, Environmental Assessment for the Near-Surface Test Facility, Hanford Reservation, Richland, Washington, DOE/EA-0052, U.S. Department of Energy, Washington, D.C., December 1978.

DOE, 1979, Technology for Commercial Radioactive Waste Management, DOE/ET-0028, U.S. Department of Energy, Washington, D.C.

DOE, 1980, Final Environmental Impact Statement: Management of Commercially Generated Radioactive Waste, DOE/EIS-0046-F, U.S. Department of Energy, Washington, D.C., October 1980.

DOE, 1981, "Program of Research and Development for Management and Disposal of Commercially Generated Radioactive Wastes; Record of Decisions," Federal Register, Vol. 46, No. 93, pp. 26677-26679, May 14, 1981.

DOE, 1982a, Environmental Assessment for the Basalt Waste Isolation Project Exploratory Shaft Construction, DOE/EA-0188, U.S. Department of Energy, Washington, D.C., August 13, 1982.

DOE, 1982b, "Department of Energy, Finding of No Significant Impact and Notice of Availability of Environmental Assessment for the Conduct of Detailed Site Through the Construction of an Exploratory Shaft on the Hanford Site," Federal Register, Vol. 47, No. 180, pp. 40820-40821.

DOE, 1982c, Site Characterization Report for the Basalt Waste Isolation Project, DOE/RL 82-3, Rockwell Hanford Operations for the U.S. Department of Energy, Washington, D.C., November 1982.

DOE, 1982d, Public Draft, National Plan for Siting High-Level Radioactive Waste Repositories and Environmental Assessment, DOE/NWTS-4, DOE/EA-151, National Waste Terminal Storage Program, U.S. Department of Energy, Washington, D.C., February 1982.

DOE, 1983, "Department of Energy, 10 CFR 960, Nuclear Waste Policy Act of 1982; Proposed General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories," Federal Register, Vol. 48, No. 26, pp. 5670-5682, February 7, 1983.

DOI, 1982, "U.S. Department of the Interior, National Register of Historic Places," Federal Register, Vol. 47, No. 22, p. 4932.

DOT, 1981, "Part 171 - General Information Regulations and Definitions; Part 172 - Hazardous Materials Table and Hazardous Materials Communications Regulations; Part 173 - Shippers-General Requirements for Shipments and Packagings; Part 174 - Carriage by Rail; Part 175 - Carriage by Aircraft; Part 176 - Carriage by Vessel; Part 177 - Carriage by Public Highway; Part 178 - Shipping Container Specifications; Part 179 - Specifications for Tank Cars; Part 191 - Transportation of Natural and Other Gas by Pipeline, Reports of Leaks; Part 192 - Transportation of Natural and Other Gas by Pipeline, Minimum Federal Safety Standards; Part 195 - Transportation of Liquids by Pipeline," Title 49, Chapter 1, Code of Federal Regulations-Transportation, U.S. Department of Transportation, Washington, D.C.

Early, T. O., Jacobs, G. K., Drewes, D. R., and Routson, R. C., 1982, Geochemical Controls on Radionuclide Releases from a Nuclear Waste Repository in Basalt: Estimated Solubilities for Selected Elements, RHO-BW-ST-39 P, Rockwell Hanford Operations, Richland, Washington, September 1982.

Energy Reorganization Act of 1974, Public Law 93-438.

EPA, 1977, "Environmental Protection Agency, 40 CFR 190, Environmental Radiation Protection Standards for Nuclear Power Operations," Federal Register, Vol. 42, p. 2860, January 13, 1977.

EPA, 1980, Pollutant Emissions, 40 CFR 51.24, Revised as of July 1, 1980.

EPA, 1982, "Environmental Protection Agency, 40 CFR 191, Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes," Federal Register, Vol. 47, No. 250, December 29, 1982, Proposed Rule.

ERDA, 1975, Final Environmental Statement - Waste Management Operations, Hanford Reservation, Richland, Washington, ERDA-1538, 2 Volumes, U.S. Energy Research and Development Administration, Washington, D.C., December 1975.

ERDA, 1977, Alternatives for Long-Term Management of Defense High-Level Radioactive Waste, Hanford Reservation, Richland, Washington, ERDA-77-44, U.S. Energy Research and Development Administration, Washington, D.C.

Fitzner, R. E. and Price, K. R., 1973, The Use of Hanford Waste Ponds and Waterfowl and Other Birds, BNWL-1738, Pacific Northwest Laboratory, Richland, Washington.

Fitzner, R. E. and Rickard, W. H., 1975, Avifauna of Waste Ponds, ERDA Hanford Reserach, Benton County, Washington, BNWL-1885, Pacific Northwest Laboratory, Richland, Washington.

Foley, M. G., Petrie, G. M., and Craig, R. G., 1981, Geological Simulation Model for a Hypothetical Site in the Columbia Plateau: Results, PNL-3542-2, Pacific Northwest Laboratory, Richland, Washington.

Friedlander, G., Kennedy, J. W., and Miller, J. M., 1964, Nuclear and Radiochemistry, John Wiley & Sons, Inc., New York.

Gephart, R. E., Arnett, R. C., Baca, R. G., Leonhart, L. S., and Spane, F. A., Jr., 1979, Hydrologic Studies Within the Columbia Plateau, Washington: An Integration of Current Knowledge, RHO-BWI-ST-5, Rockwell Hanford Operations, Richland, Washington, October 1979.

GG/GLA, 1981, Economic Geology of the Pasco Basin, Washington and Vicinity, RHO-BWI-C-109, Geosciences Group and George Leaming Associates for Rockwell Hanford Operations, Richland, Washington, July 1981.

Golden, J., Quellette, R. P., Saari, S., and Cheremisinoff, P. N., 1979, Environmental Impact Data Book, Ann Arbor Science, Ann Arbor, Michigan, 864 pp.

Harty, H., 1979, The Effects of the Ben Franklin Dam on the Hanford Site, PNL-2821, Pacific Northwest Laboratory, Richland, Washington.

Helgeson, H. C., 1968, "Evaluation of Irreversible Reactions in Geochemical Processes Involving Minerals and Aqueous Solutions--I: Thermodynamic Relations," Geochimica et Cosmochimica Acta, Vol. 32, pp. 853-877.

Jacobs, G. K. and Apted, M. J., 1981, "Eh-pH Conditions for Groundwater at the Hanford Site, Washington: Implications for Radionuclide Solubility in a Nuclear Waste Repository located in Basalt," EOS, Transactions of the American Geophysical Union, Vol. 62, p. 1065.

Johnpeer, G. D., Miller, D., and Goles, G., 1981, Assessment of Potential Volcanic Hazards, Pasco Basin, Washington, RHO-BWI-CR-130 P, Ertec Western, Inc. for Rockwell Hanford Operations, Richland, Washington, pp. 3-1 to 3-44, August 1981.

Johnson, G. E., Loveland, T. R., and Anderson, W. H., 1981, The Columbia River and Tributaries Irrigation Withdrawals Analysis Project, Executive Summary, Report No. CRT-45, U.S. Geological Survey/U.S. Army Corps of Engineers, Sioux Falls, South Dakota.

KE/PB, 1982, Engineering Study, Nuclear Waste Repository in Basalt, Project B-301, RHO-BWI-C-116, Volumes I and II, A Joint Venture of Kaiser Engineers, Inc. and Parsons Brinckerhoff Quade & Douglas, Inc. for Rockwell Hanford Operations, Richland, Washington, March 1982.

Korosec, M. A. and Schuster, J. E., 1980, The 1978-1980 Geothermal Resource Assessment Program in Washington, Open-File Report 81-3, Division of Geology and Earth Resources, Washington State Department of Natural Resources, Olympia, Washington, July 1981.

Koster van Groos, A. F., 1981, Determination of Dehydration Temperatures of a Secondary Vug-Filling Mineral (Smectite Clay) Using a Differential Thermal Analysis at Various Pressures, RHO-BWI-C-102, University of Illinois for Rockwell Hanford Operations, Richland, Washington, March 1981.

Leaming, G. F., 1981, An Evaluation of Water Resource Economics Within the Pasco Basin, RHO-BWI-C-121, Rockwell Hanford Operations, Richland, Washington, September 30, 1981.

MacNish, R. D. and Barker, R. A., 1976, Digital Simulation of a Basalt Aquifer System, Walla Walla River Basin, Washington and Oregon, Water Supply Bulletin 44, Washington State Department of Ecology, Olympia, Washington.

Murphy, P. J. and Johnpeer, G. D., 1981, An Assessment of Geothermal Resource Potential, Pasco Basin and Vicinity, Washington, RHO-BW-CR-128 P, Ertec Western, Inc. for Rockwell Hanford Operations, Richland, Washington, August 20, 1981.

Myers. C. W. and Price, S. M., eds., 1981, Subsurface Geology of the Cold Creek Syncline, RHO-BWI-ST-14, Rockwell Hanford Operations, Richland, Washington.

Myers, C. W./Price, S. M., Caggiano, J. A., Cochran, M. P., Czimer, W. J., Davidson, N. J., Edwards, R. C., Fecht, K. R., Holmes, G. E., Jones, M. G., Kunk, J. R., Landon, R. D., Ledgerwood, R. K., Lillie, J. T., Long, P. E., Mitchell, T. H., Price, E. H., Reidel, S. P., and Tallman, A. M., 1979, Geologic Studies of the Columbia Plateau: A Status Report, RHO-BWI-ST-4, Rockwell Hanford Operations, Richland, Washington.

National Environmental Policy Act of 1969, Public Law 91-190, 42 USC 4321.

Nelson, R. A., Kocherhaus, J. G., and Schnapp, M. R., 1982, In Situ and Laboratory Geotechnical Test Results from Borehole GD-1 in Southeast Utah, ONWI-400, Woodward-Clyde Consultants for the Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, Ohio, November 1982.

Noise Pollution Control Act of 1972, Public Law 92-574, 86 Stat. 1234.

NRC, 1977, Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes, NUREG-0170, U.S. Nuclear Regulatory Commission, Washington, D.C.

NRC, 1978, "Proposed Statement of General Policy, Licensing Procedures for Geologic Repositories for High-Level Radioactive Wastes," Federal Register, Vol. 43, No. 223, pp. 53869-53872, November 17, 1978.

NRC, 1981a, "Nuclear Regulatory Commission, 10 CFR 60, Disposal of High-Level Radioactive Wastes in Geologic Repositories," Federal Register, Vol. 46, No. 130, July 8, 1981, Proposed Rules.

NRC, 1981b, Disposal of High-Level Radioactive Wastes in Geologic Repositories: Licensing Procedures, Title 10, Chapter 1, Code of Federal Regulations-Energy, Part 60, U.S. Nuclear Regulatory Commission, Washington, D.C., February 25, 1981.

NRC, 1982a, Standards for Protection Against Radiation, Title 10, Chapter 1, Code of Federal Regulations-Energy, Part 20, U.S. Nuclear Regulatory Commission, Washington, D.C., April 23, 1982.

NRC, 1982b, Disposal of High-Level Radioactive Wastes in Geologic Repositories, Title 10, Code of Federal Regulations-Energy, Part 60, Subpart E, U.S. Nuclear Regulatory Commission, Washington, D.C., November 18, 1982, Final Draft.

NRC, 1982c, Packaging of Radioactive Material for Transport and Transportation of Radioactive Material Under Certain Conditions, Title 10, Chapter 1, Code of Federal Regulations-Energy, Part 71, U.S. Nuclear Regulatory Commission, Washington, D.C.

Nuclear Waste Policy Act of 1982, Public Law 97-425.

NWTS, 1982, Proceedings of the 1982 National Waste Terminal Storage Program Information Meeting, DOE/NWTS-30, Office of National Waste Terminal Storage Integration, Battelle Memorial Institute, Columbus, Ohio, December 1982.

ONWI, 1979, Site Qualification Criteria, Draft, ONWI-33(2), Office of Nuclear Waste Isolation, Columbus, Ohio.

ONWI, 1981, Engineering Feasibility Studies for Candidate Salt Domes: National Waste Terminal Storage Repository No. 1, Special Study No. 5, ONWI-283, Stearns-Roger Services Inc. for the Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, Ohio, December 1981.

ONWI, 1982, Gulf Coast Salt Domes Geologic Area Characterization Report: Introduction, Volume I, ONWI-117, Law Engineering Testing Company for the Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, Ohio, July 1982.

Orgill, M. M., Sehmel, G. A., and Bander, T. J., 1974, "Regional Wind Resuspension of Dust," Pacific Northwest Laboratory Annual Report for 1973, Part 3, Atmospheric Sciences, BNWL-1850 PT3, Battelle, Pacific Northwest Laboratories, Richland, Washington, pp. 214-219.

Pacific Northwest River Basins Commission, 1980, Irrigated Lands in the Pacific Northwest, Land Resources Committee of the Pacific Northwest River Basins Commission for the Depletions Task Force of the Columbia River Water Management Group, Vancouver, Washington.

Price, E. H., 1982, Structural Geometry, Strain Distribution, and Tectonic Evolution of Umtanum Ridge at Priest Rapids, and a Comparison with Other Selected Localities Within Yakima Fold Structures, South-Central Washington, Ph. D. Dissertation, Washington State University, Pullman, Washington; also RHO-BWI-SA-138, Rockwell Hanford Operations, Richland, Washington.

PSPL, 1982, Skagit-Hanford Nuclear Project, Preliminary Safety Analysis Report, Puget Sound Power and Light Company, Bellevue, Washington.

Rasmussen, N. H., 1967, "Washington State Earthquakes 1840 through 1965," Bulletin of the Seismological Society of America, Vol. 57, No. 3, p. 463.

Reidel, S. P. and Fecht, K. R., 1982, Uplift and Subsidence Rates in the Central Columbia Plateau and Their Relation to Siting a Waste Repository at Hanford, Washington, RHO-BW-SA-187 P, Rockwell Hanford Operations, Richland, Washington, May 1982.

Rice, D. G., 1968a, Archaeological Reconnaissance - Ben Franklin Reservoir Area, 1968, Laboratory of Anthropology, Washington State University, Pullman, Washington.

Rice, D. G., 1968b, Archaeological Reconnaissance - Hanford Atomic Works, Laboratory of Anthropology, Washington State University, Pullman, Washington.

Salter, P. F., Ames, L. L., and McGarrah, J. E., 1981a, Sorption of Selected Radionuclides on Secondary Minerals Associated with the Columbia River Basalts, RHO-BWI-LD-43, Rockwell Hanford Operations, Richland, Washington, April 1983.

Salter, P. F., Ames, L. L., and McGarrah, J. E., 1981b, The Sorption Behavior of Selected Radionuclides on Columbia River Basalts, RHO-BWI-LD-48, Rockwell Hanofrd Operations, Richland, Washington, August 1981.

Savage, J. C., Lisowski, M., and Prescott, W. H., 1981, "Geodetic Strain Measurement in Washington," Journal of Geophysical Research, Vol. 86, No. 136, pp. 4929-4940.

Smith, M. J., Anttonen, G. J., Barney, G. S., Coons, W. E., Hodges, F. N., Johnston, R. G., Kaser, J. D., Manabe, R. M., McCarel, S. C., Moore, E. L., Noonan, A. F., O'Rourke, J. E., Schulz, W. W., Taylor, C. L., Wood, B. J., and Wood, M. I., 1980, Engineered Barrier Development for a Nuclear Waste Repository Located in Basalt, RHO-BWI-ST-7, Rockwell Hanford Operations, Richland, Washington, May 1980.

Sommer, D. J., Rau, R. G., and Robinson, D. C., 1981, Population Estimates for the Areas Within a 50-Mile Radius of Four Reference Points on the Hanford Site, PNL-4010, Pacific Northwest Laboratory, Richland, Washington.

State of Washington, 1979, State of Washington Population Trends, 1979, Population, Enrollment, and Economic Studies Division, Washington State Office of Financial Management, Olympia, Washington, August 1979.

State of Washington, 1981, Forecasts of the State and County Populations by Age and Sex: 1985-2000, With Estimates for 1980, Special Report No. 36, Forecasting and Support Division, Washington State Office of Financial Management, Olympia, Washington, May 1981.

State of Washington, 1982a, State of Washington Population Trends of 1982, State of Washington, Office of Financial Management, Olympia, Washington.

State of Washington, 1982b, Forecasts of the State and County Populations by Age and Sex: 1985-1990, Special Report No. 59, Forecasting and Support Division, Washington State Office of Financial Management, Olympia, Washington.

State of Washington, 1982c, Annual Planning Report: 1982, State of Washington, Employment Security Department, Richland-Pasco-Kennewick SMSA, Olympia, Washington.

State of Washington, 1982d, Labor Area Summary, State of Washington, Employment Security Department, Richland-Pasco-Kennewick SMSA, Olympia, Washington.

Stephan, J. G., Foote, H. P., and Coburn, V. L., 1979, Well Location and Land-Use Mapping in the Columbia Plateau Area, RHO-BWI-C-61/PNL-3295, Pacific Northwest Laboratory for Rockwell Hanford Operations, Richland, Washington, October 1979.

Stobbs, J. J. and Swallow, A. J., 1962, "Effects of Radiation of Metallic Corrosion," Metallurgic Reviews, Vol. 7, No. 25.

Stone, W. A., Jenne, D. E., and Thorp, J. M., 1972, Climatolography of the Hanford Area, BNWL-1605, Battelle, Pacific Northwest Laboratories, Richland, Washington.

Tallman, A. M., Fecht, K. R, Marrath, M. C., and Last, G. V., 1979, Geology of the Separation Areas, Hanford Site, South-Central Washington, RHO-ST-23, Rockwell Hanford Operations, Richland, Washington.

Tanaka, H. H., Hansen, A. J., Jr., and Skrivan, J. A., 1974, Digital-Model Study of Groundwater Hydrology, Columbia Basin Irrigation Project Area, Washington, Water-Supply Bulletin 40, Washington State Department of Ecology, Olympia, Washington.

T-CRERC, 1982, Tri-Cities Real Estate Research Report, Tri-Cities Real Estate Research Committee, Richland, Washington.

USGS and PAG, 1981, Geodolite Observations Near Hanford, Washington, RHO-BW-CR-132 P, U.S. Geological Survey and the Performance Assessment Group, Basalt Waste Isolation Project, Rockwell Hanford Operations, Richland, Washington, October 1981.

UWGP, 1979, Annual Report on Earthquake Monitoring of Eastern Washington, Geophysics Program, University of Washington, Seattle, Washington.

Wallace, R. W., Landstrom, D. K., Blair, S. C., Howes, B. W., Robkin, M. A., Benson, G. L., Reisenauer, A. E., Walters, W. H., and Zimmerman, M. G., 1980, Topical Report on Release Scenario Analysis of Long-Term Management of High-Level Defense Waste at the Hanford Site, PNL-3363, Pacific Northwest Laboratory, Richland, Washington.

WCC, 1975, Socioeconomic Study: WPPSS Nuclear Projects 1 and 4 and Supplement, Woodward-Clyde Consultants, San Francisco, California, for Washington Public Power Supply System, Richland, Washington, April 1975.

WCC, 1980, Site Locality Identification Study: Hanford Site, Vol. I: Methodology, Guidelines, and Screening; Vol. II: Data Cataloging, RHO-BWI-C-62, Woodward-Clyde Consultants for Rockwell Hanford Operations, Richland, Washington, July 1980.

WCC, 1981, Study to Identify a Reference Repository Location for a Nuclear Waste Repository on the Hanford Site, Vol. I: Text; Vol. II: Appendixes, RHO-BWI-C-107, Woodward-Clyde Consultants for Rockwell Hanford Operations, Richland, Washington, May 1981.

Wood, B. J., 1980, Estimation of Waste Package Performance Requirements for a Nuclear Waste Repository in Basalt, RHO-BWI-ST-10, Rockwell Hanford Operations, Richland, Washington, July 1980.

WPPSS, 1974, Preliminary Safety Analysis Report, Amendment 9, Washington Public Power Supply System, Richland, Washington.

Wu, C. S., 1978, Sensitization, Intergranular Attack, Stress Corrosion Cracking, and Irradiation Effects on the Corrosion of Iron-Chromium-Nickel Alloys, ORNL/TM-6311, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Wukelic, G. E., Foote, H. P., Blair, S. C., and Begej, C. D., 1981, Monitoring Land and Water-Use Dynamics in the Columbia Plateau Using Remote-Sensing Computer Analysis and Integration Techniques, RHO-BW-CR-122 P/PNL-4047, Pacific Northwest Laboratory for Rockwell Hanford Operations, Richland, Washington, September 1981.

DOE/EA-0210

Draft Environmental Assessment for Characterization of the Hanford Site Pursuant to the Nuclear Waste Policy Act of 1982 (Public Law 97-425)

Hanford Site
Richland, Benton County, Washington

February 1983

U.S. Department of Energy
Washington D.C. 20585

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DRAFT ENVIRONMENTAL ASSESSMENT
FOR
CHARACTERIZATION OF THE HANFORD SITE
PURSUANT TO THE
NUCLEAR WASTE POLICY ACT OF 1982
(PUBLIC LAW 97-425)

HANFORD SITE
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FOREWORD

On January 7, 1983, President Reagan signed into law the Nuclear Waste Policy Act of 1982 (Public Law 97-425). This Act establishes a step-by-step process by which the President, Congress, affected individual states and Indian tribes, U.S. Department of Energy (DOE), and other Federal agencies can work together in the siting, construction, and operation of a high-level nuclear waste repository.

The DOE is required by Section 116(a) of the Act to identify states having potentially acceptable sites for a waste repository. A potentially acceptable site is defined by the Act as "...any site at which, after geologic studies and field mapping but before detailed geologic data gathering, the Department undertakes preliminary drilling and geophysical testing for the definition of the site location." By letter dated February 2, 1983, the Secretary of the DOE notified the Governor and Legislature of the State of Washington that the Hanford Site, near Richland, Washington, contains a potentially acceptable repository site.

Pursuant to Section 112 of the Act, the DOE issued Proposed General Guidelines for Recommendation of Sites for Nuclear Waste Repositories on February 7, 1983 in the Federal Register.

The next step under the Act is the DOE's nomination of five locations for site characterization, based on a consideration of the siting guidelines and the environmental assessments to be prepared for each of the five nominated sites, followed by a recommendation of three candidate sites to the President for his approval. The DOE intends to complete these actions in the summer of 1983 in order to permit the conduct of a sufficiently thorough site characterization program at each site to support the Presidential recommendation of a site for the first repository by March 31, 1987, as required by the Act.

Site characterization work at Hanford has been ongoing since 1976. The principal borehole at Hanford was approved in May 1982, and the Exploratory Shaft was begun in November 1982. An environmental assessment for Basalt Waste Isolation Project Exploratory Shaft construction was prepared by the DOE and issued in September of 1982 to meet the requirements of the National Environmental Policy Act of 1969. A finding of no significant impact (FONSI) was published in the Federal Register on September 16, 1982. The Nuclear Waste Policy Act of 1982 establishes a new requirement that an environmental assessment evaluating specific issues contained in the Act be prepared. This document is a draft of the environmental assessment required by the Act. Under the terms of the Act, site characterization work may continue at this site while certain requirements of the Act are being implemented. The final environmental assessment will accompany the nomination of the Hanford Site for site characterization, pursuant to Section 112 of the Act. Pursuant to Section 112(f) of the Act, ongoing site characterization work has been continued during the preparation of this environmental assessment.

Chapter 1.0 of the environmental assessment discusses the basis for recommending the Hanford Site for site characterization. Chapter 2.0 contains a series of background summaries of topics that are relevant to the information presented in the remainder of the environmental assessment. The material necessary to meet the requirements of Section 112(b)(1)(E) of the Act is presented in Chapter 3.0.

CONTENTS

FIGURES:

TABLES:

1.0 BASIS FOR NOMINATION OF THE HANFORD SITE

The Hanford Site, and more specifically the reference repository location, is evaluated in detail in Chapter 3.0 of this draft environmental assessment. The results of this evaluation are the basis for nominating the Hanford Site for site characterization leading to selection of the first repository site. The major conclusions from Chapter 3.0 are presented in this chapter. Based on currently available information, there do not appear to be any factors pertaining to the Hanford Site that preclude it from being nominated by the U.S. Department of Energy (DOE) as a candidate site. Several years of effort have not revealed any features that would disqualify Hanford as a potential repository site. Detailed site characterization studies are under way and an Exploratory Shaft will be completed to provide manned access to the three candidate horizons: the Cohassett flow, the McCoy Canyon flow, and the Umtanum flow of the Grande Ronde Basalt. Information obtained during these studies is necessary to determine whether the Hanford Site should ultimately be recommended as a site for development of a repository.

1.1 SITE CHARACTERIZATION SUITABILITY

The proposed siting guidelines (DOE, 1983) have been individually evaluated and the preliminary conclusions indicate that site characterization work should continue. However, full compliance with the system guidelines, program guidelines, and technical guidelines require completion of detailed site characterization studies. An evaluation of each guideline, and the preliminary conclusions resulting from the evaluation, are presented in Section 3.1.

1.2 REPOSITORY DEVELOPMENT SUITABILITY

The Act requires that each guideline be used in evaluating the suitability of the site for characterization, but that in evaluating the suitability of the site for development as a repository, only those guidelines that do not require characterization need be used. Only five of the eighteen proposed siting guidelines were determined to not require site characterization prior to assessing site suitability for development as a repository. These five technical guidelines dealt with human intrusion, surface characteristics, population density and distribution, environmental protection, and socioeconomic impacts. The candidate site, when evaluated against each of the five guidelines, did not reveal any disqualifying factors applicable to the Hanford Site (see Section 3.2). The preliminary conclusions drawn after evaluating each of the five guidelines are presented in Section 3.1.

1.3 SITE CHARACTERIZATION IMPACTS

Impacts of site characterization activities were described in a prior environmental assessment (DOE, 1982a) and were determined to pose no significant impact (DOE, 1982b) to the public health and safety and the environment. A detailed discussion of expected minor impacts is presented in Section 3.3 and in the prior environmental assessment (DOE, 1982a).

1.4 COMPARATIVE EVALUATION

A comparative evaluation of other sites and locations being considered by the DOE as potential repository sites is presented in Section 3.4. The sites and locations that have been compared are:

- Yucca Mountain on the Nevada Test Site in tuff (Nevada)
- Gibson Dome Area in bedded salts of the Paradox Basin (Utah)
- Bedded salts in the Permian Basin (Texas)
- Vacherie Salt Dome (Louisiana)
- Richton Salt Dome (Mississippi)
- Cypress Creek Salt Dome (Mississippi).

Site-specific information for some of these locations is limited, and each geologic medium has a blend of positive and negative characteristics.

1.5 DECISION PROCESS

The decision process used to select the reference repository location on the Hanford Site has taken 6 years to complete. Each step of the process evaluated the available information to select successively smaller areas for evaluation as a repository site. The reference repository location in the Cold Creek syncline on the Hanford Site was selected by the DOE in 1982. The basic steps of this siting process are discussed in Section 3.5 and the decisions made at each step are discussed in detail in the Site Characterization Report (DOE, 1982c).

1.6 REPOSITORY IMPACTS

The regional and local impacts that would be associated with a repository, if located at the Hanford Site, are expected to be minimal. An infusion of construction and operating monies over the next several decades would bolster the economy of the area. High-level waste and spent fuel will be shipped in high-integrity shielded casks that are designed to contain the wastes even in the event of an accident. Therefore, transportation impacts are expected to be minimal. Preliminary analyses of the waste isolation capability of basalts at Hanford are favorable with groundwater traveltimes to the accessible environment in excess of 10,000 years.

2.0 BACKGROUND SUMMARIES

2.1 NATIONAL WASTE TERMINAL STORAGE PROGRAM

The DOE is assigned responsibility for developing the necessary programs for the treatment, management, storage, and disposal of nuclear wastes primarily through the Atomic Energy Act of 1954, the Energy Reorganization Act of 1974, the Department of Energy Organization Act of 1977, and the Nuclear Waste Policy Act of 1982.

The DOE's commercial waste management program, the National Waste Terminal Storage (NWTS) Program, complies with the Federal laws by developing the technology and facilities to permanently dispose of commercial high-level radioactive wastes. The overall objective of the NWTS Program is to plan, develop, and implement the technology and provide the facilities for the terminal isolation of commercial high-level and transuranic radioactive waste in a manner to demonstrate waste disposal capability, to assure the public and occupational health and safety, and to protect the environment. To meet this overall objective, the NWTS Program will site, design, construct, and operate mined geologic repositories consistent with the legislated schedules. Approximately 70,000 metric tons (77,000 tons) of spent fuel will have been discharged from commercial nuclear powerplants by the year 2000. The NWTS Program is planning to have the first repository available with the capacity to dispose of that quantity of waste by 1998.

To achieve these objectives, the DOE will isolate nuclear wastes in deep, mined geologic repositories with a number of natural and man-made barriers between the wastes and the uppermost strata of the Earth's surface (the biosphere). These barriers include the waste form itself, the waste packaging, the backfills and seals of the repository, the host rock immediately surrounding the wastes, the geologic and hydrologic regime surrounding the host rock, and institutional barriers.

The NWTS Program has three field projects centered on investigating various rock types: the basalts beneath the Hanford Site (Basalt Waste Isolation Project (BWIP)), the tuffaceous rocks at the Nevada Test Site (Nevada Nuclear Waste Storage Investigation), and various salt regions throughout the United States (Office of Nuclear Waste Isolation). In addition, the DOE is studying crystalline rocks (intrusive igneous and high-grade metamorphic rocks such as granite) as a potential medium for geologic disposal. The regions presently under consideration are shown in Figure 2-1.

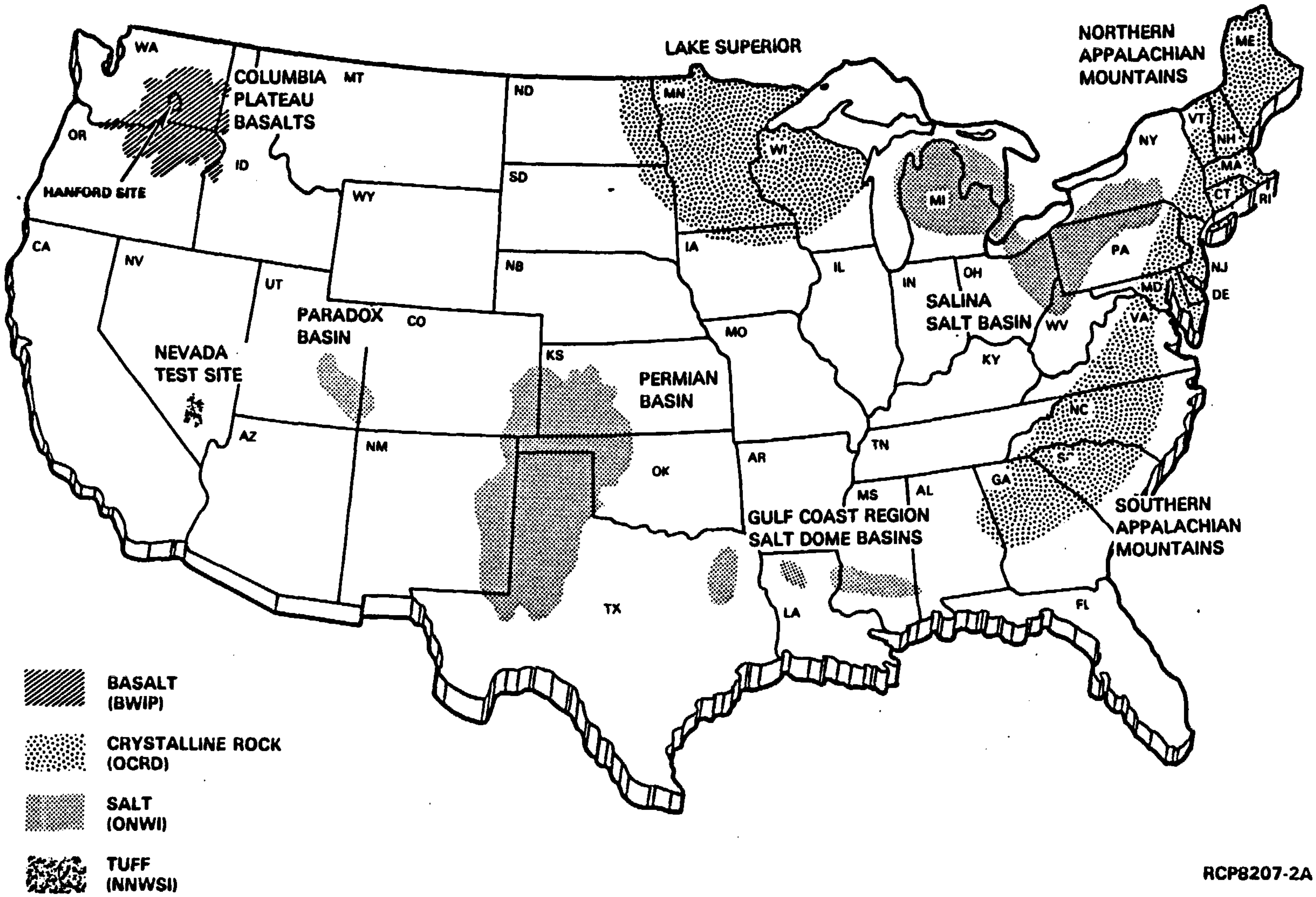

FIGURE 2-1. Regions That are Being Considered for Geologic Disposal of Radioactive Waste.

2.2 THE NATIONAL WASTE TERMINAL STORAGE SITING PROCESS

The NWTS Program siting investigations have been following a formal three-step siting process that begins with national screening and culminates in detailed site characterization of candidate sites for a nuclear waste repository. This siting process is described in the Public Draft, National Plan for Siting High-Level Radioactive Waste Repositories and Environmental Assessment (DOE, 1982d). The first phase of the siting process is site screening, which covers the activities planned to find sites favorable for waste isolation. A number of approaches have been used to initiate screening studies, with each approach eventually using common steps to arrive at and to evaluate specific sites.

The DOE has used three approaches to identify starting points for screening studies:

1. A host rock approach was initiated by identifying regions containing potentially suitable host rock types. Early in the NWTS Program, rock salt was so identified, and regions in the conterminous United States containing salt domes and bedded salt formations were delineated as starting points for site screening. The DOE has screened the United States for regions containing crystalline rocks such as granite.

2. In addition, the DOE has initiated siting studies at federally owned land tracts in Nevada and Washington (known as the Nevada Test Site and the Hanford Site), which have been committed to nuclear activities and which may contain suitable host rocks at appropriate depths for a repository.

3. Another approach, province screening, is based on scrutiny of successively smaller subdivisions of broad provinces where geohydrologic conditions include multiple natural barriers to radionuclide migration. This approach is being implemented by the U.S. Geological Survey on an experimental basis in one of eleven geohydrologic provinces of the United States. A province working group, composed of earth scientists from the states in that province and the U.S. Geological Survey, is initiating the prototypical studies.

The locations currently under study were identified using the host rock and land use approaches. The province screening, and possibly other approaches, may identify additional locations. Future NWTS Program activities will be carried out in accordance with the Nuclear Waste Policy Act of 1982.

2.3 BASALT WASTE ISOLATION PROJECT SITING PROCESS

In the DOE-NWTS Program national site screening plan, early consideration was given to the Hanford Site in Washington State because of its prior long-standing use and commitment to nuclear activities and existing Government ownership. Although the Hanford Site was selected as the study area, initial screening encompassed the Pasco Basin, which is the smallest physiographic unit with geologic and hydrologic characteristics that would influence the conditions of a repository beneath the Hanford Site.

A methodology was used to systematically and rapidly focus on areas that had a high likelihood of containing a potential repository site. A description of the methodology used during the site screening process is presented in Section 3.5 of this document. Initial screening reduced the area from about 4,145 square kilometers (1,600 square miles) to an area of about 1,800 square kilometers (700 square miles). Successive screening steps led to the identification of ten candidate sites in the central part of the Hanford Site known as the Cold Creek syncline, an area of about 180 square kilometers (70 square miles). Preliminary evaluation of the ten candidate sites made it clear that the sites were too closely matched to be differentiated between by routine ranking; therefore, a method of dominance analysis was used for this purpose. The dominance analysis showed that two of the ten candidate sites, located in the western portion of the Cold Creek syncline and designated sites A and H, had about the same dominance numerical value, a value which was significantly greater than the values for other sites. These two sites overlapped each other in area, and the combination was selected as the reference repository location. The reference repository location is shown in Figure 2-2.

Three candidate repository horizons within the reference repository location have been identified for further study: the Umtanum flow, McCoy Canyon flow, and the Cohassett flow in the Grande Ronde Basalt.

The reference repository location is an area of about 48 square kilometers (18 square miles) with nearly flat-lying terrain. An optimization study was made, using selected environmental engineering and design criteria, to identify the specific location for a principal borehole and Exploratory Shaft within the reference repository location. The location identified was in the west-central part of the reference repository location as shown in Figure 2-2.

2.4 BASALT WASTE ISOLATION PROJECT STATUS

The Hanford Site is situated in the Pasco Basin, a lowland area on the Columbia Plateau. The Columbia Plateau was formed by more than 100 basalt flows that literally flooded the region lying between the Cascade Range to the west, the Rocky Mountains to the east, the Okanagan Mountains to the north, and the Blue Mountains to the south. The reference repository location is situated in a relatively flat terrain within the Pasco Basin.

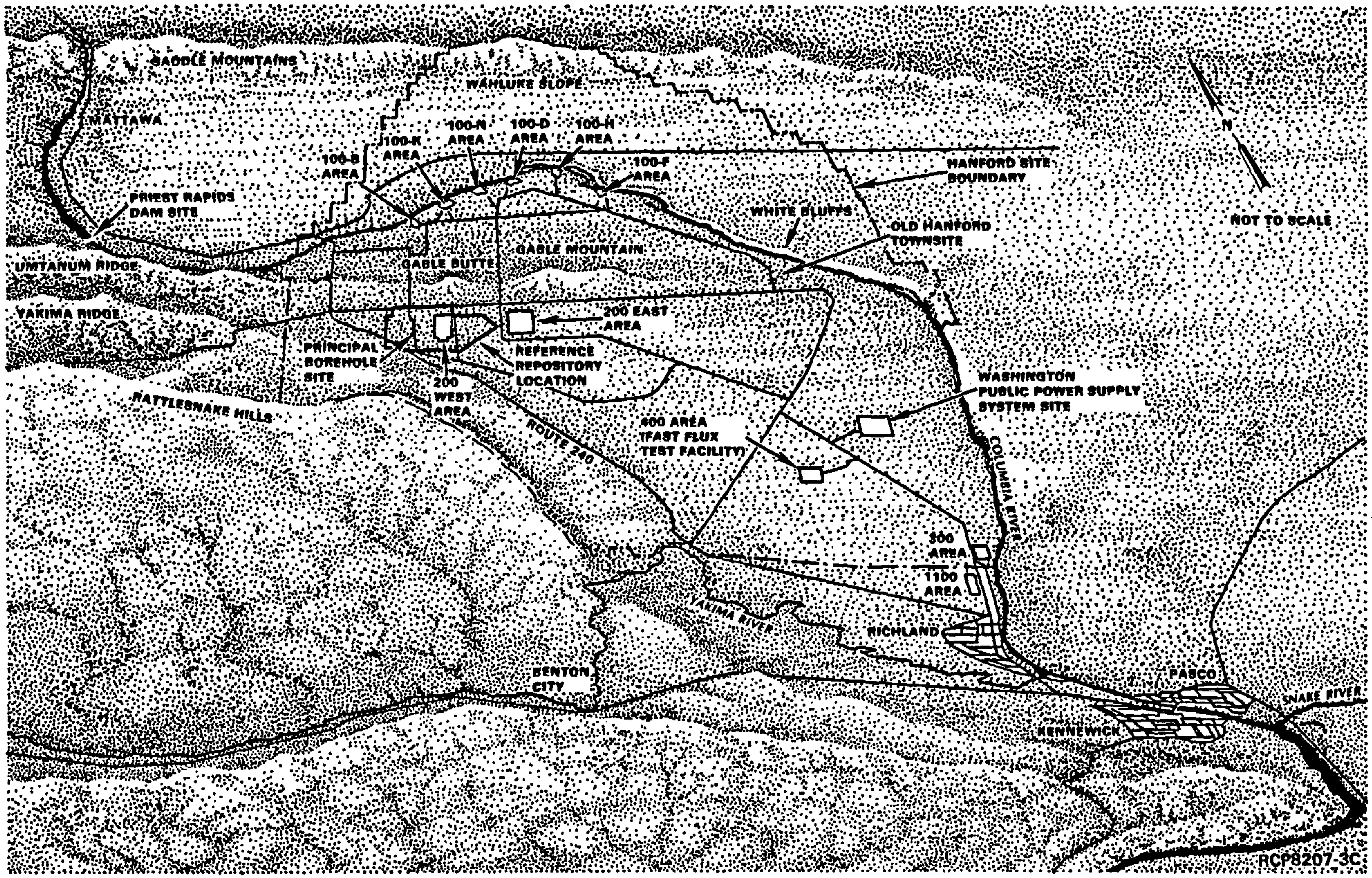

FIGURE 2-2. The Hanford Site and the Reference Repository Location.

2.4.1 Geologic Description of Candidate Area and Site

In the central portion of the Columbia Plateau where the Hanford Site is located, no pre-basalt basement rocks are exposed. The basalt flows of the Columbia River Basalt Group have been drilled to a depth of more than 3,250 meters (10,655 feet) in the Pasco Basin and a number of the flows encountered in drilling are more than 100 meters (328 feet) thick and laterally continuous. The internal structures that develop within a flow during the emplacement of the flow over the ground surface and subsequent cooling of the molten lava are termed intraflow structures. Intraflow structures are not uniform from one flow to another or even within a given flow. Intraflow structure may vary in thickness, be absent entirely from any given flow, or occur repeatedly within a single flow. However, the intraflow structure of some of the thicker flows (greater than 30 meters (100 feet)) does show considerable continuity and uniformity within the Pasco Basin.

Although basalt is a fractured and jointed rock, data from rock core samples show that the great majority of fractures within the flow interiors are filled with multiple generations of secondary minerals, such as clays. The results of laboratory and field testing indicate that the volume of unfilled fractures is small, as attested by the low total fracture porosity and permeability.

Folding and faulting of the Columbia River basalt appear to have developed at about the same time during the past 16 million years. On the basis of existing data, such as fault plane solutions and hydrofacturing tests, the principal direction of the existing stress field for the Pasco Basin is generally indicated by north-south compression. The average rate of uplift of the mountains that form the north and south boundaries of the Pasco Basin is less than 1 meter (3.28 feet) in 10,000 years and appears to have been rather uniform throughout this time period. The basalt stratigraphy, or sequence of basalt flows within the Pasco Basin, is well understood (see Fig. 2-3).

Current mineral industry operations within 100 kilometers (62 miles) of the reference repository location are limited to surface mining of diatomaceous earth, sand and gravel, and clay and stone. A small, depleted, low-pressure natural gas field was in production from 1929 to 1941 at the southern edge of the Hanford Site, and a few small gold placers have also been worked along the Columbia River. Exploration for hydrocarbons is continuing north and west of the Hanford Site. Groundwater is used for domestic, agricultural, and industrial purposes. The production of groundwater is primarily from wells less than 300 meters (984 feet) in depth. The poor quality of groundwater in the Grande Ronde Basalts restricts its use for these purposes.

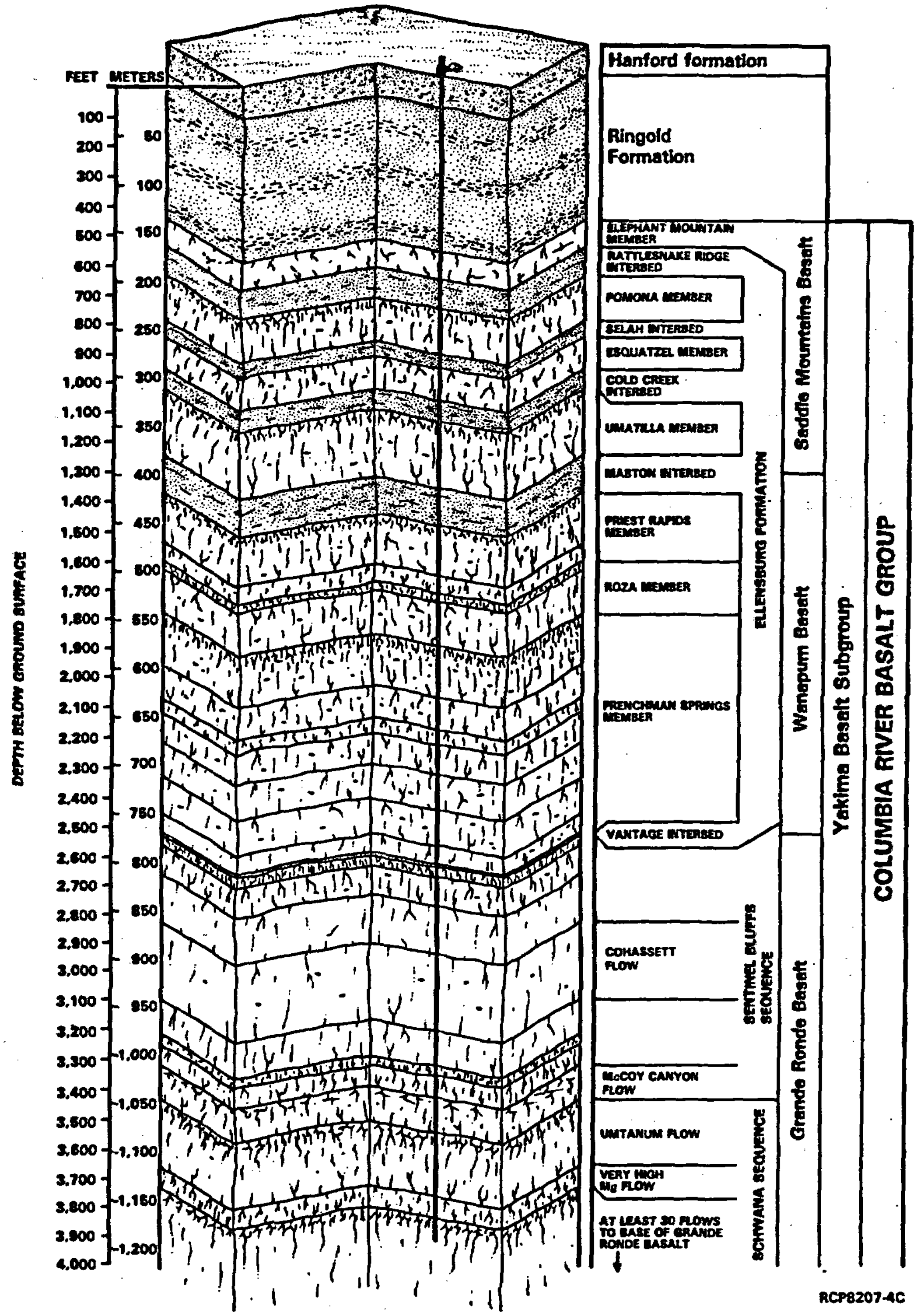

FIGURE 2-3. Stratigraphy of the Columbia River Basalt Group, Yakima Basalt Subgroup, and Intercalated and Suprabasalt Sediments Within the Pasco Basin.

Present plans in the area of site geology during detailed site characterization are to complete the determination of the geologic, mineralogic, and petrographic characteristics of the candidate repository horizon(s) and surrounding strata within the reference repository location. Work will also be continued on determining the nature and rates of past, present, and projected structural and tectonic processes within the geologic setting and reference repository location.

The reference location for a repository in basalt for the terminal storage of nuclear wastes on the Hanford Site and the candidate horizons within this reference repository location have been identified and the preliminary characterization work in support of the site screening process has been completed. Technical questions regarding the qualification of the site were identified to be addressed during the detailed site characterization phase of the DOE-NWTS Program site selection process. Resolution of these questions will be provided in the final site characterization progress report, currently planned to be issued in 1987, and in the safety analysis report to be submitted with the license application. The additional information needed to resolve these questions and the plans for obtaining the information have been identified in the Site Characterization Report that was submitted to the U.S. Nuclear Regulatory Commission (NRC) pursuant to 10 CFR 60 on November 12, 1982.

On the basis of the geotechnical data now available, the following can be concluded for the basalts underlying the Hanford Site:

- Basalt flows located more than 610 meters (2,000 feet) below the ground surface are not subject to significant erosion, and several flows appear to have thick enough flow interiors and sufficient lateral continuity to accommodate the construction of a nuclear waste repository.

- The present calculated rate of deformation poses no threat to the long-term integrity of a repository in basalt at the Hanford Site.

- The basalt stratigraphy, or sequence of basalt flows, beneath the Hanford Site is well understood and the depth to the flows can be predicted with reasonable accuracy.

- The low permeability measured in boreholes for the basalt-flow interiors indicate these portions of the flows will provide the isolation necessary to prevent the radionuclides reaching the accessible environment in concentrations above established guidelines.

- Preliminary tests indicate that the basalt rock, groundwater, and materials to be placed in terminal storage are compatible under both ambient and expected thermal stress conditions, in that they favor long-term stability.

- There is an extremely low probability of any adverse climatic impact on a repository in basalt at the Hanford Site.

- No faults have been identified on the Hanford Site that would have an adverse impact on a repository constructed at the reference repository location.

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

- There are no economic resources mined from the basalt in the vicinity of the Hanford Site at the present time, other than groundwater pumped from shallow aquifers. The Hanford Site is relatively unattractive to future subsurface mineral exploration and development within the Columbia River Basalt Group compared with other areas of the Columbia Plateau.

- The reference repository location is situated in a favorable position with respect to available transportation modes, support and service facilities, remoteness from population centers, and smoothness of the terrain.

- There is no land conflict with currently planned or existing facilities on the Hanford Site.

Fifteen issues or technical questions have been identified that need to be resolved during detailed site characterization. These issues are in the form of questions that require answers to satisfy regulatory and technical criteria. Three of these issues are designated "key issues." Key issues are those technical questions where engineers cannot substantially and economically alter a negative finding. The three key issues are as follows:

- What is the total amount (activity) of radionuclides potentially releasable to the accessible environment in a 10,000-year period, and is this amount in compliance with applicable U.S. Environmental Protection Agency (EPA) regulations?

- Can stability and isolation capability of the repository be maintained in the presence of coupled in situ, excavation-induced, and thermal-induced stresses?

- Can repository shafts, tunnels, and exploratory boreholes be constructed and sealed without causing preferential pathways for groundwater or increasing the potential for radionuclide migration from a nuclear waste repository such that compliance with applicable EPA regulations is not possible?

The additional work needed to resolve the criteria requirements has been identified (DOE, 1982c) and the methods, plans, and schedules to support this work have been outlined. All of the data needed to satisfy the criteria would be obtained during the detailed site characterization phase. Where positive resolution of the criteria requirements cannot be satisfied by technical data, performance-assessment modeling will be conducted.

2.4.2 Hydrogeology

Groundwater beneath the Hanford Site from both confined and unconfined aquifers discharges to the Columbia River. The recharge areas are the highlands adjacent to and beyond the Hanford Site to the west. The sediments overlying the basalt and those intercalated with the basalts are hydraulically the most permeable. There are some zones between flows that also transmit large quantities of water; such zones are found primarily in the upper basalt section within the Wanapum and Saddle Mountains Basalts. The flow tops and dense flow interiors of the Grande Ronde Basalt are overall hydraulically tighter than the shallower basalts and produce less groundwater than shallow basalts.

The groundwater movement is generally in an east to southeast direction within the Cold Creek syncline beneath the Hanford Site. Data on hydrologic properties, hydraulic heads, and groundwater chemistry indicate that lateral groundwater flow takes place primarily through permeable flow tops and sedimentary interbeds. Vertical groundwater flow or mixing between these different permeable layers may occur along geologic structures such as the Umtanum Ridge-Gable Mountain anticline. Some vertical leakage between high-permeability zones may also take place across the low-permeability interiors of individual basalt flows, although the quantity of such leakage is considered quite low compared to the volume of groundwater moving laterally.

Modeling of the near-field groundwater flow system around a repository indicates that the groundwater flow paths are primarily controlled by the more permeable flow tops between successive flows. Results of modeling also indicate that the minimum groundwater travel-times from the repository site to the accessible environment, a distance defined by the EPA in its proposed regulations (EPA, 1982) as 10 kilometers (6.2 miles), appear to be greater than 10,000 years. The very small quantities of radionuclides, which do ultimately travel to the accessible environment, appear to remain small and well below the EPA-proposed regulations.

Over the past several years, a number of far-field hydrologic modeling studies have been conducted by independent organizations. Each study had limiting assumptions and used the most recent data available at the time of the study. Traveltimes were estimated for groundwater movement between the repository and a discharge point at the Columbia River, a distance of 8 to 60 kilometers (5 to 35 miles) depending on the assumed flow path. Traveltimes estimated exceeded 13,000 years. Regardless of the different assumptions used, these estimated pre-waste-emplacement traveltimes are significantly longer than the NRC-proposed technical criterion (NRC, 1981a) of a 1,000-year minimum traveltime between the repository and the accessible environment.

Detailed site characterization studies in the area of hydrology are planned to verify that the pre-emplacement groundwater traveltimes near the repository are sufficiently long to meet proposed regulatory criteria. Further plans include the determination by characterization studies and laboratory tests and modeling of the total amount (activity) of radionuclides that are potentially releasable from a nuclear waste repository in basalt to the accessible environment.

2.4.3 Geochemistry

A preliminary assessment of the environmental conditions within the basalts beneath the reference repository location has been made. The parameters measured were temperature, pressure, groundwater composition, basalt mineralogy, Eh, and pH. The results of these studies have established the prevailing geochemical conditions for the candidate repository horizons of the Grande Ronde Basalt. Based on the current knowledge of these environmental conditions, matrix dissolution and leaching (ion exchange) represent the major degradation mechanisms for the waste form. General corrosion is the mechanism that will probably dominate canister degradation. At the end of the waste containment period, precipitation of new, less soluble, mineral phases from saturated solutions is the process that will likely control radionuclide concentrations in the groundwater flow system for all meaningful time periods relative to release criteria.

Plans for detailed site characterization studies in the area of geochemistry are to verify (by testing, characterization, and modeling) that the geochemical and hydrologic properties of the geologic setting (in conjunction with the waste form) will meet release requirements from the repository subsystem to the site and from the site to the accessible environment. This work includes the determination of a site-specific data base on the solubility and sorption characteristics of the nuclides contained in the waste. Work will be continued on determining the characteristics of the host rock environment (Eh, ph, groundwater composition, etc.) in support of waste package design activities and performance modeling of the waste isolation system.

2.4.4 Geoengineering

Geoengineering data on the state of in situ stress show that the ratio of the maximum horizontal stress to the vertical stress is approximately 2, and that the direction of maximum horizontal stress is consistent with the geologic evidence of north-south compression.

Determinations of strength and deformability of basalt, measured both in the laboratory and in situ, indicate that the behavior of a large rock mass measured in situ is generally different from that measured on a small specimen in the laboratory. It was found that for closely jointed rock like basalt, it is necessary to measure the thermal and mechanical properties on a large enough block to include a representative number of fractures and joints.

A large basalt block has been isolated in the Near-Surface Test Facility (a test facility located in Gable Mountain) to determine the thermal and mechanical behavior of the basalt in situ. This block measures 2 meters (6.6 feet) on a side and is cut 4.5 meters (14.8 feet) into the sidewall of the tunnel. The data from this test will be unique in that this isolated block of basalt represents the largest block of intact basalt rock ever isolated in this manner for in situ determinations.

Preliminary results from two in situ heater tests, which simulate the heat from a nuclear waste package, suggest that basalt responds to thermal loading in a predictable fashion and the walls of the storage borehole for the waste package maintain their structural integrity up to the maximum temperature measured (450°C (842°F)). Vertical deformation was more predictable than the horizontal deformation due to the large number of vertical joints in the basalt tested.

2.4.5 Near-Surface Test Facility

The Near-Surface Test Facility (Fig. 2-4) is a full-scale demonstration facility to examine how basalt, a geologic formation, is affected by heat and possibly radiation-induced stresses from the emplacement of commercial high-level nuclear waste. Electric heaters have been used in the past test programs. The Near-Surface Test Facility is located at Gable Mountain on the Hanford Site (Fig. 2-2).

Development work at the Near-Surface Test Facility will provide data for large masses of rock, necessary for determining the suitability of basalt for a commercial high-level waste repository. Additional tests planned at the Near-Surface Test Facility are to develop small-scale geomechanics instrumentation, for the purpose of measuring the disturbed rock zone around tunnel openings during excavation, determine/detect anomalies or changed conditions in advance of mining activities, determine the position of tunnel excavation with respect to overlying/underlying strata.

Tests are also being conducted in the area of excavation technology development. The purpose of these tests are to develop and/or confirm equipment and techniques to be used for the construction of at-depth facilities, and support repository design and construction. The capabilities and economies associated with a tunnel-boring machine in basalt as opposed to conventional mining techniques are to be assessed. Additional tests to develop waste emplacement/retrieval equipment are also being planned. Test objectives are to develop the technology required to construct long horizontal emplacement holes, develop techniques and demonstrate remote emplacement and retrieval of prototype waste packages for the horizontal placement configuration using prototypical handling equipment, develop techniques and procedures for emplacing backfill, and demonstrate (as a worst case situation) the retrieval of waste canisters from a horizontal emplacement hole with backfill in place.

Additional tests to demonstrate the performance of waste package backfill are also being evaluated by the BWIP.

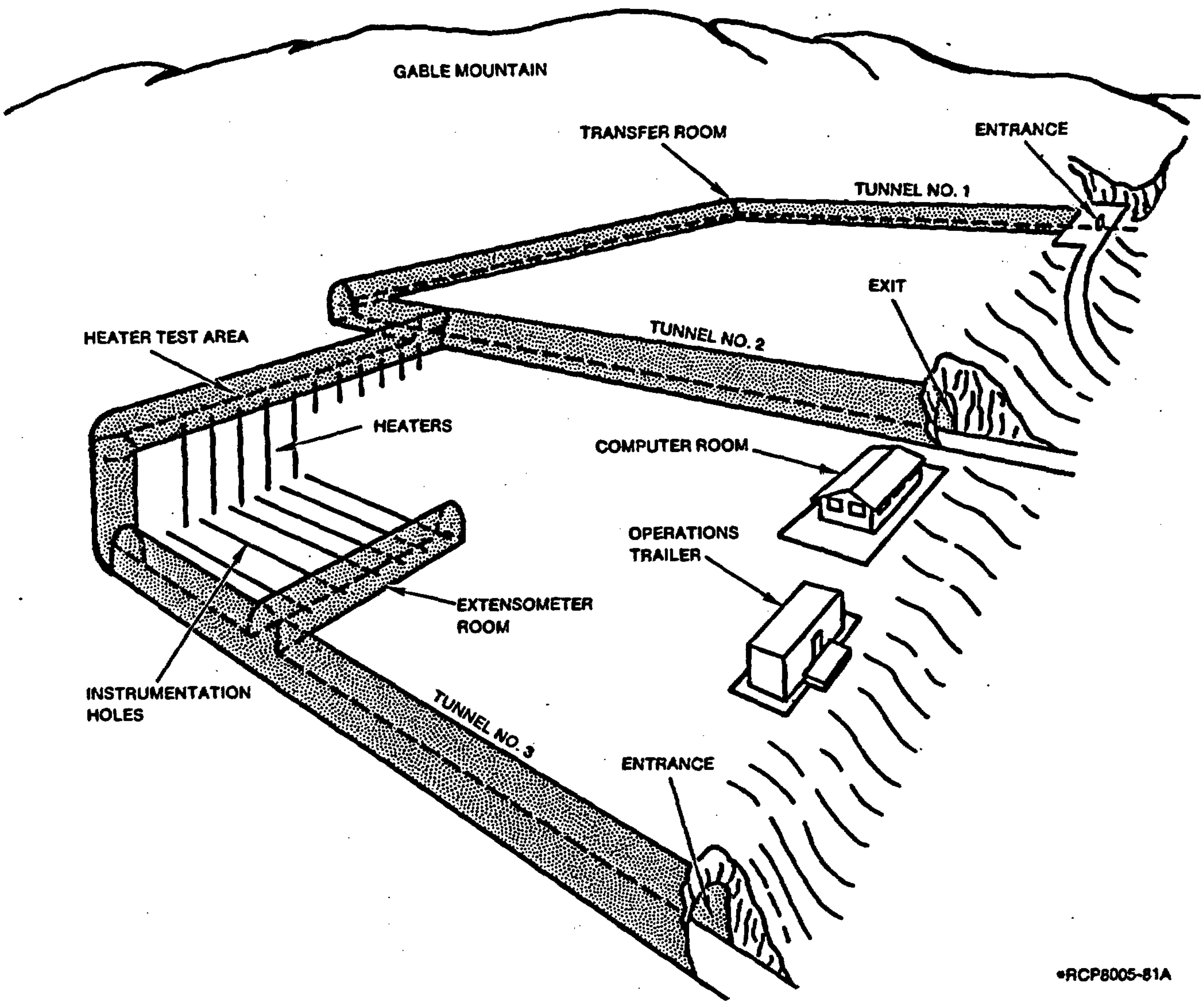

FIGURE 2-4. Conceptual Sketch, Near-Surface Test Facility.

Detailed site characterization studies in the area of geomechanics are planned to determine that the stability and isolation capability of the repository can be maintained in the presence of coupled in situ, excavation induced, and thermally induced strain. Development work will also be carried out to determine that satisfactory representative measurements or estimates of rock mass strength can be obtained and that current methods of in situ stress measurement are reliable enough to use as a basis of repository design.

2.4.6 Exploratory Shaft

The detailed characterization of a site at Hanford, which consists primarily of the selection of a site, design and design verification testing of a repository and waste package, and the construction of an Exploratory Shaft, will provide information to the DOE that is needed to aid in the determination of the suitability of a site at Hanford for use as a repository.

With a proposed site and a continuing conceptual design in preparation, the next major program phase, as noted in the Public Draft, National Plan for Siting High-Level Radioactive Waste Repositories and Environmental Assessment (DOE, 1982d), will be the detailed in situ characterization at depth. The objectives of this action are the following:

- Evaluate the effectiveness of the shaft construction method.
- Confirm the ability to seal off underground aquifers from work areas.
- Examine the effects of shaft construction on the surrounding rock.
- Measure the hydraulic properties of groundwater at the proposed repository depth.
- Characterize the rock mass of the host medium.

Assuming tests conducted in a chamber cut into the rock in Grande Ronde Basalt confirm current information about rock properties at this depth, a series of short tunnels will be driven to facilitate further detailed characterization. These tunnels will be constructed employing hard-rock mining techniques and will total approximately 305 meters (1,000 feet) in length.

The construction of an Exploratory Shaft and associated characterization activities are necessary to evaluate the adequacy of the basalt underlying the Hanford Site for use as a repository and are in keeping with 10 CFR 60 (NRC, 1981a) and the Nuclear Waste Policy Act of 1982.

2.4.7 Waste Package Development

The conceptual waste package design for commercial high-level waste forms consists of the waste form sealed in a low-carbon steel canister and surrounded by a tailored backfill composed of 75 percent crushed basalt and 25 percent bentonite clay. The repository conceptual design calls for waste to be emplaced horizontally in long boreholes. Present plans call for delayed backfilling to allow the waste canister to cool and to readily facilitate the possibility of retrieval as required by the NRC-proposed technical criteria (NRC, 1981a). Borosilicate glass is the assumed commercial high-level waste form, with spent fuel being an alternate waste form.

The waste package is being designed to provide safe handling of the waste during shipment and emplacement (as well as retrieval), to provide containment of the waste during the peak thermal period in which heat from fission product decay dominates (300 to 600 years), and, finally, to ensure the controlled and slow release of radionuclides during the period of geologic control to meet NRC-proposed release criteria (NRC, 1981a). During the thermal period (the first 1,000 years after closure), the metallic canister provides a primary function of preventing release of the waste to the general environment or to the repository and site subsystems. During the thermal period, the backfill acts also as a secondary barrier by preventing water from reaching the canister and by buffering the water near the canister, thus inhibiting corrosion.

During the period of geologic control, the primary barriers to radionuclide migration are the waste form and the backfill. The waste form functions to limit release of radionuclides and the backfill functions to retard radionuclide migration by sorption or chemical alteration to insoluble nuclide-containing secondary minerals, as well as retarding the rate of groundwater flow in the immediate vicinity of the waste form. The backfill also serves as a redundant barrier in the event that some containment is lost during the first 1,000 years after closure. There are no waste package containment requirements beyond 1,000 years, but it is expected that waste packages designed to prevent release during the period of highest heat output will provide some containment beyond the thermal period.

It was found that the iron oxide in the basalt is only partially oxidized and the equilibrium condition that now exists between the iron oxides in the basalt and the available oxygen present in the groundwater is one of low oxidation potential (Eh). Under these conditions, essentially all of the available oxygen in the environment of the emplacement hole will be consumed by reaction with the iron oxide existing in the basalt. Under these reducing conditions, many of the radionuclides are extremely insoluble and thus immobile. Corrosion of metals is also significantly reduced in an oxygen-poor environment.

Plans for detailed site characterization studies in the area of waste package development include an experimental determination of whether the very near-field interaction between the waste package and its components, the underground facility, and the geologic setting compromise the performance of either the waste package or repository. These studies will address both the radionuclide containment capability of the repository and performance of the waste package system. Further efforts are planned to upgrade the present waste package conceptual design and to perform design verification tests in support of final design and performance-assessment efforts. The role of a unique waste package borehole backfill will also be determined to ensure the operational redundance of barriers around the waste.

2.4.8 Repository Design

A conceptual repository design is being prepared for a nuclear waste repository in basalt that can handle and isolate high-level waste, spent fuel (if declared as waste), and transuranic waste. A repository cutaway that represents the present conceptual design (currently in review) including surface facilities, five access shafts, a central shaft pillar, and underground waste storage areas is shown in Figure 2-5.

The conceptual repository design, which was discussed in the Site Characterization Report (DOE, 1982c), is based on the capability to store 27,900 waste packages containing a total of 47,400 metric tons (52,140 tons) of heavy metal equivalent of reprocessed high-level waste and spent fuel declared as waste, and 32,000 packages of solidified transuranic waste. These waste forms will be isolated within the Grande Ronde Formation below the ground surface.

The present repository conceptual design includes surface waste receiving and inspection facilities, surface decontamination and packaging facilities, a shaft pillar containing five shafts connecting the surface and the underground workings, underground storage panels, transport facilities, and ancillary service systems including two separate ventilation systems.

The function of the repository is to provide long-term containment and isolation. After the storage rooms have been filled with waste packages, the storage rooms are expected to be filled with engineered backfill intended to act as a barrier against radionuclide migration. At the time of decommissioning of the repository, multiple seals will be placed in accesses between the panel areas and in the shaft pillar, and in the shafts above the repository level.

The isolation of nuclear wastes in deep, mined repositories will require the sealing of all penetrations, such as shafts, tunnels, repository rooms, or boreholes, into and nearby the repository. A research and development program is being conducted during detailed site characterization to develop and demonstrate required technology for sealing penetrations related to a repository excavated in basalt.

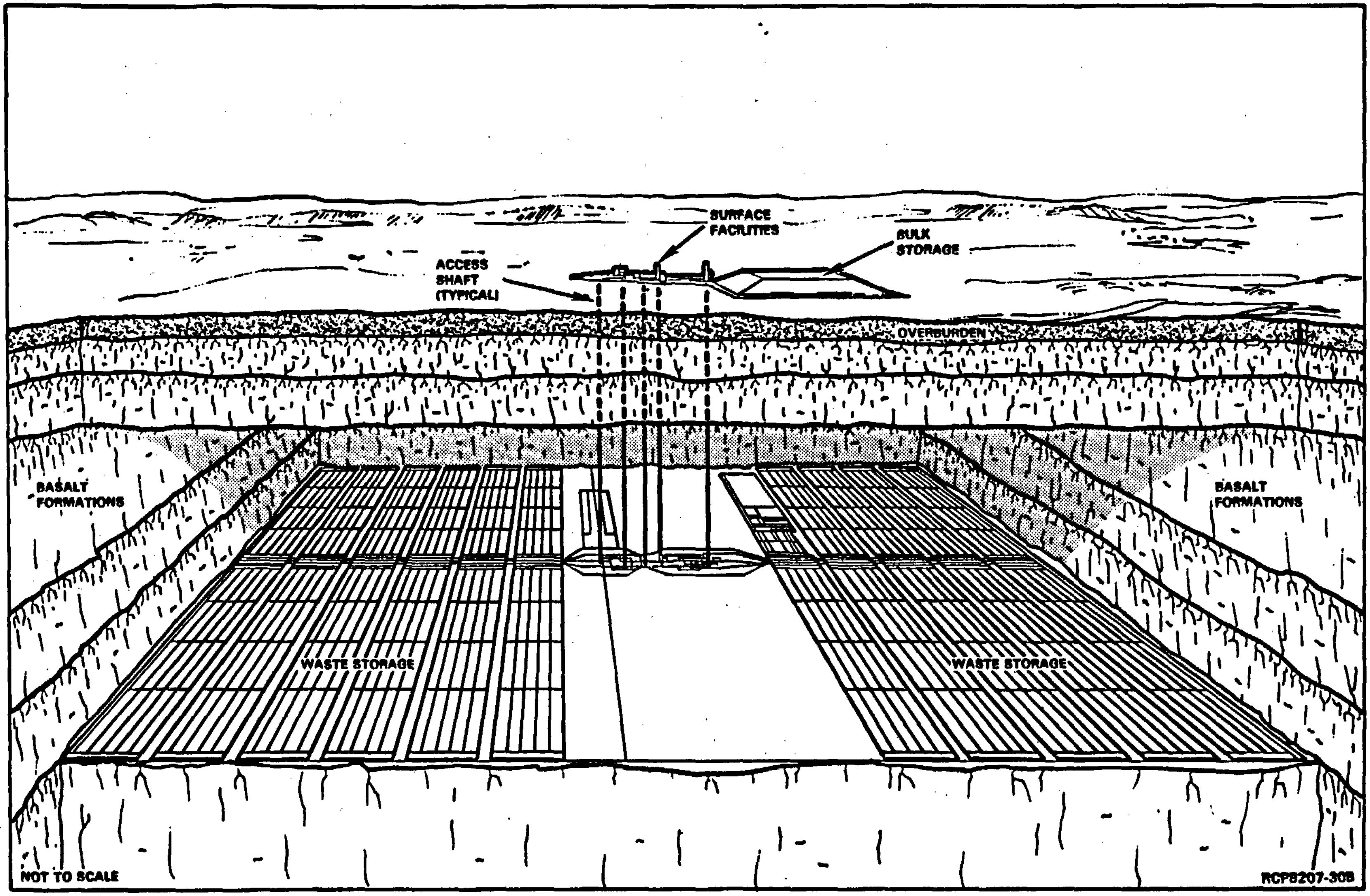

FIGURE 2-5. Conceptual Repository Cutaway.

2.5 HANFORD ENVIRONMENT

2.5.1 Hanford Site Location

The Hanford Site (Fig. 2-6 and 2-7) occupies approximately 1,500 square kilometers (570 square miles) of a semiarid region in the southeastern part of the State of Washington. The nearest population center, Richland, Washington, 1980 population 33,578 (BOC, 1981), is approximately 5 kilometers (3 miles) south of the southernmost boundary of the Hanford Site. The 1980 population within an 80-kilometer (50-mile) radius was estimated to be 417,000 (Sommer et al., 1981). This is an estimate from the actual 1980 U.S. Census data.

2.5.2 Geology-Topography

The Hanford Site is located in southeastern Washington State in the Pasco Basin (a portion of the Columbia Plateau), which is composed of large quantities of basalt overlain by thick layers of sedimentary material. The Hanford Site overlies the structural low point of the Pasco Basin and is bounded to the southwest, west, and north by large ridges that trend eastward and southeasterly from the Cascade Range, enter the Pasco Basin and die out within its confines. The Hanford Site is bounded to the east by the Columbia River and the steep White Bluffs of the Ringold Formation. To the southeast the Site is bounded by the confluence of the Yakima and Columbia Rivers and by the city of Richland.

Detailed stratigraphic and geologic data are available to characterize the Hanford Site environment (Tallman et al., 1979; ARHCO, 1976; Myers/Price et al., 1979) and have allowed subdivision of the basalts into a number of formations, members, and flows. The stratigraphic sequence beneath the Hanford Site is shown in Figure 2-3. For more detail on this topic, see Section 2.4.1.

2.5.3 Seismicity

Hanford is located in an area of historically low seismic activity (Algermissen, 1969; Algermissen and Perkins, 1976). The U.S. Geological Survey and the University of Washington have monitored earthquake activity in this region since 1969. Earthquakes recorded generally have magnitudes less than 4 on the Richter scale (Wallace et al., 1980).

The largest instrumentally recorded earthquake in the central Columbia Plateau is a magnitude 4.4 event on the Royal Slope about 85 kilometers (50 miles) north of the Hanford Site. Several earthquakes measuring modified Mercalli intensity VII to VIII have occurred in the surrounding region, but the magnitude had decreased to less than modified Mercalli intensity IV by the time the Hanford Site was reached. The largest event to occur within the Columbia Basin, the 1936 Milton-Freewater earthquake, had a modified Mercalli intensity of VII.

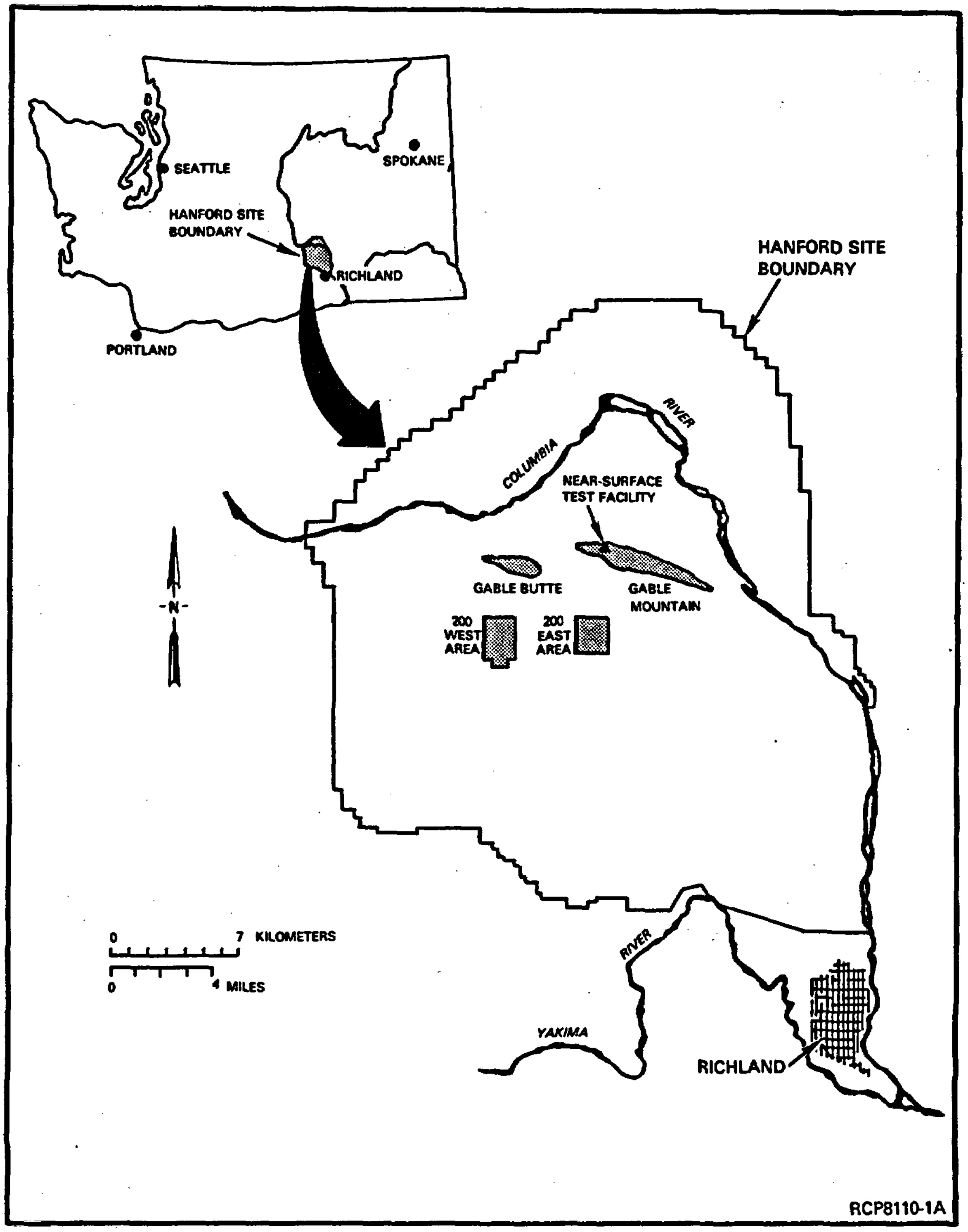

FIGURE 2-6. Location of the Hanford Site.

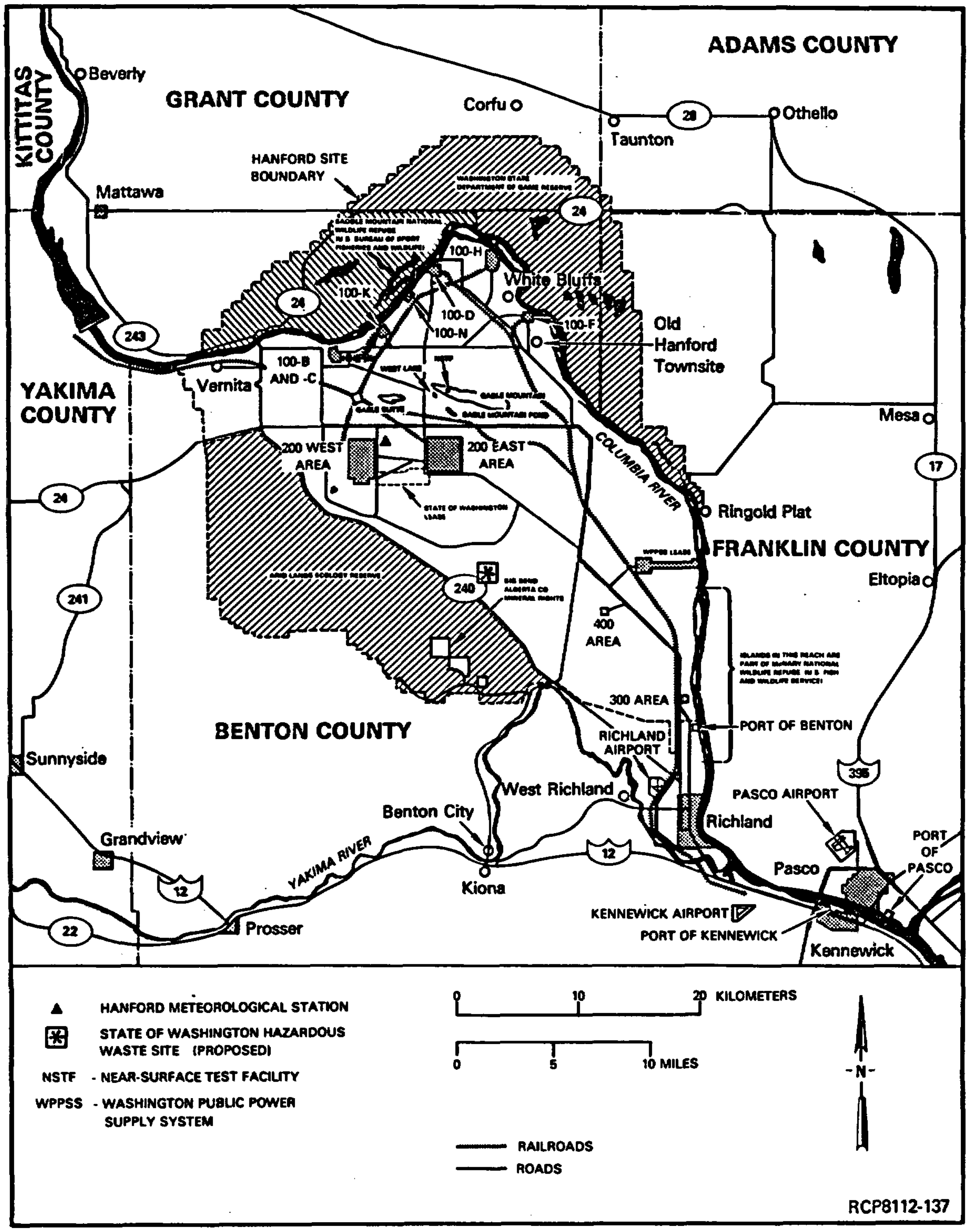

FIGURE 2-7. Location of Existing Nuclear Facilities on the Hanford Site.

Because this earthquake cannot definitely be linked to a geologic structure, it is assumed that a similar event could occur again anywhere in the Columbia Basin. This event has been designated the Hanford regional historical earthquake. The largest potential fault near Hanford is the postulated Rattlesnake-Wallula lineament, which is located at the southeast end of the Rattlesnake Hills.

2.5.4 Climatology

For general climatological purposes, meteorological data from the Hanford Meteorological Station are representative of the Hanford Site. The Hanford Meteorological Station tower is located between the 200 East and 200 West Areas and has continuously gathered data since 1944. Detailed climatological data are found in Stone et al. (1972). The Cascade Range to the west (see Fig. 2-6) greatly affects the climate of the Hanford area and forms a barrier to eastward-moving Pacific Ocean storm fronts. The mountains form a rain shadow producing mild temperatures and arid climatic conditions throughout the Pasco Basin region.

Average maximum and minimum temperatures recorded at Hanford for the month of January (the coldest month) are 3°C (37°F) and -6°C (22°F), and those for July (the warmest month of the year) are 33°C (92°F) and 16°C (61°F). Average annual precipitation is 16 centimeters (6.3 inches). The estimated average annual evaporation rate is 134 centimeters (53 inches), which essentially eliminates deep infiltration in the soil. Projections from available precipitation data indicate that a maximum accumulated annual rainfall of approximately 46 centimeters (18 inches) can be expected to have a recurrence interval of 1,000 years (ERDA, 1977) with a maximum soil penetration of 4 meters (13 feet).

Tornadoes rarely occur in the Hanford region, tend to be small, and produce little damage. Only one tornado has been observed on the Hanford Site in the last 29 years of observation. Existing data indicate that the probability of a tornado hitting a particular structure on site during any one year is an estimated six chances in a million (ERDA, 1975).

2.5.5 Hydrology

The Columbia River is the dominating factor in the Hanford Site hydrology and flows through the northern part and along the eastern boundary. The Yakima River is situated along part of the southern boundary. Groundwater exists beneath the Hanford Site in an unconfined aquifer and in confined aquifers composed of interbeds and interflow zones within the underlying basalt flows.

The Columbia River is normally about 75 to 90 meters (250 to 300 feet) below the plateau where the reference repository location is located. Under maximum probable flood conditions for the Columbia River Basin, the U.S. Army Corps of Engineers has estimated that the reference repository location would still be 60 to 75 meters (200 to 250 feet) above the highest probable water elevation (COE, 1969). Submersion of the Columbia River wetlands as a result of such flood conditions would have no direct effects on the facilities. Studies of a hypothetical 50 percent breach of the upstream Grand Coulee Dam, which would result in the devastation of downstream cities including Pasco, Richland, Kennewick, and Portland, show a flood elevation at 45 to 60 meters (150 to 200 feet) below the Exploratory Shaft site.

The water table, representing the upper limit of the unconfined aquifer, ranges from 46 to 100 meters (150 to 328 feet) beneath the ground surface and slopes toward the river. Near the Columbia River the water table fluctuates in response to river level changes and, in general, is within a few meters of the ground surface. Studies at Hanford indicate that precipitation does not directly reach the water table from the flat desert plains surrounding the reference repository location (ERDA, 1975, p. II.3-D-22).

The unconfined aquifer occurs within the sedimentary deposits referred to as the Hanford and Ringold Formations. The aquifer receives natural recharge from the Cold Creek and Dry Creek Valleys west of the Hanford Site and from runoff along the Rattlesnake Hills. Artificial recharge enters the aquifer from two groundwater mounds created by waste processing and disposal activities in the 200 East and 200 West Areas. Groundwater flows in a general west to east direction from the recharge areas and discharges into the Columbia River (ERDA, 1975, pp. II-3-D-22-27).

Groundwater also exists in the interflow zones of the basalt flows and in sedimenary interbeds referred to as the Rattlesnake Ridge, Selah, Cold Creek, and Mabton zones of the Saddle Mountains and Wanapum Basalts. Recharge to these upper confined flow systems results from precipitation and stream flow in the mountains west of Hanford. Hydrologic data acquired from wells penetrating these aquifers indicate the same general west to east groundwater movement toward the Columbia River.

2.5.6 Ecology

The Hanford Site contains large relatively undisturbed expanses that contain numerous plant and animal species suited to the semiarid environment of the region. The Columbia River also provides a habitat for aquatic species. The major facilities and activities occupy only about 6 percent of the total available land area and the surrounding wildlife is little affected by these facilities. A very extensive discussion of the Hanford Site ecology, including detailed descriptions of the aquatic ecology, Columbia River biota, terrestrial ecology, plant species, animal species, insects, and rare or endangered species is presented in ERDA (1975, pp. II.3-F-3, II.4-G-1) and DOE (1982d). A brief summary of this information is presented below.

2.5.6.1 Vegetation. The Hanford Site is within the boundaries of the sagebrush vegetation zone as it occurs in the State of Washington (Daubenmire, 1970). Approximately 40 percent of the ground area is occupied by plants at the peak of the spring growing season. Some of the Hanford Site vegetation is not indigenous. For example, cheatgrass and Russian thistle (tumbleweed), both dominant plant species, were introduced with the advent of agriculture.

Sagebrush/cheatgrass vegetation is the prevalent vegetation type in the 200 Area plateau. Typically, cheatgrass provides half of the total plant cover. Sagebrush is conspicuous because of the plant's relatively large size, with its combined plant canopies covering an estimated 18 percent of the ground (Cline et al., 1977). Tumbleweeds are of interest because they are an early invader of any cleared surface areas and continue in abundance until competition from other plans reduces their number.

Over 100 species of plants have been collected and identified for the 200 Area plateau (ERDA, 1975, p. II.3-G-39,44). Mosses and lichens appear abundantly on the soil surface; lichens commonly grow on shrub stems.

Since there are no grazing livestock on the Hanford Site, the amount of vegetation eaten by animals is small. Jackrabbits, pocket mice, and birds probably consume less than the insect species. The decomposer organisms, bacteria and fungi, consume most of the primary production after the plant parts die.

2.5.6.2 Mammals. Over 30 mammal species have been observed on the Hanford Site. Most of these are small and nocturnal (ERDA, 1975, p. II.3-G-15,49).

The mule deer is the only big game mammal present in significant numbers and, while not abundant, it uses some of the pond areas for watering and feeding. Deer tagged near the Columbia River have been observed as far as 48 kilometers (30 miles) from the Site (Fitzner and Price, 1973).

The cottontail rabbit is scattered throughout the Hanford Site. The jackrabbit is also widely distributed and is an important food item for coyotes and birds of prey. Ponds and ditches support muskrat and beaver; porcupine and raccoon are also observed while badgers occur in low numbers. The dominant small mammal is the Great Basin pocket mouse.

Coyotes are the most important mammalian predator and roam over large areas, consuming a variety of prey.

2.5.6.3 Birds. Over 125 species of birds have been observed at the Hanford Site (ERDA, 1975, p. II.3-G-17,46). The chukar partridge is the most important upland game bird and is concentrated primarily in the Arid Lands Ecology Reserve portions of the Hanford Site and the Rattlesnake Hills. Local populations exist in the Gable Mountain and White Bluffs area.

The Canada goose is probably the most important of the nesting waterfowl. Its nesting habitat is confined to the islands in the Columbia River. The river also provides a resting sanctuary for migratory ducks and geese (Fitzner and Price, 1973).

Birds associated with ponds on the 200 Area plateau have been studied (Fitzner and Price, 1973; Fitzner and Rickard, 1975). Small perching birds and others are attracted to the ponds with tree-shrub communities. Shore birds frequent all ponds and the major migrating birds stop at the ponds for rest and forage.

Birds of prey use the Hanford Site as a refuge from human intrusions, and the golden eagle and bald eagle are both winter visitors (Fitzner and Rickard, 1975).

2.5.6.4 Insects. Amost 300 species of insects have been identified at the Hanford Site (ERDA, 1975, p. II.3-G-21,51). Of the insects, the darkling ground beetle and the grasshopper are probably the most important and prevalent. Dramatic natural fluctuation of these species has been noted over the observation years.

2.5.6.5 Reptiles and Amphibians. Approximately 16 species of amphibians and reptiles have been observed at the Hanford Site (ERDA, 1975, p. II.3-G-20,46). When compared with the southwestern United States desert areas, the occurrence of these species is infrequent. Among reptiles, the side-blotched lizard is the most abundant and can be found throughout the Hanford Site. Horned and sagebrush lizards are also found but not commonly seen. The most common snake is the gopher snake; the yellow-bellied racer and the Pacific rattlesnake are also common. Striped whipsnakes and desert night snakes appear occasionally and are an important food item for birds of prey. Some toads and frogs are observed near the 200 Area ponds and ditches.

2.5.6.6 Aquatic Ecology. The Columbia River supports the dominant aquatic ecosystem and presents a very complex set of trophic relationships, which are discussed extensively in ERDA-1538 (1975, p. II.3-F-3). Several small ponds result from effluent discharge on the 200 Area plateau. The largest of these, Gable Mountain Pond, supports a simple food web based mainly on sedimented organic matter. This pond and U Pond both support introduced populations of goldfish.

2.5.6.7 Threatened or Endangered Species. No species of plant or animal registered as rare, threatened, or endangered is known to exist or depend on the habitats unique to the 200 Area plateau. However, the presence of open water on the Hanford Site attracts and supports many species of plants and animals normally rare or unknown in the general plateau area.

2.5.7 Land and Water Use

Land uses in the surrounding area include urban and industrial development, and irrigated and dryland farming. Of the irrigated crops, alfalfa hay uses 34 percent of the total area, wheat 15 percent, and potatoes about 20 percent. And in recent years grapes have also gained in importance. Fruit and hop growing is also important in the Yakima region. Water removal, from the Columbia River other than Hanford's, amounts to about 2.5×10^8 cubic meters per year (200,000 acre-feet per year) within 80 kilometers (50 miles) of the N Reactor, from an annual average river flow of about 3.4×10^3 cubic meters per second (120,000 cubic feet per second) or about 1.07×10^{11} cubic meters per year (87 million acre-feet per year).

2.5.8 Historical Sites and National Landmarks

The U.S. Department of the Interior (DOI, 1982) lists 20 historic sites for Benton, Grant, and Franklin Counties. Among these, the Ryegrass Archeological District is listed as being in the "Hanford Works Reservation" (since 1978 designated as the "Hanford Site") along the Columbia River. Other historic sites listed are: Paris Archeological Site, Hanford Island Archeological Site, Hanford North Archeological District, Locke Island Archeological District, Rattlesnake Springs Sites, Snively Canyon Archeological District, Wooded Island Archeological District, and Savage Island Archeological District. A number of archeological sites within the Hanford Site boundaries have been identified (Rice, 1968a, 1968b) and are described in detail in ERDA (1975, p. II.3-A-14).

2.6 RELATED ENVIRONMENTAL DOCUMENTATION

The Final Environmental Impact Statement: Management of Commercially Generated Radioactive Waste (DOE, 1980) presented an analysis of environmental impacts that could occur if various technologies for management and disposal of certain classes of commercially generated radioactive wastes (namely high-level and transuranic) were to be developed and implemented.

The DOE proposed a program strategy emphasizing development of conventionally mined waste repositories, deep in the Earth's geologic formations, as a means of disposing of commercially generated high-level and transuranic wastes. Based on this environmental impact statement, the DOE adopted the proposed program strategy (DOE, 1981). Included in the Final Environmental Impact Statement (DOE, 1980) are descriptions of the characteristics of nuclear waste, the alternative disposal methods under consideration, and potential environmental impacts and costs of implementing these methods.

Generic environmental impacts related to repository construction, operation, and decommissioning are analyzed in the Final Environmental Impact Statement (DOE, 1980), as are the impacts of predisposal waste treatment, storage, and transportation to the extent that they might affect the selection of a disposal option.

An Environmental Assessment for the Basalt Waste Isolation Project Exploratory Shaft Construction (DOE, 1982a) was prepared in the summer of 1982. The assessment discussed the proposed action of constructing an Exploratory Shaft at Hanford and presented five basic alternatives. The alternatives included the use of alternate site characterization methods, selection of an alternate site, delay of the proposed action, a "no action" alternative, and a "limited no action" alternative. The major environmental impact noted in the environmental assessment was the selective clearing and grading of 8 hectares (29 acres) of land. Over half of the plants in this area were destroyed and all the animals were displaced. Biological monitoring has shown that no threatened or endangered species were resident on the site. Other impacts include blowing dust due to wind erosion of disturbed soil; wet suppression of dust during construction of roadways and parking lots will be followed by surfacing with gravel. Another effect that will result from the accumulation of drill cuttings and mined rock are spoil piles. Possible mechanisms by which spoil piles can cause environmental damage are by dust emissions, chemical leaching, and mechanical slip or collapse. Existing dust-suppression techniques, which have proven effective, will be used to keep emissions from the spoil piles within applicable limits. Measures are also planned to mitigate the effects of chemical leaching and mechanical slip of collapse.

A finding of no significant impact (FONSI) for the construction of the Exploratory Shaft and associated detailed site characterization studies was published in the Federal Register on September 16, 1982 by the DOE (1982b) in compliance with the National Environmental Policy Act of 1969. Subsequent to the issuance of the FONSI, drilling operations for the Exploratory Shaft were started in November 1982.

3.0 EVALUATION OF STATUTORY REQUIREMENTS

Section 112(b)(1)(E) of the Nuclear Waste Policy Act of 1982 requires that the environmental assessment accompanying the nomination of a site for characterization as a candidate repository site include a detailed statement of the basis for such recommendation and of the probable impacts of the site and a discussion of alternative activities relating to site characterization that may be undertaken to avoid such impacts. Such an environmental assessment shall include:

i) An evaluation by the Secretary as to whether such site is suitable for site characterization under the guidelines established under subsection (a) of the Act

ii) An evaluation by the Secretary as to whether such site is suitable for development as a repository under each such guideline that does not require site characterization as a prerequisite for application of such guideline

iii) An evaluation by the Secretary of the effects of the site characterization activities at such site on the public health and safety and the environment

iv) A reasonable comparative evaluation by the Secretary of such site with other sites and locations that have been considered

v) A description of the decision process by which such site was recommended

vi) An assessment of the regional and local impacts of locating the proposed repository at such site.

The guidelines referred to above were promulgated as the Proposed General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories by the Secretary of the DOE in the Federal Register (Vol. 48, No. 26, pp. 5670-5682) on February 7, 1983.

Sections 3.1 through 3.6 of this document provide a discussion and evaluation of the six criteria established by Section 112(b)(1)(E)(i) through (vi) of the Nuclear Waste Policy Act of 1982. In Section 3.3 the evaluation of site characterization activities required by Section 112(b)(1)(E)(iii) includes a discussion of alternative site characterization activities relating to site characterization that may be undertaken to avoid such impacts.

3.1 SUITABILITY OF THE HANFORD SITE FOR SITE CHARACTERIZATION

Section 112(b)(1)(E)(i) criteria: Evaluation of whether the Hanford Site is suitable for site characterization under the proposed siting guidelines (DOE, 1983).

The DOE's proposed siting guidelines are presented in three parts: system guidelines, program guidelines, and technical guidelines. The system guidelines address the primary objectives of protecting the health and safety of the public and the environment. They relate the performance of the geologic repository system to standards for allowable releases of radioactive material and provide the basis for developing the technical criteria. The program guidelines define the policy requirements to be followed in implementing the DOE's program for selecting a repository site. The technical guidelines specify factors for the qualification and disqualification of specific sites and the conditions that would be considered favorable or potentially adverse.

When the DOE published the proposed siting guidelines, DOE recognized that it may not be possible to provide a complete evaluation of a site against all of the proposed siting guidelines at the time an environmental assessment is prepared. Where a complete evaluation has not been possible in this assessment, a discussion of the current status of activities relating to the guidelines (currently available information and a brief summary of planned activities) is presented in conjunction with a preliminary conclusion that directly relates to conformance with the proposed siting guidelines.

3.1.1 System Guidelines

A nuclear waste repository must contain and isolate radioactive material in a manner that is safe and environmentally acceptable. The DOE has proposed system guidelines to achieve these objectives and to provide a basis for the program and technical guidelines discussed in the sections that follow.

The system guidelines combine the safety and environmental objectives with applicable standards and regulations to define general requirements for system performance: (1) the period that precedes the permanent closure of the repository and (2) the period that follows closure. This division is consistent with the proposed EPA regulation, "Environmental Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes," 40 CFR 191 (EPA, 1982), which specify different numerical performance requirements for these periods.

3.1.1.1 Peformance Before Permanent Closure. System Guideline 960.3-1 (Performance Before Permanent Closure) (DOE, 1983) states that:

> *The repository operations area shall be sited and designed to comply with the limits established by the Nuclear Regulatory Commission in 10 CFR 20 and by the Environmental Protection Agency in the proposed 40 CFR 191, Subpart A, Environmental Standards for Management and Storage. A site shall be disqualified if during site investigation it becomes clear that the site, together with state-of-the-art engineered systems and controls, will preclude a repository at that site from complying with 10 CFR 20 and the proposed 40 CFR 191, Subpart A.*
>
> *(a) Favorable Conditions*
>
> *(1) A combination of meteorological conditions and low population densities such that few, if any, members of the general public would be exposed to radiation due to emissions during repository operation.*
>
> *(2) Absence of contributing radioactive releases from other nuclear facilities governed by 40 CFR 190 or the proposed 40 CFR 191 that would require consideration in accordance with 40 CFR 191.03.*
>
> *(b) Potentially Adverse Conditions*
>
> *(1) Presence of other nuclear facilities governed by the proposed 40 CFR 191 with actual or projected releases at or near the maximum value permissible under those standards.*
>
> *(2) Proximity to populated areas that could be routinely affected by repository effluents considering prevailing meteorological conditions.*

3.1.1.1.1 Summary of Available Information. Because current repository design concepts are based on the handling of prepackaged nuclear waste, routine releases of radioactive effluents to the atmosphere are not anticipated. Atmospheric dispersion may be of importance, however, in the evaluation of accidental releases, even though the magnitude of releases under hypothetical accident conditions would be very low. Data from the Hanford Meterological Station, approximately 5.8 kilometers (3 miles) east of the Exploratory Shaft site, provide a good approximation of the dispersion conditions at the reference repository location.

The stability frequency for all windspeeds currently used for Hanford dispersion calculations are shown below:

Very stable - 24 percent
Moderately stable - 32 percent
Neutral - 14 percent
Unstable - 30 percent

These data show that stability class data are skewed to both poor and good dispersion conditions, with a relatively high frequency of poor dispersion conditions. Some differences between atmospheric conditions measured at the Hanford Meteorological Station and the reference repository location are expected based on localized topographic conditions. Atmospheric dispersion models can account for some of the localized topographic influences on meteorological conditions at the reference repository location although monitoring at the site may be needed to verify the atmospheric models.

Prevailing wind directions at the Hanford Site are out of the northwest as shown in Figure 3-1. Under stable atmospheric conditions, there is also a significant frequency of winds from the west and southwest. Because access to the Hanford Site is controlled by the DOE, there are no population centers within 20 kilometers (12.5 miles) of the reference repository location (Fig. 3-2). The city of Richland, with a 1980 population of 33,578, is approximately 40 kilometers (25 miles) southeast of the reference repository location and is the closest principal downwind population center.

Atmospheric dispersion modeling has not been conducted for potential radiological accident conditions at a repository, although such calculations will be performed during preparation of the Site Recommendation Report. However, it can be qualitatively stated that the potential for a significant atmospheric release of radioactive material is minimal, considering the low probability and consequences of an accident involving solidified and containerized high-level waste. Any such releases would also be dispersed over the 40-kilometer (25-mile) longitudinal distance, ignoring the other components of dispersion.

The Hanford Site is managed by the DOE in support of commercial and defense nuclear programs. Commercial nuclear fuel cycle facilities in operation at the Hanford Site that are governed by 40 CFR 190 (EPA, 1977) or proposed regulations 40 CFR 191.03 (EPA, 1982) include nuclear fuel fabrication facilities, nuclear powerplants in various stages of construction, and a low-level waste site. Combined releases from these facilities and projected releases from a repository are expected to be well below the limits in the proposed EPA regulations (EPA, 1982). An assessment of the combined doses from commercial nuclear facilities will be included in the Site Recommendation Report (if Hanford is chosen as a repository site).

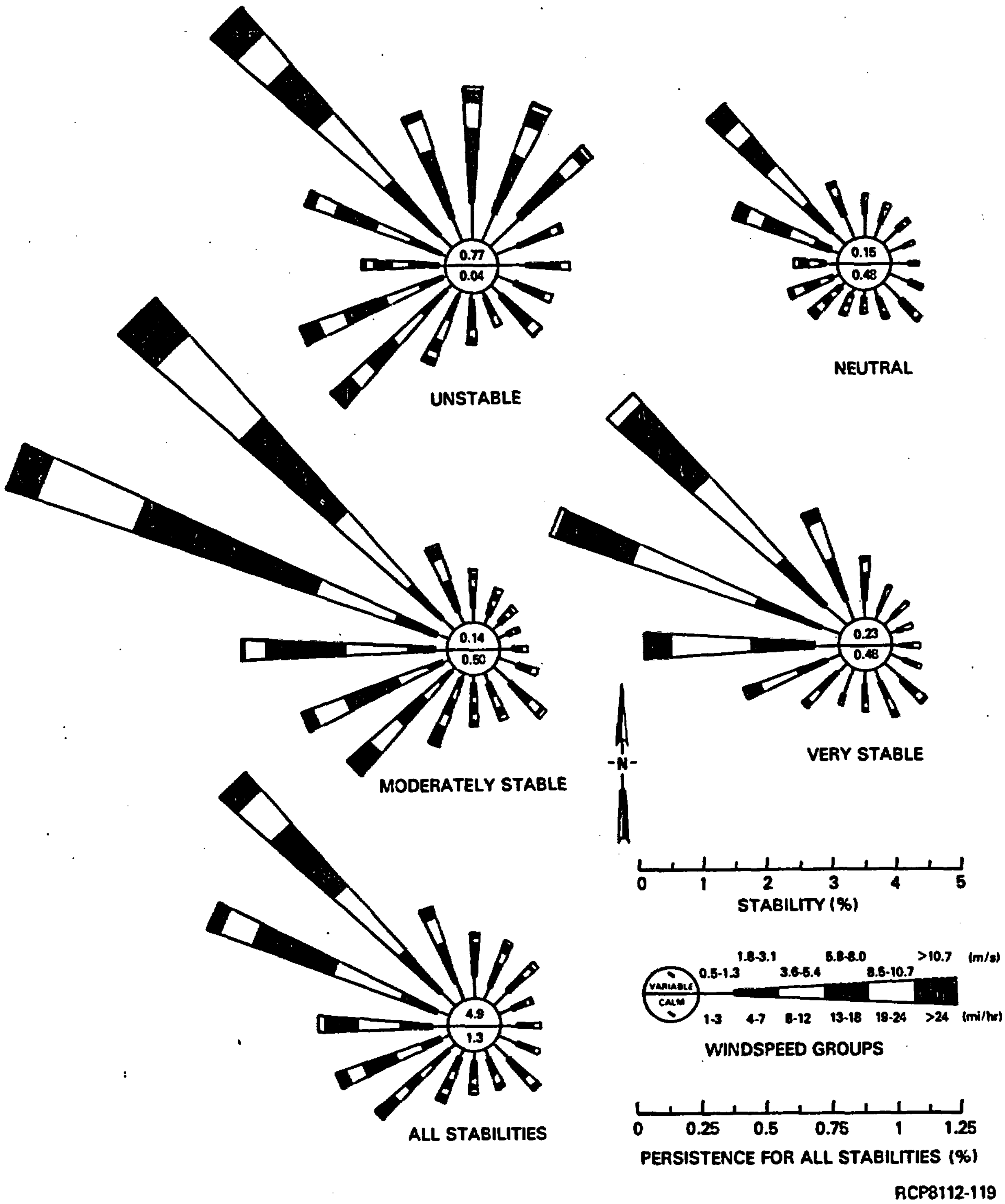

FIGURE 3-1. Wind Roses as a Function of Stability and for All Stabilities of the Hanford Meteorological Station, Based on Winds at 60 Meters (197 feet) and Air Temperature Stabilities Between 1 and 60 Meters (3 to 197 feet) for the Period 1955 through 1970. (The points of the rose represent the directions from which the winds come.)

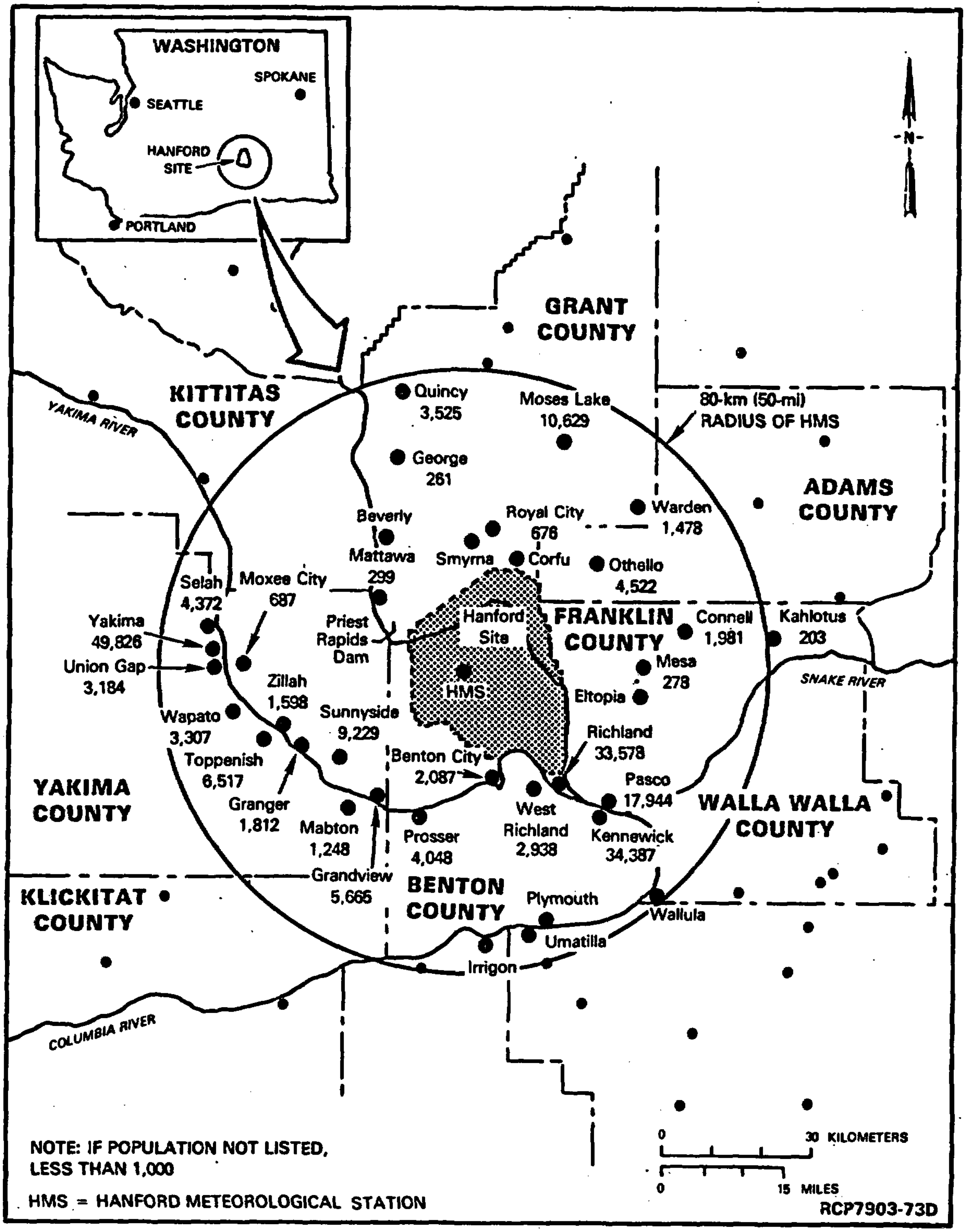

FIGURE 3-2. U.S. Census Populations for 1980 of Cities Within an 80-Kilometer (50-mile) Radius of the Hanford Meteorological Station.

3.1.1.1.2 Preliminary Conclusions. The proposed repository site possesses a number of favorable conditions that are expected to allow repository operations to comply with the limits established by the NRC in 10 CFR 20 (NRC, 1982a) and by the EPA in proposed 40 CFR 191, Subpart A (EPA, 1982). Due to the low population density of the surrounding area and the distance from the proposed repository site to population centers, routine repository operations would not be expected to result in radiation exposure to members of the general public. Repository emissions, under routine operating conditions, are not expected to contain radioactivity above natural background levels. In the final environmental impact statement (DOE, 1980), it was calculated that even for the most severe operational accident postulated for a repository (dropping a canister down the repository mine shaft) the maximum individual would receive a 70-year whole body radiation dose of 3.5×10^{-5} rem. The repository design will incorporate filtration/adsorption systems to limit radioactive emissions below the levels allowed by the NRC and EPA. Data on releases from other nuclear facilities at Hanford and specific information on expected operational releases from a repository will be gathered in order to fully evaluate this guideline in the Site Recommendation Report.

Contributing radioactive releases from other facilities at Hanford that are governed by 40 CFR 190 (EPA, 1977) or the proposed 40 CFR 191 (EPA, 1982) will require a careful evaluation to determine that the combined releases from all facilities do not exceed the limits contained in the proposed 40 CFR 191.03. Preliminary information indicates that the repository can be designed to meet the requirements of proposed 40 CFR 191.03.

3.1.1.2 Performance After Permanent Closure. System Guideline 960.3-2 (Performance After Permanent Closure) (DOE, 1983) states that:

> *The site and engineered systems shall provide reasonable assurance that, after the permanent closure of the repository, credible postulated releases of radioactive materials to the accessible environment will not exceed the quantities of radioactive materials that may enter the environment as specified in the proposed 40 CFR 191, Subpart B, Environmental Standards for Disposal. A site shall be disqualified if the characteristics that influence radionuclide transport are too complex to allow reasonable confidence of compliance with the proposed 40 CFR 191.13 when considered in conjunction with state-of-the-art engineered systems, including those required under 10 CFR 60.113.*

(a) Favorable Conditions

(1) Ground-water travel times to the accessible environment of more than 10,000 years.

(2) Geochemical conditions or ground-water volumetric flow limits that limit radionuclide releases.

(3) A geologic setting that is easily characterized or modeled with existing performance-assessment techniques.

(b) Potentially Adverse Conditions

Geologic setting, site geometries and characteristics, and radionuclide-transport characteristics that are extremely difficult to characterize and model.

3.1.1.2.1 Summary of Available Information. The site for a potential repository in basalt is at depth from ground surface greater than 900 meters (2,952 feet) and more than 700 meters (2,296 feet) from the top of the basalt sequence. The groundwater movement from a potential repository to the Columbia River has been modeled by several different organizations (DOE, 1982c). The traveltimes exceeded 13,000 years. With the accessible environment at 10 kilometers (6.3 miles) from the edge of the repository, the traveltimes would exceed at least 10,000 years and could be greater than 30,000 years. The geochemical conditions in the deep basalts limit the solubility of many radionuclides. Also, chemical interactions between the basalt and most radionuclides in the waste would retard the movement of such radionuclides relative to groundwater flow (DOE, 1982c). In addition, the layered nature of the basalt system tends to encourage horizontal movement through the basalt flow tops rather than through the more impermeable dense interiors of the basalt flows. Low-measured vertical and horizontal hydraulic gradients in the Cold Creek syncline surrounding the reference repository location increase calculated traveltimes from earlier modeling studies.

3.1.1.2.2 Preliminary Conclusions. The characteristics of the basalts are in some cases rather straight-forward and simple. In other cases, characterization and, hence, a proper understanding and modeling are more difficult and challenging. Site characterization and modeling activities are on schedule in providing an adequate understanding of the site in terms of NRC regulatory guides. The Site Characterization Report (DOE, 1982c) presents detailed data that were used to develop these preliminary conclusions. As can be seen by the information presented in Section 3.1.1.2.1, preliminary traveltimes exceed the favorable condition of 10,000 years to the accessible environment. At this time it appears that site and engineered systems will be able to control releases of radioactive materials to the accessible environment below the limits proposed in 40 CFR 191, Subpart B (EPA, 1982).

3.1.2 Program Guidelines

In discharging its responsibilities for the safe disposal of radioactive wastes, the DOE must recognize and follow national policies concerning radioactive waste disposal. Extending beyond the technical considerations of siting a safe, permanent repository, they include environmental, socioeconomic, and political considerations. These policies have been developed over the last 25 years in the course of meetings, discussions, studies, and debates between Federal, State, and local governments and participation by members of the public in meetings and hearings.

3.1.2.1 Conduct of Site Investigation. Program Guideline 960.4-1 (Conduct of Site Investigations) (DOE, 1983) states that:

> ***Studies to identify potential repository sites will consider several geologic media, different hydrogeologic settings, and lands already dedicated to the nuclear activities of the Federal Government. To the extent practicable, sites recommended for detailed characterization shall be in different geologic media.***

3.1.2.1.1 Summary of Available Information. The formal three-step siting process described in Section 2.2 of this document was used by the NWTS Program to determine that the Hanford Site appears to be a suitable site. The host rock approach had previously identified rock salt as being a suitable host rock type. Consequently, areas in the conterminous United States that contain salt domes and bedded salt formations are undergoing site screening studies. This approach was not used to select the Hanford Site for siting studies.

Another approach used by the NWTS Program was to initiate siting studies on federally owned tracts of land in Nevada and Washington that are presently committed to nuclear activities and that may contain host rocks at appropriate depths for a repository. This approach was used to initiate siting studies at the Hanford Site in southeastern Washington State. The Hanford Site has been dedicated to nuclear activities since 1943 and is underlain by many layers of basaltic rock. The combined geologic, geochemical, hydrologic, and geomechanical properties of basalt are currently considered suitable for a potential repository at Hanford. Further site characterization studies are planned throughout the next few years to enable a final decision to be made as to the suitability of the Hanford Site.

The third approach, province screening, is being implemented by the U.S. Geological Survey on an experimental basis in one of eleven geohydrological provinces of the United States. The province screening approach was developed after the Hanford Site was selected for siting studies. Consequently, this approach could not be used to select the Hanford Site for initial siting studies.

3.1.2.1.2 Preliminary Conclusions. The Hanford Site is the first site recommended by the DOE for detailed site characterization. It is expected that other sites recommended for detailed site characterization will be in geologic media other than basalt. Current studies being conducted in bedded salt, domed salt, and tuff support this conclusion.

3.1.2.2 Consultation With States and Affected Indian Tribes. Program Guideline 960.4-2 (Consultation With States and Affected Indian Tribes) (DOE, 1983) states that:

> *The DOE shall provide to State officials and to the governing bodies of any affected Indian tribe timely and complete information regarding both plans and results concerning all phases of site evaluation, investigation, and characterization and the development of a geologic repository. Written responses to written requests for information from officials of affected states or Indian tribes will be provided within no more than 30 days. In performing any aspect of the geologic repository program, the DOE shall consult and cooperate with the governor and the legislature of an affected State and the governing body of an affected Indian tribe in an effort the resolve concerns regarding public health and safety, environmental, and economic impacts of any proposed repository. If requested, or after notifying states or Indian tribes that potentially acceptable sites have been identified within a State or tribal land, the DOE shall seek to enter into binding written agreements to specify procedures for consultation and cooperation with the affected State or Indian tribe.*

3.1.2.2.1 Summary of Available Information. The activities of the BWIP have been conducted under an open information policy that allows members of the general public, State and local government representatives, members of Indian tribes, the NRC, and members of the technical community to discuss the current status of the BWIP at any time. This policy will continue during detailed site characterization and all subsequent phases of the BWIP. A summary of meetings conducted with parties that have shown interest in BWIP activities is presented in Table 3-1. This table lists the major meetings that have taken place prior to the submittal of the Site Characterization Report (DOE, 1982c) to the NRC.

In the spring of 1979, the Intergovernmental BWIP Working Group was formed by Governor Dixy Lee Ray to keep the State of Washington informed on the status of the BWIP and its relationship to the NWTS Program. In August of 1982, Governor John Spellman established the State of Washington High-Level Nuclear Waste Management Task Force, a Citizens Advisory Council, and a Technical Advisory Group. A series of five meetings with representatives from the State of Washington have been held (see Table 3-1).

TABLE 3-1. Summary of Outside Meetings Conducted by the Basalt Waste Isolation Project.

Transmittal of Site Characterization Report to NRC (and meeting with the State of Washington)	11/12/82
Meeting and tour for the Washington State High-Level Nuclear Waste Task Force[a]	10/22/82
Public hearing conducted by the Washington State Legislative Subcommittee on Radioactive Waste	10/21/82
Briefing and tour for the Pasco City Council	10/16/82
Briefing and tour for Tri-City local governments	5/20/82
Fourth meeting with the Intergovernmental BWIP Working Group[b]	4/22/82
Third meeting with the Intergovernmental BWIP Working Group	10/2/81
Third BWIP Technical Information Meeting	12/2-4/80
Yakima Indian Nation briefing and tour	8/25/80
Second meeting with the Intergovernmental BWIP Working Group	1/7/80
Second BWIP Technical Information Meeting	12/5-6/79
Washington State Legislative Workshop on nuclear waste disposal	10/12/79
Public Information Meeting, Portland, Oregon	8/9/79
Public Information Meeting, Seattle, Washington	8/8/79
Public Information Meeting, Richland, Washington	8/6/79
First meeting with the Intergovernmental BWIP Working Group	7/31/79
First BWIP Technical Information Meeting	11/17/78

[a]Established by Governor John Spellman.

[b]Established by Governor Dixy Lee Ray.

On February 2, 1983, pursuant to Section 116 of the Act, the Secretary of the DOE notified the Governor of the State of Washington that Hanford contains a potentially acceptable site for a nuclear waste repository.

3.1.2.2.2 Preliminary Conclusions. The DOE's program for characterization of the Hanford Site basalts has been conducted under an open-door policy in the past, and future activities will be carried out in accordance with this guideline. The Secretary of the DOE in his February 2, 1983 letter to the Governor of the State of Washington offered to begin the formal process of consultation and cooperation required by the Nuclear Waste Policy Act of 1982. To date, no affected Indian tribes have been designated by the Secretary of the Department of Interior. (The Yakima Indian Reservation is the nearest Indian Reservation to the Hanford Site, approximately 50 kilometers (30 miles) from the reference repository location.) The process of consultation and cooperation will follow the requirements of the Act and this guideline.

3.1.2.3 Environmental Impact Considerations. Program Guideline 960.4-3 (Environmental Impact Considerations) (DOE, 1983) states that:

Environmental impacts shall be given due consideration throughout the site-characterization and site-selection processes. The environmental assessments that accompany the nomination of sites shall include the following items as specified by Section 112 of the Act:

(a) An evaluation as to whether the site under consideration is suitable for site characterization under these siting guidelines;

(b) A preliminary evaluation as to whether the site under consideration would be suitable for a repository by comparison to those siting guidelines that can be invoked without the results of site characterization;

(c) An evaluation of the effects of site characterization activities on the public health and safety and the environment;

(d) A reasonable comparative evaluation of the site under consideration with other sites and locations that have been considered;

(e) A description of the decision process which led to the site being recommended;

(f) An assessment of the regional and local impacts of locating a geologic repository at the site being recommended.

A final environmental impact statement will be submitted in support of a decision to recommend a site to the President as suitable for the construction of a geologic repository. Written in accordance with Section 114(f) of the Act, this statement will be based on the requirements of the National Environmental Policy Act and will be the vehicle for evaluating the environmental acceptability of the recommended site in comparison to the available alternatives.

3.1.2.3.1 Summary of Available Information. The NWTS Program has followed the requirements of the National Environmental Policy Act of 1969 in its various activities. Two of the more important programmatic environmental documents are:

- Final Environmental Impact Statement: Management of Commercially Generated Radioactive Waste (DOE, 1980)
- Public Draft, National Plan for Siting High-Level Radioactive Waste Repositories and Environmental Assessment (DOE, 1982d).

During the performance of the BWIP activities, important environmental documents have been prepared for certain characterization activities. Several of these documents are listed below:

- Environmental Assessment for Exploratory Borehole Drilling Activity: Wells ARH-DC-4, -5, -6, -7, and -8, Hanford Reservation, Benton County, Washington (DOE, 1978a)
- Environmental Assessment for the Near-Surface Test Facility, Hanford Reservation, Richland, Washington (DOE, 1978b)
- Environmental Assessment for the Basalt Waste Isolation Project Exploratory Shaft Construction (DOE, 1982a).

3.1.2.3.2 Preliminary Conclusions. Environmental impacts will continue to be given due consideration during the site characterization and site selection processes. This draft environmental assessment addresses the six items listed in Program Guideline 960.4-3. The Nuclear Waste Policy Act of 1982 requires that a final environmental impact statement be prepared to support the site recommendation report. These actions are in full compliance with the purpose and intent of this program guideline. Prior to construction and operation of a nuclear waste repository, the NWTS Program will issue an environmental report that meets the requirements of 10 CFR 51, as part of the construction license application to the NRC.

3.1.2.4 Regional Distribution. Program Guideline 960.4-4 (Regional Distribution) (DOE, 1983) states that:

> *After the selection of the first repository site, a major consideration in siting additional repositories shall be regional distribution. The DOE shall consider the advantages of regional distribution in the siting of repositories to the extent that technical, policy, and budgetary considerations permit.*

3.1.2.4.1 Summary of Available Information. The NWTS Program is committed to developing a regional repository system to take advantage of suitable host rock sites in different parts of the United States. Regional repositories will allow for a more equitable distribution of impacts and/or benefits than an approach that places the burden of nuclear waste disposal on a single area. Cooperation among states in a particular region would be enhanced by this approach and common problems associated with nuclear waste could be resolved.

3.1.2.4.2 Preliminary Conclusions. Siting studies being conducted by the DOE cover various regions of the United States (see Fig. 2-1). After the first repository site is selected, the DOE will carefully consider the advantages of a regional distribution when selecting subsequent repository sites.

3.1.2.5 Schedule for the First Repository. Program Guideline 960.4-5 (Schedule for the First Repository) (DOE, 1983) states that:

> *The DOE shall nominate at least five sites determined suitable for site characterization and subsequently recommend to the President at least three of these nominated sites for detailed characterization as candidate sites. Not later than March 31, 1987, the President shall submit to the Congress a recommendation of one site from the three sites initially characterized that the President considers qualified for application for a construction authorization for a repository.*

3.1.2.5.1 Summary of Available Information. Following the issuance of siting guidelines and consultation with the Governors of affected states, at least five sites will be nominated as suitable for characterization as candidate sites. Three of these five sites will be recommended to the President not later than January 1, 1985, for selection of the first repository site as required by the Nuclear Waste Policy Act of 1982.

3.1.2.5.2 Preliminary Conclusions. This guideline states a specific procedural requirement from the Nuclear Waste Policy Act of 1982. Currently the DOE plans, budgets, and schedules are being developed to ensure compliance with this guideline.

3.1.2.6 Schedule for the Second Repository. Program Guideline 960.4-6 (Schedule for the Second Repository) (DOE, 1983) states that:

> *The DOE shall nominate at least five sites determined suitable for site characterization and subsequently recommend to the President at least three of these nominated sites for characterization as candidate sites. Not later than March 31, 1990, the President shall submit to the Congress a recommendation of a second site from any sites already characterized that the President considers qualified for a construction authorization for a second repository.*

3.1.2.6.1 Summary of Available Information. Five sites, including three additional sites not nominated to meet Section 960.4-5 of the proposed siting guidelines (DOE, 1983), will be nominated for characterization and possible selection of the second repository site. These five sites cannot include either of the two sites that were not recommended to the President by Section 960.4-5 of the proposed siting guidelines (DOE, 1983). Subsequent to this nomination, three of these five sites will be recommended to the President as suitable for site characterization not later than July 1, 1989. This action will comply with the requirements and provisions of the Nuclear Waste Policy Act of 1982.

3.1.2.6.2 Preliminary Conclusions. This guideline also states a specific procedural requirement from the Nuclear Waste Policy Act of 1982. Plans, budgets, and schedules of the DOE are being developed to meet this guideline.

3.1.3 Technical Guidelines

In selecting a site for a nuclear waste repository that is safe and environmentally acceptable, it is necessary to consider a variety of geotechnical and environmental factors. The site must provide natural barriers for waste containment and isolation. These barriers should keep radionuclides from reaching people in unacceptable quantities by (1) maintaining the waste in its emplaced location for a given period of time (providing waste containment), (2) limiting radionuclide mobility through the geohydrologic environment to the accessible environment (providing isolation), and (3) making human intrusion difficult. The technical guidelines evaluated below were prepared to define the physical, chemical, and institutional constraints required to isolate radioactive wastes. Most of the technical guidelines include favorable and potentially adverse conditions that can be evaluated to aid in determining compliance with the guideline. These conditions were taken from the final draft of the NRC's technical criteria to be issued as 10 CFR 60, Subpart E (NRC, 1982b). The summary of available information and the analysis used to make the preliminary conclusions for each guideline are contained in DOE (1982c).

3.1.3.1 Site Geometry. Technical Guideline 960.5-1 (Site Geometry) (DOE, 1983) states that:

> *The geologic repository shall be located in a geologic setting that physically separates the radioactive wastes from the accessible environment and has a volume of rock adequate for placement of the underground facility.*

This guideline deals with the depth, thickness, and lateral extent of the basaltic host rock. The stratigraphy of the reference repository location consists of a thick sequence of laterally extensive basalt flows overlain by approximately 180 meters (590 feet) of sediments. Over 50 basalt flows are present in the Pasco Basin (Fig. 3-3) down to a depth of at least 3.2 kilometers (1.9 miles). At least three candidate repository horizons, the Umtanum, Cohassett, and McCoy Canyon flows, appear to meet the thickness, lateral extent, and depth requirements needed for construction of an underground facility and for assurance that the projected releases of radionuclides would be less than those specified in Section 960.3-2 of the proposed siting guidelines (DOE, 1983).

3.1.3.1.1 Depth of Underground Facilities. Technical Subguideline 960.5-1-1 (Depth of Underground Facilities) states that:

> *The site shall allow the underground facility to be placed at a minimum depth such that reasonably foreseeable human activities and natural processes acting at the surface will not lead to a projection of radionuclide releases greater than those discussed in Section 960.3-2. The site shall be disqualified if site conditions do not allow all portions of the underground facility except the shafts to be at least 200 meters from the directly overlying ground surface.*

(a) Favorable Conditions

(1) Site conditions permitting the emplacement of waste at a minimum depth of 300 meters from the ground surface (10 CFR 60.122(b)(6)).

(2) A geologic setting where the nature and rates of the geomorphic processes that have been operating during the past million years would, if continued in the future, not affect or would favorably affect the ability of the geologic repository to isolate the waste (10 CFR 60.122(b)(1)).

(b) Potentially Adverse Conditions

A geologic setting that shows evidence of extreme erosion during the past million years (10 CFR 60.122(c)(17)).

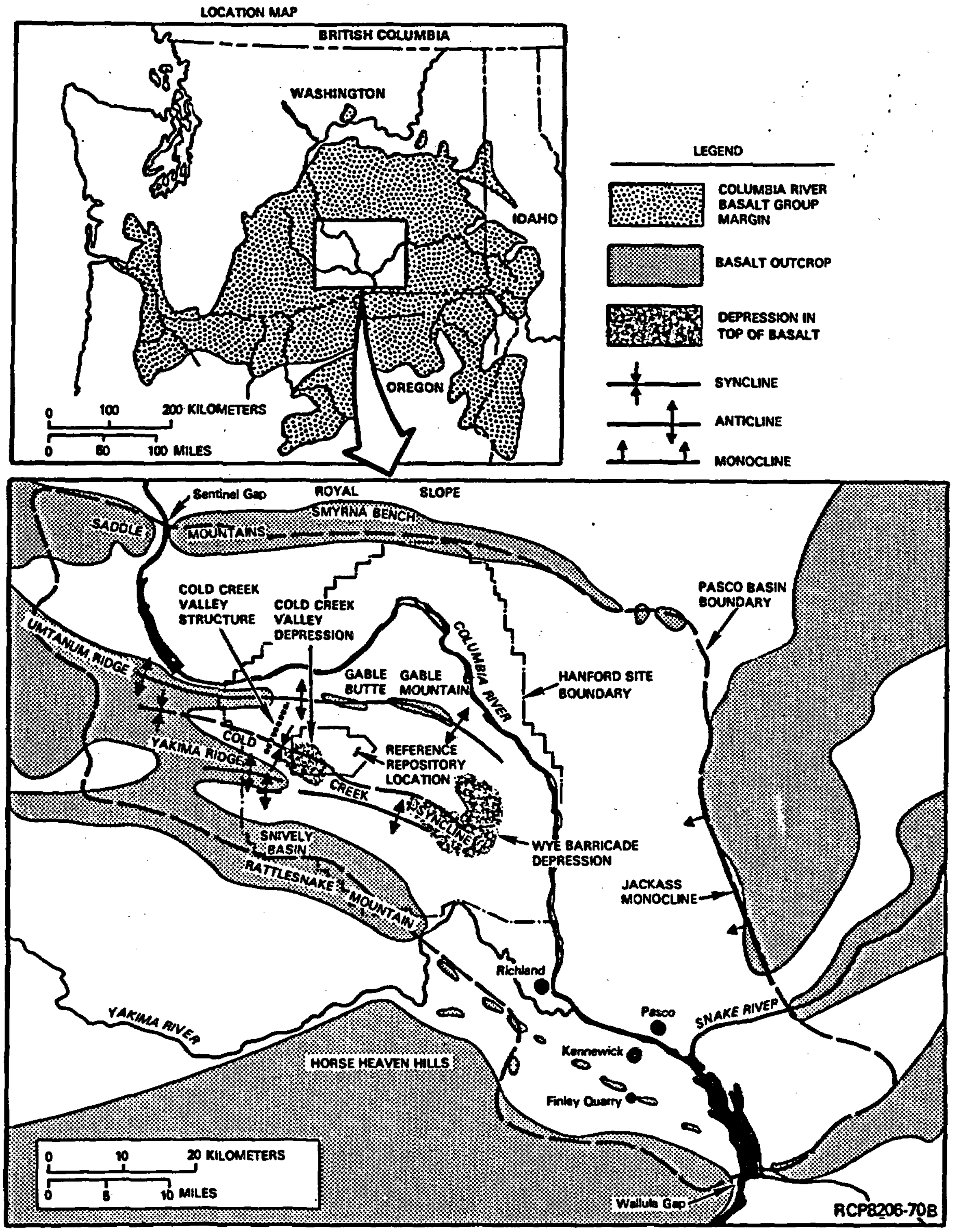

FIGURE 3-3. Extent of the Columbia River Basalt Group, Pasco Basin, and Reference Repository Location.

3.1.3.1.1.1 Summary of Available Information. Based on data from five deep boreholes within the site, the top of the uppermost candidate horizon (Cohassett flow) lies at 869 to 942 meters (2,850 to 3,092 feet) below ground surface (-646 to -746 meters (-2,118 to -2,448 feet) below sea level). The top of the McCoy Canyon flow lies 1,026 to 1,090 meters (3,365 to 3,576 feet) below ground surface (-803 to -894 meters (-2,633 to -2,932 feet) below sea level). The top of the Umtanum flow lies 1,059 to 1,135 meters (3,475 to 3,723 feet) below ground surface (-836 to -936 meters (-2,743 to -3,071 feet) below sea level). Studies show that the area of the site has, over the past 15 million years, been undergoing subsidence, and this is expected to continue into the foreseeable future (Reidel and Fecht, 1982).

Within the Pasco Basin geomorphic processes have been dominated by degradational processes on basalt ridges. Although degradation and aggradation processes were briefly accelerated during periods of catastrophic floods during the past million years, overall rates of degradation and aggradation have been relatively low. These rates are interpreted to reflect the dry climate and low rates of uplift and subsidence (WCC, 1980). The maximum credible depth of erosion is mean sea level or about 190 meters (620 feet) beneath the present surface at the site.

Geomorphic processes within the site have principally resulted in aggradation over the past million years, although degradation has occurred locally. This trend is expected to continue over the next million years.

3.1.3.1.1.2 Preliminary Conclusions. Penetration of the repository by human activity is considered very unlikely due to the proposed depth of the repository and the lack of known economically valuable recoverable resources in the reference repository location (see Sections 960.5-2-2 and 960.5-6-1 of the proposed siting guidelines (DOE, 1983)). Based on current data, the three candidate horizons at the site exceed the minimum requirement of 200 meters (656 feet) below ground surface of the underground facility. Past and current geomorphic processes are not expected to change in the foreseeable future, and the site is not expected to change from an area of subsidence to one of uplift. Therefore, the possibility of the repository being exhumed by erosion is very small. If a repository were placed in any one of the three candidate horizons, reasonably foreseeable human activities and natural processes would not be expected to cause radionuclide releases greater than those discussed in Section 960.3-2 of the proposed siting guidelines (DOE, 1983).

3.1.3.1.2 Thickness and Lateral Extent of Host Rock. Technical Subguideline 960.5-1-2 (Thickness and Lateral Extent of Host Rock) states that:

> *The thickness and lateral extent of the host rock shall accommodate the underground facility and ensure that impacts induced by the construction of the repository and by waste emplacement will not lead to a projection of radionuclide releases greater than those discussed in Section 960.3-2.*

(a) Favorable Conditions

The host rock is of sufficient extent to allow significant latitude in terms of depth, configuration, or location of the underground facility.

(b) Potentially Adverse Conditions

A volume of rock with physical properties adequate for the underground facility but laterally restricted to a small portion of the site.

3.1.3.1.2.1 Summary of Available Information. Available borehole data (five boreholes) indicate that throughout the reference repository location, the Cohassett flow is 73 to 81 meters (239 to 266 feet) thick, the McCoy Canyon flow is 34 to 45 meters (110 to 147.5 feet) thick, and the Umtanum flow is 60 to 71 meters (197 to 232 feet) thick. All three candidate repository horizons appear to be laterally continuous throughout the reference repository location and the northern Pasco Basin (see Fig. 3-3). The candidate repository horizons are known to occur at least 27.8 kilometers (16.7 miles) north, 26.4 kilometers (15.8 miles) east, 13.6 kilometers (8.2 miles) south, and 21.4 kilometers (12.8 miles) west of the center of the reference repository location.

3.1.3.1.2.2 Preliminary Conclusions. The three candidate repository horizons are both thick and laterally continuous beyond the boundaries of the reference repository location and are expected to adequately accommodate the underground facility. Potential radionuclide releases from the three candidate horizons, due to construction activities and waste emplacement, should be less than those established in Section 960.3-2 of the proposed siting guidelines (DOE, 1983). The study of field exposures of the candidate repository horizons will be continued to determine typical, short-range variations in flow thickness. New borehole data will also be used to improve the predictive accuracy of flow thickness.

3.1.3.2 Geohydrology. Technical Guideline 960.5-2 (Geohydrology) (DOE, 1983) states that:

The geohydrologic regime in which the site is located shall be compatible with waste containment, isolation, and retrieval.

Input addressing Technical Guideline 960.5-2 (DOE, 1983) centers on the hydrologic and geologic characteristics of a potential repository site. Based on data for basalt, numerical models are being developed to address questions regarding groundwater traveltimes and radionuclide concentration releases to the accessible environment under both undisturbed and reasonable scenario conditions.

The geohydrologic regime in basalt beneath the Hanford Site has characteristics favorable to waste containment and isolation. These include a tectonic setting undergoing a very low rate of deformation, rock layers of low permeability, plus groundwater traveltimes and potential radionuclide release rates well within recommended Federal guidelines. A summary discussion of present and future hydrologic conditions, hydrologic modeling, shaft construction, and dissolution features follows.

3.1.3.2.1 Present and Future Hydrologic Conditions. Technical Subguideline 960.5-2-1 (Present and Future Hydrologic Conditions) states that:

> *The present and probable future geohydrologic regime of the site shall be capable of preventing radionuclide transport for the repository to the accessible environment in amounts greater than those discussed in Section 960.3-2. The site shall be disqualified if the average pre-waste-emplacement ground-water travel time along the path of likely radionuclide travel from the disturbed zone to the accessible environment is less than 1,000 years.*
>
> *(a) Favorable Conditions*
>
> *(1) The nature and rates of hydrologic processes operating within the geologic setting during the past million years would, if continued in the future, not affect or would favorably affect the ability of the geologic repository to isolate the waste (10 CFR 60.122(b)(1)).*
>
> *(2) For disposal in the saturated zone, hydrologic conditions that provide a host rock with a low horizontal and vertical permeability; a downward or predominantly horizontal hydraulic gradient in the host rock; and a low vertical permeability and low hydraulic potential between the host rock and the surrounding hydrogeologic units; or a pre-waste-emplacement ground-water travel time along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment that substantially exceeds 1,000 years (10 CFR 60.122(b)(2)).*
>
> *(3) For disposal in the unsaturated zone, hydrogeologic conditions that provide a low and nearly constant moisture content in the host rock and the surrounding hydrogeologic units; or a water table sufficiently below the underground facility such that the capillary fringe does not encounter the host rock; or a laterally extensive low-permeability hydrogeologic unit above the host rock that would divert the downward infiltration of water beyond the limits of the underground facility; or a host rock with a high saturated permeability and an effective porosity that provides for free drainage; or a climatic regime in which precipitation is a small percentage of the potential evapotranspiration (10 CFR 60.122(b)(3)).*

(b) Potentially Adverse Conditions

None specified.

3.1.3.2.1.1 Summary of Available Information. There exists no direct method to evaluate the past groundwater environment other than through inferences using the structural/tectonic setting, groundwater chemistry, and numerical models.

By understanding the structural and tectonic stability of an area, one can infer the likelihood of generating new groundwater flow paths. Available geologic, geophysical, geodetic, and seismologic data suggest that the Pasco Basin was deforming at a low rate of strain in the Miocene and this rate has continued to the present (Rasmussen, 1967; WPPSS, 1974; UWGP, 1979; Savage et al., 1981; PSPL, 1982; Reidel and Fecht, 1982). This slow rate of deformation along known geologic structures is also expected to continue for a projected minimum 10,000-year period (see Sections 960.5-5-1 and 960.5-5-3 of the proposed siting guidelines (DOE, 1983)). Thus, groundwater flow paths as now characterized have probably extended into the past and are projected into the reasonable future.

Groundwater chemistry provides direct long-term evidence of the water's history. Present data have identified distinct groundwater chemistries in the shallow versus deep basalts, each with distinguishable isotopic signatures. The areal continuity of these chemical types and groundwater ages suggest these waters have undergone uniform geochemical processes since their infiltration. Geochemical modeling is planned to more fully understand the rock-water interactions required to produce the chemistries found (see discussion under Technical Guideline 960.5-3). These results will be coupled with the latest conceptual and numerical models to produce a reasonable projection of both past and future hydrologic processes and rates that may affect radionuclide transport.

The proposed disposal of nuclear waste in Columbia River basalt would occur within the saturated zone. Therefore, the favorable conditions quoted earlier that pertained to waste disposal in the unsaturated zone do not apply to basalt.

Groundwater within basalt moves laterally through zones of high hydraulic conductivity (within portions of interbeds and flow tops) and vertically through fractured basalt interiors (the degree of vertical movement depends on the flow's vertical transmissivity). In nonstructurally deformed areas, minimal groundwater quantities are thought to move across flow interiors separating more permeable zones. Thus, flow interiors are interpreted to act as low conductivity aquitards. Because of the greater-than-normal occurrence and length of fracturing in structurally disturbed areas (e.g., Umtanum Ridge-Gable Mountain anticline) (see Fig. 3-3), water is considered to seep vertically through such structures to a larger extent than in nondisturbed areas. As opposed to anticlines, synclines are broad, open features having undergone little structural disturbance. Thus synclinal areas, such as the location of the reference repository location, should contain less secondary fracturing and less vertical groundwater leakage compared to anticlinal areas.

Overall, groundwater moves from areas of recharge to discharge. Local reacharge areas for shallow basalts are the basalt outcrops surrounding the Pasco Basin. Regional recharge of deeper basalts is thought to be from interbasin groundwater movement. Discharge is to the major rivers (see Fig. 3-3), but the exact discharge location(s) is unknown. Along these groundwater flow paths, water is under artesian conditions. Areas of flowing artesian wells exist within the Cold Creek Valley (west of the reference repository location) and along the Columbia River where low land elevations exists.

Within the Saddle Mountains Basalt, most equivalent horizontal hydraulic conductivities for flow tops and sedimentary interbeds range between 10^{-4} and 10^{-6} meters per second (10^{1} to 10^{-1} feet per day), with a mean value of 10^{-5} meters per second (10^{0} feet per day). The majority of hydraulic conductivity values for flow tops in the Wanapum Basalt range between 10^{-4} and 10^{-7} meters per second (10^{1} to 10^{-2} feet per day), with a mean value of 10^{-5} meters per second (10^{0} feet per day). Hydraulic conductivities for flow tops within the Grande Ronde Basalt generally range from 10^{-5} to 10^{-9} meters per second (10^{0} to 10^{-4} feet per day), with a mean value of about 10^{-7} meters per second (10^{-3} feet per day).

Results of hydrologic tests across dense interior (colonnade and entablature) sections of basalt flows give horizontal hydraulic conductivities of 10^{-12} to 10^{-13} meters per second (10^{-7} to 10^{-8} feet per day). These values are thought typical of dense flow interiors. Those portions of flow tops that do not consist of interconnected vesicles and fractures are considered to have hydraulic conductivities between the lowest values reported for flow tops and those typical of flow interiors.

The variability in hydraulic conductivity for a particular stratigraphic unit probably results from areal changes in fracture/vesicular frequency and interconnections, plus differences in secondary mineral infilling. These features relate to the cooling and emplacement history of a flow in addition to any post-emplacement disturbance.

The only reported estimates of vertical conductivity for Columbia River basalt are from numerical model studies of Tanaka et al. (1974) for the Walla Walla River Basin Irrigation Project and from MacNish and Barker (1976) for the Walla Walla River Basin. Tanaka et al. (1974) estimated the vertical hydraulic conductivity for the basalt sequence to be between 10^{-12} and 10^{-10} meters per second (10^{-7} and 10^{-5} feet per day). MacNish and Barker (1976) stated that it may be as low as 10^{-8} meters per second (10^{-3} feet per day) within their area of study. These estimates were iteratively derived from a model that simulated an observed head distribution.

Numerical model simulations for the BWIP studies use the conservative value of 10^{-10} meters per second (10^{-5} feet per day) as the vertical hydraulic conductivity across basalt flows (DOE, 1982c). This is about 2 orders of magnitude larger than the mean horizontal conductivity for the columnar sections of a basalt flow as determined from downhole hydrologic testing. Vertical hydraulic conductivity field testing was initiated by the BWIP during fiscal year 1983.

Hydraulic head data collected from within the reference repository location are being integrated with Hanford-wide information to develop a more complete understanding of the groundwater system. Within the Saddle Mountains Basalt beneath the reference repository location, head elevations decrease with depth from 137 to 127 meters (449 to 417 feet). Lower heads with depth are characteristic of groundwater recharge areas such as found in the shallow basalts along the western Hanford Site. Head elevations are rather uniform within the Wanapum and Grande Ronde Basalts in the reference repository location, averaging 123 $\pm$ 1.5 meters (403 $\pm$ 5 feet) above mean sea level. These generally uniform head distributions are common in the Cold Creek syncline and are interpreted as indicating an area of lateral groundwater movement--that portion of the groundwater system not undergoing major recharge or discharge. The average areal head gradient in the deep basalts is a low 10^{-4} meter/meter (foot/foot). Groundwater from the reference repository location appears to move southeasterly.

Based on available data, hydraulic head changes in the deep basalts beneath the Hanford Site appear to be slow and of small magnitude. This is concluded upon examining long-term head monitoring records from boreholes DC-1 and DDH-3, plus several shallower monitoring wells.

An examination of hydraulic heads from piezometers placed in the Grande Ronde Basalt in borehole DC-1 indicates small head changes ($\pm$1 meter ($\pm$3 feet)) over the past decade in most piezometers following hole equilibration.

Borehole DDH-3 has a single piezometer open across two flow contacts in the Frenchman Springs Member of the Wanapum Basalt. Heads have been periodically monitored in DDH-3 since 1970. These measurements give head elevations of approximately 117 to 118 meters (384 to 387 feet) above mean sea level. Such small changes monitored over a 12-year period suggest that the overall head elevation has changed little in that portion of the Wanapum Basalt.

An active borehole monitoring program (borehole locations are shown in Fig. 3-4) is also maintained in a series of shallow boreholes completed in either the lower Saddle Mountains or upper Wanapum Basalts. These holes are located adjacent to the Columbia River, within the Cold Creek syncline, and in the Cold Creek Valley where heavy groundwater withdrawals are taking place. A summary of these data indicates that over the period for which monitoring records are available (approximately 4 years), heads in boreholes DB-1 and DB-2, sited near the Columbia River, have undergone a slow, cyclic response with a maximum head variation of $\pm$1 meter ($\pm$3 feet) having a periodicity of greater than 1 year. Very minor head variations ($\pm$0.2 meter ($\pm$0.6 feet)) have taken place in borehole DB-4, located centrally within the Cold Creek syncline and in DB-7 ($\pm$0.4 meter ($\pm$1.3 feet)), located in the southern Cold Creek syncline. In the Cold

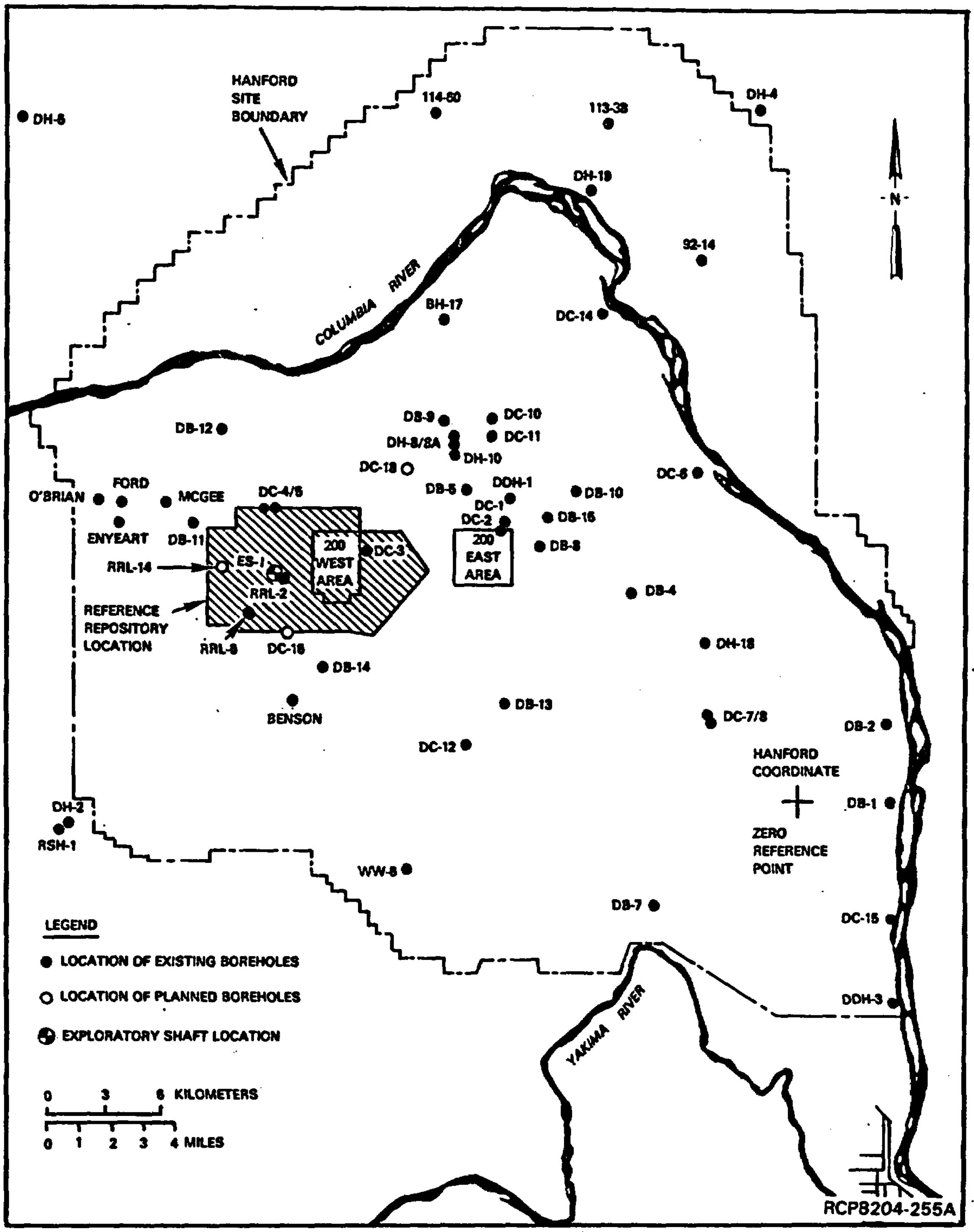

FIGURE 3-4. Location of Existing and Planned Boreholes at the Hanford Site.

Creek Valley west of the Cold Creek structural barrier mentioned earlier, water levels in DB-11 have declined 7.5 meters (24.5 feet) since 1978. This change resulted from nearby agricultural water withdrawals.

The above monitoring data indicated that hydraulic heads in the deep basalts beneath Hanford change slowly and by small amounts. Heads in shallow basalts, east of the Cold Creek structural barrier, vary by slightly larger amounts.

Distinct groundwater chemical types exist in the Columbia River basalts. Changes from one type to another occur rapidly over short stratigraphic distances. Overall, Saddle Mountains, Wanapum, and Grande Ronde groundwaters are of sodium bicarbonate, sodium chloride-bicarbonate and sodium chloride chemical types, respectively. The specific stratigraphic boundaries separating these chemical types vary by small amounts depending upon areal location. Major isotopic shifts between shallow and deep basalts also take place. Such hydrochemical and isotopic shifts (coupled with small vertical hydraulic head gradients) are believed to delineate flow system boundaries and suggest the lack of significant vertical mixing of groundwaters in structurally nondeformed areas. Studies are under way to examine the possibility of groundwater mixing along the Umtanum Ridge-Gable Mountain anticline and the Cold Creek Valley structure (see Fig. 3-3). Future geochemical modeling is also directed toward evaluating these concepts.

Modeling of the near-field groundwater flow system around a repository indicates that the groundwater flow paths are primarily controlled by the more permeable flow tops between successive flows. Results of modeling also indicate that the minimum groundwater traveltimes from the repository site to the accessible enviroment, a distance defined by the EPA in its proposed regulations (EPA, 1982) as 10 kilometers (6.2 miles) appear to be greater than 10,000 years. The very small quantities of radionuclides, which do ultimately travel to the accessible environment, appear to remain small and well below the EPA-proposed regulations.

Over the past several years, a number of far-field hydrologic modeling studies have been conducted by independent organizations. Each study had limiting assumptions and used the most recent data available at the time of the study. Traveltimes were estimated for groundwater movement between the repository and a discharge point at the Columbia River, a distance of 8 to 60 kilometers (5 to 35 miles) depending on the assumed flow path. Traveltimes estimated exceeded 20,000 years. Regardless of the different assumptions used, these estimated pre-waste-emplacement traveltimes are significantly longer than the NRC-proposed technical criterion (NRC, 1981a) of a 1,000-year minimum traveltime between the repository and the accessible environment.

A preliminary analysis of post-waste-emplacement flow paths and traveltimes has also been performed. The analysis of groundwater flow patterns for the post-closure period indicates that the thermal environment (i.e., temperature field in the vicinity of the repository) will significantly influence the natural groundwater flow paths and traveltimes. Flow paths within the thermally influenced zone are predominantly upward where buoyancy driving forces are strong; whereas, outside this zone the flow direction is controlled by the regional hydraulic gradient. The net effect is that the post-waste-emplacement traveltimes appear to be longer than those for pre-waste-emplacement conditions. This is because groundwater is being driven vertically through several additional basalt flows of low interior permeability compared to pre-waste-emplacement flow paths.

3.1.3.2.1.2 Preliminary Conclusions. Available data indicate that the local structural/tectonic setting has been undergoing a slow rate of deformation of several million years and most of this deformation occurs along existing geologic structures. Thus, new groundwater pathways are not expected to be generated in the foreseeable future and the nature and rate of hydrologic process should remain relatively constant. The horizontal hydraulic conductivities of basalt flow interiors are very low with groundwater production from the basalts restricted to limited zones within given flow tops and sedimentary interbeds. This groundwater movement is predominantly horizontal and occurs under a low hydraulic potential. Pre-emplacement groundwater traveltimes to the accessible environment substantially exceed 1,000 years. These factors lead to the preliminary conclusion that radionuclide releases will meet the limits of Section 960.3-2 of the proposed siting guidelines.

3.1.3.2.2 Hydrologic Modeling. Technical Subguideline 960.5-2-2 (Hydrologic Modeling) states that:

The geohydrologic regime shall be capable of being characterized with sufficient certainty to permit modeling to show that present and probable future conditions would lead to a projection of radionuclide releases less than those discussed in Section 960.3-2.

(a) Favorable Conditions

Sites that have simple stratigraphic and hydrogeologic sequences and a lack of structural, tectonic, or cross-cutting igneous features such that the geohydrology can be readily characterized and modeled with reasonable certainty.

(b) Potentially Adverse Conditions

(1) Potential for foreseeable human activities to adversely affect the ground-water flow system, such as ground-water withdrawal, extensive irrigation, the subsurface injection of fluids, underground pumped storage, military activities, or the construction of large-scale surface-water impoundments (10 CFR 60.122(c)(2)).

(2) *Potential for natural phenomena like landslides, subsidence, or volcanic activity of such a magnitude that they could create large-scale surface-water impoundments that could change the regional ground-water flow system (10 CFR 60.122(c)(3)).*

(3) *Potential for the water table to rise sufficiently to cause the saturation of waste-emplacement areas in the unsaturated zone (10 CFR 60.122(c)(4)).*

(4) *Potential for structural deformation--such as uplift, subsidence, folding, or faulting--that may adversely affect the regional ground-water flow system (10 CFR 60.122(c)(5)).*

(5) *Potential for changes in hydrogeologic conditions that would increase the transport of radionuclides to the accessible environment, such as changes in the hydraulic gradient, average interstitial velocity, storage coefficient, hydraulic conductivity, natural recharge, potentiometric levels, and discharge points (10 CFR 60.122(c)(6)).*

(6) *Potential for adverse changes in hydrologic conditions resulting from reasonably foreseeable climatic changes (10 CFR 60.122(c)(7)).*

3.1.3.2.2.1 Summary of Available Information. Geohydrologic studies are providing data defining the occurrence, distribution, supply, and history of basalt groundwaters. The tectonic and structural features important to understanding the long-term waste isolation potential of basalt are being defined and integrated into conceptual and numerical models. As demonstrated in the Site Characterization Report (DOE, 1982c) the local geologic and hydrologic setting can be characterized and modeled. Uncertainty in understanding the geohydrologic regime is a function of basic data input, the conceptual model, the numerical models, and how uncertainty propagates from each of these model levels to the next higher one. The degree of approximation or error in the numerical codes will be checked in the process of code verification and benchmarking.

Performance-assessment methodology is based on the conjuctive use of a set of numerical models. These models are designed to describe the coupled processes of rock stress-strain, heat transfer, groundwater flow, and radionuclide transport. The set of models are grouped into three categories: very near field (canister to room scale), near field (repository scale), and far field (groundwater basin scale). The very near-field models use a representation that considers both the fractured and porous features of the basalt medium. The near-field and far-field models use the concept of an "equivalent porous continuum" to represent the major basalt flows and confined aquifers.

For the very near-field zone, the performance models are used to compute the fractional radionuclide release rates at the boundary of the engineered barriers and candidate repository horizon. Output from near-field predictions are the concentrations of key radionuclides in the groundwater and the time-integrated activity crossing the 10-kilometer (6.2-mile) controlled zone boundary. Flow paths and traveltimes in the far-field zone (i.e., from the control zone boundary to points in the accessible environment) are determined as functions of the recharge/discharge characteristics, hydrologic properties and boundary conditions, and major structural features of the geologic system.

Very near-field analyses indicate that the fractional release rates for key radionuclides are a function of the release rate at the waste package, hydraulic properties of the emplacement horizon, and the magnitude of the thermally induced driving forces. For radionuclides with even a nominal amount of sorption (i.e., kd greater than 5.0 milliliters per gram), the retardation effects are sufficient to reduce the release rates from the repository horizon to levels well below the 10^{-5} per year proposed regulatory criterion, during the first 10,000 years (Baca et al., 1982). The very low solubility properties of major radionuclides (technetium, uranium, plutonium, americium) in the reducing (anoxic) environment of the deep basalt plays an even greater role than sorption in maintaining release rates below the proposed release criterion.

Near-field simulation results for the candidate repository horizons indicate that relatively few radionuclides are of concern within a 10,000-year waste isolation period. Most actinide elements and long-lived fission products are of little importance because of their retardation characteristics and apparently very low solubilities. The radionuclide ^{14}C appears to be a key radionuclide in the spent fuel inventory because of its mobility (i.e., nonsorbing characteristic and relatively long half-life). For the flow paths predicted from the candidate repository horizons, since average traveltimes are greater than 10,000 years to the accessible environment, the radionuclide fluxes are zero at the 10-kilometer (6.2-mile) boundary during the first 10,000 years. The radionuclide fluxes reaching the accessible environment are below the conservative maximum permissible concentration levels at the control zone boundary for all future times.

As noted in Section 3.1.3.2.1.1, far-field hydrologic modeling has been performed by several independent organizations. Each study concluded that under pre-waste-emplacement conditions, groundwater traveltimes from the repository to the accessible environment substantially exceeded the 1,000-year proposed criteria.

Several non-site-specific credible scenarios for disruptive event occurrence have been proposed in the technical literature (Arnett et al., 1980). These generic scenarios have been screened and evaluated on the basis of credibility, consistency with site-specific geologic and hydrologic knowledge, event likelihood, and release potential to preliminarily define scenarios relevant to disruption of a repository in

Columbia River basalt. Scenarios initially considered applicable consisted of the following natural, man-induced, and repository-induced events for the first 10,000 years following repository decommissioning:

- Fault zone directly or indirectly connecting the repository with the biosphere
- Shaft seal degradation or failure
- Intrusion by borehole
- Loss of integrity due to microearthquake swarm zone
- Intrusion by basaltic dike.

Dike intrusion was eliminated from consideration based on a close examination of the nature and conditions of historic basaltic extrusions. Preliminary analysis of the consequences of a microearthquake event centered at the repository indicates no significant effects over the 10,000-year period of interest. No definitive evidence was found that either magmatic intrusion by basaltic dike or a microearthquake event would have significant hydrologic effects.

Currently, with the exception of volcanism (Johnpeer et al., 1981) (see discussion under Technical Guideline 960.5-5), no attempt has been made to estimate the probabilities of occurrence of such events within the Pasco Basin. Instead, consequence analyses have been undertaken to determine their potential for disruption of a repository in basalt. In many instances, the consequences of a particular event are sufficiently small to cause the issue of probability of occurrence to be of limited or no interest; i.e., even if the probability of occurrence of an event is one, the radionuclides would be contained in the deep basalt away from the accessible environment.

The current list of plausible scenarios will be expanded to include other postulated events: (1) repository-induced phenomena, (2) man-induced phenomena, and (3) effects of climatic variation. If it is determined that an event or process has a potentially significant consequence, the overall risk will be calculated from the consequence and the probability of occurrence.

3.1.3.2.2.2 Preliminary Conclusions. The basalt geohydrologic environment can be characterized and appears to be a suitable setting for the long-term isolation of radionuclides under nondisruptive and reasonable disruptive scenario conditions. Studies are under way or planned to examine the effects from additional disruptive scenarios associated with man-induced or natural phenomena. These modeling efforts are necessary to make a final determination that radionuclide releases are less than those specified in Section 960.3-2 of the proposed siting guidelines (DOE, 1983)

3.1.3.2.3 Shaft Construction. Technical Subguideline 960.5-2-3 (Shaft Construction) states that:

The geohydrologic regime of the site shall allow the construction of repository shafts and maintenance of the integrity of shaft liners and seals.

(a) Favorable Conditions

Absence of large highly transmissive aquifers between the host rock and the land surface.

(b) Potentially Adverse Conditions

Rock or ground-water conditions that would require complex engineering measures in the design and construction of the underground facility or in the sealing of boreholes and shafts (10 CFR 60.122(c)(21)).

3.1.3.2.3.1 Summary of Available Information. Approximately 15 water-bearing horizons having hydraulic conductivities of greater than or equal to 10^{-5} meters per second (1 foot per day) have been identified beneath the reference repository location. These horizons could produce water inflows of several tens to several thousand liters (gallons) per minute. Potential high-production horizons include sedimentary interbeds within the Saddle Mountains Basalt, flow tops in the Priest Rapids, Roza, and Frenchman Springs members of the Wanapum Basalt plus selected flow tops in the Grande Ronde Basalt.

Groundwater inflows can be controlled in a shaft sunk by blind hole drilling through the use of drilling muds and additives. If a shaft is sunk by conventional mining techniques (blasting and mucking), water inflow is controlled by freezing or grouting. The Exploratory Shaft will be completed by blind hole drilling.

The blind hole drilling technique will seal aquifers by floating a circular steel liner into the shaft hole and then filling the annulus between liner and rock with grout. Grout will be pumped into the annulus in stages from the bottom up such that the fluid that maintains the hydrostatic pressure is gradually displaced. After the grout has set, the steel liner and grout can be removed in zones of competent rock. This is necessary to allow access to the candidate repository horizons or to install impermeable barriers for decommissioning of the repository.

The drilling, blasting, and mucking shaft-sinking technique requires that control of aquifers be accomplished before the shaft is emplaced. Control is achieved by either pressure grouting or freezing. Both techniques require holes to be bored into the aquifer before blasting the shaft. Grout is pumped into the aquifer from small holes radiating from the shaft and then allowed to set before blasting continues. The freezing technique uses a circle of boreholes drilled from the surface to conduct freezing liquids to the aquifers. The water is frozen in the aquifer prior to blasting. With either technique, the blasted shaft is lined with reinforced concrete to provide a more complete and permanent seal. In zones where water inflow is small enough to be controlled by pumps, freezing or grouting would not be necessary. Sealing the shaft for decommissioning would be similar to that planned for the blind hole drilling technique.

3.1.3.2.3.2 Preliminary Conclusions. The water-bearing horizons that could pose a potential inflow concern during shaft construction have been identified. Water inflow rates have been calculated based on measured heads and equivalent hydraulic conductivities. The construction of the Exploratory Shaft at Hanford will show that large-diameter shafts can be blind bored to repository depth, and intersected aquifers can be sealed off from the shaft.

3.1.3.2.4 Dissolution Features. Technical Subguideline 960.5-2-4 (Dissolution Features) states that:

> *The site shall be such that any subsurface rock dissolution that may be occurring or is likely to occur would not lead to a projection of radionuclide releases greater than those discussed in Section 960.3-2. The site shall be disqualified if it is shown that active dissolution fronts would cause significant interconnection of the underground facility to the site hydrogeologic system during the first 10,000 years.*
>
> *(a) Favorable Conditions*
>
> *No evidence that the host rock within the operations area was subject to dissolution during the past million years.*
>
> *(b) Potentially Adverse Conditions*
>
> *Evidence of dissolution such as breccia pipes or dissolution cavities (10 CFR 60 122(c)(11)).*

3.1.3.2.4.1 Summary and Conclusions. This guideline does not apply to hard rocks such as basalt. No further evaluation of this guideline is necessary.

3.1.3.3 Geochemistry. Technical Guideline 960.5-3 (Geochemistry) (DOE, 1983) states that:

> *The site shall have geochemical characteristics compatible with waste containment, isolation, and retrieval. The site shall be such that the chemical interactions among radionuclides, rock, ground water, and engineered components would not lead to a projection of radionuclide releases greater than those discussed in Section 960.3-2.*

(a) *Favorable Conditions*

(1) *The nature and rates of the geochemical processes operating within the geologic setting during the past million years would, if continued in the future, not affect or would favorably affect the ability of the geologic repository to isolate the waste (10 CFR 60.122(b)(1)).*

(2) *Geochemical conditions that promote the precipitation or sorption of radionuclides; inhibit the formation of particulates, colloids, and inorganic and organic complexes that increase the mobility of radionuclides; or inhibit the transport of radionuclides by particulates, colloids, and complexes (10 CFR 60.122(b)(4)).*

(3) *Mineral assemblages that, when subjected to the expected thermal loading, will remain unaltered or will be altered to mineral assemblages with equal or increased capability to inhibit radionuclide transport (10 CFR 60.122(b)(5)).*

(b) *Potentially Adverse Conditions*

(1) *Ground-water conditions in the host rock--including chemical composition, high ionic strength, or oxidizing or reducing conditions and pH--that could increase the solubility or chemical reactivity of the engineered barrier systems (10 CFR 60.122(c)(8)).*

(2) *Geochemical processes that would reduce the sorption of radionuclides, result in the degradation of the rock strength, or adversely affect the performance of the engineered barrier systems (10 CFR 60.122(c)(9)).*

(3) *For disposal in the saturated zone, ground-water conditions in the host rock that are not chemically reducing (10 CFR 60.122(c)(10)).*

3.1.3.3.1 Summary of Available Information. Demonstration of the compatibility of a nuclear waste repository in basalt with this guideline requires an assessment of the nature and rates of long-term (past 1 million years) geochemical processes operating within the basaltic geologic setting. In addition, the geochemical conditions that affect the stability of the basalt and engineered barriers system, and the solubility and transportation of radionuclides must be addressed.

Determination of actual geochemical conditions during the last 1 million years can be determined indirectly by using groundwater age data and by interpreting secondary-mineral assemblages. Secondary-mineral assemblages are present within the basalt that have wide stability ranges whose ages of deposition are not known precisely. However, the ages of the oldest secondary minerals are almost certainly greater than 1 million years.

The geochemistry of the groundwater in the reference repository location and surrounding area tends to be buffered by reaction with basalts that constitute the bulk of the rocks at depth. Because of the relatively high rock-to-water ratios and because the rock and groundwater compositions do not change appreciably with time and the thermal gradient remains constant, changes in groundwater chemistries would most likely result from an influx of oxygenated surface waters. Such an influx is likely to be very slow; both theoretical considerations and experimental results indicate that such water would react with basalt and become strongly reducing. Thus, oxidization conditions are not expected to persist.

The current understanding of the prevailing geochemical conditions in the candidate repository horizons in the reference repository location is summarized in Table 3-2.

TABLE 3-2. Environmental Conditions in the Candidate Repository Horizons.

Parameter	Flow		
	Cohassett	McCoy Canyon	Umtanum
Depth range* (m)	912.3 - 992.1	1,059.2 - 1,099.4	1,099.4 - 1,170.1
Mean temperature (°C)	51.2	56.0	58.2
Mean hydrostatic pressure (MPa)	9.2	10.4	11.0
pH	9.5 $\pm$ 0.05	9.5 $\pm$ 0.05	9.5 $\pm$ 0.05
Eh (V)	-0.45 $\pm$ 0.07	-0.45 $\pm$ 0.07	-0.45 $\pm$ 0.07

*Below surface (top of flow to bottom of flow).

Work to develop a more complete understanding of the nature of the groundwater chemistry and Eh-pH controlling mechanisms is under way. Based on the current data set, Jacobs and Apted (1981) have suggested that dissolution of basalt glass and the precipitation of secondary minerals may be responsible at both ambient and elevated temperatures. Indirect Eh measurements (oxygen depletion) from preliminary 200°C (392°F) basalt-groundwater hydrothermal experiments support the proposed mechanism and suggest control to be very rapid (within several hundred hours). Additionally, steady-state solution compositions from these experiments are very similar to the composition of in situ groundwaters. These preliminary results suggest that the mechanism(s) controlling solution chemistry, pH and Eh, are similar at both ambient and elevated temperatures. Further refinement and confirmation of these concepts will result from carefully designed basalt hydrothermal experiments and detailed in situ analyses of the basalt-groundwater system.

Thermal loading of the groundwater-saturated repository will result in hydrothermal interactions in the waste/barrier/basalt system. The dominant process will be gradual dissolution of coexisting primary solid phases. Dissolution will be accompanied by precipitation and growth of an assemblage of secondary alteration phases that are more stable under the given repository conditions (Helgeson, 1968). Primary phases include silicates and oxides in basalt, backfill, and waste form components, and metals or alloys for canister components.

The various dissolution and growth mechanisms for each solid are qualitatively similar, yet can be meaningfully divided along the functional requirements of each component of the waste package. Canister materials should be selected to be relatively inert to groundwater. Groundwaters with Eh and pH conditions similar to those in the candidate repository horizons generally lead to low corrosion rates for proposed canister materials (e.g., carbon steel).

The dissolution of basalt (and, by extension, backfill and buffer components) and attendant growth of secondary alteration phases will control (buffer) the geochemical parameters within the repository. This is because basalt, especially the glassy portion, is volumetrically the dominant reactive solid phase. Also, the alteration phases formed, such as clays and zeolites, will significantly absorb radionuclides and retard their migration to the accessible environment.

The basalt geochemical environment can affect radionuclide transport by controlling radionuclide solubility and sorption behavior--the two dominant retardation mechanisms in the basalt geohydrologic system. Available data suggest that both solubility and sorption controls are important factors in limiting radionuclide releases to the accessible environment.

The solubility amd mobility of a radionuclide is dependent on the environmental conditions (Eh, pH, temperature, stable complexes, etc.) of the geohydrologic system. Theoretical solubility estimates of a variety of important actinide and fission products are available for conditions anticipated in the Grande Ronde basalt geochemical environment (Early et al., 1982). In addition, some experimental data has been collected by the BWIP. These theoretical and experimental studies generally confirm that the strongly reducing and alkaline groundwaters encountered in a nuclear waste repository in basalt result in lowered solubilities for many key radionuclides. Specifically, reducing conditions led to the formation of low oxidation states for many radionuclides that inhibit production of stable complex species. In addition, it appears that the high pH promotes the precipitation of most actinides in the form of oxides and hydroxides. Insufficient solubility data are available for other important radionuclides. Static and dynamic (flow-through) experiments that will address this question are in progress.

Investigation of the specific dissolved radionuclide species in Grande Ronde Basalt groundwater has been approached theoretically (Early et al., 1982), but experimental confirmation is lacking. The possibility that formation of organic complexes and/or colloids might occur has been considered and specific studies to resolve these issues are either planned or in progress.

Radionuclide distribution coefficient values have been determined for the sorption of the majority of the key radionuclides on representative geologic materials under conditions applicable to geohydrology for the basalt system (Salter et al., 1981a, 1981b; Ames, 1980; Ames and McGarrah, 1980a, 1980b, 1980c). These distribution coefficient values are used currently in radionuclide transport models to evaluate the radionuclide retardation capabilities of the basalt geohydrologic system (Wood, 1980; Arnett et al., 1981). However, this method has two basic limitations: (1) it assumes equilibrium (i.e., a reversible system) and (2) it assumes that sorption is linearly dependent on radionuclide concentration. In addition, the measured distribution coefficient values do not distinguish between precipitation and sorption reactions. The assumptions, implicit in the use of simple distribution coefficient based models, are not valid for all radionuclides; sorption isotherms are often nonlinear, and some sorption reactions can be controlled kinetically and/or can be irreversible.

To improve the evaluation of radionuclide retardation for use in transport modeling, radionuclide sorption-desorption isotherms are currently being determined for the basalt geohydrologic system (Salter et al., 1981a, 1981b). These isotherm "equations" describe sorption as a function of radionuclide concentration and will replace the distribution coefficient values in the retardation equation. Sample radionuclide distribution coefficient values, however, can be used to qualitatively evaluate the retardation capabilities of the geohydrologic system and to establish reasonable experimental parameters for more advanced sorption experiments (kinetic and flow-through sorption). Kinetics and reversibility of the radionuclide sorption reactions in the basalt geohydrologic system are also being determined. Kinetic sorption equations, where applicable, can be used in place of equilibrium sorption isotherms to determine radionuclide retardation. Present investigations of both equilibrium and kinetic sorption behavior, over the range of repository conditions, and the development of mathematical functions (sorption isotherms, etc.) to describe this behavior will permit a more accurate assessment of radionuclide retardation.

Available groundwater chemistry data, results from basalt solids characterization studies and sorption isotherm experiments, suggest that the suite of observed secondary minerals and hydrothermal alteration products in the host basalt and backfill material strongly sorb many key radionuclides under anticipated environmental conditions. Sorption-desorption and kinetics studies are continuing and will help provide additional refinement in sorption systematics for input to radionuclide transport modeling efforts.

3.1.3.3.2 Preliminary Conclusions. Present Eh-pH, chemical, and secondary mineralogical conditions in the basalt geochemical system seem to be the result of rock-water interaction processes that have been operative at least during the Quaternary. The basalt mineralogy and the high rock-water ratio seem to effectively buffer the groundwater composition against significant change.

Available geochemical data indicate that the candidate repository horizons at the Hanford Site provide effective containment and isolation for many radionuclides present in high-level nuclear waste. Groundwaters from these basalt flows are strongly reducing (Eh = -0.45 ± 0.07 volt) and alkaline (pH = 9.5 ± 0.5). These factors tend to enhance the stability of metallic components of the waste package and lead to decreased solubilities and increased sorption of many radionuclides. The role of colloid formation in the basalt geochemical system currently is being addressed experimentally. Hydrothermal alteration of the backfill/basalt system results in formation of a variety of stable mineral assemblages such as clays and zeolites, which have superior sorptive capabilities. These geochemical characteristics lead to the preliminary conclusion that projected releases of radionuclides will not exceed the limits in Section 960.3-2 of the proposed siting guidelines (DOE, 1983).

3.1.3.4 Rock Characteristics. Technical Guideline 960.5-4 (Rock Characteristics) (DOE, 1983) states that:

The site shall have geologic characteristics compatible with waste containment, isolation, and retrieval.

Input addressing Technical Guideline 960.5-4 (DOE, 1983) centers on data regarding the effect of geomechanical, chemical, thermal, and radiation-induced stresses on basalt and the ability to develop, operate, and close a repository without undue hazard to repository personnel. Discussions in this section are based primarily on conceptual repository and waste package design considerations (KE/PB, 1982) and on information obtained through field and laboratory tests, including the BWIP Near-Surface Test Facility at Gable Mountain (see Fig. 3-3).

3.1.3.4.1 Physical Properties. Technical Subguideline 960.5-4-1 (Physical Properties) states that:

The site shall provide a geologic system that is capable of accommodating the geomechanical, chemical, thermal, and radiation-induced stresses that are expected to be caused by interactions between the waste and the host rock.

(a) Favorable Conditions

None specified.

(b) Potentially Adverse Conditions

Potential for such phenomena as thermally induced fractures, hydration and dehydration of mineral components, brine migration, or other physical, chemical, or radiological phenomena that could lead to projections of radionuclide releases greater than those discussed in Section 960.3-2.

3.1.3.4.1.1 Summary of Available Information. Field data on thermal spalling and slabbing of the candidate repository horizons have not yet been obtained; however, information for the Pomona flow has been generated during tests at the Near-Surface Test Facility. Full-Scale Heater Test #2, which was conducted for 2 years, subjected the Pomona basalt to temperatures up to 490°C (914°F) at the borehole wall. It has been estimated that the temperature at the borehole wall within the repository host rock will be subjected to temperatures up to approximately 300°C (572°F) (DOE, 1982c). No spalling or slabbing was observed in the before-heating and after-heating photographs. However, several minor instances of opening of existing small fractures and creation of new small fractures were observed. Analysis of the probable cause and extent of these features is ongoing. Although this information is of a somewhat qualitative nature with regard to predicting the response of the basalt under actual repository conditions where some openings will be larger and stresses higher, the indication is that basalt has a stronger resistance to thermal degradation than do most other rock types. A summary of basalt characteristics including porosity, density, thermal conductivity, Young's modulus, Poisson's ratio, and tensile strength are presented in Section 3.4.

Hydrous mineral phases such as clays, which are present in the host basalt and will be a major component of the waste package backfill, are susceptible to dehydration reactions during heating. These reactions are accompanied by loss of volume. Studies on smectite clay by Koster van Groos (1981) show that the temperature of loss of interlayer water is pressure dependent and occurs at 130°C (266°F) under atmospheric conditions and 430°C (806°F) at a pressure of 30 megapascals. During the early period of the repository, the ambient pressure will be nearly atmospheric and thermal modeling of the very near-field environment suggest that temperatures will be high enough to cause dehydration of backfill and basalt clays. Eventually, resaturation will occur and the clay minerals will reversibly rehydrate and swell. Studies show that shrinking/swelling processes accompanying dehydration/rehydration reactions have no deleterious effects on the waste package or the surrounding host basalt. Further testing to confirm this conclusion is nearing completion.

As noted in the discussion of Technical Guideline 960.5-3 (DOE, 1983), the geochemical environment of the groundwater in the candidate repository horizons tends to be buffered by its interaction with basalt and will tend to remain constant as long as the temperature does not change. Basalt-water hydrothermal studies at 150°C (302°F) and 300°C (572°F) (Apted and Myers, 1982) indicate that while the specific rock-water reactions, which occur under these conditions, may differ from those at lower temperatures in this system, groundwater compositions still are effectively buffered and large chemical perturbations are avoided. Hydrothermal studies at 100°C (212°F) to complement those already completed are in progress.

At the low neutron flux levels associated with nuclear waste, measurable neutron-induced radiation effects on barrier materials are not expected to occur during the period of isolation in the repository. Hence, the major concern in evaluating candidate barrier materials, including the host rock, is the effect of the gamma radiation. Incidental radiation can affect the stability of barrier materials by affecting changes in (1) bulk physical structure, (2) any protective layer, and/or (3) chemistry of the intruding groundwater. During the containment period, alpha and beta radiation will not penetrate the canister (to the surrounding media). The effects of alpha radiation on groundwater will be evaluated under the assumption that the containment is lost. Researchers have concluded that gamma radiation principally affects the groundwater and does so by producing chemical changes (radiolysis) through excitation and ionization processes (Stobbs and Swallow, 1962; Byalobzheskii, 1970; Wu, 1978). The primary radiolysis process in aqueous solutions is the decomposition of water to form short-lived radicals (e^-_{aq}, H^+, OH^-, HO_2) and the longer-lived molecular products, H_2 and H_2O_2. If, in some manner, the radiolytic hydrogen is continuously removed from the system, the oxidation potential (Eh) of the solution could increase and remain high. This increase in Eh would be generally deleterious to the stability of canister materials and could also lead to an increase in solution concentrations (and, hence, release rates) of multivalent radionuclides.

Conversely, it can be hypothesized that, in a sealed and decommissioned repository constructed in basalt, where highly reducing conditions (e.g., low Eh) are expected to be imposed by the host rock (Jacobs and Apted, 1981), a high-hydrogen fugacity will tend to suppress the deleterious effects of radiolysis reaction on Eh. Thus, the corrosiveness and solution properties of any intruding groundwater may be unaffected or minimally affected by radiation.

Currently available data indicate radiation effects on candidate backfill materials should not affect the important functional characteristics (e.g., a chemical/physical barrier to water and radionuclide transport) (Friedlander et al., 1964). This, however, will be verified through testing in a high-intensity gamma field. In addition, tests to evaluate the effect of high-intensity gamma field on canister corrosion may be conducted.

3.1.3.4.1.2 Preliminary Conclusions. Currently available data suggest that the site is capable of accommodating the geomechanical, chemical, thermal, and radiation-induced stresses that are expected to be caused by interactions between the waste and the host rock without fracturing. Indication is that basalt has a stronger resistance to thermal degradation than do most other rock types. In addition, shrinking/swelling processes accompanying dehydration/rehydration reactions indicate no deleterious effects on the waste package or the surrounding host basalt. Basalt-water hydrothermal studies at 150°C (302°F) and 300°C (572°F) (Apted and Myers, 1982) indicate that while specific rock-water reactions, which occur under these conditions, may differ from those at lower temperatures in this system, groundwater compositions still are effectively buffered and large chemical pertubations are avoided. Currently available data also indicate radiation effects on candidate backfill material should not affect the important functional characteristics. However, this will be verified through testing in a high-intensity gamma field. In addition, tests to evaluate the effect of high-intensity gamma field on canister corrosion and to confirm the effect of dehydration/rehydration reactions will be conducted.

3.1.3.4.2 Operational Safety. Technical Subguideline 960.5-4-2 (Operational Safety) states that:

The site shall be such that the construction, operation, and closure of underground areas will not cause undue hazard to repository personnel. The site shall be disqualified if the applicable safety requirements of the DOE and NRC could not be met.

(a) Favorable Conditions

None specified.

(b) Potentially Adverse Conditions

(1) Rock conditions that would require complex engineering measures in the design and construction of the underground facility or in the sealing of boreholes and shafts (10 CFR 60.122(c)(21)).

(2) Geomechanical properties that would not permit underground openings to remain stable until permanent closure (10 CFR 60.122(c)(22)).

3.1.3.4.2.1 Summary of Available Information. The stability of repository openings is directly influenced by the properties of the host rock and by the state of stress around the openings. If stresses resulting from the natural setting and from thermal loading cannot be adequately accommodated by the rock mass, the possibility for failure of the rock and for creation of pathways for radionuclide migration is introduced. In order to ensure safe conditions for repository operation and to preserve the isolation capability of the host rock, the stability of the openings must be maintained throughout the life of the repository. Therefore, an adequate understanding of in situ stress conditions and rock mass properties is of significant importance.

There are inherent difficulties associated with assessing mine stability in the absence of direct access to candidate horizons from a shaft or tunnel. Measurement of in situ stress from the surface still involves uncertainties, and rock mass properties can only be roughly estimated using laboratory data. However, empirical knowledge accumulated over the past few decades indicates that laboratory-measured rock properties from core samples, along with measurements of in situ stress and observations of geologic structure made from exploratory boreholes, are of significant value for a preliminary assessment of opening stability.

Hydraulic fracturing stress measurements conducted in five basalt flows on the Hanford Site have generally shown a trend of increasing maximum principal stress with depth. The maximum principal stresses were measured in the horizontal plane and average orientations were found to be in a range from N. 16° E. to N. 25° E. for all deep flows tested.

In borehole RRL-2, the in situ stress ratio in the Cohassett flow was found to be approximately 20 percent lower than for the Umtanum flow (approximately 2:1). While no measurements have been made in the McCoy Canyon flow, one test series conducted approximately 35 meters (115.5 feet) above it in Grande Ronde Basalt Flow 7 showed in situ stress levels comparable to the Umtanum flow. Regardless of depth, the ratio of maximum principal stress to vertical stress is in the 2.0:1 to 2.5:1 range.

A very preliminary estimate is that average maximum principal stress magnitudes greater than 80 megapascals or average stress ratios (greater than 3.0) (maximum horizontal to vertical) are the upper limits beyond which construction of a repository could be economically unattractive. Future numerical modeling and design analysis efforts will attempt to confirm this estimate.

In general, the uniaxial compressive strength and deformation modulus of the entablature and colonnade of the candidate horizons are similar, while the flow top is much weaker and more deformable. Uniaxial compressive strengths for flow-top and breccia zones are typically less than 25 percent of those for interior zones in the flow. Vesicular zones tend to be somewhat stronger, but still have strengths only 35 to 65 percent of the dense interior zones. The uniaxial compressive strength of the Cohassett flow interior, which includes the entablature and colonnade, is 62 percent of that for the Umtanum flow and 73 percent of that for the McCoy Canyon flow; however, all three can be considered high-strength rocks. There appears to be no substantial differences in deformation modulus values between the candidate horizons, except for an anomalously low value for the McCoy Canyon colonnade.

Thermal and thermomechanical properties measured for samples from the Cohassett and Umtanum flows in RRL-2 were very similar. Values for the specific heat and the thermal expansion coefficient differed by less than 3 percent for the two flows. Values for thermal conductivity for the Umtanum flow were approximately 85 percent of those for the Cohassett. These differences are not of major significance from a design standpoint.

Using Bieniawski's (1979) geomechanics classification system, the rock mass rating values for all three candidate flows are in reasonable agreement. Only one of the six parameters in the system (specifically the rock quality designation) differs for the flows. With all three flows in the "good rock" category, estimated rock mass strength and roof support requirements would be the same.

Use of the Q system classification method (Barton et al., 1974) also results in the conclusion that all three candidate flows fall in the "good rock" category. However, Q system estimates of deformation modulus and support requirements differ between flows more than do estimates using the geomechanics classification system. The differences arise from the fact that the Q system incorporates the in situ stress level into the calculation using the stress reduction factor. This factor is a function of the ratio of the uniaxial compressive strength to the maximum principal stress for the flow in question. Since the Cohassett flow samples have shown the lowest compressive strength values, a corresponding low strength-to-stress ratio results in a reduced modulus estimate and a somewhat increased support requirement.

3.1.3.4.2.2 Preliminary Conclusions. As a result of a review of in situ stress information, results of laboratory and field tests to determine physical, mechanical, thermal, and thermomechanical properties of basalt, and estimates of rock mass characteristics based on the geomechanics classification systems, some conclusions regarding the operational safety of the repository can be made. The stress conditions at all the candidate horizons should permit construction of a repository. Tunnels can be constructed using either tunnel boring machines or the drill and blast method. The classification of the candidate horizons as "good rock" by both Bieniawski's (1979) method or the Q method (Barton et al., 1974) indicates that tunnels will usually require only light support. The strength and deformation modulus of the basalt during normal operations and at limited temperatures indicates that the basalt is not expected to deform significantly during operation of the repository. Therefore, placing of tunnel seals should require no complex engineering methods. Construction of the Exploratory Shaft will yield valuable information relating to shaft construction and, consequently, repository construction techniques that will not result in undue hazards to repository personnel.

Analysis of the known geologic and hydrologic conditions, as summarized in this draft environmental assessment and detailed in the Site Characterization Report (DOE, 1982c), indicates that compliance with applicable safety regulations can be achieved.

3.1.3.5 Tectonic Environment. Technical Guideline 960.5-5 (Tectonic Environment) (DOE, 1983) states that:

The site shall be located in a geologic setting where the effects of current or reasonably foreseeable tectonic phenomena will not lead to a projection of radionuclide releases greater than those discussed in Section 960.3-2.

Input addressing Technical Guideline 960.5-5 (DOE, 1983) centers on an evaluation of faulting and seismicity, igneous activity, and uplift, subsidence, and folding within and in the vicinity of the reference repository location. Available data regarding these conditions indicate that the reference repository location is in an area of relatively low seismicity compared to adjacent seismo-tectonic provinces. No seismic events have been related to specific structure within the Pasco Basin. Most faults are associated with anticlinal ridges and are interpreted to be contemporaneous with folding. The reference repository location is in the broad flat-lying Cold Creek syncline, interpreted to be relatively undeformed. Long-term uplift and subsidence rates have been determined to be low and appear to have continued from at least 14 thousand years ago to present. The last Columbia River basalt flow was erupted 6 million years before present and only very minor tephra deposits have occurred from Cascade volcanics in the last 6 million years. Preliminary assessment of the tectonic setting of the reference repository location indicate that the tectonic effects will not lead to a projection of releases of radionuclides greater than those specified in Section 960.3-2 of the proposed siting guidelines (DOE, 1983).

3.1.3.5.1 Faulting and Seismicity. Technical Subguideline 960.5-5-1 (Faulting and Seismicity) states that:

The site shall be located in a geologic setting where faults that might affect waste isolation, if any, can be identified and shown to have hydrologic properties and seismic potentials that will not lead to a projection of radionuclide releases greater than those discussed in Section 960.3-2.

(a) Favorable Conditions

(1) The nature and rates of faulting, if any, operating within the geologic setting during the past million years would, if continued in the future, not affect or would favorably affect the ability of the geologic repository to isolate the waste (10 CFR 60.122(b)(1)).

(2) The nature and rates of faulting, if any, operating within the geologic setting during the past million years would, if continued into the future, have less than one chance in 10,000 over the next 10,000 years of leading to releases of radioactive waste to the accessible environment (proposed 40 CFR 191.13).

(b) *Potentially Adverse Conditions*

(1) Faults in the geologic setting that may adversely affect the regional ground-water flow system (10 CFR 60.122(c)(5)).

(2) Evidence of active faulting within the geologic setting during the past million years (10 CFR 60.122(c)(12)).

(3) Historical earthquakes that, if repeated, could affect the site significantly (10 CFR 60.122(c)(13)).

(4) Indications, based on correlations of earthquakes with tectonic processes and features (e.g., faults), that either the frequency of occurrence or the magnitude of earthquakes may increase (10 CFR 60.122(c)(14)).

(5) More frequent occurrences of earthquakes or earthquakes of higher magnitude than are typical of the region in which the geologic setting is located (10 CFR 60.122(c)(15)).

3.1.3.5.1.1 Summary of Available Information. The site is located in the Cold Creek syncline, a part of the Yakima Fold Belt that is characterized by long narrow anticlines and broad synclines. Most faults within the fold belt are associated with anticlinal fold axes, are thrust or reverse (although normal faults are also present), and are interpreted to be contemporaneous with folding. Deformation of the fold belt appears to have continued on existing structures, and stress appears localized in steeply dipping strata and on existing structures. Faults of major displacement are not anticipated in the shallow-dipping synclinal strata on the basis that only a few tectonic features that have been found in the thousands of meters of core drilled within the Pasco Basin synclines and on the basis of mechanical analysis studies conducted by Price (1982).

Strain on the anticlinal fold areas has resulted in faults which, in places, have cut strata as young as Quaternary in age. Faults cut Quaternary sediments on anticlines in the central Gable Mountain area (about 8 kilometers (4.5 miles) northeast of the reference repository location) and at Finley Quarry in the Horse Heaven Hills (see Fig. 3-3). Long-term displacement rates on the Gable Mountain fault based on the offset of Quaternary sediments are calculated to be very low (less than 5.00×10^{-6} meters per year (16.0×10^{-6} feet per year)) (PSPL, 1982). The low displacement rate on this fault is consistent with other geologic and "contemporary" data sources that suggest deformation has been proceeding at an average low rate of strain over at least the last 14 million years.

Historical and instrument data indicate that the Pasco Basin and the reference repository location are areas of relatively low seismicity compared to adjacent seismo-tectonic provinces in eastern Washington. Seismicity in the central Columbia Plateau is confined to a thin 28-kilometer (17.5-mile) crust and is characterized by temporally and spatially limited swarms of low magnitude (less than 3.5) shallow earthquakes that may be characteristic of brittle deformation in basalt. Deep earthquakes (greater than 6 kilometers (3.8 miles)) responding to the same stress regime, occur as single events or mainshock-aftershock sequences, appear more diffuse in spatial distribution, and do not generally appear to be related to shallow events. Differences in recurrence (b value) and pattern activity suggest the basalt may behave in a more brittle manner than rocks beneath the basalt in which some aseismic deformation may be occurring.

Focal mechanism solutions in the central Columbia Plateau from ongoing seismic monitoring indicate that a nearly north-south, nearly horizontal compression with a nearly vertical axis of least compression exists today. This stress regime is supported by geodolite observations (Savage et al., 1981; USGS and PAG, 1981) and appears to be the same regime that resulted in the nearly east-west folds on subparallel thrust and reverse faults and steeply dipping northwest and northeast-trending faults in the Yakima Fold Belt that bounds the Pasco Basin. This stress regime apparently has been unchanged for more than 14 million years.

Historic earthquakes have been felt in only a few areas and have been small, except for two moderate-sized events near Umatilla (modified Mercalli intensity III) in 1893 and the Milton-Freewater area (modified Mercalli intensity VII) in 1936. The largest events recorded during 12 years of instrumental monitoring in the central Columbia Plateau are concentrated near the Saddle Mountains and Frenchman Hills north of the Hanford Site. The largest instrumentally recorded earthquake in the central Columbia Plateau is a magnitude 4.4 event on Royal Slope about 85 kilometers (50 miles) north of the Hanford Site. The surface facilities will be designed for a ground acceleration of 0.25 g, which corresponds to a magnitude greater than 4.4 event. No events have been recorded in the reference repository location.

Earthquakes in the central Columbia Plateau are not presently associated with mapped geologic faults, nor do hypocenters align in a manner that suggest the presence of unmapped faults. Swarms have occurred in the flanks of the Saddle Mountains structure (see Fig. 3-3), which is faulted, but the events do not correspond with mapped faults. Swarms have also occurred elsewhere where there are no mapped geologic structures.

3.1.3.5.1.2 Preliminary Conclusions. Completed studies suggest faulting and seismicity in the geologic setting of the reference repository location do not appear to present significant problems regarding Section 960.5-5-1 of the proposed siting guidelines (DOE, 1983). The reference repository location in the Cold Creek syncline contains relatively undeformed strata in an environment where bordering anticlines apparently have been deforming slowly at low average rates of strain. The patterns and rates of deformation have apparently been continuously in operation for at least 14 million years and can be assured to continue over the next few thousand to tens of thousands of years. Major structures have been identified, and it is assumed that future strain will be localized on these structures; however, the more detailed mechanics of the deformation process remain to be assessed. The low rate of strain is also apparent in the relatively low seismicity of the central Columbia Plateau and Hanford Site. The seismicity and stress field of the central Columbia Plateau will continue to be monitored as part of detailed site characterization.

Uncertainties regarding the location of folds or faults, geologic (long-term) and contemporary rate of deformation, geologic structures, and seismicity of the geologic setting with respect to the site will be addressed during detailed site characterization. These specific studies to resolve uncertainties are necessary to make a final conclusion that seismic factors will not lead to a projection of radionuclide releases greater than those discussed in Section 960.3-2 of the proposed siting guidelines (DOE, 1983).

3.1.3.5.2 <u>Igneous Activity</u>. Technical Subguideline 960.5-5-2 (Igneous Activity) states that:

> *The site shall be located in a geologic setting where centers of igneous activity during the past million years, if any, can be identified and shown to have no effects that will lead to a projection of radionuclide releases greater than those discussed in Section 960.3-2.*
>
> *(a) <u>Favorable Conditions</u>*
>
> *(1) The nature and rates of igneous processes within the geologic setting during the past million years would, if continued into the future, not affect or would favorably affect the ability of the geologic repository to isolate the waste (10 CFR 60.122(b)(1)).*
>
> *(2) The nature and rates of igneous activity, if any, in the geologic setting during the past million years would, if continued into the future, have less than one chance in 10,000 over the next 10,000 years of leading to releases of radioactive material to the accessible environment (proposed 40 CFR 191.13).*
>
> *(b) <u>Potentially Adverse Conditions</u>*
>
> *(1) The presence in the geologic setting of intrusive dikes, sills, or stocks that may adversely affect the regional ground-water flow system (10 CFR 60.122(c)(5)).*

(2) Evidence of igneous activity within the geologic setting during the past million years (10 CFR 60.122(c)(16)).

3.1.3.5.2.1 <u>Summary of Available Information</u>. The distribution and age of volcanic rock within the reference repository location and Columbia Plateau are known with a high degree of confidence from surface mapping and boreholes that penetrate the basalt. Detailed studies of the Columbia River Basalt Group have provided extensive information for utilization or analysis of the nature and origin of lava; these data indicate the last eruption of Columbia River basalt occurred over 6 million years before present, with vent areas located east of the Hanford Site. There has been no igneous activity within the reference repository location during the past million years.

Cascade volcanism has periodically produced ash falls recorded in and around the reference repository location in the sedimentary record since about 15 million years before present. The distance of the site from these volcanoes, however, has resulted in only minor (maximum of several centimeters) ash accumulations.

Terrestrial heat flow measurements provide data related to the potential for renewed igneous activity. Present knowledge of the Columbia Plateau is from published data (Blackwell, 1978; Korosec and Schuster, 1980) and thermal measurements made in conjunction with hydrologic testing of the Hanford Site wells. All available data indicate low heat flow, not indicative of likely future volcanic activity.

The volcanic history of the area, terrestrial heat flow measurements, and the volcanic history of the Cascades provide data for an assessment of future igneous activity (Johnpeer et al., 1981; Murphy and Johnpeer, 1981). This assessment has shown that the probability for assessment induced events from igneous activity disturbing the integrity of a repository is exceedingly low.

3.1.3.5.2.2 <u>Preliminary Conclusions</u>. The reference repository location is within an area where the probability for renewed igneous activity has been assessed to be a less than one chance in 10,000 over the next 10,000 years (Johnpeer et al., 1981; Murphy and Johnpeer, 1981). Minor airfall tephra from the Cascade Range is likely to be deposited on the site in the next 10,000 years, but would not affect repository performance.

3.1.3.5.3 <u>Uplift, Subsidence, and Folding</u>. Technical Subguideline 960.5-5-3 (Uplift, Subsidence, and Folding) states that:

The site shall be located in a geologic setting where significant uplift, subsidence, or folding, if any, that has occurred during the past million years can be identified and shown to have hydrologic, seismic, and erosional implications that will not lead to a projection of radionuclide releases greater than those discussed in Section 960.3-2.

(a) *Favorable Considerations*

(1) *The nature and rates of uplift, subsidence, and folding within the geologic setting during the past million years would, if continued into the future, not affect or would favorably affect the ability of the geologic repository to isolate the waste (10 CFR 60.122(b)(1)).*

(2) *The nature and rates of tectonic deformation in the geologic setting during the past million years would, if continued into the future, have less than one chance in 10,000 over the next 10,000 years of leading to releases of radioactive material to the accessible environment (proposed 40 CFR 191.13).*

(b) *Potentially Adverse Considerations*

(1) *The occurrence in the geologic setting of folds that may adversely affect the regional ground-water flow system (10 CFR 60.122(c)(5)).*

(2) *Evidence of active uplift, subsidence, or folding within the geologic setting during the past million years (10 CFR 60.122(c)(12)).*

3.1.3.5.3.1 Summary of Available Information. Areas of subsidence and uplift and the rate at which this deformation has occurred have been determined for the time period from 15 to 10.5 million years before present and estimated from 10.5 million years before present to the present. The development of structurally controlled topography since at least the Miocene indicates that the reference repository location is in a portion of the Pasco Basin that has been subsiding for the last 15 million years. Simultaneously, uplift was occurring on the ridges that bound the basin. Rates of subsidence and rates of uplift were relatively low with calculations suggesting that they ranged between 40 and 70 meters (131 to 230 feet) per million years from 15 to 10.5 million years before present. Continuing subsidence in the basin and uplift on the ridges is suggested by sediment-filled basins and the fact that the present structural relief can be explained by extrapolating the Miocene growth rates to the present (Reidel and Fecht, 1982).

Estimates of faulting due to folding also suggest slow continued growth of the folds to the present time. Measurements of faulting (PSPL, 1982) suggest decreasing displacement with decreasing age; slip rates are calculated to be in the order of less than 10 meters (33 feet) per million years.

Geodolite observations of the Hanford net and the pattern of seismicity are used to determine the contemporary rate of deformation. Geodolite surveys (Savage et al., 1981; USGS and PAG, 1981) suggest that nonuniform compression is continuing at a rate of about 0.04 to 0.02 millimeter (0.0016 to 0.0008 inch) per year.

Taken together, the "geologic" and "contemporary" data suggest that the reference repository location is in a slowly subsiding syncline surrounded by anticlinal ridges that are growing at a very slow rate. The continued pattern of folding since the Miocene also indicates that deformation is, and has been, concentrated along anticlinal ridges and future deformation can be expected to occur along these trends.

3.1.3.5.3.2 Preliminary Conclusions. The reference repository location is in a slowly subsiding syncline (1 centimeter (0.39 inch)) in next 10,000 years) surrounded by anticlines growing at a slow rate. Deformation is concentrated in the anticlines and minimal deformation occurs in the syncline. Currently available projections of subsidence in the site at slow rates are not anticipated to change the groundwater flow systems, seismicity, or erosion at the site. Release rates of radionuclides greater than those specified in Section 960.3-2 of the proposed siting guidelines (DOE, 1983) as a result of deformation are not expected. Further site characterization will be focused on assessing whether deformation has been continuous from about 14.5 million years before present or has occurred in periodic pulses. Work will also include an assessment of whether such deformation has been basinwide or localized on specific structures and will include continued seismic monitoring and periodic geodetic surveillance.

3.1.3.5.4 Human Intrusion. Technical Guideline 960.5-6 (Human Intrusion) (DOE, 1983) states that:

> *The site shall be located to reduce the likelihood that past, present, or future human activities would cause unacceptable impacts on meeting the isolation guidelines discussed in Section 960.3-2.*

Input addressing Technical Guideline 960.5-6 centers on a discussion of the potential for natural resources at the site and on land ownership and control as it pertains to human intrusion. As the reference repository location is currently on DOE-controlled land and resource potential is considered to be low, human intrusion related to resource exploration is not likely to be of concern during the operational and early post-closure phases of the repository. However, as previously discussed under Technical Subguideline 960.5-2-2, intrusion by borehole (possible due to exploration activities) has been determined to be a disruptive event warranting evaluation. Studies evaluating this scenario will be carried out as part of the hydrologic and performance-assessment modeling work currently under way.

3.1.3.5.4.1 Natural Resources. Technical Subguideline 960.5-6-1 (Natural Resources) states that:

> *The site shall be such that the exploration history or relevant past use of the site or adjacent areas can be determined and can be shown to have no unacceptable impact on meeting the isolation guidelines discussed in Section 960.3-2. The site features shall make human intrusion unlikely or, in combination with engineered systems, mitigate the consequences of intrusion to within the limits discussed in Section 960.3-2.*
>
> *(a) Favorable Conditions*
>
> *Natural-resource concentrations that are not significantly greater than the average condition for the region.*
>
> *(b) Potentially Adverse Conditions*
>
> *(1) The presence of naturally occurring materials, whether identified or undiscovered, within the site in such form that (i) economic extraction is currently feasible or potentially feasible during the foreseeable future or (ii) such materials have greater gross value or net value than the average for other areas of similar size that are representative of, and located in, the geologic setting (10 CFR 60.122(c)(18)).*
>
> *(2) Evidence of subsurface mining for resources within the site (10 CFR 60.122(c)(19)).*
>
> *(3) Evidence of drilling within the site for any purpose other than repository-site characterization (10 CFR 60.122(c)(20)).*

3.1.3.5.4.1.1 Summary of Available Information. An inventory and economic assessment (GG/GLA, 1981) of known minerals or fossil fuel resources within a 100-kilometer (60-mile) radius of the proposed site have shown that no known economic resource would preclude the siting of a repository at Hanford. Current exploratory drilling by Shell Oil Company has not found any economical quantities of natural gas but exploratory drilling is continuing.

Groundwater resources development within the vicinity of the reference repository location has been administratively controlled by the DOE and its predecessor agencies. Groundwater production within the Saddle Mountains Basalt is 3.8 to 386 liters (1 to 10^2 gallons) per minute and 3.8 to 386 liters (1 to 10^2 gallons) per minute within the Wanapum Basalt. Although certain zones within the Grande Ronde Basalt yield water at rates up to about 38 liters (10 gallons) per minute, these zones are presently not economically exploitable, due to water treatment requirements and high drilling costs.

No mining has occurred within the reference repository location, and all drilling activity has been documented. No drilling has occurred within the reference repository location to potential repository depths except that completed for preliminary characterization.

3.1.3.5.4.1.2 Preliminary Conclusions. The quantity and value of potential natural resources within the reference repository location does not make it more attractive to resource exploration or development than the surrounding areas in the geologic setting (GG/GLA, 1981). Existing boreholes are known and documented and no mining activity has occurred within the reference repository location. Continued exploratory drilling around the Pasco Basin for natural gas has not proven any economical quantities. A brief discussion of a modeling analysis of borehole intrusion is contained in the discussion of Technical Guideline 960.5-2-2.

3.1.3.5.4.2 Site Ownership and Control. Technical Subguideline 960.5-6-2 (Site Ownership and Control) states that:

> *The site shall be located on land for which the Federal Government can obtain ownership, control access, and obtain all surface and subsurface rights required under 10 CFR 60.121 to ensure that surface and subsurface activities at the site will not lead to a projection of radionuclide releases greater than those discussed in Section 960.3-2.*
>
> *(a) Favorable Conditions*
>
> *Present ownership and control of land and rights as required by 10 CFR 60.121.*
>
> *(b) Potentially Adverse Conditions*
>
> *Land-use conflicts involving land dedicated by the Federal Government for potentially incompatible purposes.*

3.1.3.5.4.2.1 Summary of Available Information. Lands within the reference repository location and the remainder of the Hanford Site have been under the jurisdiction of the Federal Government since 1943-1944. The Hanford Site is presently managed by the DOE. The lands designated for the repository consist of acquired lands plus Section 10 and part of Section 4, Township 12 North, Range 25 East of the Willamette Meridian, which is public domain. Sections 10 and 4 have been withdrawn from all forms of appropriation under the public land laws including the mining and mineral leasing laws and have been reserved for use by the U.S. Atomic Energy Commission in connection with its Hanford Operations. The pertinent part of the applicable Public Land Order 1273 reads as follows:

> "Subject to valid existing rights, the following-described public lands in Washington are hereby withdrawn from all forms of appropriation under the public-land laws, including the mining and the mineral-leasing laws, and reserved for use of the Atomic Energy Commission in connection with its Hanford Operations."

All functions of the U.S. Atomic Energy Commission with respect to the Hanford Site and certain other locations have been transferred to the Secretary of Energy. As a result, Sections 10 and 4, Township 12 North, Range 25 East of Willamette Meridian, are under the jurisdiction of the DOE, which holds that land pursuant to the above-described provisions of Public Land Order 1273.

Most of the Hanford Site south of the Columbia River is fenced and/or posted to prohibit access by unauthorized personnel.

3.1.3.5.4.2.2 Preliminary Conclusions. The Hanford lands were placed under Federal jurisdiction in 1943-1944. Since Federal jurisdiction predates local, regional, and state planning for the area, Hanford lands are designated as an existing special use area in all land use plans. Compatibility of the repository with other DOE land use plans at the Hanford Site is assured by the integration of the project into overall Hanford land use planning activities. Access to the reference repository location can only be gained by passing through one of the several security check points. The Federal Government's ownership of the Hanford Site results in compliance with Technical Subguideline 960.5-6-2 (DOE, 1983).

3.1.3.5.5 Surface Characteristics. Technical Guideline 960.5-7 (Surface Characteristics) (DOE, 1983) states that:

> *The site and its surrounding area shall be such that surface characteristics or conditions can be accommodated by engineering measures and can be shown to have no unacceptable effects on repository operation and waste isolation as discussed in Sections 960.3-1 and 960.3-2.*

This section includes a discussion of surface water, terrain, meteorology, and offsite hazards.

Shallow flash flooding of the reference repository location may result from a 100-year flood in the Cold Creek. Catastrophic flooding may result from future continental glaciation. Engineering measures will accommodate Cold Creek flooding and studies will be done to assess the effect of a catastrophic flood on groundwater recharge.

The terrain of the reference repository location is, in general, flat lying and no major engineered measures are required. Occassional high wind and associated duststorms may require some additional safety precautions. The reference repository location is on DOE land committed to nuclear activities.

3.1.3.5.5.1 Surface-Water Systems. Technical Subguideline 960.5-7-1 (Surface-Water Systems) states that:

> *The site shall be such that the surficial hydrologic system, both during expected climatic cycles and during extreme natural phenomena, will not cause unacceptable impacts on repository operation or waste isolation as discussed in Sections 960.3-1 and 960.3-2.*
>
> *(a) Favorable Conditions*
>
> *None specified.*
>
> *(b) Potentially Adverse Conditions*
>
> *(1) Potential for foreseeable human activities to adversely affect the ground-water flow system, such as extensive irrigation or the construction of large-scale surface-water impoundments (10 CFR 60.122(c)(1)).*
>
> *(2) Potential for flooding the underground facility, whether through the occupancy and modification of floodplains or through the failure of existing or planned man-made surface-water impoundments (10 CFR 60.122(c)(2)).*

3.1.3.5.5.1.1 Summary of Available Information. A number of dam failure scenarios have been evaluated by the U.S. Army Corps of Engineers (COE, 1951) including failure of Grand Coulee Dam. These scenarios account for flow augmentation due to failure of earthen portions of dams downstream from Grand Coulee Dam and consequent releases of their respective storage volumes. The most extreme scenario evaluated (and considered as the worst case) was that of a 50-percent breach of Grand Coulee Dam. The flood resulting from this release does not reach the reference repository location.

The only remaining site for a potential dam on the Columbia River in the United States is approximately at river kilometer 560 (mile 336) (proposed Ben Franklin Dam). Harty (1979) has provided a detailed analysis of the possible effects of the proposed Ben Franklin Dam and reservoir on the Hanford Site activities. In particular, this study addressed transient adjustments of the shallow groundwater system. No analysis was made of the potential impact on groundwater systems deeper than the unconfined system.

The reference repository location is situated outside and above the limits of the Columbia River floodplain. However, it is possible that the location could be subjected to shallow flash flooding from the ephemeral Cold Creek stream during the anticipated 100-year-long preclosure phase of a repository. The inundation at the reference repository location that would be associated with a 100-year flash flood event would be of limited areal extent. Further studies including topographic surveys and analyses will be undertaken to quantify the exact extent and depth of such an event. These studies will be performed with topographic resolution that is detailed enough to support engineering decisions with respect to mitigation measures, should they be determined to be appropriate.

Within the range of climatic conditions probable at the reference repository location within the next 10,000 years, catastrophic flooding (as was associated with the last period of continental glaciation) represents the most significant potential impact. Geologic field data indicate that the maximum flood level achieved within the Pasco Basin from Pleistocene flooding was on the order of 370 meters (1,215 feet). The duration and number of floods is not known, but each probably consisted of short-lived crests. Floodwaters within the basin are believed to have subsided over a period of weeks. The net residual effect of this event on conditions at the reference repository location was that of sediment deposition.

A number of studies have been conducted to predict future ice ages. One model predicts that glaciation may advance into northern Washington within 10,000 years (Foley et al., 1981), while another estimates that the probability of ice cover at Hanford in the next million years is 50 percent (Bull, 1979, 1980). The maximum advance of continental glaciation in the Pleistocene was about 130 kilometers (80 miles) north of the Hanford Site.

The potential for vertical movement of groundwater resulting from standing floodwaters within the Pasco Basin will be assessed using numerical simulation. The sensitivity of regional groundwater flow models to adjustment of recharge parameters will also be evaluated in future studies.

Information that can be used to evaluate growth trends in irrigated agriculture has been gathered by Stephan et al. (1979), Wukelic et al. (1981), Pacific Northwest River Basins Commission (1980), and Johnson et al. (1981). These reports involve inventorying and assessing regional land use trends using various survey methods and/or remote sensing. Additionally, Leaming (1981) provided an assessment of water resource economics within the Pasco Basin. This report addressed the economic likelihood of various scenarios of surface groundwater use.

3.1.3.5.5.1.2 Preliminary Conclusions. The reference repository location is sited above the floodplain of the major rivers flowing into the Pasco Basin. Flooding resulting from dam break scenarios also does not reach the proposed repository site. Shallow water inundation of the surface facilities that could occur during a 100-year flash flood event of the Cold Creek ephemeral stream will be mitigated by engineering measures. Studies are planned to evaluate the impact on waste isolation resulting from human activities and floodwater from catastrophic flooding resulting from potential future glaciation.

Irrigation utilizing groundwater resources, or the construction of surface-water impoundments, near the Hanford Site, is not expected to adversely affect the groundwater flow system. It is not expected that the surficial hydrologic system will cause unacceptable impacts on repository operation or waste isolation as discussed in Sections 960.3-1 and 960.3-2 of the proposed siting guidelines (DOE, 1983).

3.1.3.5.5.2 Terrain. Technical Subguideline 960.5-7-2 (Terrain) states that:

The site shall be located in an area where the surface terrain features do not unacceptably affect repository operation.

(a) Favorable Conditions

Generally flat terrain.

(b) Potentially Adverse Conditions

Road and rail access routes that encounter steep grades, sharp switchbacks, slope instability, or other potential sources of hazard to incoming waste shipments.

3.1.3.5.5.2.1 Summary of Available Information. The reference repository location is located in the basin and valley terrain in the western Pasco Basin. The terrain consists of the low-sediment-filled portion of the basin. The reference repository location is generally flat and featureless with a gentle southerly slope (less than 5 percent) except for the Umtanum Ridge bar in the northern portion of the site. Relief on this bar is about 30 meters (98 feet) and it has a southerly slope of about 15 percent. The slope on the bar has been stable since the bar was formed during the Pleistocene.

3.1.3.5.5.2.2 Preliminary Conclusions. The terrain in the site is essentially flat and featureless, except for the south slope of the Umtanum Ridge bar in the northern part of the site. The slope of the bar and the generally flat and featureless terrain of the site present no access or slope stability problems or other hazards with respect to meeting the intent of Section 960.5-7-2 of the proposed siting guidelines (DOE, 1983).

3.1.3.5.5.3 Meteorology. Technical Subguideline 960.5-7-3 (Meteorology) states that:

The site shall be located where anticipated meteorological conditions would not result in the projection of unacceptable effects on repository operations.

(a) Favorable Conditions

None specified.

(b) Potentially Adverse Conditions

None specified.

3.1.3.5.5.3.1 Summary of Available Information. For general climatological purposes, meteorological data collected at Hanford by the U.S. Weather Bureau from 1912 to 1945 and by the Hanford Meteorological Station from 1945 to present are representative of the Hanford Site. These data were combined into a single set of data for the period 1912 to 1970 by Stone et al. (1972).

Tornadoes rarely occur in the Hanford region and are generally of short duration, with short narrow paths. Tornadoes and funnel clouds have only been observed three times on the Hanford Site since 1916.

Duststorms are relatively common in the Hanford area and occur most frequently in the March through May period and during September. On the average, there are 8.3 duststorms per year (Orgill et al., 1974). Duststorms are recorded in the meteorological record when visibility becomes restricted to 10 kilometers (6.3 miles) or less. Major contributors to airborne dust or sand in the Hanford region are local construction activities, the surface soil itself, and surrounding agricultural land activities.

Stagnation occurs when low windspeeds and restricted mixing coexist, permitting an abnormal buildup of pollutants from sources within the region. A stagnation lasting 20 days can be expected one season in 20; a 10-day stagnation period can be expected every other season. Only one season in three will fail to produce a stagnation period of at least 8 days.

3.1.3.5.5.3.2 Preliminary Conclusions. None of these meteorological conditions are believed to have unacceptable effects on repository operation. Onsite meteorological parameters will be monitored in the future. Severe and extreme meteorologic phenomena that will be considered for design and operating bases of the repository have been identified and include, among others, high winds, extreme temperatures, severe duststorms, and lightning (DOE, 1982c). These conditions can be accommodated by engineering measures such that there will be no unacceptable effects on repository operation.

3.1.3.5.5.4 Offsite Hazards. Technical Subguideline 960.5-7-4 (Offsite Hazards) states that:

The site shall be such that present and projected effects from nearby industrial, transportation, and military installations and operations including atomic energy defense activities, can be accommodated by engineering measures and can be shown to have no unacceptable impacts on repository operation.

(a) Favorable Conditions

Siting on lands already committed for DOE nuclear reservations.

(b) Potentially Adverse Conditions

(1) The presence of nearby potentially hazardous facilities.

(2) Siting close enough to an atomic energy defense facility to compromise or interfere with the use of that facility for defense purposes.

3.1.3.5.5.4.1 Summary of Available Information. Nearby hazards were considered as part of the reference repository site identification process. In relation to nearby potential hazards of the Hanford Site, the three major areas of concern used in site screening procedures were:

- Proximity of repository to transportation routes
- Industrial/military installations and operations
- Gas or petroleum pipelines/storage areas.

Surface site screening performed by Woodward-Clyde Consultants (WCC, 1980, 1981) required any candidate site locations to be at least 1 kilometer (0.6 mile) from areas with a potential for explosion, generating missiles, noxious vapors, highways, interstate highways, railroads, and navigable waterways rendered. The DOE Hanford Site is already committed to several nuclear activities. No adverse affects on other nuclear activities carried out on the Hanford Site are expected.

3.1.3.5.5.4.2 Preliminary Conclusions. The reference repository location is near the center of the Hanford Site, which is already committed to nuclear activities. It was selected so that effects from present and projected industrial, transportation, and military installations have no unacceptable impacts on repository operation. Therefore, the reference repository location is expected to comply with this subguideline.

3.1.3.5.6 Population Density and Distribution. Technical Guideline 960.5-8 (Population Density and Distribution) (DOE, 1983) states that:

The site shall be located to limit the potential risk to the population. The site shall be so located that risk to the population from repository operation does not exceed system-performance guidelines. A site shall be disqualified if it would fail to comply with EPA's standard for radiation doses received by members of the public as a result of the management and storage of these wastes (proposed 40 CFR 191, Subpart A).

3.1.3.5.6.1 Population Near The Site. Technical Subguideline 960.5-8-1 (Population Near the Site) states that:

> *The site shall be located away from population concentrations and urban areas. A site shall be disqualfied if any surface facility of a repository would need to be located in a highly populated area or adjacent to an area one mile by one mile having a population of not less than 1,000 individuals.*
>
> *(a) Favorable Conditions*
>
> *Remoteness from population centers (10 CFR 60.122(a)(7)).*
>
> *(b) Potentially Adverse Conditions*
>
> *A population density and distribution such that projected releases could result in the exposure of many people.*

3.1.3.5.6.1.1 Summary of Available Information. Information pertaining to the proximity of the Hanford Site to population centers can be obtained from the 1980 census. The nearest population center to the Hanford Site is Richland, Washington, which had a population of 33,578 in 1980 (BOC, 1981). Intensive farming is carried out along the Yakima River Valley to the south of Rattlesnake Hills and to the east. West of the Hanford Site is the U.S. Army's Yakima Firing Center, which has restricted access. There are approximately 11,700 workers associated with the Hanford Site.

Understanding demographic patterns in the vicinity of a proposed repository site at the Hanford Site is an important part of socioeconomic impact analyses. The 1980 census data on the population of incorporated cities and counties within 80 kilometers (50 miles) of the Hanford Meteorological Station are shown in Figure 3-2. Current and projected population statistics for Benton and Franklin Counties and the primary socioeconomic impact area are given in Section 3.6 of this document. Cities and towns outside the impact area have absorbed only a small amount of growth from the larger area. Unincorporated portions of the bicounty area, however, received a significant percentage (41.7 percent) of the growth between 1970 and 1980. Since the rate of a city's population growth tends to decrease as it matures, the distributional pattern of growth in the bicounty and primary impact areas will almost certainly be different than in the past. Growth patterns will also be affected by future construction of bridges across the Columbia River and the growth or decline of various economic sectors.

As can be seen in Table 3-3, most of the growth during the past decade in Benton County can be attributed to the large number of people (78.3 percent) moving into the area (migration) rather than to natural increase (birthrate). In Franklin County less than half of the growth in population can be attributed to migration.

TABLE 3-3. Components of Population Change by County and State.

Area	Population size[a]		Population change 1970-1980		Change (%) 1970-1979[b] due to:	
	1970	1980	Number	Percent	Natural increase	Net migration
Benton County	67,540	109,444	41,904	62.0	21.7	78.3
Franklin County	25,816	35,025	9,209	35.7	59.3	40.7
Washington State	3,413,244	4,130,163	716,919	21.0	42.3	57.7

[a]BOC (1981).

[b]State of Washington (1979), Table 14. Comparable data were not yet available for 1980.

High levels of net in-migration tend to be selective of the age group between 20 and 65. This is illustrated by the data presented in Table 3-4. The bicounty area is forecasted to have increasingly higher proportions of its population concentrated in this age group.

3.1.3.5.6.1.2 Preliminary Conclusions. The Hanford Site is located in an area of low population density and away from population areas and urban concentrations. There appears to be no significant problems with respect to meeting System Guideline 960.3-1 (DOE, 1983).

TABLE 3-4. Population Distribution by Age and Sex.*

Area	Age category	1970		1980		1990	
		Population distribution (%)					
		Male	Female	Male	Female	Male	Female
Benton County	0-19	42.9	40.7	36.4	34.2	33.4	32.0
	20-64	51.0	52.5	57.0	58.1	59.8	59.9
	65+	6.1	6.8	6.6	7.7	6.8	8.1
Franklin County	0-19	43.1	41.4	36.8	35.4	34.1	32.8
	20-64	51.0	51.3	56.8	56.5	59.4	58.6
	65+	5.8	7.3	6.3	8.1	6.6	8.6
Washington State	0-19	38.9	36.7	32.4	30.8	30.2	28.9
	20-64	53.0	52.7	58.9	57.6	60.8	58.7
	65+	8.2	10.6	8.7	11.6	9.0	12.4

*State of Washington (1981).

3.1.3.5.6.2 Transportation. Technical Subguideline 960.5-8-2 (Transportation) states that:

> *The cost and other impacts of transporting radioactive waste to a repository shall be considered in selecting the repository sites. Consideration shall be given to the proximity of locations where radioactive waste is currently generated or temporarily stored and the transportation and safety factors involved in moving such waste to a repository.*
>
> *(a) Favorable Conditions*
>
> *Ability to select transportation routes that minimize risk to the general population.*
>
> *(b) Potentially Adverse Conditions*
>
> *Site locations requiring the concentration of transportation routes through highly populated areas.*

3.1.3.5.6.2.1 Summary of Available Information. Transportation costs and other impacts were considered in nominating the Hanford Site for site characterization. The Hanford Site is not located near a concentration of commercial nuclear powerplants. This will require relatively long transportation routes to the Hanford Site from various parts of the United States. Current estimates are that approximately 90 percent of waste shipped to a potential repository at Hanford will be by rail and the remaining 10 percent by truck.

3.1.3.5.6.2.2 Preliminary Conclusions. The establishement of transportation routes to the Hanford Site are necessary to evaluate potential risks to the general population. These DOE studies are currently under way and will be one of the many factors that will be considered in selecting a repository site. A detailed evaluation of transportation factors associated with a repository at Hanford would be presented in an environmental impact statement prepared to support the Site Recommendation Report if Hanford is recommended by DOE as a repository site. Section 3.6 of this document contains an analysis of transportation factors related to siting a nuclear waste repository at Hanford. It is expected that the requirements of this guideline can be met.

3.1.3.5.7 Environmental Protection. Technical Guideline 960.5-9 (Environmental Protection) (DOE, 1983) states that:

The site shall be such that a repository can be constructed and operated in a manner that provides reasonable assurance that the environment will be adequately protected, for this and future generations. The site shall be located so as to reduce the likelihood and consequences of potential environmental impacts, and these impacts shall be mitigated to the extent reasonably achievable. A site shall be disqualified if a repository would result in an unsatisfactory adverse environmental impact that threatens the health or welfare of the public or the quality of the environment and cannot be mitigated. A site shall be disqualified if it is located within the boundaries of a significant nationally protected natural resource, such as a National Park, National Wildlife Refuge, or Wilderness Area, and its presence conflicts irreconcilably with the previously designated use of the site.

(a) *Favorable Conditions*

(1) *Ability to meet all procedural and substantive environmental requirements applicable to the site, at the Federal, State, and local level, with assurance and within time constraints.*

(2) *Adverse environmental impacts, to present and future generations, can be avoided or reduced to an insignificant level through the application of reasonable mitigating measures.*

(b) *Potential Adverse Conditions*

(1) *Probable conflict with applicable Federal, State, or local environmental requirements.*

(2) *Significant adverse environmental impacts that cannot be avoided or minimized.*

(3) *Proximity to, or direct adverse environmental impacts of the repository or its support systems on, a component of the National Park System, the National Wildlife Refuge System, the Wild and Scenic River System, the National Wilderness Preservation System, or National Forest Land.*

3.1.3.5.7.1 Summary of Available Information. The reference repository location is situated on DOE's 1,500-square-kilometer (570-square-mile) Hanford Site, which has been dedicated to nuclear activities since 1943. Environmental analyses conducted for the DOE's existing nuclear activities suggest that compliance with environmental laws and regulatory requirements would not be a problem if a repository is located at Hanford. The Hanford Site is not located within the boundaries of a significant nationally protected natural resource. Construction and operation of a repository would not be inconsistent with existing land use plans. No adverse environmental effects that threaten the health or welfare of the public or the quality of the environment, which cannot be mitigated, have been found.

3.1.3.5.7.2 Preliminary Conclusions. Information currently available leads the DOE to believe that a repository can be constructed and operated at Hanford in the manner that assures that the environment will be adequately protected in compliance with this guideline. A final conclusion will be reached after additional environmental studies are conducted. Design of a repository would mitigate any resulting environmental impacts to the extent reasonably achievable. Detailed documentation of this site's acceptability under this guideline would be included in the environmental impact statement accompanying the Site Recommendation Report if the Hanford Site is ultimately selected by the DOE for recommendation to the President as a repository site.

3.1.3.5.8 Socioeconomic Impacts. Technical Guideline 960.5-10 (Socioeconomic Impacts) (DOE, 1983) states that:

The location of the site shall be such that any significant adverse social and/or economic impacts on communities and regions resulting from repository construction, operation, and decommissioning or the transportation of radioactive waste to the site can be accommodated by reasonable mitigation or compensation.

(a) *Favorable Considerations*

(1) *Locally available labor.*

(2) *Potential for repository-related increases in local employment, increases in business sales, increases in government revenues, or improvements in community services.*

(b) *Potentially Adverse Conditions*

(1) *The existence of, or the potential for, a lack of the necessary labor force or a lack of local suppliers.*

(2) *A projected substantial decrease in community services due to repository development.*

(3) *Conditions where the development, construction, operation, or decommissioning of a repository may require any purchase or acquisition of water rights that will have a significant adverse effect on the present or future development of the area.*

3.1.3.5.8.1 Summary of Available Information. The available information on socioeconomic impacts is reviewed in Section 3.6 of this report.

3.1.3.5.8.2 Preliminary Conclusions. Preliminary analysis indicates that there will be no significant adverse social and/or economic impacts on nearby communities and regions resulting from repository construction, operation, and decommissioning, or the transportation of radioactive wastes. A technically qualified labor force (except for the hard-rock miners) is located nearby in the Tri-Cities and the surrounding areas. This area has a history of providing for the needs of large construction projects on the Hanford Site.

3.2 SUITABILITY OF THE HANFORD SITE FOR REPOSITORY DEVELOPMENT

Section 112(b)(1)(E)(ii) criteria: Evaluation of whether the site is suitable for development as a repository under each guideline that does not require site characterization as a prerequisite for application of the guideline.

In order to evaluate this guideline, it is necessary to define "site characterization" for the BWIP as those "activities, whether in the laboratory or in the field, undertaken to establish the geologic condition and the ranges of parameters of a candidate site relevant to the location of a repository, including borings, surface excavations, excavations of exploratory shafts, limited subsurface lateral excavations and borings, and in situ testing needed to evaluate the suitability of a candidate site for the location of a repository, but not including preliminary borings and geophysical testing needed to assess whether site characterization should be undertaken" (Nuclear Waste Policy Act of 1982).

It has been determined that for the purposes of this draft environmental assessment, only the last five technical guidelines can be applied without conducting site characterization activities. These guidelines are:

- 960.5-6 Human Intrusion
- 960.5-7 Surface Characteristics
- 960.5-8 Population Density and Distribution
- 960.5-9 Environmental Protection
- 960.5-10 Socioeconomic Impacts.

Some of these guidelines specifically include disqualifying factors that would cause a candidate site to be eliminated from further consideration for a nuclear waste repository. Based upon available information, none of these disqualifying factors contained in Technical Guidelines 960.5-6 through 960.5-10 are known to exist at or near the reference repository location.

The guideline on "Human Intrusion," and its subguidelines dealing with "Natural Resources" and "Site Ownership and Control" were evaluated in Section 3.1. The preliminary conclusions indicate that the reference repository location is considered suitable for repository development under the requirements of Technical Guideline 960.5-6, "Human Intrusion." No disqualifying factors are associated with this guideline.

The "Surface Characteristics" guideline, and its attendant subguidelines, were evaluated in Section 3.1 and the reference repository location was found to be in compliance with the stated requirements. The preliminary conclusions drawn earlier indicate that the candidate site is considered suitable for repository development in accordance with Technical Guideline 960.5-7, "Site Characteristics." This guideline also does not contain disqualifying factors.

The guideline dealing with "Population Density and Distribution," and its associated subguidelines, were evaluated in Section 3.1 of this draft environmental assessment. The preliminary conclusions indicate that the candidate site is considered suitable for repository development under the requirements of Technical Guideline 960.5-8.

Two disqualifying factors are integral components of the guideline. The disqualifying factor dealing with radiation doses that might be received by members of the general public as a result of a nuclear waste repository must be considered in the design of the repository and waste packages, the selection of backfill material, as well as the specific characteristics possessed by the candidate site. No geologic or hydrologic information gathered to date indicates that a repository at the candidate site might endanger the health and safety of the public. The second disqualifying factor deals with population density concerns near the candidate site. These population density factors do not exist at or near the candidate site.

An evaluation of the "Environmental Protection" guideline is presented in Section 3.1. To date, no site characteristics have been identified which would indicate that this disqualifying factor dealing with unsatisfactory adverse environmental impacts would apply to the candidate site. The other disqualifying factor deals with the location of a candidate site within the boundaries of a significant nationally protected natural resource (i.e., National Park, Wilderness Area, etc). The candidate site at Hanford is not within a nationally protected natural resource area.

The guideline concerned with "Socioeconomic Impacts," was evaluated in Section 3.1 and is examined in more detail in Section 3.6 of this draft environmental assessment. The preliminary conclusions reached in Section 3.1 indicate that the candidate site meets the requirements of Technical Guideline 960.5-10 and may be considered suitable for repository development under this guideline. There are no disqualifying factors associated with this guideline.

3.3 SITE CHARACTERIZATION IMPACTS AND ALTERNATIVES

Section 112(b)(E)(iii) criteria and alternatives: Evaluation of the effect of site characterization activities at the Hanford Site on public health and safety and the environment. Also included in this section is an analysis of alternative site characterization activities that may be undertaken to avoid such impacts.

3.3.1 Screening Process Potential Impacts

The screening process, per se, has no physical interaction with the environment. The process itself uses existing information, or information gathered for collateral purposes, in the compilation of map overlays. These overlays provide a topographic representation of various characteristics of the areas depicted (e.g., proximity to population zones of given densities, presence of known geologic anomalies, etc.). Each overlay represents land areas considered unusable or less than desirable for one particular reason. Taken in the aggregate, the overlays depict all land areas within the boundaries of the Hanford Site that currently available information shows to be less than optimum for a high-level nuclear waste repository (WCC, 1981).

3.3.2 Survey and Characterization Potential Impacts

A wide variety of geologic and hydrologic techniques have been employed to survey and characterize areas of the Hanford Site as the BWIP selected the Exploratory Shaft site. Most processes, such as aerial and satellite photography and magnetometer surveys, have no discernible environmental effect and, accordingly, did not require environmental documentation.

Borehole drilling has sufficient potential impact to require a brief environmental evaluation of each proposed drill site. Since the beginning of the screening process in 1978, the BWIP has drilled, reentered and deepened, or conducted tests in approximately 36 boreholes on the Hanford Site. Twenty of these were shallow holes to investigate unconfined aquifers and did not penetrate into the basalt for any appreciable distance, if at all.

Borehole locations were selected to acquire necessary data while minimizing environmental impact. It was recognized that, in the shrub-steppe ecology of the Hanford Site, land-surface disturbance would constitute the greatest potential for adverse environmental impact, due to the potential of increased wind- and water-driven erosion and loss of wildlife habitat. Each potential drill site was examined to ensure that: (1) it was located as close as possible to existing roads, (2) it was not within a wetland, (3) it was not within a known archaeological site, and (4) site activities would not adversely impact any threatened or endangered plant or animal species.

Land surface disturbance at the typical drill site was limited to selective clearing and grading of a 0.4-hectare (1.0-acre) site, construction of about 300 meters (1,000 feet) of single-lane dirt road, digging and lining of a 6- by 9- by 1.2-meter (20- by 30- by 4-foot) mud pit, and laying of a 45- by 90-meter (150- by 300-foot) compacted gravel drilling-support pad. This activity, and subsequent drilling, resulted in the production of some airborne dust and regulated air pollutants (particulates, sulfur oxides, carbon monoxide, hydrocarbons, photochemical oxidants, and nitrogen oxides). Dust emissions were controlled with wet-suppression techniques in compliance with General Regulation 80-7 of the Benton-Franklin-Walla Walla Counties Air Pollution Authority (APCA, 1980). Regulated pollutant emissions averaged less than 570 kilograms (1,250 pounds) per month per site, well below the EPA's limit of 45 metric tons (50 tons) per year for a major stationary source (EPA, 1980).

The borehole resulting from such an operation was typically 15.25 centimeters (6 inches) in diameter and up to 1,260 meters (4,200 feet) deep. Current plans call for all such holes to be permanently plugged at the conclusion of testing. The mud pit will be refilled, and the drilling sites will be returned, as closely as practicable, to their natural states.

Additional boreholes are planned to be drilled during the next few years of site characterization activities. The main purpose for the new boreholes will be to provide hydrologic data necessary to more fully define the hydrologic system beneath and beyond the Hanford Site. The DOE does not believe that such data are available from other sources. Knowledge of the hydrologic system is an important component of performance-assessment models used to predict nuclide migration away from a potential repository. For each new borehole, an environmental evaluation will be prepared to ensure that impacts are minimized.

3.3.3 Exploratory Shaft Impacts

The impacts of the Exploratory Shaft construction operation and decommissioning were addressed in the environmental assessment (DOE, 1982a). The following information is summarized from that earlier environmental assessment. No new information has been developed that would alter that analysis.

3.3.3.1 Construction Impacts. The major construction impact is the selective clearing and grading of 8 hectares (20 acres) of shrub-steppe terrain. More than half the plants within this area will be destroyed and all the animals will be displaced. Ongoing biological monitoring continues to show no threatened or endangered species resident upon the proposed Exploratory Shaft site.

The Exploratory Shaft site is in an area subjected to high winds, with monthly gusts in excess of 65.0 kilometers (40.4 miles) per hour. Under such conditions, wind erosion of disturbed soil can become a problem. The DOE is using approved soil-stabilization techniques, including wet suppression of dust during construction of roadways and parking lots, followed by surfacing with gravel.

The paucity of rainfall at Hanford, coupled with the high relative porosity of the surface soil at the shaft site (Gephart et al., 1979), make a storm drain system unnecessary. These same characteristics allow the effective disposal of site sewage by means of a septic tank/drain field complex. Structural materials of such a system are virtually inert, and the contemplated system will be very small, compared to similar active systems for the 200 West Area and deactivated systems associated with abandoned military cantonments nearby. No significant environmental effects are anticipated.

Site buildings will be either trailers or prefabricated steel buildings assembled at the site on pre-poured concrete slabs. Normal occupancy of the surface structures will average about 30 persons, most of whom will remain indoors throughout their shifts. This combination of low personnel density, prefabricated construction, and little personnel outdoor movement during working hours will combine to minimize long-term impacts on wildlife.

The most significant environmental effects directly related to shaft construction will be those resulting from digging mud pits and from accumulating drill cuttings and mined rock, called "muck," in spoil piles. The mud pit complex will cover approximately 0.4 hectare (1.0 acre) with a series of shallow pits, subdivided by baffles and dikes and surrounded by low berms approximately 2 meters (6.6 feet) high. The pits will be covered and lined to prevent evaporation and seepage. The majority of mud pit impact will result from soil disturbance and unavoidable fugitive dust emissions during construction. Appropriate suppression techniques will be employed to keep dust emissions within applicable limits.

The actual volume of material to be removed from the shaft and test chamber is approximately 7,700 cubic meters (272,000 cubic feet). The volume of this material will increase to approximately 17,000 cubic meters (600,000 cubic feet) upon removal, due to fragmentation and loose packing in a spoil pile. In addition, up to 12,000 cubic meters (424,00 cubic feet) of fragmented basalt mined from the tunnels will constitute an adjacent spoil pile. The possible mechanisms by which spoil piles can cause environmental damage are by dust emissions, chemical leaching, and mechanical slip or collapse. Existing dust suppression techniques, which have proven effective, will be used to keep emissions from the spoil pile within applicable limits of General Regulation 80-7 of the Benton-Franklin-Walla Walla Counties Air Pollution Authority (APCA, 1980). The miniscule size of this pile, compared to piles produced by commercial mining activities at other locations, will greatly simplify this effort.

Detailed chemical analysis will be made to determine the composition of the rock that will constitute the pile. (Samples will be obtained in advance from a nearby borehole to the proposed shaft depth.) On the basis of this analysis, appropriate chemical effluent monitoring plans and physical barriers, such as dikes, berms, and liquid collection sumps, will be established, if necessary, to prevent rain from leaching chemicals from the spoil pile into the site surface.

Conservative mining practice will be followed in establishing the slope of the spoil pile sides, taking into consideration the changes in angle of repose that may be caused by saturation by heavy rainfall. This will preclude impacts due to landslip or collapse of the spoil pile, which will be located well away from areas frequented by personnel to enhance personnel safety.

With the exception of sewage, which will be disposed of through the site leach field, all construction wastes and refuse will be collected and trucked from the site for disposal in the existing Hanford Site landfill facility.

The Hanford Site is within the "South-Central Washington Intra-State Air Quality Control Region" as defined by the EPA (Golden et al., 1979). This entire region is classified by the EPA as a Category II air quality region. Airborne emissions from diesel equipment used during construction are not expected to present any significant impact, due to the limited amount of such equipment to be used, the scarcity of other activities, and the generally good atmospheric mixing in the area of the site. The use of central station-generated electrical power, wherever possible, further reduces potential impacts from fossil fuel exhaust emissions. Emissions of regulated air pollutants (particulates, sulfur oxides, carbon monoxide, hydrocarbons, photochemical oxidants, and nitrogen oxides) from the site are expected to be de minimus. Consequently, the project will not be a major stationary source under EPA regulations and, therefore, will not be subject to Prevention of Significant Deterioration (PSD) (EPA, 1980) permitting review.

The remoteness of the site from human habitation and from occupied Hanford facilities mitigates the effects of any high drilling-noise levels. Drilling activities will generate noise levels that could reach 110 decibels immediately adjacent to the noise sources. Effective muffler systems will be used on heavy equipment during construction to minimize adverse environmental impacts. Impacts on members of the general public will meet the requirements of the Noise Pollution Control Act of 1972, which requires that "noise levels do not exceed 70 decibels at the nearest habitation."

While visible from Route 240, the aesthetic impact of the site will be minimal. About 2.3 kilometers (1.4 miles) of existing gravel road will be upgraded by adding gravel. A new gate and guard station was added at the outside fence. The most prominent feature, the drill rig, will not be near or on a line of sight to any scenic view or outlook and, in any case, will be in place only a short time. The site buildings will be small and will be similar to numerous structures in the area.

Laying of the site waterline from the 200 West Area did require clearing of a 6.2-meter (20-foot) wide strip of ground 4.8 kilometers (3 miles) long. Construction of the overhead powerline caused partial disturbance to a 4.6-meter by 10.4-kilometer (15-foot by 6.5-mile) area. No streams, rivers, or wetlands were crossed or impacted. Natural vegetation will be allowed to reestablish itself along both rights-of-way.

Since these construction impacts are confined to the Hanford Site, no public health or safety impacts are expected. Access to the Hanford Site by members of the general public is prohibited, except for specific highways.

3.3.3.2 Operational Impacts. Following construction of the surface support facilities and the completion of the shaft and test chamber, a few years of testing will ensue, followed by construction of a series of tunnels. Once the tunneling activity is completed, the Exploratory Shaft and its associated support facilities will enter a period of extensive testing. The potential environmental impacts associated with this operational phase will be minor compared to the potential impacts of construction. The most significant source of dust, noise, and effluent production will be the commuter vehicles used by site personnel at the beginning and ending of each shift. Assuming the limiting case of no car pooling and two 35-person shifts, a maximum of 70 motor vehicles would be moving in the Exploratory Shaft vicinity for approximately 10 minutes at shift change. For comparison, shift change at nearby nuclear powerplants under construction involves the movement of several thousands of motor vehicles.

Due to elevated temperatures encountered at depth, shaft ventilating air will also be cooled to maintain an acceptable environment for personnel working in the test chamber. Air will be compressed to about 3.75 atmospheres (55 pounds per square inch) by high-pressure blowers, routed through a series of coolers, dryers, and chillers, and then carried to the subsurface through two 15-centimeter (6-inch) embedded shaft service lines. This air will circulate and return to the surface through the shaft. The overall rate of release of heat at the surface will be less than 500 kilowatts. This is approximately 0.1 percent of the rate of release of heat from the Fast Flux Test Facility, a nearby nuclear test reactor that releases all energy produced as heat.

It should be reemphasized that the basic purpose of the test activities to be carried out in the shaft, shaft station, and tunnels is the detailed characterization of the basalt at the proposed storage horizon with respect to its potential ability to contain a high-level nuclear waste repository. If test results or a change in program direction make the site inappropriate for further characterization, test activity will cease and the shaft will be decommissioned.

3.3.3.3 Potential Accident Impacts. The most environmentally severe potential site accidents involve fires in site facilities and the possibility of a magazine explosion.

The Exploratory Shaft site is within the area served by the Hanford Fire Department. Site design was predicated on any single building involved in a fire becoming a total loss, as the expected fire department-response time will be approximately 20 minutes. Separation between buildings and the metal exterior of the buildings provide reasonable assurance that fire will not spread from building to building, while cleared areas around buildings and the cleared strip surrounding the site fence are designed as firebreaks to prevent facility fires from spreading to the surrounding vegetation. The Hanford Fire Department has off-road fire-fighting vehicles and extensive training and experience in their use to limit and suppress brushfires.

These considerations, coupled with the lack of sources of ignition found in industrial facilities (welding, flammable vapors, etc.), indicate that the Exploratory Shaft facilities will not contribute significantly to fire-related environmental impact at Hanford.

Inside the revetment, separate structures will contain a maximum of 910 kilograms (2,000 pounds) of 60 percent gel Class B explosive, or equivalent, and 400 detonators. In the extremely unlikely event of accidental detonation, the structures and revetments are designed to prevent the resulting blast-and-fragmentation effects from damaging the facilities or surrounding habitat.

None of the impacts of potential accidents are expected to be felt away from the Hanford Site. Thus, no public health or safety impacts are anticipated.

3.3.3.4 Decommissioning Impacts. Upon completion of Exploratory Shaft construction and testing activities, a decision will be made from among four options: (1) development of the site for use as a high-level radioactive waste facility, (2) use of the facility for generic research and development activities such as a Test and Evaluation Facility (such a decision would have to be supported, however, by a separate environmental document), (3) holding the site for consideration at a future date for use as a radioactive waste repository, or (4) immediate decommissioning. A decommissioning process at this stage of development would not have to consider any nuclear-related effects, since no nuclear material would have entered the shaft. The primary area of concern would, therefore, become the minimization of further disturbance of the site surface.

The effects of the decommissioning process would be very similar in type and magnitude to the effects of site preparation, with the major exception that wildlife disruption would be relatively minor, since the site will have been inhabited by personnel continuously until decommissioning.

The most significant potential impacts of this process will be emissions of dust and exhaust fumes, consumption of petroleum, generation of noise, and possible leaching of acidic or caustic chemicals from the spoil pile. The dust emission potential will be greatly reduced by wet suppression techniques from a spray system that will be used later to assist in area revegetation, while the vehicle exhaust will make a negligible contribution to the overall Hanford output. Approximately 37,900 liters (10,000 gallons) of diesel fuel will be consumed by heavy machinery, and considerable noise will be generated in the immediate area. The intensity and pitch of this noise will be very similar to those of grading operations in a residential subdivision, and in any event will be conducted in such a remote area as to be far less than 70 decibels at the nearest human habitation. By the time the shaft will have been completed, the chemistry of the rock removed from the various strata will be well known, and approved mitigative measures associated with leaching will be taken, if necessary.

In the event that the Exploratory Shaft becomes a part of a nuclear waste repository in basalt, the shaft would be decommissioned using the same practices and procedures planned for the rest of the repository. These procedures will be described in detail in the environmental documentation that will be written for the repository.

3.3.4 Potential Environmental Impacts of Alternatives

In the course of developing the proposed action (i.e., detailed site studies through the construction of an Exploratory Shaft) several alternative actions were considered. These alternatives are:

- "No action"
- Limited "no action"
- Delayed action
- Alternate Exploratory Shaft site
- Alternate Exploratory Shaft design.

The following is a summary of the alternative actions and the potential environmental impacts of these alternatives.

3.3.4.1 "No Action" Impacts. In the broad sense, the "no action" alternative for this activity was defined as the cessation of all actions relating to site characterization. Included would have been all survey and characterization activities, such as drilling and seismograph emplacement, any remaining screening actions and reviews, and all siting, designing, and construction activities related to an Exploratory Shaft. Information collected to date would be transferred to archives, fieldwork teams would be disbanded, and support contracts terminated. All dedicated equipment would be stored, issued to other Hanford projects, or sold as excess. Following these actions, all project personnel would cease all efforts related to shaft location selection, shaft design, and shaft construction. (It should be mentioned that this case was treated to provide a baseline for consideration; such an action conflicts with the current version of 10 CFR 60.10 (NRC, 1981b), which is the "site characterization" section of the rule concerning high-level nuclear waste repositories.)

The immediate direct physical impact of this course of action would have been the avoidance of all the effects discussed in Section 3.3.3 that relate to shaft area preparation, shaft facilities construction, shaft boring, testing, and decommissioning. Most impacts associated with area screening and test drilling had already occurred, since these programs had been conducted for several years.

The most severe and most immediate effect of such an action would have been socioeconomic in nature. Termination of the effort would have resulted in loss of employment of 200 workers, supporting 500 dependents and providing 600 support positions for the local economy. A more severe impact, although one difficult to quantify, would have been the markedly increased ratio of costs to benefits that early termination of the program would cause. The selection/characterization effort was initiated to acquire detailed geophysical knowledge of the properties of Columbia River basalts as they relate to high-level nuclear waste disposal. To have stopped short of adequate characterization would have reaped no benefit for much of the impact and expenditure, as the information to be gained from the shaft is synergistically coupled to the information in hand and is necessary to determine the viability of the Columbia River basalt as a potential disposal medium.

The consideration of indirect (DOE, 1982a) impacts resulting from adoption of the "no action" alternative required a realization that large quantities of high-level commercial nuclear waste currently exist. This situation makes inevitable some form of disposal, a circumstance recognized by the DOE in its acceptance of the responsiblity to develop technologies for management and disposal of commercially generated high-level nuclear wastes (DOE, 1980). The process selected by the DOE to discharge this responsibility includes the detailed characterization of several potential sites representing the potentially suitable geologic medium. Adoption of the broad "no action" alternative for the BWIP Exploratory Shaft would have terminated characterization of basalt in general, as well as the basalt at Hanford in particular. This would have left the question of suitability for waste disposal of the stable rock underlying large areas of the country unanaswered, a situation that would have left the volume of high-level commercial nuclear waste unchanged, while reducing the potential sites and areas available for its disposal.

3.3.4.2 <u>Limited "No Action" Alternative Site Characterization Impacts.</u> Under a narrower definition of "no action," an Exploratory Shaft would not be constructed, nor would surface support facilities be erected. However, ongoing BWIP characterization activities, including drilling of small-diameter boreholes, field surveying, and data analysis, would continue, with the interim objective of acquiring increasingly more detailed geoscientific information.

The direct effect of the adoption of this course of action would have been the prevention of all effects described in Section 3.3.3 that directly related to the shaft and its surface support area. This part of the program, with its increased personnel needs and requirements for clearing and grading a limited land area, would have disappeared. However, effects of other forms of data gathering would have accumulated indefinitely. Assuming the need for some finite level of data to support a repository site recommendation report, and further assuming that an Exploratory Shaft would not have been constructed, extensive drilling activities would have continued in an attempt to supply the needed information. The accumulated effect of clearing the land, grading sites, and excavating mud pits at more that 20 borehole sites would have equalled or exceeded the effects on the environment for construction of the shaft, and the sheer number of small-diameter holes would have tended to degrade the integrity of the potential site. In short, at this stage, Exploratory Shaft construction is considered to be a more environmentally efficient data-gathering process than small-diameter hole drilling and allied processes.

3.3.4.3 <u>Delayed Action Impacts</u>. Adoption of a delayed action alternative would have required cessation of site characterization activities for some finite period of time, after which the proposed course of action would have been continued. There would have been no difference in direct environmental impact between this alternative and the present proposed action, beyond the obvious change in time of occurrence.

A negative, secondary impact would result, however, inasmuch as some program costs would have continued during the period of inactivity, and in all probability, several of the more highly skilled technical persons necessary to efficient Exploratory Shaft construction would have left the project. Resumption of characterization activities would have then required some combination of key personnel acquisition and on-the-job training. The result of this course of action, as compared to drilling the Exploratory Shaft at this time, would have been the generation of the same direct environmental impacts at substantially greater costs to acquire the same data.

3.3.4.4 <u>Alternate Site Impacts</u>. The DOE is implementing various approaches to screen land areas and select sites suitable for detailed characterization to determine their potential as sites for deep geologic nuclear waste repositories. One of the approaches being implemented defined current land use as a basis for identifying areas where site exploration would be conducted. The Hanford Site has been committed to nuclear activities for nearly 40 years and may contain suitable host rocks at appropriate depths for a repository. Consequently, the DOE has requested the BWIP to screen and characterize areas, as appropriate, within the boundaries of the Hanford Site and in the Pasco Basin.

The entire Hanford Site is underlain by basalt flows, and many specific locations could have been selected on the basis of existing data that would have met minimum criteria for construction of an Exploratory Shaft. A number of reasonable sites may exist on the Hanford Site; however, the Exploratory Shaft site was determined to be the optimal site based on the site screening process (WCC, 1981). The extensive surveying and geosciences data-gathering activities performed to date have led to the conclusion that no better site can be selected now for detailed characterization (WCC, 1981). Few, if any, other locations are as well characterized as the currently designated Exploratory Shaft site, since characterization activity has been concentrated there since its selection. This would have implied additional environmental impact in direct proportion to the number of boreholes deemed necessary to characterize the alternate location to the same level of detail as existed for the reference location and would have resulted in unnecessary costs and delays.

Selection of the Exploratory Shaft location included an iterative design process, inasmuch as the shaft and repository designs are site specific. The selection process was primarily dominated by environmental considerations. For these two reasons, selecting an alternate Exploratory

Shaft site at Hanford would have required the expenditure of additional resources in resurvey and redesign activities and would not have necessarily resulted in a site that is in any way superior to the present proposed site.

3.3.4.5 Alternative Exploratory Shaft Design Potential Impacts. Alternatives to the proposed shaft design included alternate methods of shaft construction, varying the number of shafts, and varying the size, number, and location of underground test chambers. Some variations of the design of surface support facilities were also possible as a function of the shaft design. The environmental effects of such variations would have been minimal, relating mostly to small differences in sizing of the surface support area and its facilities.

A somewhat more significant difference in effect would have resulted from a change in shaft construction methodology. The only other current method of sinking a shaft is that of drilling shot holes, blasting, and mechanically removing the fragmented overburden. (This is the principal conventional mining technique of the mineral industry.) Employing this method for the penetration of aquifers requires the use of auxiliary techniques to prevent flooding in the shaft. Depending on the volumetric flow rates of the aquifers encountered, these techniques involve some combination of shaft pumping, drilling through blowout preventers near the bottom of the shaft, and injecting high-pressure grout in an annulus ahead of the advancing shaft, or drilling a series of wells around the prospective shaft location and injecting highly chilled brine to freeze the groundwater around the shaft location until the shaft can be excavated and cased.

Due to the volumetric flow rates of the aquifers the Exploratory Shaft must penetrate, probably all three of these techniques would have been required in conjunction with a conventional drill-and-blast shaft. Compared to the proposed support facilities for a bored shaft, the necessary brine chilling plant would have been large, costly and energy intensive.

Considering the primary purpose of the Exploratory Shaft is that of rock characterization, conventional drill-and-blast methods, used in conjunction with aquifer freezing, would have altered the subterranean environment for some distance from the shaft axis. Fracturing from the blasting process would have extended into the surrounding rock, and the drilling process, to be successful, would have markedly altered shaft area thermodynamics. All of these effects would have reduced the credibility of data gathered from the test areas due to the pertubations caused by shaft construction. In summary, use of this method would have increased the environmental cost/benefit ratio, causing increased expenditures of resources and increased surface environmental impact to acquire a given amount of data.

3.4 COMPARATIVE EVALUATION WITH OTHER SITES

3.4.1 Introduction

The Nuclear Waste Policy Act of 1982 requires, in Section 112(b)(1)(E)(iv), that the environmental assessment prepared to accompany each site nomination include:

> "...a reasonable comparative evaluation by the Secretary of such site with other sites and locations that have been considered."

Section 3.4 of this document was prepared to address this requirement.

The comparative evaluation includes the other sites and locations currently under consideration, as specified in the Nuclear Waste Policy Act of 1982. One site currently under consideration is Yucca Mountain, on the Nevada Test Site, in a rock type known as tuff (Fig. 3-5). Another potential site is in the vicinity of Gibson Dome near Davis Canyon in the Paradox Basin, which is a bedded salt formation underlying Utah. Other bedded salt locations within the Permian Basin are being studied with possible sites in Deaf Smith and Swisher Counties, Texas. And finally, three salt domes (Vacherie, Richton, and Cypress Creek) are being studied as potential sites for a repository in Louisiana and Mississippi. Thus, the Hanford candidate site will be compared with the following:

1. Yucca Mountain on the Nevada Test Site in tuff (Nevada)
2. Gibson Dome Area in bedded salts of the Paradox Basin (Utah)
3. Bedded salts in the Permian Basin (Texas)
4. Vacherie Salt Dome (Louisiana)
5. Richton Salt Dome (Mississippi)
6. Cypress Creek Salt Dome (Mississippi).

At least five of these seven sites will be nominated for site characterization and subsequently at least three will be recommended to the President for detailed characterization. Once detailed site characterization is complete, one site from the three will be selected for the first repository site.

3.4.2 Factors Used to Evaluate Sites

The principal documents used to develop this comparison of rock types include the previous chapter of this draft environmental assessment, Doctor et al. (1982), Nelson et al. (1982), NWTS (1982), and ONWI (1981, 1982).

Because the various sites have widely different data bases, it is difficult to compare them. Each candidate site has some favorable and some less favorable characteristics against which decision makers must develop a technical consensus concerning the medium's isolation capability. This isolation results from both inherent favorable rock properties plus engineering components to enhance isolation.

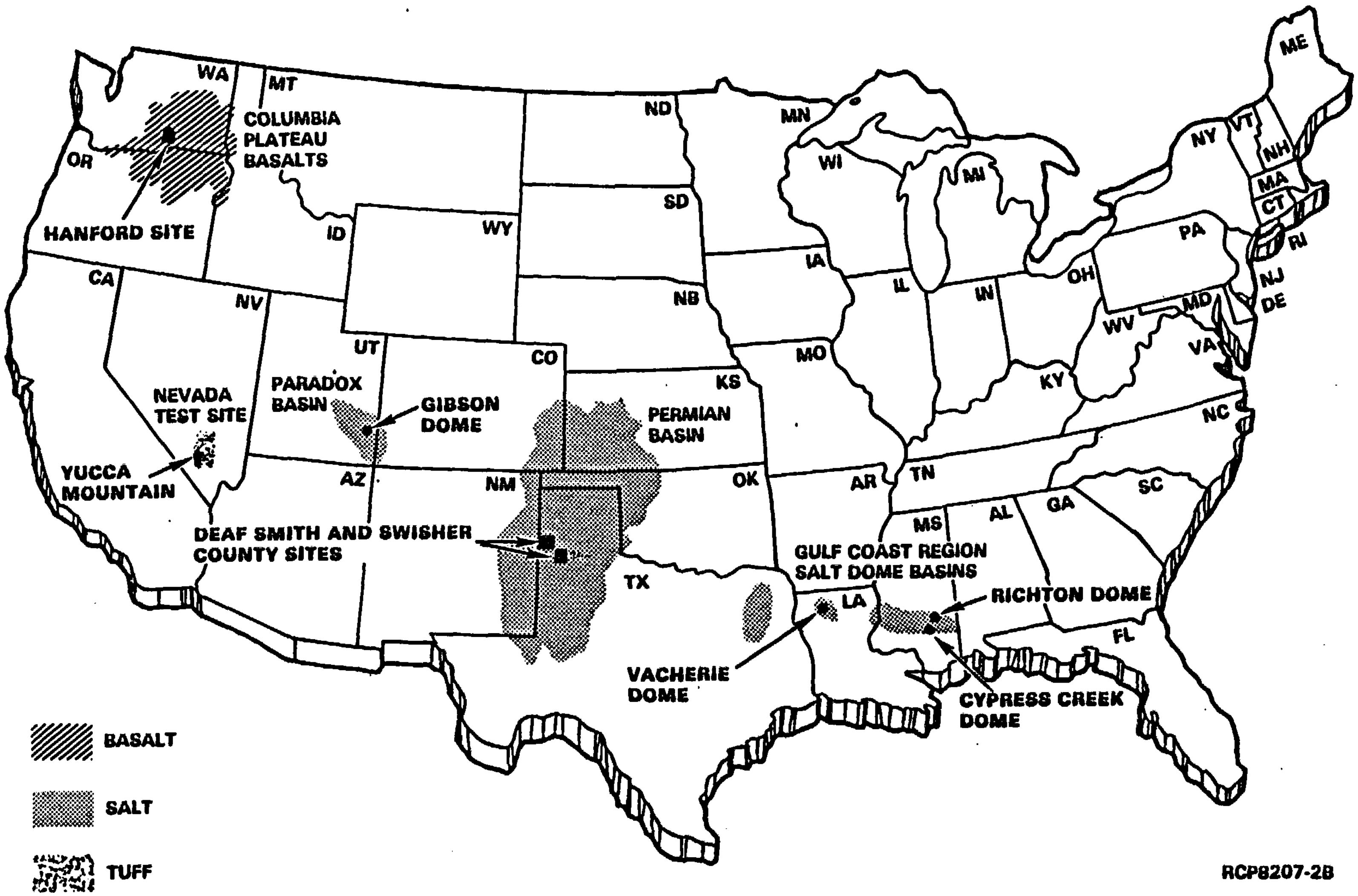

FIGURE 3-5. Specific Geologic Sites Under Active Consideration for the Disposal of Radioactive Waste.

It should be noted that the environment assessments accompanying other nominations may contain additional information or analysis relative to the factors contained in this section. Updated information or analysis will appear in the final environmental assessment nominating the Hanford Site.

3.4.3 Site Geometry

Though site geometries in the various geologic media differ, each appears to have sufficient depth, thickness, and lateral extent to meet proposed siting guidelines.

3.4.3.1 Depth of Underground Facilities. If a repository were constructed in basalt at the Hanford Site, it would be located in one of three candidate basalt flows in Grande Ronde Basalt. These are the Cohassett, McCoy Canyon, or Umtanum flows, which lie 869 to 942 meters (2,850 to 3,092 feet), 1,026 to 1,090 meters (3,365 to 3,576 feet), and 1,059 to 1,135 meters (3,475 to 3,723 feet) below ground surface, respectively.

If constructed in tuff at the Nevada Test Site, the repository would probably be in the Topopah Spring Member about 365 meters (1,200 feet) below ground surface. This formation is in the unsaturated zone (i.e., above the water table).

At the Gibson Dome in Utah, a repository would probably be constructed in the Paradox Formation. The top of this horizon is about 823 meters (2,700 feet) below ground surface.

If constructed in bedded salt of the Permian Basin, the repository would be constructed in the Lower San Andres Formation. In the areas of interest (Deaf Smith and Swisher Counties, Texas) these salt beds range in depth from about 610 meters (2,000 feet) to 792 meters (2,600 feet) below ground surface.

If a repository were constructed at either the Vacherie, Richton or Cypress Creek Domes, it would be placed at depths of 792 meters (2,600 feet), 660 meters (2,150 feet), and 732 meters (2,400 feet), respectively.

3.4.3.2 Thickness and Lateral Extent of Host Rock. For the proposed Hanford site, three laterally continuous basalt flows with thick, dense interiors are under consideration: the Cohassett, McCoy Canyon, and Umtanum. In the reference repository location, the Cohassett flow is 73 to 81 meters (239 to 266 feet) thick, the McCoy Canyon flow is 34 to 45 meters (110 to 148 feet) thick, and the Umtanum flow is 60 to 71 meters (197 to 232 feet) thick. These flows are found throughout the Pasco Basin, a region several tens of kilometers across in any direction.

The thickness of the Topopah Springs tuff under consideration at the Nevada Test Site is about 73 meters (240 feet). These formations extend for several kilometers in all directions from the proposed repository site.

The salt formation considered in the Paradox Basin is about 73 meters (240 feet) thick and extends for tens of kilometers in any direction.

Two salt formations studied in the Permian Basin are each over 38 meters (125 feet) thick and extend for tens of kilometers in any direction.

At the Vacherie Salt Dome, the usable salt thickness extends from about 236 meters (775 feet) to 914 meters (3,000 feet) in depth. The net area available for repository construction covers approximately 7 square kilometers (1,760 acres).

The usable salt dome thickness at the Richton Dome, extends from about 221 meters (725 feet) to 914 meters (3,000 feet) in depth. The net area available for repository construction covers about 15 square kilometers (3,760 acres).

The usable salt dome thickness at the Cypress Creek Dome extends from about 387 meters (1,270 feet) to 914 meters (3,000 feet) in depth. The net area available for repository construction is about 8.6 square kilometers (2,130 acres).

3.4.4 Geohydrology

With the exception of tuff, each candidate geologic medium possesses rocks of low permeability overlain by aquifers of various production rates. (Tuff has low permeability and the proposed repository level lies above the water table.) Groundwater traveltimes and radionuclide transport rates predicted through preliminary modeling for basalt appear very favorable for waste isolation. Modeling studies are under way for tuffs at the Nevada Test Site and for the salt sites.

3.4.4.1 Present and Future Hydrologic Conditions. Groundwater within the basalts at the Hanford Site moves laterally through limited zones of high permeability existing within some sedimentary interbeds and flow tops. These zones are separated by aquitards of low hydraulic conductivity comprised of basalt flow interiors and the hydraulically tight portions of flow tops. The three basalt candidate horizons are located in basalt flows having interior hydraulic conductivities of about 10^{-11} to 10^{-13} meters per second (10^{-6} to 10^{-8} feet per day).

Available geologic data suggest that the Pasco Basin was deforming at a low rate of strain in the Miocene and this rate has continued to the present. This slow deformation along known geologic structures is expected to continue into the foreseeable future. Therefore, groundwater flow paths, as now characterized, have probably extended into the past and are projected to continue into the reasonable future.

The proposed repository location in tuff on the Nevada Test Site is in the unsaturated zone. Here the water table lies approximately 500 meters (1,640 feet) below ground level. The amount and rate of moisture movement through the unsaturated zone is estimated to be small, although data are few. The regional groundwater flow direction is east and south from Yucca Mountain under a variable head gradient. This variability probably results from structurally controlled flow paths. Vertical head gradients appear to vary little to a depth of 1,100 meters (3,600 feet). Between 1,100 and 1,806 meters (3,700 to 5,920 feet) an upward head gradient is suggested. Transmissivities in the saturated zone are as high as several hundred square meters per day depending on the degree of fracturing. Hydraulic conductivities can vary several orders of magnitude within given stratigraphic units. The largest hydraulic conductivities typically occur within 100 meters (328 feet) of the water table.

The hydrostratigraphy of the Paradox Basin area consists of an upper unit of relatively low water yield receiving recharge from surface sources, a very low permeability middle unit in which a repository might be located, and a deep brine aquifer unit recharged at discrete locations. The generalized groundwater flow directions are to the south and west.

The hydrostratigraphy in the Permain Basin consists of an upper fresh water aquifer unit, a middle relatively impervious unit in which the repository would be located, and a deep, brine aquifer unit. The regional flow is downward to the deep aquifer, and at very low flow rates.

The Vacherie Dome is overlain by 163 meters (535 feet) of alternating silts, clays, and sand of variable hydraulic conductivities. The finer sediments, clays, and calcareous zones appear to be aquitards. Sandy lenses have hydraulic conductivies of approximately 10^{-5} meters per second (approximately 1 foot per day). Eighty meters (265 feet) of gypsum, brecciated limestone, and anhydrite caprock having unmeasured hydrologic properties overlie the salt dome. Groundwater flow in the caprock is primarily through fractures, joints, and solution channels. The salt itself probably has a low hydraulic conductivity.

The Richton Dome is overlain by 158 meters (520 feet) of interbedded sand and clay with some mudstone, siltstone, and lignite. The hydraulic conductivity of these sediments average approximately 10^{-5} meters per second (approximately 1 foot per day). This overlies 64 meters (210 feet) of caprock composed of gypsum and anhydrite having a hydraulic conductivity of approximately 10^{-5} meters per second (approximately 1 foot per day) The hydraulic conductivity of the caprock and caprock-salt interface are similar. The hydraulic conductivity of the salt dome itself has not been measured, although it is expected to be very low. The regional groundwater flow near the dome appears to be southward.

The Cypress Creek Dome is overlain by 360 meters (1,180 feet) of interbedded sand and clay with an overall hydraulic conductivity of about 10^{-4} meters per second (about 10 feet per day). These sediments overlie 62 meters (203 feet) of caprock composed of anhydrite, gypsum, and sandstone. The hydraulic conductivity of this caprock is about 10^{-5} meters per second (1 foot per day). The hydraulic conductivity of the caprock-salt interface is about 2 orders of magnitude less than the caprock itself. The hydraulic conductivity of the salt dome has not been measured though it is probably very low. The regional groundwater flow direction near the dome appears to be south.

Site-specific measurements of salt's hydraulic conductivity at each of the bedded and dome sites are planned.

3.4.4.2 Hydrologic Modeling. Very near-field (canister to room scale) modeling in the Hanford Site basalts indicates that for those radionuclides with even a nominal amount of sorption (i.e., kd greater than 0.5 milliliter per gram), the retardation effects are sufficient to reduce release rates from the repository horizons to levels well below the 10^{-5} per year proposed regulatory criterion during the first 10,000 years. The very low-solubility properties of major radionuclides (technetium, uranium, plutonium, americium) in basalt's reducing environment plays an even greater role than sorption in maintaining release rates below the proposed release criteria (EPA, 1982).

Near-field (repository-scale) simulation results in basalt indicate that relatively few radionuclides are of concern within a 10,000-year waste simulation period. Most actinide elements and long-lived fission products are of little importance because of their retardation characteristics and very low solubilities. Far-field simulation results in basalt indicate that groundwater traveltimes to the accessible environment (10-kilometer (6.2-mile) distance from repository boundary) exceed 30,000 years; the total traveltime to the Columbia River southeast of the repository is predicted to be in excess of 100,000 years.

Preliminary modeling of the Nevada Test Site (including the Yucca Mountain portion) is under way. Estimates of groundwater traveltimes and radionuclide transport rates to the accessible environment are not available.

Detailed site characterization of the salt sites are not available. However, regional hydrologic models are available. Therefore, hydrologic modeling of groundwater flow and radionuclide transport are based on expected regional conditions. These studies suggest that groundwater traveltimes are long and that radionuclides would not reach the accessible environment for well over 10,000 years.

3.4.4.3 Shaft Construction. For the repository located in basalt, a choice of conventional drilling and blasting, blind boring, or a combination of these methods may be used for sinking shafts. Grouting or freezing in advance of shaft sinking would be necessary to control groundwater if the conventional drill and blast method is chosen.

Groundwater present in strata overlying the candidate repository horizons can be controlled by engineering techniques and will not preclude construction of shafts.

In the unsaturated tuff at the Nevada Test Site, it is anticipated that the amount of water draining into the shaft constructed by drilling and blasting or blind boring will be small and easily handled. No special construction or maintenance techniques are anticipated. There is much construction experience in similar nearby formations stemming from weapons testing.

Groundwater present in strata overlying the Paradox and Permian Basin sites and the Vacherie, Richton, and Cypress Creek Salt Domes can be controlled by standard engineering techniques and will not preclude shaft construction.

3.4.4.4 Dissolution Features. Basalt is impervious to dissolution. There are no dissolution features in the basalt flows considered for the Hanford repository.

Rocks considered for repository construction at the Nevada Test Site are not soluble. No conceivable future changes in the geohydrologic system could cause dissolution of the tuffs at Yucca Mountain.

Dissolution features are possible in salt deposits. No dissolution features have been identified near the Gibson Dome area in the Paradox Basin. Some dissolution has been reported in the upper salts at the Permian Basin sites and is suspected in the salt-caprock interface of the Vacherie, Richton, and Cypress Salt Domes. Dissolution of salt in the lower portions of these domes has not been determined.

3.4.5 Geochemistry

The basalt geochemical environment at Hanford is favorable for isolating waste because of a high sorption capacity, low waste solubility, and no rock dissolution potential. These basic characteristics appear shared with tuff at the Nevada Test Site. Salt possesses low solute sorption, low waste solubility, and the possibility of rock dissolution.

3.4.5.1 Site Geochemistry. Hydrochemical data from the Hanford Site characterize the shallow basalt groundwaters as sodium bicarbonate chemical types, with low total dissolved solids (300 to 500 milligrams per liter) overlying a deep sodium chloride system having higher total dissolved solids (600 to 1,200 milligrams per liter).

Present Eh-pH, chemical, and secondary mineralogical conditions in the basalt geochemical system seem to be the result of rock-water interaction processes that have been operative at least during the Quaternary. The basalt mineralogy and the rock-water ratio appear to effectively buffer the groundwater composition against significant change.

Available geochemical data indicate that the candidate repository horizons at Hanford provide effective containment and isolation for many radionuclides present in high-level nuclear waste. Groundwaters from these basalt flows are strongly reducing (Eh = -0.45 ± 0.07 volt) and alkaline (pH = 9.5 ± 0.5). These factors enhance the stability of metallic components of the waste package and lead to decreased solubilities and increased sorption of many radionuclides. Hydrothermal alteration of the backfill/basalt system results in formation of a variety of stable phases such as clays and zeolites, which have superior sorptive capabilities.

Groundwater beneath Yucca Mountain at the Nevada Test Site is a sodium bicarbonate chemical type with total dissolved solids ranging from 175 to 900 milligrams per liter. Water near the water table does contain some oxygen. This is generally undesirable for the multivalent waste elements that normally show the lowest solubilities for the lower oxidation state species found in the absence of oxygen. Water in the unsaturated zone is also presumed to be oxidizing. The groundwater's pH is neutral (approximately 7.2), a condition tending to minimize solubility of waste elements. Concentrations of ionic species that might act as complexing agents (and, thus, possibly enhance radionuclide mobility) are low.

The mineralogy of tuff is generally favorable for sorption. Clays and zeolites, which inhibit the movement of radionuclides, are common throughout the stratigraphic units that underlie the Yucca Mountain site. The Calico Hills unit, which lies directly below the unsaturated Topopah Spring Member, is largely made up of zeolites. Matrix diffusion, a bulk process which may involve adsorption and diffusion of waste elements into the rock matrix, is also thought to be an important retardation mechanism at the Yucca Mountain site.

Few data are available concerning the site-specific geochemical environment at each of the salt sites. However, groundwater chemistry should change with depth at each site. The sequence of change would probably be that of a fresh water calcium bicarbonate groundwater overlying more saline sodium chloride waters. With depth, pH would also increase. A salt environment should be slightly reducing, thus contributing to low solubilities for actinides. However, the sorptive capacity of salt itself is very low, so the sorptive surfaces for radionuclide retardation would be from mineral and/or sedimentary lenses (clay, silt, etc.) inclusions.

3.4.6 Rock Characteristics

Technology exists for the design and construction of a repository in each candidate geologic medium as well as the sealing of exploratory boreholes. All facilities will meet appropriate safety requirements. The geomechanical-, chemical-, thermal-, and radiation-induced stresses expected in each host rock from waste emplacement are under study.

3.4.6.1 Geomechanical Parameters. Parameters used for the conceptual design of the Hanford repository are shown below. These values are based on a large number of tests and are representative of properties expected in basalt flows at the repository location. Preliminary average geomechanical parameters for the Topopah Spring Member at the Nevada Test Site are also shown.

Site	Porosity (%)	Density (g/cm^3)	Thermal conductivity (W/m^oC)	Young's modulus (GPa)	Poisson's ratio	Tensile strength (MPa)
Hanford Site (basalt)						
(Apparent)	2.8					
(Total)	7.3	2.8	1.16	67.6	0.25	14.8
Nevada Test Site (tuff)	12	2.2	1.7	28	0.28	3.5
Generic Salt Sites*	1.0	2.2	6.6	36	0.25	--

3.4.6.2 Constructibility. Shaft construction at the Hanford Site presents a challenge because of the depth, diameter, and possible groundwater inflows. The Exploratory Shaft Program will serve to assess the effectiveness of blind boring through basalt to the required depth. Experience gained by successfully completing large-diameter (2.3- to 3.0-meter (7.5- to 10-foot)) shafts to over 1,500-meter (5,000-foot) depths in basaltic rock at Amchitka Island, Alaska will be used by the BWIP. Groundwater inflow will be controlled by engineering measures.

The Yucca Mountain site in Nevada presents no significant problems in construction of either shafts or the repository. There is much construction experience in similar geologic materials from the underground weapons testing program.

Construction in salt is easier than hard rocks because it is softer and easier to drill and mine. The Gibson Dome in the Paradox Basin has low rainfall and a mesa and valley topography. These conditions may necessitate transport of water to the site.

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*Site-specific geomechanical parameters are being determined. Parameters are dependent on temperature, confining pressure, and the specific formation.

The Permian Basin site has flat topography and abundant groundwater supplies. Groundwater control measures will need to be undertaken as the shaft penetrates the upper aquifers.

Shaft drilling at the Vacherie, Richton, and Cypress Creek Domes require penetrating 200 to 400 meters (600 to 1,400 feet) of overlying sediments and caprock before reaching the salt stock.

3.4.7 Tectonic Environment

One Quaternary age fault is identified on the Hanford Site outside of the reference repository location. Quaternary faulting exists in the Nevada Test Site near Yucca Mountain and in the Paradox Basin. Faulting in the Permian Basin and salt dome sites appears to be pre-Quaternary. Each geologic medium lies in a zone of low seismicity. The probability of igneous activity at any site is very low.

3.4.7.1 Faulting and Seismicity. Faulting in the Hanford Site is associated with anticlinal ridges and appears contemporaneous with folding. Strain on anticlinal folds has resulted in faults that, in places, have cut Quaternary strata. Faults of major displacement are not anticipated in the shallow dipping strata of synclinal areas, such as the Cold Creek syncline where the repository site is proposed. Historical and instrument data indicate that the Pasco Basin is an area of low seismicity. The largest event recorded during 12 years of instrument monitoring of the central Columbia Plateau is a magnitude 4.4 event on Royal Slope, north of Pasco Basin and about 50 kilometers (80 miles) north of the repository site. No earthquake has been recorded in the repository site.

Faulting of Quaternary age at the Nevada Test Site is localized in the basins. No known faults of Quaternary age occur on Yucca Mountain (the faults that are present are older than 2 million years). Faults located near Yucca Mountain whose latest movement is of Quaternary age are the Rock Valley fault (27 kilometers (17 miles) distant) and a fault in Crater Flat (8 kilometers (5 miles) distant). The peak acceleration of ground motion that would occur at Yucca Mountain (assuming that nearby faults were to become active and produce a maximum magnitude earthquake of 7 or 8) is about 0.4 g based on historical records of earthquakes within a radius of about 96 kilometers (60 miles) of Yucca Mountain. Studies of ground motion from underground weapons tests at the Nevada Test Site indicate that peak accelerations at Yucca Mountain from this source would not exceed 0.3 g.

Quaternary faults in the vicinity (at least 16 kilometers (10 miles) distant) of the Gibson Dome, Paradox Basin, include: the Lockhart Fault and associated faults, the Needles Fault Zone, Shay Graben, and Bridger Jack Graben. Both the Shay Graben and Needles Fault Zones exhibit evidence of Quaternary movement. This is an area of low seismicity.

Quaternary age faults of tectonic origin have not been identified in the siting area of the Permian Basin. This is an area of low seismicity.

Strata surrounding the Vacherie Dome show increases in dip typical of those around salt diapirs. Over the central portion of the dome, several faults have been inferred in profile and mapped on the surface. These faults are believed to be pre-Quaternary in age because of the undeformed nature of the overlying sediments and stream terraces. The Vacherie Dome, as well as the Richton and Cypress Creek Domes, are in areas of low seismicity.

Some faulting is indicated in the region immediately surrounding the Richton Dome but no faulting is suggested over the dome itself. These deeper faults are considered to be pre-Quaternary in age. The dome has been considered to be stable over the past several million years, but no site-specific evidence is available.

Strata surrounding the Cypress Creek Dome are essentially flat lying except for upturning along the dome's margin. No site-specific data are available concerning local faulting or the dome's stability.

3.4.7.2 Igneous Activity. Lava flows underlying the Hanford Site erupted 6 to 16.5 million years ago from fissures in the eastern and southern portions of the Columbia Plateau. The basalt flows in the Pasco Basin have a thickness of over 3,000 meters (9,840 feet). Since 6 million years before present, there has been no igneous activity within the vicinity of the Hanford Site. The annual probability of renewed igneous activity has been estimated to be less than 10^{-8}.

Igneous activity, principally volcanism, has been a major feature of the Nevada region around Yucca Mountain during the geologic past. Yucca Mountain itself is a thick volcanic sequence that was formed 12 to 15 million years ago. Since then, volcanic activity has waned. The last major period of volcanism ended about 8 million years ago; small basalt outpourings occurred 1.1 to 0.3 million years ago in Crater Flat. The nearest of these basaltic eruptions is 6.4 to 8 kilometers (4 to 5 miles) southwest of Yucca Mountain. Based on studies of the occurrence of volcanism in Nevada and adjacent parts of California, the annual probability of disruption of a repository at Yucca Mountain by basaltic volcanism is calculated to be in the range of 10^{-8} to 10^{-10}.

There is no known Quaternary igneous activity in the vicinity of the salt sites.

3.4.8 Human Intrusion

The basalts at Hanford and tuffs at Nevada have low resource values, while moderate resource values are associated with the salt sites. The Hanford Site and the Nevada Test Site are Government-owned properties. The potential development of a repository is consistent with current land use at either of these sites. The salt sites are located on either public or private lands.

3.4.8.1 Natural Resources. An inventory and economic assessment of known mineral or fossil fuel resources within a 100-kilometer (60-mile) radius of the proposed repository site at Hanford has shown that no known economic resource would preclude the siting of a repository at Hanford. Based on current data, the quantity, gross and net value, and commercial potential of such resources appear to be less than or equal to the remainder of the Columbia Plateau and the western United States. Groundwater resources within the vicinity of the three candidate basalt flows are presently not considered economically exploitable due to low quantities, required water treatment, and drilling costs. Shallow groundwater resources do exist at the Hanford Site.

There are apparently no geothermal, fuel, or mineral resources that would be attractive to future generations near the Yucca Mountain site in Nevada. Groundwater does exist beneath Yucca Mountain; however, it seems unlikely that this resource would prove attractive because of the great depth (500 meters (1,650 feet)) to water, rugged topography, and the fact that equivalent groundwater resources exist nearby at shallower depths in more accessible basins.

The Gibson Dome in the Paradox Basin lies outside known areas of occurrence of coal. Several uranium and vanadium prospects exist, but they are not currently operational. No hydrocarbon deposits of economic significance have been encountered near the site. The Gibson Dome is not associated with any natural resources. There is no evidence of subsurface mining or drilling within locations considered for repository development. The salt in the Paradox Formation is not of a quality useful for commercial or culinary purposes. Shallow groundwater resources do exist.

There are no known mineral deposits in the proposed siting areas of the Permian Basin. Any human intrusion would likely result from the exploration for oil and gas. Exploration interest has increased recently. There are no natural resource concentrations in the Permian Basin that are significantly greater than the average condition for the region that warrants economic extraction. Although there is historical evidence of drilling activities for oil and gas within Deaf Smith and Swisher Counties, the locations under consideration are not associated with hydrocarbon production or other resource recovery operations. The salt in the Permian Basin is not of a quality that would be used for commercial or culinary purposes. There is no evidence of subsurface mining at the locations considered. Shallow groundwater resources exist in the Permian Basin.

There are no known mineral deposits, other than the salt, in the vicinity of Vacherie Dome; however, lignite deposits might be commercially mined 9.6 to 16 kilometers (6 to 10 miles) from the dome. Potential mineral resources at Vacherie Dome include sand, groundwater, gravel, salt, gypsum, anhydrite, lignite, oil, and gas. However, the availability of more abundant, shallower, and more profitable mineral resources elsewhere in the Gulf Coast region might preclude major developments at the Vacherie Dome. All but the northwest flank of the dome have been drilled for oil or gas exploration. No production zones were found. The probability of finding substantial quantities of oil or gas is considered low. Shallow fresh water groundwater resources exist above the dome as well as the Richton and Cypress Creek Domes.

There is no known mineral deposits in the vicinity of Richton Dome other than salt. Sulfur and oil explorations have not resulted in production of these commodities. Exploration for sulfur has occurred in the caprock of the dome; however, mining for sulfur did not follow. There has been petroleum exploration adjacent to the dome. None of these resources presently have encouraging economic potential.

There is a producing oil field adjacent to Cypress Creek Dome, though production has declined during the past 10 years. A small oil and gas field is also located on the flanks of the dome. Although the dome is situated along the extension of a productive trend, indications are that the near-dome area has a poor-to-fair potential for future hydrocarbon production. Other mineral resources are not considered to have a commercial potential in today's economics and markets.

3.4.8.2 Site Ownership and Control. The Hanford Site is owned and controlled by the Government and has been dedicated to nuclear activities for 40 years.

The Yucca Mountain site in Nevada and adjacent areas is under Federal Government control. The northern portion of the site is on the Nellis Air Force Bombing Range, the southern portion is on land administered by the Bureau of Land Management, and a small portion on the Nevada Test Site is administered by the DOE. At present, the Bureau of Land Management land is not closed to entry, but the U.S. Air Force and DOE lands are. The U.S. Air Force land under exploration has no surface facilities and is used only for aircraft overflights. The Bureau of Land Management portion has never been used for any purpose except in the current exploration for a repository site. The land would have to be withdrawn for repository use.

Land near Gibson Dome in the Paradox Basin is privately owned. The site is bounded by Canyonlands National Park. This proposed repository site is on public land under the jurisdiction of the Bureau of Land Management. The land would have to be withdrawn for repository use.

Potential repository sites in the Permian Basin are privately owned farmland. The Federal Government would have to obtain ownership, control access, and obtain surface and subsurface rights to this land if dedicated for repository use.

The land above the Vacherie and Richton Domes is privately owned. The entire Cypress Creek Dome is within the boundaries of DeSoto National Forest. A portion of Cypress Creek Dome land is also owned and managed by the U.S. Forest Service. The U.S. Forest Service, in turn, has granted use of the land to the Mississippi National Guard. Some parcels of Cypress Creek Dome are also owned by the State of Mississippi and are managed for the benefit of Mississippi schools. The land above all three dome sites would have to be acquired before repository use.

3.4.9 Surface Characteristics

Appropriate engineering designs can be undertaken at each proposed repository site to mitigate the effects of potential flash floods or inclement weather conditions. The only possible impact from adjacent installation at any of the sites is ground motion from weapons testing at the Nevada Test Site.

3.4.9.1 Surface Water Systems. The primary surface water features adjacent to the Hanford Site are the Columbia and Yakima Rivers. Runoff into these rivers is extremely low because of small annual precipitation. West Lake is the only natural pond on the Hanford Site. It is about 1 meter (3 feet) deep, covers about 40,000 square meters (9.6 acres), and is 5 kilometers (3 miles) northeast of the reference repository location.

A number of flooding scenarios have been examined by the BWIP including probable maximum flood, dam failures, and river blockage due to landslides. The most extreme scenario evaluated was a 50 percent breach of Grand Coulee Dam. The floods resulting from these releases do not reach the reference repository location. There is a 60 percent probability that the extreme southwest corner of the repository location could be subject to shallow flash flooding from the ephemeral Cold Creek during the 100-year-long postclosure phase of a repository. This flooding potential would not affect an underground repository and engineering measures would be sufficient to keep any floodwaters from existing surface facilities.

There are no perennial streams or lakes near the Yucca Mountain site. The flooding potential of ephemeral Fortymile Wash and its tributaries, as it might impact the Yucca Mountain site, has been analyzed. The maximum potential floods are estimated to have a rise of 7.6 meters (25 feet) and will stay within the confines of present channel of Fortymile Wash. However, maximum potential floods in the tributaries feeding Fortymile Wash may exceed channel capacities and inundate some areas. Therefore, the potential for flooding must be a design consideration for both access routes and surface facilities. This flooding potential can be mitigated through a combination of proper selection of building sites and diversion measures.

The Davis Canyon site near Gibson Dome in the Paradox Basin does not include areas covered by major rivers, lakes, or streams. The canyon is drained by intermittent streams that flow into Indian Creek which drains into the Colorado River. Surface facilities can be constructed outside the probable maximum flood boundaries.

The Deaf Smith and Swisher County locations in the Permian Basin do not include areas covered by major rivers, lakes, or streams. The surface facilities can be constructed outside the probable maximum flood boundaries.

Vacherie Dome is drained mostly by Bashaway Creek to the east and by intermittent tributaries of Palmer's Creek to the west. Based upon the dome and floodplain boundaries, about 15 percent of the surface above Vacherie Dome would be flooded in the event of a 500-year flood. Earthen flood protection is recommended and drainage diversion plus nominal fill may be required.

Richton Dome is in the Leaf River watershed and is drained by several creeks radiating from the dome. Based on 500-year floodplain maps, approximately 20 percent of Richton Dome could be subject to flooding. However, the remaining 17 square kilometers (6.6 square miles) are located outside the floodplain. This is an adequate area to site the repository.

The major creek draining the Cypress Creek Dome is Cypress Creek. It is part of the Black Creek drainage to the south. Intermittent streams originating north and east of the dome flow into the Leaf River drainage basin. Approximately 52 percent of the dome would be inundated by the 500-year floodplain. About 4.9 square kilometers (1.9 square miles) of the dome are outside the floodplain and would be usable as a repository site. Nevertheless, earthwork would be recommended for flood protection. This effort may require the draining and filling of swamps.

3.4.9.2 Terrain. Terrain around the proposed repository site at Hanford is nearly flat and should pose no problems for construction of surface facilities.

The Yucca Mountain site in Nevada is somewhat rugged having a maximum topographic relief of about 335 meters (1,100 feet). However, there are some relatively flat areas in selected mountain drainages and along the edges of the mountain. Access routes need not cross rugged terrain. Although there are some constraints on the design of surface facilities and access routes, these can be minimized by prudent site selection for facilities and through proper engineering.

The Gibson Dome area in the Paradox Basin is characterized by mesa and valley "badlands" topography. The candidate site occupies a low broad valley surrounded by high mesas. There are no topographic constraints in locating a repository. However, major access routes to the proposed repository site would have to be constructed.

The surface topography of the Permian Basin is essentially flat and would not restrict construction of surface facilities. Site locations have little topographic relief broken by numerous shallow playa lakes and a few intermittent creek beds. No terrain constraints have been identified precluding a repository in this area.

The Vacherie Dome is characterized by low hills drained by a small stream. The surface topography is essentially flat and would not restrict the construction of surface facilities.

The Richton Dome is characterized by moderate topographic relief and some stream dissection. The surface topography is nearly flat and would not restrict the construction of surface facilities.

The Cypress Creek Dome is characterized by rolling hills and a low area drained by a small stream. Low relief exists near the site, and there are no slope-related hazards present.

3.4.9.3 Meteorology. The Hanford Site is classified as a mid-latitude semiarid desert with cool, wet winters and warm, dry summers. This area is in the rain shadow of the Cascade Range, which accounts for the relatively low annual rainfall of 15 to 18 centimeters (6 to 7 inches), variation of wind patterns, and some moderation of temperature. In winter, a chinook (warm and dry) wind from the southwest can result in a sudden large temperature rise (11°C (20°F) per hour), rapid melting of snow (if present), and strong gusty winds. Occasionally, an incursion of cold arctic air results in relatively low temperatures (less than -18°C (0°F). The mean monthly temperatures for January and July, the coldest and warmest months of the year, are -1.4°C (29.5°F) and 24.7°C (76.5°F) respectively. Anticipated meteorological conditions at the reference repository location would not impact repository operations.

The climate of Yucca Mountains on the Nevada Test Site is arid with hot summers and dry winters. Temperatures exceeding 37.8°C (100°F) are common during the summer. Temperatures below 0°C (32°F) occur on occasion during much of the year. More than half the precipitation is snow. High precipitation rates have occurred from local convective storms. These storms can cause surface flooding. High winds are associated with winter storms and thunderstorms. Winds have been estimated as high as 160 kilometers (100 miles) per hour. Lightning is most frequent during July and August. Yucca Mountain is prone to lightning strikes, because of high elevation compared to surrounding basins.

The Paradox Basin exists in a semiarid mid-latitude climate. In the Permian Basin, dispersion conditions are generally favorable in this semiarid mid-latitude climate. The Vacherie, Richton, and Cypress Creek Domes are all in Class II air-quality control regions in a humid subtropical climate. Severe weather (i.e., hurricanes and tornadoes) does occur in these areas. This does not preclude the construction of a repository, but specific design criteria would have to be met by the repository structures to ensure that adverse weather conditions do not impact repository operations.

3.4.9.4 Impact From Adjacent Installations. The Hanford Site occupies approximately 1,460 square kilometers (570 square miles). Existing facilities and operational areas on the Hanford Site are identified by area numbers (see Fig. 2-4). Each area is a controlled or limited access area enclosed by a fence. Operation and maintenance of the above Hanford Site facilities would have no impact on the proposed repository.

At the Nevada Test Site, all industrial and transportation facilities are many kilometers (miles) from the Yucca Mountain site and should have no impact on repository operations. The only effect existing facility operations would have is that of ground motion from underground nuclear tests and unusual noise levels from overflights of military aircraft.

There are no industrial, transportation, or military installations in the vicinity of the Gibson Dome, Paradox Basin. A nearby abandoned air strip should have no impact on repository operations.

In the vicinity of Vacherie Dome, several small airports, low-altitude training routes, and industrial facilities exist. An operating repository should not be impacted by these industrial areas.

There are no nuclear or industrial facilities in the Richton Dome area. The Richton airport is nearby. This should not impact an operating repository.

Nuclear or industrial facilities do not exist near the Cypress Creek Dome. It lies entirely within the boundary of the DeSoto National Forest. Under a special use permit from the U.S. Forest Service, the area is used as a bomb-firing range and tank field as part of the Camp Shelby Military Reservation. An agreement with the area's present users would be necessary to avoid impacting repository operations.

3.4.10 Demography

All sites are located in low population areas. Waste transport and repository operation risk studies are not completed at any proposed repository site.

3.4.10.1 Population. The Hanford Site lands are within the Federal Government's jurisdiction. Adjoining lands are privately owned, with the exception of those areas controlled by the State of Washington, county, and city governments. The closest Indian Reservation is owned by the Yakima Nation, and is located approximately 26 kilometers (16 miles) west of the Hanford Site, 50 kilometers (30 miles) from the proposed repository location. The three towns nearest the proposed repository site are Richland (35 kilometers (22 miles)), Kennewick (45 kilometers (28 miles)), and Pasco (45 kilometers (28 miles)). Their 1980 populations were 33,578; 34,397; and 17,944 respectively.

There are no people living within a radius of 20 kilometers (12 miles) of the Yucca Mountain site in Nevada. The nearest community is the town of Lathrop Wells (65 people), located 22 kilometers (14 miles) to the south. Beatty (900 people) is about 264 kilometers (165 miles) west. Las Vegas, population 500,000, is approximately 160 kilometers (100 miles) from Yucca Mountain.

At all five salt sites there are fewer than 1,000 individuals located in a 2.6-square-kilometer (1-square-mile) area adjacent to the potential surface facility site. The population density of these areas is low, averaging less than 1 person per square kilometer (1.5 persons per square mile) near the Gibson Dome site, 5 persons per square kilometer (14 persons per square mile) in the siting area of the Permian Basin, 6 persons per square kilometer (15 persons per square mile) near the

Richton Dome site, 8 persons per square kilometer (20 persons per square mile) at the Vacharie Dome site, 6 persons per square kilometer (15 persons per square mile) in the area of the Cypress Creek Dome. None of these dome sites are in a standard metropolitan statistical area.

3.4.10.2 Risk From Transportation and Operation. Evaluation of specific highway and rail routes for transporting radioactive waste to specific proposed repository sites has not been completed. Detailed studies are under way and results will be discussed in the Site Recommendation Report. Transportation risk comparisons among all proposed repository sites can be made qualitatively, since such risks are directly related to transportation distance. Although the geographic locations of future waste sources are uncertain, current sources are predominantly located in the eastern United States. Transportation risks associated with western repository sites (e.g., Washington and Nevada) therefore, would be expected to exceed those for more centrally located sites, such as the Gulf Coast Salt domes. However, since previous environmental impact studies of nuclear waste transportation have shown the transportation risks to be small in comparison to other commonly accepted risks.

3.4.11 Environmental Protection

None of the potential repository sites compared here is located in a significant nationally protected natural resource. The acceptability of the environmental impacts of a repository at each of the recommended sites will be evaluated in more detail in the environmental impact statement prepared to support the Site Recommendation Report.

3.4.11.1 Air Quality. Air-quality control regions are designated as Class I, Class II, or Class III. Class I regions have very stringent air-pollution control requirements; Class II and Class III regions have progressively less stringent requirements. All of the potential repository sites compared here are within Class II regions. However, Canyonlands National Park, which is a Class I region, is within 2.4 kilometers (1.5 miles) of the proposed Gibson Dome site in the Paradox Basin. Airborne particulate emissions are a potential problem at this site and may require special mitigation measures to prevent deterioration of air quality.

3.4.11.2 Water Quality. No surface water is available on or near the Yucca Mountain site and the nearest private use of groundwater is about 22 kilometers (14 miles) away. Groundwater quality in these private wells is generally good. The well that would support detailed site characterization supplies potable water. The reference repository location at the Hanford Site does not contain any potable surface water resources. The upper unconfined aquifer beneath the reference repository location supplies high quality potable water to private wells off of the Hanford Site. Water to be used to support detailed site characterization studies, however, would be provided by the Hanford water supply system which withdraws water from the Columbia River. The Gibson Dome contains no potable surface or groundwater resources. No fresh-water aquifers are located at either of the sites in the Permian Basin or the salt domes.

3.4.11.3 Ecology/Wildlife Protection. The Hanford, Nevada, Gibson Dome, and Permian sites contain no threatened or endangered flora or fauna. The salt domes may have threatened or endangered species. The desert tortoise and Mohave fishhook cactus are given special consideration where they occur near the Yucca Mountain site.

3.4.11.4 Cultural Resources. Cultural resources include those resources that have significant scientific, educational, historical, archaeological, architectural, or recreational value. Although the Department of the Interior lists a number of historic sites (DOI, 1982) on or near the Hanford Site, none of these are near the reference repository location. At the Yucca Mountain site, there are 72 archaeological sites that are considered potentially eligible for listing; one trail eligible for listing is adjacent to Yucca Mountain. The Gibson Dome contains several historical sites and contains isolated artifacts. Historical sites are located in towns in the Permian Basin. There are no known prehistoric or historic sites on or near the salt domes.

3.4.11.5 Noise. The remoteness of both the Nevada and the Hanford sites from human habitation and from occupied facilities ensures that noise pollution requirements will be met. Construction activities will generate increased noise levels for short periods of time at all sites. Noise levels, if unmitigated, might present a problem at the Gibson Dome Site; noise levels are not expected to be a problem at the other salt sites. Mitigation measures, such as mufflers for engines and line-of-sight noise barriers, could be used at any site if needed to reduce noise to allowable limits.

3.4.11.6 Solid Waste Disposal. The major solid waste will be mine spoils. The area occupied by the spoils will be about 8 hectares (20 acres) at all potential sites compared here. Without mitigation measures, fugitive dust depositions and rainwater runoff from the spoil piles may be a problem at all the salt sites because of the effects of salt on vegetation and crops. Mitigation measures at the Permian Basin site might include a thick earthen cover over the spoil piles. A possible mitigation meausure at the Gibson Dome is to transport the material offsite for disposal in nearby abandoned mines. Material from the three salt domes might be deposited in the Gulf of Mexico. Fugitive dust depositions and rainwater runoff from spoil piles at Nevada and Hanford are not expected to be a problem because of the more benign nature of the excavated material and the more arid climates. Small amounts of other solid wastes would be generated by construction and operation of repository facilities at all sites.

3.4.11.7 Aesthetics. The Nevada Test Site is not visible from publicly accessible locations. Construction facilities would have limited visibility from the Canyonlands National Park near the Gibson Dome and in the Permian Basin. Facilities would be largely concealed by wooded areas at the salt dome sites. While the reference repository location at Hanford is visible from Route 240, the aesthetic impact of the site will be minimal. Surface facilities for the construction and operation of a repository would be similar to numerous structures on the Hanford Site.

3.4.12 Socioeconomic Impacts

No adverse socioeconomic impacts are expected at either the Hanford Site or the Nevada Test Site. Some adverse impacts may occur at the salt sites.

3.4.12.1 Site Impacts. The available information on socioeconomic impacts at the Hanford Site is reviewed in Section 3.6.2 of this draft environmental assessment. Preliminary analysis indicates that there will be no adverse social and/or economic impacts on nearby communities or regions resulting from construction of a repository at the Hanford Site.

The Yucca Mountain site in Nevada is devoted to nuclear activities, principally the testing of nuclear weapons. A large work force of craftsmen, professionals, and scientists already work at the Nevada Test Site. The additional work force needed to construct and operate a repository would be a small percentage increment to the present work force. There would be no significant impact on existing community and governmental facilities and services. Additional road and railroad construction to the proposed repository site would pose no engineering problems.

The socioeconomic conditions at all five salt sites would be affected by increased employment, increased business and government revenue, and increased demands on community services. The available labor force and supplies in these areas are limited; therefore, the additional work force needed to construct and operate a repository would be a large percentage increment to the present work force. However, adverse impacts could be easily mitigated.

Two locations, the Gibson Dome in the Paradox Basin and the Permian Basin, may require acquisition of water rights. Also, the Cypress Creek Dome location is part of the DeSoto National Forest, which is used as a revenue source by local and state governments and is used by the United States military for training.

3.5 DESCRIPTION OF THE DECISION PROCESS

Section 112(b)(1)(E)(v) criteria: Description of decision process by which the reference repository site was recommended.

The NWTS Program siting investigations have been following a formal three-step process that begins with national screening and culminates in detailed site characterization of candidate sites for a nuclear waste repository. This siting process is described in the Public Draft, National Plan for Siting High-Level Radioactive Waste Repositories and Environmental Assessment (DOE, 1982d). (See Section 2.2 for more detail on the siting process.) In 1978, the DOE established the BWIP and initiated a site-screening study to identify locations within the Hanford Site where a repository for nuclear waste could be sited. This section summarizes the site-screening study conducted at Hanford. This study consisted of a series of screening steps, based on geotechnical, safety, socioeconomic, and statutory guidelines, that progressively reduced the size of the land area to that which would be subject to detailed characterization. The site-screening study was limited to the Hanford Site (Fig. 3-6) by virtue of its long-standing use and commitment to nuclear activities (DOE, 1982d) and its existing government ownership. However, to provide a broader scope from which to study processes that might affect the Hanford Site, initial screening encompassed the Pasco Basin (Fig. 3-6). The Pasco Basin is the smallest physiographic unit that includes the Hanford Site and that may reasonably form the boundaries of the geologic and hydrologic subprovinces that influence conditions at Hanford. This screening would also determine whether there are any apparent, obviously superior site localities in a natural region (i.e., the Pasco Basin, outside of the Hanford Site) (WCC, 1980, Vol. I).

In October 1978, the BWIP awarded a contract to Woodward-Clyde Consultants, San Francisco, California, to conduct the Hanford Site screening. This study would lead to the identification of site localities, areas of about 26 to 130 square kilometers (10 to 50 square miles), having a high likelihood of containing suitable sites for locating a repository for nuclear wastes. The methodology used for screening site localities consisted of the following items:

- Identification of objectives and development of guidelines for application to the study area
- A multistep screening process that permits the application of guidelines to smaller and smaller areas until the site localities have been identified
- Development of a data base of appropriate scope and detail that could be utilized for defining the conditions within the areas defined in each substep of the screening process.

3.5.1 Identification of Objectives and Development of Basalt Waste Isolation Project Siting Guidelines

There were seven key assumptions guiding the site locality identification study (WCC, 1980, Vol. I) that were important in establishing the objectives and developing guidelines. Restated, these are the following:

- The repository will require licensing involving the NRC, other Federal agencies, and possibly State and local entities.
- The design and operation of most surface facilities will be governed by existing safety and environmental licensing requirements.

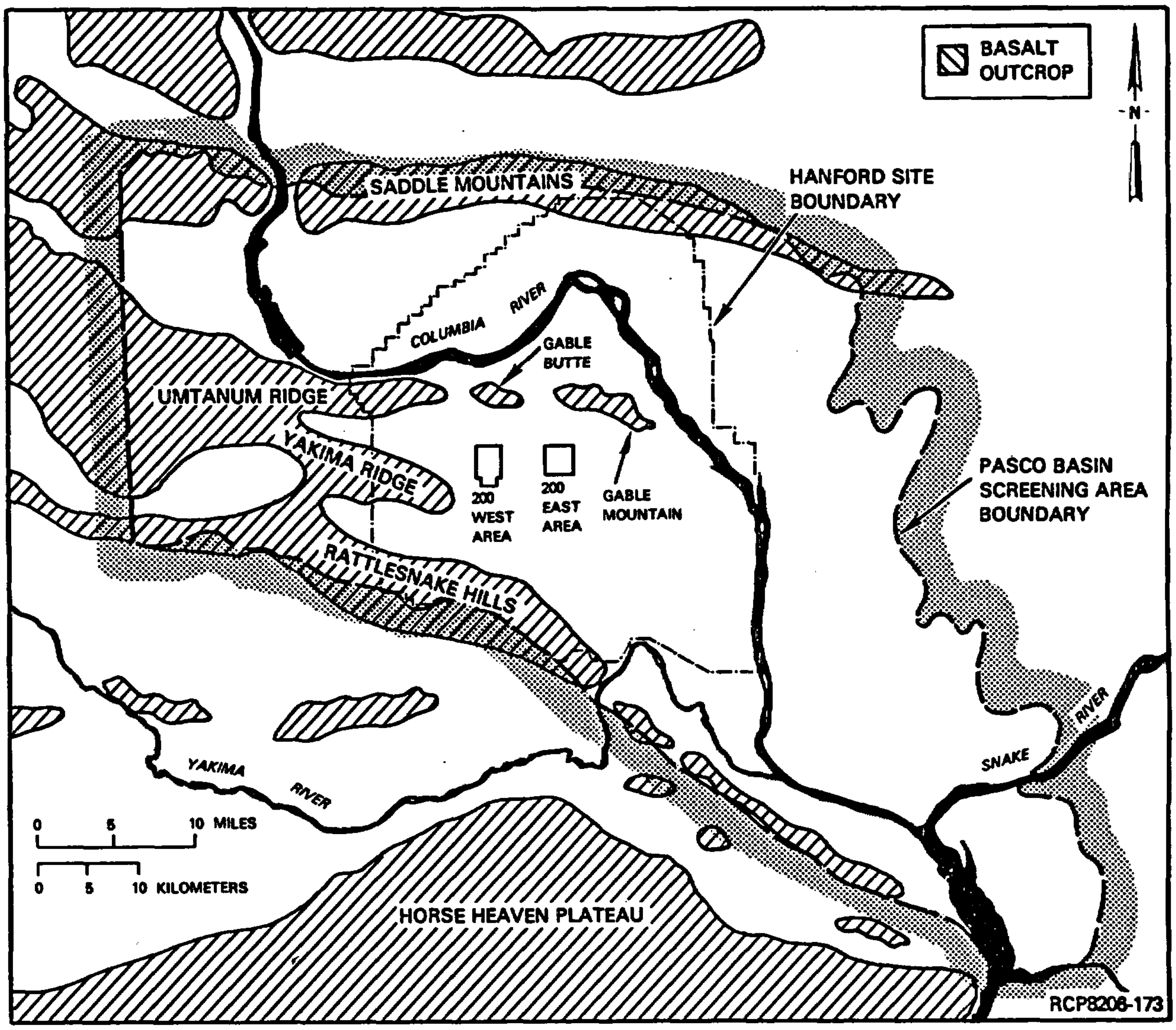

FIGURE 3-6. Pasco Basin Screening Area and Hanford Site Boundaries.

- Nominal design and performance characteristics for the repository have been estimated.

- The long-term safety-related characteristics of the host rock system can be estimated and can be used in the selection guidelines.

- The repository will be designed for two time frames: relatively short emplacement and retrieval phase and a much longer isolation phase.

- The site locality identification study will be based on available data; siting guidelines will be based on currently available technology.

- The repository licensing requirements will be written in the style of other nuclear fuel cycle facilities.

On the basis of these assumptions, several objectives were established to reflect specific characteristics of the repository facilities, as well as conditions and concerns with the study area. The hierarchy of objectives provide the framework for choosing and applying guidelines to identifying site localities. It was deduced from a proposed general statement of policy for licensing requirements for a repository (NRC, 1978) that to be accepted as suitable the site must meet the following objectives:

- Maximize public health and safety

- Minimize adverse environmental and socioeconomic impact

- Minimize cost necessary to attain the requisite levels of safety, as well as costs of mitigation.

The objectives were then expanded and restated to bear on conditions or events that could be associated with an underground repository. The safety objective was particularized to state: maximize public health and safety in relation to natural hazards, man-made hazards and events, and repository-induced events. The environmental objective was particularized as: minimize adverse environmental and socioeconomic impact related to construction, operation, and closure and surveillance. The cost objective was particularized by stage of repository development: minimize system costs related to construction and impact mitigation, operation and maintenance, closure, decommissioning, and surveillance (WCC, 1980, Vol. I).

For each of the objectives established, one or more "consideration" or technical matter of concern was identified to describe the subject matter that must be addressed in order to orient the siting study toward achievement of the objectives. These considerations reflect characteristics, conditions, or processes in the study area. For each consideration defined, a measure was selected or developed to allow differentiation between areas or localities in terms of the consideration.

For some considerations, a specific level of achievement was required or implied by statute, regulation, technological limitations, or gross economic considerations. In these cases, a limit was established for the appropriate measure. The value of the measure at which the limit was set was an "inclusionary" guideline. For those considerations where no specific level of achievement was required, the measure itself was the guideline and was used to characterize or classify areas and localities with similar characteristics. These were called "classifying" guidelines.

The considerations, measures, and guidelines used for the site locality identification study are found in WCC (1980, Vol. I, Table III-3). A detailed discussion of background and rationale for selecting the various measures and guidelines is presented in WCC (1980, Vol. I, Appendix A).

3.5.2 Screening for Site Localities

The first step in screening the Pasco Basin was to define candidate areas (Fig. 3-7). Screening involved the use of inclusionary guidelines which represent a total of nine considerations under the work objectives of maximizing public health and safety, minimizing adverse environmental impacts, and minimizing system costs. A relisting of the considerations, measures, and guidelines used at this step is found in WCC (1980, Vol. I, Table IV-2). The candidate area defined by the composite overlay is shown in Figure 3-7.

The second step in the screening of the Pasco Basin was to delineate subareas. Seven inclusionary considerations and guidelines were used in this screening step and are found in WCC (1980, Vol. I, Table IV-3). When the overlays depicted these seven guidelines (fault rupture, flooding, ground failure, erosion denudation, hazardous facilities, induced seismicity, and site-preparation costs) were compiled, the resulting subareas, shown in Figure 3-8, were identified. These subareas were then carried into the next step in screening to identify site localities.

Site localities were identified first through an evaluation of the subareas based on the classifying guidelines presented in WCC (1980, Vol. I, Table III-3). A detailed discussion of each of these classifying guidelines is given in the Appendix of WCC (1980, Vol. I). Included in the information provided in the said Appendix is a statement on the relevance to siting and the approach used for employing the guideline. The evaluation of subareas was conducted in two steps:

- Evaluation of subareas within the Pasco Basin screening area outside of the Hanford Site

- Evaluation of the subareas within the Hanford Site.

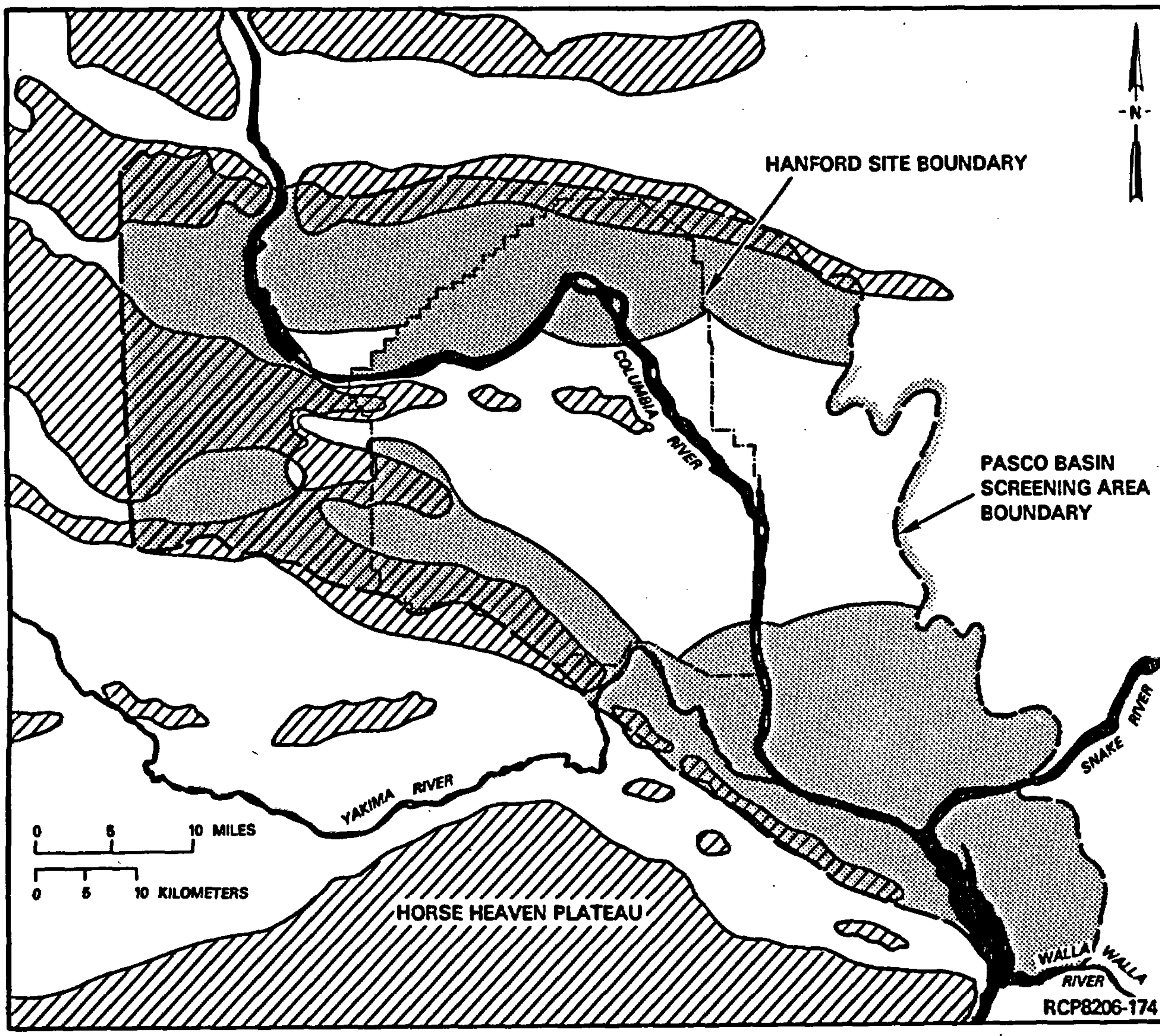

FIGURE 3-7. Candidate Area (outlined with shaded area).

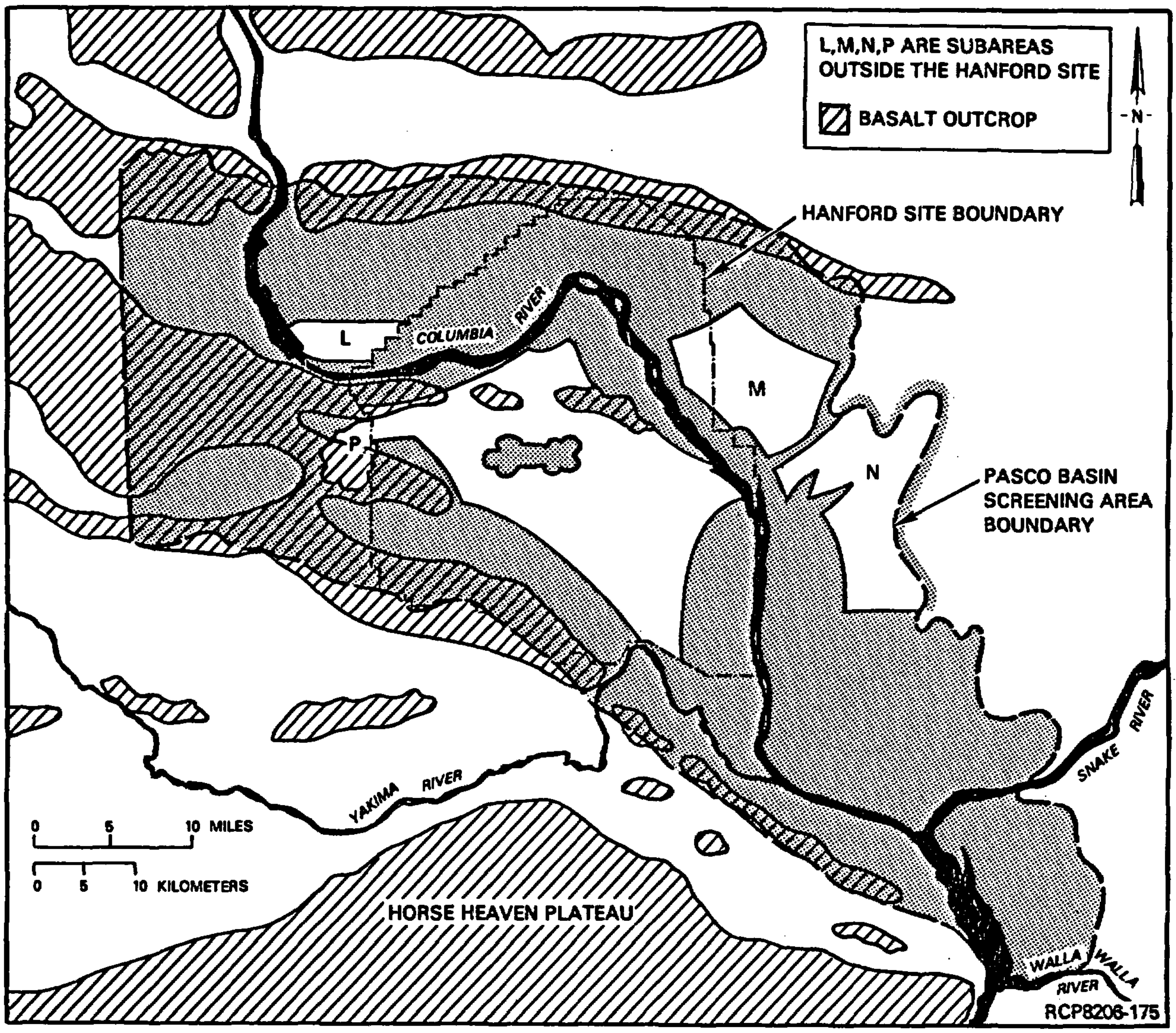

FIGURE 3-8. Subareas (unshaded).

The first step was designed to determine whether any apparent, obviously superior site localities occur in the subareas outside the Hanford Site. The results of this evaluation indicated that three of the four subareas that were outside the Hanford Site (L, M, and N, Fig. 3-8) were used for irrigated farming and were also in close proximity to the Columbia River. The fourth subarea (designated by the letter P in Fig. 3-8), in addition to being used for irrigated farming, was an area where the bedrock dip was greater than 5 degrees; one of the baseline conditions for the repository host rock was a flow dip of less than 5 degrees (WCC, 1980, Vol. I). On the basis of land use, hydrology, and bedrock dip, these sites were not obviously superior to those found within the Hanford Site and, therefore, no further consideration was given to these subareas (WCC, 1980, Vol. I).

The second step in the evaluation of subareas within the Hanford Site and prior to the identification of site localities was to study the available surface and subsurface areas separately and to evaluate the impact of the surface versus the subsurface screens. In all circumstances the subsurface considerations took precedence over the surface considerations. If the subsurface screening showed obvious superiority, the surface screen was downgraded. An overlay was made of the Hanford Site showing both inclusionary and classifying guidelines that affected the subsurface (bedrock dip, microseismicity, and hydrology). The results of this screening are shown in Figure 3-9. A second composite overlay was made using those guidelines that affect the surface (aircraft impact, transportation, protected ecological areas, terrain ruggedness, flooding, landslides, erosion, denudation, and hazardous facilities). The results of this screening are shown in Figure 3-10. The area resulting by combining the surface and subsurface screens was believed to be more suitable and has a higher likelihood of containing suitable waste repository sites. In addition, the area delineated by these combined screens continued to provide sufficient area and adequate geotechnical conditions for the identification of several site localities. The combined area resulting from the application of surface and subsurface screens was then examined to identify site localities.

The general size of a site locality is less than 130 square kilometers (50 square miles) and more than 26 square kilometers (10 square miles), and five site localities were identified. The location of these five site localities designated H-1 through H-5 is shown in Figure 3-11. One site was north of Gable Mountain, west of the Columbia River (H-1); one site was north of Gable Mountain, east of the Columbia River (H-2); and three sites were south of Gable Mountain (H-3, -4, and -5). The three site localities south of Gable Mountain were defined somewhat arbitrarily to maintain equal size. A small subarea west of site locality H-3 (Fig. 3-10) was not considered further due to its small size, which would preclude a repository based on a subsurface area of 26 square kilometers (10 square miles) (including a buffer zone).

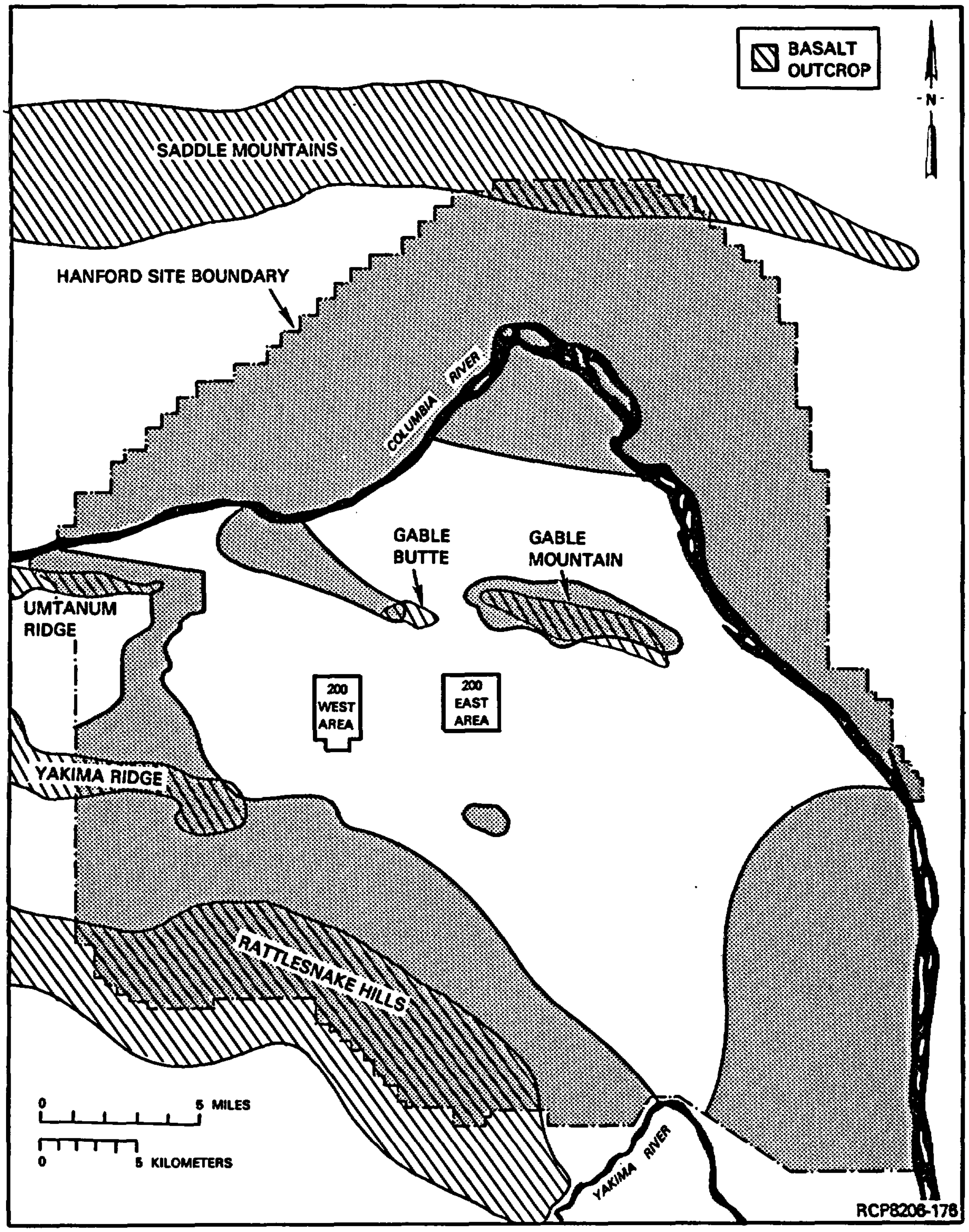

FIGURE 3-9. Available Subsurface Areas on the Hanford Site (unshaded).

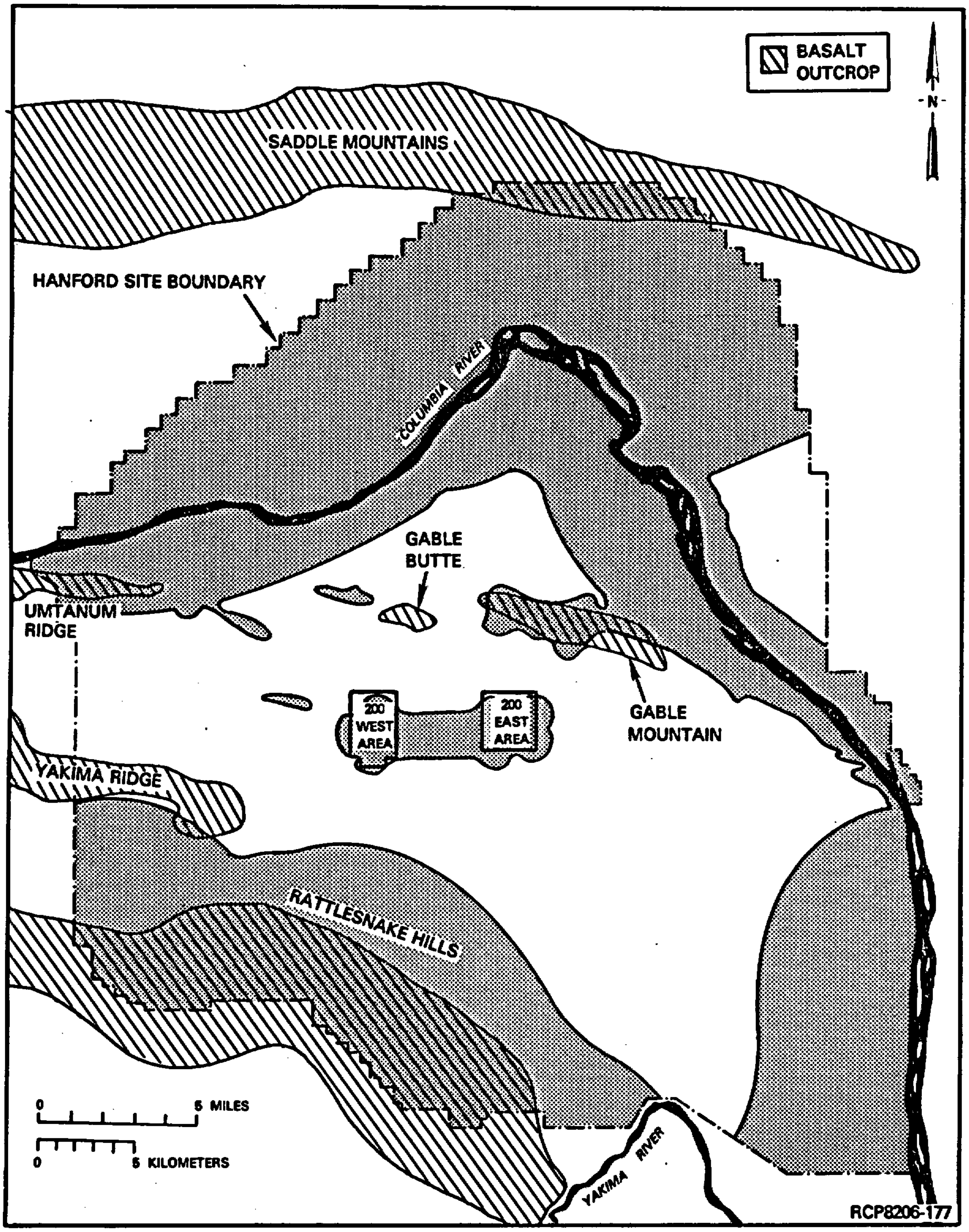

FIGURE 3-10. Available Surface Areas on the Hanford Site (unshaded).

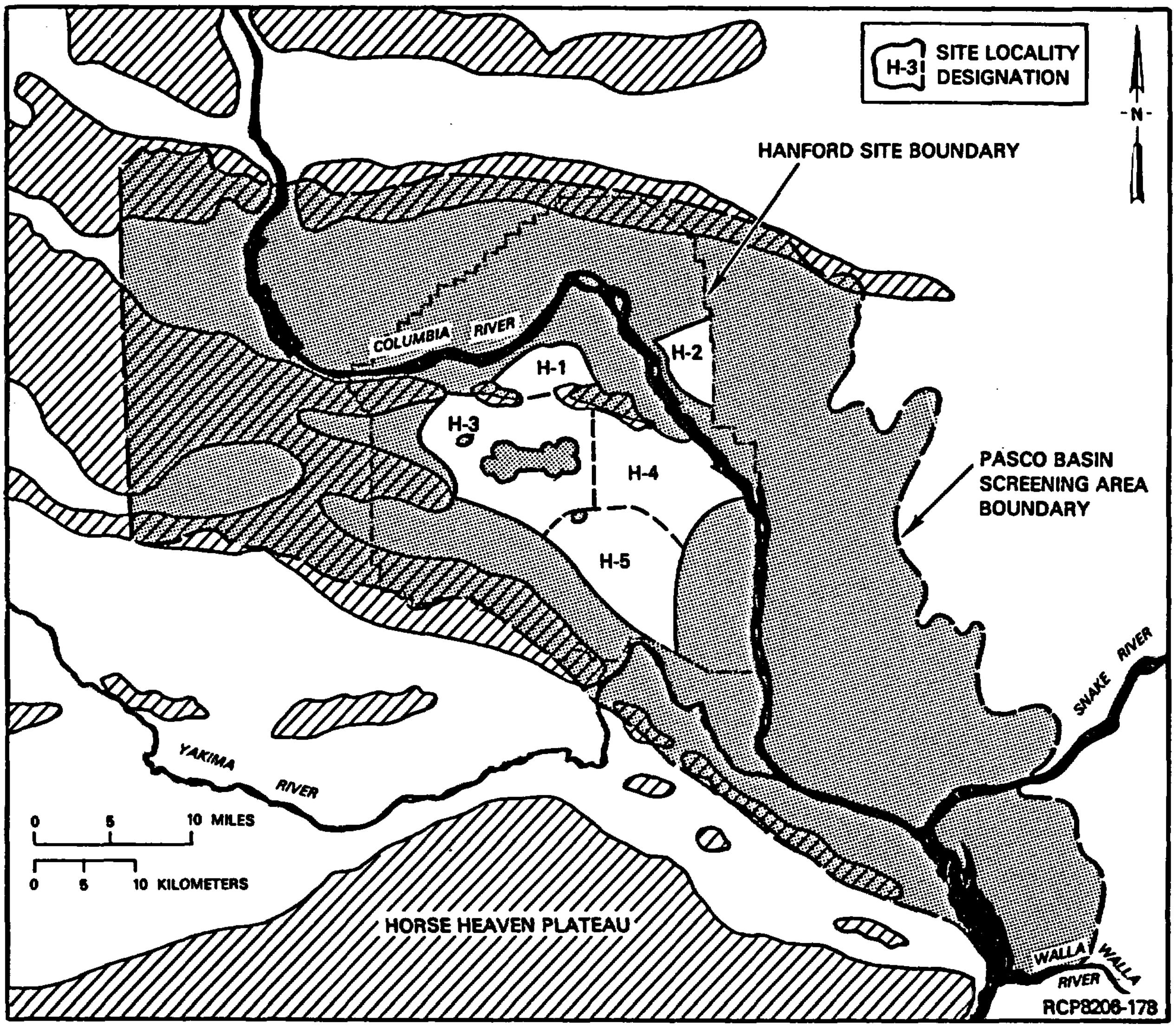

FIGURE 3-11. Site Localities.

To characterize the existing conditions within each site locality and to provide a basis for evaluating the site localities with respect to identifying candidate sites in the next steps of the siting process, 23 descriptive parameters were selected representing geology, hydrology, seismology, land use, ecology, and man-made hazards. Estimated ranges of the existing conditions in each of the five site localities are given in WCC (1980, Vol. I, Table IV-4).

Figure 3-12 is a schematic representation of the screening methodology leading to the identification of site localities on the Hanford Site.

The documentation of the site locality identification study is found in WCC (1980, Vol. I and II). Volume I describes the methodology, guidelines, and screening process. Volume II describes the data compilation and cataloging. The major sources of site-specific characterization data were three integration reports published by the BWIP: RHO-BWI-ST-4 (Myers/Price et al., 1979); RHO-BWI-ST-5 (Gephart et al., 1979); and RHO-BWI-ST-7 (Smith et al., 1980).

3.5.3 Identification of Reference Repository Location

In October 1979, the contract with Woodward-Clyde Consultants was renewed to continue the site-screening study through the identification of a reference repository location. The initial step was identifying candidate sites within the five site localities. The size of a candidate site was determined from the repository baseline conditions (WCC, 1980, Vol. I, Table III-1). An area of about 26 square kilometers (10 square miles) was selected which would include surface and subsurface facilities and an exclusion area buffer zone. Screening guidelines assured that each locality would support at least one candidate site (BWIP, 1980).

The identification of candidate sites was based on a selective and successive examination and evaluation of the range of conditions for the 23 parameters described in WCC (1980, Vol. I, Table IV-42). These parameters were selected to reflect the concerns of the objectives of the siting study. Other considerations were also given to established NRC reactor siting criteria, the Office of Nuclear Waste Isolation draft site-qualification criteria (ONWI, 1979), NRC draft repository criteria, National Academy of Sciences guidelines, and Rockwell Hanford Operations technical requirements. The relationship of the Office of Nuclear Waste Isolation (ONWI, 1979) generic repository criteria and the site-specific consideration used for candidate site identification is given in BWIP (1980) and in BWIP (1981a).

BASALT WASTE ISOLATION PROJECT
GUIDELINE DEVELOPMENT

OBJECTIVES:	NUMBER OF SPECIFIC CONSIDERATIONS	NUMBER OF MEASURES	SCREENING GUIDELINES INCLUSIONARY	SCREENING GUIDELINES CLASSIFYING
• MAXIMIZE PUBLIC HEALTH AND SAFETY	19	26	23	22
• MINIMIZE ADVERSE ENVIRONMENTAL IMPACT	6	7	5	2
• MINIMIZE COST	2	3	0	3

SCREENING PROCESS

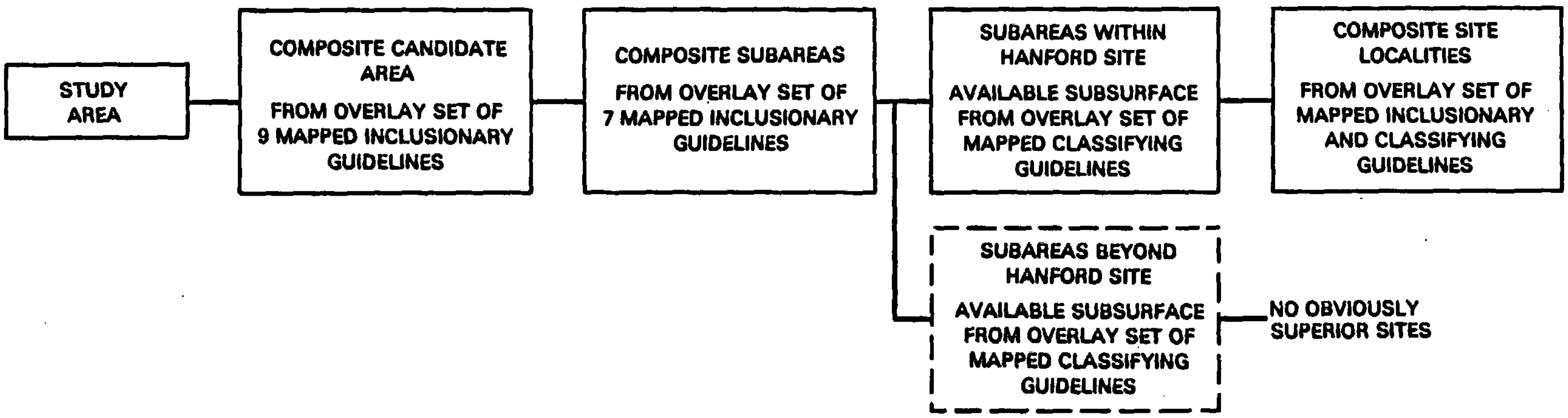

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FIGURE 3-12. Schematic Representation of the Screening Methodology.

To identify candidate sites, screening overlays representing the range of conditions and area affected by each parameter under consideration were superimposed. The results of this overlay process were used to identify the portion within each locality which tended to maximize the desirable characteristics with regard to the parameters. Nine candidate sites were thus identified within the site localities, lettered R through Z in Figure 3-13. Seven of the nine candidate sites (R through X) lie in a group, within the Cold Creek syncline, a major structural feature of the Pasco Basin. Two other candidate sites (Y and Z) lie just outside this structure (WCC, 1981).

Once the candidate sites were identified, the emphasis of the siting process shifted from one of narrowing the area within the Pasco Basin under consideration to the identification of a reference repository location and an alternate repository location from among the candidate sites. The process used is not an overlay of maps, but a formal comparison of the available data through a ranking process, known as decision analysis. Decision analysis is a systematic process that helps decision makers in comparing alternative courses of action. The approach to this process consists of four steps (WCC, 1981):

- Structuring the problem in terms of criteria and developing measures by which alternatives can be quantitatively compared
- Describing the consequences of each alternative in terms of the measures
- Determining preferences for different consequences
- Synthesizing the information to logically rank order the alternatives and performing sensitivity analyses.

The procedure stresses flexibility for ease of implementation, yet incorporates consistency checks for ensuring accuracy and defensibility of the analyses.

Preliminary ranking was performed to identify a subset of candidate sites from the nine sites originally identified. Five attributes (indicated in WCC, 1981, Table V-3), for which data were available to compare the sites, were applied following the dominance analysis process. The results of the application are as follows:

Ranks first	U
Ranks second	V
Could rank third	R, T, W
Could rank fifth	S
Could rank sixth	X, Y, Z.

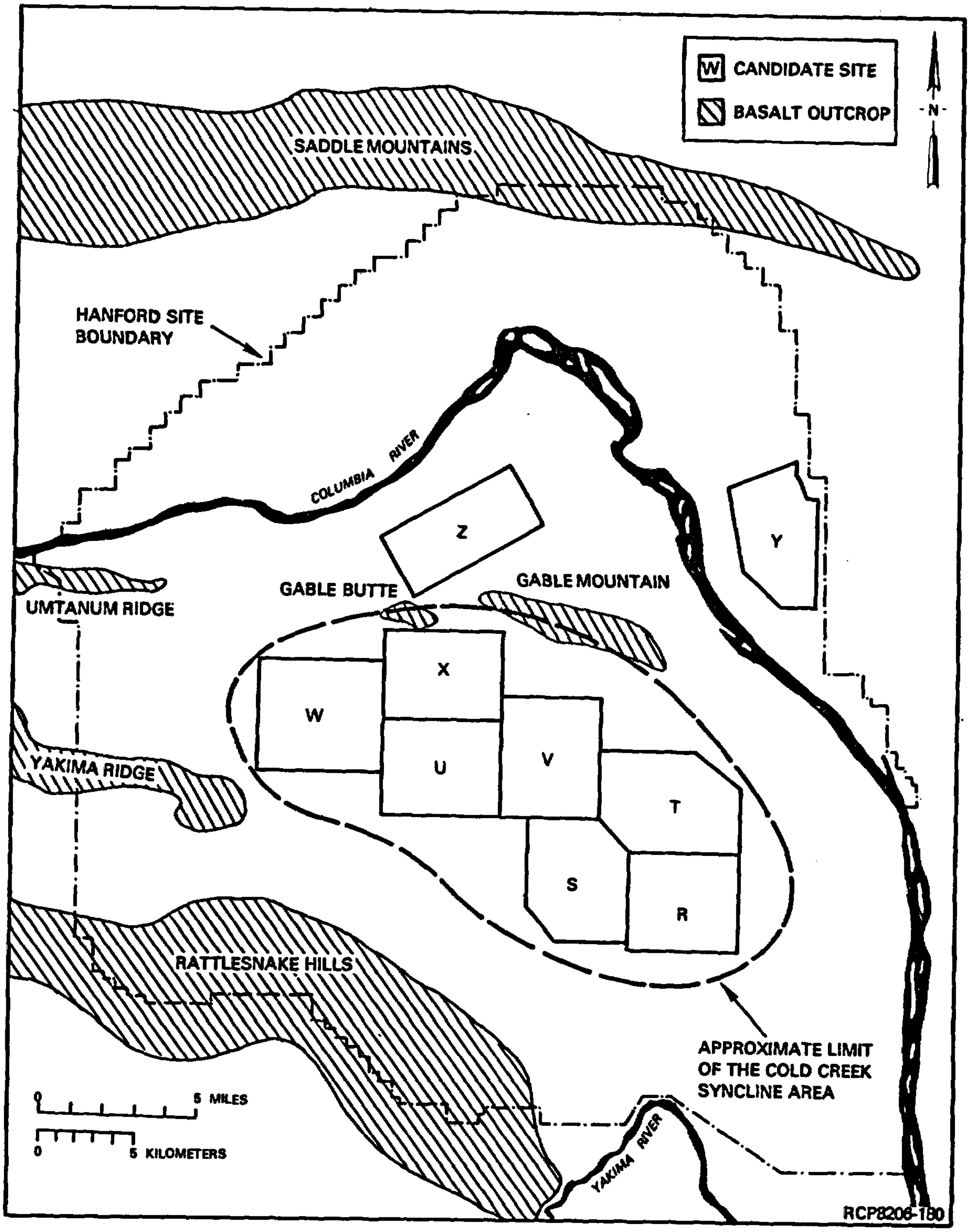

FIGURE 3-13. Candidate Sites on the Hanford Site.

Meetings between geotechnical specialists from Rockwell Hanford Operations and Woodward-Clyde Consultants confirmed that the attributes were appropriate to use and that their relative importance was also appropriate (WCC, 1981).

Candidate sites U and V, which ranked first and second, respectively, clearly were favorable for further studies. The choice for a third candidate site from among R, W, and T was not clearly defined. A review of site conditions showed that candidate sites Y and Z, near the Columbia River, were not technically superior to those in the Cold Creek syncline and were too close to the potential discharge zone (the Columbia River) as well as distant from transportation, safety, and support facilities. For these reasons the two candidate sites, Y and Z, were removed from further study (WCC, 1981).

The remaining seven contiguous candidate sites in the Cold Creek syncline displayed geologic and physical similarities throughout the siting process. These sites were renamed A through G (Fig. 3-14) and were then considered for further evaluation to identify a reference repository location. However, because the seven contiguous sites appeared to be so closely matched, further evaluation of the Cold Creek syncline was based on a more detailed study in the siting area (WCC, 1981). Results of the geologic fieldwork were subsequently summarized in Myers and Price (1981).

Because of the linear trends resulting from the geophysical studies in the Cold Creek syncline (Myers and Price, 1981, Appendix B), it was considered necessary to reevaluate the boundaries of the seven candidate sites (A through G). For ease of comparison with previous work, the original candidate site boundaries (A through G) were maintained and three additional candidate site boundaries were superimposed on portions of the original seven sites, but outside of the influence of the more prominent geophysical lineaments. These additional sites were designated H, J, and K (see Fig. 3-15).

Preliminary evaluation of the ten candidate sites (A through H, J, and K) makes it clear that the sites were too closely matched to be differentiated between by routine ranking. A more rigorous application of the decision analysis process was required. Procedures differ primarily in the detail of data available. To this end, an enlarged data base was compiled, referred to as a criteria matrix. The text of the criteria matrix is an exhaustive description of physical, socioeconomic, and biological conditions at the candidate sites using information available as of a cutoff date of May 16, 1980. That text as well as a description of the procedure followed to complete each descriptor, rationale for inclusion in the criteria matrix, and additional supportive data is included in WCC (1981, Appendix A).

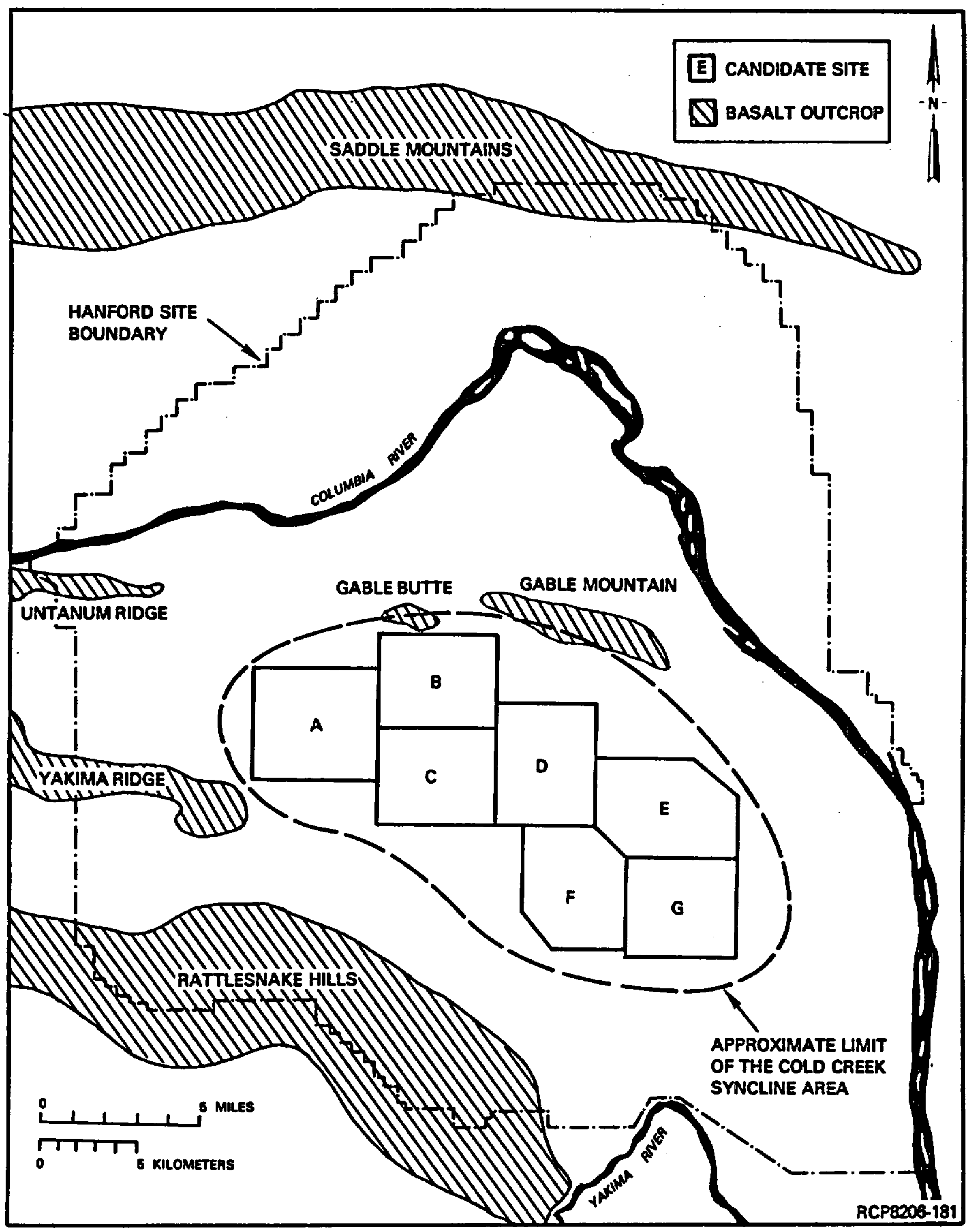

FIGURE 3-14. Initial Candidate Sites in the Cold Creek Syncline Area.

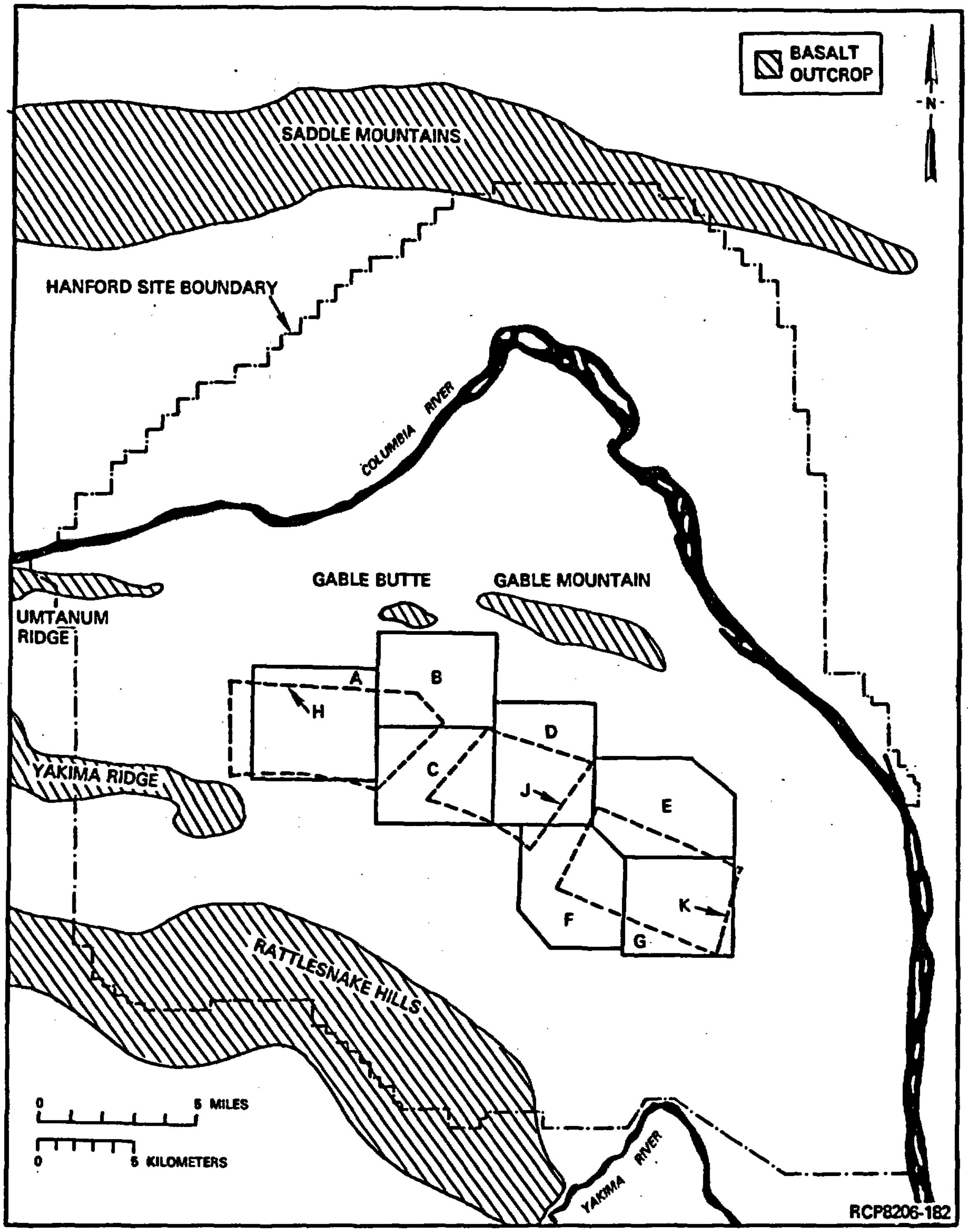

FIGURE 3-15. Ten Candidate Sites. The three superimposed candidate sites (H, J, and K) avoid prominent geophysical lineaments.

From a detailed evaluation of criteria and data comprising the criteria matrix, criteria were selected that could be used to differentiate between the candidate sites. The ten ranking criteria selected were: bedrock fractures and faults, lineaments, potential earthquake sources, groundwater traveltimes, contaminated soil/contaminated groundwater/surface facilities, host flow interior, tiers, vegetative natural communities, unique microhabitats, and special species (WCC, 1981).

As mentioned above, the site ranking was done using the method of dominance analysis. This was carried out by a siting committee formed of technical representatives from Woodward-Clyde Consultants and Rockwell Hanford Operations. Once the ranking criteria were defined, they were applied to each candidate site. The siting committee judged each site utilizing available published and unpublished data as outlined by the criteria matrix and their own professional judgment. The favorable or unfavorable consequence of each site in terms of the measures for each ranking criteria was then established (WCC, 1981).

The next step of dominance analysis was the determination of preference for a series of consequences. This became necessary because there were a number of criteria and alternative variations, and a simple dominance analysis was too difficult to perform. Ordinal dominance analysis was used to proceed with ranking (WCC, 1981).

Ordinal dominance analysis allows the assessment of tradeoffs to determine the relative importance of the measures used in differentiating among candidate sites. Tradeoffs were assessed by the siting committee. They were examined in two ways: First, given a hypothetical site with all the criteria at the most desirable levels and given that one criterion had to be changed to its least desirable level, which one would be changed? The criterion selected for this question had the least weight. The question was then repeated progressively until all criteria were ranked.

The second way of assessing tradeoffs required the determination of how much one was willing to give up from one criterion to enhance a second criterion. This rank ordering should agree with the first method (WCC, 1981). The results of the weighting procedure pointed up two features:

- In the site-ranking process, the siting committee had a strong consensus that environmental impact and man's activities criteria were useful only to differentiate among otherwise identical sites (no weight was placed on these criteria).

- The siting committee could not agree on the relative importance of the internal structures of the basalt flows (tiers versus thickness of flow interiors).

The final step was synthesizing the information for ranking. This step merely involved the siting committee's discussion and evaluation of all sites with respect to the ranking criteria, site characteristics, and analysis method.

The results of the ordinal dominance analysis are shown in Table 3-5. In this table, it is shown that six criteria formed the basis of ranking. The relative values assigned to each criterion were determined by means of scale or distance or a simple numerical scale based on level of acceptability. The additive numerical functions were determined based on the site-ranking-value terms indicated in Table 3-5. The results of the ranking show that site H is dominant over all other sites. Site A, which is almost totally included within Site H, has about the same dominance numerical value (4.68 and 4.66, respectively). These two sites were combined to form the reference repository location (Fig. 3-16).

Site J (see Fig. 3-15), another of the new sites designated to avoid the aeromagnetic anomalies in the Cold Creek syncline, was classified as the alternate site. The numerical dominance value of the J site was 3.70 (see Table 3-5). Table 3-5 shows that for the three most important criteria (considered by the siting committee), lineaments, host flow thickness, and tiering, candidate sites A and H rated numerically higher than all other sites with candidate site J ranked third. The reference repository location and the alternate repository location are shown in Figure 3-17.

The reference repository location consists of about 47 square kilometers (18 square miles) of nearly flat-lying terrain. The basalt formations underlying the reference repository location are buried by as much as 198 meters (650 feet) of sediments and are relatively flat lying.

The Columbia River Basalt Group within the Cold Creek syncline has been sampled at three locations to a depth of about 1,220 meters (4,000 feet), but only limited work has been conducted on the reference repository location. The field data indicate that the top of the basalts can be used to reasonably reflect the geologic structure of the underlying basalt flows.

Documentation of the study to identify a reference repository location on the Hanford Site is contained in WCC (1981, Vol. I and II).

3.5.4 Identification of Principal Borehole Site

With the identification of the A-H site as the reference repository location, the BWIP in conjunction with Kaiser Engineers, Inc. and Parsons Brinckerhoff Quade & Douglas, Inc., the architect-engineer for the BWIP, met to locate a proposed site for a principal borehole for an exploratory shaft. Two tentative locations for a repository shaft pillar within the reference repository location were proposed. These were situated about 1.6 kilometers (1 mile) apart west of the 200 West Area. The principal borehole and the Exploratory Shaft were considered directly relatable structurally and functionally to the shaft pillar area for the repository.

TABLE 3-5. Ordinal Dominance Analysis of Candidate Sites.

Candidate Site Relative Value Matrix

Candidate site	Lineaments (l')	Host flow (h)	Tiers (t)	Potential earthquake (p)	Groundwater travel (g')	Bedrock fractures (b)
A	0.92	0.67	1.00	0.75	0.25	0.54
B	0.25	1.00	0.67	0.63	0.50	0.19
C	0.50	0.58	0.67	0.47	0.50	1.00
D	0.33	0.75	0.33	0.88	1.00	0.32
E	0.33	0.67	0.00	1.00	1.00	0.24
F	0.00	0.00	0.33	0.00	0.25	0.92
G	0.42	0.00	0.00	0.41	0.00	0.00
H	1.00	0.67	1.00	0.69	0.25	0.38
J	0.58	0.67	0.33	0.63	1.00	0.81
K	0.58	0.17	0.00	0.38	0.25	0.00

Ordinal Dominance Analysis Table

Site-ranking value	l'	l'+h	l'+t	l'+h+t	l'+h+t +p	l'+h+t +p+g'	l'+h+t +p+g'+b	Site dominated by
A(0.834)	1.84	2.51	2.84	3.51	4.26	4.39	4.66	H
B(0.496)	0.50	1.50	1.17	2.17	2.79	3.05	3.15	A,H,J
C(0.550)	1.00	1.58	1.67	2.25	2.72	2.97	3.47	A,H
D(0.495)	0.66	1.41	0.99	1.74	2.62	3.12	3.28	A,H,J
E(0.442)	0.66	1.33	0.66	1.33	2.33	2.83	2.95	A,C,D,H,J
F(0.088)	0	0	0.33	0.33	0.33	0.46	0.92	All
G(0.255)	0.84	0.84	0.84	0.84	1.25	1.25	1.25	A,C,H,J,K
H(0.860)	2.00	2.67	3.00	3.67	4.36	4.49	4.68	--
J(0.584)	1.16	1.83	1.49	2.17	2.79	3.28	3.70	A,H
K(0.366)	1.16	1.33	1.16	1.33	1.71	1.84	1.84	A,H,J

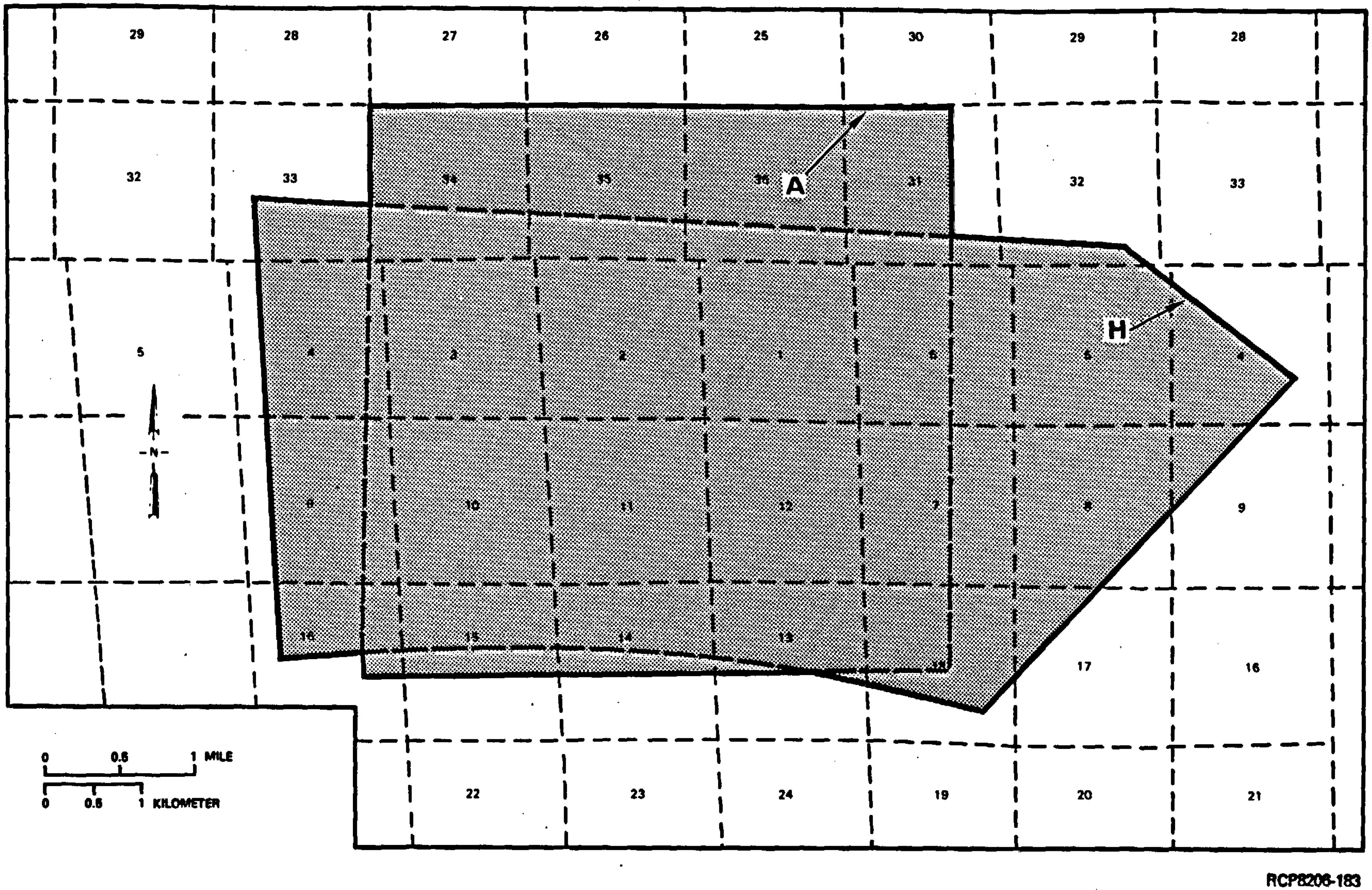

FIGURE 3-16. Reference Repository Location (A-H site).

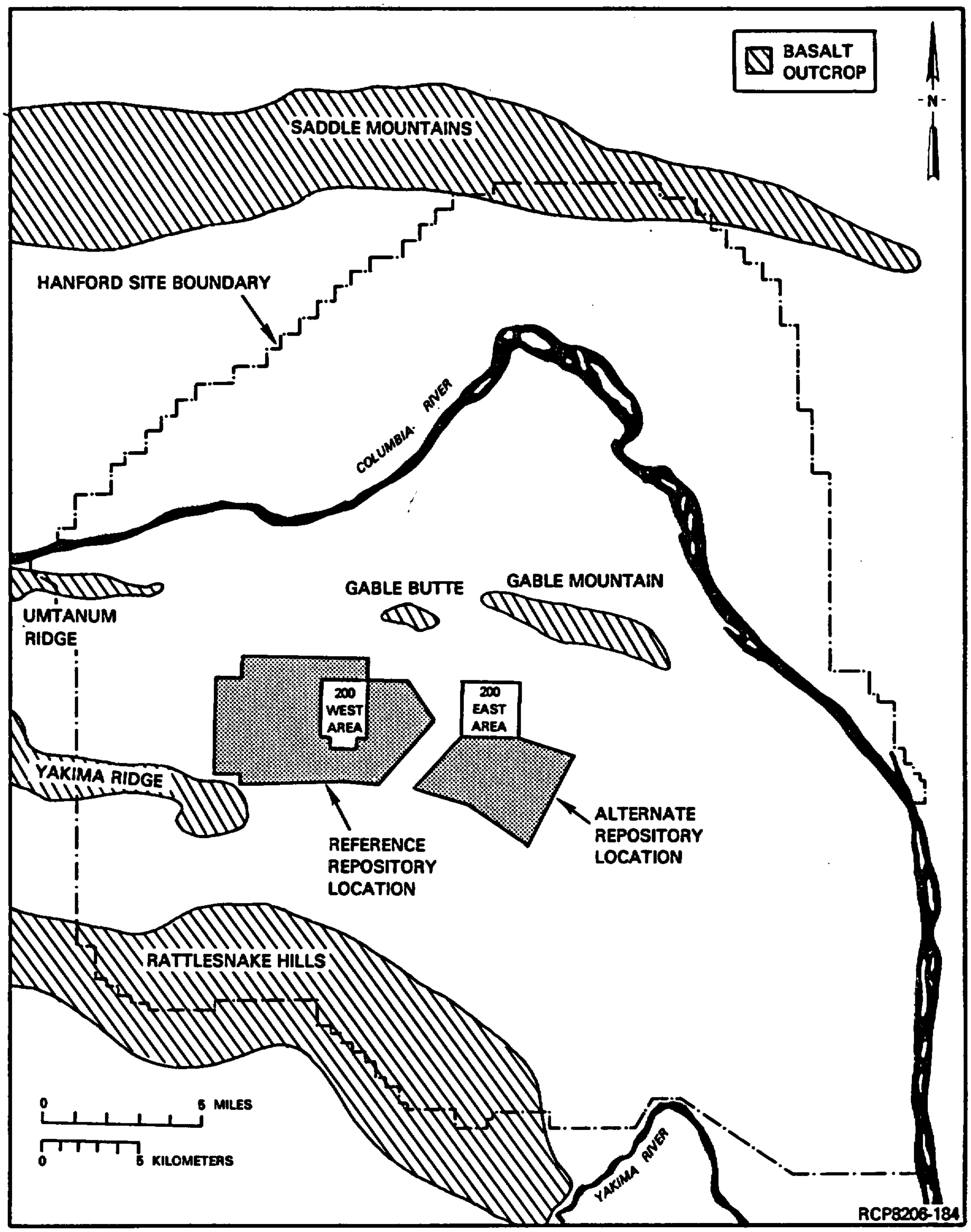

FIGURE 3-17. Location of the Reference Repository Location and Alternate Repository Location.

The limited site characterization information available from the reference repository location required that several shallow boreholes be drilled to the top of basalt to confirm the overall dip of the basalt units. Two of these boreholes were drilled to a depth of 456 meters (1,500 feet) to elevate structural continuity of the flow units. The results confirmed an overall dip of less than 1 degree across the reference repository location. The axis of the Cold Creek syncline was also determined more precisely. Figure 3-18 is a contour map of the top of basalt beneath the reference repository location and shows the location of boreholes drilled for characterization.

To enable selection of a specific location for construction of the principal borehole for the Exploratory Shaft, exclusion-area criteria were developed to aid in the selection of a specific location (BWIP, 1981b). These criteria are land use, surface contamination, groundwater contamination, Exploratory Shaft, and repository orientation.

A composite overlay of the reference repository location is shown in Figure 3-19, which is the result of screening of land use considerations, surface contamination, groundwater contamination, and Exploratory Shaft set-back requirements. This composite shows that the area remaining for consideration is in Sections 2, 3, 10, and 11 in the western half of the reference repository location. Within this area, adequate space exists for location of the Exploratory Shaft and repository area (WCC, 1980, Vol. I).

Other desirable features were also utilized to pick the specific location for a principal borehole for the Exploratory Shaft. Regarding the feature of minimum surface grade, the entire surface area in Sections 2, 3, 10, and 11 is nearly level, which means that the surface facilities could be located at any spot in this area with minimal surface grading. As a means of minimizing power and water costs, consideration was given toward locating the principal borehole close to the separations area where services are available. Since the engineering design of the repository will not be completed until information is obtained from depth, it is desirable to reserve as much room as possible for the repository location. To ensure flexibility, it would be desirable to locate it near the intersection of Sections 2, 3, 10, and 11, thereby providing the most area for movement of the repository. The location of the principal borehole should also be near the intersection of Sections 2, 3, 10, and 11. This is the location of an existing borehole, RRL-2, which has been cored to a depth of about 1,211 meters (3,973 feet).

On the basis of the site characterization work and the engineering studies, the DOE determined in May 1982 that the optimal area for siting a principal borehole for the Exploratory Shaft was near the intersection of Sections 2, 3, 10, and 11.

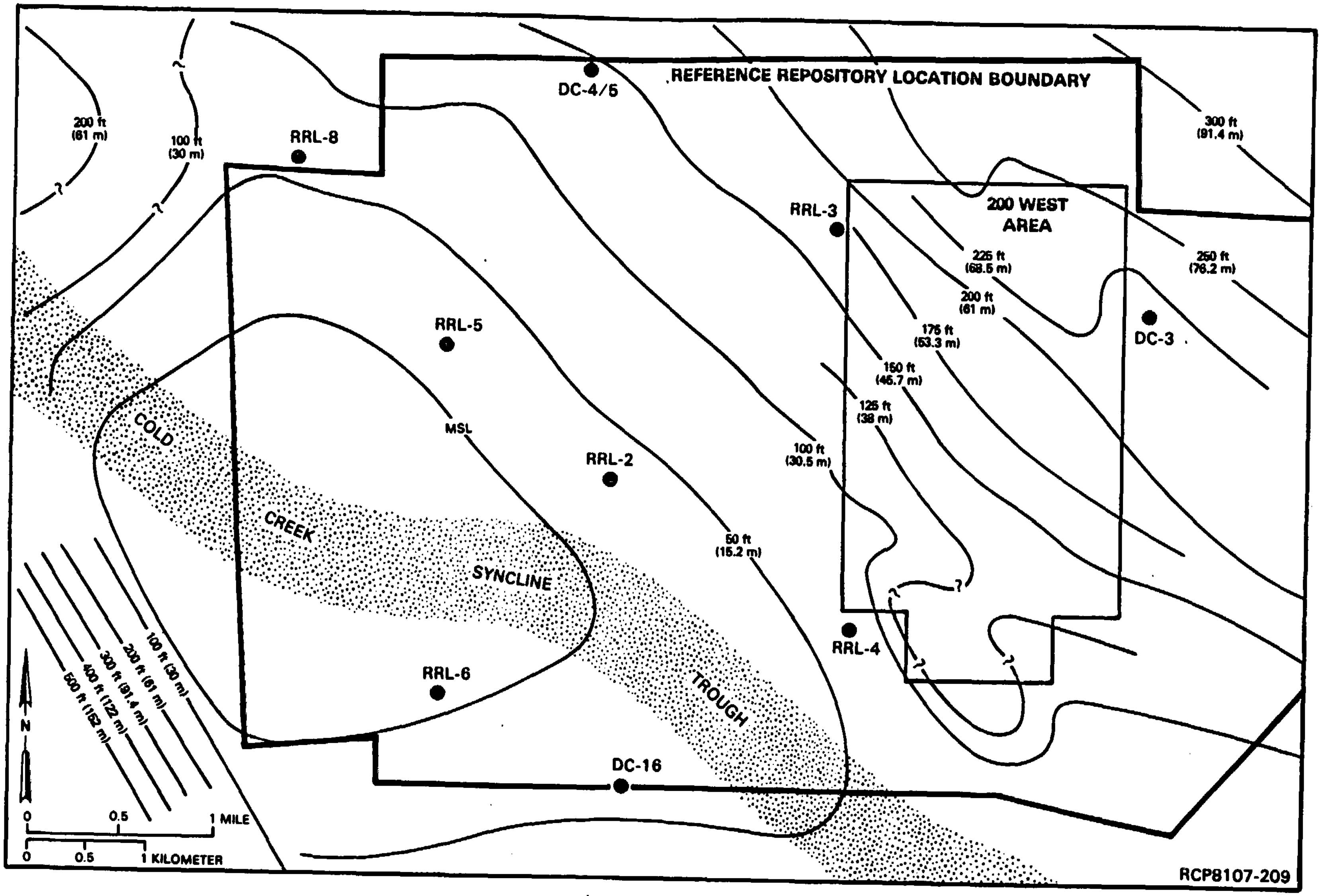

FIGURE 3-18. Top-of-Basalt Contours in the Reference Repository Location.

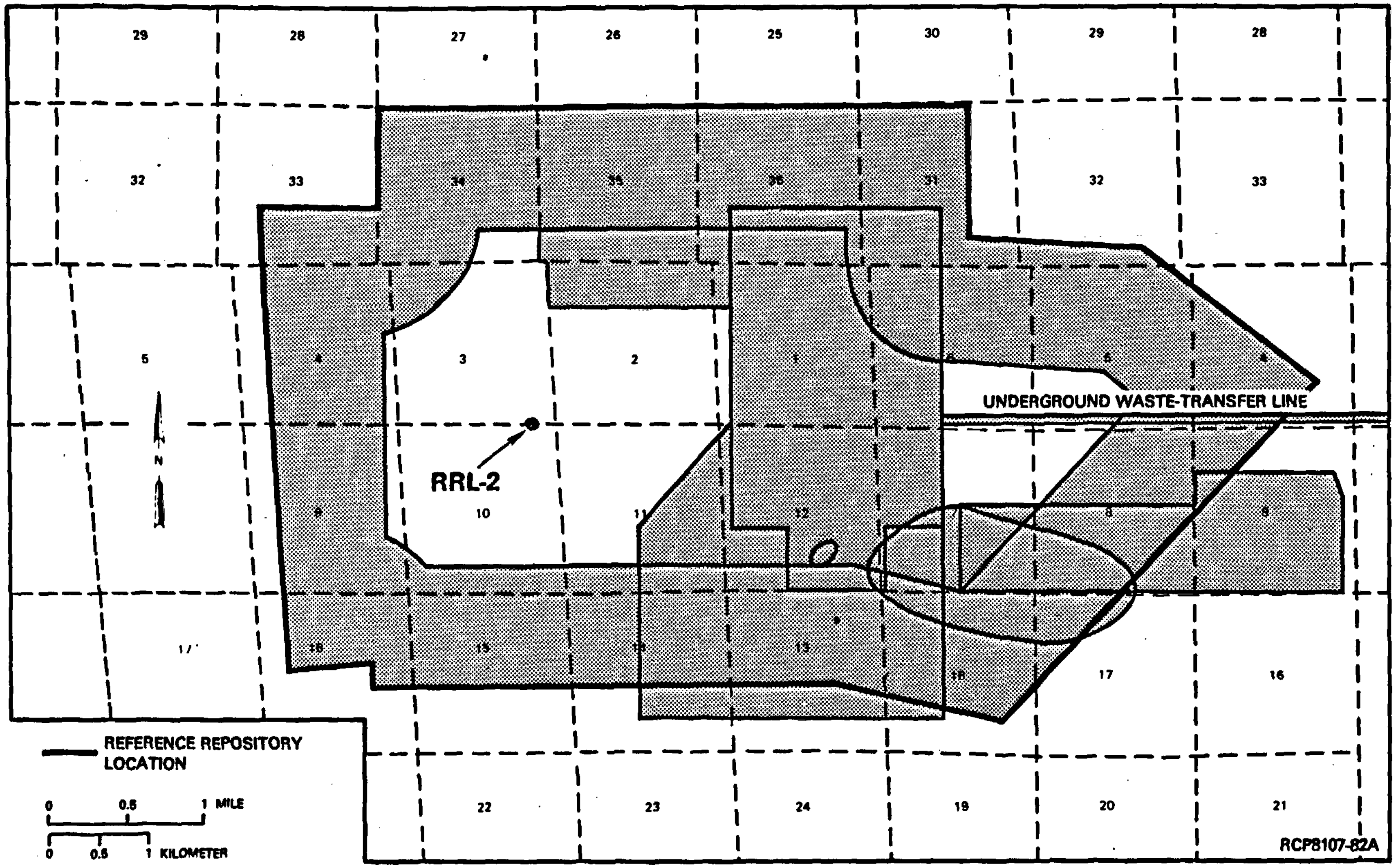

FIGURE 3-19. Composite Overlay Showing Suitable Areas for Siting Within the Reference Repository Location (unshaded areas within the A-H site).

3.6 REGIONAL AND LOCAL IMPACT ASSESSMENT OF A PROPOSED REPOSITORY

Section 112(b)(1)(E)(vi) of the Act requires an assessment of the regional and local impacts of locating a proposed repository at the site nominated for site characterization. Regional and local impacts of locating a nuclear waste repository at the Hanford Site include construction impacts, socioeconomic impacts associated with construction and operation, and transportation impacts associated with operation. Regional and local impacts are divided between those impacts that affect areas outside the Hanford Site (i.e., regional) and those impacts limited to the Hanford Site (i.e., local).

The Final Environmental Impact Statement: Management of Commercially Generated Radioactive Waste (DOE, 1980) presents an analysis of environmental impacts that could occur if various technologies for the disposal of radioactive waste were to be developed and implemented. The Final Environmental Impact Statement (DOE, 1980) is based on generic information rather than specific data. The impact assessment presented here is specific for a nuclear waste repository at Hanford, but is based on preliminary design information and must be considered as a predecessor of more detailed analyses to be prepared as more information becomes available. Such detailed analyses will be included in the environmental impact statement accompanying the Site Recommendation Report, if the reference repository location at Hanford is ultimately selected by the DOE for recommendation to the President as a repository site.

3.6.1 Construction Impacts of a Proposed Repository

Construction impacts associated with building a repository on the Hanford Site are mainly local impacts; i.e., impacts are limited to the Hanford Site. Major construction impacts are associated with surface facilities including development away from the repository site and development at the repository site.

3.6.1.1 Development Away From the Repository Site. Development away from the repository site consists of transportation facilities, utilities, and the visitors' center.

Transportation to the repository site will be provided by connections to the existing Hanford Site road and railroad networks. Rail traffic, originating at the Burlington Northern Railroad yard in Pasco will be transferred at the Hanford Site boundary to Hanford locomotives. A helicopter landing pad will also be provided at the repository site.

Incoming utilities consist of water, electric power, and telephone. Raw water will be supplied from the Columbia River by an existing river pump station, which will be modified by the addition of new pumps and other facilities. A new buried pipeline will connect these new pumps to the repository site. Two new 138-kilovolt transmission lines, routed over separate parallel rights-of-way, will connect the repository to the Hanford Site power system. A new overhead telephone line will connect the repository to the Hanford Site telephone network.

A visitors' center will be located at the intersection of the repository access road and an existing Hanford Site road.

By making connections with existing Hanford Site facilities, environmental impacts away from the repository site will be minimized. Also, prior to decisions regarding construction, environmental evaluations will be conducted and used as input to the final decisions. Construction practices to minimize impacts will be employed including dust suppression, soil stabilization, and allowing natural vegetation to reestablish along rights-of-way.

3.6.1.2 Development at the Repository Site. The repository site will consist of a 80-hectare (200-acre) central process area located over and contained within the surface projection of the 588-hectare (1,455-acre) subsurface facility. Surrounding the projection of the subsurface facility to the surface is a 2-kilometer (6,560-foot) control zone with an area of approximately 3,840 hectares (9,000 acres). The total area enclosed by the outside boundary of the control zone is approximately 4,247 hectares (10,500 acres). The entire central process area will be surrounded by a double security fence.

The major construction impacts at the repository site will be the selective clearing and grading of over 80 hectares (200 acres) of shrub-steppe terrain (i.e., all of the central process area plus an area outside the central process area for a parking lot, helicopter landing pad, and a mine water percolation pond). Any topsoil stripped at this time will be stockpiled for future replacement and planting. All of the plants within this area will be destroyed and all of the animals will be displaced. Ongoing environmental monitoring, however, continues to show no threatened or endangered species residing within the proposed repository site.

Following clearing and grading, the culverts, drainage structures, and the lower, large-diameter storm sewers will be installed. Excavations and embankments will be formed; storm drainage ditches and structures will be constructed. Dust and erosion control measures will continue during the entire construction phase until final paving, erosion control, and planting are provided.

The remoteness of the site from human habitation and from occupied Hanford facilities mitigates the effects of any high construction noise levels. Effective muffler systems will be used on heavy equipment during construction to minimize adverse environmental impacts. Impacts on members of the general public will meet the requirements of the Noise Pollution Control Act of 1972, which requires that "...noise levels do not exceed 70 decibels at the nearest habitation."

3.6.2 Socioeconomic Impacts of a Proposed Repository

The preliminary socioeconomic analysis in this section will focus on the anticipated cause and effect relationship between the construction and operation activities of a nuclear waste repository at Hanford and the demographic, economic, public service and social characteristics of the region containing the proposed repository located in basalt. The primary concern will be the identification of the size and distribution within the region of the demographic and economic impacts and their effect on community infrastructure. The analysis will also acknowledge the distinction between objectively measured changes in the socioeconomic conditions that are likely to occur in the study area and the subjective evaluations of those changes by the people who stand to be affected.

This is a prospective analysis of construction and operation activities that are not expected to begin until 1990. In addition, those activities are currently projected to last about 80 years before all activities are terminated. The current repository conceptual design is preliminary and subject to refinement and change. In addition, the study region has a history of volatility with respect to rapid change in socioeconomic conditions. Uncertainty in the scope of BWIP activities coupled with uncertainty in projecting baseline socioeconomic conditions far into the future dictate that this analysis will be general in focus and tentative in drawing conclusions about likely socioeconomic impacts.

Financial and technical assistance to a state in which a repository is sited is provided for in Section 116 of the Nuclear Waste Policy Act of 1982. Federal assistance would be designed to mitigate the impact on such state of the development of a repository. Specific details of this program have not been developed at this time.

3.6.2.1 Study Region. The study region is defined for the purposes of this analysis as the area surrounding the local project site (Hanford Site) that is expected to experience the major share of demographic, economic and infrastructure impacts from a potential repository. Prior analyses of project development activities on the Hanford Site by the Washington Public Power Supply System (WCC, 1975) have shown that the majority of in-migrant workers live in one of the Tri-Cities (Richland, Pasco, or Kennewick) or nearby Benton City or West Richland. With the recent Washington Public Power Supply System work force cutbacks and generally depressed economic conditions, claims for unemployment insurance by former Washington Public Power Supply System employees indicate that some of the Hanford work force live in Yakima County as well as many of the smaller outlying communities. Although these communities will continue to grow along with future growth in employment opportunity in and around the Tri-Cities, the study region as defined here will receive most of these new workers as residents and, therefore, will be faced with most of the potential socioeconomic impacts (both beneficial and adverse) of the project. Economic impacts will likely be even more concentrated in the study region than demographic impacts, given past patterns of the purchases of goods and services and the distribution of revenues associated with Hanford activities.

The judgment of the significance of any socioeconomic impacts due to a repository, especially those impacts that can be quantified, will largely be made relative to the projected baseline condition. In the following section, the expected repository work force will be examined in a general way and compared, in subsequent sections, with socioeconomic attributes of the study region such as housing availability, schooling, and local transportation systems. Given the uncertainty regarding future labor force conditions in the region, the analysis of project work force will provide a crude estimate of the demographic growth that could be caused by the project and will specify the assumptions on which this estimate is based.

3.6.2.2 Project Work Force. The entire project is assumed to proceed through four distinct stages beginning in 1990 and lasting a total of 82 years. Each of these stages involves a different set of activities and requires a specialized labor force to conduct these activities. The attributes of the potential repository that constitute important determinants of socioeconomic impacts are the size of the work force, the required skills of the work force, and the timing of the work activities over each of the four project stages. The discussion of the project work force in this report reflects the most current information available based on ongoing conceptual design efforts. However, this information is acknowledged to be preliminary and subject to changes in technical design considerations and in the scheduling of the proposed project activities.

The first component of the construction phase covers a 7-year period from 1990 to 1996. This phase involves the construction of surface facilities (service and storage), several access shafts, and subsurface facilities. A significant component of the construction work force will involve mining activities. This is an important consideration for the assessment of socioeconomic impacts because workers with the requisite mining skills are not likely to be found in the region's labor force. If workers with skills not readily available in the local area must in-migrate from outside areas, the implied growth in the area could cause socioeconomic impacts if the number of immigrants exceeds the ability of the community to absorb these impacts.

The second component is the operational phase. This phase is expected to last 24 years (from 1997 to 2020). It is the period of maximum activity, involving the mining of panels, drilling of storage holes and the receipt, packaging and emplacement of waste materials. The third component is the caretaker phase, lasting 31 years (from 2021 to 2051) and involving a greatly reduced level of manpower activity needed to meet the 50-year retrievability requirement. The final component is the backfilling phase, lasting 20 years (from 2052 to 2071).

An estimate of the total primary work force requirement is presented in Table 3-6. Since the mining component represents skills so specialized that most of this labor force component can be expected to in-migrate, the mine work force is estimated separately. When the nuclear waste repository in basalt conceptual design is developed in greater detail, the socioeconomic analysis will be able to estimate work force requirements and local availability more precisely.

TABLE 3-6. Estimated Basalt Waste Isolation Project Work Force Requirements[a] by Project Phase and Estimated In-Migration Caused by Project.

Project phase	Project period	Number of years	Mine work force	Other work force	Total average annual work force[b]	Estimated number of in-migrants[c]
I. Construction	1990 - 1996	7	300	300	600	1,600
II. Operation	1997 - 2020	24	200	750	950	2,500
III. Caretaker	2021 - 2051	31	--	130	130	300
IV. Backfill	2052 - 2071	20	--	210	210	500

[a]Work force data are preliminary estimates and are subject to further revision.

[b]Average annual work force figures are intended to reflect the number of workers that would be required on the job each day during the indicated project phase. Not enough scheduling information is available at this time to allow for an estimate of the variability of work force requirements within each phase (e.g., peak requirements). Average annual work force estimates were developed from preliminary estimates of total man-hours or man-days in each phase, assuming 2,000 hours or 250 days per man-year.

[c]Total number of in-migrants includes estimated in-migrating primary workers, secondary workers and the dependents of both primary and secondary workers. In-migrating primary workers are crudely estimated here by assuming that 95 percent of the mine work force and 50 percent of all other workers will in-migrate. Assuming a secondary employment multiplier of 1.9, new jobs in the secondary support section are estimated and it is further assumed that 50 percent of these secondary jobs will be filled by new in-migrants. Finally, each in-migrant worker is assumed to be accompanied by 1.5 dependents. These assumptions regarding propensity to in-migrate depend in turn on uncertain future levels of unemployment in the region and on concurrent construction activity, both of which help determine local labor availability. The calculated number of in-migrants has been rounded to two significant digits.

The need for a large number of workers having hard-rock mining skills is a characteristic of this project that is unique in comparison with other Hanford projects. Unless local workers can be trained in the required mining skills, almost all the miners needed during the construction and operation phases of the nuclear waste repository in basalt will have to in-migrate to the area.

Whether the level of primary work force in-migration is signficantly larger than that implied by the need for miners depends on several factors. First, the craft skills needed for repository construction and operation must be compared with the availability of local workers possessing these skills. Second, the craft unions play an important role in the assignment of available workers to available jobs. Third, any wage differential between BWIP jobs and comparable jobs at other projects will influence the propensity for employed workers to switch jobs. Fourth, and perhaps most important, the timing of BWIP activities relative to the timing of other industrial activities planned during this period of time can either reduce or increase the need for additional outside workers. The ability of the project to employ local workers would have a positive economic and psychological impact for the area, but it is new people coming in who can cause change to occur. Depending on its magnitude and perceived severity, such change could cause negative socioeconomic impacts.

As shown in Table 3-6, the total population impact caused by a major development project is typically larger than the number of primary workers needed on that project. However, in an area such as the Tri-Cities that has experienced several cycles of rapid population change, the secondary employment response to changing opportunity may significantly lag fluctuations in primary employment demand. For example, secondary business may not leave the area as soon as the primary activity is reduced. Secondary employment has stronger ties to the area compared with transient construction employment.

Different but simultaneous activities that draw from a common labor pool essentially compete for scarce labor resources. To the extent that the supply of workers having the needed skills is less than the demand, workers will either in-migrate or commute from long distances. This could become a burden upon the community if these workers need housing, schooling and other services that may be in short supply. The main determinant of socioeconomic impacts can be traced to the match between the pressures a project places upon a community (demographic, fiscal, services and social) and the ability of the community to meet those pressures in a planned, orderly, cost-effective way. In the case of the BWIP, the projected work force requirements and estimated project in-migration is small relative to recent Hanford Site activities and these effects can be expected to be spread across several large communities in Benton, Franklin, and Yakima Counties. However, actual work force requirements and patterns of in-migration will have to be monitored closely after the project is initiated because experience at other large development sites indicates that engineering conceptual designs tend to underestimate actual peak work force experience, largely due to scheduling problems that occur during the construction phase.

3.6.2.3 Demography. This study region has experienced dynamic swings in population, including sustained growth and sudden declines. The demographic fortunes of this region have been primarily driven by employment opportunities associated with Hanford Site developments, though more recently the manufacturing and agriculture sectors have exerted an increasingly influential and stabilizing effect on the region. Data on population size and distribution for Benton and Franklin Counties and the five major municipalities that constitute the study region are provided in Table 3-7. In addition, data are provided on population forecasts for the years 1985 and 1990. The 1990 forecasts made in 1982 are on the order of 20 percent lower than those prepared only one year earlier, a net difference of more than 37,000 persons expected in the bicounty area over the next 8 years. The current expectation, therefore, is for the bicounty area and the study region to grow in size by only about 4 percent over the 1980 to 1990 decade. This is compared with a growth of 54.8 percent over the prior decade, 1970 to 1980, an unusually rapid rate of growth.

Most of this growth can be attributed to net in-migration of population to the area in response to the rapid expansion of employment opportunity during the 1970-1980 decade. Net in-migration in this period accounted for 80 percent of Benton County's growth and almost 36 percent of Franklin County's growth. The balance of total growth is due to natural increase, the excess of births over deaths. Pinpointing the components of growth in each of the municipalities that constitute the study region is more difficult, however, because these cities have also grown due to annexation of adjacent unincorporated areas. According to a recent analysis, "...from 1970 to 1980, the cities of Richland, Pasco, Kennewick, and West Richland had expanded their municipal boundaries by 51 percent" (State of Washington, 1982c).

Population forecasts for this region are quite uncertain at best, even when looking only a few years into the future. Population forecasts covering the 80-year lifespan of the BWIP activities would be very difficult. There is no way to accurately anticipate developments in the economy of this area over such a long time frame. Several useful observations can be made, however. First, the economy of the region is becoming increasingly diversified and hence is likely to show greater stability in the future than in the past. Second, the sheer numbers of people living and working in the study region are now and can reasonably be expected to remain large relative to the potential additional population influx that this proposed repository might cause. Based on the very rough numbers provided in Table 3-6, the BWIP in-migration, when dispersed residentially over the municipalities both within and outside of the defined study region, is not likely to amount to even 2 percent of the baseline population. This effect is small compared with the population and employment dynamics experienced in the study region in recent years. Notwithstanding the painful effects of the recent Washington Public Power Supply System employment cutbacks, population in the area is expected to grow between 1980 and 1990 but at a rate far below the explosive growth experienced during the prior decade.

TABLE 3-7. Population Size and Distribution Based on Census, Current Estimates, and Forecasts for Benton and Franklin Counties and Municipalities in the Basalt Waste Isolation Project Study Region--1970-2000.

Municipality by county	Census and current estimates			Actual change (%) 1970-1980	Forecasts[d]		Forecast change (%) 1980-1990
	1970[a,b]	1980[a,c]	1981[c]		1985	1990	
Benton	67,540	109,444	111,700	62.0	103,994	112,475	2.8
*Benton City	1,070	2,087	1,970	95.0			
*Kennewick	15,212	34,397	35,350	126.1			
*Richland	26,290	33,578	33,550	27.7			
*West Richland	1,107	2,938	3,934[a]	165.4			
Balance of County	23,861	36,444	36,896	52.7			
Franklin	25,816	35,025	36,200	35.7	33,500	37,591	7.3
*Pasco	13,920	18,425	19,050	32.4			
Balance of County	11,896	16,600	17,150	39.5			
Bicounty Total	93,356	144,469	147,900	54.8	137,494	150,066	3.9
NWRB Study Region[e]	57,599	90,837	93,854	57.7	86,600[f]	94,500[f]	4.0
State Total	3,413,244	4,132,180	4,264,000	21.1	4,339,000	4,603,000	11.4

NOTE: NWRB = nuclear waste repository in basalt.

[a]Actual census count.

[b]State of Washington, 1979.

[c]State of Washington, 1982a.

[d]State of Washington, 1982b.

[e]The five incorporated cities listed above (denoted by *) comprise the study region for this analysis. Although this area includes some people living in unincorporated areas, that component cannot be accurately measured with currently available data.

[f]Forecasts for the study region are based on a projected 63 percent share of the respective bicounty forecasts.

3.6.2.4 Economy. Up until mid-1981, the economy in the Tri-Cities metropolitan area had been one of the most rapidly growing in the nation. The economic base in the Tri-Cities in 1981 was distributed into four major sectors: Hanford construction activities (primarily Washington Public Power Supply System facilities) accounted for 36 percent; research and development (including DOE activities) accounted for 39 percent; agriculture and related agro-business accounted for 20 percent, and other manufacturing accounted for the remaining 5 percent. The most significant decline in employment during 1982 has been due to the loss of Washington Public Power Supply System jobs. Employment losses are expected to increase through the end of fiscal year 1983. Total unemployment in the Tri-Cities has increased from about 7,300 persons in 1981 to 12,200 by November 1982 or from 8.9 percent to 15.4 percent of the resident civilian labor force (State of Washington, 1982c, 1982d). Nonagricultural wage and salary employment in the Tri-Cities for fiscal year 1981 and projected for fiscal year 1983 is shown in Table 3-8. Significant losses in jobs for the area over this period are principally due to lost construction jobs and smaller associated lost employment in the secondary support sectors of the local economy. The manufacturing and agriculture sectors can anticipate small gains over this time, however.

As with population forecasts, it is exceedingly difficult to anticipate the BWIP impacts on the region's economy years into the future. Current conceptual design estimates suggest that about $33 million in wages may be expended annually for construction labor and another $113 million a year for other direct construction costs. By way of comparison, the Hanford Site payroll exceeded $400 million in 1978. Annual direct operating costs are currently estimated to be under $60 million per year. The fiscal impact that these figures represent for the study region will depend upon economic conditions at the time the construction and operation phases are undertaken. Although the amounts involved are not large compared with the massive capital projects experienced at the Hanford Site in recent years, they will likely be welcomed for the stabilizing effect they would exert on the economy.

3.6.2.5 Housing. Housing impacts are directly related to the growth or decline of population and the health of the economy in the study region. The demand for housing created by development activity such as the BWIP depends not only on the number of new in-migrating workers expected in the study region but also on their family size, income level, and preference for housing type. Housing impacts are less likely if currently available housing stock can absorb the influx of new people than if new construction is required. However, since vacancy rates vary by type and quality of housing, some in-migrants may experience difficulty obtaining the housing of their choice and means.

TABLE 3-8. Nonagricultural Wage and Salary Employment in the Richland-Kennewick-Pasco Standard Metropolitan Statistical Area, Fiscal Year Averages, 1981 and Projected 1983 (State of Washington, 1982c).

Type of employment	Fiscal year average employment			
	1981		1983	
	Number	Percent	Number	Percent
Total	62,380	100.0	54,600	100.0
Total manufacturing	9,080	14.6	9,810	18.0
Food and kindred products	2,140	3.4	2,410	4.4
Printing and publishing	330	0.5	330	0.6
Chemicals	5,620	9.0	6,080	11.1
Primary and fabricated metals	350	0.6	350	0.6
Other manufacturing	640	1.0	640	1.2
Mining	40	0.1	40	0.1
Construction	12,180	19.5	6,630	12.1
Transportation, communications, and utilities	2,410	3.9	2,350	4.3
Wholesale and retail trade	11,450	18.4	10,550	19.3
Finance, insurance and real estate	1,590	2.5	1,510	2.8
Services	15,590	25.0	14,110	25.8
Government	10,040	16.1	9,600	17.6

According to a recent housing study for the Tri-Cities Standard Metropolitan Statistical Area (T-CRERC, 1982), the study region's housing sector is experiencing "...a virtual depression." Due primarily to the Washington Public Power Supply System employment cutbacks, high interest rates and a sluggish economy, the region's housing construction activity has declined over 90 percent during 1982, vacancies have increased dramatically, particularly for apartment units (over 22 percent according to one survey), and prices for rental units have begun to drop. Nevertheless, financing is difficult to find at a reasonable rate, and new single family units are in the high price range.

The potential for housing impacts due to the BWIP can be roughly estimated by comparing a projection of housing demand due to project-induced in-migration with project housing availability. Housing demand is estimated on the basis of 1.1 primary or secondary in-migrant job holders per household. This assumption recognizes that the spouses of some primary or secondary workers will themselves hold a primary or secondary job. In addition, some unrelated workers will likely share housing. Based on the projected number of in-migrant primary and secondary workers to the study region during the operations phase of the BWIP, a need for about 900 housing units is estimated. Conservatively assuming that the ratio of housing units to total population that existed around 1980 will be obtained during the operations phase (0.35 to 1) and a comparable vacancy rate of about 2 percent (below current levels but more reasonable over the long run), and a baseline population of around 100,000 people in the study region, then perhaps 700 housing units would be available in the study region itself and several hundred more in other portions of the Standard Metropolitan Statistical Area. Since some of the projected in-migrants can be expected to seek housing outside this area, existing vacant units may be able to accommodate the remaining new families.

While it is possible that housing could be affected by the BWIP, the overall anticipated demographic and economic effect of the BWIP is likely to be less than for projects that the region's housing market has been able to accommodate without serious impact in the past. The housing construction industry has been very responsive to rapidly changing housing needs in the region.

3.6.2.6 <u>Local Transportation</u>. Local traffic congestion has been recognized as one of the major socioeconomic impacts of rapid growth in the study region in the past. Heavy rush-hour traffic flows have been experienced in the Tri-Cities, particularly during the period of very rapid population growth and high Hanford Site employment in the recent past. Since the employment declines and subsequent net out-migration from the area due to the Washington Public Power Supply System cutbacks, traffic congestion has noticeably abated. However, future growth in the region could cause the traffic problem to recur. The major municipalities are arranged geographically in a linear pattern with respect to the Hanford Site that tends to create transportation bottlenecks during periods of heavy use. Recognizing this problem, transportation planning has received special attention in the region, and a number of recent and prospective developments suggest that future problems in this regard are much less likely than in the past. For example, several bridges are under construction or under consideration that would provide more direct access for Franklin County residents to the Richland area and the Hanford Site. A public transportation system went into service in May 1982 and the DOE operates a shuttle bus system from Richland to the Hanford Site.

Forecasts of possible transportation impacts due to the BWIP are difficult to make given uncertainty in both the project configuration and the local economy. Based on the work force information presented in Section 3.6.2.2, an estimate of the number of cars to be added to the daily commuter traffic during the operations phase would be on the order of 700 vehicles per day during the operations phase. This represents approximately 400 vehicles commuting to the Hanford Site and approximately 300 vehicles added to the general commuter traffic that is generated by secondary workers. This estimate is based on an assumed 1.4 persons per vehicle on average. This is also a maximum estimate because it assumes no use of mass transit. Given that these commuters are residentially dispersed within the region, this implied addition to local traffic flow is quite small and adverse impacts are unlikely.

3.6.2.7 Public Services. Socioeconomic impacts associated with public services are not expected to be significant. The size of the direct project effects are small relative to the fluctuations, both up and down, that have been experienced in the study region over the last decade. This large variation in demand for public services has sometimes exceeded service system capacity but generally services have been adequately provided. The study region has planned for and accommodated itself well to the rapid growth it has experienced. The recent economic declines and loss of activity has been experienced as more painful than rapid growth. Therefore, it seems likely that BWIP-related growth will be viewed as positive. If it makes up for slack demand for services during a periodic economic down time, that would be viewed as a beneficial impact. If the project activity adds to concurrent future growth, the study region should be able to assimilate that as well.

Given the small demographic impact of the BWIP relative to the projected baseline, the impacts on public services are expected to be insignificant. For example, the level of fire and police protection is not likely to be affected. Education impacts can be estimated roughly by assuming that 25 percent of the new in-migrant population is school-age (5 to 19). On this basis, the BWIP might bring in 600 new students during the operation phase or about 2 percent of the current Tri-Cities school enrollment. Given that these students would be distributed over several school districts and assuming expected growth in the school systems over the next 10 to 80 years commensurate with projected population growth, the school system should be able to absorb the new growth with no adverse impact.

Little increase in demand for health care facilities and personnel is expected due to the project. Projected new in-migration would require less than three beds and one physician at the prevailing ratio of beds and physicians to population. Currently, health care facilities within the study region are implementing expansion plans, and the BWIP is not expected to have any adverse health care impacts.

Finally, the projected population in-migration due to BWIP is not likely to cause any direct impacts on available park land nor cause recreational facilities to be overused.

3.6.2.8 Utilities. Utilities are comprised of the power and communications systems, water and sewer systems, and the solid waste services. Impacts from BWIP activities are not expected to be significant; however, the effect of population increase in the Tri-Cities needs to be carefully assessed by utility planners. Of the utilities, water and sewer systems are particularly sensitive to population increases. Several of the systems within the Tri-Cities were approaching capacity before the recent economic decline. Sewer treatment facilities that are currently being upgraded in the city of Richland are designed to handle the needs of a population of 68,500. The level of growth implied by the BWIP is not expected to adversely impact the utilities.

3.6.2.9 Long-Term Socioeconomic Impacts. Potential long-term impacts that could be caused by the BWIP include economic, political, aesthetic and cultural effects. Impacts of this sort tend to be evaluated subjectively and are difficult to measure. Long-term economic impacts include the potential impacts that implementation of a nuclear waste repository at the Hanford Site could have on public perceptions of the suitability of the study region for diversified industrial development.

Aesthetic impacts are expected to be small primarily because the repository site is remotely located with respect to population settlement. Therefore, visual and noise impacts will be minimal. Regarding the potential for cultural impacts, care will be taken to ensure that repository construction does not disrupt any known or potential historical or archeological sites that may be located on the Hanford Site.

3.6.3 Transportation

The repository will be designed to receive spent fuel, high-level waste, and transuranic waste; the repository may receive high-level waste from defense-related nuclear activities, subject to future policy decisions. Shipments by both truck and rail will be accommodated.

Shipments of nuclear waste to the repository will be in accordance with applicable Federal regulations. Currently, the NRC and the U.S. Department of Transportation regulate the transportation of radioactive materials. Transportation and packaging criteria and standards are outlined in the Code of Federal Regulations (NRC, 1982c; DOT, 1981). The environmental impacts of transportation activities are addressed in Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes (NRC, 1977).

The normal radiological impacts of nuclear waste transportation are small in comparison to naturally occurring ambient radiation levels. The potential radiological consequences of transportation accidents are controlled primarily by the highly damage-resistant shipping containers required under current Federal regulations. Although these radiological impacts are of less significance, they are directly related to transportation distance. The localized environmental impacts due to transportation will be determined in part by the availability and capacity of existing highway and rail routes and the existence of heavily populated areas along these routes. If selected as a repository, the environmental impact statement that will be prepared to support the Site Recommendation Report will provide detailed information on the environmental impacts of waste transportation.

Both spent fuel and high-level waste will be shipped in specially designed casks. Spent fuel has been shipped in the United States for many years. Massive, heavily shielded shipping casks are available for both truck and rail transport of spent fuel from current-generation nuclear power reactors. Most spent fuel casks will accept either pressurized-water-reactor or boiling-water-reactor spent fuel by using different fuel baskets. These casks are designed to contain the spent fuel even in the event of an accident. More detailed information on existing spent fuel shipping casks is presented in Technology for Commercial Radioactive Waste Management (DOE, 1979). The existing spent fuel shipping casks were designed to transport short-cooled (6 months or less) irradiated fuel; however, most spent fuel transport will involve fuel that has been cooled for at least several years. Consequently, there appears to be considerable incentive to build a fleet of casks specifically designed for this long-cooled fuel because its lower thermal and radiation output would permit an increase in cask capacity and a reduction in handling costs.

Solidified high-level waste will be shipped in casks similar to those for spent fuel. Prior to shipment, the waste will be packaged in cylindrical steel canisters, currently assumed to be 0.3 meter (1 foot) in diameter by 3 meters (10 feet) long. The configuration differences between spent fuel and high-level waste shipping cask designs are dictated by the differences in waste form/package dimensions, thermal power, and radiation levels; high-level waste is a more concentrated waste form than the spent fuel from which it is produced.

The split between rail and truck shipments cannot be forecast with certainty, due to numerous economic and logistics considerations. Rail shipments are generally favored over truck shipments due to their significantly larger payloads. However, since some nuclear power reactors do not currently have rail spurs at their sites, it is assumed that about 10 percent of spent fuel shipments will be by truck and 90 percent by rail. It is assumed that all commercial high-level waste shipments will be by rail.

The shipping cask capacities assumed in estimating numbers of shipments to the repository are as follows:

	Truck cask	Rail cask
Spent fuel assemblies--pressurized water reactor	2	12
Spent fuel assemblies--boiling water reactor	5	32
High-level waste canisters (0.3 meter (1 foot) diameter x 3 meters (10 feet) long)	Not applicable	12

The current repository design basis specifies a total of approximately 70,000 metric tons (77,000 tons) of spent fuel or its equivalent quantity of commercial high-level waste to be shipped to the repository during the initial 24 years of operation. This design basis includes the assumption that one-half of this total will be in the form of spent fuel and the other half will be in the form of reprocessing plant high-level waste. On these bases, the average annual shipments to the repository will consist of 168 truck shipments of spent fuel, 246 rail shipments of spent fuel, and 55 rail shipments of commercial high-level waste. These annual average shipments total to 469, or between 1 and 2 shipments per day.

3.6.4 Summary Conclusions

The regional and local impacts that might be associated with a proposed repository located at the Hanford Site are expected to be minimal. An infusion of construction and operating monies over the next several decades would bolster the economy of the area without deleteriously affecting the environment. Preliminary analyses of the waste isolation capability of basalts at Hanford are favorable and final analyses will have to be approved by the NRC prior to operation of a repository at the Hanford Site.

4.0 GLOSSARY

<u>accessible environment</u> -- the atmosphere, the land surface, surface waters, oceans, and the parts of the lithosphere that are more than 10 kilometers (6.2 miles) in any direction from the original location of any of the radioactive waste in a disposal system.

<u>aquifer</u> -- a zone of rock below the surface of the earth that readily transmits water and is capable of producing water as from a well.

<u>capillary fringe</u> -- a zone in which the pressure is less than atmospheric, overlying the zone of saturation and containing capillary interstices.

<u>containment</u> -- confinement of the radioactive wastes within prescribed boundaries (e.g., within a waste package).

<u>disqualifying conditions</u> -- a condition that, if present at a candidate site, would eliminate that site from further consideration; a single disqualifying condition is sufficient.

<u>disturbed zone</u> -- that portion of the controlled area whose physical or chemical properties have changed as a result of underground facility construction or heat generated by the emplaced radioactive waste such that the resultant change in properties may have a significant effect on the performance of the geologic repository.

<u>Eh</u> -- a measure of the oxidation reduction potential (volts); the difference in potential measured in a cell having both oxidized and reduced form of an element (measured) and the standard hydrogen electrode potential.

<u>engineered barrier</u> -- man-made components of a disposal system designed to prevent the release of radionuclides into the geologic medium involved; such term includes the high-level radioactive waste form, high-level radioactive waste canisters, and other materials placed over and around such canisters.

<u>fault</u> -- a fracture in the earth's crust along which movement parallel to the fracture plane has displaced one side of the fracture relative to the other side.

<u>faulting</u> -- the tectonic process that results in displacement along a fault.

<u>favorable condition</u> -- a condition that, if present, will not necessarily qualify a site relative to a specific criterion but will enhance confidence that subsequent analysis will show that the criterion can be met.

<u>fugacity</u> -- the escaping tendency of a substance in a heterogeneous mixture, by which a chemical equilibrium responds to altered conditions.

geologic repository -- any system licensed by the NRC that is intended to be used for, or may be used for, the permanent deep geologic disposal of high-level radioactive waste and spent nuclear fuel, whether or not such system is designed to permit the recovery, for a limited period during initial operation, of any materials placed in such system. Such term includes both surface and subsurface areas at which high-level radioactive waste and spent nuclear fuel handling activities are conducted.

geologic setting -- the tectonic, geologic, hydrologic, and geochemical systems of a region in which a site is or may be located.

highly populated area -- the population center associated with a Standard Metropolitan Statistical Area.

host rock -- rock within which radioactive waste is emplaced for disposal.

hydrologic properties -- those properties of rocks and water, including their chemistry, that influence the flow of groundwater.

igneous activity -- emplacement (intrusion) of molten rock material into solid rocks in the earth's crust or expulsion (extrusion) of such material onto the earth's surface or into its atmosphere or water bodies.

isolation -- inhibiting the transport of radioactive material in the subsurface so that the amounts and concentrations of this material entering the accessible environment will be kept within prescribed limits.

models -- conceptual definitions and associated mathematical representations that simulate the response of a repository system under natural or perturbed conditions. An example is a hydrologic model to predict groundwater travel or radionuclide transport from the waste-emplacement area to the accessible environment.

permanent closure -- final backfilling of the underground facility and the sealing of shafts and boreholes.

potentially adverse condition -- a condition that, if present, will not disqualify a site relative to a specific criterion but will require additional analysis, specific site characterization, or identification of compensating or mitigating factors before qualifying the site.

pre-waste-emplacement -- under conditions that exist before repository development.

qualifying condition -- a condition that, if met, indicates that a site is acceptable with respect to a specific criterion.

Quaternary (Period) -- the youngest of the periods of the Cenozoic Era, extending from approximately 1.8 million years ago to the present.

radioactive waste -- high-level radioactive waste and spent nuclear fuel.

repository -- geologic repository.

saturated zone -- that part of the Earth's crust beneath the deepest water table in which all voids, large and small, are ideally filled with water under pressure greater than atmospheric.

site -- a surface location and the underlying rocks, including the underground facility and extending through a control zone from which incompatible activities will be restricted after permanent closure.

system performance -- the total, integrated result of all acting processes and events caused by or affecting a repository.

tectonic -- of, pertaining to, or designating the rock structure and external forms resulting from deformation of the earth's crust.

underground facility -- the underground structure, including mined openings and backfill material, but excluding shafts, boreholes, and their seals.

unsaturated zone -- the zone between the land surface and the deepest water table; it includes the capillary fringe. Generally, water in this zone is under less than atmospheric pressure, and some of the voids may contain air or other gases at atmospheric pressure. Beneath flooded areas or in perched water bodies the water pressure locally may be greater than atmospheric.

5.0 REFERENCES

Algermissen, S. T., 1969, "Seismic Risk Studies in the United States," in Proceedings of the Fourth World Conference on Earthquake Engineering, Santiago, Chile, January 1969.

Algermissen, S. T. and Perkins, D. M., 1976, A Probabilistic Estimate of Maximum Acceleration in Rock in the Contiguous United States, Open-File Report 74-416, U.S. Geological Survey, Denver, Colorado.

Ames, L. L., 1980, Hanford Basalt Flow Mineralogy, PNL-2847, Pacific Northwest Laboratory, Richland, Washington.

Ames, L. L. and McGarrah, J. E., 1980a, Basalt Radionuclide Distribution Coefficient Determinations FY 1979 Annual Report, PNL-3146, Pacific Northwest Laboratory, Richland, Washington.

Ames, L. L. and McGarrah, J. E., 1980b, Investigation of Basalt-Radionuclide Distribution Coefficients: Fiscal Year 1980 Annual Report, RHO-BWI-C-108/PNL-3462, Pacific Northwest Laboratory for Rockwell Hanford Operations, Richland, Washington, December 1980.

Ames, L. L. and McGarrah, J. E., 1980c, High-Temperature Determination of Radionuclide Distribution Coefficients for Columbia River Basalts, RHO-BWI-C-111/PNL-3250, Pacific Northwest Laboratory for Rockwell Hanford Operations, Richland, Washington, December 1980.

APCA, 1980, General Regulation 80-7 of the Benton-Franklin-Walla Walla Counties Air Pollution Control Authority, Board of Directors of the Benton-Franklin-Walla Walla Counties Air Pollution Control Authority, Richland, Washington, published May 6, 1980, effective July 1, 1980.

Apted, M. J. and Myers, J., 1982, Comparison of the Hydrothermal Stability of Simulated Spent Fuel and Borosilicate Glass in a Basaltic Environment, RHO-BW-ST-38 P, Rockwell Hanford Operations, Richland, Washington, July 1982.

ARHCO, 1976, Preliminary Feasibility Study on Storage of Radioactive Wastes in Columbia River Basalts, ARH-ST-137, Atlantic Richfield Hanford Company, Richland, Washington.

Arnett, R. C., Baca, R. G., Caggiano, J. A., Price, S. M., Gephart, R. E., and Logan, S. E., 1980, Preliminary Hydrologic Release Scenarios for a Candidate Repository Site in the Columbia River Basalts, RHO-BWI-ST-12, Rockwell Hanford Operations, Richland, Washington, November 1980.

Arnett, R. C., Mudd, R. D., Baca, R. G., Martin, M. D., Norton, W. R., and McLaughlin, D. B., 1981, Pasco Basin Hydrologic Modeling and Far-Field Radionuclide Migration Potential, RHO-BWI-LD-44, Rockwell Hanford Operations, Richland, Washington, June 1981.

Atomic Energy Act of 1954, Public Law 83-703

Baca, R. G., Wilde, R. T., Arnett, R. C., and Deju, R. A., 1982, Performance Assessment for a Repository in Basalt: A Summary of Preliminary Results, RHO-BW-SA-248 P, Rockwell Hanford Operations, Richland, Washington, September 1982.

Barton, N., Lein, R., and Lunde, T., 1974, "Engineering Classification of Rock Masses for the Design of Tunnel Support," Rock Mechanics, Vol. 6, pp. 189-236.

Bieniawski, Z. T., 1979, "The Geomechanics Classification in Rock Engineering Applications," in Proceedings of the 4th International Society of Rock Mechanics, Montreaux, Switzerland.

Blackwell, D. D., 1978, "Heat Flow and Energy Loss in the Western United States," in Cenozoic Tectonics and Regional Geophysics of the Western Cordillera, Smith, R. B. and Eaton, G. P., eds., Memoir 152, Geological Society of America.

BOC, 1981, 1980 Census of Population and Housing, Washington, PHC80-V-49, Advance Reports, Bureau of the Census, U.S. Department of Commerce, Washington, D.C., March 1981.

Bull, C., 1979, "Glaciological Parameters of Disruptive Event Analysis," in A Summary of FY-1978 Consultant Input for Scenario Methodology Development, Scott, B. L., Benson, G. L., Craig, R. A., and Harwell, M. A., eds., PNL-2851, Pacific Northwest Laboratory, Richland, Washington.

Bull, C., 1980, Glaciological Parameters of Disruptive Event Analysis, PNL-2863, Pacific Northwest Laboratory, Richland, Washington.

BWIP, 1980, Identification of Candidate Sites Suitable for a Geologic Repository in Basalt Within Hanford, RHO-BWI-LD-24, Rockwell Hanford Operations, Richland, Washington.

BWIP, 1981a, Comparison of NWTS-33(2) Criteria and BWIP Screening Considerations, RHO-BW-EV-1 P, Rockwell Hanford Operations, Richland, Washington.

BWIP, 1981b, The Identification of a Preferred Site for the Exploratory Shaft Within the Reference Repository Location (RRL): Hanford Site, RHO-BWI-ST-16, Rockwell Hanford Operations, Richland, Washington.

Byalobzheskii, A. V., 1970, Radiation Corrosion, AEC-TR-7096, U.S. Atomic Energy Commission, Washington, D.C.

Cline, J. F., Vresh, D. W., and Rickard, W. H., 1977, "Plants and Soil on a Sagebrush Community on the Hanford Reservation," Northwest Science, Vol. 51, No. 6, p. 70.

COE, 1951, Artificial Flood Possibilities on the Columbia River, U.S. Army Corps of Engineers, Washington District, Washington, D.C.

COE, 1969, Lower Columbia River Standard Project Flood and Probable Maximum Flood, U.S. Army Corps of Engineers, North Pacific Division, Portland, Oregon.

Daubenmire, R., 1970, Steppe Vegetation of Washington, Technical Bulletin 62, Experimental Station, Washington State University, Pullman, Washington.

Department of Energy Organization Act of 1977, Public Law 95-91.

Doctor, P. G., Oberlander, P. L., Rice, W. A., Devary, J. L., Nelson, R. W., and Tucker, P. E., 1982, A Technology Demonstration: Geostatistical and Hydrologic Analysis of Salt Areas, PNL-4129, Pacific Northwest Laboratory, Richland, Washington, September 1982.

DOE, 1978a, Environmental Assessment for the Exploratory Borehole Drilling Activity: Wells ARH-DC-4, -5, -6, -7, and -8, Hanford Reservation, Benton County, Washington, DOE/EA-0048, U.S. Department of Energy, Washington, D.C., June 1978.

DOE, 1978b, Environmental Assessment for the Near-Surface Test Facility, Hanford Reservation, Richland, Washington, DOE/EA-0052, U.S. Department of Energy, Washington, D.C., December 1978.

DOE, 1979, Technology for Commercial Radioactive Waste Management, DOE/ET-0028, U.S. Department of Energy, Washington, D.C.

DOE, 1980, Final Environmental Impact Statement: Management of Commercially Generated Radioactive Waste, DOE/EIS-0046-F, U.S. Department of Energy, Washington, D.C., October 1980.

DOE, 1981, "Program of Research and Development for Management and Disposal of Commercially Generated Radioactive Wastes; Record of Decisions," Federal Register, Vol. 46, No. 93, pp. 26677-26679, May 14, 1981.

DOE, 1982a, Environmental Assessment for the Basalt Waste Isolation Project Exploratory Shaft Construction, DOE/EA-0188, U.S. Department of Energy, Washington, D.C., August 13, 1982.

DOE, 1982b, "Department of Energy, Finding of No Significant Impact and Notice of Availability of Environmental Assessment for the Conduct of Detailed Site Through the Construction of an Exploratory Shaft on the Hanford Site," Federal Register, Vol. 47, No. 180, pp. 40820-40821.

DOE, 1982c, Site Characterization Report for the Basalt Waste Isolation Project, DOE/RL 82-3, Rockwell Hanford Operations for the U.S. Department of Energy, Washington, D.C., November 1982.

DOE, 1982d, Public Draft, National Plan for Siting High-Level Radioactive Waste Repositories and Environmental Assessment, DOE/NWTS-4, DOE/EA-151, National Waste Terminal Storage Program, U.S. Department of Energy, Washington, D.C., February 1982.

DOE, 1983, "Department of Energy, 10 CFR 960, Nuclear Waste Policy Act of 1982; Proposed General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories," Federal Register, Vol. 48, No. 26, pp. 5670-5682, February 7, 1983.

DOI, 1982, "U.S. Department of the Interior, National Register of Historic Places," Federal Register, Vol. 47, No. 22, p. 4932.

DOT, 1981, "Part 171 - General Information Regulations and Definitions; Part 172 - Hazardous Materials Table and Hazardous Materials Communications Regulations; Part 173 - Shippers-General Requirements for Shipments and Packagings; Part 174 - Carriage by Rail; Part 175 - Carriage by Aircraft; Part 176 - Carriage by Vessel; Part 177 - Carriage by Public Highway; Part 178 - Shipping Container Specifications; Part 179 - Specifications for Tank Cars; Part 191 - Transportation of Natural and Other Gas by Pipeline, Reports of Leaks; Part 192 - Transportation of Natural and Other Gas by Pipeline, Minimum Federal Safety Standards; Part 195 - Transportation of Liquids by Pipeline," Title 49, Chapter 1, Code of Federal Regulations-Transportation, U.S. Department of Transportation, Washington, D.C.

Early, T. O., Jacobs, G. K., Drewes, D. R., and Routson, R. C., 1982, Geochemical Controls on Radionuclide Releases from a Nuclear Waste Repository in Basalt: Estimated Solubilities for Selected Elements, RHO-BW-ST-39 P, Rockwell Hanford Operations, Richland, Washington, September 1982.

Energy Reorganization Act of 1974, Public Law 93-438.

EPA, 1977, "Environmental Protection Agency, 40 CFR 190, Environmental Radiation Protection Standards for Nuclear Power Operations," Federal Register, Vol. 42, p. 2860, January 13, 1977.

EPA, 1980, Pollutant Emissions, 40 CFR 51.24, Revised as of July 1, 1980.

EPA, 1982, "Environmental Protection Agency, 40 CFR 191, Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes," Federal Register, Vol. 47, No. 250, December 29, 1982, Proposed Rule.

ERDA, 1975, Final Environmental Statement - Waste Management Operations, Hanford Reservation, Richland, Washington, ERDA-1538, 2 Volumes, U.S. Energy Research and Development Administration, Washington, D.C., December 1975.

ERDA, 1977, Alternatives for Long-Term Management of Defense High-Level Radioactive Waste, Hanford Reservation, Richland, Washington, ERDA-77-44, U.S. Energy Research and Development Administration, Washington, D.C.

Fitzner, R. E. and Price, K. R., 1973, The Use of Hanford Waste Ponds and Waterfowl and Other Birds, BNWL-1738, Pacific Northwest Laboratory, Richland, Washington.

Fitzner, R. E. and Rickard, W. H., 1975, Avifauna of Waste Ponds, ERDA Hanford Reserach, Benton County, Washington, BNWL-1885, Pacific Northwest Laboratory, Richland, Washington.

Foley, M. G., Petrie, G. M., and Craig, R. G., 1981, Geological Simulation Model for a Hypothetical Site in the Columbia Plateau: Results, PNL-3542-2, Pacific Northwest Laboratory, Richland, Washington.

Friedlander, G., Kennedy, J. W., and Miller, J. M., 1964, Nuclear and Radiochemistry, John Wiley & Sons, Inc., New York.

Gephart, R. E., Arnett, R. C., Baca, R. G., Leonhart, L. S., and Spane, F. A., Jr., 1979, Hydrologic Studies Within the Columbia Plateau, Washington: An Integration of Current Knowledge, RHO-BWI-ST-5, Rockwell Hanford Operations, Richland, Washington, October 1979.

GG/GLA, 1981, Economic Geology of the Pasco Basin, Washington and Vicinity, RHO-BWI-C-109, Geosciences Group and George Leaming Associates for Rockwell Hanford Operations, Richland, Washington, July 1981.

Golden, J., Quellette, R. P., Saari, S., and Cheremisinoff, P. N., 1979, Environmental Impact Data Book, Ann Arbor Science, Ann Arbor, Michigan, 864 pp.

Harty, H., 1979, The Effects of the Ben Franklin Dam on the Hanford Site, PNL-2821, Pacific Northwest Laboratory, Richland, Washington.

Helgeson, H. C., 1968, "Evaluation of Irreversible Reactions in Geochemical Processes Involving Minerals and Aqueous Solutions--I: Thermodynamic Relations," Geochimica et Cosmochimica Acta, Vol. 32, pp. 853-877.

Jacobs, G. K. and Apted, M. J., 1981, "Eh-pH Conditions for Groundwater at the Hanford Site, Washington: Implications for Radionuclide Solubility in a Nuclear Waste Repository located in Basalt," EOS, Transactions of the American Geophysical Union, Vol. 62, p. 1065.

Johnpeer, G. D., Miller, D., and Goles, G., 1981, Assessment of Potential Volcanic Hazards, Pasco Basin, Washington, RHO-BWI-CR-130 P, Ertec Western, Inc. for Rockwell Hanford Operations, Richland, Washington, pp. 3-1 to 3-44, August 1981.

Johnson, G. E., Loveland, T. R., and Anderson, W. H., 1981, The Columbia River and Tributaries Irrigation Withdrawals Analysis Project, Executive Summary, Report No. CRT-45, U.S. Geological Survey/U.S. Army Corps of Engineers, Sioux Falls, South Dakota.

KE/PB, 1982, Engineering Study, Nuclear Waste Repository in Basalt, Project B-301, RHO-BWI-C-116, Volumes I and II, A Joint Venture of Kaiser Engineers, Inc. and Parsons Brinckerhoff Quade & Douglas, Inc. for Rockwell Hanford Operations, Richland, Washington, March 1982.

Korosec, M. A. and Schuster, J. E., 1980, The 1978-1980 Geothermal Resource Assessment Program in Washington, Open-File Report 81-3, Division of Geology and Earth Resources, Washington State Department of Natural Resources, Olympia, Washington, July 1981.

Koster van Groos, A. F., 1981, Determination of Dehydration Temperatures of a Secondary Vug-Filling Mineral (Smectite Clay) Using a Differential Thermal Analysis at Various Pressures, RHO-BWI-C-102, University of Illinois for Rockwell Hanford Operations, Richland, Washington, March 1981.

Leaming, G. F., 1981, An Evaluation of Water Resource Economics Within the Pasco Basin, RHO-BWI-C-121, Rockwell Hanford Operations, Richland, Washington, September 30, 1981.

MacNish, R. D. and Barker, R. A., 1976, Digital Simulation of a Basalt Aquifer System, Walla Walla River Basin, Washington and Oregon, Water Supply Bulletin 44, Washington State Department of Ecology, Olympia, Washington.

Murphy, P. J. and Johnpeer, G. D., 1981, An Assessment of Geothermal Resource Potential, Pasco Basin and Vicinity, Washington, RHO-BW-CR-128 P, Ertec Western, Inc. for Rockwell Hanford Operations, Richland, Washington, August 20, 1981.

Myers. C. W. and Price, S. M., eds., 1981, Subsurface Geology of the Cold Creek Syncline, RHO-BWI-ST-14, Rockwell Hanford Operations, Richland, Washington.

Myers, C. W./Price, S. M., Caggiano, J. A., Cochran, M. P., Czimer, W. J., Davidson, N. J., Edwards, R. C., Fecht, K. R., Holmes, G. E., Jones, M. G., Kunk, J. R., Landon, R. D., Ledgerwood, R. K., Lillie, J. T., Long, P. E., Mitchell, T. H., Price, E. H., Reidel, S. P., and Tallman, A. M., 1979, Geologic Studies of the Columbia Plateau: A Status Report, RHO-BWI-ST-4, Rockwell Hanford Operations, Richland, Washington.

National Environmental Policy Act of 1969, Public Law 91-190, 42 USC 4321.

Nelson, R. A., Kocherhaus, J. G., and Schnapp, M. R., 1982, In Situ and Laboratory Geotechnical Test Results from Borehole GD-1 in Southeast Utah, ONWI-400, Woodward-Clyde Consultants for the Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, Ohio, November 1982.

Noise Pollution Control Act of 1972, Public Law 92-574, 86 Stat. 1234.

NRC, 1977, Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes, NUREG-0170, U.S. Nuclear Regulatory Commission, Washington, D.C.

NRC, 1978, "Proposed Statement of General Policy, Licensing Procedures for Geologic Repositories for High-Level Radioactive Wastes," Federal Register, Vol. 43, No. 223, pp. 53869-53872, November 17, 1978.

NRC, 1981a, "Nuclear Regulatory Commission, 10 CFR 60, Disposal of High-Level Radioactive Wastes in Geologic Repositories," Federal Register, Vol. 46, No. 130, July 8, 1981, Proposed Rules.

NRC, 1981b, Disposal of High-Level Radioactive Wastes in Geologic Repositories: Licensing Procedures, Title 10, Chapter 1, Code of Federal Regulations-Energy, Part 60, U.S. Nuclear Regulatory Commission, Washington, D.C., February 25, 1981.

NRC, 1982a, Standards for Protection Against Radiation, Title 10, Chapter 1, Code of Federal Regulations-Energy, Part 20, U.S. Nuclear Regulatory Commission, Washington, D.C., April 23, 1982.

NRC, 1982b, Disposal of High-Level Radioactive Wastes in Geologic Repositories, Title 10, Code of Federal Regulations-Energy, Part 60, Subpart E, U.S. Nuclear Regulatory Commission, Washington, D.C., November 18, 1982, Final Draft.

NRC, 1982c, Packaging of Radioactive Material for Transport and Transportation of Radioactive Material Under Certain Conditions, Title 10, Chapter 1, Code of Federal Regulations-Energy, Part 71, U.S. Nuclear Regulatory Commission, Washington, D.C.

Nuclear Waste Policy Act of 1982, Public Law 97-425.

NWTS, 1982, Proceedings of the 1982 National Waste Terminal Storage Program Information Meeting, DOE/NWTS-30, Office of National Waste Terminal Storage Integration, Battelle Memorial Institute, Columbus, Ohio, December 1982.

ONWI, 1979, Site Qualification Criteria, Draft, ONWI-33(2), Office of Nuclear Waste Isolation, Columbus, Ohio.

ONWI, 1981, Engineering Feasibility Studies for Candidate Salt Domes: National Waste Terminal Storage Repository No. 1, Special Study No. 5, ONWI-283, Stearns-Roger Services Inc. for the Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, Ohio, December 1981.

ONWI, 1982, Gulf Coast Salt Domes Geologic Area Characterization Report: Introduction, Volume I, ONWI-117, Law Engineering Testing Company for the Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, Ohio, July 1982.

Orgill, M. M., Sehmel, G. A., and Bander, T. J., 1974, "Regional Wind Resuspension of Dust," Pacific Northwest Laboratory Annual Report for 1973, Part 3, Atmospheric Sciences, BNWL-1850 PT3, Battelle, Pacific Northwest Laboratories, Richland, Washington, pp. 214-219.

Pacific Northwest River Basins Commission, 1980, Irrigated Lands in the Pacific Northwest, Land Resources Committee of the Pacific Northwest River Basins Commission for the Depletions Task Force of the Columbia River Water Management Group, Vancouver, Washington.

Price, E. H., 1982, Structural Geometry, Strain Distribution, and Tectonic Evolution of Umtanum Ridge at Priest Rapids, and a Comparison with Other Selected Localities Within Yakima Fold Structures, South-Central Washington, Ph. D. Dissertation, Washington State University, Pullman, Washington; also RHO-BWI-SA-138, Rockwell Hanford Operations, Richland, Washington.

PSPL, 1982, Skagit-Hanford Nuclear Project, Preliminary Safety Analysis Report, Puget Sound Power and Light Company, Bellevue, Washington.

Rasmussen, N. H., 1967, "Washington State Earthquakes 1840 through 1965," Bulletin of the Seismological Society of America, Vol. 57, No. 3, p. 463.

Reidel, S. P. and Fecht, K. R., 1982, Uplift and Subsidence Rates in the Central Columbia Plateau and Their Relation to Siting a Waste Repository at Hanford, Washington, RHO-BW-SA-187 P, Rockwell Hanford Operations, Richland, Washington, May 1982.

Rice, D. G., 1968a, Archaeological Reconnaissance - Ben Franklin Reservoir Area, 1968, Laboratory of Anthropology, Washington State University, Pullman, Washington.

Rice, D. G., 1968b, Archaeological Reconnaissance - Hanford Atomic Works, Laboratory of Anthropology, Washington State University, Pullman, Washington.

Salter, P. F., Ames, L. L., and McGarrah, J. E., 1981a, Sorption of Selected Radionuclides on Secondary Minerals Associated with the Columbia River Basalts, RHO-BWI-LD-43, Rockwell Hanford Operations, Richland, Washington, April 1983.

Salter, P. F., Ames, L. L., and McGarrah, J. E., 1981b, The Sorption Behavior of Selected Radionuclides on Columbia River Basalts, RHO-BWI-LD-48, Rockwell Hanofrd Operations, Richland, Washington, August 1981.

Savage, J. C., Lisowski, M., and Prescott, W. H., 1981, "Geodetic Strain Measurement in Washington," Journal of Geophysical Research, Vol. 86, No. 136, pp. 4929-4940.

Smith, M. J., Anttonen, G. J., Barney, G. S., Coons, W. E., Hodges, F. N., Johnston, R. G., Kaser, J. D., Manabe, R. M., McCarel, S. C., Moore, E. L., Noonan, A. F., O'Rourke, J. E., Schulz, W. W., Taylor, C. L., Wood, B. J., and Wood, M. I., 1980, Engineered Barrier Development for a Nuclear Waste Repository Located in Basalt, RHO-BWI-ST-7, Rockwell Hanford Operations, Richland, Washington, May 1980.

Sommer, D. J., Rau, R. G., and Robinson, D. C., 1981, Population Estimates for the Areas Within a 50-Mile Radius of Four Reference Points on the Hanford Site, PNL-4010, Pacific Northwest Laboratory, Richland, Washington.

State of Washington, 1979, State of Washington Population Trends, 1979, Population, Enrollment, and Economic Studies Division, Washington State Office of Financial Management, Olympia, Washington, August 1979.

State of Washington, 1981, Forecasts of the State and County Populations by Age and Sex: 1985-2000, With Estimates for 1980, Special Report No. 36, Forecasting and Support Division, Washington State Office of Financial Management, Olympia, Washington, May 1981.

State of Washington, 1982a, State of Washington Population Trends of 1982, State of Washington, Office of Financial Management, Olympia, Washington.

State of Washington, 1982b, Forecasts of the State and County Populations by Age and Sex: 1985-1990, Special Report No. 59, Forecasting and Support Division, Washington State Office of Financial Management, Olympia, Washington.

State of Washington, 1982c, Annual Planning Report: 1982, State of Washington, Employment Security Department, Richland-Pasco-Kennewick SMSA, Olympia, Washington.

State of Washington, 1982d, Labor Area Summary, State of Washington, Employment Security Department, Richland-Pasco-Kennewick SMSA, Olympia, Washington.

Stephan, J. G., Foote, H. P., and Coburn, V. L., 1979, Well Location and Land-Use Mapping in the Columbia Plateau Area, RHO-BWI-C-61/PNL-3295, Pacific Northwest Laboratory for Rockwell Hanford Operations, Richland, Washington, October 1979.

Stobbs, J. J. and Swallow, A. J., 1962, "Effects of Radiation of Metallic Corrosion," Metallurgic Reviews, Vol. 7, No. 25.

Stone, W. A., Jenne, D. E., and Thorp, J. M., 1972, Climatolography of the Hanford Area, BNWL-1605, Battelle, Pacific Northwest Laboratories, Richland, Washington.

Tallman, A. M., Fecht, K. R, Marrath, M. C., and Last, G. V., 1979, Geology of the Separation Areas, Hanford Site, South-Central Washington, RHO-ST-23, Rockwell Hanford Operations, Richland, Washington.

Tanaka, H. H., Hansen, A. J., Jr., and Skrivan, J. A., 1974, Digital-Model Study of Groundwater Hydrology, Columbia Basin Irrigation Project Area, Washington, Water-Supply Bulletin 40, Washington State Department of Ecology, Olympia, Washington.

T-CRERC, 1982, Tri-Cities Real Estate Research Report, Tri-Cities Real Estate Research Committee, Richland, Washington.

USGS and PAG, 1981, Geodolite Observations Near Hanford, Washington, RHO-BW-CR-132 P, U.S. Geological Survey and the Performance Assessment Group, Basalt Waste Isolation Project, Rockwell Hanford Operations, Richland, Washington, October 1981.

UWGP, 1979, Annual Report on Earthquake Monitoring of Eastern Washington, Geophysics Program, University of Washington, Seattle, Washington.

Wallace, R. W., Landstrom, D. K., Blair, S. C., Howes, B. W., Robkin, M. A., Benson, G. L., Reisenauer, A. E., Walters, W. H., and Zimmerman, M. G., 1980, Topical Report on Release Scenario Analysis of Long-Term Management of High-Level Defense Waste at the Hanford Site, PNL-3363, Pacific Northwest Laboratory, Richland, Washington.

WCC, 1975, Socioeconomic Study: WPPSS Nuclear Projects 1 and 4 and Supplement, Woodward-Clyde Consultants, San Francisco, California, for Washington Public Power Supply System, Richland, Washington, April 1975.

WCC, 1980, Site Locality Identification Study: Hanford Site, Vol. I: Methodology, Guidelines, and Screening; Vol. II: Data Cataloging, RHO-BWI-C-62, Woodward-Clyde Consultants for Rockwell Hanford Operations, Richland, Washington, July 1980.

WCC, 1981, Study to Identify a Reference Repository Location for a Nuclear Waste Repository on the Hanford Site, Vol. I: Text; Vol. II: Appendixes, RHO-BWI-C-107, Woodward-Clyde Consultants for Rockwell Hanford Operations, Richland, Washington, May 1981.

Wood, B. J., 1980, Estimation of Waste Package Performance Requirements for a Nuclear Waste Repository in Basalt, RHO-BWI-ST-10, Rockwell Hanford Operations, Richland, Washington, July 1980.

WPPSS, 1974, Preliminary Safety Analysis Report, Amendment 9, Washington Public Power Supply System, Richland, Washington.

Wu, C. S., 1978, Sensitization, Intergranular Attack, Stress Corrosion Cracking, and Irradiation Effects on the Corrosion of Iron-Chromium-Nickel Alloys, ORNL/TM-6311, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Wukelic, G. E., Foote, H. P., Blair, S. C., and Begej, C. D., 1981, Monitoring Land and Water-Use Dynamics in the Columbia Plateau Using Remote-Sensing Computer Analysis and Integration Techniques, RHO-BW-CR-122 P/PNL-4047, Pacific Northwest Laboratory for Rockwell Hanford Operations, Richland, Washington, September 1981.