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TECHNICAL REVIEW
ON THE
SITE CHARACTERIZATION REPORT (SCR)
FOR THE
BASALT WASTE ISOLATION PROJECT (BWIP)

Final Report
April 15, 1983

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Prepared for
STATE OF WASHINGTON
Energy Facility Site Evaluation Council
High-Level Nuclear Waste Management Task Force

Golder Associates

Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

May 19, 1983

Mr. Nicholas Lewis, Chairman
High Level Nuclear Waste Management Task Force
EFSEC
Mail Stop PY-11
Olympia, WA 98504

Subject: Task 1- Evaluation of the SCR at BWIP

Dear Nick:

As directed by you under our contract, we have completed Task 1 of the project, i.e., our best-level-of-effort review of the Site Characterization Report (SCR) submitted 15 November 1982 by the U.S. Department of Energy (DOE) for the Basalt Waste Isolation Project (BWIP) at Hanford, Washington. Enclosed is our final report for this Task 1, consisting of Executive Summaries of each section/chapter contained in the SCR, as well as an introductory Preface and an Appendix containing documentation of our 15 April 1983 presentation of results to the Task Force.

We trust that you and the Governor's Task Force will find this technical document useful in the process of protecting the interests of the State of Washington in matters related to the potential siting of a high-level nuclear waste repository at Hanford. Should you have any questions or require other assistance, please feel free to call.

Sincerely,

GOLDER ASSOCIATES

David L. Pentz
Project Manager

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PREFACE

In accordance with the U.S. Nuclear Regulatory Commission's (NRC) licensing process, as set forth in 10CFR60 (NRC, 1981), the U.S. Department of Energy (DOE) submitted to NRC on November 15, 1982 a Site Characterization Report (SCR) (RHO, 1982) for a potential deep geologic repository site for disposal of high-level nuclear waste (HLW) in basalt at Hanford, Washington; the prime DOE contractor for the Basalt Waste Isolation Project (BWIP) is Rockwell. The purpose of this SCR is to present the site selection process, the available information regarding the potential site and preconceptual repository designs, and also to identify remaining issues and plans for their resolution, all as outlined in NRC's Regulatory Guide 4.17 entitled "Standard Format and Content of Site Characterization Reports for High-Level-Waste Geologic Repositories" (NRC, 1982). It was anticipated that the DOE would update the SCR periodically prior to submittal to the NRC of a license application for construction authorization. However, the Nuclear Waste Policy Act of 1982 was enacted subsequent to the submittal of the SCR. This Act requires a document (i.e., a Site Characterization Plan or SCP) which is similar to the SCR, but more comprehensive. It is now expected that an SCP will be produced for BWIP later this year. In order to facilitate this process, the NRC has offered a draft opinion on the SCR, issuing a Draft Site Characterization Analysis (DSCA) (NRC, 1983) in response to DOE's initial SCR submittal. The state in which the site is located (the State of Washington, in this case) also has the opportunity to participate in the review process, as established by the Nuclear Waste Policy Act of 1982. Hence, the State of Washington, under the instruction of the Governor and the coordination of the Energy Facility Site Evaluation Council (EFSEC), has established the High Level Nuclear Waste Management Task Force for this purpose. Golder Associates, Inc. (GAI) of Bellevue, Washington, a geotechnical/mining consulting firm with extensive experience in HLW disposal, was retained in February 1983 to provide technical support to the Task Force.

In order to assist the Task Force in their review of the initial BWIP SCR, GAI has been directed by the Task Force to critically review with a best-level-of effort the SCR and produce an executive summary for each section/chapter contained therein. The critical and salient points of each SCR section/chapter (i.e., existing data and interpretations/applications, as well as proposed plans/tests) have thus been identified and evaluated with respect to technical adequacy. The intent of this review has been constructive, so as to identify areas for which, in GAI's opinion, additional information is needed in order to satisfy State concerns prior to license application for construction authorization.

It should be recognized that because of the unprecedented nature of storing and ultimately disposing of HLW in a repository, additional information will become available with time as investigations continue. Also, the licensing process consists of several steps, at which it must be demonstrated with increasing assurance that performance of the repository system (in terms of public health and safety) will be acceptable. The SCR is a preliminary document to the licensing process, for which the NRC and affected states and affected Indian Tribes may offer opinions regarding what additional information will be needed to provide them with such reasonable assurance (at license application for construction authorization) and whether the plans present

will accomplish that goal. Hence, it is not necessary (or even expected) that all of the information which will be required at license application be available at this stage, e.g., detailed repository design and performance assessment. Rather, the available information should be presented, the additional information perceived to be required should be identified, and plans for achieving the additional information should be presented in sufficient detail to assure that the additional information will be obtained.

Based on the above perspective, GAI has evaluated the technical adequacy of the SCR content. GAI believes that many of the aspects of the SCR are adequate for this stage, i.e., either the existing data base is adequate for licensing or the additional information required for licensing has been properly identified and adequate plans presented for acquiring this information. In the interest of brevity, this review has focused on those aspects which should be emphasized prior to license application for construction authorization and are in GAI's opinion inadequately or improperly addressed in the current SCR. It should be emphasized that, although the perceived deficiencies of the SCR are focused on, the intent of this review has been constructive so that any actual deficiencies can be identified early on and corrected prior to licensing. In order to develop public acceptance, as well as technical concurrence, which will be necessary for development of a repository at Hanford, it is important that these discussions be open. This has been the intent of GAI's review.

The chapters of the SCR can be categorized into several main groups:

- Chapter 2 presents DOE's process for selecting the reference repository location (RRL)

- Chapters 3 through 9 present the existing data base for the RRL and DOE's present interpretation of that data base

- Chapters 10 and 11 present DOE's conceptual design information regarding the repository (surface and subsurface) and waste package, which take into consideration DOE's present interpretaton of the RRL data base

- Chapter 12 presents DOE's methodology for assessing performance of the repository system (i.e., the site in conjunction with design)

- Chapters 13 through 16 presents DOE-identified unresolved issues and DOE's plans for their resolution

- Chapter 17 presents DOE's site characterization program, which comprises a portion of their plans for issue resolution

- Other chapters and appendices.

As directed by the Task Force, an executive summary has been produced for each section/chapter contained in the SCR. Each such executive summary follows the same format, i.e.:

- Synopsis

  The synopsis is an abstract of the executive summary, briefly summarizing first the contents of the subject chapter (as presented by DOE in the SCR) and then GAI's evaluation of the technical adequacy of that content. It is intended that a non-technical audience could read this synopsis and be sufficiently informed regarding the general content of the subject chapter and its perceived deficiencies. This section has been written as far as possible to minimize detailed technical jargon. This step has some difficulties in that this will necessarily remove detailed discussion of all but the more important issues.

- Summary of Technical Content Presented by DOE in SCR Chapter

  This section summarizes the content presented by the DOE in the subject chapter of the SCR, as perceived by GAI, generally in technical terms where appropriate and by reference if necessary. This section is included so that the following section, "GAI's Evaluation of Technical Adequacy of DOE's SCR Chapter," would be placed in context within the same document. GAI has striven to faithfully precis the DOE presentation in the SCR. Although this cannot be done without filtering, it is not intended that any of GAI's opinions regarding this content be included in this summary. GAI cannot, however, assert that bias may not have inadvertently entered into this section.

- GAI's Evaluation of Technical Adequacy of DOE's SCR Chapter

  This section summarizes GAI's evaluation of the technical content presented by the DOE in the subject chapter of the SCR, as previously summarized. This evaluation, generally in technical terms where appropriate, is concerned with the technical adequacy of the contents, specifically:

  - adequacy of the existing data base, in terms of
    - accuracy, i.e., is the data presented regarding any significant aspect correct or is it suspect?
    - sufficiency, i.e., is the data regarding any significant aspect perceived to be enough for the purposes of an SCR or has that aspect been insufficiently addressed at this time?
    - comprehensiveness, i.e., have all significant aspects been addressed or have any been ignored at this time?
  - adequacy of plans for supplementing the existing data base (to correct any deficiencies, as noted above) sufficiently for the purposes of providing enough data and analyses necessary in a license application for construction authorization.
  - appropriateness of the interpretation of the existing data base and the application of that interpretation in repository design and future construction/operation/decommissioning or in the assessment of repository performance, both long and short term.

> Clearly, this evaluation incorporates GAI's opinions, especially regarding the relative significance of the various pertinent aspects of the repository system. Hence, a brief statement regarding GAI's opinion on the significant aspects which should be addressed by the DOE in the subject chapter precedes the evaluation. It is intended that the technical audience can read this evaluation and be sufficiently informed regarding the technical adequacy (especially specific deficiencies) of the subject chapter, as presented by the DOE. It is not intended that solutions for all perceived deficiencies be offered by GAI.

Subsequent to the preparation and submittal of draft executive summaries for each section/chapter contained in the SCR, GAI presented the major findings of their review to the Task Force on April 15, 1983. Copies of the viewgraphs used in this presentation are included here as an appendix.

The final executive summaries contained here reflect comments by members of the Task Force and others which were generated as a result of both the draft executive summaries and the presentation to the Task Force.

1. EXECUTIVE SUMMARY OF SCR CHAPTER 1 - INTRODUCTION

1.1 Synopsis

Chapter 1 of the SCR provides an overview of the regional setting of the Hanford Site and a general discussion of the events that led up to the present site screening and site characterization work. Brief descriptions of the geography and geology of the Hanford Site are presented to provide the reader with some background information for ease in following the more detailed discussions in the subsequent chapters. The purpose of the Site Characterization Report (SCR) is also put in context with the DOE repository siting and development process. In GAI's opinion, the information presented by DOE in this chapter is both appropriate and adequate as an introduction to the SCR.

1.2 Summary of Technical Content Presented by DOE in SCR Chapter 1

Chapter 1 of the SCR discusses the background and purpose of a DOE repository development program, as well as the structure and purpose of the SCR. In addition, the geography and geology of Hanford are briefly discussed.

DOE's Hanford Repository Site is located in broad, relatively flat, thick basalt flows in southeastern Washington. Concern regarding technical uncertainties in the long-term storage of nuclear waste in underground sites prompted drilling investigations in the mid-1960's at the Hanford Site. In the mid-1970's, Federal commercial radioactive waste management programs were expanded in the form of the National Waste Terminal Storage (NWTS) Program to identify potential repository sites in several different types of geologic media. The program includes research and development to support design, licensing, construction, operation and decommissioning of a repository. In April 1981, the DOE formally adopted a strategy to (1) develop mined geologic repositories for disposal of commercially generated high-level and transuranic radioactive waste and (2) undertake research and development of the necessary technology to ensure safe long-term containment and isolation.

The stated mission of the DOE program at Hanford (known as the Basalt Waste Isolation Project or BWIP) is to identify potential geologic repository sites in basalt within the Hanford Site, and to design the necessary facilities and develop the technology for permanent isolation of radioactive wastes in basalt formations. The Hanford Site is an area of approximately 570 square miles located in the Pasco Basin. Elevation varies from about 400 feet in the central part (Columbia River) to more than 4000 feet on the western boundary. The nearest population center is Richland, Washington.

The Columbia River Basalt Group are approximately 10,000 foot thick lava flows formed 6 to 16 million years ago. Overlying this group and between its three major subdivisions are sedimentary interbeds and formations composed of volcanic debris and flood deposits. As a result of stress through geologic time, folding, fracturing and faulting has developed. The reference repository location is in the flat-lying Cold Creek Syncline, overlain by about 600 feet of sediments. The reference repository location is on the western edge of Hanford, encompassing parts of the State Highway 240.

The SCR serves as a DOE planning document (in accordance with 10CFR60) and defines specific siting objectives, policies and criteria, and identifies the activities and their timing needed to accomplish the objectives.

The SCR focuses on DOE's geological and hydrological studies, development of nuclear waste packages and repository engineering studies with special emphasis on the development of performance standards for radionuclide release rates for the component systems. The purpose of the SCR is to provide the status of and identify the data necessary for the detailed site study phase and the plans for acquiring the data, including construction of an exploratory shaft and in situ testing. Following completion of the detailed site studies, the basalt reference repository location will be considered along with other candidate sites in the U.S. as the site recommended by DOE for repository construction.

Chapter 1 concludes with a brief description of the content of each of the subsequent chapters in the SCR.

1.3 GAI's Evaluation of Technical Adequacy of DOE's SCR Chapter 1

In GAI's opinion, the Introduction presents a balanced and informative orientation to the purpose, scope and content of the SCR. The tables and figures clearly show the regional/geological setting of the site and the chapter summaries present a useful guide to selective reading of the report.

2. EXECUTIVE SUMMARY OF SCR CHAPTER 2 - DECISION PROCESS FOR CHOOSING A REFERENCE REPOSITORY LOCATION AND AN ALTERNATE REPOSITORY LOCATION

2.1 Synopsis

Chapter 2 of the SCR presents the decision methodology, as well as its application, which has been used by DOE to select its reference repository location (RRL) at Hanford. This topic is important for the following reasons:

- The national significance of the project
- The necessity, both in terms of cost and of schedule, to identify a qualified site as quickly as possible
- The goal of DOE to conduct its repository decision making in an open and defensible manner.

DOE presents a brief discussion of the national repository siting strategy and its relationship to the activities underway at Hanford. DOE also discusses the Hanford site selection methodology and the factors considered, including technical, environmental and legal factors. The application of this methodology is discussed at length by DOE, describing the screening of the 1600 square mile Pasco Basin down to nine candidate sites. A formal decision methodology is described and then applied to identify the reference and alternate repository locations from these nine sites. DOE also presents a discussion of the exploratory shaft location selection process, as well as the ongoing decision analysis to determine the depth, or horizon, at which the repository will be located, if built.

In GAI's opinion, the site selection methodology presented by DOE in Chapter 2 of the SCR has the following limitations:

- The site selection methodology used by DOE was constrained at the outset by the requirement that only basalts underlying the Hanford Reservation, and to a minor extent the Pasco Basin, would be the focus of the repository siting effort. As a result, although DOE may have identified a qualified or suitable basalt site(s) within the Hanford Reservation, they may not have identified the best basalt site(s) within the Hanford Reservation, the State of Washington, or the continental U.S. It must be emphasized however that the site selection methodology needs only to produce a qualified site, and not necessarily the best site.

- The site selection methodology has inconsistencies in its application. Specific examples are the lack of consideration of environmental factors (except in early stages) and of new data obtained after the site selection process has been completed.

- The site selection methodology is subjective. This is demonstrated especially in the numerical assignment of importance, or decision weights, to the various decision factors. This process, however, is clear and has been carried out by technically capable personnel.

2.2 Summary of Technical Content Presented by DOE in SCR Chapter 2

Chapter 2 of the SCR presents the decision process DOE has used in selecting reference and alternate repository locations on the Hanford Site. Specifically, DOE presents:

- An overview of the national siting strategy
- The methodology used for identifying sites at Hanford
- The technical factors considered in siting
- The environmental factors considered in siting
- The legal and institutional factors considered in siting
- The application of this methodology to identify sites
- The process, and application of that process, to select a shaft site
- The selection of the repository depth or horizon.

The national repository siting strategy (in place prior to passage of the Nuclear Waste Policy Act of 1982) involves six steps, each focusing on a smaller area in order to identify and characterize licensable sites in an economic and timely manner. The six steps are:

(1) National survey/regional selection
(2) Regional surveys
(3) Area surveys
(4) Location surveys
(5) Detailed site characterization (including exploratory shaft)
(6) Site recommendation and selection.

Steps (1) through (4) comprise what DOE calls the site screening phase. The DOE effort at Hanford has completed these first four steps and, with the issuance of the SCR, is beginning Step (5), which will include the construction of an exploratory shaft to the prospective repository horizon. DOE presents the specific goal of its site screening effort to be "to identify a reference repository location (RRL) and an alternate repository location within the Hanford Site."

DOE presents the details of its site identification methodology, which consists of the following four steps:

(1) Identification of the objectives of siting, and development of screening and ranking guidelines that form the basis for area identification

(2) Development of a data base of appropriate scope and detail that could be utilized for defining the conditions within the areas defined in each step of the siting process

(3) Implementation of a multistep screening process that permits the application of guidelines to smaller and smaller areas until candidate sites are identified

(4) Utilization of a uniform ranking process to preferentially order the candidate sites, based on the application of ranking guidelines, to ultimately identify the RRL and an alternate repository location.

DOE presents a detailed description of the process and methodology of each of these steps.

Eight topics have been considered in developing technical factors to be used in the screening process. These factors, which have been derived from programmatic direction and draft regulations, fall into the following topics:

- Geology and tectonics
- Hydrology
- Meteorology
- Geochemistry
- Geomechanics
- Resource evaluation
- Human activity
- Site conditions potentially affecting system costs.

Evaluation of these topical areas has led DOE to develop thirty-six explicit site screening guidelines. Some guidelines are quantitative, such as the minimum thickness of dense basalt of 100 feet, while others are qualitative, such as the need to consider the locations with respect to commercial jet and military air routes.

Eight topics have been considered in developing environmental factors to be used in the screening process. These topics are:

- Radiology
- Ecology
- Air quality
- Water quality
- Land resources and use
- Aesthetics
- Historic, archaeological and cultural resources
- Socioeconomic impacts.

These topics have been examined by DOE, resulting in the development of additional specific site screening guidelines.

DOE has considered three legal and institutional factors which, although directing the siting process, have not resulted in any additional siting guidelines. These three factors are:

- Be open and accessible to the public
- Include efforts to inform and educate the public
- Involve a variety of interest groups to build acceptance as well as technical consensus.

Additionally, DOE has examined the Federal, State and Local legal framework to identify any factors which must be introduced into the siting process in order to comply with the law. Although the rules proposed and promulgated by NRC have been identified as being applicable to the siting process, no existing state or local regulations have been found to affect the siting process.

DOE discusses the application of this methodology to identify sites. Starting with the entire Pasco Basin, of which Hanford makes up approximately 40% by area, thirteen guidelines have been used to screen the entire Pasco Basin down to the Pasco Basin Candidate Area. Seven more detailed guidelines have been used to screen the candidate area down to six subareas. Four of these subareas are located either partially or totally outside of the Hanford Site, and have not been considered for a variety of reasons, including conflict with ongoing or potential agricultural activities. The remaining subareas have been screened according to topographical and environmental considerations, resulting in the identification of five site localities, each with an area of between ten and fifty square miles, and all within the Hanford site. The five localities have been subdivided into nine candidate sites. Twenty-three criteria have been used to screen these sites. A quantitative ranking has been performed, identifying the preferential order of sites and resulting in the identification of the reference and alternate repository locations.

Quantitative details of the ranking process are provided by DOE. In order to rank the sites, ten site characteristics have been identified and assigned scoring values and decision weights. The distance from geological lineaments carries 48 percent of the decision weight. The estimated thickness of the Umtanum flow and the estimated tiering within the Umtanum flow each carries 16 percent. The distance from potential earthquake sources has been assigned 13 percent of the decision weight. Finally, the expected groundwater travel time and the distance from bedrock fractures and faults carries, respectively, 4 and 3 percent of the decision weight. The remaining environmental factors carry no weight in the decision process, except as a "tie-breaker." These factors includes the degree of contamination, the density of "special" or threatened or endangered species, the degree of natural vegetative communities and the presence of unique microhabitats.

To select an exploratory shaft site within the RRL, DOE has drilled six boreholes to the top of the basalt to determine the dip of the flows. Additionally, DOE has considered the degree of surface radioactive contamination in order to avoid highly contaminated areas. DOE has selected an exploratory shaft site approximately 1 km east of State Highway 240 and about 2 km due west of the 200 West Area. To initiate the exploratory shaft program, DOE has continuously cored a principal borehole to a depth of about 4000 feet, providing DOE with the first "in situ" samples from depth at the RRL.

DOE discusses its identification of the candidate repository horizons. Throughout the project, the Umtanum basalt flow has been considered as the favorite horizon. DOE has now decided that the identification of the reference repository horizon should be subject to a more rigorous decision analysis method. Thus, DOE has now identified a second candidate horizon, i.e., the middle Sentinel Bluffs flow, which is shallower than the Umtanum and for which there is generally less data available at present. A decision on which flow to select is expected to be made by DOE in May, 1983.

2.3 GAI's Evaluation of Technical Adequacy of DOE's SCR Chapter 2

In GAI's opinion, a defensible decision process should be developed and used to select a site(s), especially due to the national significance and

visibility/sensitivity of repository siting. This methodology should start with the identification of the objectives and associated quantitative criteria for the entire repository system, and then determining the manner and extent to which a site can contribute to meeting these system objectives/criteria. These system objectives/criteria should include, but not be limited to, consideration of long-term performance (e.g., EPA criteria for radionuclide transmission to the accessible environment as given in draft 40CFR191); these system objectives/criteria should at least include all of those which will be considered during the licensing process. Favorable and unfavorable site characteristics can thus be identified, and their relative significance with respect to contributing to meeting the system objectives/criteria assessed. Explicit guidelines should then be developed for site screening/selection, e.g., by assigning weights to the values of each significant site characteristic, which is a measure of the extent to which the system objectives/criteria would be met by that value. In some cases, the presence of certain characteristics or values of certain characteristics will, by themselves, make it very unlikely that such a site would be able to meet the system objectives/criteria; such "fatal flaws" should constitute exclusionary criteria under the guidelines, so that such a site would be deemed unsuitable and excluded from further consideration. The guidelines should then be universally applied by assessing the actual characteristics for each potential site, and then determining (e.g., through the weights) the extent to which the system objectives/criteria will be met by that site. The potential sites can then be prioritized in terms of how well they meet the system objectives/criteria, and the "best" site then selected. GAI believes that, if such a process is explicitly and adequately followed, the site screening/selection process will be defensible and, moreover, the selected site will have the best chance of those considered for licensing action.

In GAI's opinion, the site selection methodology presented by DOE in Chapter 2 of the SCR has limitations in the following areas:

- Constraints of site selection methodology
- Consistency of application of site selection methodology
- Subjectivity of site selection methodology.

Each of these is discussed separately below.

DOE constrained the site selection process to the Hanford Reservation based on prior land use considerations and existing Federal ownership. Hence, the "best" basalt site may not have been selected. However, 10CFR60 does not require the "best" site to be selected, rather only that a "qualified" site be selected, where a qualified site is one which meets the performance criteria set by EPA (i.e., 40CFR191) and NRC (i.e., 10CFR60). Thus, the fact that DOE may not have selected the "best" basalt site is not relevant. DOE is, however, constrained to show with reasonable assurance in the license application (if submitted) that the selected site is a "qualified" site.

GAI's believes that the application of the site selection methodology is inconsistent. Two examples of inconsistencies are the considerations of environmental impacts and new data within the methodology. Although DOE states that one of its major siting objectives is to "minimize adverse

environmental impacts," no weight is given in the final siting decision to environmental considerations. Although certain environmental factors have been considered by DOE in area screening, GAI believes that by not considering environmental impacts in the final siting decisions DOE is apparently implying that all candidate sites are environmentally equivalent and/or that existing environmental quality is not a siting factor but rather may become a design consideration when and if detailed repository performance analyses are made for a license application. Similarly, DOE does not consider new data in their siting methodology. This is evidenced by the continuation of exploratory shaft activities at the RRL in spite of the drilling results of the principal borehole (RRL-2), which showed only about 84 feet of dense basalt in the Umtanum. If this thickness had been available for the siting decision process, then presumably the current RRL would have been rejected. DOE avoids this eventuality by shifting its focus to the middle Sentinal Bluffs flow, which in the principal borehole (RRL-2) has a thickness of dense basalt in excess of 100 feet, as a candidate repository horizon. It should be pointed out that the RRL was selected partially on the basis of the expected characteristics of the Umtanum, which are irrelevant for other repository horizons. As stated earlier, the consequence of the inconsistencies in the siting process may be small, provided the RRL proves subsequently to be a qualified site.

In GAI's opinion, the selection methodology is subjective. For example, DOE assigns twelve times more importance to the distance from a lineament than to the groundwater travel time from the repository to the environment, and has assigned no weight to the environmental impacts of project development. Although the relative weighting is clearly subjective and subject to differences in technical opinion, the consequences on the defensibility of the siting process should be minimal provided the RRL is subsequently shown to be qualified.

In conclusion, GAI believes that given DOE's requirement to constrain the potential site to the Hanford Reservation and the minimal site specific data related directly to performance which was available, the siting process could not have been conducted in any other significantly different manner. However, the siting process does not, in GAI's opinion, address the likelihood of subsequently demonstrating that the selected site will be licensable.

3. EXECUTIVE SUMMARY OF SCR CHAPTER 3 - GEOLOGIC DESCRIPTION OF THE REFERENCE REPOSITORY LOCATION AND THE SURROUNDING AREA

3.1 Synopsis

Chapter 3 of the SCR presents the available data regarding geologic conditions at the Hanford Site. These data cover all aspects of geologic conditions and include information relevant to the physiography, geomorphology, stratigraphy, structure, tectonics and seismicity of the site. This information contributes to the determination of repository design and to the assessment of overall repository performance.

The geologic data presented by DOE come from both direct observation and testing (e.g., field mapping, rock drilling and chemical analysis) and indirect observation (e.g., geophysical surveys). The available data on the deep, potential repository horizons, i.e., the middle Sentinel Bluffs flow (approximately 250 feet thick and 3000 feet deep) and the Umtanum flow (approximately 225 feet thick and 3600 feet deep), in the reference repository location (RRL) come from a combination of direct and indirect observation techniques.

The available data have been interpreted by DOE to show that there are no known geologic structures which would prevent locating a repository at the RRL and that there are no known stratigraphic or lithologic characteristics which would preclude locating a repository in one of the two candidate horizons. However, it is recognized by DOE in the SCR that additional data must be acquired to adequately assess the stratigraphy and lithology, including the lateral variation, of the candidate repository horizons.

In GAI's opinion, the geologic data presented by DOE in Chapter 3 of the SCR is accurate, sufficient, and comprehensive, except (as recognized by DOE) regarding the stratigraphy and lithology, including lateral variability, of the candidate repository horizons. Furthermore, based on the presented data, GAI concurs in general with DOE's present geologic interpretations.

3.2 Summary of Technical Content Presented by DOE in SCR Chapter 3

Chapter 3 of the SCR discusses the geology of the RRL and the surrounding area, with particular emphasis on the available data regarding the geologic characteristics of the potential repository horizons (i.e., the Umtanum and middle Sentinel Bluffs flows). These flows are two of a thick sequence of flows which comprise the Columbia River Basalt Group. Flows of the Columbia River Group were erupted from fissures in the earth's surface between 16.5 and 6 million years ago. The flows covered much of eastern Washington, central Oregon and parts of Idaho before cooling. Following extrusion, the basalt flows were deformed into anticlinal folds (some with associated faults) separated by very broad, open synclines. The RRL is located within the Cold Creek syncline.

The types of data presented may be summarized according to the following key topics and methods of data acquisition:

- Surficial characteristics and processes (physiography and geomorphology), by
  - reconnaissance and detailed mapping
  - photogeologic interpretation.
- Stratigraphy of potential repository host rocks, by
  - regional and detailed mapping
  - analyses of major and trace element geochemistry, borehole geophysics, paleomagnetics, and petrography
  - detailed core and outcrop studies of intraflow structures.
- Geologic structure, by
  - regional mapping
  - detailed mapping of the Pasco Basin and the Yakima folds
  - core logging
  - interpretation of remote sensing and geophysical studies, including seismic reflection and refraction, magnetic, gravity and magnetotelluric surveys.
- Tectonic setting, by
  - distribution and ages of basalt flows
  - analysis of strain distribution in selected Yakima folds
  - tectonic models from the kinematic analysis of structural elements
  - seismology and in situ stress measurements.
- Seismicity, by
  - historic seismicity
  - microearthquake monitoring using permanent and portable seismograph arrays
  - studies of earthquake focal mechanism solutions.
- Long-term regional stability, by
  - analysis of uplift rates calculated from age, distribution and thickness of basalt flows
  - geodetic surveys
  - earthquake focal mechanism solutions and in situ stress measurements
  - tectonic models of the Pasco Basin area.

In addition to the presentation of these data, the following observations and conclusions have been made by DOE:

- The RRL is located in the basin and valley terrain of the Pasco Basin, which occupies the southwestern part of the Central Plains Section of the Columbia Basin subprovince of the Columbia Intermontane physiographic province. Geomorphic units of the RRL area consist of catastrophic flood bars and alluvial plains, which remain virtually unchanged since late Pleistocene time.

- Bedrock of the Pasco Basin consists of three formations (Grande Ronde, Wanapum and Saddle Mountains) of the Columbia River Basalt Group. The basalt section is interbedded with sediments of the Ellensburg Formation and is overlain by the Ringold Formation and catastrophic flood deposits (see SCR Figure 3-17, which has been modified and included here).

- The middle Sentinel Bluffs flow is about 250 feet thick and occurs at a depth of approximately 3000 feet. The Umtanum flow is about 225 feet thick and occurs at a depth of approximately 3600 feet. Both flows are relatively flat-lying (i.e., dips are generally less than 1°), but show lateral variations in thickness in the area of the RRL on the order of tens of feet.

- Intraflow structures within basalt flows appear to be of three types (see SCR Figure 3-27), although characteristics change gradationally between each of the three. The type of intraflow structure within any particular flow may be determined on the basis of fracture abundance and geometry, and the size and abundance of vesicles, flow-top breccia and pillows. Intraflow structures show considerable lateral variation and cannot be predicted with certainty.

- Known faults in the Yakima Fold subprovince of the Columbia Plateau are associated with anticlinal folds and probably developed at the same time that folding occurred. Some faults within the Plateau are known to displace Quaternary sediments. These faults are all associated with anticlines.

- The RRL is located in the Cold Creek syncline. Although this is a very broad and open structure, some faults a few centimeters to one meter in width have been observed in basalt cores from the syncline. These faults are considered to have been produced by strain accompanying folding of the syncline.

- The RRL is considered to lie in an area of intact bedrock based on the available structural and geophysical information, although several aeromagnetic anomalies within this area and surrounding areas may correspond to bedrock structures.

- The Columbia Plateau is an area of low seismicity. The largest historic event (5.75 magnitude) occurred in 1936 in the Milton-Freewater area (approximately 70 miles to the southeast). Microearthquake swarms have been recorded at many locations in the Columbia Plateau, including some shallow events south of the RRL. Some small deep events (greater than 6 km) have also been recorded at the southern border of the RRL.

- Deformation of the Pasco Basin continues to occur at a very slow rate. Tectonic processes are therefore not considered to be a factor which might potentially have a significant impact on performance of a repository at the RRL.

- The area of the RRL is considered to be relatively unattractive for future subsurface mineral exploration compared with other areas of both the

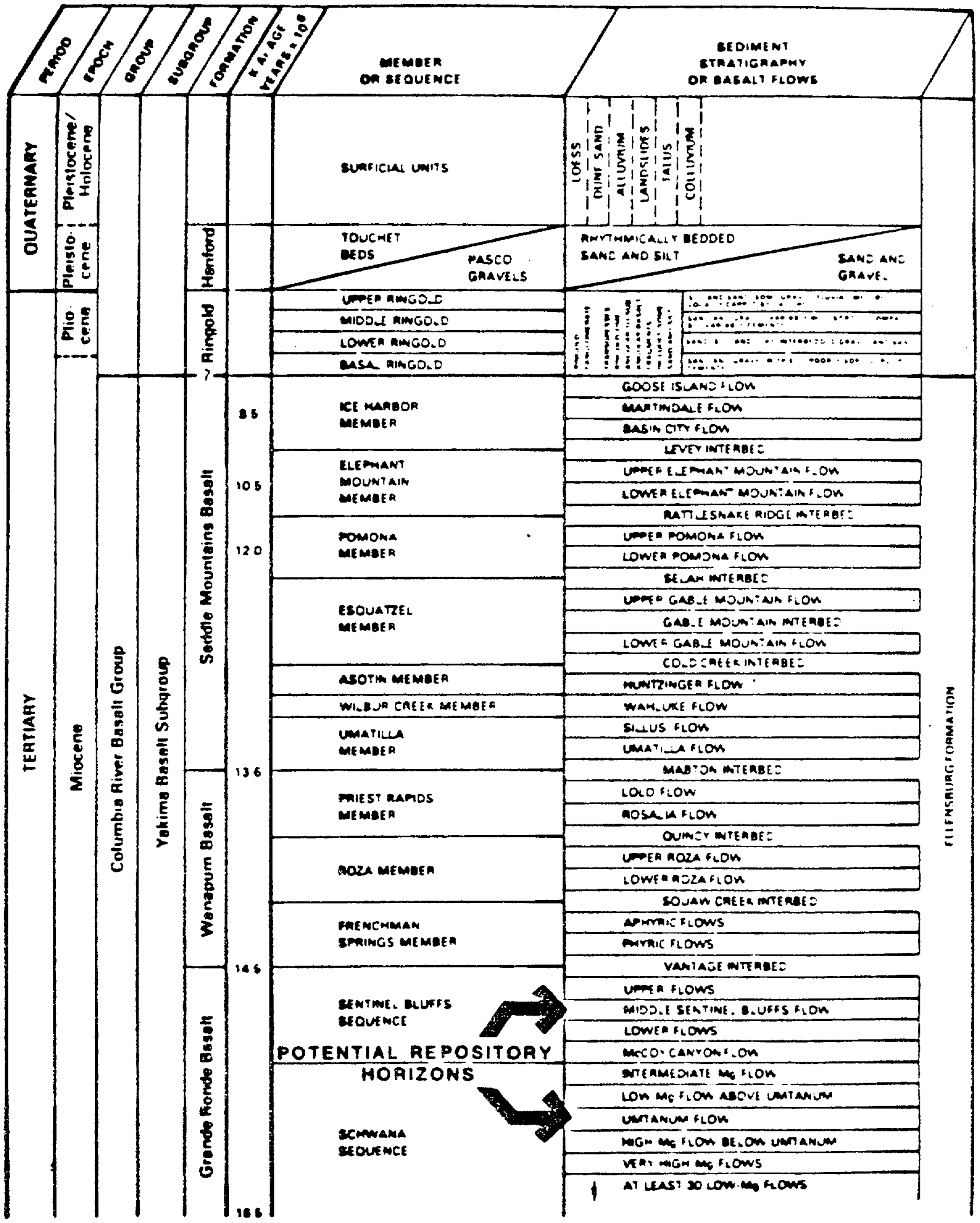

FIGURE 3-17. Stratigraphic Nomenclature, Pasco Basin, Cold Creek Syncline. (modified from SCR)

Columbia Plateau and the United States, although specific comparisons have not been made with areas of recent exploratory drilling for gas and oil on some anticlines in the Yakima Fold Belt.

3.3 GAI's Evaluation of Technical Adequacy of DOE's SCR Chapter 3

In GAI's opinion, the geologic conditions of the site should be adequately assessed, especially as a basis for repository design (e.g., depth and thickness of the repository horizon, including the potential variability over the area of interest) and to establish the geometric framework for the groundwater model. Thus, the lateral geologic variability of basalt flows should be assessed not only for the candidate repository horizon(s), but also for those horizons which will affect performance.

In GAI's opinion, the large body of geologic data presented (and referenced) by DOE and DOE's interpretations are adequate for the purpose of an SCR, with the qualification (as noted by DOE in the SCR) that additional data need to be acquired regarding stratigraphy and lithology of the candidate repository horizons and all horizons where a geologic understanding is necessary to predict groundwater transport conditions. GAI believes that this additional information is necessary to improve understanding of intraflow structures and thereby allow refinement of design and performance parameters. Secondarily, GAI believes that the attractiveness of the RRL for subsurface mineral exploration should be reassessed in light of recent exploratory oil and gas drilling within the region.

4. EXECUTIVE SUMMARY OF SCR CHAPTER 4 - GEOENGINEERING

4.1 Synopsis

Chapter 4 of the SCR presents the data available on geoengineering at Hanford, where geoengineering refers to the mechanical and thermal behavior of the affected rock (i.e., how the stresses in the rock will change and the rock thus deform and possibly fracture as underground openings are excavated and heated, and how the rock will heat up after the waste has been placed). This information is essential for repository design, especially of underground openings (including excavation and support), waste package layout, and backfilling/sealing, as well as for prediction of long-term performance.

Individual test results have generally not been presented by DOE, only referenced, except for a few "typical" examples. Rather, data have been summarized which pertain to the in situ stresses and mechanical and thermal properties of the potential repository horizons (i.e., the Umtanum and middle Sentinel Bluffs flows) and another flow (Pomona) in which the Near Surface Test Facility (NSTF) is located. The purpose of NSTF is primarily for developing test techniques and proving models for eventual use at the repository horizon, and secondarily for assessing the properties of the Pomona for comparison. DOE concludes that, although the existing geoengineering data is in some ways deficient, it is adequate for conceptual repository design and will be sufficiently improved following ongoing and future testing for licensing purposes.

GAI has several concerns regarding the adequacy of the existing geoengineering data base, specifically:

- Although individual test results have generally not been presented, some unexplained aberrant results have been observed, which questions the validity of some data, especially regarding in situ stress.

- Generally, insufficient data has been acquired regarding those characteristics/relationships which have been considered to assess the true variability.

- Not all of the significant geoengineering characteristics and relationships, which are necessary for repository design/analysis, have been addressed; especially, no data has been acquired regarding the characteristics (especially strength) of the rock mass (i.e., intact rock coupled with fractures containing secondary minerals) comprising the potential repository horizons and other affected zones.

DOE's plans for future testing to correct the above noted deficiencies in the existing geoengineering data base have only been alluded to here (see SCR Chapter 17).

Due to the above noted deficiencies in the existing geoengineering data base, DOE has justifiably been reluctant to draw conclusions regarding geoengineering. However, in GAI's opinion, preliminary interpretations of the existing geoengineering data base should be made (using engineering judgement and explicitly incorporating uncertainties) for development of test plans and for conceptual repository design/analysis. However, this application to

repository design has only been alluded to here (see SCR Chapter 10) and in any case cannot be accomplished until the interpretation is complete. GAI believes that DOE has not taken into proper account the significant effects of rock fractures (especially on rock mass strength) with respect to repository design (especially stability of underground openings); hence, DOE's present conceptual repository design may not be conservative with respect to the geoengineering aspects.

4.2 Summary of Technical Content Presented by DOE in SCR Chapter 4

Chapter 4 of the SCR discusses geoengineering at Hanford, specifically the data available regarding the in situ stress field and mechanical and thermal properties of the potential repository horizons (i.e., the Umtanum and middle Sentinel Bluffs flows) and another flow (Pomona) in which the NSTF is located. Each of these flows exhibits columnar jointing (from cooling) and consists of several zones, i.e., the entablature (middle zone of small, regular columns), colonnade (upper and lower zone of massive, irregular columns), and interflow (flow top and contact zones above and below colonnade). The "rock mass" is the assemblage of rock blocks, and thus consists of both intact rock (competent and unbroken rock) and discontinuities (fractures or joints), which are separations in the otherwise continuous fabric and hence, planes of weakness.

The data available on the following geoengineering characteristics have been summarized by DOE:

- Mechanical properties, i.e., regarding strength and deformability, from
  - laboratory tests on intact rock core from the entablature, colonnade, and interflow zones of the Umtanum, middle Sentinel Bluffs, and Pomona flows
  - in situ tests on the rock mass from the Pomona (NSTF), including only deformability determinations from borehole jacking and jointed block test (Step I - single-slot flatjack test with heaters)
  - laboratory tests on jointed rock core from the Umtanum, including only peak strength determinations.

- Thermal/thermomechanical properties, i.e., regarding heat flow and thermal expansion, from
  - laboratory tests on intact rock core from the entablature of the Umtanum, middle Sentinel Bluffs, and Pomona flows
  - in situ tests on the rock mass from the Pomona (NSTF), including only heat flow determinations from full scale heater tests (1 and 2).

- In situ stress field from
  - hydraulic fracturing tests in the Roza and Umtanum flows
  - overcoring and hydraulic fracturing in the Pomona (NSTF).

In addition to the presentation of the above data, the following observations and conclusions have been made by DOE:

- Intact basalt is strong and brittle, and exhibits significant variation; specifically

- the intact Pomona is denser and stronger than the intact Umtanum
- while substantial variation in mechanical properties of intact rock exists in any flow zone, the mechanical properties of intact rock in the entablature and colonnade are similar within each flow, and the intact interflows are less competent
- strength of intact rock decreases with temperature and increases with confining stress, while deformability of intact rock is essentially independent of temperature and confining stress.

- Rock mass mechanical behavior is generally less favorable than that of the intact rock, due to the presence of discontinuities (which are planes of weakness). These discontinuities are primarily in the form of truncated columns oriented from vertical to horizontal and of 1/2 to 1 foot maximum dimensions in the entablature. Most fractures in the entablature have narrow apertures (openings of less than 0.5 mm) and contain secondary minerals, while more open fractures (several mm) are associated with flow tops or bottoms.

- Regarding heat flow
  - heat flow properties of intact rock are a function of temperature
  - rock mass heat flow can be predicted relatively accurately based on properties of intact rock
  - rock mass thermal displacements can be predicted well in directions parallel to the columns and poorly in the perpendicular direction.

- The maximum in situ horizontal stress is 2.3 times the vertical overburden stress and is oriented N23°E (perpendicular to the axis of the Cold Creek Syncline), while the minimum in situ horizontal stress is 1.3 times the vertical overburden stress and is oriented perpendicular to the maximum horizontal stress.

- Regarding effects on repository construction
  - in situ stresses and rock mass strength at the candidate repository horizons will not pose a major problem to repository construction
  - possibility of rock bursting is remote
  - rock spalling under thermal loads is not likely
  - excavation methods (i.e., drill-and-blast or tunnel boring methods) will affect repository design and performance due to rock mass disturbance, but based on limited experience in conditions similar to the repository there is no clear preference.

- Regarding the performance of specific tests conducted in the NSTF, which might be conducted later in the repository horizon(s)
  - borehole jacking worked, but gave questionable results
  - single-slot flatjack test with heaters worked, but borehole deformation gages which were used generally did not survive at higher temperatures
  - full scale heat test (1 and 2) worked, especially thermocouples and borehole extensometers performed well, but borehole deformation gages and vibrating wire stress meters had problems at high temperatures
  - overcoring had difficulties and gave questionable results because of jointing
  - hydraulic fracturing worked well.

4.3 GAI's Evaluation of Technical Adequacy of DOE's SCR Chapter 4

In GAI's opinion, the mechanical properties (i.e., strength and deformability), in conjunction with the in situ stress field, should be assessed for the volume of rock mass around prospective underground openings in order to adequately design these openings (in terms of excavation and support) and predict their performance (i.e., deformation and stability). Similarly, thermal properties (i.e., thermal conductivity, diffusivity, specific heat thermal expansion), in conjunction with the in situ temperature field, should be assessed for the volume of rock mass which will be heated in order to adequately design waste package layout (in terms of spacing and age) and predict heat flow and temperature increases; these temperature increases are expected to affect the mechanical behavior (i.e., increasing deformations and weakening the rock) and have an effect on both hydrology and geochemistry. Furthermore, it is GAI's opinion that this assessment of geoengineering characteristics (which may have significant natural variability) should be based on an interpretation of a data base, which should be adequate to give low enough uncertainty in this assessment. This uncertainty (resulting from deficiencies in the data base) should be explicitly evaluated.

Although much data has been summarized and many of the qualifications/limitations of this data and the resulting conclusions have been discussed by DOE, GAI has some additional concerns regarding the technical adequacy of this information and how it will be applied.

In GAI's opinion, the existing geoengineering data base presented by DOE is inadequate in several respects.

The uncertainty associated with the existing individual geoengineering data has not been evaluated because the details of the performance of each test, especially regarding results and representativeness of the sample used, are not presented by DOE. Standard procedures are referenced by DOE for the various tests, where available, or the procedure briefly described for tests such as the jointed block test and full scale heater test. Individual test results are not presented by DOE, only referenced, except for some typical examples of results for the single-slot flatjack test, full scale heater test (1 and 2), and hydraulic fracturing. Assuming adequate QA/QC has been followed in the performance of standard tests, the results can be considered to be accurate. However, the following possible exceptions have been observed by GAI which lead to the conclusions that there is, in many cases, significant uncertainty in the geoengineering data presented by DOE:

- The use of a linear stress failure criterion (i.e., Mohr-Coulomb in terms of cohesion and friction angle) to describe strength of rock (intact rock, discontinuities, or rock mass) and linear elastic parameters (Young's modulus and Poisson's ratio) to describe deformability are generally poor approximations of rock's typical non-linear nature, and thus result in additional uncertainty.

- There is much more scatter in the strength and deformability measurements on intact rock from laboratory tests, especially for the Umtanum (see SCR Table 4-2, Figure 4-2), than would be expected from natural variability,

which suggests that either the samples used may not have been representative (e.g., containing fractures) or that testing errors may have occurred.

- The deformation modulus values determined from the borehole jacking method are suspect in that the scale of the sample is small and strongly affected by undetected joints; there is wide scatter in the results (see SCR Table 4-4) probably due to such joints and the results are somewhat inconsistent (low in comparison) with other generally more reliable tests (e.g., flatjack tests).

- The determination of stress in the wall of an opening by the single-slot flatjack test using vibrating wire stressmeters entails significant uncertainty, as shown in the wide range of results (see SCR Figure 4-6); although the deformation modulus determined by the flatjack test has been reported, the method by which this determination was made (apparently nonstandard) has not been discussed.

- The determination of peak shear strengths for individual discontinuities by triaxial lab tests (see SCR Tables 4-6 and 4-7) include some aberrant results, specifically inconsistent trends (in DC-8/1,112.1 and DC-8/1,100.2 the stress ratio at failure should monotonically decrease towards a residual value with increasing confining stress; these results suggest possible test errors) and unrealistically low results (in DC-4/1,111.9 and DC-4/1,123.2 the results indicate either a very weak undetected infilling material, e.g., clay, or possible test errors).

- The heat flow properties are not properly defined, in that specific heat and mass heat capacity appear to have been used interchangeably; although the definition of specific heat is essentially correct, it is dimensionless (mass heat capacity has the dimensions shown) and the definition of thermal diffusivity in terms of specific heat is incorrect (it should be in terms of mass heat capacity). This confusion leads one to suspect data regarding this property.

- The determination of in situ stresses by hydraulic fracturing involves significant uncertainties, especially in the maximum horizontal stress and to a lesser extent, in the minimum horizontal stress, due to the assumptions involved. The assumption that no fluid intrudes into the rock prior to fracturing may be invalid so that the actual pore pressure is not known, as assumed. Also, the assumption that the stress parallel to the borehole (i.e., the vertical stress) is the intermediate principal stress and has no effect on the results (so that fracture will initiate and propagate in a plane along the axis of the borehole perpendicular to the minimum principal stress) may be invalid. Rather, it has been concluded that the vertical stress is the minor principal stress so that, although the crack initiates parallel to the axis of borehole, it may twist undetected beyond the annulus of the borehole to a plane perpendicular to both the axis of the borehole and the vertical stress (rather than the minimum horizontal stress), as suggested by the horizontal cracks in the borehole wall (see SCR Figure 4-19). Also, the summary of test results (see SCR Table 4.11) is inconsistent with the typical example test results

(see SCR Figures 4.17 and 4.18), which suggests additional uncertainty in the data; interestingly, the shut-in pressure shown in the typical example test results is approximately equal to the vertical overburden pressure, which would also suggest that the crack may have propagated in a horizontal plane. In addition, the in situ stress determinations made at NSTF (see SCR Table 4-12) differ significantly in magnitude between methods (overcoring versus hydrofracturing), and the orientations derived from both methods are perpendicular to those observed in DB-15 and DC-12 and to what would be expected from the anticlinal structure, again suggesting additional uncertainty in the data. Finally, the presence of core discing indicates maximum stress ratios with a significantly higher lower bound than 1, as reported by DOE.

In GAI's opinion, the existing geoengineering data base is presently neither completely sufficient nor comprehensive, i.e., generally not enough data has been acquired regarding each characteristic considered nor have all the significant characteristics (and their relationships with conditioning parameters) been addressed. In most cases, DOE has recognized these deficiencies and has suggested that these deficiencies are either presently being corrected or will be in the future. However, other approaches should also have been used (and may still be in the future) in assessing certain characteristics, especially:

- Regarding determination of mechanical properties of discontinuities, direct shear tests could have been performed on core and on large scale samples obtained from the NSTF and exposures.

- Regarding determination of rock mass mechanical characteristics (strength and deformability); there are empirical methods available for assessing these as well as analytical models which combine the more easily determined behavior of the components (intact rock, discontinuities, and pore fluid). Such methods, which themselves often entail significant uncertainty, could have been used to estimate and then partially verify the characteristics.

- Regarding determination of rock mass thermal properties, the single-slot flatjack test data could have been used.

- Regarding determination of the in situ stress field, the presence of core discing yields more information than has been presently utilized, and the determination of stresses around an opening (e.g., by single-slot flatjack test) could have been used; standard deformation measurements could have been made to support the determination of stress in the wall at NSTF.

- Observation/monitoring during construction of the NSTF offered an opportunity to accurately assess rock mass characteristics, as well as excavation/support methods under certain conditions.

Certain significant characteristics (or the relationships of certain significant characteristics with conditioning parameters) which are important to repository design/analysis, have not been addressed by DOE in this chapter. Most importantly, no data on any rock mass characteristics have been presented

by DOE at this time for the reference repository horizons or overlying strata, except for the Pomona (NSTF), for which there is no data regarding rock mass strength (peak and residual), creep, or thermomechanical properties, only for deformability (as a function of temperature) and heat flow. There is also no data regarding the characteristics of intact rock or discontinuities of any horizon except the Umtanum, middle Sentinel Bluffs, and Pomona, and even in these flows no data has been presented for the following significant characteristics/relationships:

- Shear strength of intact rock from the middle Sentinel Bluffs and non-entablature zones of the Umtanum
- Residual shear strengths or creep for intact rock in any zone or flow
- Mechanical properties of discontinuities in any flow except the Umtanum, and even in the Umtanum data is presented only for peak shear strengths (and not residual shear strengths or stiffnesses)
- Temperature effects on any mechanical properties of middle Sentinel Bluffs
- Thermal properties of intact rock from any but the entablature zones, and even these do not include the effect of confining pressure or of jointing
- Anisotropy of properties in any flow or zone (except in the Pomona where modulus anisotropy and heat flow anisotropy in the horizontal plane were determined from borehole jacking and full scale heater tests, respectively)
- Correlation of properties with density/porosity of intact rock or roughness/aperture of discontinuities, or with scale of sample
- Secondary minerals contained within fractures, and the possibly detrimental effects of heat on their mechanical properties.

In addition to ignoring certain significant material characteristics, there is no data (or references) presented by DOE regarding in situ temperatures anywhere at Hanford or in situ stresses other than in limited zones in the Umtanum and Roza (eight or more km away) and Pomona (NSTF).

DOE's plans for future testing are only alluded to here (see SCR Chapter 17 - Site Characterization Program). It is GAI's opinion that this additional testing should produce high quality data (i.e., with low uncertainty) and result in a comprehensive and sufficient data base, which can be readily and defensibly interpreted and then applied to repository design/construction. It is especially important that rock mass characteristics (especially strength) of the repository horizon(s), as well as all other affected zones, and the in situ stress field be adequately assessed, using data from a variety of available sources. This will require access (by exploratory shaft) and subsequent in situ testing. Suitable site-specific correlations should be developed between the significant characteristics (e.g., rock mass strength) and more easily measured physical properties (e.g., joint spacing, orientation, aperture), so that these physical properties can be determined over wide areas to assess the variability of the rock mass characteristics. Predictive performance models should also be site-verified. In terms of test details, as developed at NSTF, the conditions (especially stresses) at depth may be very different so that conclusions drawn from NSTF regarding test methodology may be invalid; e.g., although flatjacks worked well at NSTF, they may not have sufficient capacity to reestablish high stresses, whereas overcoring may be more reliable at such higher stresses.

Due to the deficiencies in the existing geoengineering data base, DOE has justifiably been reluctant to draw conclusions regarding geoengineering, i.e., interpretation and application. However, in GAI's opinion, these deficiencies should not preclude preliminary interpretations of the existing geoengineering data base which incorporate engineering judgement; i.e., the deficiencies in the existing geoengineering data base (especially uncertainty in individual data) should first be assessed and then the data combined in a coherent manner consistent with accepted engineering principles. This interpretation should assess and incorporate all sources of uncertainty (including possible errors/biases in data and ignorance), as well as natural variability, preferably in the form of probability distributions for each characteristic/relationship. Statistical distributions of data, as presented by DOE, may be misleading in predicting or estimating the actual distribution of values of characteristics, as the data on which they are based may be biased and insufficient. Where the data base is insufficient (e.g., complete ignorance or lack of data), there would clearly be large uncertainty (expressed as a wide probability distribution). Due to natural variability, there will in any case be residual uncertainty in the value even as the deficiencies in the data base are eliminated.

The estimated geoengineering characteristics of the rock mass (i.e., mechanical and thermal/thermomechanical characteristics, as well as the effects of temperature on the mechanical characteristics, and in situ stress and temperature), including uncertainty, will be applied to repository design and construction. This application to repository design has only been implied (see SCR Chapter 10 - Repository Design). However, it appears that intact rock characteristics, which may be significantly different than the appropriate rock mass characteristics (especially strength and deformability), have been used by DOE in the conceptual design. If this is the case, DOE's conceptual design has been based on generally unconservative assessments of material characteristics. For example, DOE's conclusion that neither support or rock bursting will be a problem may be invalid. Also, there are empirical procedures, based not only on the limited experience in basalt presented, which are available for excavation/support design, but have not been discussed by DOE. It is GAI's opinion that the degree of natural jointing will significantly affect performance and thus design, which has apparently not been fully appreciated by DOE. For example, increasing and flattening the span of underground openings in response to the perceived in situ stress field may be inadvisable due to the nature of jointing at Hanford. Detrimental loosening of the rock mass may also occur if the excavation/support procedures are not carefully controlled, both in tunnels and horizontal waste emplacement holes (if used).

In conclusion, GAI believes that the existing geoengineering data base, and its subsequent interpretation and application, is inadequate in the following respects:

- Potential biases/errors in data have not been fully assessed, especially regarding in situ stresses.

- Not enough data has been obtained for many characteristics, especially within the middle Sentinel Bluffs flow.

- Not all significant characteristics have been adequately addressed, especially the physical characteristics and mechanical properties of discontinuities.

- The uncertainty in the assessment of each significant characteristic (i.e., interpretation of the data base) has not been adequately addressed.

- The application of geoengineering data to repository design/analysis, especially regarding stability of underground openings, the waste emplacement/retrieval schemes (horizontal vs. vertical), and long-term performance, has not been adequately addressed.

5. EXECUTIVE SUMMARY OF SCR CHAPTER 5 - HYDROGEOLOGY

5.1 Synopsis

Chapter 5 of the SCR presents data describing the hydrogeology at the Hanford Site. Since groundwater flow is generally believed to be the major potential release mechanism from a waste repository, adequate knowledge of the hydrogeologic conditions at Hanford is critical for long-term performance assessment and design of the engineered barrier system.

DOE's characterization of the hydrogeologic system has been based upon testing and monitoring in single, small-diameter coreholes drilled at various locations within the Pasco Basin. Specific data obtained from the coreholes include geologic information, hydraulic parameters, hydraulic heads and hydrochemistry.

A conceptual model of the groundwater flow system has been presented by DOE. It consists of horizontally layered basalt flows comprised of permeable flow tops and relatively impermeable colonade/entablature zones. Sedimentary interbeds occur between some basalt flows and are of relatively high permeability. Groundwater flow is thought to be primarily horizontal from the reference repository location (RRL) with a slight upward hydraulic gradient. Groundwater discharge from the RRL is believed to occur into the Columbia River near Wallula Gap.

GAI is concerned with several aspects of the hydrogeology data base and future testing plans of DOE, as presented in the SCR. Specifically, it is GAI's opinion that:

- The representativeness of hydraulic parameters measured in small-diameter coreholes is questionable. Existing data are from spot measurements and probably do not represent the large-scale values required for performance modeling. Large-scale multiple-hole pump tests are needed to measure representative hydraulic parameters. However, DOE's plans for such tests, as presented in the SCR, are not adequate in GAI's opinion.

- Values of hydraulic head measured using packer technology are inadequate. GAI believes that long-term measurements of hydraulic head in permanent piezometer installations are necessary for refinement of the conceptual model and calibration of performance models. DOE's plans, as presented in the SCR, do not indicate that this deficiency will be corrected by future work.

- Hydrogeologic boundaries formed by geologic structures are inadequately defined by DOE. GAI believes that DOE's proposed hydrogeologic testing is inadequate to investigate hydrogeologic boundaries to the level necessary for performance modeling.

- DOE's conceptual model of groundwater flow, as given in the SCR, is not uniquely supported by the data. GAI believes that other conceptual models consistent with the data are plausible and should be considered.

- Hydrochemistry data are cited by DOE as major evidence in support of their conceptual groundwater model. GAI considers many of DOE's conclusions regarding hydrochemistry speculative and does not believe that current hydrochemistry data can be used as conclusive evidence in support of the DOE conceptual model of groundwater flow.

5.2 Summary of Technical Content Presented by DOE in SCR Chapter 5

Chapter 5 of the SCR discusses the hydrogeology of the Hanford Site. Studies have been conducted at regional (i.e., Columbia River Plateau), Pasco Basin and site-specific (RRL) scales. Data presented by DOE are primarily derived from hydrogeologic investigations conducted by Rockwell Hanford Operations within the Pasco Basin for the specific purpose of investigating the suitability of the site for a waste repository. Hydrogeologic data for other regions in the Columbia River Plateau are derived largely from other investigations for purposes other than characterization of the Hanford Site.

Aspects of the hydrogeologic system which are described by DOE include:

- Hydrogeologic units in the Pasco Basin, including glacial/fluvial sediments, the Ringold Formation and the Saddle Mountains - Wanapum - Grande Ronde basalt flow sequence

- Hydraulic parameters, including measured values of horizontal hydraulic conductivity, effective porosity and dispersivity, and inferred values of vertical hydraulic conductivity

- Hydraulic heads in the upper sedimentary units and underlying basalts

- Hydrochemistry of groundwater in the basalts.

Specific data presented by DOE in Chapter 5 of the SCR include:

- Hydrogeologic units in the basalt determined from
  - core samples from small-diameter (3 inch) holes
  - geophysical logs; in particular neutron-neutron logs used to differentiate dense basalt (colonade/entablature) from flow tops and interbeds.

- Hydraulic parameters, including
  - horizontal hydraulic conductivity measured using packer test technology in single, small-diameter holes and one dual-hole test in DC-7/8 representative of a scale of approximately 50 feet
  - effective porosity and dispersivity measured by tracer test methods in hole DC-7/8.

- Hydraulic head measurements from
  - numerous open wells completed into the upper sedimentary aquifers
  - water levels measured in packed-off intervals in basalt as part of the drill and test sequence.

- Hydrochemical characteristics of groundwater sampled during the drill and test sequence, including
  - major ions

- minor and trace elements
- dissolved gases
- temperature, pH, Eh
- stable isotopes (oxygen-18, deuterium, carbon-13, sulfur-34)
- radioactive isotopes (carbon-14, tritium, chlorine-36).

On the basis of these data, DOE has developed a conceptual hydrologic model of the Hanford Site which envisions a layered flow system comprised of permeable basalt flow tops and sedimentary interbeds separated by dense colonade/entablature zones of very low vertical permeability. Horizontal groundwater flow is thought to be generally southeast from the RRL, although the possibility of a northward flow component towards the Gable Mountain - Umtanum Ridge anticline is indicated. Vertical hydraulic gradients generally indicate a slight upward flow. Groundwater discharge from the Saddle Mountains, Wanapum and Grande Ronde basalts is thought to occur into the Columbia River near Wallula Gap and along the reach between Sentinel Gap and Priest Rapids Dam.

The following observations and conclusions about the hydrogeologic system in the Pasco Basin are presented by DOE in SCR Chapter 5:

- The flow system in the basalt is under confined conditions with confinement provided by the dense colonade/entablature zones.

- Lateral groundwater flow is dominant in the flow tops and interbeds. Horizontal hydraulic conductivities measured in coreholes range from approximately 10^{-9} to 10^{-2} m/s in these units.

- Limited vertical leakage occurs across dense basalt zones in non-structurally deformed areas. Vertical hydraulic conductivity is inferred to be less than or equal to 10^{-12} m/s. Greater vertical leakage is believed to occur in areas containing geologic structures, such as the Gable Mountain - Umtanum Ridge anticline. Sedimentary interbeds have no discernible influence on the vertical distribution of hydraulic head.

- A significant hydrogeologic boundary exists several miles west of the RRL at the mouth of the Cold Creek Valley. Nearly 100 meters of head drop in the Mabton interbed have been observed across this boundary. Other structural discontinuities can have a significant influence on groundwater flow.

- The general direction of lateral groundwater flow in the basalts is towards the southeast in the Cold Creek Syncline. The principal area of groundwater discharge is suspected to be south of the Hanford Site near Wallula Gap.

- Hydrochemical data indicate a lack of significant vertical groundwater mixing between major basalt units. This evidence is used to support a very low value of vertical hydraulic conductivity for dense basalt.

5.3 GAI's Evaluation of Technical Adequacy of DOE's SCR Chapter 5

Groundwater flow is universally recognized as the major potential escape mechanism for radionuclides from a waste repository. Technical criteria

currently proposed by the NRC specifically address groundwater in the overall performance objectives, including requirements that EPA criteria must be met, general provisions pertaining to the geologic setting which state that pre-emplacement groundwater travel times should exceed 1000 years unless specific exception is granted, and siting requirements specifying various favorable and potentially adverse conditions relating to groundwater. Thus, it is mandated that the groundwater system be evaluated and predicted with a relatively high degree of certainty. In the opinion of GAI, this requires that representative bulk hydraulic parameters be measured in the field, that long-term hydraulic heads be measured, that hydrogeologic boundaries be evaluated by field testing, and that a conceptual model or models be formulated which can account for the observed conditions.

Although Chapter 5 of the SCR contains a large volume of hydrogeologic data, these data have been obtained primarily from packer tests in small-diameter coreholes. Most of the information is in summary form and little backup of raw data is provided either in the SCR or in the references cited. Furthermore, testing and analytical techniques are not discussed in the SCR at a level of detail which allows an assessment of the overall quality of data and analytical results to be made. However, the tests conducted appear to GAI to be state-of-the-art for small-diameter, single coreholes and, providing that adequate QA/QC has been followed and that bentonite drilling mud has no effect, the results should be valid spot measurements.

GAI has the following specific concerns related to the adequacy of the existing data base, interpretation and analysis of data, and adequacy of plans for further hydrogeologic evaluations, as presented by DOE in SCR Chapter 5:

- Hydraulic Parameters

  Field measurements of horizontal hydraulic conductivity have been made only in small-diameter coreholes using packer techniques. Holes have first been cored using bentonite drilling mud which could tend to plug the formation and decrease the measured hydraulic conductivity. The actual effects of using bentonite are not known currently, although DOE asserts that holes have been adequately developed to remove all mud. Resulting values are essentially spot measurements representative only of the immediate area around the corehole and not necessarily the hydrogeologic unit on a large scale. No reliable bulk (large scale) measurements of this parameter exist. In addition, no field measurements of vertical hydraulic conductivity have been made.

  Field measurements of effective porosity and dispersivity have been conducted in only one flow top interval in a dual borehole set located outside of the RRL. Results are uncertain due to non-standard test responses. However, the approximate value of effective porosity from the test (i.e., 10^{-4}) does not correspond to the value used in the performance modeling assessments (i.e., 10^{-2}). This difference alone could result in the overprediction of travel times by a factor of 100.

  Matrix diffusion, which is potentially a very positive aspect of waste containment at the Hanford Site, has not been measured or even considered,

based upon the information presented by DOE in SCR Chapter 5. This process has been shown to be significant in granitic rock, resulting in an effective retardation of solutes by diffusion into the rock matrix from fractures. GAI believes that this effect should be considered at Hanford and that measurement of matrix diffusion is realistic based upon current technology.

A problem related to measurement of hydraulic parameters is that of determining whether measured values are representative at a scale appropriate for performance modeling. Existing data indicate extremely wide variations in measured parameters (e.g., horizontal hydraulic conductivity) which may be the result of natural variation or non-representative tests (i.e., test volumes are too small). In either case, GAI believes that it is not currently possible to predict or interpolate parameter values between measured locations with a reasonable degree of certainty. Because of the uncertainties in hydraulic parameters, it is not currently possible, in GAI's opinion, to predict travel times with any reasonable level of confidence.

Many of the problems related to parameter uncertainty could be solved by utilizing large-scale testing techniques instead of small-scale single borehole techniques. It is standard procedure in hydrogeologic investigations to utilize multiple-hole pump tests to determine horizontal and vertical hydraulic conductivity in layered systems. Large-scale tests result in bulk parameter values rather than spot values and yield valuable information about aquifer continuity and hydrogeologic barriers. However, although the Hanford Site has the advantage of being testable on a large scale by standard techniques (e.g., multiple hole pump tests), DOE plans for supplementing the hydrogeologic data base (see SCR Chapter 13 - Site Issues and Plans) indicate that single-hole tests will continue to be the fundamental testing method at Hanford. Four dual-borehole sets and two multiple-hole sets are planned, but only one of the proposed multiple-hole tests is located near the RRL and its scale is small with respect to the repository dimensions. GAI has low confidence in the reliability of existing hydraulic parameters and does not believe the currently proposed testing program will be adequate to produce a sufficient data base on hydraulic parameters, as is needed to defensibly predict the repository's performance.

- <u>Hydraulic Head</u>

Measurements of hydraulic head have been made by DOE primarily using packer technology rather than permanent piezometer completions. It is GAI's opinion and experience that long-term monitoring in permanent installations is necessary to determine representative hydraulic heads. Short-term measurements in packed-off intervals are subject to effects from packer leakage, the existence of the open hole above the packer interval, and transient effects introduced by drilling.

GAI believes that the distribution of measured hydraulic head supports several different interpretations of the groundwater flow system, not just

DOE's interpretation as presented in the SCR. For instance, the quality of head data is not sufficient to determine whether flow is going north or south from the RRL. This problem is compounded by the fact that observed horizontal and vertical hydraulic gradients in the Pasco Basin are apparently low, thus small errors in measurement could introduce significant differences in the flow system interpretation.

DOE proposes to continue to collect head measurements during the drill and test sequence and although it is assessing the need for time-variant measurements, no plans are presented for installation of reliable devices for long-term head measurement. GAI considers the existing data inadequate and does not believe the proposed plans will yield the accurate head information needed to formulate conceptual models and calibrate performance models.

- Hydrogeologic Boundaries

  Large-scale discontinuities (including the Cold Creek and the Gable Mountain-Umtanum Ridge structures) and small-scale discontinuities (including inverted fans and fracture zones) are known to exist in the Pasco Basin. However, hydrogeologic characteristics and effects of discontinuities in the Pasco Basin are currently unknown because no hydrogeologic tests to investigate these features have been conducted by DOE. DOE plans to evaluate the Cold Creek structure using a multiple-hole pump test in the Cold Creek Valley and the Gable Mountain-Umtanum Ridge structural zone by a single corehole. No plans are presented to test other potential hydrogeologic boundaries.

  GAI considers the current data related to hydrogeologic boundaries insufficient and the proposed plans inadequate to produce the level of information needed in performance assessments. It is GAI's opinion that conventional multiple-hole tests would provide much of the needed information. GAI expects that small-scale features could potentially increase the bulk vertical hydraulic conductivity several orders of magnitude higher than is currently assumed by DOE.

- Conceptual Groundwater Models

  In GAI's opinion, data presented by DOE in the SCR do not support a unique conceptual model of the groundwater flow system. For example, current data could be used to support a system with significant vertical permeability, with areally discontinuous layers, or with flow dominated by the effects of hydrogeologic barriers.

  GAI considers the acquisition of reliable long-term hydraulic heads and the use of large-scale hydrogeologic tests essential to further refinement of the conceptual flow system model. This is particularly important if the lateral geologic variability of intraflow structure is taken into account. However, GAI believes it is unlikely that the DOE's proposed testing program, as presented in the SCR, will yield the required information.

- Hydrochemistry

  Hydrochemistry data in the SCR are not, in GAI's opinion, presented in a normal scientific format. Lacking are the description of sampling methods, the listing of basic data and the presentation of data in unbiased graphical summaries. GAI considers conclusions relating to the low degree of vertical groundwater mixing, which have been supposedly drawn from this data, to be premature. Further consideration should be given to potential vertical mixing based upon the determination of hydraulic parameters and gradients. GAI does not believe that hydrochemistry alone can be used to support the conclusion that vertical mixing is insignificant.

  Several other hydrochemical interpretations are questionable in GAI's opinion. For example, holes DC-14 and DC-15 (located near the Columbia River) are cited as examples of low vertical mixing because sharp chemical breaks occur within the vertical profile between the Wanapum and Grande Ronde. Hole DC-12 (located near the RRL) exhibits no major chemical breaks between the Wanapum and Grande Ronde, though this is not given as evidence for significant vertical leakage. Another problem is the lack of correction in Carbon-14 ages for the effects of methanogenesis and the failure to consider models of geochemical evolution.

  In summary, GAI does not consider the existing hydrochemistry data sufficient to support any particular conceptual groundwater flow model. In GAI's opinion, primary evidence for conceptual models should be derived from physical parameters and testing, with hydrochemistry constituting secondary information.

In conclusion, GAI believes that the hydrogeologic system in the Pasco Basin is poorly understood at this time and that there is a high degree of uncertainty regarding the direction of flow and point of discharge for groundwater in these deep basalts. Measured values of horizontal hydraulic conductivity vary over many orders of magnitude even within the same stratigraphic unit measured at different locations. Measured vertical and horizontal hydraulic gradients show little overall consistency in magnitude and direction over the site. The effects of internal and external hydrogeologic boundaries are largely unknown. However, it is not clear to GAI that DOE recognizes the large uncertainties which currently exist with respect to the hydrogeologic system (see Chapter 12 - Performance Assessment). Also, the potential impact of a repository at the RRL in constraining groundwater resource development, and thereby agricultural development, in areas outside of Hanford have not been addressed by DOE. For example, GAI believes that subsurface dewatering during repository construction and operation could adversely affect groundwater resource development nearby, and that after closure groundwater resource development may have to be constrained so as to not increase the hydraulic gradient (and thus decrease the groundwater travel time) from the repository to the accessible environment.

6. EXECUTIVE SUMMARY OF SCR CHAPTER 6 - GEOCHEMISTRY

6.1 Synopsis

Chapter 6 of the SCR presents available data on the geochemistry of the Hanford Site groundwater and host rock, as well as of the candidate waste forms which may be placed in a basalt repository. This data is essential to predict the long-term performance, and thus potential hazards to the public, of a repository at Hanford. Further, because the waste package and barrier design process is ongoing, the accurate characterization of site geochemistry provides critical feedback on corrosion and nuclide transport feedback in determining the adequacy of designs.

DOE presents data on the host rock geochemistry, describing the variations, compositions, and structures of the host basalt and of secondary minerals which fill the extensive fracture system found in the Hanford basalts. DOE shows that the basalt at the candidate repository horizons is mainly composed of SiO_2, Al_2O_3, FeO and CaO, with numerous other constituents of minor concentrations. DOE identifies the secondary minerals as being clay minerals, zeolites, silica minerals and other miscellaneous species. DOE presents data on the groundwater geochemistry based on water samples taken from five boreholes. It shows the groundwater from the candidate repository horizons to be reducing, with relatively low dissolved solid content, and to have a pH ranging from 8.8 to 10.1. The middle Sentinel Bluffs and Umtanum horizons are found, respectively, to be between 51°C and 58°C, and to have an ambient hydrostatic head of between 1350 and 1610 psi. DOE discusses the chemistry of candidate waste forms and barrier materials, acknowledging that virtually no relevant data exists in this area (see also SCR Chapter 11). DOE presents its available data on elemental solubility and sorption characteristics, acknowledging again that virtually no relevant data exists, and that which does exist has large uncertainty associated with it. DOE also discusses natural analogs to a nuclear waste repository in basalt, including naturally occurring material forms that are being considered for use in the repository as well as the relative hazard comparison of a repository and a uranium ore body.

GAI has several concerns regarding DOE's assessment of site geochemistry, specifically:

- Although DOE's effort to characterize the host rock geochemistry appears to be well founded and moving in a technically defensible direction, significantly more data need to be acquired.

- In order to improve DOE's understanding of the groundwater chemistry affecting waste package corrosion, significantly more data needs to be acquired. Additionally, DOE's predictions of repository pH and Eh are far more uncertain than previously acknowledged due to observed inconsistencies in the measurement of pH as a function of temperature.

- There is considerable uncertainty in DOE's assumptions regarding the presence of oxygen in the vicinity of the waste package when resaturation occurs; the result being an uncertainty in the corrosion environment that

the waste package will be subjected to in a repository at Hanford.

- DOE has apparently no relevant data on the chemistry of waste form and package materials in an environment relevant to a basalt repository, and this lack of data introduces considerable uncertainty into the ongoing package design effort.

- DOE has no relevant data on the solubility of radionuclides under geochemical and environmental conditions anticipated in a repository at Hanford, and as a result, cannot technically defend an assessment of repository performance which takes credit for solubility without acknowledgement of very large uncertainties.

- DOE has only very limited geochemical sorption data taken under marginally relevant conditions, and thus cannot technically defend a performance analysis of a repository which takes credit for sorption in basalt until substantially more data is acquired.

- Discussion of natural analogs has little real relevance to a nuclear waste repository in basalt unless such analogies can be demonstrated to have equivalent environmental conditions.

6.2 Summary of Technical Content Presented by DOE in SCR Chapter 6

Chapter 6 of the SCR summarizes available data on the geochemistry of the Hanford Site. DOE presents discussions of the geochemistry of the host rock and groundwater, of the chemistry of man-made materials to be placed in the repository (waste, engineered barrier materials), of geochemical retardation mechanisms, and of natural analogs to a nuclear waste repository in basalt.

The host rock geochemistry is dominated by basalt and the various minerals and clays which fill the numerous cooling cracks and fractures which occur in the basalt. The basalt in the horizons under consideration for repository development (known as the Grande Ronde Basalt) is mainly composed of SiO_2, Al_2O_3, FeO and CaO in descending order of concentration, with SiO_2 making up slightly more than fifty weight percent. Lesser occurring constituents include MgO, Na_2O, TiO_2, K_2O, P_2O_5 and MnO.

The secondary minerals found in the Grande Ronde Basalts are dominated by clay minerals and zeolites, with small fractions of silica minerals, gypsum, calcite and pyrite. These secondary minerals also dominate the vesicular rock found in the flow tops and bottoms, and will also influence radionuclide flow in these regions. According to DOE, these secondary minerals exhibit wide compositional variations, making individual mineral characterization a very difficult task.

The groundwater chemistry at the candidate repository horizon is only briefly described by DOE due to data limitations. The groundwater is estimated to be relatively reducing in nature. The pH is estimated to be between 8.8 and 10.1 at the repository horizons. Total dissolved solids are estimated to be less than 0.1 weight percent in concentration. The ambient temperature is estimated to be between 51°C and 58°C, and the water pressure is projected to

be between 1350 and 1610 psi, respectively, for the middle Sentinel Bluffs and Umtanum horizons. The pH of the Hanford groundwater is found to increase with temperature. While this expected relationship of pH to temperature has not been quantified, reference is made to an earlier report by one of DOE's contractors which estimates that at 300° C, which is roughly the maximum temperature that would be observed in a basalt repository, the pH would drop to about 6.2 (see M.J. Smith, et al, "Engineered Barrier Development for a Nuclear Waste Repository in Basalt: An Integration of Current Knowledge," RHO-BWI-ST-7, pages 2-124, Rockwell Hanford Operations, Richland, Washington, May 1980). The oxidation potential, or Eh, of the Hanford groundwater is estimated to be negative, that is, reducing rather than oxidizing. DOE points out, however, that measurement of this parameter can be subject to large measurement errors, and thus estimates of the Eh are quite uncertain. DOE states that N_2 is the dominant dissolved gas in the Hanford groundwater, with methane being a minor fraction. DOE does not present details, however, of methane occurrences in its drilling program.

In discussing the chemistry of waste forms and barrier materials, DOE summarizes material presented in SCR Chapter 11. The most important statement by DOE in this regard is an acknowledgement that there is virtually no chemical data on the performance of package and barrier materials that is relevant to the geochemical environment that will be found in a basalt repository. DOE does point out that sodium bentonite, while expected to be stable chemically in a basalt repository, can have its effectiveness reduced in the presence of potassium, which occurs in a very minor concentration in the secondary minerals in the Grande Ronde Basalts. DOE states that there is a need in backfill materials for a constituent to selectively sorb nuclides which are not greatly influenced by basalt or bentonite. These radionuclides include technetium, iodine, selenium and neptunium.

DOE presents a summary of available data on radionuclide solubilities and sorption characteristics. In discussing solubilities, DOE presents estimates of the solubilities of uranium, plutonium, americium and neptunium under very basic (pH=10) conditions. DOE points out that it has no experimental data to support these estimates. In discussing sorption, DOE states that there is virtually no sorption data that is relevant to Hanford environmental conditions. DOE does present very preliminary experimental sorption data on ten selected isotopes, including the influence of temperature on sorption. However, this data is acknowledged to be for temperature and oxygen conditions quite different than expected in a repository at Hanford. DOE presents its best estimates of sorption coefficients for the ten isotopes in Hanford groundwater, based upon the limited data in hand.

DOE discusses analogies to a repository at Hanford which are found in nature. Discussions are presented regarding the similarities of volcanic glass to borosilicate glass, focusing on the observed chemical stability of volcanic glass over periods up to one million years, as well as upon the rates of devitrification of volcanic glass observed in nature. The stabilities of naturally occurring copper metal and iron metal, as well as of naturally occurring clay minerals, are discussed and compared to conditions expected in a repository at Hanford. The radiologic hazards associated with naturally occurring uranium ore bodies are compared to the potential hazards of a nuclear waste repository at Hanford.

DOE presents a very brief discussion of related field tests which have been conducted in granite formations in Sweden and Nevada. However, they point out that there is limited applicability of these tests to a repository at Hanford.

Finally, DOE refers to SCR Chapter 15 which includes a discussion of geochemical issues that it perceives to still be unresolved, and plans for their resolution.

6.3 GAI's Evaluation of Technical Adequacy of DOE's SCR Chapter 6

In GAI's opinion, the defensible characterization of the chemistry of the Hanford site groundwater and geology, as well as the engineered materials (waste form, waste package, and backfill material) that may go into a repository is important in determining and assuring that the long-term performance of a repository is acceptable. The characterization of the chemistry is also essential in guiding the design and development of the waste package and backfill.

In GAI's opinion, although DOE's geochemical characterization effort at Hanford has parts which are technically defensible, there are some technical issues, specifically regarding:

- Host rock geochemistry
- Groundwater geochemistry
- Dissolved gases
- Chemistry of waste package and barrier materials
- Radionuclide solubility data
- Sorption data
- Natural analogs.

Issues regarding each of the above topics are discussed separately below.

In characterizing the host rock geochemistry, DOE demonstrates an appropriate understanding of the relevant technical data. One area of technical concern, which presumably will be addressed during the exploratory shaft program, is the determination of the distribution of specific secondary minerals within the fractures of the reference repository horizon. Because transport of any radionuclides from the repository will be primarily along the fractures, identification and characterization of specific secondary minerals in fractures is, in GAI's opinion, essential to reliably predict releases to the accessible environment. Also, as hot water may flow through these fractures, the solubilities of these secondary minerals in such conditions, and the resulting effect on waste package corrosion and waste transport, should be assessed.

In the area of groundwater geochemistry, it is GAI's opinion that DOE should acquire significantly more data before reliable predictions of the waste package corrosion environment can be made. One technical question which arises is the specific value of pH which should be assumed to exist at the repository horizon. Although DOE presents data which indicates that the mean measured pH of groundwater at its two reference repository horizons is 9.5, DOE has previously predicted that the pH for these two horizons should be

somewhat higher than the mean of this data indicates and would be different for the two horizons. If these data are correct, then the geochemical environment which the waste package will be exposed to will be slightly more corrosive, that is, a less basic pH. Clearly, this uncertainty points to the need for more data. In addition, this inconsistency points to the need for DOE to adopt a much more conservative design and development approach (see SCR Chapter 11 - Waste Package). Supporting this need for a more conservative approach is the acknowledgement by DOE that the measurement of oxidation potential, or Eh, can be subject to large measurement errors. Because of potential errors in measurement, Eh is calculated based upon pH, a quantity which is also in question.

In discussing dissolved gases, it is GAI's opinion that there is considerable uncertainty in the assumptions made by DOE that (1) no oxygen is available to oxidize package materials in groundwater in the repository horizon, and (2) oxygen that will be present in the repository at the time of decommissioning will react with the highly reducing basaltic groundwater prior to water reaching the waste package. In work currently being performed by GAI for NRC, the time to resaturate the entire repository, including backfill material surrounding the waste package, is predicted to be considerably shorter than estimates being used by DOE (within one hundred years versus 2000 years, as assumed by DOE). As stated earlier, there is an uncertainty in the actual value of pH and Eh that will be encountered in the repository by the waste package. Thus, there is an uncertainty in the real geochemical conditions that the waste package and barrier material will be exposed to. It is not GAI's assertion that the waste package will definitely be exposed to a more corrosive environment than currently assumed by DOE. This assertion would require real and relevant data which, by DOE's admission, is currently lacking. Rather it is GAI's opinion that these uncertainties should be explicitly acknowledged by DOE and factored into the basalt program by adopting a considerably larger degree of design conservatism until reliable data is obtained which might support a less conservative design. Further, DOE should adopt a more conservative approach to predicting repository performance, acknowledging the uncertainties rather than adopting discrete and indefensible predictions of performance.

In its discussion of the chemistry of the waste package and barrier materials, DOE acknowledges the virtual non-existence of relevant data on performance in the geochemical environment anticipated in a repository at Hanford (see SCR Chapter 11 - Waste Package). It is GAI's opinion that this data gap is an important issue at this stage of the program. The lack of this information demonstrates that any performance assessment which incorporates waste package and barrier materials should correctly present the current degree of uncertainty. Until more defensible data is acquired, an appropriate degree of conservatism should be incorporated in these elements. DOE does not appear, in GAI's opinion, to assign sufficient significance to the absence of data.

In its discussion of radionuclide solubility data, DOE acknowledges the absence of relevant data. The only solubility data presented is for four elements measured under oxygen and pH conditions that are irrelevant to a nuclear waste repository at Hanford. Further, DOE makes no recognition of the temperature dependence of elemental solubilities. In spite of this lack of

data, DOE presents the following conclusion, which GAI believes cannot be technically supported at this time with the current data base:

> "Based on solubility, the maximum possible release rates for all the radionuclides considered will be below the NRC 10^{-5} proposed release rate criterion (NRC, 1981) and the draft cumulative release criterion (EPA, 1981)."

On the other hand, DOE does acknowledge the need to measure solubilities under reducing conditions, but not under the thermal environments expected in a repository.

Regarding sorption data, although DOE has performed a few sorption experiments for ten isotopes in simulated basalt groundwater, these have been under oxidizing rather than reducing conditions. Additionally, DOE reports only one sorption experiment in which Hanford groundwater temperature was varied. The results of these experiments currently exhibit relatively large uncertainties. Further, the data in hand is, by DOE's acknowledgement, not relevant to the geochemical conditions which will be found in a repository at Hanford. Thus, it is GAI's opinion that research should be performed by DOE before it can credibly and defensibly establish its values and distributions of sorption coefficients. Further, it is GAI's opinion that, in light of these data gaps, DOE cannot currently defensibly predict the long-term performance of a nuclear waste repository at Hanford without explicit recognition of the very large uncertainties in their predictions.

Regarding natural analogs to a basalt repository, GAI believes that while performance of naturally occurring structures (i.e., volcanic glass, copper, iron and clay minerals) is perhaps indicative of performance trends, that they are of limited value in predicting the performance of a repository at Hanford. This is because, as DOE acknowledges, none of the naturally occurring minerals discussed have been subject to the environmental conditions expected in a repository at Hanford. Thus, none of the material's performances can be extrapolated to a nuclear waste repository. Further, GAI believes that the comparison of the relative hazard of a repository to a uranium ore body may be misleading. This is because the development of a repository is a conscious decision by the governing institutions in which the costs, risks and benefits may be weighed, accepted or rejected in spite of its potential hazard relative to a naturally occurring ore body.

In conclusion, it is GAI's opinion that DOE has begun to establish a foundation from which it may be possible to develop a comprehensive understanding of the Hanford Site geochemistry. Currently, however, it is GAI's opinion that in certain key data areas, especially elemental solubilities and sorption coefficients under anticipated repository conditions, there is virtually no defensible and relevant information available. This deficiency is, in principle, acknowledged by DOE. However, the result of the deficiency is to cast a large degree of uncertainty on current predictions of long-term repository performance.

7. EXECUTIVE SUMMARY OF SCR CHAPTER 7 - SURFACE HYDROLOGY

7.1 Synopsis

Chapter 7 of the SCR presents the data available on surface hydrology at Hanford, including streamflow characteristics, water control structures, historic floods and flood potential, water use and demand, and surface water quality. This information can be important in considering repository design, as floods along surface drainages caused by natural events or a dam failure might reach a repository, causing disruption of operations and radioactive contamination of the water which could adversely affect users downstream.

The Columbia River and its major tributaries, i.e., the Yakima, Snake and Walla Walla Rivers, are the dominant surface water features within the Pasco Basin. The reference repository location (RRL) lies along the divide between the Columbia and Yakima Rivers, with the southwestern two-thirds lying within the drainage of Cold Creek, a tributary of the Yakima.

Priest Rapids Dam is the major water control structure in the area. Another dam has been proposed on the Columbia along the Hanford reach, which could raise groundwater levels a maximum of about 5 meters (16 feet) at the RRL.

The potential for floods on the Columbia and Yakima Rivers has been greatly reduced as a result of the construction of water control structures, and none of the scenarios presented by DOE in the SCR would inundate the RRL. However, it is not clear whether a flash flood along Cold Creek would affect a repository at the RRL

Surface water accounts for over 90 percent of the total water used in Benton and Franklin Counties, with irrigation and industrial usage comprising 22 and 76 percent of the water demand, respectively. The Washington State Department of Ecology has designated the Columbia River within the Pasco Basin as a Class A (excellent) stream, which requires that industrial uses be compatible with all other uses. The annual demand for water in these two counties is expected to increase between 36 and 265 percent in the next 100 years, with an increase of about 83 percent being most likely.

Water quality along the Columbia River within the Pasco Basin is monitored at two locations by the U.S. Geological Survey and by Pacific Northwest Laboratory at four locations. Data collected by Pacific Northwest Laboratory indicate that Hanford operations have had a minimal impact upon Columbia River water quality.

Low-level radioactive materials have been discharged into the Columbia River since 1944. However, since the closure of the last once-through cooled reactor in 1971, radionuclide levels in river sediments and aquatic organisms have been decreasing. No contamination to the Yakima River from Hanford operations other than some minimal additions of groundwater with slightly elevated nitrate levels has been found.

In GAI's opinion, the data base compiled by DOE in Chapter 7 of the SCR appears to be accurate, sufficient and comprehensive, primarily because of the

extensive information previously gathered on the Hanford Site for its other uses. The interpretation of these data seems to be reasonable with the only unresolved issue being an assessment of the plausibility and consequences of an intense flash-flood event in Cold Creek.

7.2 Summary of Technical Content Presented by DOE in SCR Chapter 7

Chapter 7 of the SCR discusses surface hydrology at Hanford, specifically the data available regarding the streamflow characteristics, water control structures, historic floods and flood potential, water use and demand, and surface water quality. This information has been gleaned largely from studies conducted in conjunction with Hanford's other operations.

The Hanford Site lies within the Pasco Basin of the Columbia River drainage system. The Pasco Basin is located near the center of the Columbia Plateau and occupies about 4,850 square kilometers (1,900 square miles). The Columbia River is the primary surface stream and is joined by the Yakima, Snake and Walla Walla Rivers within the basin.

The reference repository location (RRL) is situated along the divide between the Columbia and Yakima River watersheds. The southwestern two-thirds of the RRL lies within the Cold Creek drainage. Cold Creek and its tributary, Dry Creek, are ephemeral streams that drain into the Yakima River along the southern boundary of the Hanford Site.

Streamflow characteristics of the Columbia and Yakima Rivers are monitored by the U.S. Geological Survey (USGS), which has gaging stations below Priest Rapids Dam on the Columbia and at Kiona on the Yakima. Streamflow records indicate that current annual flow rates for the Columbia range between 1,020 and 4,530 cubic meters (36,000 and 160,000 cubic feet) per second, while those for the Yakima range between 36.8 and 567 cubic meters (1,300 and 20,000 cubic feet) per second.

Major water control structures are located along nearly the entire length of the Columbia River within the United States, the primary exception being the Hanford reach. The most important of these structures in the Hanford region is Priest Rapids Dam, which is located upstream from the site. Another damsite (Ben Franklin Dam) has been proposed for construction on the Columbia River along the Hanford reach. The rise in groundwater levels resulting from such an impoundment could reach a maximum of about 5 meters (16 feet) at the westernmost edge of the RRL.

The maximum floods recorded for the Columbia River occurred in 1894 and 1948, with peak discharge rates at the Hanford reach of approximately 20,950 and 19,540 cubic meters (740,000 and 690,000 cubic feet) per second, respectively. The maximum floods on record for the Yakima River occurred in 1906, 1933 and 1948. The discharge magnitudes of these three floods were 1,870, 1,900 and 1,050 cubic meters (66,000, 67,000 and 37,000 cubic feet) per second, respectively. The potential for floods of these magnitudes has been greatly reduced as a result of upstream regulation of flows by water control structures. Nevertheless, the probable maximum flood for the Columbia River below Priest Rapids Dam has been calculated to be 39,650 cubic meters

(1,400,000 cubic feet) per second. The floodplain associated with such a flood would inundate the 100 Areas, but would not affect the central portion of the Hanford Site. Flooded areas resulting from a 100-year flood on the Yakima River would not reach the RRL either.

Two other catastrophic events which could result in flooding portions of the Hanford Site are dam failures and river blockage due to landslides along the Columbia River. Inundated areas resulting from the latter would be similar to those due to the probable maximum flood. However, a 50 percent breach of Grand Coulee Dam could result in a possible discharge of 227,000 cubic meters (8,000,000 cubic feet) per second near N Reactor on the Hanford Site. The region inundated by such a dam failure scenario would include not only the 100 Areas, but the 300 Areas, Washington Public Power Supply System nuclear plants and nearly all of the city of Richland, as well. Nevertheless, the central portion of the Hanford Site would remain largely unaffected, although a small arm of flood water would inundate the lowlands between Gable Butte and Gable Mountain.

The RRL lies primarily within the Cold Creek drainage system, which can be described as ephemeral and discontinuous. The potential for flooding along Cold Creek has apparently not been assessed by DOE.

Surface water usage in the Pasco Basin is primarily for irrigation and industrial purposes, which account for 22 and 76 percent of the basin water demand, respectively. Total water use for Benton and Franklin Counties is predominantly obtained from surface water sources, with groundwater withdrawals comprising less than ten percent of the total demand.

The annual demand for water in Benton and Franklin Counties is expected to increase 83 percent in the next 100 years, from 2.45 billion cubic meters (1,986,300 acre-feet) in 1980 to 4.48 billion cubic meters (3,632,000 acre-feet) in 2080. Low and high projections of increased surface water demand are estimated at 36 and 265 percent, respectively. Surface water availability greatly exceeds this increased demand, assuming that no further extra-basin constraints are imposed.

Thirty-six surface water intakes are known to exist along the Columbia River in the Pasco Basin. The total quantity of water withdrawn is currently about 1.237 billion cubic meters (1,002,000 acre-feet) per year.

Biological surveys of the Hanford reach indicate that crustacean zooplankton are the dominant invertebrates living in the Columbia River. In addition, 43 species of fish have been collected from this reach in over 30 years of research.

Surface water quality of the Columbia River in the Pasco Basin is dependent upon the quality of Columbia River water entering the basin, the quality of tributary rivers, groundwater discharge, discharges associated with Hanford site operations, other industrial discharges, municipal discharges and agricultural effluents. The Washington State Department of Ecology has designated the reach within the Pasco Basin as a Class A (excellent) stream, which means that industrial uses of the river must be compatible with all other uses, including sanitary, recreation and wildlife.

Monitoring of surface water quality is conducted by both the USGS and Pacific Northwest Laboratory (PNL). The USGS maintains two monitoring stations along the Hanford reach of the Columbia River and one each on the Yakima, Snake and Walla Walla Rivers. PNL obtains water quality data from four locations above, along and immediately below the Hanford Site boundaries along the Columbia. Data collected by PNL lead to the conclusion that Hanford operations have had a minimal impact upon the quality of Columbia River water, as all parameters monitored have been well within state or federal limits, both upstream and downstream from the Hanford Site.

USGS data indicate that the mean monthly temperature distribution within the Columbia River does not change significantly as the river flows through the basin. The distribution of mean monthly temperatures within the Snake River are similar to those within the Columbia. However, those within the Yakima River vary significantly, probably as a result of its considerably lower flow and distance upstream from the head of the artificial lake on the Columbia.

In one study of Columbia River water, the concentration of suspended sediment varied considerably, generally being about 100 times greater in the spring than in the fall. This increase in suspended matter was accompanied by a dramatic increase in the percentage of clay-size material.

Low-level radioactive materials have been discharged into the Columbia River since 1944. These contaminants have largely been deposited on river sediments, which have been found to be present in three different distributions: (1) a fairly constant, uniformly distributed layer, (2) concentrated "contamination deposits" consisting of a mixture of cobalt-60, cesium-137 and europium-152 in approximately equal proportions, and (3) discrete particles containing cobalt-60. However, since the closure of the last once-through cooled reactor in 1971, the radionuclide burden of the sediments has been decreasing. In fact, measurable body burdens of fission-produced radionuclides in the biota of the river ecosystem were shown to decrease to essentially undetectable levels within 18 to 24 months after discharge from the once-through cooling systems was ceased.

Some portions of the groundwater flow entering the Columbia River from the unconfined aquifer beneath the Hanford Site are known to be contaminated with tritium. Tritium discharges from the N Reactor are also added to the river's flow. However, no statistically significant increase in tritium concentration is apparent in samples taken upstream and downstream from the site, due to the large dilution of tritium-rich waters discharging to the Columbia River by the tritium-poor river water.

No contamination to the Yakima River resulting from Hanford operations has been found, except for some minimal additions of groundwater with slightly elevated nitrate levels.

7.3 GAI's Evaluation of Technical Adequacy of DOE's SCR Chapter 7

In GAI's opinion, the surface hydrology at Hanford should be adequately assessed in order to determine the potential for floods along surface drainages (e.g., caused by natural events or a dam failure) to reach the

repository and cause disruption of operations and radioactive contamination of the water downstream. Such an assessment should discuss streamflow characteristics, water control structures, historic floods and flood potential, water use and demand, and surface water quality.

In GAI's opinion, the surface water information compiled by DOE in Chapter 7 of the SCR appears to be accurate, sufficient and comprehensive enough to characterize the surface hydrology of the Pasco Basin and the RRL. The absence of any perennial streams within the vicinity of the RRL relegates the consideration of surface water hydrology to a relatively minor role in repository assessment.

Realistically, contamination in measureable amounts can only reach the Columbia River through the groundwater system, and therefore, such an evaluation is outside the scope of this chapter (see SCR Chapter 5 - Hydrogeology). However, it is within the realm of possibility, although remote, that intense flash-flooding along Cold Creek could affect a repository at the RRL, possibly resulting in disruption of operations and contamination of surface water in Cold Creek which could reach the Yakima River. DOE, based on the lack of discussion presented in SCR Chapter 7, has apparently not assessed the plausibility and consequence of such an event. In GAI's opinion, this should be assessed by DOE within the scope of the evaluation of surface water hydrology. Thus, the detailed resolution of topographic relief within the vicinity of the RRL, which is required to determine whether mitigation measures are appropriate, should be undertaken by DOE.

8. EXECUTIVE SUMMARY OF SCR CHAPTER 8 - CLIMATOLOGY, METEOROLOGY AND AIR QUALITY

8.1 Synopsis

Chapter 8 of the SCR presents the data available on climatology, meteorology and air quality at Hanford, including temperature, precipitation, prevailing wind direction and velocity, severe weather phenomena, dispersion conditions, air quality standards, paleoclimate and possible future climatic variations. This information is important in that surface facilities should be designed to withstand extreme climatic events, and construction and operation of the repository should not degrade air quality appreciably.

The general climate of the Hanford region is classified as a midlatitude semiarid desert with cool, wet winters and warm, dry summers. The climate in this region is greatly influenced by the surrounding topography.

The primary sources of regional and local climatic information in the Hanford area are data collected by the U.S. Weather Bureau near the Hanford Site from 1912 to 1945 and the Hanford Meteorological Station from 1945 to the present. These climatological records are supported by data from several other meteorological systems in the area.

The mean annual precipitation at the Hanford Meteorological Station is 161 millimeters, and the potential evapotranspiration is estimated at approximately 747 millimeters per year. The average annual air temperature is 11.8°C and the annual mean wet-bulb temperature is 6.6°C. The annual mean relative humidity is 54.3 percent and the annual mean dew point is 1°C.

The mean prevailing wind directions at the Hanford Meteorological Station are either west-northwest or northwest for every month of the year. Windspeed is lowest in December and highest in June. In addition, windspeed during June and July is usually lower in the morning and higher in the afternoon.

Severe weather phenomena are generally rare or unknown in the Hanford region, with the exception of duststorms of which an average of about 150 occur each year.

Air quality standards have been established by the U.S. Environmental Protection Agency, which has designated the Hanford region as a Class II area. In addition, the Benton-Franklin-Walla Walla Counties Air Pollution Control Authority has adopted local emissions regulations. Any emissions from the construction and operation of a waste repository will have to comply with both federal and local regulations. As little is known about such emissions, their impact on air quality can only be stated in general terms. Nevertheless, these emissions are expected to be low. However, as dispersion evaluations based on Hanford Meteorological Station data indicate that there has been a high incidence of both good and poor conditions for the dispersion of air pollutants, some short-term periods of reduced air quality might occur during construction of the reference repository.

Good paleoclimatic data are unavailable at the Hanford Site, and thus such data cannot be incorporated into the design and operation of a repository at the reference repository location (RRL).

In GAI's opinion, the data base compiled by DOE in Chapter 8 of the SCR appears to be accurate, sufficient and comprehensive, primarily because of the extensive information previously gathered on the Hanford Site for its other uses. The interpretation of these data seems reasonable. Although the paucity of paleoclimatic data and quantitative information on potential air quality impacts resulting from repository construction and operation render predictions of future effects difficult, it seems unlikely that more of these types of data can be readily obtained in the immediate future.

8.2 Summary of Technical Content Presented by DOE in SCR Chapter 8

Chapter 8 of the SCR discusses the climatology, meteorology and air quality at Hanford, specifically the data available regarding the temperature, precipitation, prevailing wind direction and velocity, severe weather phenomena, dispersion conditions, air quality standards, paleoclimate and possible future climatic variations. This information has been obtained largely from studies conducted in conjunction with Hanford's other operations.

The general climate of the Hanford region is classified as a midlatitude semiarid desert with cool, wet winters and warm, dry summers. The regional climate is largely influenced by major topographic features, as it lies in the rain shadow of the Cascade Range to the west and is protected from arctic air masses by the Rocky Mountains to the north and east. Locally, Yakima and Rattlesnake Ridges to the west and south, as well as the Saddle Mountains to the north, have a significant effect on precipitation, winds and temperatures.

The primary sources of regional and local climatic information in the Hanford area are data collected by the U.S. Weather Bureau near the Hanford Site from 1912 to 1945 and the Hanford Meteorological Station from 1945 to the present. In addition, these climatological records are supported by: the Hanford radio-telemetered automatic weather-station system, Arid Lands Ecology Reserve climatology system, N Reactor meteorological tower system, Washington Public Power Supply System, Inc., nuclear plant no. 2 meteorological system and the Fast Flux Test Facility meteorological system.

The mean annual precipitation at the Hanford Meteorological Station is 161 millimeters. Fifty-two percent of this total falls during the period from November through February, with snowfall accounting for about 45 percent of the precipitation from December through February. Statistics on the 48-hour probable-maximum winter precipitation are not currently available at the Hanford Meteorological Station. The potential evapotranspiration, estimated at approximately 747 millimeters per year, greatly exceeds the mean annual precipitation. The annual mean relative humidity is 54.3 percent, with a high of 80.0 percent occurring in December and a low of 32.2 percent in July.

The average annual temperature at the Hanford Meteorological Station is 11.8°C and the annual mean wet-bulb temperature is 6.6°C. The annual mean dew point is 1°C.

Prevailing wind in the region generally varies from northwest to southwest, although local topographic features and diurnal wind circulations can produce significant variations. Windspeed is also variable, generally being lower in the winter and higher in the summer. In addition, windspeed during the summer is usually lower in the morning and higher in the afternoon. The mean prevailing wind directions at the Hanford Meteorological Station are either west-northwest or northwest for every month of the year. The highest mean windspeed of 4.1 meters per second occurs in June and the lowest, 2.7 meters per second, in December. June and July have the largest diurnal range in windspeed, which is approximately 3 meters per second. All windspeed data were collected from a height of 12.7 meters above the ground. Equations for estimating wind erosion are applicable only to agricultural field operations, and consequently no estimates have been made for the Hanford area.

Severe weather phenomena are generally rare or unknown in the Hanford region. On the average the State of Washington experiences less than one tornado each year and thunderstorms in the Hanford area occur on the average of between ten and eleven days per year, although they have occurred during all months except November and January. Severe thunderstorms accompanied by lightning and/or hail are rare at the Hanford Site, averaging less than one per year and never more than two days in one year. Freezing rain occurs an average of seven days per year and only between November and March. However, duststorms are relatively common in the Hanford region, with an average of about 150 occurring each year.

A number of severe and extreme meteorological phenomena will be considered by DOE as bases for design and operation of a repository at the RRL. Accordingly, all repository surface structures will be designed for a Class III tornado region and to withstand a basic wind velocity of 36 meters per second. If the American National Standards Institute value of 98 kilograms per square meter for snow packs in the Hanford region is used as the design snow load for repository surface structures and a snow density of 0.1 gram per cubic centimeter is assumed, then this value would correspond to a snow depth of 0.98 meters. Such a snow load is asserted by DOE to be conservative, as the maximum snow depth reported is 53.3 centimeters and it seldom exceeds 15 centimeters. The minimum and the maximum temperatures on record are -32 and 46°C, respectively, and therefore all repository surface facilities and equipment will be designed to withstand such temperature extremes. Thunderstorm and lightning-strike frequencies average 10 to 11 and 0.225 per year, respectively. Consequently, these phenomena will be considered by DOE in the design of repository surface structures. The maximum dust loading of approximately 160 milligrams per hour per cubic meter (estimated for the Hanford area during the period from 1953 to 1970) will be used by DOE in assessing the design and operation of repository plant filters. Blowing and drifting snow may also be of importance in this assessment, but the prerequisites for such phenomena are seldom met in the Hanford area.

High air-pollution potential exists in the Hanford region during the fall and winter, when low windspeeds are accompanied by restricted mixing. The mixing height is defined as the height above the surface through which relatively vigorous vertical mixing occurs. No monthly mixing-height data are available for the Hanford region. However, seasonal maximum mixing-height data are

available for Spokane, where the average annual afternoon mixing height is approximately 1,500 meters, with a maximum of about 2,500 meters during the summer and a minimum of about 500 meters during the winter. The major cause of air pollution in the Hanford area is dust occurring during windy periods. The most significant sources are cultivated fields in the surrounding area.

One of the more important meteorological requirements for the RRL is evaluation of dispersion conditions. The Hanford Meteorological Station data have been the historical basis for such evaluations, and they indicate that there has been a high incidence of both good and poor dispersion conditions. Although conditions at the RRL are expected to be similar, some differences between conditions at the RRL and the Hanford Meteorological Station may be anticipated based on local topography, particularly with respect to windflow and circulation patterns.

The probable impact on air quality resulting from the construction and operation of a repository at the RRL has been stated in general terms by DOE. Windblown dust could be a problem, but presumably the large size of the basalt fragments should preclude most problems. In addition, emissions from vents may contain elevated levels of gases released from the Earth (i.e., radon, etc.), as well as from the underground operations.

The National Ambient Air Quality Standards, published by the U.S. Environmental Protection Agency (EPA), define the maximum prevention-of-significant-deterioration increments for three classes of areas. Most of the Pacific Northwest, including the Hanford Region, is Class II, and therefore, any emissions from the construction and operation of a nuclear waste repository at the RRL will have to meet EPA air quality requirements. In addition to the Federal regulations, local emissions regulations are specified in general regulation 80-7 of the Benton-Franklin-Walla Walla Counties Air Pollution Control Authority.

Good paleoclimatic data are unavailable at the Hanford Site or from the surrounding area, thus prehistorical climatic extremes cannot be determined and incorporated into the design and operation of a repository at the RRL. Nevertheless, the paleoclimate of eastern Washington, including the Hanford region has been characterized by pronounced climatic changes during the Quaternary. For the most part, temperatures have been cooler and precipitation greater during the past million years than they are at present. No ice reached the Hanford area during the last major glacial episode, but a number of catastrophic floods of unprecedented magnitude resulting from the sudden release of water from ice-dammed lakes inundated the area. These floods, and other lesser floods, were responsible for laying down the Pasco gravel beds and the Touchet beds of glaciofluvial deposits on the basalt formations in the Pasco Basin. Besides the decrease in temperature and increase in precipitation that accompanied the last glaciation, windflow and circulation patterns were probably altered. It has been postulated that cold northerly surface winds may have been prevalent over eastern Washington during the glacial maximum, which shifted to southwesterly winds as the ice sheet retreated.

The prediction of future climatic variations is difficult and requires numerous assumptions. Nevertheless, it seems likely that, in the absence of significant counteracting atmospheric effects by man's activities, the largest temperature changes will be toward continued cooling. Paleoclimatic information on regional precipitation is insufficient for future projections. However, it seems unlikely that the mean annual precipitation will vary by more than a factor of two. Large changes in windflow and circulation patterns may occur if the continental ice sheet returns and cold northerly winds could become prevalent. If an ice advance does begin in the near geologic future, it will be accompanied by a lowering of sea levels and invigorated downcutting by surface streams. In addition, it is possible that more catastrophic floods could occur during a future glaciation, and ice might even reach as far south as the Hanford Site itself.

8.3 GAI's Evaluation of Technical Adequacy of DOE's SCR Chapter 8

In GAI's opinion, the climatology, meteorology and air quality at Hanford should be adequately assessed in order to design surface facilities so they are able to withstand extreme climatic events and insure that construction and operation of the repository do not degrade air quality appreciably. Such an assessment should discuss the temperature, precipitation, prevailing wind direction and velocity, severe weather phenomena, dispersion conditions, air quality standards, paleoclimate and possible future climatic variations at the site.

In GAI's opinion, the historical climatic, meteorologic and air quality data compiled by DOE in Chapter 8 of the SCR appear to be accurate, sufficient and comprehensive enough for the purposes of designing and operating a repository at the RRL. Although the paucity of paleoclimatic data at the Hanford Site and surrounding areas renders any prediction of long-term climatic changes difficult, the studies cited that have been conducted around the periphery of the Columbia Plateau lend credence to the general statements made in the SCR. Air quality impacts resulting from the construction and operation of a repository are also difficult to predict; however, with proper design these potential impacts can generally be effectively mitigated. Hence, although it seems unlikely that additional relevant paleoclimatic data or information regarding air quality impact can be readily obtained by DOE in the immediate future, this is not of major concern.

9. EXECUTIVE SUMMARY OF SCR CHAPTER 9 - ENVIRONMENTAL, LAND-USE, AND SOCIOECONOMIC CHARACTERISTICS

9.1 Synopsis

Chapter 9 of the SCR presents data available on the environmental, land-use, and socioeconomic characteristics of the Hanford Site, the reference repository location (RRL), and the communities surrounding Hanford. This data is important because it serves as a baseline in determining the significance of repository development at Hanford, with respect to public health and safety, environmental insult and social burden.

DOE presents detailed data on the Hanford ecology and existing radiological contamination. DOE concludes that the RRL is currently contaminated with ^{90}Sr and ^{137}Cs concentrated in plants and soils up to 100 times above Hanford median concentrations. DOE presents details on land use, land ownership, aesthetics and recreation facilities, and historical, archaeological, and cultural resources. DOE also presents characteristic data describing the area's demography, economy, social service facilities, and governmental/ institutional organizations. DOE concludes that there are no issues in these areas to be resolved. The implications of this conclusion is that there are no environmental or socioeconomic issues to be resolved prior to possible selection of Hanford as a repository site and submittal of a license application.

In GAI's opinion, the information compiled by DOE in Chapter 9 of the SCR appears to be accurate, sufficient, and comprehensive. However, GAI has identified the following four potential issues pertaining to environmental, land-use, and socioeconomic characteristics, which in their opinion should be resolved:

- The levels of radioactive contamination currently existing at the RRL, and the potential for unacceptable contamination of public roads and for the unacceptable radiation exposure of workers as a result of site development activities, such as those ongoing which are associated with the construction of an exploratory shaft.

- The discrepancies in the DOE presentations as to the exact position of the RRL, whether it extends into the "Arid Lands Ecology Reserve" which bounds the southwestern edge of Hanford, and the appropriateness of that designation if found to include parts of the Reserve.

- The absence of an accounting of the potential public risks and social burdens associated with transportation activities in the development and operation of a repository at Hanford.

- The absence of an accounting of the potential social burdens associated with the transient construction work force that would accompany the construction of a repository at Hanford.

DOE does not acknowledge these or any other unresolved issues in the areas discussed in this Chapter 9 of the SCR.

9.2 Summary of Technical Content Presented by DOE in SCR Chapter 9

Chapter 9 of the SCR presents an abundance of statistical data describing the environmental, land-use and socioeconomic characteristics of the Hanford Site, the reference repository location (RRL) and the surrounding communities.

In discussing the environmental characteristics, DOE focuses on describing the ecology and radiological background. The DOE has done extensive characterization, sampling and analysis of the Hanford ecology. DOE presents characteristics and inventories of the vegetation, mammals, birds, reptiles and amphibians, insects, special and unique habitats, and threatened and endangered species that are indigenous to the Hanford Site. The DOE concludes that there are no federally recognized threatened or endangered species of plants or mammals known to inhabit the RRL. DOE acknowledges sitings of bald eagles, classified as threatened by the State of Washington, within the RRL. DOE further acknowledges the current review of the status of four plant species by the U.S. Fish and Wildlife Service for future consideration as threatened or endangered species. DOE states that, while these species are known to occur on the Hanford Site, it is not known whether they inhabit the RRL.

The DOE has conducted extensive radiologic surveys of the RRL. DOE concludes that there is existing substantial radioactive contamination of the RRL. The contamination derives from the routine operations of the Hanford facilities, and most likely those within the 200 West Area which is adjacent to the RRL. DOE states that small animal access to radioactive food supplies within the 200 West Area, and subsequent deposition of animal fecal matter outside of the 200 West Area is one likely source of contamination. The levels of contamination in the RRL have been measured at selected locations. At one sample station within the RRL, approximately one mile west of the 200 West Area, concentrations of ^{137}Cs and ^{90}Sr have been found in plants and soils that are stated by DOE to be up to 100 times higher than the median concentration for the Hanford area. Radiation dose rates resulting from 200 West Area operations and contamination have been measured by DOE at the boundary of the 200 West Area and RRL to be between 65 and 81 mR/yr in excess of natural background. DOE states that two radioactive waste ponds also are located within the RRL. These decommissioned ponds have been found to be contaminated with very high levels (compared to Hanford median values) of ^{137}Cs and ^{90}Sr. Finally, DOE notes an increase in plutonium contamination (^{239}Pu and ^{240}Pu) contained in the vegetation of one sampling station within the RRL.

In describing the land-use characteristics of the Hanford Site, DOE presents a summary of the current uses and features of Hanford and the nearby adjoining communities. In detailed maps (see SCR Figures 9-1, 9-2 and 9-5), DOE implies that a portion of the RRL lies within the Arid Lands Ecology Reserve, which borders Hanford on the southwest edge. However, conflicting maps are presented. DOE reviews the agricultural resources in the vicinity of Hanford, as well as the major transportation facilities serving Hanford and the Tri-Cities area. A discussion of land ownership is also presented which reviews the major landowner-agencies, as well as tribal and commercial rights. DOE also reviews recreational land uses and designations, as well as the

historical, archaeological and cultural resources in the vicinity of Hanford.

DOE describes the socioeconomic characteristics of the communities surrounding Hanford in some detail. Included in their description are discussions of community demography, economy and employment, service facilities, including transportation services, and government and institutional organizations.

DOE concludes by stating that "no items discussed within this chapter are considered to be unresolved."

9.3 GAI's Evaluation of Technical Adequacy of DOE's SCR Chapter 9

In GAI's opinion, enough accurate data should be acquired to develop a sufficient and comprehensive baseline of the environmental, land-use and socioeconomic characteristics of the Hanford Site and surrounding localities prior to the selection and development of a repository. Through this baseline, critical issues can be identified and resolved both before and during the construction and operation of the repository. Also, this baseline is essential in quantifying the public health and safety, the insult of the proposed project on the environment, and the potential social burdens of the project.

In GAI's opinion, the information presented by DOE in Chapter 9 of the SCR appears to be accurate, sufficient and comprehensive for characterizing the environmental, land-use, and socioeconomic conditions at Hanford at this stage of the siting process. However, although DOE states that there are no unresolved issues associated with these topics, GAI believes that there are four unresolved issues which may affect the viability of a repository at the RRL, as well as which impact the public health, safety and well-being:

(1) Radiological contamination.

There is a necessity to prevent the spread of radioactive contamination outside of the confines of the Hanford Site, as well as the minimization of radiation exposure to workers. According to DOE, the radioactive contamination of the RRL is substantial. Compared with the median contamination levels on Hanford, ^{137}Cs and ^{90}Sr contamination in vegetation and soils have been measured by DOE in individual samples to be up to 1000 and 1300 times, respectively, above normal at the RRL. No data is presented by DOE to establish median contamination levels off the Hanford Site in areas where man's actions have not already lead to contamination of the environment. Given the existing levels of contamination, DOE does not address precautions to be taken to assure that radioactive contamination is not spread onto State Highway 240, which passes through the RRL, and beyond. Such contamination may occur as a result of routine site excavation, preparation and development activities (such as those already under way in the exploratory shaft development effort). Further, DOE does not discuss the finding, which can be drawn from the data presented in the SCR, that this contamination may be ongoing, and not simply a remnant of earlier activities at Hanford. This finding is drawn from cases of increased environmental contamination in identified sampling locations over the two sampling years of 1978 and 1979 (see SCR Tables 9-8 and 9-9). Finally, in regard to contamination, DOE does

not address precautions that must be taken to ensure that repository construction workers, including those present during the exploratory shaft phase, are not exposed to unacceptable levels of radioactively contaminated dusts, as well as to unacceptable whole body exposure levels. In GAI's opinion, the radioactive contamination levels are of significance in that there is a potential for contamination of publically accessible lands and for unacceptable radiation exposures of workers in this unique project, and further that as a result of this potential, DOE should make a full accounting of this possibility to ensure that the health and safety of the community is maintained at all phases of the project.

(2) Consistency in land use.

DOE presents conflicting maps which lead to confusion as to the exact extent of the RRL. However, with the section discussing land use, detailed maps show that the repository location partially extends into the "Arid Lands Ecology Reserve" which borders the southwest edge of the Hanford Site. DOE does not present any discussion of what the appropriate uses are of the lands designated to be in this reserve, nor does it explicitly state the exact position of the RRL. Thus, it is not possible to determine whether or not the RRL has been designated appropriately and in a manner that is consistent with the Arid Lands Ecology Reserve's purpose. If DOE intends to withdraw parts of the Arid Lands Ecology Reserve for use in the repository, then this presumably should be done with full disclosure and consistent with NEPA.

(3) Transportation.

While DOE has presented the available transportation facilities and systems that serve the Hanford area, DOE has not examined the public risks and social burdens that are associated with the transportation aspects of the development and operation of a nuclear waste repository at Hanford. The public risks from transportation will result from the non-radiologic consequences of increased vehicular activity during repository construction and throughout operations, as well as from the radiologic consequences of rail, barge or truck movement of nuclear waste onto a repository site. The social burdens which will result from repository development and operation will include the degradation of public roads, rail crossings, and rail facilities, as well as the potential interference of repository-related barge traffic (if any) with the traditional commerce and pleasure activities associated with the Columbia River. Further, there is a potential for a degradation of the aesthetics in the communities adjoining Hanford due to noise and effluents which result from transportation activities. Finally, there is an increased social burden associated with the prospect of continuous movement of highly radioactive material through the largely agricultural communities of southwestern Washington, including the Tri-Cities. These transportation burdens and risks are endemic to all of the communities of eastern Washington due to the reality that the majority of the commercial nuclear wastes which might ever be buried at Hanford are currently located in the eastern United States and must therefore be transported through eastern Washington to Hanford if it becomes a repository. It is GAI's opinion that this issue of transportation should be fully addressed prior to license application, as a part of the site characterization process.

(4) Potential socioeconomic impacts.

DOE has apparently not accounted for the potential socioeconomic impacts associated with the transient work force required to construct a repository at Hanford. While DOE does present survey-type data characterizing the social infrastructure in and around the Tri-Cities, DOE also acknowledges the recent social burdens placed on the Tri-Cities by delays and cancellations of major Federal and commercial projects at Hanford. Because of the current socio-economic situation at Hanford, the consequences of and intended solutions to any increased burdens that are associated with a repository project should be addressed at Hanford prior to submission of a license application.

In conclusion, GAI believes that, given the early stage of the project, DOE has adequately characterized the environmental background, the land use factors and the socioeconomic factors of significance at Hanford. GAI does believe, however, that there are four unresolved issues dealing with radiological contamination, consistency in land use, transportation, and potential socioeconomic burdens. GAI believes that these issues should be resolved prior to submittal of a license application.

10. EXECUTIVE SUMMARY OF SCR CHAPTER 10 - REPOSITORY DESIGN

10.1 Synopsis

Chapter 10 of the SCR presents a description of DOE's conceptual repository design for Hanford. This design description is important because the engineered components, in conjunction with the site, will determine performance, both short-term construction/operation and long-term waste containment/isolation. Hence, the repository must be designed and subsequently constructed and operated for the given site conditions so as to assure that the repository system objectives (e.g., public and personnel safety over both the short and long terms) and associated criteria are met. However, because of the uncertainties in the assessment of site conditions and in the interaction of the engineered components with these site conditions and with each other, the design should be conservative enough (e.g., with planned contingencies) to sufficiently demonstrate at license application that the objectives/criteria will be met. Although detailed repository design is not required in the SCR, the design should be sufficiently described so as to identify those site conditions which are critical to the performance of the repository system (i.e., the site in conjunction with the engineered components), and thus should be focused on in site characterization prior to license application.

DOE's design description includes the layout and purposes of the components which comprise the surface facilities, access shafts, and subsurface facilities. Essentially, the subsurface facilities (about 1500 acres at about 3700 feet depth) consist of a central shaft pillar, main access ways (tunnels), an experimental panel, a contact waste storage panel, and 21 high level waste storage panels; each high-level waste storage panel (about 38 acres each) consists of four parallel tunnels with 200 foot long horizontal waste emplacement holes extending between. There will be a total of five operational shafts, all located in the shaft pillar, to provide transport of waste, personnel, equipment, material, excavated basalt, backfill, utilities, water disposal, and ventilation/cooling. The surface facilities consist of off-site development (e.g., transportation, utilities, etc.), a secured 200 acre control process area arranged around the shafts, and a control zone (extending 2 km beyond the surface projection of the subsurface facilities). The waste handling system provides for receipt, handling, and placement of about 1400 canisters (2370 MTHM) of 10-year old commercial high-level waste or spent fuel per year plus 1600 55-gallon drums of commercial low-level transuranic (contact) waste per year for 20 years. The service systems, especially ventilation and cooling, are integrated into the layout.

It is presently planned by DOE that one panel will be filled with waste each year and then temporarily blocked off. Some undetermined time after all panels have been filled (i.e., 20 to 50 years after the first waste has been placed, where 50 years is the stated retrievability period), the holes and panels will be backfilled at a rate of one panel per year. However, if performance is unsatisfactory, the waste may be retrieved at any time, also at the rate of one panel per year. At decommissioning, all underground openings (including shafts and boreholes) will be sealed.

Although GAI recognizes that a detailed repository design is not required in the SCR, the conceptual repository design is perceived to be currently inadequate. A conceptual design is important at this stage of the process because it enables the data acquisition plans to be placed in perspective. It is also important since the design will affect engineered barriers and thus the predicted long term performance of the repository. The operational safety of the repository will require stable openings both for men and for storage of nuclear waste.

GAI believes that the designs presented in the SCR are, in some cases, contradictory and insufficiently detailed to enable adequate evaluation of test plans. Most importantly, GAI believes that DOE should present a detailed description of the design process which will be used to finalize the conceptual design prior to a license application for construction authorization and subsequently during construction. Detailed layouts are not appropriate at this time since there is not sufficient specific data available on geologic variability and hence geoengineering parameters. However, the criteria or methodology for making ongoing design decisions (e.g., planned design contingencies) should be addressed. Included in these descriptions should be statements describing the potential conditions which would lead to decisions to retrieve waste during the operational phase. In addition to these scenarios, the methodology which would be used to decide on how much waste and under what conditions the waste should be retrieved should be presented. The description of the design and retrieval process is thus essential to evaluate the information needs and associated plans for site characterization.

Secondarily, GAI believes that:

- The current design of underground openings may not be conservative in some respects, in that
  - intact rock strengths at room temperature, rather than the appropriate (and much lower) rock mass strengths at elevated temperatures, have been used to establish allowable stresses in the basalt.
  - contrary to DOE design criteria, overstressed zones will probably occur in many places, including the corners of placement rooms, around the essentially square reaming access drifts, and at the intersections of underground openings.
  - the rock support system, especially its removal prior to backfilling, has not been justified.
  - the in situ stresses may be higher than those assumed by DOE for the design of underground openings.

- The dense zone of the reference repository horizon (i.e., Umtanum) has been subsequently observed by DOE (in drill hole RRL-2) to be only 84 feet thick, so that some of the openings in the multiple level shaft pillar may be close to or within the less competent flow top. Also, some grade (i.e., change in elevation) is typically provided in underground openings to promote drainage, so that the repository level may intersect the flow top at some point or be stepped to avoid that intersection. Intraflow geological variability, and thus predictability, especially regarding the

geometry of the dense zone, is considered to be a significant issue, and it is not clear how contingencies for these potential conditions will be incorporated in design. Thickness of the dense zone appears, based on present available information, to be less of a problem in the middle Sentinel Bluffs flow (i.e., the alternative repository horizon).

- Insufficient (and in some cases outdated) information has been presented regarding backfilling and sealing. Especially, the objectives/criteria for backfill/seals have not been defined, nor is the schedule for backfilling clear; apparently, backfill may not begin until after all waste has been emplaced due to shaft transport availability and ventilation capacity, and even then can only proceed at a rate of one panel per year. The design of backfill/seals, and the associated construction methods to achieve that design and the test methods to verify that design and assess especially their long-term performance, have not been adequately discussed. Although DOE asserts that they will backfill/seal all openings, it should be pointed out that there is no mandatory requirement for backfill.

- Retrieval of waste packages, if required, may be relatively difficult, especially if (1) the waste emplacement hole has been previously backfilled, (2) loose rock should fall from the unsupported crown of the hole to block the passage, or (3) the in-hole waste emplacement device should malfunction. These difficulties could be compounded due to the length of the holes. Also, the current waste package horizontal emplacement scheme may cause accelerated degradation of the package.

10.2 Summary of Technical Content Presented by DOE in SCR Chapter 10

Chapter 10 of the SCR presents a description of DOE's conceptual repository design for Hanford. This description includes primarily the layout and purposes of the components which comprise surface facilities, access shafts, and subsurface facilities. In addition to these physical components, the conceptual waste handling systems and service systems (including ventilation) have been briefly presented. This design description has been based on certain design assumptions, many of which have been defined and justified herein. In addition, the techniques for constructing shafts and other underground openings, and for backfilling and sealing underground openings have been briefly discussed.

The conceptual design basis includes the following primary assumptions:

- Regarding receipt and emplacement of waste
  - 50/50 mix (by weight) of commercial high-level waste (CHLW) and spent fuel will be received and emplaced at a rate of about 1400 canisters/year or 2370 metric tons of heavy metal (MTHM)/year; CHLW or spent fuel will arrive (by truck or rail) already packaged (and thus packaging facilities will not be required on site) after at least 10 years of storage.
  - commercial low-level transuranic (contact) waste (non-heat producing) in 55 gallon drums will be received and emplaced at a rate of about 1600 drums/year.

- the receipt/emplacement period will continue for 20 years, so that a total inventory of 47,400 MTHM (CHLW and spent fuel) and 32,000 drums of contact waste will exist underground at the end of the operational period.

- Regarding the layout of facilities
  - underground development will be incremental, so that one year's worth of CHLW/spent fuel will be emplaced in a separate area (i.e., panel) which will then be sealed off; hence, there will be a total of 20 panels (plus one contingency panel) for 20 years of operation.
  - access shafts will be located in one shaft pillar, so as to concentrate the surface facilities and thus minimize the surface area to be controlled, and to minimize the number of shafts and be able to complete them (and thus have the ventilation system operable) prior to further repository development.
  - two separate ventilation systems will be required for underground facilities/operations, so that air from waste storage areas, which is possibly radioactive, will neither enter areas where mine development is occurring (to protect workers) nor mix with relatively clean mine development exhaust (to minimize the amount of exhaust which must be monitored and possibly treated/filtered).

- Regarding design of subsurface facilities
  - the repository will be in the dense interior of the Umtanum, at a depth of about 3700 feet; DOE states that this design would be conservative (involve "less technologic risk") if applied to the shallower and thicker middle Sentinel Bluffs flow, the alternative horizon for which less is known.
  - the in situ stresses at the repository level are at a ratio of maximum horizontal stress to vertical stress of 2:1 and to minimum horizontal stress of 1.5:1.
  - the in situ temperature at the repository level is 58°C.
  - the rock properties are as given in SCR Table 10-4, including a uniaxial compressive strength of 29,000 psi.
  - the maximum allowable compressive stress is 27,000 psi in basalt at any opening.
  - the maximum allowable temperatures are 500°C for CHLW, 380°C for spent fuel, 430°C for canister and overpack, 300°C for backfill and basalt at the storage hole or emplacement room.

- Regarding retrievability/backfilling/sealing
  - the retrievability period will be 50 years (after emplacement of first waste) to provide a planned contingency which will be maintained until a license amendment has been granted authorizing full decommissioning and sealing; if retrieval is necessary, the rate of retrieval would be about the same as waste emplacement (i.e., one panel per year).
  - all openings will eventually be backfilled/sealed some time after waste emplacement and prior to decommissioning.

Based on the above conceptual design basis, the subsurface facilities (see SCR Figure 10-10) will encompass about 1500 acres (about 11,000 feet by 5,800 feet), and will consist of:

- Shaft pillar (see SCR Figure 10-8), in which all of the shafts will be located and which will also provide for waste transfer, bulk materials handling, maintenance, stores, service equipment, personnel and administrative functions, as well as ventilation control. The shaft pillar will be located in the middle of a "bow-tie" arrangement, based on an evaluation of alternatives with respect to minimal ventilation air travel and haulage distances.

- Main access ways (tunnels), which will connect subsurface areas and provide for transport of men, material, and waste, as well as ventilation. These tunnels will include a confinement air return (exhaust from waste storage areas) at the perimeter of the repository.

- Experimental panel, which will be located near the shaft, be operable through the retrieval period, and provide for
  - testing experimental mining systems
  - testing alternative configurations for disposal
  - developing repository seals
  - developing monitoring/calibrating systems
  - testing backfill/retrieval procedures.

- Contact waste storage panel, which will be located adjacent to the shaft pillar and be operable through the retrieval period.

- Waste storage panels (see SCR Figure 10-11), which will be located some undefined distance off the main access ways and be 100 feet apart; a total of 20 panels, plus one contingency panel, will be arranged so that about half are on each side of the shaft pillar and half of those will be on each side of the main access ways. Each panel will consist of two parallel placement rooms about 20 feet wide by 10 feet high separated by 200 feet, and reaming access drifts about 10 feet wide by 10 feet high which are parallel to and 200 feet outside each of the placement rooms. The shape of the placement rooms have been chosen to reduce pre-heat stress concentrations around the openings. There will be several cross cuts of undefined size at several locations linking the four parallel tunnels.

  Horizontal, circular waste storage holes, 27 inches in diameter and 200 feet long, will extend between the four parallel tunnels, but will be staggered so that a hole in one wall will be midway between holes on the opposite wall. It has been assumed that a length of 200 feet is the longest which is compatible with constructability and waste emplacement. A pilot hole will first be blind drilled with compressed air, and then the hole will be backreamed using a technique not yet developed.

  The waste storage holes will be oriented parallel to the maximum horizontal stress (perpendicular to the minimum horizontal stress) and the room oriented perpendicular to that direction. These orientations have been chosen to minimize the pre-heat stress conditions around the opening of the waste emplacement hole.

The pitch (or spacing) of waste emplacement holes and the density of waste packages (which are 15 inches in diameter and are placed end-to-end with 6 inches of space in the hole) have been determined so as to match the temperature and stress criteria in the hole or in the room. Hence, based on unreferenced thermomechanical analyses, CHLW will be placed 17 canisters/hole in holes 107 feet apart and spent fuel (specifically PWR) will be placed 13 canisters/hole in holes 60 feet apart; hence, each panel will be about 2500 feet long by 660 feet wide (38.3 acres). Under identical conditions, except with increased horizontal stresses (specifically, a maximum horizontal stress to vertical stress ratio of 3:1), the pitch would increase to 715 feet for CHLW and to 250 feet for spent fuel (PWR) at undefined package density.

It is expected that all underground openings (except waste storage holes) will be excavated by drilling and controlled blasting techniques, although mechanical excavation (e.g., by tunnel boring machine) will be considered. Support of the openings, primarily to prevent detrimental loosening of the rock mass, will consist of grouted rock bolts on a regular pattern, supplemented with shotcrete and wire mesh, as required.

All underground openings will be backfilled using a mixture of crushed excavated basalt (maximum 2-1/2" size) and bentonite (both powder and pellets). This backfill will be prepared and mixed at the surface, and then transported to the panel to be backfilled using the muck transport system in reverse. A fill fence (of aluminum) will be built up at one end of the room as it is being filled. The backfill will be dumped and spread initially by dozers in 8 inch horizontal layers, and then dampened and mechanically compacted. As the available headroom reduces, first conventional low profile equipment will be utilized in the same way, and finally a presently undeveloped "traveling shield" will be utilized to place and compact (by ramming) the remaining backfill in essentially vertical layers.

Although the decision of whether to backfill immediately after waste emplacement or much later will not be made until after the initial verification period (first five years of operation), it has been assumed by DOE in design and analysis that backfilling will be deferred until 50 years after first waste emplacement, i.e., after the retrievability period.

All underground openings, as well as shafts and boreholes, will be sealed (see SCR Figure 10-17) at decommissioning, using presently undeveloped methods, to complement the waste package and site in meeting long-term performance criteria.

Based on the conceptual design basis, the access shafts will include:

(1) Confinement air exhaust shaft, which will remove the spent ventilation air from the waste storage, retrieval, or backfill operations. This shaft will be 11 feet in diameter and will be equipped with an inspection hoist and sump pump at the bottom.

(2) Waste transport shaft, which will provide for transporting radioactive waste between the surface facilities (waste handling building) and the repository horizon. This shaft will be 12 feet in diameter and will have a counterbalanced waste transport cage, inspection hoist, and both a bumper (for impact protection) and sump pump at the bottom.

(3) Confinement air intake shaft, which will provide fresh air for waste storage operations. This shaft will be 12 feet in diameter and will be equipped with an inspection hoist, chilled water lines (for cooling), and a sump pump at the bottom.

(4) Service shaft, which will supply and remove the personnel, material/supplies, and equipment necessary to carry out the underground mining and waste disposal activities, and will also provide mine intake ventilation. This shaft will be 16 feet in diameter, and will have a counterbalanced 8 feet by 12 feet cage, a ladderway, water lines, and a sump pump at the bottom.

(5) Basalt transport shaft, which will hoist mined rock (muck) to the surface and return it (and additives) for backfill, and will also exhaust air from mining development to the surface. This shaft will be 14 feet in diameter, and will have two 10-ton basalt hoisting skips, an inspection cage, lines for utilities/water disposal, and pump stations (for water disposal).

Although the exploratory shaft (whose relationship to the repository has not been defined) will be blind bored, the access shafts are presently expected to be only blind bored through the upper water-problem areas and then conventionally sunk (i.e., drilling and blasting, possibly with grouting or freezing ahead) through the lower zones. Shafts, as well as other underground openings and boreholes, will be sealed (see SCR Figure 10-18) at decommissioning, using presently undeveloped methods, to complement the waste package and site in meeting long-term performance criteria.

Based on the conceptual design basis, the surface facilities will consist of off-site development and a secured central process area (see SCR Figure 10-3); there will also be a control zone (about 3.6 miles by 4.6 miles) which extends 2 km beyond the surface projection of the subsurface facilities. Offsite development will include transportation to the site (rail, road, and helicopter), utilities (water, electric power, and telephone), non-project off-site monitoring stations, a visitor's center, and a repository water percolation pond. Within the central process area (about 200 acres), the following facilities will be arranged around the shafts (see SCR Figure 10-4):

- Confinment exhaust ventilation building (over Shaft No. 1)
- Waste handling building (over Shaft No. 2)
- Confinement air intake building (over Shaft No. 3)
- Personnel and material access facility (over Shaft No. 4)
- Basalt headframe and material access facility (over Shaft No. 5)
- Administrative area (including administrative building, gatehouse, fire station, security headquarters, industrial safety building, and training center)
- Maintenance building

- Utility facilities (including substations, standby generator building, sewage treatment area, and water storage treatment and pumping facilities)
- Waste receiving facilities (including classification yard, inspection pits, cask storage yards, distribution tracks and roads, and docks for unloading full and returning empty shipping casks)
- Basalt storage pile
- Drill core storage building and warehouse
- Underground tanks for fuel storage and magazines for storage of explosives
- Subsurface water retention ponds and process waste evaporation ponds
- Exhaust stacks and cooling towers.

The radioactive waste handling system, which serves the primary function of the repository, will be integrated into the layout of facilities, and allows for safe receipt, handling, and placement of waste.

The service systems will be integrated into the facility layout, and include:

- Bulk handling of basalt, aggregate, cement/additives/bentonite, shotcrete/concrete/room backfill
- Material and supplies handling
- Electric power - normal, standby, and uninterruptible
- Communications
- Instrumentation, control, and alarm, both local and central
- Water supply
- Fire protection
- Low-level radioactive waste management/disposal, on site
- Non-radioactive material disposal, on site
- Physical security
- Ventilation and cooling.

Ventilation has been designed to provide separation of development and waste storage activities, and will be controlled underground by stoppings, airlock doors, and regulators. The system has been sized on the assumption of filling one panel per year with waste and then essentially blocking that panel off (i.e., no ventilation) until it is to be backfilled, again at a rate of one per year. After backfilling of a panel, unless retrieval is required, there will be no further ventilation requirements for that panel. Due to the high ambient temperatures underground (about 58°C) and especially if panels with radioactive waste must be reentered (i.e., for backfilling or retrieval), the ventilation air will be chilled (see SCR Figure 10-7) to provide an acceptable working environment.

10.3 GAI's Evaluation of Technical Adequacy of DOE's SCR Chapter 10

In GAI's opinion, the repository must be designed to satisfy specific criteria, especially safety in short-term construction/operation and long-term waste containment/isolation (as given by NRC in 10CFR60 and EPA in 40CFR191), as well as constructed within a reasonable time frame at reasonable cost and minimal socioeconomic/environmental impact. Indeed, it will have to be demonstrated (with a given level of certainty) at each step of the licensing

process that these criteria will be met by the proposed design at the selected site. As the engineered components in conjunction with the site will determine performance, the repository should be designed and subsequently constructed and operated with the given site conditions in mind. However, the assessment of these site conditions (i.e., geology, geoengineering, hydrology, geochemistry, and to a lesser extent surface hydrology, climatology/meteorology/air quality, and environmental/land-use/socioeconomic characteristics) in many cases entails significant uncertainties, as do the interactions between some of these conditions and the engineered components, so that there will generally be significant uncertainties in the prediction of repository performance. Generally, these uncertainties must be either reduced (e.g., by acquiring more data and better defining the site conditions) or mitigated (e.g., by making conservative assumptions regarding site conditions) in order to sufficiently demonstrate compliance with the criteria; sometimes a flexible design approach can be utilized whereby the design details are refined or modified during construction as the actual site conditions become known (e.g., designed contingencies). In any case, the repository design should be conservative enough so that, in conjunction with the uncertainties in site conditions, achievement of the criteria can be sufficiently demonstrated at each step of the licensing process, especially initial license application.

GAI believes that, although a detailed repository design is not required in the SCR, the design should be sufficiently described in the SCR so as to identify those site conditions which are critical to the design and performance, and thus should be focused on in site characterization prior to license application. Hence, conceptual design of a repository is necessary to identify information needs and evaluate the adequacy of the site characterization plans. The current lack of data is such as to limit tne supportable detail of the design. This limitation will not be entirely removed at the time of the initial license application for construction authorization. Presuming a site is grantec a construction authorization, the design will have to be capable of responding to a variety of geological and geoengineering conditions. The breadth of these conditions will be a function of the natural variability actually encountered.

For these reasons, a conceptual design of the underground portion of a repository at Hanford must detail a discussion of the range of natural conditions currently anticipated from existing data. In addition, the conceptual design should detail the decision process which will allow actual data to be incorporated in the design process (i.e., by modification) and into construction. This process should include design objectives and analyses, as a minimum.

When this description of a conceptual design has been presented, then the proposed plans for site characterization can be placed within context and its adequacy evaluated.

Based on the above, GAI has several concerns regarding the repository design, as presented by DOE in Chapter 10 of the SCR, especially regarding the design of underground openings and their subsequent backfilling and sealing, and the related issue of retrievability. These, and other concerns, are discussed in detail below.

Contrary to DOE's assertions of adequate conservatism, GAI believes that the current design presented in the SCR is not necessarily conservative in several key areas. Specifically, GAI believes that (1) DOE's maximum allowable design stress is too high (i.e., unconservative) and (2) this maximum allowable design stress will be exceeded in many locations. Although GAI does not agree that it is imperative, as DOE suggests, to maintain stresses everywhere around openings at levels below the uniaxial strength, this is generally a conservative approach (as overstressed zones of limited extent often develop around underground openings with no ill effects). However, if this approach is used, GAI believes that the maximum allowable design stress should be set at a value significantly below the rock mass strength at elevated temperatures, and not just below the much higher intact rock strength at room temperature, as used by DOE. The primary impact of a lower maximum allowable design stress would be a decrease in the thermal loading from an average of 70 kW/acre over the panel, thus extending the dimensions of each panel in order to store the same inventory. The analyses used by DOE to assess the induced stresses are apparently simplified and have not considered stress concentrations which will occur at many places, including the corners of placement rooms, around the essentially square reaming access drifts, and at the intersections of underground openings. These stress concentrations coupled with the possibility of higher in situ stresses than assumed would also result in a reduced allowable thermal loading. Also, as partially recognized by DOE, GAI believes that rock bursting may be a problem at such high stress conditions.

Although GAI agrees with DOE that it is important to provide rock support as soon as possible after excavation to prevent detrimental loosening of the rock mass, it is not apparent to GAI how the rock support system was designed, and what support pressure is expected and whether that will be sufficient. Also, GAI does not understand either why or how the support system will be removed prior to backfilling, as described by DOE; stability problems may result should the support system be removed. Similarly, regarding the shafts, neither the support system (during and after construction) nor the allowable design stress in zones other than the entablature through which the shaft will pass have been discussed by DOE. However, GAI believes that the issue of shaft design can be relatively easily resolved, although GAI again does not understand why or how (without causing stability problems) the shaft liner will be removed prior to sealing, as described by DOE. Regarding the horizontal waste emplacement holes, GAI has some concern that, due to the fractured nature of the basalt and because the holes will be unsupported possibly for an extended period of time, there may be some instability problems (especially with blocks falling from the crown) and some detrimental loosening of the rock mass immediately above the hole.

GAI believes that the potentially small thickness of the Umtanum dense zone (observed to be only 84 feet thick in at least one location) may complicate design. For example, some openings in the multiple-level shaft pillar, as presented by DOE, may be in or close to the less competent flow top, possibly necessitating increased support. Similarly, as underground openings are typically provided with some elevation change to promote drainage, some outer parts of the repository may intersect the flow top, or the repository level may have to stepped to avoid that intersection, causing transportation problems. Based on available information, it does not appear at this time

that thickness will be a problem in the middle Sentinel Bluffs flow. However, in either horizon, geological variability, and thus predictability, is of major concern. Although GAI agrees with DOE that exploratory drifts and pilot holes during construction are useful in this regard, GAI believes that insufficient details are presented regarding how and where they will be performed and, most importantly, how the results will subsequently be incorporated in planned design contingencies.

In addition to the above concerns regarding repository design, GAI has the following observations:

- Regarding layout of underground openings
  - the relationship of the exploratory shaft to the repository layout, especially to the experimental panel, is not clear.
  - the orientation of the repository with respect to the in situ stresses is shown (see SCR Figure 10-2) as 60 degrees from stated DOE criteria, i.e., the line of shafts should be oriented at about N30°E instead of E-W. It should be noted that hydrogeological evaluations may indicate that the orientations should be controlled only be such hydrogeological criteria, and that in situ stresses are of secondary importance.
  - although GAI generally agrees with incremental development, it may be useful to consider alternating placement rooms and reaming access drifts, with emplacement holes extending between.

- Regarding construction of underground openings
  - 200 feet long horizontal waste emplacement holes are assumed by DOE to be the longest which can be constructed and have waste emplaced, although no justification has been presented. Indeed, the back reaming techniques to be used in construction have not yet been developed and tried.
  - the feasibility of tunnel boring machines or other mechanical excavators for use in constructing underground openings has not been discussed.
  - potential problems with stability during shaft construction in less competent zones has not been discussed. It will be difficult to extrapolate the results of the smaller diameter, totally blind-bored exploratory shaft to the proposed mixed-construction methods of the larger diameter access shafts.

- Regarding waste emplacement, the dimensions of the waste packages have not been given, except for a 12.5 foot length (see SCR Figure 10-5) for which 17 packages will not fit in a 200 foot long hole. GAI suspects that the density was picked as being the maximum (and not necessarily the optimum, as stated by DOE) number possible per hole. This high density of waste packages might cause high temperatures in the waste packages and immediately adjacent materials. Also, GAI suggests that the waste package support systems may cause accelerated waste package corrosion/degradation and should be evaluated as part of the optimization studies.

- Regarding activities in the experimental panel, which DOE states will continue through the operation period, GAI believes that some of these activities may be required to be completed prior to license application, rather than after construction authorization, as implied by DOE.

- Regarding ventilation, although GAI concurs that two separate ventilation systems are desirable, it appears that this may be difficult to achieve and control. Also, the system appears to be limited in that it has been sized for developing one panel per year and for either placing waste in one panel or backfilling one panel per year.

- Regarding dewatering, although pump stations are said to be located in Shaft No. 5, there is no discussion by DOE of dewatering the repository, i.e., the rate of inflow expected and how it will be collected.

- Regarding surface facilities, no justification is given by DOE for allowable foundation loads and no seismic design information has been discussed; indeed, the relationship of allowable bearing pressure to the size of the foundation has not been discussed. Also, it is not clear how and where non-radioactive wastes will be disposed of on-site, as stated by DOE.

Regarding backfilling, GAI has the following concerns:

- When and why will backfilling occur? DOE states in one section that no backfilling will occur until after all excavation has occurred, partly because the basalt transport shaft will be used to transport backfill, and in another place that no backfilling will occur until after the 50-year retrievability period. Elsewhere (see SCR Figure 10-14), the option of backfilling immediately after emplacement is contemplated. Still elsewhere, DOE concludes that based on undefined thermal analyses, backfill must be deferred at least 10 years in order to keep backfill temperatures within the criteria, which have not been justified. Can, in fact, backfilling occur at the same time as waste emplacement in the same or different panels with the given ventilation system? Backfilling at the rate of one panel per year appears to be slow. How will panels be sealed off after waste emplacement and prior to backfilling? If backfilling is deferred, then water in the panel and the effects of cooling on the heated rock mass (i.e., opening of discontinuities) may become problems.

- How will backfill be placed and compacted? Although DOE states that holes will be pneumatically backfilled, the procedures are not discussed, especially their problems with respect to adequate QA/QC. The procedures presented for backfilling the rooms are based on room dimensions (20 feet high) for vertical emplacement of waste; a traveling shield 20 feet wide may not be feasible. Will similar procedures be used for other underground openings, and how will these activities be ventilated? Why is an aluminum fill fence used, and is it left in or removed?

- What type of backfill will be used and why? Although a mixture of crushed basalt and bentonite (pellets and powder) is specified, the relative amounts or size distributions are not discussed, and the reason for using bentonite in the room not presented (e.g., high sorption, etc.)

- How will long-term performance of backfill be adequately assessed during the operating period, much less prior to initial license application?

Regarding retrieval, GAI believes that DOE should identify the potential conditions which might dictate retrieval of some or all waste packages, and discuss the process by which decisions regarding retrieval will be made. Some consideration should be given as to how retrieval can be safely and effectively carried out under potentially adverse conditions. Specifically, GAI believes that retrieval of defective waste packages could be relatively difficult with long horizontal waste emplacement holes, especially under any of the following conditions:

- If the hole has previously been backfilled
- If loose rock should fall from the unsupported roof of the hole to partially or completely block the passage
- If the in-hole waste package transport mechanism should malfunction.

These difficulties in retrieval could be compounded due to the potential distance into the rock from an accessible opening at which the problems might occur. Also, if the room has been backfilled, it may be difficult to cool the room/backfill sufficiently for remining activities.

Regarding seals, GAI has the following concerns:

- In defining preliminary seal requirements
  - dispersion and diffusion have been ignored
  - the computer code FLOW is undefined
  - uncertainties are ignored
  - how individual radionuclides are considered is not clear
  - explicit redundancy of barriers (for conservatism) has not been considered.

- The seal design(s) are not apparent. For example, how will disturbed zones or boreholes be sealed? Why have different types of "structural" barriers (e.g., concrete and basalt blocks with mortared joints) been mixed in the same design? The dimensions presented are unjustified (e.g., for the sand-clay plug, see SCR Figure 10-14b), and in some cases may be outdated (e.g., tunnel diameter of 23 feet). Although used interchangeably (see SCR Figure 10-14b), compressed bentonite blocks and mortared basalt blocks are very different. How will contact grouting occur?

- How will long-term seal performance be assessed? Will there be any seal demonstration, such as a shaft seal demonstration in the exploratory shaft, and if so when (e.g., prior to initial license application)? Even so, the long-term performance will be difficult to assess.

In conclusion, it is GAI's opinion that, although a detailed design is neither required nor even appropriate (due to a lack of sufficient information) at this time, DOE has not presented sufficient detail regarding some aspects of the conceptual design and, regarding some others, has been contradictory. Most importantly, however, DOE has not presented the decision process which they will use to develop the conceptual design through final design and into construction/operation. Secondarily, GAI believes that:

- DOE's design of underground openings may in some respects not be conservative.

- Geological variability, and thus predictability (especially regarding thickness of the Umtanum dense zone, the reference repository horizon), is a major issue, and how this will be handled by DOE using design contingencies is not clear.

- Insufficient information has been presented by DOE regarding backfill and sealing, especially related to (1) the objectives and criteria of each, (2) how and when long-term performance of each will be assessed, and (3) the schedule for backfilling, so that the adequacy of current engineered barrier design cannot be evaluated at this time.

- Retrieval from long horizontal waste emplacement holes may entail significant difficulties, and has not been discussed sufficiently by DOE to evaluate at this time. Especially, as part of the design process, the potential retrieval scenarios (i.e., the conditions that should be considered) should be presented, together with an outline of the process which will be used to make decisions regarding retrieval.

11. EXECUTIVE SUMMARY OF SCR CHAPTER 11 - WASTE PACKAGE

11.1 Synopsis

Chapter 11 of the SCR presents available data on the characteristics, performance and development of waste packages for a nuclear waste repository at Hanford. This information is fundamental both in the design and construction of a repository, as well as in the determination of the long-term performance of a repository, especially related to the determination of the rate of release of radionuclides to the geologic system and eventually the accessible environment.

DOE presents a discussion of waste form characteristics which are generic to all geologic media. DOE presents its reference waste forms to be commercial spent fuel and borosilicate glass for both defense and commercial high-level wastes, adding that other wastes, such as transuranics, are under consideration by DOE for inclusion in a repository. DOE presents its current waste emplacement design concept of emplacing steel-canistered wastes into long, horizontal boreholes drilled between mined tunnels, and pneumatically backfilling around the canister with a mixture of sodium bentonite pellets/powder and crushed basalt. In the area of waste canister development, DOE states that extensive research and development has enabled and justified a dramatic simplification of its conceptual waste package design, removing the multiple corrosion barrier materials previously assumed and replacing them with a thick steel canister. DOE also reviews some of its ongoing research and development activities at the Hanford Site, pertaining to waste package development.

In GAI's opinion, the components of DOE's reference waste package designs cannot be technically defended as being conservative at this time because:

- There is virtually no relevant data on the performance of any of the waste package components (including waste forms and canister materials) under geochemical/environmental conditions expected in a repository at Hanford.

- The assumptions made to perform the simplified performance analyses may not be conservative, e.g., the corrosive environment in a repository at Hanford may have been underestimated due to potential overestimates (by a factor of 20 or more) of the time required to resaturate the repository and waste package.

GAI also believes that, because of the apparently large uncertainties as to the types of wastes that will be disposed of in the repository, DOE should consider all candidate wastes, including TRU wastes, which may be disposed of in a repository prior to making a determination of site suitability.

11.2 Summary of Technical Content Presented by DOE in SCR Chapter 11

Chapter 11 of the SCR presents a lengthy description of waste form characteristics, waste package emplacement design concepts, waste package materials, the emplacement conditions that waste packages are expected

to encounter in a repository at Hanford, and a simplified assessment of waste package performance.

In describing waste form characteristics, DOE presents the possible range of wastes which might someday be emplaced in a commercial repository. These include solidified, reprocessed high-level waste from both the commercial nuclear power sector, as well as from defense activities (weapons production, naval propulsion, etc.), unreprocessed spent fuel from commercial nuclear power plants, and commercial transuranic wastes. DOE limits its waste form data presentation to solidified high-level wastes and spent fuel, excluding transuranic wastes because their inclusion in repositories "is under DOE-Headquarters review at this time."

DOE presents extensive descriptive data on borosilicate glass (a candidate high-level waste form), alternate high-level waste forms, and spent fuel. The majority of the data is "generic," as no experiments have yet been conducted which measure nuclide release characteristics under environmental conditions anticipated in a repository at the Hanford (see SCR pages 11.1-9 and -13). While DOE's statements apply only to solidified high-level waste forms, data is also not presented for spent fuel under expected repository conditions.

DOE presents the "candidate reference solidified waste form" to be borosilicate glass for both commercial and defense wastes. Little performance data is presented for glass that is applicable to a repository at Hanford. DOE presents the baseline spent fuel package concept as fuel pins that have been disassembled from their assembly and close-packed in a canister. As with high-level waste glass, little applicable performance data is presented for spent fuel. DOE cautions, however, that preliminary data suggests that ^{99}Tc may be difficult to contain if the waste package does not survive for at least 1000 years.

DOE presents a summary of previous and current waste package emplacement design concepts for a repository at Hanford. The current reference design concept (see SCR Figure 11-6) involves the horizontal emplacement of spent fuel or commercial, solidified high-level waste (does not apply to DOE reference defense high-level waste canister because of size constraints) in boreholes drilled between repository tunnels. These boreholes will contain several canisters (see SCR Chapter 10 - Repository Design), which are made of ductile iron. A six inch annulus surrounding the waste packages will be pneumatically filled with sodium bentonite pellets/powder and crushed basalt, loose mixed in a 25 percent bentonite - 75 percent basalt mixture by volume.

DOE presents brief performance data on alternate waste package materials. Comprehensive data is not presented, because "estimates of waste package component reliability have not been made to date" (see SCR page 11.2-10). For its reference canister material, ductile iron, DOE presents no data measured for conditions expected in a repository at Hanford. They do, however, present one data point for the corrosion of iron under oxidizing conditions for a simulated Hanford groundwater.

DOE presents a qualitative and subjective discussion of the properties and possible performance of the barrier materials (i.e., a bentonite-basalt

mixture) placed around the canister. DOE points out that it is yet to be determined whether backfills will be required or used. Further, it states that all barrier design and selection has been done on the basis of data in the literature and other programs. DOE presents no data on expected barrier performance and acknowledges that little to no data exists on the predicted behavior of candidate barrier materials in the presence of radiation fields expected in a repository.

DOE presents a discussion of emplacement conditions expected in the repository, including both host and man-induced conditions. DOE briefly discusses the host geochemistry, pointing out that repository-level groundwater at Hanford is saturated with silica, and highly concentrated with F^-, SO_4^{--} and Cl^-. Ambient temperatures are known, with reasonable confidence to be between 51°C and 58°C, depending on depth. DOE predicts waste canister peak temperatures at about 250°C in less than ten years and dropping to 150°C at 150 years (see SCR Figure 11-12). These calculations presume a resaturation of the host rock in about 400 years, and a resaturation of the package backfill in about 2000 years. However, calculations are for a previous design concept of vertical waste emplacement in the floor of the repository, which has now been superceded by the horizontal emplacement configuration. Hydrostatic and lithostatic pressures anticipated at repository depths are presented. In discussing the reactivity of repository level groundwater, DOE presents a parametric equation describing pH as a function of temperature, asserting that on the basis of experimental data, Hanford groundwater has a declining pH with increasing temperature. DOE also presents a parametric representation of groundwater Eh. A qualitative discussion of the radiation environment anticipated in the vicinity of the waste package is presented, along with limited package performance data.

DOE presents a simplified analysis of the performance of a reference waste package. DOE adopts "conservative" assumptions on the hydrology of the site and on the environments and circumstances of package and repository failure. Assuming that solubility constraints limit the rate of release of radionuclides from a waste form, DOE concludes that with its waste package, and for the ten selected isotopes examined, the predicted repository performance is between three and nine orders of magnitude better than required by the draft EPA standards.

DOE briefly presents an alternate, more complex waste package and reviews the major conclusions of the entire chapter, including an acknowledgement of the sparcity of relevant data and the finding that, based on the limited data, earlier conservative waste package designs can be greatly simplified to the current reference waste package.

11.3 GAI's Evaluation of Technical Adequacy of DOE's SCR Chapter 11

In GAI's opinion, the design and development of the waste package is a fundamental and critical part of the repository program. The waste package must serve as the primary containment for radionuclides for at least 1000 years, as specified in NRC's draft 10CFR60. The rate at which nuclides will subsequently be released from the waste package will also determine the degree of radionuclide retention and holdup that must be provided by the engineered barriers and the host geology.

In GAI's opinion, there are several critical issues with regard to the DOE waste package effort as presented in the SCR, specifically in the following areas:

- The types of wastes that may be disposed of in a repository at Hanford
- The absence of relevant waste form data
- The predictions of the corrosion environments that packages may be exposed to
- The removal of waste package design conservatism by DOE
- The unsupported assumptions used by DOE to support waste package development

DOE states that only spent fuel, commercial high-level waste, and defense high-level waste are discussed in the SCR, and that there is great uncertainty about what wastes will actually be placed in a repository. DOE also states that other transuranic waste forms are not discussed in the SCR because of ongoing discussions at "DOE-Headquarters." Yet in the Project Plan issued by the Assistant Secretary for Nuclear Energy on April 15, 1982, the waste inventories and types that are to be disposed of in a repository are stated. Thus, it is apparent that DOE may not know even the types of wastes that may be destined for disposal in a repository at Hanford, and therefore cannot adequately assess the suitability of the Hanford Site until the potential health and safety consequences associated with the disposal of all candidate waste forms has been adequately examined.

Although a great deal of generic waste form data describing spent fuel and glass wastes is presented, this data has very little applicability to waste performance in a repository at Hanford. DOE acknowledges this in stating that "no accurate measurements of the leachability of these commercial waste glass forms under conditions applicable to a nuclear waste repository in basalt have been made" (see SCR pages 11.1-9 and -13). Yet in spite of this admission, DOE has drawn many conclusions about waste form performance and adequacy. It is GAI's opinion that DOE does not present the data with which to assert the performance or adequacy of any waste form in a basalt repository at Hanford. Furthermore, GAI believes that any calculations of repository performance which utilize a prediction of package releases should be assigned very little validity and large uncertainties because of this data gap.

The discussion regarding waste package design concepts for a repository at Hanford also suffers, in GAI's opinion, from the absence of relevant data and thus unsupported conclusions. Indicative of this weakness is the assertion made by DOE that "Because of an extensive research and development program conducted by the BWIP to characterize the basalt site, sufficient site specific data are now available to reevaluate and simplify the initial conceptual waste package design" (see SCR page 11.2-1). In contrast, DOE states that it has no relevant data on the performance of waste forms in a basalt site, and also that there is virtually no data on the corrosion characteristics of the "reference" iron waste package in Grande Ronde groundwater under expected repository conditions. Thus, in GAI's opinion, this "simplification" cannot be supported on the basis of a predicted benign geochemical environment, because DOE presents no data with which to determine whether or not the repository environment is or is not benign toward a waste package or form.

Part of DOE's conclusion about the benign repository environment is founded in a belief that resaturation of the backfill material surrounding the package will not occur for up to 2000 years (see SCR Figure 11-12 and page 11.2-4). If this is the case, then temperatures in the vicinity of the package, once water has reached it, will be on the order of 100°C, leading to reducing groundwater conditions. However, work currently being performed by GAI for the NRC offers an alternate view. Using data obtained from DOE, GAI predicts resaturation times to range from a few months to less than one hundred years. If such shorter periods of time are shown to be more likely, the temperature in the vicinity of the package at resaturation may be on the order of 250°C (see SCR Figure 11-12). The result of this is likely to be, in GAI's opinion, a more corrosive geochemical environment at the waste package than DOE is currently designing for. GAI is concerned that, in not being sufficiently conservative in its design approach, DOE may develop waste packages which do not meet health and safety standards proposed by NRC.

In discussing the functions of the various waste package components, DOE asserts that failure of both the backfill and the package is unlikely. However, it is GAI's opinion that (1) DOE does not have the data with which to actually predict package performance, and (2) DOE's backfill scheme may have failures simply as a result of the complexities and imperfections in the pneumatic backfill methods. Thus, while DOE believes theirs is a conservative package design, it is GAI's opinion that the design cannot at this time be credibly defended as being conservative.

DOE concludes that their evaluation of the waste package's performance in a repository at Hanford is "conservative analyses of repository performance since containment for all waste packages was assumed to fail in a water saturated repository 1,000 years after closure" and because "radionuclide solubilities rather than leach rates are used to limit radionuclide release." It is GAI's opinion that DOE's assumptions which leads them to state that the analysis is conservative are unsupportable. The first assumption made is that all waste packages fail simultaneously at 1000 years. While the simultaneous failure of all packages is extremely unlikely, the likelihood of their failure at or before 1000 years cannot be assessed because, as stated earlier, DOE presents no relevant data on the corrosion rates of their reference iron canister materials in Grande Ronde groundwater under repository conditons. The second assumption is that resaturation will have reoccurred by 1000 years. DOE believes this is conservative because it predicts resaturation at 2000 years. However, as stated previously, using data supplied by DOE, GAI has calculated resaturation to occur as early as a few months after closure and within one hundred years. Finally, DOE believes the analyses are conservative because of the assumption that release is controlled by solubility limitations rather than leaching. However, the values of solubility that DOE uses are indefensible in GAI's opinion and are, in one case, in conflict with data they present elsewhere in the SCR. For example, in SCR Chapter 6, DOE presents no real data on solubilities of the four elements considered, and states that the values listed are estimates, unsubstantiated by experimental evidence. Further, in the case of americium, DOE states (see SCR Chapter 6) that americium solubilities may be "less than 10^{-9} mole per liter at pH=10." Yet in the performance analysis, DOE shows that an isotopic solubility of Am-243 of 10^{-12} was assumed. At 1000 years, GAI calculates that Am-243 will be about

25 mole percent of the total americium inventory; thus, this value, by DOE's own estimates presented in the SCR, should not be 10^{-12} but at least 3×10^{-10}. Yet, even with this correction to attain consistency, no values of solubility can at this time be defended, in GAI's opinion, because of the absence of actual appropriate measurements.

In conclusion, GAI's fundamental criticism of the DOE waste package effort is that DOE has, by their own statements, virtually no relevant data with which to predict the performance of waste packages, or with which to justify its modification of the conceptual waste package design. This lack of data means, in GAI's opinion, that at present DOE cannot reliably predict the performance of the Hanford Site if credit for the waste package is incorporated in the analysis. Further, it is GAI's opinion that DOE cannot defend its current waste package design as being sufficiently conservative. Thus, it is GAI's opinion that this is a significant deficiency in the DOE program and should be rectified prior to initial license application.

12. EXECUTIVE SUMMARY OF SCR CHAPTER 12 - PERFORMANCE ASSESSMENT

12.1 Synopsis

Chapter 12 of the SCR presents performance issues for a repository located at the Hanford Site, and methods and computer models for calculating potential releases of radioactive material to the accessible environment. This chapter also presents the results of preliminary modeling studies to assess the suitability of the deep basalts at Hanford for waste disposal. This information is essential as it integrates all other activities (such as waste package and repository design) to predict the long-term performance (regarding radionuclide isolation) of a repository at Hanford.

DOE indicates that the major performance issues are based directly on demonstrating compliance with the NRC draft technical criteria (stated in 10CFR60) and the EPA proposed standard (stated in 40CFR191), and that this will require a comprehensive risk assessment. The alternative mathematical and computer models on which this assessment should be based are presented by DOE and described, as well as the approach to developing a system for performance analysis. Specific modeling studies to calculate groundwater travel times through the geologic media, and to predict potential problem radionuclides and their rate of release from the underground repository are described. Cumulative releases of radionuclides to the accessible environment are also predicted by DOE and methods for evaluating uncertainties in both site data and models are presented. Generally, DOE proposes to use an assessment methodology based on the consideration of a broad range of conditions to provide sufficient assurance that the model predictions compensate for uncertainties, and thus give reasonable expectation of compliance with the EPA draft regulations. Preliminary studies completed by DOE have not used the above stated methodology. However, DOE concludes that the expected groundwater flow paths from the candidate repository horizons are predominantly horizontal and confined to the deep basalts, and suggests that low nuclide solubilities and long groundwater travel times to the accessible environment (defined as 10 km from the repository) will likely ensure compliance with both NRC draft technical criteria and EPA draft regulations.

GAI has several concerns regarding the adequacy of the performance assessment material presented by DOE, specifically:

- Significant apparent uncertainties are associated with all existing numerical groundwater flow models of the Pasco Basin and reference repository location. The numerical sophistication of the numerical codes is high, but the most significant uncertainty is in the validity of the conceptual groundwater flow model. These uncertainties include:
  - uncertainties in the existing data due to testing methodology
  - uncertainties due to natural variability of critical hydrogeologic and geochemical parameters
  - uncertainties due to largely unknown boundary conditions
  - uncertainties in the modeling which couples thermomechanical effects on mass transport.

The consequence of these uncertainties is that DOE's prediction of travel time at this stage in the process does not represent the entire range of possibilities and, as a point estimate, appears to be substantially higher than reasonably conservative evaluations would predict.

- DOE recognizes major uncertainties in the data base and numerical models and presents a methodology based on "systematic and conservative analyses that provide bounding estimates of radionuclide migration." In GAI's opinion, this is unlikely to provide a clear and defensible analysis of site performance, and a more rigorous approach to uncertainty analysis may well be required.

- The approach to comprehensive risk assessment outlined has not been adequately followed to date by DOE. Model studies are neither comprehensive nor demonstrably conservative, and the conclusions on radionuclide releases are not adequately represented in the context of the stated uncertainties in the models and data. More confidence in the current numerical results is implied than is demonstrated by DOE.

- The results of performance assessment studies to date are based on DOE's existing numerical groundwater model. Until such time that a unique groundwater model can be defensibly developed by measured data, performance analyses should include a range of groundwater models incorporating the various identified components of uncertainty. Since performance analyses will be required to defend the requirement or adequacy of the data base at the time of a license application, and presumably prior to this time, erroneous conclusions may have been drawn by using overly optimistic estimates of data.

In conclusion, GAI believes that the discussion of the performance issues adequately identifies the over-riding concerns in performance assessment, and that methods presented to calculate performance are generally comprehensive and satisfactory. GAI's concerns are focused on the adequacy of the conceptual models, the data bases, and the treatment of data and model uncertainties. In GAI's opinion, the predicted results obtained to date do not demonstrate compliance with any reasonable degree of confidence.

12.2 Summary of Technical Content Presented by DOE in SCR Chapter 12

Chapter 12 of the SCR discusses repository performance assessment at Hanford, which addresses containment and isolation of radioactive wastes to assure conformance with regulatory standards. The scope of this chapter is limited to repository performance assessment related to the post-closure phase; performance assessment for the operating phase will not be addressed by DOE until the repository conceptual design is completed. The information presented in this chapter is concerned with four major aspects of performance assessment:

- Identification of major performance issues
- The methodology developed for assessing repository system performance
- Review of performance analyses completed prior to this SCR
- Results of performance analyses completed specifically for this SCR.

DOE identifies four performance issues and the regulations which define these issues, including:

- The initial containment time provided by the engineered system, including the waste package and the underground facility (NRC 10CFR60)
- The rate of radionuclide release from the emplacement horizon to the geologic medium following loss of containment (NRC 10CFR60)
- The pre-waste emplacement groundwater flow paths through the geologic medium and groundwater travel time from the repository disturbed zone to the accessible environment (NRC 10CFR60)
- The total activity (of individual radionuclides) leaving the boundaries of a specified control zone around the repository (EPA 40CFR191).

DOE indicates that a defensible prediction of releases to the accessible environment will require a comprehensive risk assessment that:

- Identifies plausible release modes, considering the geotechnical factors and physical processes of significance
- Estimates the probability for each release mode
- Conservatively bounds the consequences of releases.

This activity will include the use of predictive models to determine:

- Groundwater flow paths and travel times for anticipated geologic conditions and postulated disruptive conditions
- Radionuclide transport, accounting for waste package degradation, waste form leaching and solubility, groundwater flow, thermal and geochemical conditions.

DOE concludes that consideration of a broad range of geologic/hydrologic/geochemical conditions will provide sufficient assurance that the model predictions compensate for uncertainties, and thus give a reasonable expectation of compliance with the EPA draft regulations. The SCR also points to sub-issues in Chapters 13 and 16, related to assessing the reliability of numerical models in predicting system performance.

DOE's performance assessment methodology is based on identification of mechanisms that can lead to radionuclide releases and the quantification of potential releases from these mechanisms. DOE generally categorizes phenomena that can induce radionuclide release as (1) natural phenomena or processes, (2) man-induced effects, or (3) repository construction induced effects. Site specific release scenarios are to be selected based on event credibility, probability of release, and consistency with site data and knowledge. A final list of disruptive event scenarios for the Hanford Site has not been completed. Three that are currently being evaluated by DOE include an interconnecting fault, shaft seal degradation or failure, and borehole intrusion.

DOE states that the consequence of potential releases is to be determined using mathematical models in three subregions. These are very near field (canister to room scale), near field (repository scale), and far field (basin

scale), and each subregion model will be developed specifically to portray the dominant processes in appropriate detail. Sources of uncertainty in model predictions are identified by DOE as uncertainties in mathematical models, errors in field measurements, errors in interpretation of the spatial variation of discrete data points, and incomplete geohydrologic characterization.

DOE identifies several methods of dealing with these uncertainties, and concludes that the rigorous application of uncertainty analysis is extremely difficult because:

- It requires a large quantity of measured data
- Characterization of a site may be limited to assure that natural barriers are not compromised.

The methodology adopted in the SCR is therefore based on the use of systematic and conservative analyses that provide bounding estimates of radionuclide migration. The approach includes:

- Coupled heat, groundwater flow and radionuclide transport models in fractured and/or porous media
- Parametric and sensitivity analysis of release scenarios
- Decision- or logic-tree strategy to guide parametric studies.

A set of mathematical models has been formulated by DOE's contractors for use in detailed performance analyses to represent the four major processes involved in waste isolation, namely rock stress/strain, heat transfer, groundwater flow, and solute transport. DOE provides a summary of the computer codes (representing these mathematical models) both developed and/or applied in the BWIP studies, and being evaluated for planned performance calculations. DOE also indicates how selected codes can be integrated into a system model, and states that documentation for the codes to be used by the BWIP is being prepared.

The procedure adopted by DOE to verify the correctness of the code algorithms includes comparison with analytical test case results and testing against other computer codes using realistic simulation problems. The numerical models identified for use by DOE are in various stages (undefined) of development and verification. In addition, efforts (undefined) are underway to compare model results to data from field or laboratory experiments. The process of demonstrating that a computer model adequately represents physical reality is termed "model validation".

Several performance analysis (hydrologic and solute transport) studies completed by DOE to assess preliminary long-term repository performance are presented. These are categorized as:

(1) Far-field studies to assess compliance with the NRC proposed technical criteria for groundwater transit time
(2) Very near-field studies to assess compliance with the NRC proposed technical criteria for repository radionuclide releases
(3) Near-field studies to assess compliance with the EPA draft regulations.

Each of these is discussed separately below.

(1) The results of early far-field hydrologic studies by several of DOE's contractors are presented. The hydrologic models generally represented the major basalt formations as continuous, multi-layer (5 or less) confined aquifer systems extending across the Pasco Basin. From these models, DOE presents predicted groundwater travel times to the accessible environment ranging from 13,000 to 7 million years over distances of 8 km to 65 km. These variations were stated by DOE to be due to different data sets and assumptions used. DOE concludes, however, that additional hydrologic data are needed to demonstrate a satisfactory understanding of flow path orientation and travel times.

(2) A preliminary very near-field performance assessment (using a simple one-dimensional waste transport model) has been performed for DOE to determine the hazardous radionuclides that could be released from a repository in basalt and to back-calculate the maximum permissible release rates from the engineered system to the accessible environment. The intent was to define radionuclide releases that exceed the proposed (NRC) criteria for the site for both base case and fault scenarios. From these analyses, DOE lists radionuclides that can potentially be released at rates which would exceed those specified by the NRC proposed criteria. DOE concludes that additional geochemical data are needed to properly evaluate solubility limited release rates for many radionuclides.

(3) A preliminary near-field performance analysis that was completed specifically for this SCR is presented by DOE. Using the 2-dimensional numerical model PORFLO to simulate coupled flow and solute transport, the groundwater flow path and travel time, radionuclide concentration and total radionuclide activity crossing a specified boundary were calculated. Two candidate horizons were evaluated by DOE, for expected natural conditions and for a postulated fault near the repository, using a multi-layer (40) geologic model. The SCR provides details of the geologic and hydrologic data used in the model, including:

- hydraulic conductivity (horizontal and vertical)
- hydraulic heads and gradients
- specific storage coefficients
- porosities
- sorption coefficients
- mass dispersivities
- groundwater temperature
- thermochemical data.

The assumptions made for this analysis are stated in the SCR to be:

- the repository contains 10-year old spent fuel
- the repository is completely backfilled and sealed
- the waste package and engineered barriers contain the waste for 1000 years after closure, i.e., all canisters fail simultaneously after 1000 years

- radionuclides are released to the groundwater in the repository at a constant fractional rate of 10^{-5} per year
- long-term predictions of waste migration considered only ^{14}C, which was selected because of its long half life, high specific activity, radiological significance and zero sorption in basalt.

The results presented by DOE in the SCR indicate groundwater travel times to the accessible environment (i.e., 10 km away) ranging from 30,000 to 41,000 years for all cases considered. At 10,000 years, the plume of contaminated water (concentrations of ^{14}C) extends laterally only 3 km from the repository and upwards 150 m to 200 m for the cases considered. The postulated fault has essentially no effect on repository performance in terms of either the travel time or migration of ^{14}C. From these results, the DOE concludes that potential releases from the reference repository will most likely meet the EPA proposed standard, since radionuclides are unlikely to reach the accessible environment (at 10 km) in a 10,000 year period.

The primary conclusions developed by DOE in the SCR from the available modeling studies are:

(1) Regarding the far-field

- Calculated pre-waste emplacement groundwater travel times significantly exceed the 1000 year travel time from the repository to the accessible environment specified in the NRC proposed regulations.
- The differences in the predicted results reflect uncertainty in the existing hydrologic conceptual model, and it is stated that a more complete hydrologic characterization of the basalts will be needed. The SCR lists parameters where lack of data contributes to this uncertainty, including hydraulic head profiles, hydraulic conductivity, porosity and an understanding of groundwater flow patterns at the Hanford Site.

(2) Regarding the very near-field

- Solubility of radionuclides is a dominant factor which can limit the repository release rates to levels well below the NRC proposed criteria for many radionuclides, particularly technetium, americium, neptunium, and plutonium.
- There is no incentive for a complex waste package with an extended containment capability.
- High sorptive properties of basalt will retard the movement of radionuclides such as cesium, strontium, radium, and americium.
- A reliable data base on solubility and related thermodynamic properties of key radionuclides should be developed to minimize uncertainties in this factor.

(3) Regarding the near-field

- The post-waste emplacement groundwater travel times from the repository to the reference boundary (i.e., 10 kilometers from the edge of the repository) are estimated to be greater than 10,000 years, ignoring the travel time through the engineered barriers.
- The groundwater flow paths from both candidate repository horizons are predominantly horizontal and are restricted to the deep basalt flows.
- The transport of mobile long-lived radionuclides, such as ^{14}C, is limited to about 200 vertical meters and less than a few kilometers horizontally after 10,000 years.
- The release of ^{14}C across the reference boundary (at 10 kilometers) remains well below the EPA draft (1981) regulations for both no-disruption and postulated fault zone conditions.
- The degree of confidence in the current numerical prediction is not quantified, but DOE suggests that the predictions may be bounding estimates because of certain conservative assumptions in the analysis.

12.3 GAI's Evaluation of Technical Adequacy of DOE's SCR Chapter 12

In GAI's opinion, assessing the performance of the proposed repository at Hanford is the key activity which will determine whether or not the site and design are safe enough to meet Federal performance standards. Because performance assessment is the means by which DOE will predict whether or not the site and design will protect and maintain the health, safety and well being of the public, it is GAI's opinion that repository performance analysis must be comprehensive and adequate, as well as technically unassailable.

While DOE indicates that resolution of performance issues will be achieved using predictive models for groundwater flow and radionuclide transport and that proof of compliance with the technical criteria and regulations will depend on the reliability of numerical models to predict system performance, it is GAI's opinion that, although this general philosophy is appropriate, DOE has not adequately demonstrated in the SCR how certain key elements of the modeling process will be evaluated. Specifically, GAI is concerned with DOE's approach to predictive modeling, defining release scenarios and treating uncertainties, as discussed below.

In the SCR, DOE lists a large number of potential release scenarios, but presents no discussion of which are plausible for the Hanford Site or their probability of occurrence. In GAI's opinion, the approach to comprehensive risk assessment outlined in the SCR has not been followed through to date by DOE because a defensible identification of plausible disruptive event scenarios for the Hanford Site has not been completed. Also, events which may damage the waste package and/or the engineered barrier system after the repository is decommissioned, and their effects on release rates, are not considered by DOE. Rather, the emphasis is entirely on disruptive events that may affect the transport of waste through the geologic system.

While DOE recognizes that major uncertainties exist in both the data base and in the use of numerical models, these uncertainties are not explicitly discussed nor is an attempt made to quantify them. In fact, DOE implies that a rigorous application of uncertainty analysis methods cannot be used to demonstrate compliance. It is GAI's opinion that the analysis in the SCR does not use conservative parameters and assumptions. Further, in GAI's opinion, the alternative methodology presented in the SCR, i.e., that of "systematic and conservative analyses that provide bounding estimates of radionuclide migration", will not provide a clear and defensible analysis of site performance unless:

- The range of data used is demonstrated to be representative of all field measurements
- The spatial variation of discrete data points is quantified
- All credible conceptual geological/hydrological models are evaluated on a common basis, using alternative interpretations of the available data
- The uncertainties or "conservatisms" in the test methods and mathematical models are explicitly defined and evaluated, i.e., the effect of a given parameter on the results should be determined.

DOE presents methods by which these points can be addressed, including code benchmarking and verification for numerical models and statistical techniques for data analysis. The extent to which these techniques have been used is not, however, specified in the SCR. In particular, the performance analysis results are determined using one geologic/hydrologic interpretation (conceptual model), with relatively small differences in the data inputs.

In GAI's opinion, a rigorous approach to uncertainty analysis is a more comprehensive and technically defensible approach to predicting repository performance. While parametric and sensitivity analyses can certainly provide boundary solutions, the extent to which these solutions are conservative may not be readily apparent. It is also noted that the methodology presented by DOE has not been applied to analyses completed to date and presented in the SCR.

The listing of computer codes that may be used in performance analyses is apparently quite comprehensive, and codes are available to handle non-linear rock properties, non-isothermal groundwater flow, advection and diffusion processes, and single or multi-component and decay chain nuclide transport. It is GAI's opinion that these codes represent state-of-the-art capability, and that the DOE's approach to building up a system model is correct.

However, the information presented in the SCR does not clearly address several important issues:

- Which computer codes will be used by DOE in its system model for performance analyses of the Hanford Site?
- What steps are being taken to validate those models to be used?
- What rules will be applied to convert field data to system model data?

DOE indicates that some of this work is ongoing. The performance analyses presented in the SCR have involved only a very small number of the codes listed. It is GAI's opinion that the SCR should indicate:

- The type of analysis and level of detail that DOE believes is necessary for each step of the performance analysis
- The codes which are best suited to dealing with these defined steps
- The system model preferred by DOE and likely to be used for performance assessment.

The performance assessment studies can be described as hydrologic and/or solute transport. GAI's concerns are discussed separately below for the (1) far field, (2) very near field, and (3) near field.

(1) Regarding the far-field performance assessment (hydrologic only) presented by DOE, it is GAI's opinion that there are several points of concern regarding DOE's interpretation of the groundwater system at Hanford:

- The conceptual groundwater model presented in the SCR does not account adequately for the effects of structural and stratigraphic discontinuities that are recognized (by DOE) in the Columbia River Basalts. The oversimplification of the hydrogeologic system in the SCR makes the validity of DOE's numerical model so uncertain that little confidence can be placed on current estimates of groundwater travel time.

- There are large uncertainties in the value of hydraulic parameters presented in the SCR, due to

  - no measured values of vertical hydraulic conductivity or matrix diffusion
  - only one measure of effective porosity and dispersivity
  - only single-hole tests and no large-scale tests
  - large non-systematic variations in measured parameter values from single-hole tests
  - complex distribution of measured hydraulic head data (i.e., unknown boundary conditions).

- Existing models presented by DOE are uncalibrated because of insufficient hydraulic head data, and thus the predicted results cannot be considered defensible. Reference to other modeling efforts by DOE contractors to support the prediction of long groundwater travel times is indefensible, since all modeling has been done with the same basic data set.

The SCR does not include any quantitative results of sensitivity studies of groundwater flow at the Hanford Site. DOE planning documents (cited in SCR Chapter 13) indicate that the current level of predictive accuracy for critical hydraulic parameters is very low (e.g., 5 orders of magnitude for vertical hydraulic conductivity). Relatively simple parametric studies completed by GAI for the NRC's draft SCA (NRC, 1983) indicate that groundwater travel times from less than 100 to over 100,000 years are possible using the parameter values presented by DOE in the SCR.

While DOE has recognized (i) the need for a more complete hydrologic characterization of the basalts, (ii) the uncertainties in the existing conceptual model, and (iii) the data deficiencies, a discussion of the impact of these uncertainties is not included in the conclusions drawn on site performance, and DOE states that a high degree of confidence can be placed on predicted groundwater travel times. GAI's opinion is that unless reliable boundary conditions and hydraulic parameters are determined during site characterization and until a defensible conceptual groundwater model is developed, little confidence can be attached to performance assessment results from any numerical code at this time.

(2) The very near-field release rate performance assessment presented by DOE is based on a simple one-dimensional transport model, which evaluates horizontal transport only through a basalt flow top (top of the Grande Ronde) and an interbed zone (base of the Saddle Mountains). While DOE states that this is a very conservative analysis since containment for all waste packages was assumed to fail simultaneously in a water saturated repository at 1000 years after closure, GAI, in recent work for the NRC, has calculated that existing data supports repository resaturation times of less than 100 years after closure, and that saturated conditions contribute to package corrosion and loss of containment. Therefore, GAI does not consider this assumption to be conservative.

GAI concurs with the conclusion drawn by DOE from these analyses that a waste package with an extended containment capability is not necessary, as the problem nuclides identified are long-lived. It is GAI's opinion, however, that sorption or matrix diffusion data for almost all nuclides under expected repository conditions are virtually non-existent, as stated by DOE in SCR Chapter 6. The conclusion made by DOE concerning the retardation of certain nuclides based on high sorptive properties of basalt is therefore not, in GAI's opinion, yet substantiated.

GAI generally concludes that this analysis does correctly point to the most likely problem nuclides. However, because of the simple nature of the model, the lack of sorption/solubility data, and the unknown (unquantified) conservatisms in the model, GAI considers that the results of this work are of limited interest. It does, however, point to the critical need for reliable and defensible sorption/solubility data and/or diffusion for all potential problem radionuclide species.

(3) The near-field studies presented by DOE were undertaken using a numerical model (PORFLO), with options for modeling the coupled processes of groundwater flow, heat transfer and radionuclide transport. The conceptual model is based largely on previous interpretations of geologic/hydrologic field data, and GAI's concerns on this point have been previously stated.

Long-term predictions by DOE of waste migration are based on one key nuclide, ^{14}C. While this may provide a useful indication of nuclide transport potential (because it is not sorbed by basalt), it is GAI's opinion that this cannot be considered as a comprehensive performance analysis with respect to compliance with the EPA standard. It is not clear, for example, whether any radionuclides other than ^{14}C were evaluated. While the results presented in

the SCR are consistent with the type of model and data used, it is GAI's opinion that the conclusions drawn by DOE are related entirely to the specific model used and cannot be generalized to reflect expected repository performance. GAI believes that:

- It has not been demonstrated that either a 1000 year package life or a fractional release rate of 10^{-5} per year from the engineered systems is achievable.

- Groundwater travel times to the accessible environment may be significantly overestimated.

- Groundwater flow paths are specific to the model and data used.

- Releases of ^{14}C across the 10 km reference boundary (equal to zero in the results presented) are dominated by the long travel times; alternative groundwater models may be shown to provide more critical releases.

It is not clear from the work presented by DOE how the predicted results may be considered as bounding estimates, i.e., the conservatisms in the work have not been adequately demonstrated or supported. In fact, DOE states that "...the lack of a general consensus in these (groundwater flow path) predictions clearly reflects the uncertainty in the existing hydrologic conceptual model", yet also asserts that "Studies conducted to date by Rockwell and other independent organizations unanimously agree that the minimum travel time from the repository to the accessible environment ... is likely to be on the order of 10,000 years or longer." It is GAI's opinion that these two statements are inconsistent.

It is apparent that release from the engineered system may be required to be treated much more carefully if it is demonstrated that the amount of credit that can be taken from the geologic setting is limited (e.g., due to data or model uncertainties). For example, this consideration may require re-examination of vertical emplacement concepts with a porous, highly sorptive backfill in the rooms above.

In conclusion, it is GAI's opinion that:

- DOE's discussion of the performance issues adequately identifies the concerns in performance assessment.
- DOE's assessment methodology represents a comprehensive and satisfactory approach, with the exception of treatment of uncertainties in data and conceptual models.
- The model studies reported by DOE are not comprehensive and do not follow the outlined assessment methodology. These studies are not conservative because of insufficient data and do not always use parameter values presented in other SCR chapters.
- Performance of the Hanford Site cannot be defensibly predicted at this time, due to existing large uncertainties in geology, hydrology, and geochemistry and lack of adequate definition of engineered barriers.

13. EXECUTIVE SUMMARY OF SCR CHAPTER 13 - SITE ISSUES AND PLANS

13.1 Synopsis

Chapter 13 of the SCR presents the four technical issues dealing specifically with the Hanford Site's geology and hydrology (see SCR Chapters 2 and 5, respectively) that DOE believes are necessary and sufficient to determine project and site suitability in these areas. Additionally, DOE presents work elements, with their status and plans, which they believe when completed will resolve the four issues. DOE further presents work elements related to ongoing environmental characterization and monitoring, while also stating that there are no unresolved issues dealing with surface hydrology, meteorology, climatology, air quality and environmental, land use and socioeconomic characteristics of the Hanford Site. DOE also presents ongoing and planned research and development efforts, with some explanation of how these activities relate to the work elements identified. Finally, DOE presents the criteria which are guiding the DOE program in these areas, and relates them to both the identified issues and work elements. This information is critical in determining the course of the DOE program and the likely directions and conclusions.

GAI has formed the following opinions regarding the site issues and plans presented by DOE in SCR Chapter 13:

- DOE does not provide sufficient information to determine whether or not resolution of the identified four technical issues is necessary and sufficient for site selection and subsequent licensing, as pertaining to site geology and hydrology. GAI believes that there are additional issues which must be resolved in the areas of site geology, hydrology, surface hydrology, and environmental, land-use, socioeconomic characteristics.

- If the extensive set of work elements presented by DOE is defensibly and comprehensively completed, then GAI agrees that the four identified issues will likely be sufficiently resolved. However, GAI believes that additional surface hydrology and environmental issues are not addressed by the work elements, and the hydrologic work elements are deficient in several ways.

- DOE's explanations of the project activities do not sufficiently clarify the work elements nor confirm that these work elements will be defensibly and comprehensively completed, especially prior to initial license application.

13.2 Summary of Technical Content Presented by DOE in SCR Chapter 13

Chapter 13 of the SCR presents the issues identified by DOE regarding geology, hydrogeology, surface hydrology, climatology, meteorology, air quality, performance assessment, and environmental, land-use and socioeconomic characteristics, and work plans for their resolution; performance assessment issues discussed in this chapter relate specifically to the site's hydrology, with remaining performance topics discussed elsewhere (see SCR Chapter 16 -

Performance Assessment Issues and Plans). DOE asserts that the issues stated in this chapter are all that must be resolved in these areas prior to selecting the Hanford Site as a suitable repository site and submitting a license application to NRC.

In these areas, DOE identifies four issues, with the first one considered to be a key issue:

(1) 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 appropriate U.S. Environmental Protection Agency (EPA) regulations?

(2) What are the geologic, mineralogic, and petrographic characteristics of the candidate repository horizons and surrounding strata within the reference repository location?

(3) What are the nature and rates of past, present, and projected structural and tectonic processes within the geologic setting and reference repository location (RRL)?

(4) Are the pre-waste-emplacement groundwater travel times near the repository sufficient to assure compliance with U.S. Nuclear Regulatory Commission (NRC) proposed technical criteria?

DOE identifies sixty-one discrete work elements, with their status and plans, that in their opinion must be accomplished to adequately resolve these issues:

- Geology-related work elements, including
  - corehole drilling, including corelogging, sampling, petrographic analysis, geophysical logging, fracture orientation, spacing and in-filling measurements
  - studies of the regional structural setting, including location of folds and faults in the Pasco Basin, gridded gravity surveys, and seismic refraction surveys
  - studies of regional deformation rates and seismicity
  - prediction of changes caused by waste emplacement
  - determination of disruptive events and their effects (i.e., faults)
  - determination of long-term geologic stability.

- Hydrology-related work elements, including
  - single-, dual-, and multiple-hole tests near the RRL; multiple-hole or "cluster test" to be conducted at a new drill-site, designated DC-16 A, B and C
  - single- and dual-hole tests in the Cold Creek Syncline
  - single-hole tests in areas of the Pasco Basin outside the Cold Creek Syncline
  - limited hydrologic testing from portholes in the exploratory shaft
  - continued hydrochemical sampling during the drill and test sequence; some sampling from old holes and the exploratory shaft
  - further definition of aquifer geometry and hydraulic interactions between aquifers; determination of vertical hydraulic conductivity using ratio tests

- determination of the influences of structures
- further refinement of the conceptual groundwater model
- simulation of groundwater flow using numerical models
- simulation of repository performance by numerical models and comparison with EPA criteria
- consideration of uncertainties in performance predictions
- determination of effects of disruptive events
- determination of long-term changes to the groundwater system, including natural and man-induced changes.

In addition to these sixty-one work elements, DOE identifies two additional work elements, with their status and plans, related to the environmental and socioeconomic areas:

(1) Establishment of baseline conditions, including water resources, water use, mineral resources, land use, land ownership

(2) Assessment of environmental or socioeconomic changes which could affect repository performance.

In the balance of the SCR Chapter 13, DOE reviews its ongoing and planned project activities in the area of site geology, hydrology, surface hydrology, climatology/meteorology/air quality, and environmental/land-use/socioeconomic characteristics, and relates these activities to the work elements and issues previously presented. In particular, DOE presents a logic diagram (see SCR Figure 13-4) that indicates how the main activities are linked, as well as the points at which the issues will be resolved.

Additionally, DOE lists the specific programmatic and regulatory criteria that it is using to control this program and shows the work elements that individually satisfy the specific criteria. The criteria that DOE is applying are taken from the July, 1981 draft rules published in 10CFR60 by NRC and from DOE programmatic guidelines contained in DOE/NWTS 33(1,2,3 and 4).

DOE concludes by stating that (1) the resolution of the identified four issues will satisfy all technical criteria currently recognized by DOE in the areas of geology, hydrology, and environmental characteristics, (2) these issues will be adequately resolved by accomplishing the identified work elements, and (3) the ongoing and planned activities at Hanford will result in the satisfactory achievement of these work elements and resolution of the issues.

13.3 GAI's Evaluation of Technical Adequacy of DOE's SCR Chapter 13

In GAI's opinion, a set of issues should be identified whose resolution is demonstrated to be both necessary and sufficient for site selection and subsequent licensing, as pertaining to site geology, hydrogeology, surface hydrology, climatology/meteorology/air quality, and environmental/land-use/socioeconomic characteristics. A comprehensive set of work elements should then be identified which, if completed, are both necessary and sufficient to demonstrably resolve these identified issues. Work (both on-going and planned) in this area should then be related solely to the efficient completion of these work elements. Other issues, work elements, or project activities must be considered as superfluous.

Hence, based on the above, GAI has formed opinions on the technical adequacy of DOE's description of the issues, work elements and project activities, as presented in this SCR Chapter 13. A discussion of GAI's views on each follows. In reviews of previous SCR chapters (especially SCR Chapters 3, 5, 7, 8 and 9), GAI has stated its opinions of issues that should be considered by DOE or of perceived deficiencies in project activities. These are briefly repeated here.

Regarding site issues, it is GAI's opinion that quantification of the variability of the stratigraphy and lithology of the candidate horizons (especially thickness of the dense zone) is a site geology issue that is not given sufficient importance by DOE. In the area of site hydrogeology, it is GAI's opinion that determination of a singular, technically defensible conceptual model of groundwater flow is the principal site hydrology issue that DOE has not given sufficient importance. In the area of surface hydrology, it is GAI's opinion that the potential for and characteristics of a flash flood in Cold Creek is the major site issue which DOE has not addressed. In the areas of climatology, meteorology and air quality, GAI supports DOE's conclusion that there are currently no outstanding site issues. In the environmental, land-use and socioeconomic area, it is GAI's opinion that DOE has failed in the SCR to acknowledge at least four site issues: (1) the potential for radioactive contamination of public roads due to the high levels of radioactive contamination measured in the surface soil and vegetation of the RRL; (2) the appropriateness of designating portions of the Arid Lands Ecology Reserve to be included in the RRL; (3) the absence of accounting for the potential public risks and social burdens associated with the transportation activities associated with the development and operation of a repository; and (4) the absence of accounting of the potential social burdens of the temporary work force associated with constructing a repository.

Regarding work elements, it is GAI's opinion that work elements have not been identified which will fulfill the environmental and socioeconomic, as well as surface hydrology, site issues identified by GAI as being unresolved. It is further GAI's opinion that if all the work elements identified by DOE are defensibly and comprehensively completed, then the remaining issues identified by GAI as being unresolved will likely be resolvable. Further, it is GAI's opinion that the hydrologic work elements presented by DOE are insufficient in the following areas:

- The number of large-scale multiple-hole tests is considered inadequate to determine representative hydraulic parameters, particularly horizontal and vertical hydraulic conductivity.
- Long-term measurements of hydraulic head at various locations in the Pasco Basin are not planned; permanent piezometer completions are considered necessary.
- Plans for tests to define hydrogeologic boundaries are considered inadequate; large-scale multiple-hole pump tests are considered necessary.

Regarding project activities, it is GAI's opinion that no project activities are planned which would resolve the surface hydrology and environmental site issues which GAI has identified. Further, it is GAI's opinion that DOE's presentation of project activities does not provide a high degree of confidence that the work elements identified by DOE will be defensibly and comprehensibly completed, because DOE's descriptions of the planned project activities are lacking in detail.

In conclusion, it is GAI's opinion that sufficient resolution of the four issues identified by DOE, as well as any others that may arise, in the areas of site geology and hydrology will be likely through the comprehensive and defensible completion of the work elements listed; however, additional issues remain unresolved in the areas of surface hydrology and environmental/land-use/socioeconomic characteristics. It is also GAI's opinion that DOE's presentation of issues, work elements and project activities lacks sufficient detail and explanation; additionally, GAI believes that the hydrogeologic work elements are deficient in several respects. Further, based on descriptions provided for the project activities, it is not clear that DOE will defensibly and comprehensively complete each work element with its current program plans, especially prior to initial license application.

14. EXECUTIVE SUMMARY OF SCR CHAPTER 14 - GEOENGINEERING AND REPOSITORY DESIGN ISSUES AND PLANS

14.1 Synopsis

Chapter 14 of the SCR presents the four technical issues dealing with geoengineering and repository design (see SCR Chapters 4 and 10, respectively) that DOE believes are necessary and sufficient to determine project and site suitability in these areas. Additionally, DOE presents numerous specific work elements, with their status and plans, which they believe when completed will resolve the four issues. DOE also presents ongoing and planned research and development efforts, with some explanation of how these efforts relate to the work elements identified. Finally, DOE presents the criteria which are guiding the DOE program in these areas, and relates them to both the identified issues and work elements. This information is critical in determining the course of the DOE program and the likely directions and conclusions.

GAI has formed the following opinions regarding the geoengineering and repository design issues and plans presented by DOE in SCR Chapter 14:

- DOE does not provide sufficient information to determine whether or not resolution of the identified four technical issues is necessary and sufficient for site selection and subsequent licensing, as pertaining to geoengineering and repository design. GAI believes that there are additional issues which must be resolved.

- If the extensive set of work elements presented by DOE is defensibly and comprehensively completed, then GAI agrees that the four identified issues will likely be sufficiently resolved, as will any additional issues pertaining to geoengineering or repository designs which are likely to arise. However, GAI believes that the work elements are not discussed in sufficient detail (especially regarding schedule) and that several additional items should be considered.

- DOE's explanations of the project activities do not sufficiently clarify the work elements nor confirm that these work elements will be defensibly and comprehensively completed, especially prior to initial license application.

14.2 Summary of Technical Content Presented by DOE in SCR Chapter 14

Chapter 14 of the SCR presents the issues identified by DOE regarding geoengineering and repository design, and work plans for their resolution. DOE asserts that the issues stated in this chapter are all that must be resolved in the areas of geoengineering and repository design prior to selecting the Hanford Site as a suitable repository site and submitting a license application to NRC.

In the area of repository design, construction, and operations, DOE identifies four issues, with the first and fourth considered to be key issues:

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

(2) Can satisfactory representative measurements or estimates of rock-mass strength be obtained?

(3) Are current methods of in situ stress measurement used at depth reliable enough to provide satisfactory data for design requirements?

(4) 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 appropriate U.S. Environmental Protection Agency (EPA) regulations is not possible?

DOE identifies twenty-six discrete work elements, with their status and plans, that in their opinion must be accomplished to adequately resolve these issues:

(1) Determine the methodology for design and analysis of subsurface openings and their support systems.

(2) Evaluate the effect of underground construction sequence on the stability of openings.

(3) Determine the magnitude and the rate of deformation of tunnels and canister boreholes resulting from in situ, excavation-induced, and thermal-induced stresses, and how deformation is affected by backfill.

(4) Determine the magnitude and distribution of excavation-induced stresses for single and multiple openings.

(5) Determine the magnitude and distribution of thermal stresses in the rock mass for the proposed waste package storage configuration.

(6) Determine from case history evaluations the combinations of stress fields, rock properties, geologic structural features, and mine geometries that are typical of rock burst-prone areas, and assess the probability of rock bursts at or near the repository site.

(7) Document occurrences of dynamic instability of test excavations at depth at the repository site.

(8) Determine the spatial variation of in situ stresses in the region of the repository.

(9) Determine the potential for subsidence caused by mine openings.

(10) Define the acceptable range of test results for intact rock and rock-mass characteristics to support design activities.

(11) Measure rock strength and deformation characteristics on a laboratory and rock-mass scale as a function of stress, time, temperature, and moisture.

(12) Measure rock thermal properties on a laboratory and rock-mass scale as a function of stress, time, temperature, and moisture.

(13) Develop and validate mechanical, thermal, and thermomechanical models for performance of in situ tests and for design and performance of the repository.

(14) Develop stress measurement methods that will yield valid data in closely jointed basalt.

(15) Establish methods of validating measured in situ stress data.

(16) Evaluate and select methods of excavation and rock support that can economically and safely be constructed and at the same time maintain isolation capability of the engineered system.

(17) Develop or adapt instrumentation and test methods to measure the nature and extent of rock-mass disturbance caused by candidate excavation methods and stress redistribution around tunnels and boreholes.

(18) Identify performance requirements for sealing boreholes, tunnels, shafts, and rooms containing nuclear waste.

(19) Select materials and develop testing techniques required to meet repository room and tunnel sealing criteria.

(20) Determine the effect of temperature, rock-mass deformation, groundwater flow, and groundwater chemistry on materials used for seals.

(21) Develop grouts and grouting techniques that ensure acceptable sealing of the disturbed rock zone.

(22) Determine the effects of temperature, rock-mass deformation, and time on the permeability of the sealed rock zone.

(23) Select materials and develop testing techniques required to meet borehole sealing criteria.

(24) Develop construction and test techniques required to meet repository tunnel and shaft sealing criteria.

(25) Prepare final specifications for sealing boreholes, tunnels, shafts, and rooms containing nuclear waste.

(26) Develop methods and equipment for backfilling and sealing the repository, and demonstrate their effectiveness.

In addition to these twenty-six work elements, DOE identifies forty-nine additional work elements, with their status and plans, that are unrelated to any issues, but are related to specific technical criteria (e.g., 10CFR60) used by DOE concerning repository design, construction, and operations. In addition to design related work elements (e.g., backfill/seal design, rock support design, design layout/ orientation/geometry, design flexibility/contingencies, etc.), many of these additional work elements are related to the following topics:

- Safety systems, including identification, reliability assessment (especially under adverse conditions), and monitoring/control requirements
- Waste handling systems, including identification, reliability assessment, and shielding/isolation requirements (including ventilation)
- Personnel operating conditions, including monitoring and control requirements for
  - airborne radioactivity
  - intrusion of gas or water
  - fire or explosions
- Requirements regarding
  - emergency response and personnel egress
  - safe handling of dangerous materials, e.g., explosives and radioactive surface effluent
  - personnel training
  - controlled access
  - seismic design
  - criticality assessment
  - adequate construction records and geotechnical monitoring
  - utilities, ventilation, and hoisting
  - retrieval
  - decommissioning.

In the area of performance confirmation, DOE asserts that there are no unresolved issues. However, DOE identifies the following ten discrete work elements, with their status and plans, that are unrelated to any issues, but are related to certain technical criteria concerning performance confirmation:

(1) Determine which characteristics of the natural and engineered systems need to be measured or monitored for performance confirmation, and establish any required baseline values for those characteristics prior to repository construction.

(2) Develop a plan for comparing confirmation data and conditions during construction and operation with design data and conditions to determine if significant differences exist that will require modification to the design or construction method.

(3) Measure rock strength and deformation characteristics on a laboratory and rock-mass scale as a function of stress, time, temperature, and moisture.

(4) Measure rock thermal properties on a laboratory and rock-mass scale as a function of stress, time, temperature, and moisture.

(5) Deploy instrumentation, as required, to reliably measure stresses, deformation, temperature, and pore pressures until backfill is emplaced.

(6) Conduct field tests, as required, of borehole plugging to demonstrate that materials and emplacement methods meet requirements.

(7) Conduct field tests, as required, of repository room, tunnel, and shaft backfill placement to demonstrate that materials and emplacement methods meet requirements.

(8) Conduct field tests, as required, of repository tunnel and shaft seals to demonstrate that materials and emplacement methods meet functional requirements.

(9) Develop, as required, instrumentation, techniques, and procedures for monitoring the integrity of the waste package in situ.

(10) Develop a laboratory testing and monitoring program, as required, to evaluate the internal and external condition of representative waste packages subjected to a simulated repository environment.

In the balance of this SCR Chapter 14, DOE reviews its ongoing and planned project activities in the geoengineering and repository design areas, and relates these activities to the work elements and issues previously presented. In particular, DOE presents a logic diagram (see SCR Figure 14-2) that indicates how the main activities are linked, as well as points at which the issues will be resolved. These activities include:

- Exploratory shaft
  - conceptual design
  - site selection
  - principal borehole drilling and testing
  - phase I & II design and testing plan
  - phase I drilling and sinking demonstration
  - phase II construction
  - phase I & II testing.

- Nuclear waste repository in basalt
  - functional design criteria
  - conceptual design
  - engineering studies
  - upgraded conceptual design
  - Title I design.

- Repository seals
  - design criteria
  - candidate materials and emplacement equipment for tunnel/shaft seal test
  - laboratory tests
  - tunnel/shaft seal test.

- Rock mechanics
  - planning
  - initial data base for design and performance evaluation
  - data base for Title I design.

- Equipment and instrument
  - BWIP development needs
  - development.

- Mine model codes development and user manual preparation.

Additionally, DOE lists the specific programmatic and regulatory criteria that it is using to control this program and shows the work elements that individually satisfy the specific criteria. The criteria that DOE is applying are taken from the July, 1981 draft rules published in 10CFR60 by NRC and from DOE programmatic guidelines contained in DOE/NWTS 33(1,2,3 and 4).

DOE concludes by stating that (1) the resolution of the identified four issues will satisfy all technical criteria currently recognized by DOE in the areas of geoengineering and repository design, (2) these issues will be adequately resolved by accomplishing the identified work elements, and (3) the ongoing and planned activities at Hanford will result in the satisfactory achievement of these work elements and resolution of the issues.

14.3 GAI's Evaluation of Technical Adequacy of DOE's SCR Chapter 14

In GAI's opinion, a set of issues should be identified whose resolution is demonstrated to be both necessary and sufficient for site selection and subsequent licensing, as pertaining to geoengineering and repository design. A comprehensive set of work elements should then be identified which, if completed, are both necessary and sufficient to demonstrably resolve these identified issues. Work (both ongoing and planned) in this area should then be related solely to the efficient completion of these work elements. Other issues, work elements, or project activities must be considered as superfluous.

Hence, based on the above, GAI has formed opinions on the technical adequacy of DOE's description of the issues, work plans, and project activities, as presented in this SCR Chapter 14. A discussion of GAI's views on each follows. In reviews of previous SCR chapters (especially SCR Chapters 4 and 10), GAI has stated its opinions of issues that should be considered by DOE or of perceived deficiencies in project activities. These are briefly repeated here.

Regarding geoengineering and repository design issues, those which DOE has identified as being necessary to resolve before the Hanford Site can be considered suitable for licensing have not been shown to be both necessary and sufficient for determining site suitability in the areas of geoengineering and repository design. It is stated that these issues are derived from SCR Chapters 4 and 10 which deal, respectively, with geoengineering and repository design. However, the derivation of these issues from SCR Chapters 4 and 10 is not obvious to GAI. It is apparent that the four issues identified can be simply restated as the issues of demonstrating stability of underground openings and the safe containment of radionuclides within a repository. Although these may be important issues, there may be other undefined ones, as well. For example, GAI believes that the thickness of the dense zone of the Umtanum, and the variability of that thickness and of other characteristics, is an issue affecting repository design which must be resolved. Similarly, GAI believes that retrievability and personnel safety, although addressed as work elements, are issues affecting repository design which must be resolved. Also, DOE asserts that there are no issues regarding performance confirmation. However, GAI believes that prediction of long-term performance, which must rely on modeling and cannot otherwise be confirmed, will require modeling verification and explicit incorporation of uncertainties, both in the input and in the model itself. Hence, in GAI's opinion, DOE does not provide a suitable basis for determining whether resolution of only the identified four issues is necessary and sufficient to determine acceptability in the geoengineering and repository design areas.

Regarding work elements, it is GAI's opinion that if those work elements represent discrete pieces of work that were to be performed, and if these "work pieces" were defensibly and comprehensively completed, then DOE would likely have a good grasp on geoengineering and repository design. However, most of the work elements presented by DOE are unrelated to the identified issues, again suggesting that the set of issues is not comprehensive. Although DOE discusses the status and plans of each identified work element, GAI believes that in many cases:

- The status is overstated, i.e., rather than simply stating what has been done to date, some work elements are explained, justified, and plans presented, all under the heading of status.
- The plans are not clear, i.e., insufficient details are presented regarding how and especially when some work elements will be accomplished.
- The interrelationships of work elements are not clear, i.e.:
  - some work elements are very similar, or even identical
  - cross referencing of some work elements is incomplete
  - occasionally, reference has been made to another work element for status/plans, which then simply references back; in at least one case, a work element references itself.
- The priorities of the work elements have not been justified.

For example, GAI has the following specific comments regarding the identified work elements:

- Regarding site characteristics
  - in situ stresses should be inferred from core discing and backfigured from the monitored response of underground excavations, as well as from other methods; the problems with hydraulic fracturing (see SCR Chapter 4) should be evaluated, and overcoring methods should be emphasized
  - direct testing of the rock mass should be emphasized, as borehole and laboratory tests are generally of too small a scale
  - uncertainties, as well as variability, of the site characteristics should be assessed.

- Regarding analysis of underground openings
  - mechanical modeling should include 3-D effects and consider the anisotropic, non-linear elastic-plastic behavior of the basalt
  - uncertainties should be explicitly incorporated in the analysis
  - limited failure zones around openings are generally acceptable, and should be considered
  - monitored test sections, where excavation/support systems are tried, should be utilized
  - modeling, and not just empirical observations, should be used to evaluate rock bursting potential
  - effects of ventilation/cooling and heating cycles, and also drying/wetting cycles, should be assessed.

- Regarding backfilling/sealing/retrieval
  - the objectives of backfill, especially regarding low permeability, have not been justified and should be presented
  - the methods for assessing the long-term performance characteristics of backfill and seals should be identified and evaluated
  - the stresses acting on, and the criticality of, the densely placed horizontal waste packages should be assessed
  - the relationship of the guarded straddle packer (which measures permeabilities) to borehole sealing should be identified
  - methods and problems of retrieval should be identified and evaluated.

In GAI's opinion, it is not assured that the set of work elements presented by DOE will be adequately completed, and thus issues left unresolved, on the basis of both the lack of detail regarding the plans for work elements and the previously noted perceived deficiencies in the DOE program (see review of SCR Chapters 4 and 10).

Regarding project activities, those presented by DOE do not, in GAI's opinion, clarify work elements nor confirm that they will be completed in a defensible manner. Although the applicable work elements which apparently will be completed with each project activity are listed, the project activities' explanations do not, in GAI's opinion, always provide this confidence. Further, it is not apparent how each of the work elements listed are related to the project activities. For example, appropriate data acquired from the ES-Phase I and II test programs will apparently not be incorporated in the rock mechanics data base for repository Title I design (see SCR Figure 14-2). Similarly, it appears that uncertainties in the data base will be neither assessed nor incorporated in analyses. As a secondary concern, it is not apparent in every case when these project activities, and thus the work

elements, will be completed. This schedule should depend on when and to what extent the related issues must be resolved, which has not been discussed. Based on the information presented by DOE, GAI does not believe that the set of work elements can be completed prior to the scheduled initial license application. For example, it is not apparent when field tests or demonstrations of backfilling or sealing will be conducted, but it does not appear that they are scheduled for completion prior to construction authorization. This schedule should be clarified as it relates to initial license application.

In conclusion, it is GAI's opinion that sufficient resolution of the four issues identified by DOE, as well as any others that may arise, in the areas of geoengineering and repository design will be likely through the comprehensive and defensible completion of the work elements listed. However, it is also GAI's opinion that DOE's presentation of issues, work elements and project activities lacks sufficient detail and explanation. Further, based on descriptions provided for the project activities, it is not clear that DOE will defensibly and comprehensively complete each work element with its current program plans, especially prior to initial license application.

15. EXECUTIVE SUMMARY OF SCR CHAPTER 15 - WASTE PACKAGE AND SITE GEOCHEMISTRY ISSUES AND PLANS

15.1 Synopsis

Chapter 15 of the SCR presents the seven technical issues dealing with waste package development, characterization of site geochemistry and confirmation testing (see SCR Chapters 11 and 6) that DOE believes are necessary and sufficient to determine project and site suitability in these areas. Additionally, DOE presents numerous specific work elements, with their status and plans, which they believe when completed will resolve the seven issues. DOE also presents ongoing and planned research and development efforts, with some explanation of how these efforts relate to the work elements identified. Finally, DOE presents the criteria which are guiding the DOE program in these areas, and relates them to both the identified issues and work elements. This information is critical in determining the course of the DOE program and the likely directions and conclusions.

GAI has formed the following opinions regarding the waste package and site geochemistry issues and plans presented by DOE in SCR Chapter 15:

- DOE does not provide sufficient information to determine whether or not resolution of the identified seven technical issues is necessary and sufficient for site selection and subsequent licensing, as pertaining to the waste package and site geochemistry.

- If the work elements presented by DOE are defensibly and comprehensively completed, then GAI agrees that the seven identified issues will likely be sufficiently resolved, as will any additional issues pertaining to the waste package or site geochemistry which are likely to arise.

- DOE's explanations of the project activities do not sufficiently clarify the work elements nor confirm that these work elements will be defensibly and comprehensively completed, especially prior to initial license application.

15.2 Summary of Technical Content Presented by DOE in SCR Chapter 15

Chapter 15 of the SCR presents the issues identified by DOE regarding waste packages and site geochemistry, and work plans for their resolution. Additionally, DOE presents issues and plans for the testing and performance confirmation program. DOE asserts that the issues stated in this chapter are all that must be resolved in the areas of waste package development and geochemical characterization prior to selecting the Hanford Site as a suitable repository site and submitting a license application to NRC.

In the area of waste package design, DOE identifies two issues:

(1) Does the very near field interaction between the waste package and its components, the underground facility, and the geologic setting compromise waste package or engineered system performance?

(2) Is a unique [package] borehole backfill required?

DOE identifies seventeen discrete work elements, with their status and plans, that in their opinion must be accomplished to adequately resolve these issues:

(1) Determine the maximum operating temperature limits for waste form, backfill, canister and host rock.

(2) Determine conditions that affect the design of waste packages, including thermal loading, mechanical loading and chemical environment during handling, shipment, emplacement, retrieval and after repository decommissioning.

(3) Determine the effect of the waste package radiation environment on near-field geochemistry, waste package, and barrier material performance.

(4) Determine the projected solubilities, kinetic behavior, and distribution of aqueous species for key radionuclides which might be released from the waste package.

(5) Determine the extent of Eh-pH and groundwater compositional control by the host basalt after repository closure.

(6) Determine susceptibility of candidate canister materials to degradation in the repository near-field environment.

(7) Determine design properties, including thermal, physical, mechanical and chemical for waste package component materials and host rock.

(8) Determine the effect of radiation on the performance of the waste form, backfill, and near-field host rock.

(9) Determine the release rate of candidate waste forms in the repository near-field environment.

(10) Determine the formation and stability of radionuclide complexes and/or colloids over expected repository near-field and far-field conditions.

(11) Determine the chemical properties and inflow rate of groundwater and their effect on canister corrosion during the 1000-year containment period.

(12) Determine the extent to which the interaction between the canister materials, waste form, backfill and host rock in a saturated environment results in retardation of radionuclides.

(13) Assess the impact of waste storage in a borehole with no backfill on waste containment and isolation.

(14) Determine the need for special tailoring agents in backfill to moderate the corrosivity (Eh and pH) of the groundwater contacting the canister.

(15) Determine the characteristic of the backfill materials required to retard the flow of groundwater to the canister. Identify potential backfill materials with these characteristics.

(16) Define the characteristics of the backfill material required to reduce the rate of radionuclide release from the waste package. Identify backfill materials with these characteristics.

(17) Determine if a waste package backfill is required to provide acceptable containment in the event of premature canister failure.

In addition to these seventeen work elements, DOE identifies eight additional items, with their status and plans, that are related to waste package development, but are directed at either regulatory compliance or design interface.

In the area of characterization of the site's geochemistry, DOE identifies the following four issues critical to the site's performance:

(1) Are the geochemical and hydrologic properties of the geologic setting (in conjunction with the waste forms) sufficient to meet or exceed U.S. Nuclear Regulatory Commission (NRC) proposed waste isolation requirements?

(2) What is the relative importance of waste form leach rate versus solubility of key radionuclides in the near field environment for controlling release?

(3) Can valid Eh measurements for the candidate repository horizons in the reference repository location be made either by potentiometric measurement or indirectly by measurement of dissolved redox couples?

(4) To what degree does the geologic setting retard migration of key radionuclides from the engineered system in meeting U.S. Environmental Protection Agency (EPA) draft release criteria?

In addition to the first set of work elements listed earlier, DOE identifies four additional work elements, with their status and plans, that in their opinion must be accomplished to adequately resolve these issues:

(1) Determine the effect on radionuclide mobility of changes in the primary and secondary mineralogical conditions in the near field and far field of the repository, along the expected pathway to the biosphere.

(2) Demonstrate that geochemical conditions in the near and far field are such that transport of radionuclides is retarded for sufficient time to satisfy waste isolation requirements.

(3) Determine acceptable release rates of key radionuclides from the engineered system as a function of containment time, groundwater travel time to the accessible environment, and water flow through the repository.

(4) Determine the method and technique that can be utilized to provide valid in situ Eh measurements for the reference repository location (RRL).

DOE also lists three additional work elements, with their status and plans, which support basic engineering and regulatory needs, but which are not necessary to resolve these issues.

Finally, in the area of testing and performance confirmation, DOE lists only one issue:

(1) How can very near-field waste/barrier/rock materials interaction data, as measured experimentally, be extrapolated over time to reasonably assure that overall waste package and repository performance meets regulatory criteria?

According to DOE, this issue is fundamental to demonstrating in the regulatory process that a repository system that is designed and developed over a period of up to one hundred years will perform for the thousands of years mandated by the EPA and NRC.

DOE identifies eight work elements, with their status and plans, that in their opinion must be accomplished to adequately resolve this issue:

(1) Determine appropriate statistical techniques so that laboratory and field materials interaction data can be extrapolated over time to provide a reasonable assurance of long-term performance of the engineered system.

(2) Determine the thermodynamic and kinetic arguments that can be used to extrapolate short-term (less than 2 years per experiment) materials test (hydrothermal) data.

(3) Develop and/or use numerical modeling techniques to predict the environmental conditions, package degradation, and radionuclide behavior of emplaced wastes in or near the engineered system.

(4) Determine what natural analogues of waste package components can be used to verify the compatibility of the waste package with the repository environment.

(5) Develop an acceptance test procedure for waste packages.

(6) Determine and conduct field, engineering and in situ testing as may be appropriate to meet design needs and U.S. Nuclear Regulatory Commission (NRC) proposed performance requirements.

(7) Determine suitability of using non-radioactive chemical analogues for actual waste forms in the hydrothermal testing program.

(8) Determine requirements for monitoring. Define parameter, methodology, interpretive criteria and actions.

In the balance of this SCR Chapter 15, DOE reviews its ongoing and planned project activities in the waste package, geochemistry, and performance areas, and relates these activities to the work elements and issues previously presented. In particular, DOE presents a logic diagram (see SCR Figure 15-3) that indicates how the main activities are linked, as well as the points at which the issues will be resolved.

Additionally, DOE lists the specific programmatic and regulatory criteria that it is using to control this program and shows the work elements that individually satisfy the specific criteria. The criteria that DOE is applying are taken from the July, 1981 draft rules published in 10CFR60 by NRC and from DOE programmatic guidelines contained in DOE/NWTS 33(1,2,3 and 4).

DOE concludes by stating that (1) the resolution of the identified seven issues will satisfy all technical criteria currently recognized by DOE in the areas of waste package development, geochemistry, and confirmation testing, (2) these issues will be adequately resolved by accomplishing the identified work elements, and (3) the ongoing and planned activities at Hanford will result in the satisfactory achievement of these work elements and resolution of the issues.

15.3 GAI's Evaluation of Technical Adequacy of DOE's SCR Chapter 15

In GAI's opinion, a set of issues should be identified whose resolution is demonstrated to be both necessary and sufficient for site selection and subsequent licensing, as pertaining to the waste package and site geochemistry. A comprehensive set of work elements should then be identified which, if completed, are both necessary and sufficient to demonstrably resolve these identified issues. Work (both ongoing and planned) in this area should then be related solely to the efficient completion of these work elements. Other issues, work elements, or project activities must be considered as superfluous.

Hence, based on the above, GAI has formed opinions on the technical adequacy of DOE's description of the issues, work plans and project activities, as presented in this SCR Chapter 15. A discussion of GAI's views on each follows. In reviews of previous SCR chapters (especially SCR Chapters 6 and 11), GAI has stated its opinions of issues that should be considered by DOE or of perceived deficiencies in project activities. These are briefly repeated here.

Regarding waste package and site geochemistry issues, those which DOE has identified as being necessary to resolve before the Hanford Site can be considered suitable for licensing have not been shown to be both necessary and sufficient for determining site suitability in the areas of geochemistry, waste package and confirmation testing. It is stated that these issues are derived from Chapters 6 and 11 which deal, respectively, with geochemistry and waste package. However, the derivation of these issues from Chapters 6 and 11 is not obvious to GAI. It is apparent that the seven issues identified are secondary to the primary issue of demonstrating the safe containment of radionuclides within a repository. Although this may be the most important issue, there may be other undefined one, as well. In GAI's opinion, DOE does

not provide a suitable basis for determining whether resolution of these seven issues is necessary and sufficient to determine acceptability in the waste package and geochemistry areas.

Regarding work elements it is GAI's opinion that, if those work elements represent discrete pieces of work that were to be performed, and if these "work pieces" were defensibly and comprehensively completed, then DOE would likely have a good grasp on waste package development and site geochemistry. However, these work elements are evidently not the fundamental pieces of research and development, but rather an additional set of work items exist which have no obvious and direct relationship to the work elements. In GAI's opinion, it is not assured that the set of work elements presented by DOE will be adequately completed, and thus the set of issues will be left unresolved, on the basis of both the lack of detail on the relationship of the work elements to the actual programmatic activities and the previously noted perceived deficiencies in the DOE program (see review of SCR Chapters 6 and 11).

Regarding project activities, those presented by DOE do not, in GAI's opinion, clarify work elements nor confirm that they will be completed in a defensible manner. The project activities list applicable work elements which apparently will be completed with project activity. However, the project activities' explanations do not, in GAI's opinion, always provide this confidence. For example, an activity to prepare a hot cell for experiments is listed as partially or completely fulfilling eight work elements. Further, it is not apparent how each of the work elements listed are related to the project activities. As a secondary concern, it is not apparent in every case when these project activities, and thus the work elements, will be completed. This schedule should depend on when and to what extent the related issues must be resolved, which has not been discussed. This schedule should be clarified as it relates to initial license application.

In conclusion, it is GAI's opinion that sufficient resolution of the seven issues identified by DOE, as well as any others that may arise, in the area of waste package and site geochemistry will be likely through the comprehensive and defensible completion of the work elements listed. However, it is also GAI's opinion that DOE's presentation of issues, work elements and project activities are presented without sufficient detail and explanation. Further, based on descriptions provided for the project activities, it is not clear that DOE will defensibly and comprehensively complete each work element with its current program plans, especially prior to initial license application.

16. EXECUTIVE SUMMARY OF SCR CHAPTER 16 - PERFORMANCE ASSESSMENT ISSUES AND PLANS

16.1 Synopsis

Chapter 16 of the SCR presents three technical issues dealing with post-closure repository performance assessment (see SCR Chapter 12) that DOE believes are necessary to determine project and site suitability in this area. The chapter also refers to other performance related issues (see SCR Chapters 13, 14 and 15) which must be resolved as an integral part of the overall performance assessment activity. Additionally, DOE presents several specific work elements, with their status and plans, which they believe when completed will resolve the three issues. DOE also presents ongoing and planned research and development efforts, with some indication of how these efforts relate to the work elements identified. Finally, DOE presents the criteria which are guiding the DOE program in these areas, and relates them to both the identified issues and work elements. This information is critical in determining the course of the DOE program and the likely directions and conclusions.

GAI has formed the following opinions regarding the performance assessment issues and plans presented by DOE in SCR Chapter 16:

- DOE does not demonstrate that the three technical issues are a comprehensive set of performance assessment concerns. In addition, DOE does not provide sufficient information to determine how performance related issues presented in other chapters of the SCR support the three technical issues in SCR Chapter 16, or whether the resolution of those issues is necessary and sufficient for site selection and subsequent licensing.

- DOE does not demonstrate how regulatory performance objectives will be achieved. GAI believes that DOE has neglected issues related to pre-closure performance assessment, e.g., in the areas of protection against radiation exposures and retrievability of waste.

- If the work elements presented by DOE are defensibly and comprehensively completed, then GAI agrees that the three identified issues will likely be sufficiently resolved, as will any issues associated with performance assessment identified in other chapters of the SCR. However, GAI believes that a defensible approach must include a clear resolution of the treatment of data and modeling uncertainties, which is not adequately addressed by DOE in SCR Chapter 16.

- DOE's explanations of the project activities do not sufficiently clarify the work elements nor confirm that these work elements will be defensibly and comprehensively completed, especially prior to initial license application.

16.2 Summary of Technical Content Presented by DOE in SCR Chapter 16

Chapter 16 of the SCR presents the issues identified by DOE regarding post-closure performance assessment, and work plans for their resolution. DOE also presents work elements for pre-closure repository performance assessment, for which no issues have been identified.

DOE asserts that the aim of post-closure performance assessment is the integration of information obtained from site, repository, and waste package studies, design activities, and field and in situ testing, using conceptual and numerical models. Therefore, post-closure issues and many work elements listed by DOE in this SCR Chapter 16 are comparable to those found in SCR Chapters 13, 14 and 15, and their resolution is tied to work elements in those chapters. No new issues related to post-closure performance assessment are identified by DOE in this SCR Chapter 16.

Pre-closure performance assessment activities are focused on assessing the safety of the operating repository, under both normal and accidental operating conditions, to provide assurance that the repository can be operated so as to ensure the safety of operating personnel and the general public. However, as stated by DOE, this subject and the approach to its resolution are only addressed in summary fashion.

DOE presents an analysis of the work needed to meet NRC draft criteria for repository performance, organized into the following categories:

- Pre-emplacement site performance
- Post-closure performance of the engineered system
- Post-closure performance of the waste isolation system
- Pre-closure repository performance.

DOE provides information on status and plans only for new work elements specific to performance assessment. Work elements that have been described previously in SCR Chapters 13, 14 and 15 are merely listed as a statement of work.

In the area of pre-emplacement site performance, DOE identifies one issue:

(1) Are the pre-waste emplacement groundwater travel times near the repository sufficient to assure compliance with U.S. Nuclear Regulatory Commission (NRC) proposed technical criteria?

DOE identifies eight discrete work elements that, in their opinion, must be accomplished to adequately resolve this issue, of which only the following three have not been discussed in other chapters of the SCR:

(1) Prepare a systems description for post-closure repository performance defining all subsystem models (including those used for pre-emplacement assessment), as well as the criteria on which they are based.

(2) Conduct verification, validation, and benchmarking of all codes used for performance assessment.

(3) Document codes and prepare user manuals in accordance with regulatory guides and national quality assurance standards.

DOE states that work elements (1) and (2) have not yet been initiated, and work element (3) has just been formally initiated. The other five work elements referred to cover the development of a conceptual hydrologic model and appropriate numerical codes, the prediction of groundwater travel times and associated uncertainties, and the determination of how the geologic setting complements the engineered system.

In the area of post-closure performance of the engineered system, DOE identifies one issue:

(1) Does the very near-field interaction between the waste package and its components, the underground facility, and the geologic setting compromise waste package or engineered system performance? (i.e., What is the maximum expected release rate from the engineered system, and does the geologic setting prevent the waste package containment objective from being achieved?)

DOE identifies nineteen discrete work elements that, in their opinion, must be accomplished to adequately resolve this issue. Three of these work elements have been previously cited for the pre-emplacement site performance issue. The remaining sixteen are discussed in other chapters and include the following general topics:

- Waste/package/backfill/rock interactions and compatibility
- Extrapolation of laboratory/field data and short-term materials test data
- Numerical modeling to predict environmental conditions/package degradation/radionuclide behavior
- Effects of construction and thermal-induced stresses and seismic events on stability of openings
- Development and validation of models for repository design and performance
- Performance requirements for repository sealing and requirements for engineered barriers
- Effects of temperature, rock deformation and time on the permeability of sealed rock zones
- Radionuclide sorption requirements for backfill materials.

In the area of post-closure performance of the waste isolation system, DOE identifies one issue:

(1) 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 appropriate U.S. Environmental Protection Agency (EPA) regulations?

DOE identifies nine discrete work elements that, in their opinion, must be accomplished to adequately resolve this issue, of which only one has not been cited previously in this review or discussed in other chapters:

(1) Perform a post-closure performance assessment for the waste isolation system for inclusion in the license application.

DOE states that this work has not yet started. Three of the nine work elements have been previously cited for the pre-emplacement site performance issue. The remaining five are discussed in other chapters and include the following general topics:

- The effects and probability of occurrence of disruptive events and potentially unfavorable scenarios
- Development of a conceptual hydrologic model and appropriate numerical codes
- Prediction of radionuclide mass fluxes to the accessible environment and the bounds of uncertainty associated with these predictions.

In the area of pre-closure repository performance, no issues have been identified by DOE. However, DOE identifies six discrete work elements which support this area of interest:

(1) Prepare an operating performance systems description identifying all engineered system structures, subsystems, and components important to safety.

(2) Prepare a preliminary pre-closure repository safety assessment for normal operations and accidental conditions, based on the repository and waste package conceptual designs.

(3) Select and characterize preclosure failure scenarios.

(4) Determine the impact of the dynamic effects of equipment failure on safety-related systems and components.

(5) Determine the requirements necessary to assure that safety-related systems provide adequate protection to construction and operations personnel.

(6) Prepare a pre-closure safety performance assessment for normal operations and for accidental failure scenarios, including preventive and mitigative measures, for inclusion in the license application.

DOE states that work elements (3) and (6) have not yet been initiated. Although not stated explicitly, DOE implies that work elements (2), (4) and (5) have also not been initiated.

In the balance of this SCR Chapter 16, DOE reviews its ongoing and planned project activities in the area of performance assessment, and relates these activities to the work elements and issues previously presented. In particular, DOE presents a logic diagram (see SCR Figure 16-3) that indicates

how the main activities are linked, as well as the points at which the issues will be resolved.

Additionally, DOE lists the specific programmatic and regulatory criteria that it is using to control this program and shows the work elements that individually satisfy the specific criteria. The criteria that DOE is applying are taken from the July, 1981 draft rules published in 10CFR60 by NRC and from DOE programmatic guidelines contained in DOE/NWTS 33 (1,2,3 and 4).

DOE concludes that the information provided in this SCR Chapter 16 is an integration of the performance oriented work elements taken from preceding SCR chapters and serves to identify how the DOE will approach verification of performance of a nuclear waste repository at Hanford. DOE also concludes that the information resulting from completion of the work elements cited will demonstrate whether or not the issues on post-closure performance assessment can be resolved.

16.3 GAI's Evaluation of Technical Adequacy of DOE's SCR Chapter 16

In GAI's opinion, a set of issues should be identified whose resolution is demonstrated to be both necessary and sufficient for site selection and subsequent licensing, as pertaining to the assessment of repository performance. A comprehensive set of work elements should then be identified which, if completed, are both necessary and sufficient to demonstrably resolve these identified issues. Work (both ongoing and planned) in this area should then be related solely to the efficient completion of these work elements. Other issues, work elements, or project activities must be considered as superfluous.

Hence, based on the above, GAI has formed opinions on the technical adequacy of DOE's description of the issues, work plans, and project activities,as presented in this SCR Chapter 16. A discussion of GAI's views on each follows. In reviews of previous SCR Chapters (especially SCR Chapter 12), GAI has stated its opinions of issues that should be considered by DOE or of perceived deficiencies in project activities. These are briefly repeated here.

Regarding performance assessment issues, the three issues (all related to post-closure performance assessment) which DOE has identified as being necessary to resolve before the Hanford Site can be considered suitable for licensing are all directed specifically toward satisfying either the NRC draft technical criteria or the EPA proposed standard. That is, they are issues identified by the regulatory process. The DOE also refers here (and in SCR Chapter 12) to comparable issues, or sub-issues, that are discussed in SCR Chapters 13, 14 and 15 and which must be resolved as an integral part of the overall performance assessment activity. In GAI's opinion, the relationship between "sub-issues" identified elsewhere, and their significance in resolving the overall performance issues presented here, is not clearly presented by the DOE. For example, a major concern surrounding the conceptual hydrologic model could be stated as:

> "Can the uncertainties in the conceptual hydrologic model and data base be reduced (by testing) so that compliance with the NRC draft criteria for pre-waste emplacement groundwater travel times can be defensibly demonstrated."

Thus, for example, if a "best estimate" travel time of 8000 years to the accessible environment is predicted by DOE, but the range of uncertainty is two orders of magnitude (800 to 80,000), can compliance with the NRC proposed criteria be defended? Other similar examples abound. In GAI's opinion, DOE does not demonstrate that the stated performance assessment issues are the only relevant ones, or that resolution of all other sub-issues alluded to will be necessary or sufficient to demonstrate that long-term waste isolation can be achieved.

Although DOE presents no issues for pre-closure performance assessment, the NRC draft technical rule (10CFR60) contains two performance objectives for repository operations:

- Protection against radiation exposures and releases of radioactive material (60.111(a))
- Retrievability of waste (60.111(b)).

In GAI's opinion, the satisfactory demonstration that these two objectives can be met should form the basis for at least two additional (pre-closure) issues.

Regarding work elements, it is GAI's opinion that if those work elements regarding pre-emplacement site performance and post-closure performance of the engineered system and waste isolation system are defensibly and comprehensively completed, then DOE would likely have a good grasp on site performance assessment. However, the technical link between many of these work elements and the issues which they are intended to support is neither stated nor obvious. That is, it is not clear how completing the work element will contribute to resolving the issue. In GAI's opinion, the lack of detail and connection with the issues provides no assurance that the set of work elements will be adequately completed.

Furthermore, DOE identifies six work elements for pre-closure repository performance which do not support any stated issue. Little detail of the work is provided here (or under project activities) and it is therefore not clear to GAI what DOE perceives the pre-closure performance assessment objectives to be. The work elements appear to be oriented toward protection against radiation exposures; however, little reference is made to work elements which would support definition and resolution of the retrievability issue. In GAI's opinion, DOE has not demonstrated that these work elements will achieve a satisfactory resolution of pre-closure operational safety concerns, or demonstrate compliance with the regulatory performance objectives.

Regarding project activities, those presented by DOE are well summarized in a logic diagram (see SCR Figure 16-3), which indicates their interrelationships and relative sequence in time. However, they do not, in GAI's opinion, sufficiently clarify work elements (with one or two exceptions) nor confirm

that they will be completed in a defensible manner. In addition, although the project activities list applicable work elements, the description of activities do not, in GAI's opinion, always demonstrate how the work elements will be satisfied. GAI has the following specific comments, which reflect several of GAI's concerns:

- The systems description for post-closure repository performance includes the development of a broad technical information base. The activity description appears to GAI to be comprehensive, but contains no reference to the treatment of data uncertainties and their importance to performance assessment. Even though a significant amount of data currently exists (and is published), the applicable work elements are stated by DOE to be not yet initiated. Therefore, the extent to which the existing data satisfies the work elements, and how it is regarded by DOE, is not obvious.

- The method of benchmarking computer codes will apparently consist of comparative simulations using data representative of the actual repository setting. The activity description implies that achieving "reasonable consensus between the independent code predictions" will be the judge of benchmarking. However, it is GAI's opinion that equivalent codes (independent, although likely to be similar) using standard data will generally provide similar results; what is more important is the quantification of model uncertainty, as distinguished from uncertainty in the input. DOE does not, in GAI's opinion, address this issue in this activity.

- The validation of performance assessment codes will apparently be based on both laboratory data and field data, the latter obtained during ongoing site characterization activities. DOE states that validation of a code will be considered complete when "a sufficient degree of correlation is achieved between model prediction and the measured data." In principle, GAI concurs with this position, as long as this correlation is not simply achieved by calibration of the code. However, while some codes (e.g., stress-strain, groundwater flow) may be validated in a relatively short time under standard site characterization conditions, others (e.g., waste package corrosion, disolution, waste diffusion and sorption) will be much more difficult to validate using short-term field data, which is all that will be available. In GAI's opinion, DOE should state which codes they expect to validate under in situ conditions, which will be validated using laboratory data alone, and what effect the relative uncertainties are likely to be on performance assessment.

- DOE states that post-closure repository performance assessments will include post-waste emplacement numerical modeling, uncertainty analysis and consequence analysis. The description of activities for this fundamental aspect of the whole system is brief and imprecise. There appears, in GAI's opinion, to be a shift in approach toward uncertainty analysis from the approach advocated in SCR Chapter 12, where it was stated that a rigorous uncertainty analysis approach would not be used, as it required, amongst other things, a large quantity of measured data. Here, the activities refer to "deterministic models and conservative data"

together with the "application of probabilistic transport models ..... using distributions of mass-flux values." GAI considers that DOE's discussion of their approach to resolving this critical aspect of performance assessment is inadequate and perhaps contradictory. GAI suggests that a comprehensive explanation of the methodology for making numerical assessments of repository performance (including the incorporation of all uncertainties) is essential to evaluating many aspects of the issues and plans at Hanford.

In conclusion, it is GAI's opinion that sufficient resolution of the three issues identified by DOE, as well as any others that may arise, in the area of performance assessment will likely be achieved through the comprehensive and defensible completion of the work elements listed; however, it is not apparent to GAI that DOE has adequately considered data and modeling uncertainties, especially their impact on performance prediction/assessment. It is also GAI's opinion that DOE's presentation of issues, work elements and project activities lacks sufficient detail and explanation. Further, based on descriptions provided for the project activities, it is not clear that DOE will defensibly and comprehensively complete each work element with its current program plans, especially prior to initial license application.

17. EXECUTIVE SUMMARY OF SCR CHAPTER 17 - SITE CHARACTERIZATION PROGRAM

17.1 Synopsis

Chapter 17 of the SCR presents a description of the ongoing Site Characterization Program at Hanford. This program is intended to integrate many of the work elements presented by DOE in SCR Chapters 13 through 16 for the resolution of issues which are necessary and sufficient to demonstrate site suitability, as required for a currently scheduled initial license application in September 1988.

The in situ testing aspects of the Site Characterization Program are contained within the Exploratory Shaft Program, which has been divided into two phases:

- Phase I will provide for access to the repository horizon and for an assessment to be made regarding the suitability of the site to serve as a Test Evaluation Facility (TEF). Phase I, currently scheduled for completion in January 1985, consists of deep borehole(s) from the surface, a six foot inside diameter shaft blind bored and lined through the Umtanum, shaft breakout (i.e., removing the liner and tunneling about 40 linear feet) at the selected repository horizon (either the Umtanum or the middle Sentinel Bluffs, tentatively to be decided in May 1983 based on borehole data), and associated testing in deep borehole(s) from the surface and boreholes drilled through portholes pre-installed in the shaft.

- Phase II will provide additional information so that an assessment regarding the suitability of the site to serve as a repository can be completed. Phase II, currently scheduled for completion in March 1987, consists of up to 1000 linear feet of additional tunnels at the selected repository horizon and associated testing (including horizontal boreholes).

Based on the review of DOE's existing data base (i.e., site conditions, as given in SCR Chapters 3-9, and engineered components, as given in SCR Chapters 10 and 11) and issues and plans (i.e., as given in SCR Chapters 13-16), GAI believes that DOE has not clearly established the information needs (i.e., type and level) to be addressed by their Site Characterization Program. For example, GAI believes that (1) the additional information (i.e., in addition to the existing data base) required for a site suitability assessment has not been clearly defined, and (2) it will also be necessary to obtain information sufficient for repository design and quantitative performance assessment, and not just for site suitability assessment (assuming that site suitability assessment does not include repository design and performance assessment), during the Site Characterization Program and prior to license application. In any case, GAI believes that the details regarding testing (including a consideration of the uncertainty in test results) which have been presented by DOE are insufficient to evaluate whether the type and amount of information that will be obtained will be adequate for a site suitability assessment, or for repository design and performance assessment. Of special concern to GAI is how DOE will extrapolate the assessment of site characteristics and engineered components in the exploratory shaft and associated underground

development to the operational repository. This extrapolation will be (1) from a limited zone to a large area, where geologic variability is expected, (2) generally from small-scale to large-scale, and (3) generally from short-term to long-term performance. Hence, GAI believes that the methodology to be used in formulating the test program, which must be flexible to take into account new information and yet assure that the information needs will be fulfilled, should be clarified.

17.2 Summary of Technical Content Presented by DOE in SCR Chapter 17

Chapter 17 of the SCR presents a description of the Site Characterization Program at Hanford, which is designed to integrate the work elements presented by DOE in SCR Chapters 13 through 16 for the resolution of identified issues. The in situ testing aspects of this program consist of an exploratory shaft extending from the surface through the Umtanum and limited underground tunneling in the candidate horizon, and associated boreholes, borehole testing, laboratory testing and in situ testing. DOE asserts that this program will result in the completion of those work elements which will resolve the issues that are necessary and sufficient to demonstrate site suitability, as required for an initial license application in September 1988.

DOE has identified the following issues in SCR Chapters 13 through 16 (with the first three identified as key issues), which are related to the proposed regulatory and technical criteria (derived from NRC 10CFR60, DOE NWTS-33 (1) to (4), EPA 40CFR191, etc.) and thus must be resolved:

- 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 appropriate 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 appropriate U.S. Environmental Protection Agency (EPA) regulations is not possible?

- What are the geologic, mineralogic, and petrographic characteristics of the candidate repository horizons and surrounding strata within the reference repository location (RRL)?

- What are the nature and rates of past, present, and projected structural and tectonic processes within the geologic setting and reference repository location (RRL)?

- Are the pre-waste emplacement groundwater travel times near the repository sufficient to assure compliance with U.S. Nuclear Regulatory Commission (NRC) proposed technical criteria?

- Does the very near-field interaction between the waste package and its components, the underground facility, and the geologic setting compromise waste package or engineered system performance? (i.e., What is the maximum expected release rate from the engineered system, and does the geologic setting prevent the waste package containment objective from being achieved?)

- Is a unique borehole backfill required?

- Are the geochemical and hydrologic properties of the geologic setting (in conjunction with the waste forms) sufficient to meet or exceed U.S. Nuclear Regulatory Commission (NRC) proposed waste isolation requirements?

- What is the relative importance of waste form leach rates versus solubility of key radionuclides in the near-field environment for controlling release?

- Can valid Eh measurements for the candidate repository horizons in the reference repository location (RRL) be made either by potentiometric measurement or indirectly by measurement of dissolved redox couples?

- To what degree does the geologic setting retard migration of key radionuclides from the engineered system in meeting U.S. Environmental Protection Agency (EPA) draft release criteria?

- How can very near-field waste/barrier/rock materials interaction data, as measured experimentally, be extrapolated over time to reasonably assure that overall waste package and repository performance meet regulatory criteria?

- Can satisfactory representative measurements or estimates of rock-mass strength be obtained?

- Are current methods of in situ stress measurement used at depth reliable enough to provide satisfactory data for design requirements?

DOE has then identified numerous work elements, again in SCR Chapters 13 through 16, which in their opinion will resolve the various issues when completed. In addition to discussing the status and plans for each work element, DOE has identified the ongoing and proposed project activities which in their opinion will complete the work elements. These project activities include the Exploratory Shaft Program, which consists of the construction and subsequent operation of in situ test facilities at the selected site.

The in situ test facilities will consist of a six foot (inside diameter) shaft through the Umtanum and the excavation of up to 1000 linear feet of tunnels within the candidate horizon, which will tentatively be selected (between the Umtanum and the middle Sentinel Bluffs flows) in May 1983. The shaft will be blind bored and telescoped, i.e., 14 foot diameter with 156 inch ID casing to about 100 foot depth, 12 foot diameter with 112 inch ID liner to about 640 foot depth, and 110 inch diameter with 72 inch ID steel liner over the total

depth. In blind boring, the shaft will be kept full of drilling mud to stabilize the hole, and then the closed-end six foot steel liner will be floated and grouted in place. The liner will have "portholes" (for drilling through) installed at preselected locations. Utility lines for underground development will be located in the grout liner, i.e., in the annulus between the steel liner and the rock. Underground development will be initiated by "shaft breakout", i.e., removing the liner over 120 to 180° at the selected depth and tunneling for about 40 feet. Underground excavation will be by drilling and controlled blasting techniques. The total length of underground excavation will be limited to about 1000 linear feet due to ventilation constraints. Surface facilities in support of the Exploratory Shaft Program will cover about 20 acres. Upon completion of the program and if a repository is built, the in situ test facilities will either be incorporated in or isolated (by seals) from the repository.

Phase I of the Exploratory Shaft Program consists of drilling a deep borehole and constructing the shaft and shaft breakout, with associated testing and analysis, and is currently scheduled to be completed in January 1985. Phase I will provide for access to the repository horizon and for an assessment of the suitability of the site to serve as a Test Evaluation Facility (TEF). DOE identifies the following five technical objectives for Phase I activites, and relates the work elements previously identified in SCR Chapters 13 - 16 to each:

(1) Provide the design information required for shaft design and selection of porthole locations and ascertain the overall suitability of the proposed location for an exploratory shaft at the reference repository location (RRL).

(2) Demonstrate that an exploratory shaft can be sunk at the reference repository location (RRL) and assess the construction method.

(3) Verify that an exploratory shaft can successfully seal off the groundwater system and evaluate the effects of shaft construction on the surrounding rock at the reference repository location (RRL).

(4) Measure the hydraulic properties (e.g., hydraulic conductivity) of the candidate repository horizon selected for breakout to provide input to a preliminary estimate of its isolation capability in the vicinity of the exploratory shaft.

(5) Conduct geomechanics tests (e.g., in situ stress measurements) and provide a preliminary rock-mass characterization of the candidate repository horizon selected for breakout.

DOE identifies the key parameters and their predicted values related to each of the above objectives, and identifies the following tests by which they will be assessed:

- Core logging, from principal borehole and portholes
- Water sampling, from portholes
- Borehole geophysics, in principal borehole

- Borehole hydrology tests and head measurements, in principal borehole and portholes
- Laboratory tests on rock core, including
  - geological
  - physical
  - thermal
  - mechanical
  - thermomechanical
- Laboratory hydrochemistry test on water samples
- In situ tests, including
  - hydrofracturing, in principal borehole
  - overcoring, in portholes and shaft breakout
  - extensometer monitoring, in shaft breakout
  - rock bolt load cell monitoring, in shaft breakout
  - jacking tests
  - borehole deformation
  - underground mapping, in shaft breakout
- Shaft drilling surveillance.

Phase II of the Exploratory Shaft Program consists of excavating the additional tunnels at the repository horizon, with associated testing and analysis, and is currently scheduled to be completed in March 1987. Phase II will provide information so that an assessment regarding suitability of the site to serve as a repository can be made. DOE identifies the following three technical objectives for Phase II activities, and relates the work elements previously identified in SCR Chapters 13 - 16 to each:

(1) Provide geotechnical information to enable characterization of a volume of the candidate repository horizon selected for breakout to allow a decision on the suitability of this site for a repository.

(2) Measure the hydraulic properties (e.g., hydraulic conductivity) of the reference repository site to establish the isolation capability of the candidate repository horizon selected for breakout to meet U.S. Nuclear Regulatory Commission (NRC) proposed requirements.

(3) Confirm the applicability of thermomechanical data from the Near-Surface Test Facility (NSTF) to the candidate repository horizon selected for breakout.

DOE identifies the key parameters related to each of the above objectives, and identifies the following tests to be conducted in the candidate horizon by which they will be assessed:

- Exploratory boreholes and core logging
- Mining surveillance, extensometer monitoring and microseismic (acoustic emission) monitoring
- Underground mapping
- Overcoring and hydrofracturing
- Water sampling and laboratory testing
- Water inflow monitoring
- Borehole hydrology tests and head measurments

- Large-scale water flow test (optional)
- Small-scale heater test.

DOE presents schedules for the Exploratory Shaft Program, for the resolution of identified issues, and for initial license application. DOE suggests that additional tests may be conducted after Phase II, although not necessarily prior to initial license application. Also, DOE lists the SCR sections and work elements which address issues previously identified by NRC, related to radionuclide transport, stability, repository design, engineered barriers, and institutional concerns.

17.3 GAI's Evaluation of Technical Adequacy of DOE's SCR Chapter 17

In GAI's opinion, a comprehensive set of issues related to technical criteria (at least those contained in 10CFR60 and 40CFR191) should be defined (by discussions between DOE and NRC) which must be resolved with an agreed level of confidence prior to license application. Once these issues and their confidence levels have been progressively defined, the type and level of information required for the adequate resolution of these issues can be determined, i.e., the acceptable level of uncertainty of significant parameters can be defined. The present type and level of information available (i.e., the existing data base) can then be identified (e.g., site conditions, as given in SCR Chapters 3 through 9, and engineered components, as given in SCR Chapters 10 and 11) and compared with what would be required to adequately resolve the issues. Perceived deficiencies in the existing data base would thus constitute "information needs" which must be fulfilled prior to license application. The capabilities of available tests, to fulfill these specific "information needs", can be assessed, and those tests or combinations of tests which best (in terms of time, cost, and reliability/accuracy without jeopardizing isolation) fulfill the "information needs" should then be selected and conducted during site characterization and prior to license application.

Based on the above and on the review of other chapters of the SCR, GAI has several concerns regarding DOE's Site Characterization Program, as presented in SCR Chapter 17. As previously discussed in the review of SCR Chapters 13 through 16, GAI believes that DOE has not currently identified all of the pertinent issues which must be adequately resolved prior to license application. This may be partly due to a lack of consensus as to the extent to which criteria must be demonstrably met at each licensing step, particularly license application. For example, GAI believes that in addition to determining site suitability, the Site Characterization Program will need to provide information sufficient for repository design and performance analysis, as it must be sufficiently demonstrated in the initial license application that the repository system (i.e., the site in conjunction with engineered components) will have a high probability of performing satisfactorily. Although DOE has identified many of the types of information (e.g., hydraulic head) required for the resolution of site suitability issues, it is GAI's opinion that they have not identified all of the significant characteristics and furthermore that they have not described even qualitatively the acceptable level of uncertainty for each. In many cases, although DOE has identified (in other chapters of the SCR) in summary form the existing data base, they have not related this existing information to the level of information which is

required at license application, and thus have not established justifiable "information needs". Furthermore, DOE has not, in GAI's opinion, presented sufficient detail regarding the type (as well as the techniques and procedures), the number, the general locations and orientations of tests to be performed so as to adequately fulfill the "information needs". GAI recognizes that details of the program necessarily cannot be defined until access has been achieved and that the program must remain flexible to take into account new information. However, GAI believes that the program methodology should be sufficiently discussed to assure that the "information needs", although possibly changing with time, will be fulfilled.

GAI has the following specific comments regarding the technical adequacy of DOE's Site Characterization Program, as presented in SCR Chapter 17:

- Regarding Phase II objectives, information should be obtained during Phase II to allow for repository design and to sufficiently reduce the uncertainty in site characteristics for performance assessment, as required for a license application for construction authorization.

- Regarding selection of the candidate horizon, the decision process is not presented in sufficient detail; especially, it is not clear how the relative importance of the various characteristics will be determined and weights assessed, nor is it clear whether observed values of characteristics will simply be identified as favorable vs. unfavorable or the relative impact of all possible values considered.

- Regarding in situ test facility design
  - the layout objectives should be justified, as this will affect operation and test results.
  - the relationship of the test facility to the actual operating repository should be defined, as this will affect the validity of extrapolating characteristic assessments and may possibly influence repository performance.
  - the dimensions and orientation have not been discussed, and thus cannot be evaluated.
  - a six-foot diameter shaft may be unduly restrictive considering the horizontal drilling and testing to be conducted within it and the amount of subsurface development and testing which must be serviced through it, possibly resulting in scheduling problems and limitations in allowable equipment dimensions; especially, the diverter assembly (or blow out preventor) which will be attached to the porthole may be on the order of two feet long, reducing the room available for drilling and associated activities down to four feet.

- Regarding construction techniques
  - the exploratory shaft will be blind bored only, whereas the repository shafts are presently anticipated to be blind bored and drill/blast; hence, only blind-boring at a small scale will be investigated and the shaft constructability question not completely resolved.
  - the underground facility will apparently (as implied by DOE on SCR page 17.2-3) be excavated as quickly as possible, with in GAI's opinion insufficient concern for monitoring, evaluation of alternative mining

techniques, or possible licensing requirements (should the facility become integrated into the repository); hence, potentially valuable and easily available information might not be obtained, and licensing may be complicated should the facility be incorporated in the repository.

- Regarding measurement of characteristics
  - hydrologic and waste transport characteristics need to be assessed for all the possibly affected overlying materials, and not just the repository horizon.
  - hydrologic tests are required to define the hydrogeologic boundaries of the system in which the repository may be placed.
  - hydrologic tests in horizontal boreholes (especially for vertical hydraulic conductivity) may not be of sufficient scale to be representative of the rock mass; rather, multiple hole pump tests are needed (see review of SCR Chapter 13).
  - during shaft drilling, mud may invade a significant distance into the rock mass, which will substantially reduce and possibly invalidate measured hydraulic conductivities and porosities in that zone.
  - insufficient information is presented regarding the types of piezometers to be used and how they will be sealed, so that the uncertainty in the measurement of hydraulic heads cannot be evaluated.
  - the length of horizontal boreholes appears to be limited; these holes should be as long as possible, especially within the repository horizon, so as to characterize a larger volume and reduce extrapolation.
  - at depth, the emphasis should be on overcoring rather than hydrofracturing for in situ stress measurement, due to the possible problems with hydrofracturing in the expected stress conditions (see review of SCR Chapter 4) and the potentially detrimental fracturing which occurs.
  - in situ tests to assess rock mass strength are not adequately discussed, nor are tests for assessing rock mass modulus and the characteristics of discontinuities, and thus cannot be evaluated.
  - it is not apparent that natural variability of specific characteristics over the affected volumes will be assessed, i.e., a major factor in assessing the uncertainty and predictability of those characteristics.

- Regarding sealing
  - verification of the shaft seal/liner will only be obtained at the shaft breakout station in the repository horizon and will only be applicable to the given construction method (i.e., blind-boring in a small diameter shaft), so that the question of shaft sealing will not be totally resolved.
  - insufficient details are provided for decommissioning the test facility, should it be necessary to isolate it from the repository, and thus cannot be evaluated.

In conclusion, although concurring with DOE that in situ testing at depth is required to assess the suitability of the site at Hanford, GAI believes that DOE has not clearly established the "information needs" to be addressed by their Site Characterization Program. Also, insufficient details have been presented by DOE regarding the methodology they will use to select and design specific tests (considering the uncertainties in their results) which will be

included in this program to adequately fulfill the possibly changing "information needs". Rather, GAI believes that the "information needs" and the test program in response to those needs should be logically and explicitly derived in this SCR and future updates.

18. EXECUTIVE SUMMARY OF SCR CHAPTER 18 - QUALITY ASSURANCE

18.1 Synopsis

Chapter 18 of the SCR presents the Quality Assurance (QA) Program in support of the Basalt Waste Isolation Project (BWIP). Detailed information is presented by DOE regarding responsibilities and methods for identification and control of items and processes, inspection and control of measuring and test equipment, records, and audits.

It is GAI's opinion that the BWIP QA Program, as presented in this SCR Chapter 18, appears to be in conformance with the eighteen criteria of 10CFR50, Appendix B and meets the applicable requirements of ANSI/ASME, NQA-1. As with any QA program, its effectiveness will ultimately be determined by its implementation and application. However, GAI believes that insufficient detail has been presented by DOE regarding their QA Plan (i.e., quality and technical procedures), which is necessary in order to evaluate the quality of data produced and the reliability of repository design/construction/operation/performance.

18.2 Summary of Technical Content Presented by DOE in SCR Chapter 18

Chapter 18 of the SCR presents QA programs with specific recognition of the particular needs of the various activities from site characterization to repository performance assessment on a section by section basis.

Development and coordination of the QA program at BWIP is the direct responsibility of the BWIP Safety and QA Division Director in concert with the BWIP Project Manager. A BWIP management chart is presented. DOE-Richland Office Operations has delegated responsibility to develop and implement QA programs to its prime contractor, Rockwell Hanford Operations (RHO). DOE remains responsible for the content of the programs. The Director-RHO QA Function is responsible for the establishment and certification of proper implementation of the generic QA programs for RHO. He has the authority to stop work and withhold items or activities for use.

The QA program has been established to satisfy the requirements of NQA-1 (ANSI/ASME) which complements the QA program requirements of 10CFR60. These requirements have been endorsed by the Secretary of the DOE, the Director-Division of Waste Repository Deployment and the Manager-DOE-Richland Office Operations.

RHO policy requires the maintenance of an effective QA program to assure the requisite level of quality in all areas of contractor performance without compromise to quality or schedule. The program provides for the use of special techniques, equipment and skills in QA control and verification, as defined in the QA program plan for BWIP. This plan also provides for the use of computer code programs. Software is available for both developmental and production QA.

Based on importance to nuclear safety and degree of quality effort required, QA levels are assessed for design and construction by RHO. The adequacy of any one program is regularly assessed in quarterly reviews with DOE, in executive control meetings, and in program team meetings.

A documented training program has been established at BWIP to ensure that QA standards and operational proficiency are maintained. Other principal contractors are required to train and qualify their personnel in accordance with the same NQA-1 (ANSI/ASME) requirements.

A baseline control concept has been established to identify controlling documents of BWIP criteria and requirements. This ensures that all work is accomplished using the same traceable data. Project management plans and functional procedures manuals have been established to order the sequence of design activities, requirements and procedures and to define responsibilities and requirements for review, approval, release and revision. Policy requires that independent third party reviews be conducted for evaluation and approval of all engineering documentation. Where appropriate, qualification/acceptance tests and a formal peer-review process are also specified.

Procurement-Document-Control practices of all the principal contractors are subject to review by RHO QA Function. All BWIP purchase requisitions, invitations to bid, purchase orders, service agreements and consultant-service contracts require approval by RHO QA Function for adequate quality provisions. Each principal contractor is required to establish measures that control the preparation, issue and change of documents that affect quality. Both technical and administrative documents require internal review to ensure adequacy and inclusion of appropriate quality requirements. RHO has established an operating-document-control system to monitor documents required at work locations.

Control of the procurement of items and services is the responsibility of each contractor. This practice is monitored and reviewed by the DOE-Richland Operation Office. RHO suppliers are qualified, documented and filed. Prospective suppliers are subject to a supplier-quality-system evaluation.

Organizational responsibility has been documented for the selection, procurement and inventory maintenance of those spare parts that ensure safety and continuity of operation. RHO QA Function performs receiving inspection services to ensure quality of products and services and completion of specified quality assurance records.

Measures have been established to ensure that adequate identification is maintained on items or traceable records of items to prevent inadvertent use of incorrect materials or loss of sample identity. Special processes, i.e., processes in which the results are highly dependent upon the control of the process or operator skill and in which the quality of the product cannot be easily determined by inspection or testing, are subject to a special-process-control system.

Inspections for the BWIP QA Program are planned based on the significance of the activity to program objectives. In-process, source, receiving and in-service inspections are planned, including second-level inspection (surveillance) according to the type of activity. Inspections are performed by qualified personnel who do not perform or supervise or report to supervisors of the activity being inspected.

Controlled test procedures are detailed by RHO for major test programs to verify conformance of items to specified requirements. The architect-engineer prepares a detailed acceptance-test procedure in accordance with criteria established in the Hanford Plant Standards System.

A RHO QA Calibration System has been documented. This plan defines responsibility and procedures for regularly scheduled calibrations of specific items (tools, gauges, instruments, etc.) used for acceptance inspection or calibration or collection of data requiring control.

Procedures have been documented in the RHO Material and QA Functions Procedures Manual for the handling, storing and shipping of procured and fabricated items.

Contractors involved in inspection and testing activities during construction and fabrication are required to indicate the status of individual items either on or immediately adjacent to the items. Contractors are required to document these measures in appropriate procedures and instructions, and also prescribe the authority for application and removal of status indicators.

A standard non-conformance report form has been developed that provides for item identification, hold tag number, inspection criteria, non-conformance description, disposition and justification, approvals, and close-out. Items that do not conform to specified requirements are controlled to prevent inadvertent installation or use.

Significant conditions that differ from those normally encountered during the course of routine verification activities, require documentation as to identification, cause and corrective action, and are reported to appropriate levels of management.

A QA Records System is defined, implemented and enforced in accordance with a records management plan and implementing procedures established by RHO. To prepare for potential licensing requirements for the exploratory shaft, should it eventually be considered for use as an operating repository shaft, a construction-acceptance-inspection record system has been established by RHO.

Planned and scheduled quality assurance audits are conducted by the DOE, RHO, other principal contractors and subcontractors, where required. An audit schedule is established annually. The auditing organizations are required to select and assign auditors who are independent of any direct responsibility for performance of the activities they will audit.

18.3 GAI's Evaluation of Technical Adequacy of DOE's SCR Chapter 18

In GAI's opinion, a formal Quality Assurance (QA) Program, which is in conformance with the eighteen criteria of 10CFR50, Appendix B (NRC, 1980) and meets the applicable requirements of ANSI/ASME NQA-1 (ANSI/ASME, 1979, 1981a, and 1981b), is required in order to ensure satisfactory repository design, construction, and operation at Hanford. As stated by NRC in Regulatory Guide 4.17 (NRC, 1982):

> "The description should include all QA measures applicable to all technical programs . . . The QA methods should be described in sufficient detail to allow NRC to make an independent evaluation of the reliability, reproducibility, uncertainty limits, analytic sensitivity, and limitation of data acquisition and analysis methods that have been used during site screening and will be used during site characterization."

The NRC Regulatory Guide 4.17 requires a summary of the methods, techniques, and analyses used in tests or experiments, and a detailed description of the procedures expected to be used. It is essential that data acquisition and analysis be of high quality and controlled and documented in such a fashion that uncertainties and limitations associated with it can be fully understood and quantified. Thus, in order to adequately evaluate these procedures it is necessary for specifics such as testing methods, instrumentation, environmental controls, documentation, nonconformance/corrective action, methods of analysis, and applicability and limitations of testing and instrumentation in acquiring the necessary information, be outlined for each activity to be performed. This would provide for a detailed picture of how DOE plans to achieve their goals.

GAI believes that, if applied as presented by DOE in this SCR Chapter 18, the QA Program satisfactorily addresses the following issues:

- Organization

  The organization structures are adequately documented for both the BWIP management organization and the Rockwell Hanford Operations (RHO) Organization.

- Quality Assurance Program

  The documented QA program for BWIP is in compliance with applicable standards and regulations.

- Design Control

  The design control process for BWIP satisfactorily addresses the definition, control and verification of design.

- Procurement Document Control

  RHO has taken appropriate measures to ensure that adequate quality requirements are referenced in documents for procurement of items and services.

- Instructions, Procedures and Drawings

  RHO has complied with applicable standards and regulations by developing documented instructions, procedures, and drawings which prescribe activities affecting quality, and include quantitative and qualitative acceptance criteria for determining that prescribed activities have been satisfactorily accomplished.

- <u>Document Control</u>

  To ensure that correct documents are being employed, RHO has satisfactorily established control measures for the preparation, issuance and change of documents that specify quality requirements or prescribe activities affecting quality.

- <u>Control of Purchased Items and Services</u>

  The procurement of items and services for BWIP appropriately includes source evaluation and selection, source inspection, audit, and examination of items or services upon delivery or completion.

- <u>Identification and Control of Items</u>

  RHO has established sufficient controls to ensure that only correctly identified and accepted items are used or installed.

- <u>Control of Processes</u>

  Satisfactory measures have been established to ensure that special processes that control or verify quality are performed by qualified personnel using qualified procedures in accordance with specified requirements.

- <u>Inspection</u>

  An adequate inspection program complying with applicable regulations and standards has been planned and executed by RHO.

- <u>Test Control</u>

  Tests required to adequately verify conformance of items and functions to specified requirements are planned, executed and documented.

- <u>Control of Measuring and Test Equipment</u>

  Measuring and test equipment are satisfactorily controlled to maintain accuracy within necessary limits.

- <u>Handling, Storage and Shipping</u>

  Handling, storage, cleaning, packaging, shipping and preservation of items for BWIP are sufficiently controlled to prevent damage or loss and to minimize deterioration.

- <u>Inspection, Test and Operation Status</u>

  RHO has established measures to assure that the status of inspection and test activities are adequately identified to ensure that required inspections and tests are performed, and to ensure that items which have not passed the required inspections and tests are not inadvertently installed, used or operated.

- Control of Non-Conforming Items

  Items that do not conform to specified requirements are satisfactorily controlled to prevent inadvertent installation or use. However, GAI questions the appropriateness of the application of the term "geologic environment" to this particular criterion.

- Corrective Action

  RHO has adequately established measures to ensure that conditions adverse to quality are promptly identified and corrected, and verified by means of follow-up measures.

- Quality Assurance Records

  RHO has satisfactorily established a QA Records System for BWIP which ensures that records which furnish documentary evidence of quality are correctly specified, prepared and maintained.

- Audits

  An adequate system of planned and scheduled audits, complying with applicable standards and regulations and which verifies compliance with all aspects of the QA program and determines its effectiveness, has been established by RHO.

In conclusion, GAI believes that the BWIP QA program, as presented in this SCR Chapter 18, appears to be in conformance with 10CFR50, Appendix B and ANSI/ASME, NQA-1. As with any QA program, its effectiveness will ultimately be determined by its implementation and application. However, GAI believes that insufficient detail has been presented by DOE regarding their QA Plan (i.e., quality and technical procedures), which is necessary in order to evaluate the quality of data produced and the reliability of repository design/construction/operation/performance.

19. EXECUTIVE SUMMARY OF SCR CHAPTER 19 - IDENTIFICATION OF ALTERNATE SITES

19.1 Synopsis

Chapter 19 of the SCR presents a summary overview of the approach to and status of site selection being carried out for non-basalt media types under the National Waste Terminal Storage (NWTS) Program. These media, listed in order of priority in timing and level of effort (all below that for basalt), are volcanic tuff (at the Nevada Test Site), bedded and domal salt, granite and other crystalline rocks, and other media. Site characterization reports for tuff and salt are anticipated in June and July, 1983, respectively.

In GAI's opinion, the information presented by DOE in Chapter 19 of the SCR provides a good appreciation of the status of site screening studies. However, the factors or criteria relevant in implementing the site screening approaches are not discussed. GAI considers it desirable to know the technical basis for the site selection and characterization priorities, specifically for the Hanford Site compared to other regional sites in tuff, salt, granite, etc. Suitable summaries or references should be included for this purpose.

19.2 Summary of Technical Content Presented by DOE in SCR Chapter 19

Chapter 19 of the SCR addresses the manner in which alternative sites were selected by DOE for further study, and presents the current status with regard to site selection and characterization at various alternative sites, other than Hanford. Basalt, volcanic tuff and salt (domal and bedded) are the primary media presently under consideration by DOE, and current schedules for initial submittal of site characterization reports are November 1982, June 1983 and July 1983, respectively. In addition, ONWI is studying crystalline rocks as potential long-term options for geologic disposal.

Siting investigations being carried out under the NWTS Program follow a formal three step siting process:

(1) Site screening, where DOE has utilized three approaches to initiate screening:

- a host-rock approach, in which potentially suitable media types are selected and suitable regions in the coterminous United States for each of these media are reviewed

- screening studies of sites within federally owned land which are already committed to nuclear activities

- province screening, in which successively smaller subdivisions of large areas where geohydrologic conditions present multiple barriers to radionuclide migration are focused on; the province screening approach is experimental and restricted to only one of the eleven geohydrologic provinces of the United States, although it may be used to identify alternative sites for later repositories.

(2) Detailed site characterization, which has been or is presently being carried out only for Hanford and the Nevada Test Site.

(3) Site selection for licensing, where national, state and local participation in public meetings and hearings will review the process by which a site is recommended and deemed suitable.

DOE's screening studies for bedded and domal salt have addressed four regions: the Gulf Coast salt domes, and the Paradox, Permian and Salina salt basins. Two domes (Richton in Mississippi and Vacherie in Louisiana) have been selected from eight on the Gulf Coast as being worthy of further study. One of four potentially suitable sites in the Paradox Basin (bedded salt) has been recommended for detailed site characterization and investigation. The Permian Basin is presently in the preliminary site location phase in preparation for site characterization planning studies. Work on the Salina Basin has been deferred indefinitely. A site characterization report for the prime salt site is currently planned to be submitted to the NRC by DOE in July 1983.

Investigations of potential suitable sites of various rock types within the Nevada Test Site have focused on the tuffaceous media of Yucca Mountain. Exploration and characterization efforts have been restricted to this area, and it is currently planned that a site characterization report will be submitted to the NRC by DOE in June 1983. Preliminary design work has begun in preparation for an exploratory shaft.

Studies for other alternative sites in granite, other crystalline rocks or other media have not progressed to the stage of detailed site study. Liaison is being maintained with studies in granite by Canadian and Swedish authorities and regional literature-phase studies have begun. National screening surveys for alternatives in other media has not progressed beyond the planning stage.

19.3 GAI's Evaluation of Technical Adequacy of DOE's SCR Chapter 19

In GAI's opinion, SCR Chapter 19 presents an adequate broad overview of the current status of DOE's process of site selection (screening, site characterization and selection) for non-basalt regions. This information provides an appreciation of the relative stages achieved in the process for the various potential sites and the level of effort and emphasis being placed for each of the media and sites. Although this is informative, it does not explain what factors or criteria were considered by DOE in implementing the site screening approaches used. Without this more detailed information, it is not, in GAI's opinion, possible to assess how the BWIP site compares with other sites in other regions in the United States, and thus not possible to defend the selection of BWIP as a primary early candidate site. GAI believes that a summary or reference to any ranking type comparisons performed to establish regional priorities is essential and should be contained in SCR Chapter 19.

It should be noted that subsequent to submittal of this SCR, the Nuclear Waste Policy Act of 1982 was passed. In response to this legislation, which among other things establishes siting schedules and requirements, the DOE is presently formulating "General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories" (10CFR960) to be used in selecting sites. Thus, the site screening/selection process, as well as its status, discussed by DOE in this chapter of the SCR may soon become outdated.

A. EXECUTIVE SUMMARY OF SCR APPENDICES

A.1 Synopsis

The Appendices of the SCR contain a glossary of technical terms, acronyms, and abbreviations used throughout the SCR. In GAI's opinion, the appendices are an adequate, comprehensive list of definitions useful for the technical interpretation of the SCR.

A.2 Summary of Technical Content Presented by DOE in SCR Appendices

The Appendices of the SCR contain two items:

(1) A glossary, in alphabetical order, of technical terms used in the SCR. These encompass geologic, engineering, geohydrologic and specifically nuclear waste terminology, and also definitions of nuclear industry terms, as adopted in the SCR.

(2) An alphabetical list of acronyms and abbreviations for institutions, engineering terms, and units.

A.3 GAI's Evaluation of Technical Adequacy of DOE's SCR Appendices

In GAI's opinion, the glossary of technical terms, acronyms, and abbreviations presented in the SCR represent a useful and adequate reference for reading and writing documents relating to the SCR and other associated studies on geologic nuclear waste repositories.

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APPENDIX

ACCOMPANYING DOCUMENTATION PRESENTED TO THE TASK FORCE ON APRIL 15, 1983

REVIEW OF
SITE CHARACTERIZATION REPORT
FOR THE
BASALT WASTE ISOLATION PROJECT

APRIL 15,1983

PRESENTED TO

GOVERNOR'S HIGH-LEVEL WASTE MANAGEMENT
TASK FORCE

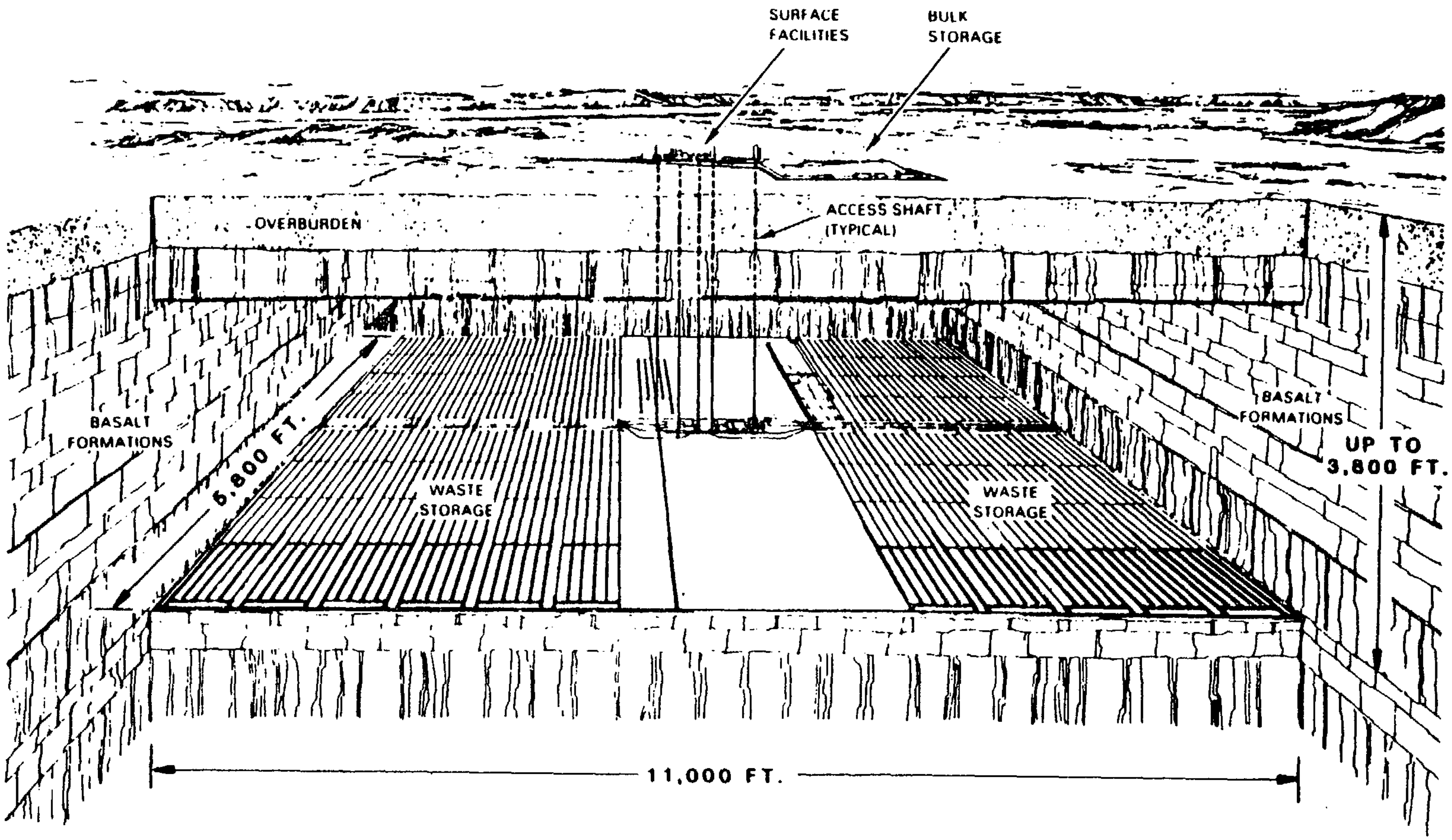
BY
GOLDER ASSOCIATES, INC.

BELLEVUE, WASHINGTON

ROLE OF GOLDER ASSOCIATES

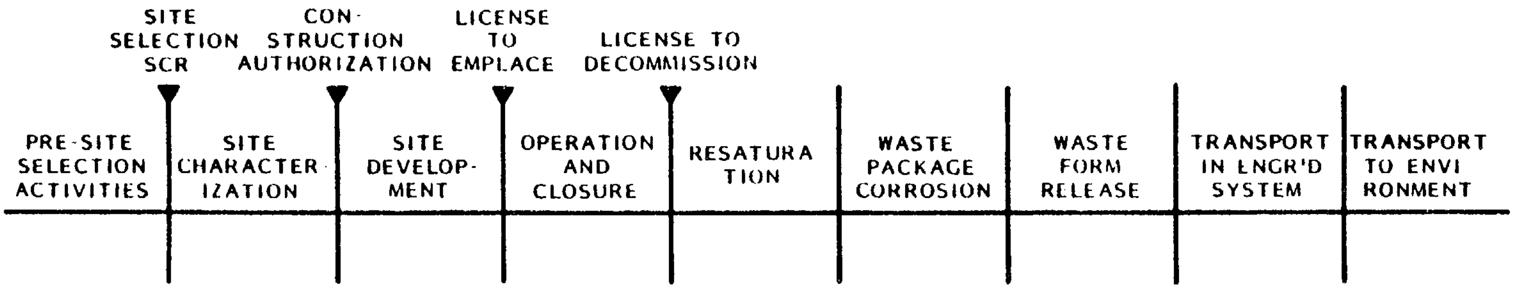
- REVIEW SCR
- PROVIDE EXECUTIVE SUMMARY OF EACH SCR CHAPTER
  - DETAIL CRITICAL AND SALIENT POINTS
  - COMMENT ON TECHNICAL ADEQUACY OF DATA, DESIGNS, PLANS
  - IDENTIFY MAJOR TECHNICAL ISSUES TO BE RESOLVED

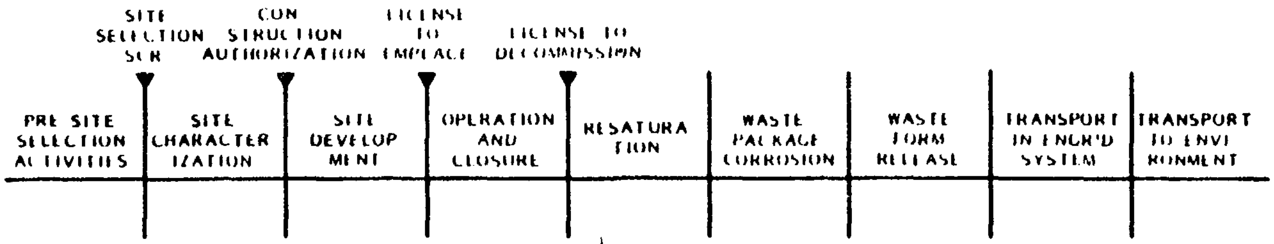
REPOSITORY CUTAWAY



(SCR Figure 10-1)

REPOSITORY DEVELOPMENT AND LONG-TERM PERFORMANCE

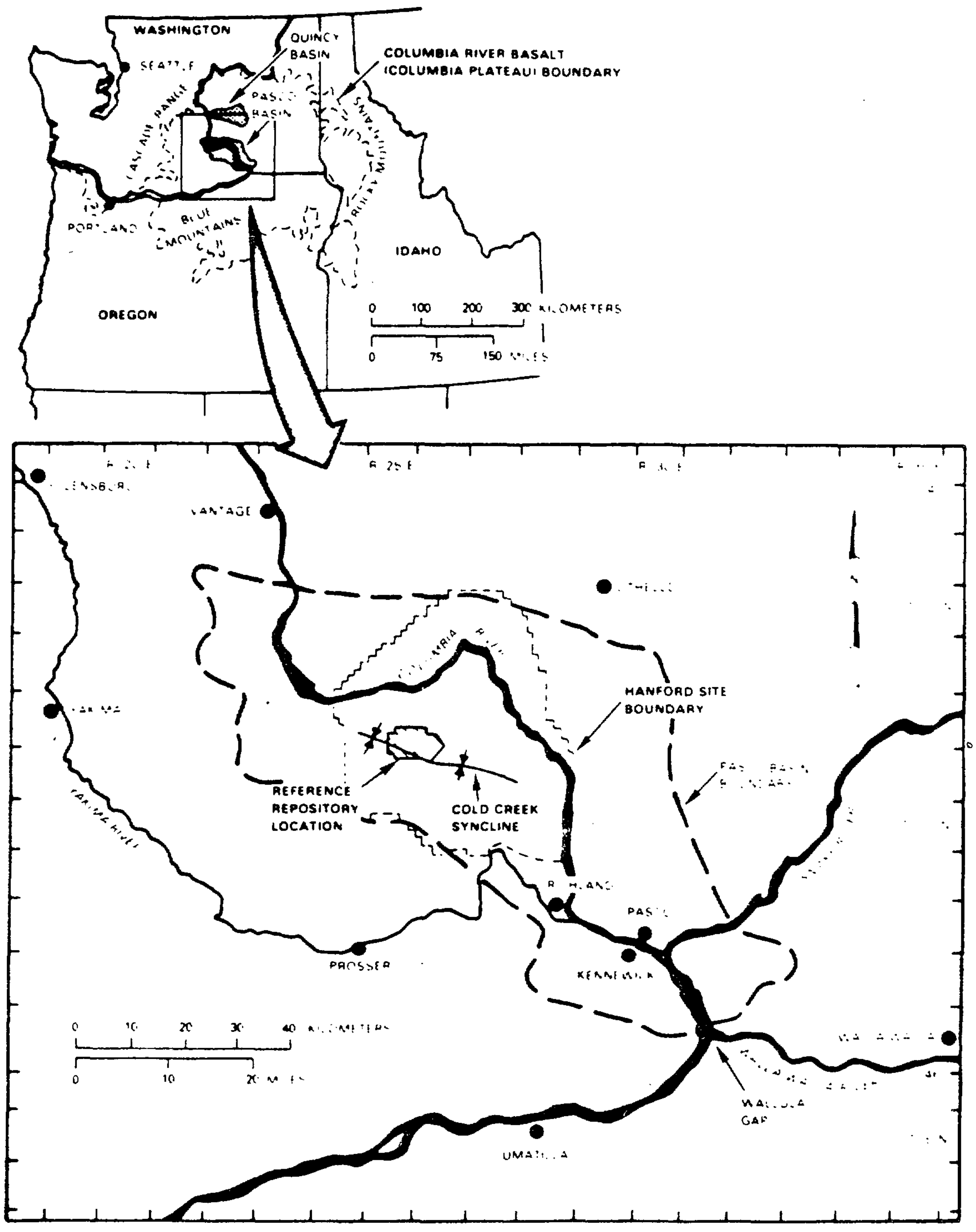




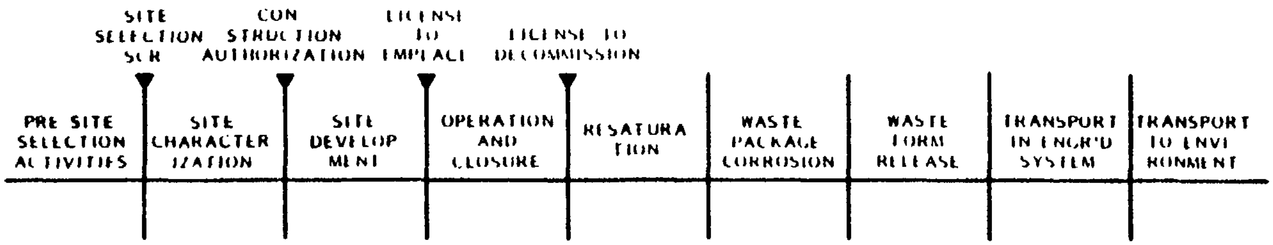
SITE SELECTION EVALUATION

- BECAUSE OF CONSTRAINT TO SITE ON HANFORD, OTHER BASALT SITES IN PACIFIC NORTHWEST MAY HAVE EQUAL OR GREATER PROBABILITY OF BEING QUALIFIED
- LITTLE INFORMATION RELATED DIRECTLY TO PERFORMANCE AVAILABLE FOR SITE SELECTION
- SITE SELECTION PROCESS WAS SUBJECTIVE
- WEAKNESS IN SITING NOT CRITICAL, PROVIDED SITE AND DESIGN ARE SHOWN TO BE QUALIFIED (I.E., MEET LICENSING CRITERIA)

REFERENCE REPOSITORY LOCATION



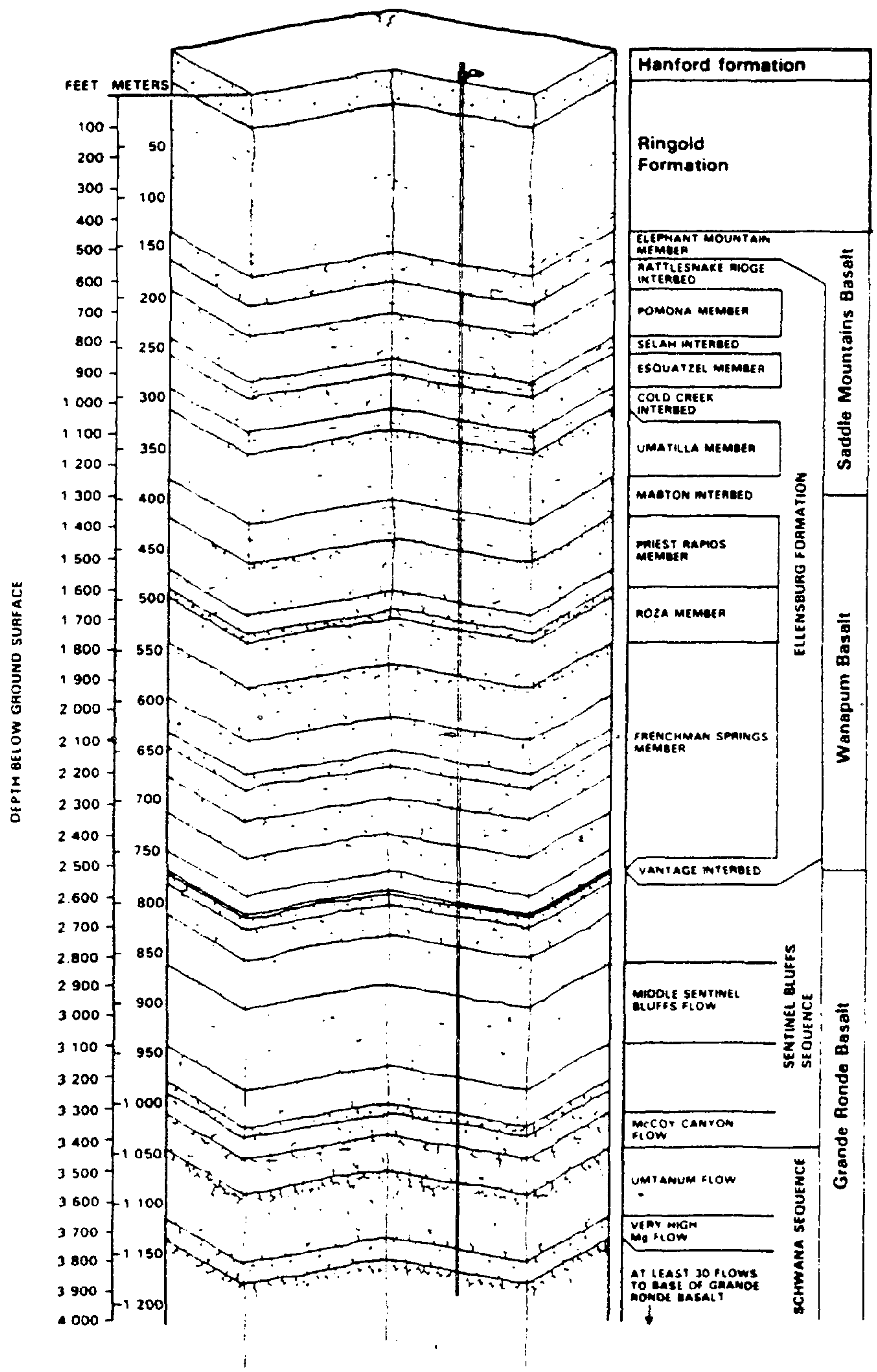
(SCR Figure 3-1)



GEOLOGY
SCR CONTENT

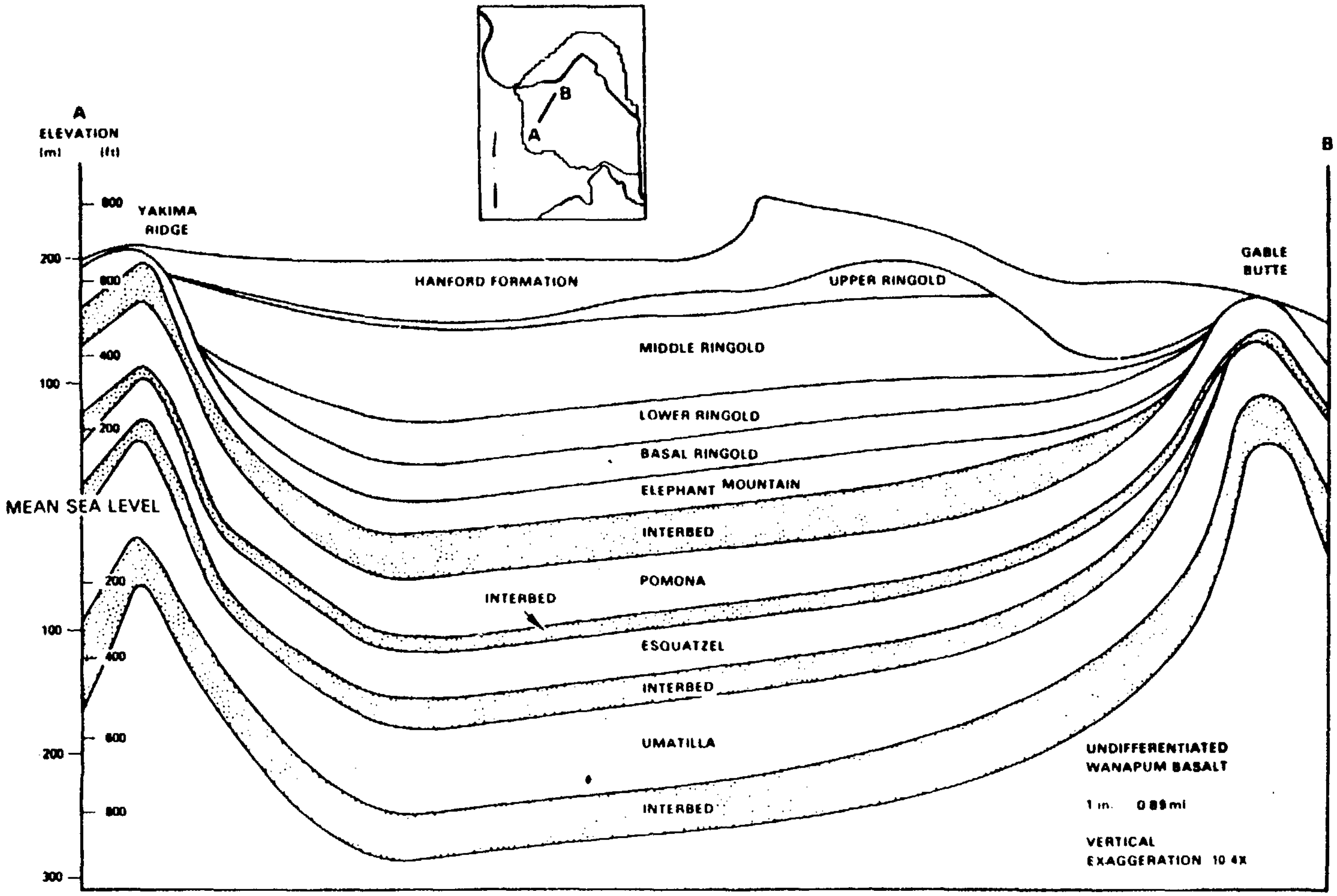
- DATA FROM FIELD SOURCES
- SEQUENCE OF BASALT FLOWS
  - SADDLE MOUNTAIN
  - WANAPUM
  - GRANDE RONDE
- FOLDING
- INTRAFLOW STRUCTURE
  - FLOW TOP AND BOTTOM
  - ENTABLATURE
  - COLONNADE

STRATIGRAPHY OF THE REFERENCE REPOSITORY LOCATION



(After SCR Figure 1-4)

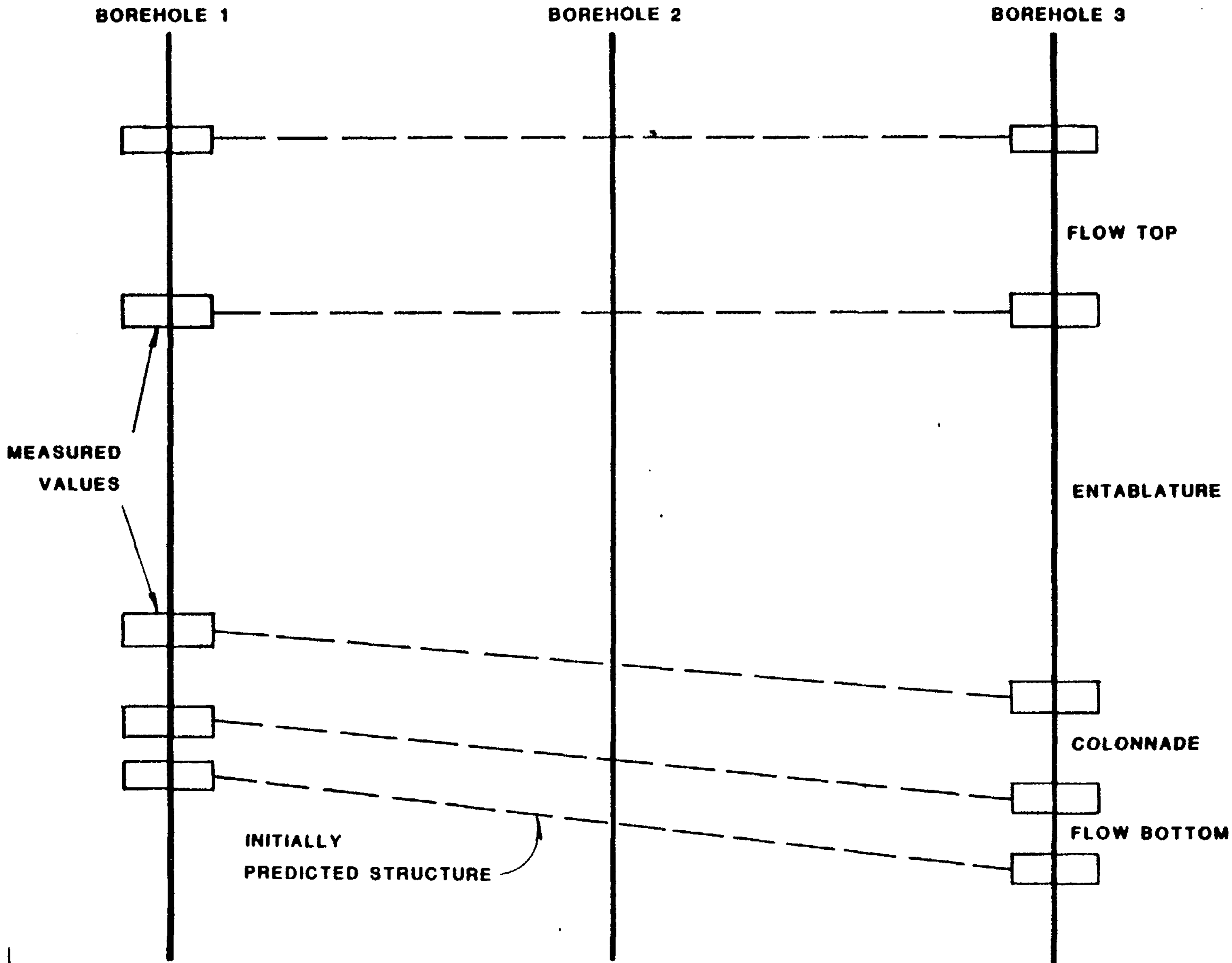
GEOLOGIC STRUCTURE

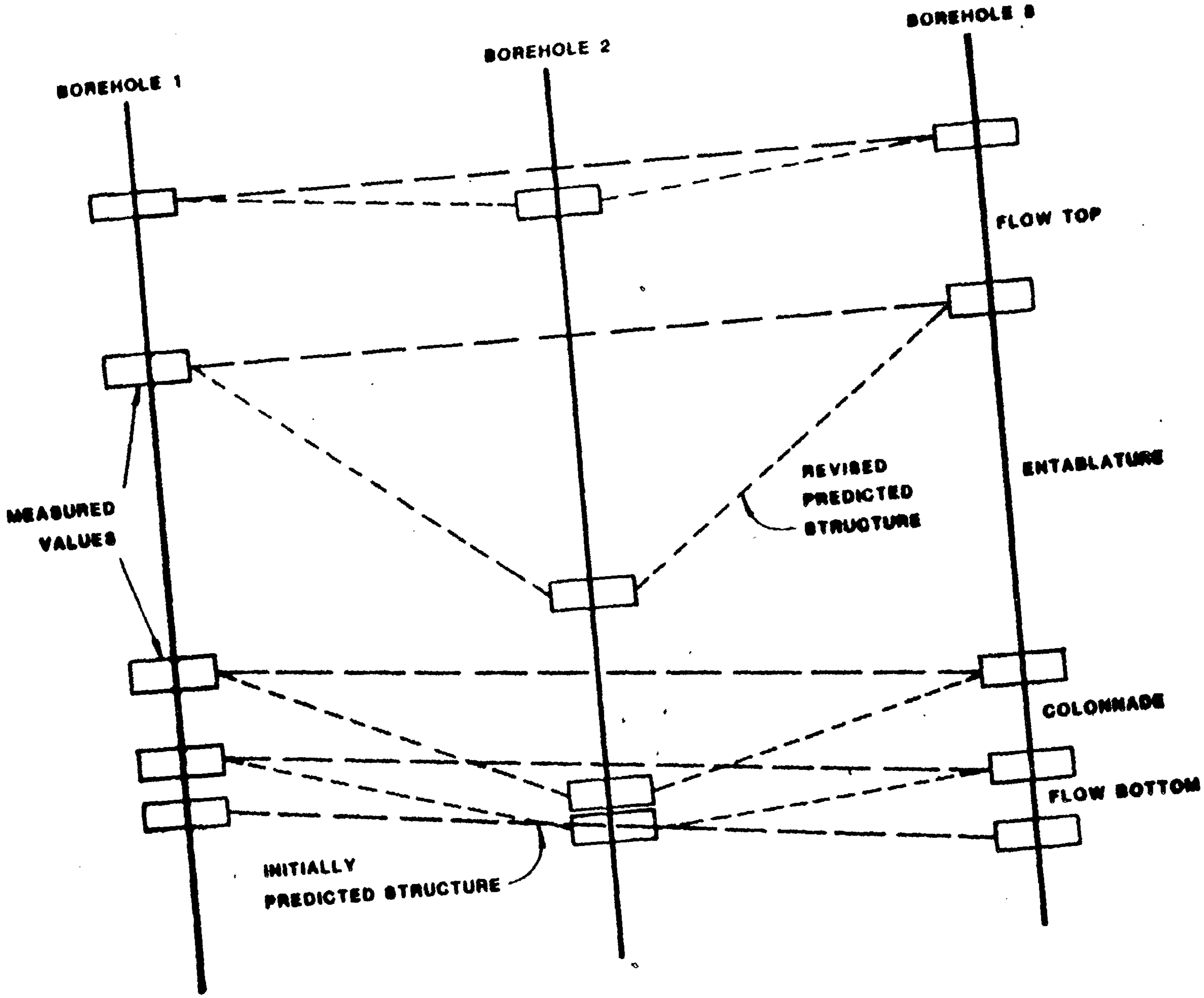


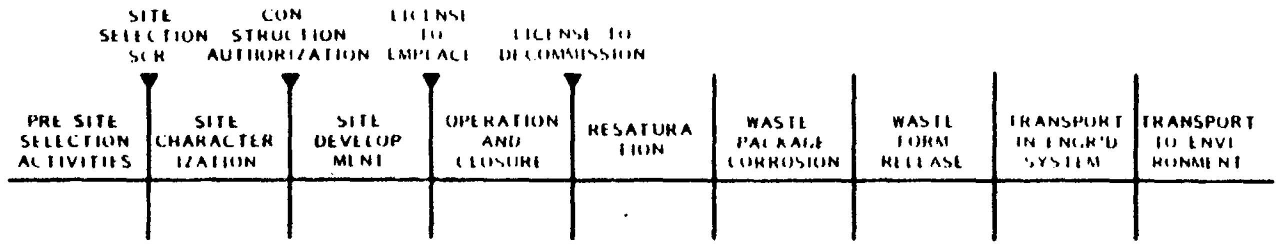
(SCR Figure 3-16)

CLIFF EXPOSURE - UMTANUM FLOW

(SCR Figure 3-29)

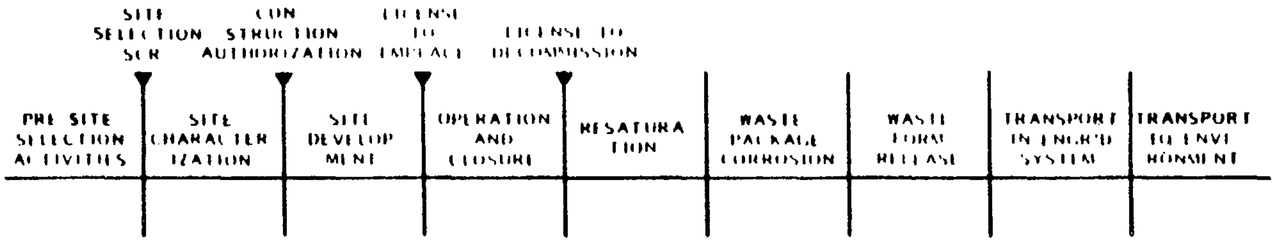

BOREHOLE 1
BOREHOLE 2
BOREHOLE 3
FLOW TOP
MEASURED
VALUES
ENTABLATURE
COLONNADE
FLOW BOTTOM
INITIALLY
PREDICTED STRUCTURE


BOREHOLE 1
BOREHOLE 2
BOREHOLE 3
FLOW TOP
ENTABLATURE
COLONNADE
FLOW BOTTOM
MEASURED
VALUES
REVISED
PREDICTED
STRUCTURE
INITIALLY
PREDICTED STRUCTURE



GEOLOGY EVALUATION

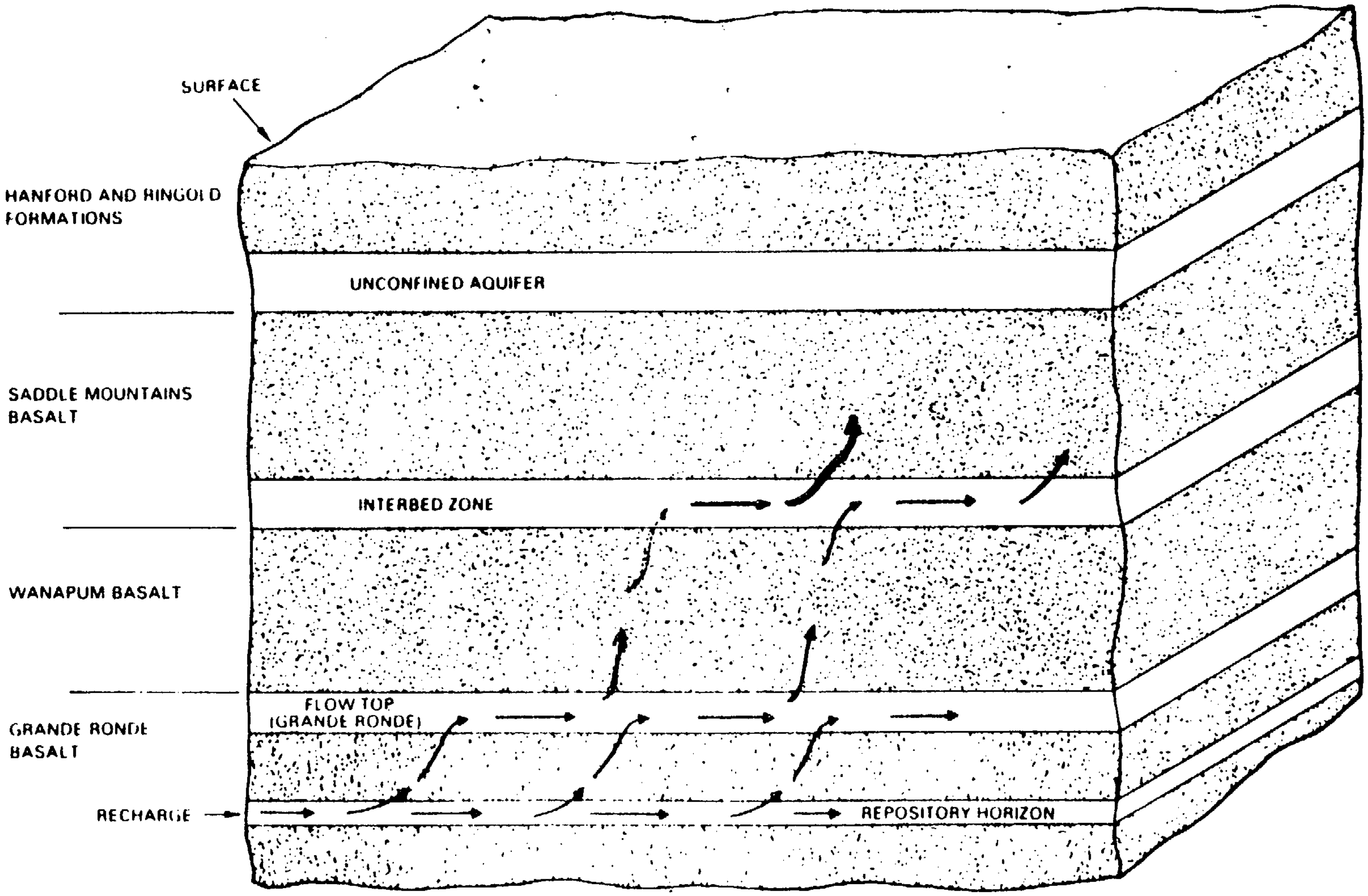
- ADEQUATE INITIAL DATA BASE EXCEPT FOR INTRAFLOW VARIABILITY
- SUITABLE DATA BASE INTERPRETATION



HYDROGEOLOGY
SCR CONTENT

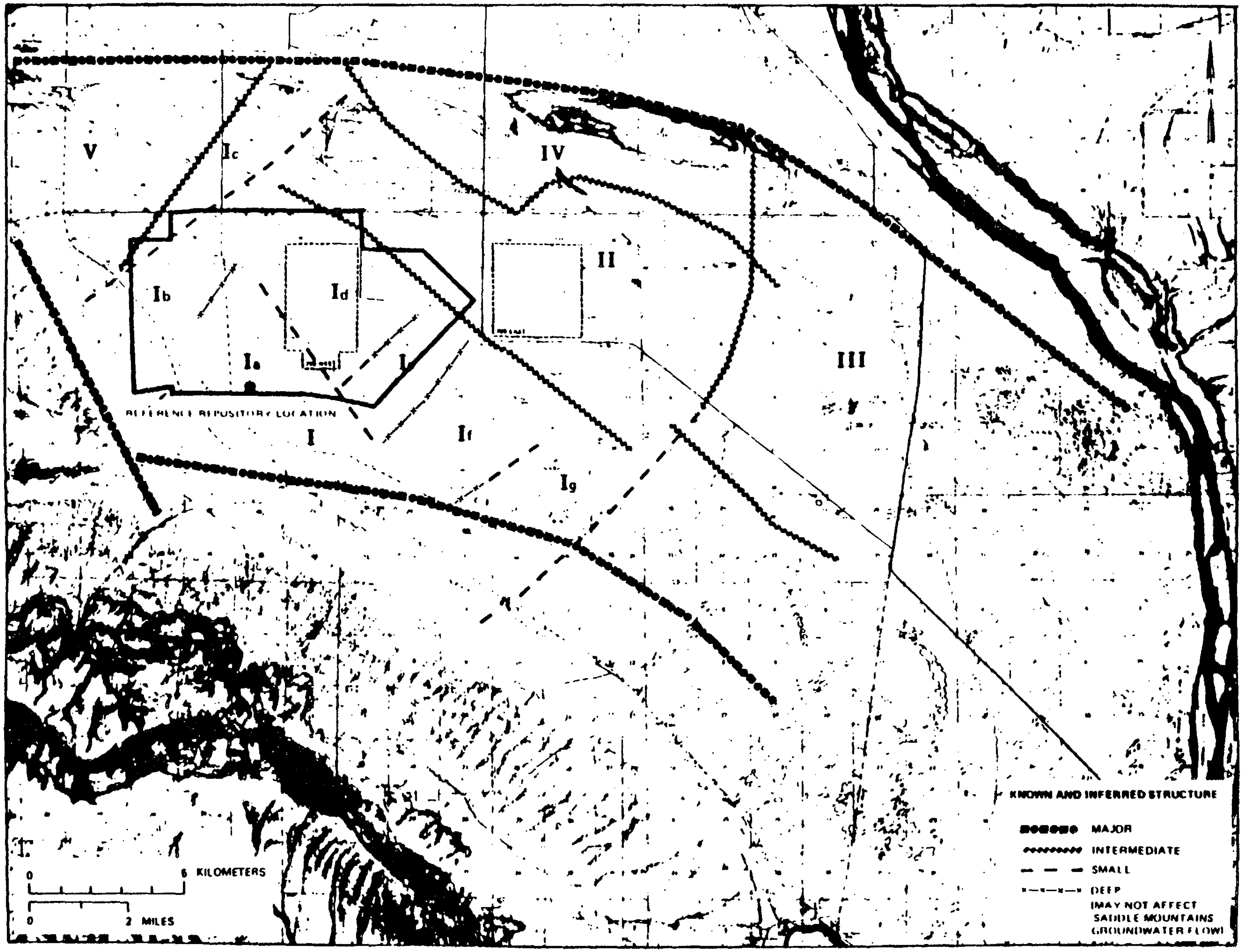
- DATA OBTAINED FROM SMALL BOREHOLES ON
  - HYDROGEOLOGIC UNITS
  - HYDRAULIC PARAMETERS
  - HYDRAULIC HEADS
  - HYDROCHEMISTRY
- CONCEPTUAL GROUNDWATER MODEL
  - HORIZONTALLY LAYERED FLOW SYSTEM
  - HIGH PERMEABILITY FLOWTOPS AND INTERBEDS
  - LOW PERMEABILITY COLONNADE AND ENTABLATURE
  - GRADIENT, TO SE
  - DISCHARGE IN WALLULA GAP
  - UNDEFINED HYDROGEOLOGIC BOUNDARIES

SCHEMATIC GROUNDWATER FLOW PATH

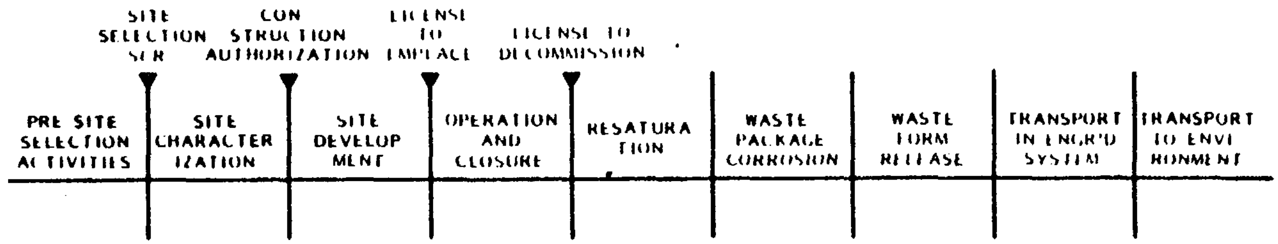


(SCR Figure 11-20)

HYDROGEOLOGIC BOUNDARIES



(SCR Figure 3-52)

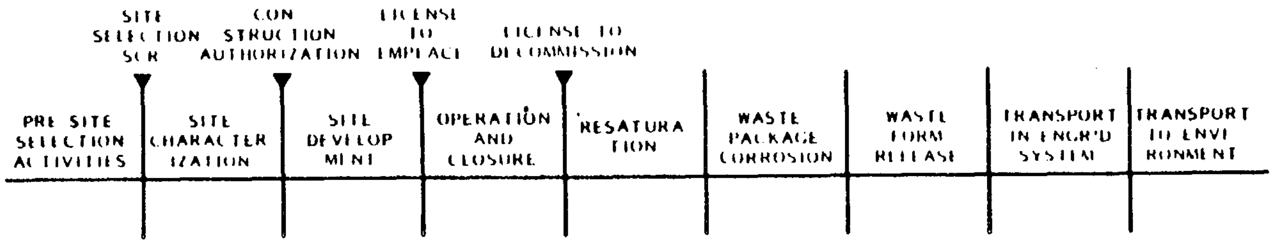


HYDROGEOLOGY EVALUATION

- DATA DEFICIENCIES IN
  - HYDRAULIC PARAMETERS
  - HYDRAULIC HEAD
  - NO DATA ON HYDROGEOLOGIC BOUNDARIES
- CONCEPTUAL GROUNDWATER MODEL
  - DOE MODEL NOT UNIQUELY SUPPORTED BY EXISTING DATA
  - LARGE UNCERTAINTIES IN DATA NOT ACCOUNTED FOR IN MODEL

    DATA VARIABILITY

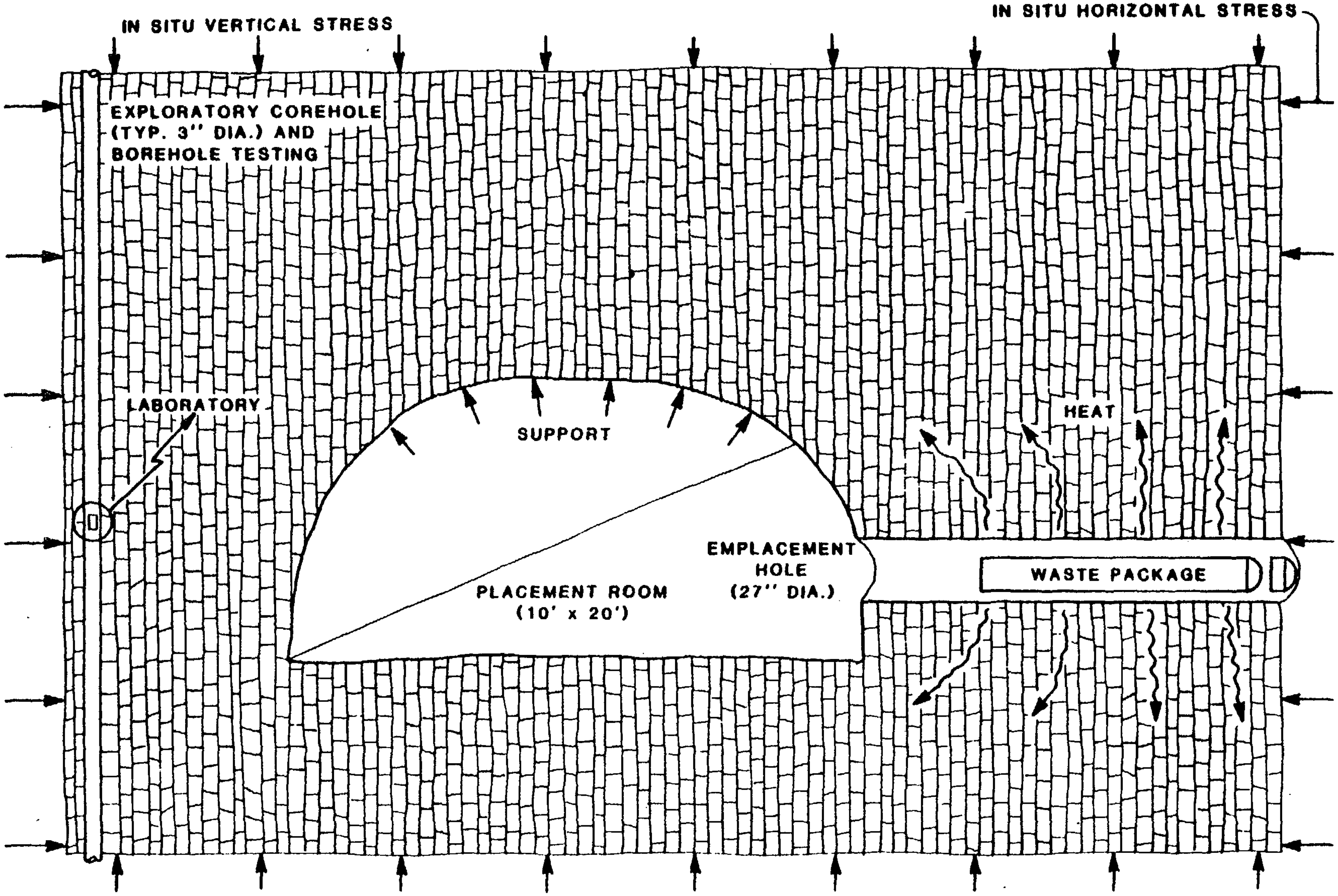
    ACQUISITION METHODS

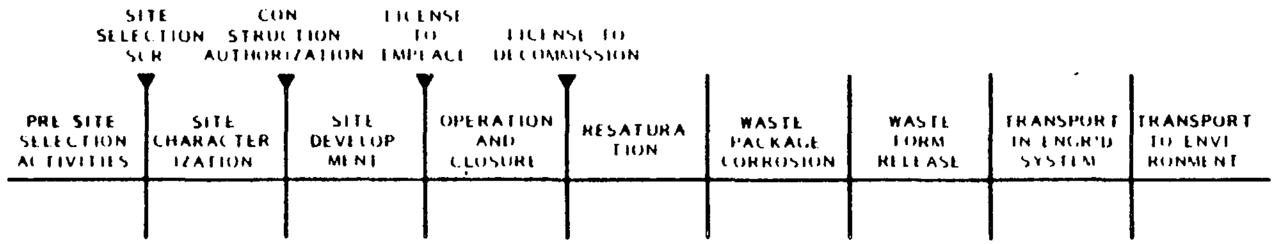


GEOENGINEERING SCR CONTENT

- DATA ON
  - MECHANICAL PROPERTIES
  - THERMO/THERMOMECHANICAL PROPERTIES
  - IN SITU STRESSES
- INTERPRETATION OF DATA
  - BASALT IS STRONG AND BRITTLE
  - BASALT IS HIGHLY FRACTURED
  - HEAT FLOW IS PREDICTED WELL
  - THERMAL DISPLACEMENTS ARE UNCERTAIN
  - HORIZONTAL IN SITU STRESS IS HIGH
  - NO CONSTRUCTION PROBLEMS ARE ANTICIPATED
  - NSTF WAS USEFUL

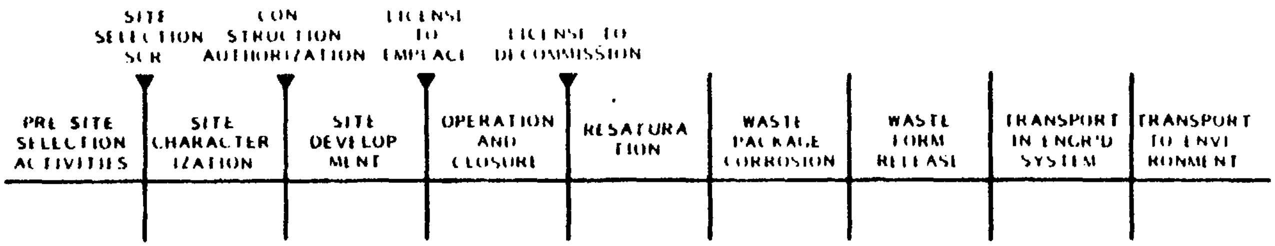
GEOENGINEERING





GEOENGINEERING EVALUATION

- DATA BASE DEFICIENCIES
  - UNCERTAINTIES NOT DEFINED
  - INSUFFICIENT DATA ON CRITICAL PARAMETERS
  - UNTESTED CHARACTERISTICS AND CONDITIONS
- TEST PLANS PRESENTED ACKNOWLEDGE SOME DATA DEFICIENCIES BUT INSUFFICIENTLY DETAILED
- QUESTIONABLE INTERPRETATION OF DATA
  - IN SITU STRESSES WITH HYDRAULIC FRACTURING
  - ASSUMPTIONS ON MASS STRENGTH
  - UNCERTAINTIES NOT ASSESSED
  - QUESTIONABLE EXTRAPOLATION OF NSTF RESULTS TO CANDIDATE HORIZONS



REPOSITORY DESIGN
SCR CONTENT

- CONCEPT DESIGN INFORMATION ON
  - SURFACE FACILITIES
  - ACCESS SHAFTS
  - SUBSURFACE FACILITIES
  - WASTE HANDLING SYSTEMS
  - SERVICE SYSTEMS
  - OPERATIONS

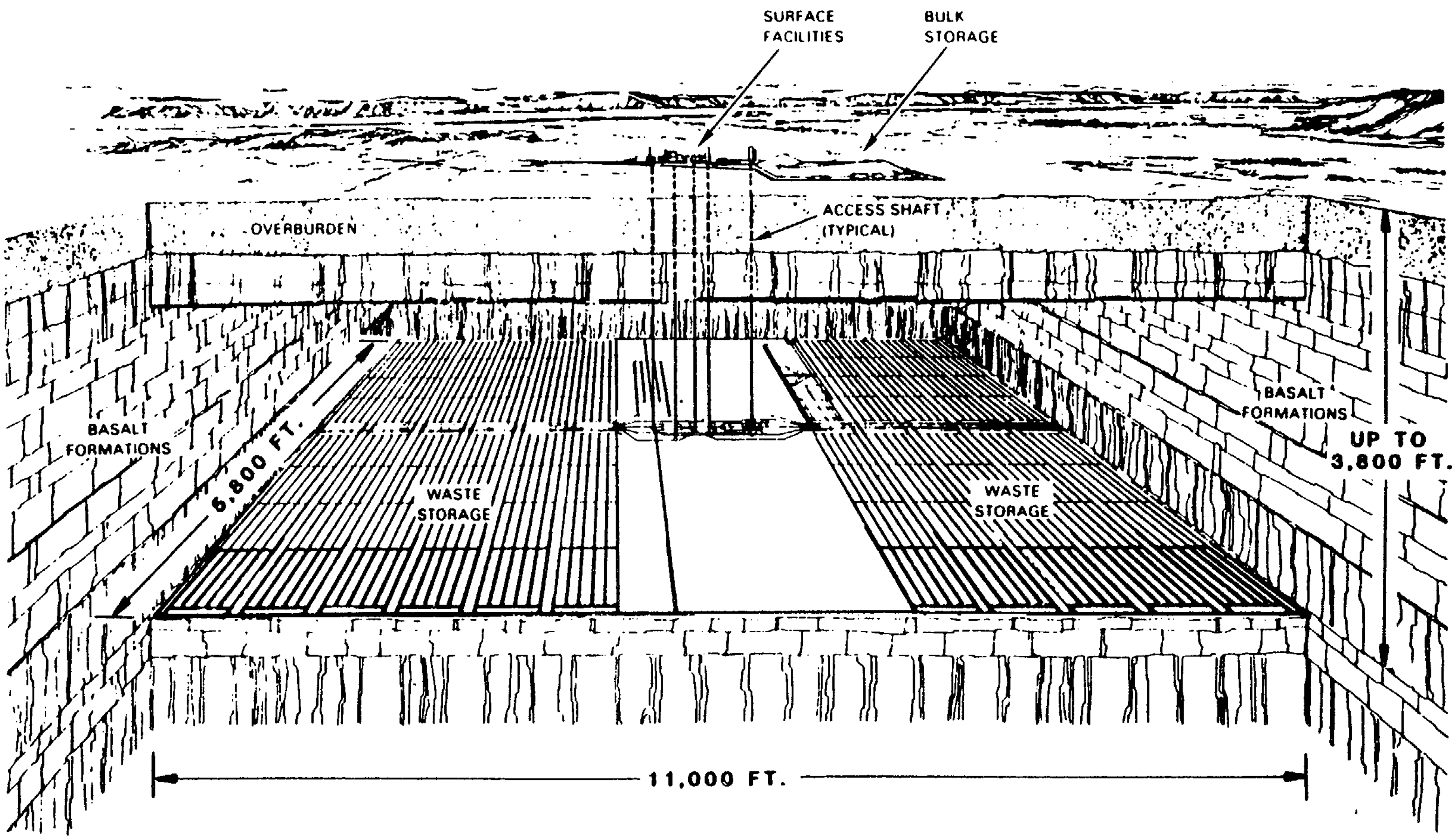
    ANNUAL EMPLACEMENT CYCLE

    ANNUAL BACKFILL CYCLE

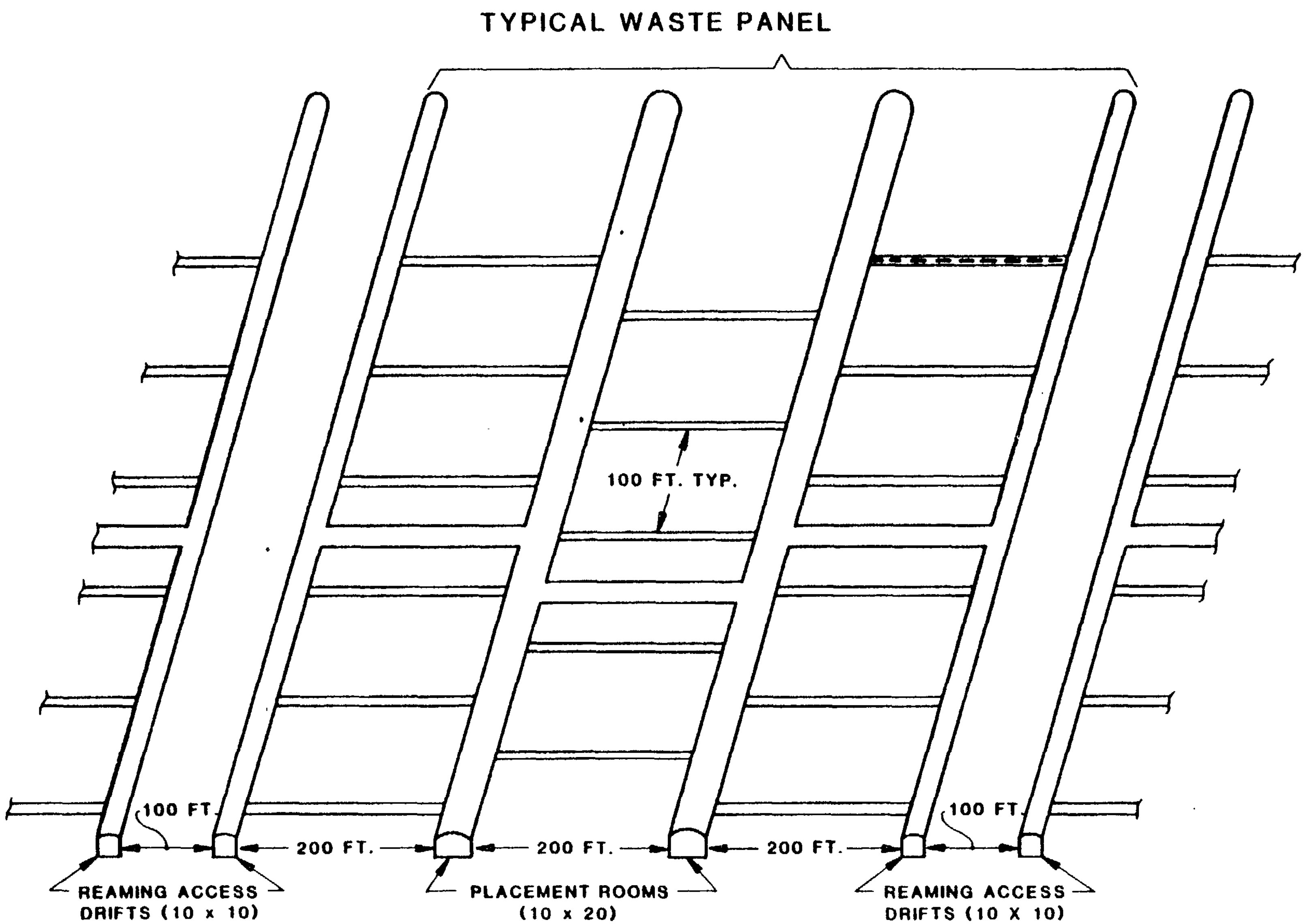
    RETRIEVAL

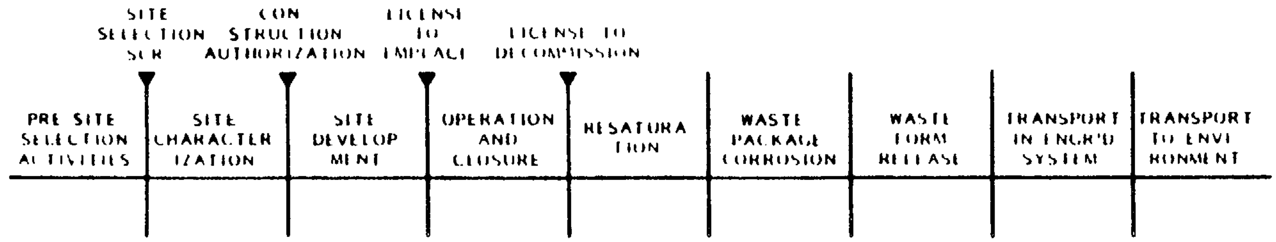
    DECOMMISSIONING

REPOSITORY CUTAWAY



(SCR Figure 10-1)


TYPICAL WASTE PANEL
100 FT. TYP.
100 FT.
200 FT.
200 FT.
200 FT.
100 FT.
REAMING ACCESS DRIFTS (10 x 10)
PLACEMENT ROOMS (10 x 20)
REAMING ACCESS DRIFTS (10 X 10)

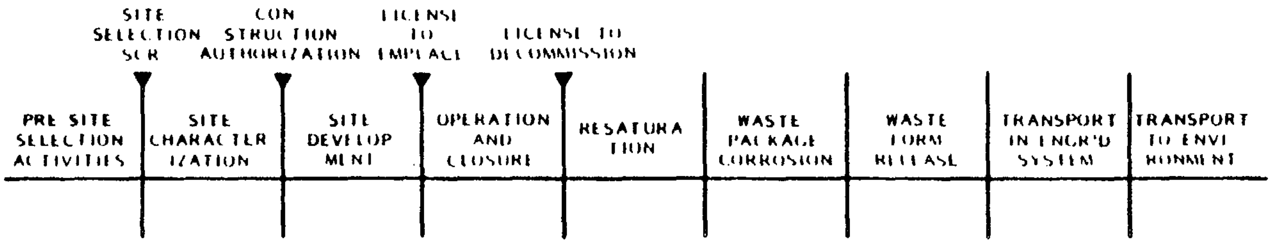


REPOSITORY DESIGN EVALUATION

- DESIGN DESCRIPTION SUFFICIENT EXCEPT
  - UNDERGROUND OPENINGS
  - DESIGN PROCESS UNDEFINED, E.G., DESIGN CONTINGENCIES, THICKNESS VARIATIONS
  - DESIGN OF ENGINEERED BARRIERS
  - RETRIEVAL ASSESSMENT
- PERFORMANCE AND DESIGN CONFIRMATION DETAILS LACKING
- IN SITU TESTING PLANS ARE POTENTIALLY INCOMPLETE

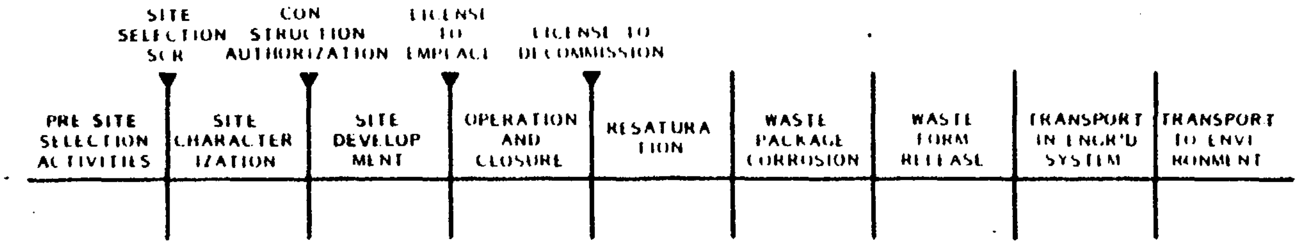
CLIFF EXPOSURE - UMTANUM FLOW

(SCR Figure 3-29)



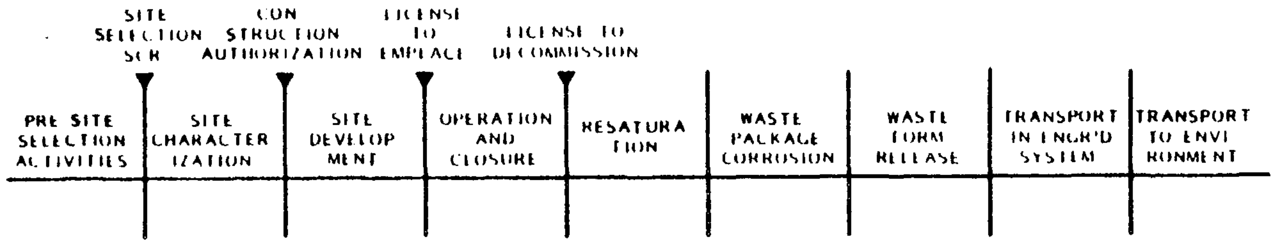
GEOCHEMISTRY SCR CONTENT

- HOST ROCK AND SECONDARY MINERAL GEOCHEMISTRY
- GROUNDWATER CHEMISTRY
  - pH
  - Eh
  - TEMPERATURE AND PRESSURE
- RADIONUCLIDE SOLUBILITIES
- RADIONUCLIDE SORPTION CHARACTERISTICS



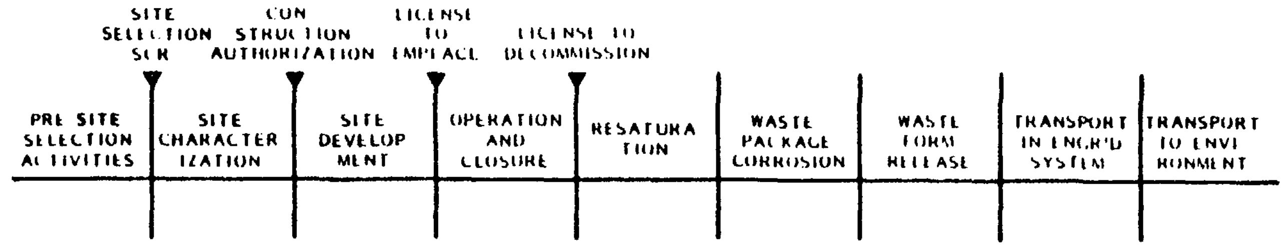
GEOCHEMISTRY EVALUATION

- CORROSION ENVIRONMENT HIGHLY UNCERTAIN
  - pH AND Eh
  - DISOLVED GASES
    - OXYGEN
    - NITROGEN
    - METHANE
- NO RELEVANT SOLUBILITY DATA REPORTED
- TRANSPORT ENVIRONMENT UNCERTAIN
  - SORPTION DATA UNDER OXYDIZING CONDITIONS
  - IMPACT OF SECONDARY MINERALS



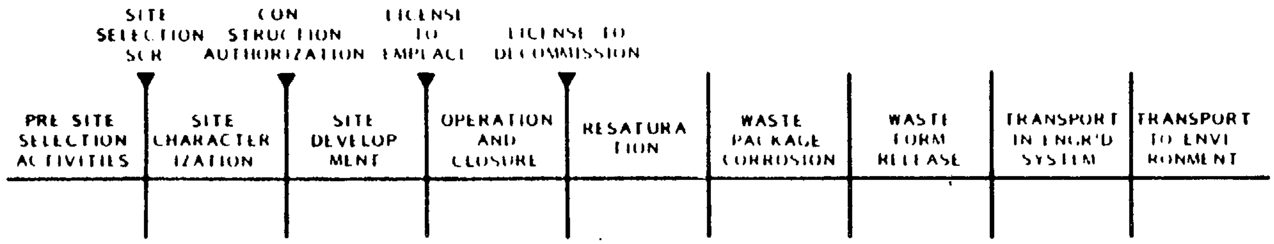
WASTE PACKAGE SCR CONTENT

- WASTE FORM CHARACTERISTICS
  - SPENT FUEL
  - HIGH-LEVEL WASTE GLASS
  - LEACH RATES
- WASTE EMPLACEMENT DESIGN CONCEPTS
  - STEEL CONTAINER
  - HORIZONTAL EMPLACEMENT
  - PNEUMATICALLY BACKFILLED
- WASTE CONTAINER CORROSION DATA
- PACKAGE R & D PROGRAM BASED ON
  - EXPECTED CORROSION CONDITIONS
  - RESATURATION AT 2000 YEARS
  - EXPECTED CORROSION TEMPERATURES



WASTE PACKAGE EVALUATION

- WASTE PACKAGE CORROSION RATES AND LIFETIME ARE VERY UNCERTAIN
- RATES OF NUCLIDE RELEASES ARE VERY UNCERTAIN
- R & D PROGRAM ASSUMING CONDITIONS WHICH MAY NOT BE CONSERVATIVE WITH RESPECT TO CORROSION ENVIRONMENT AND RESPONSE

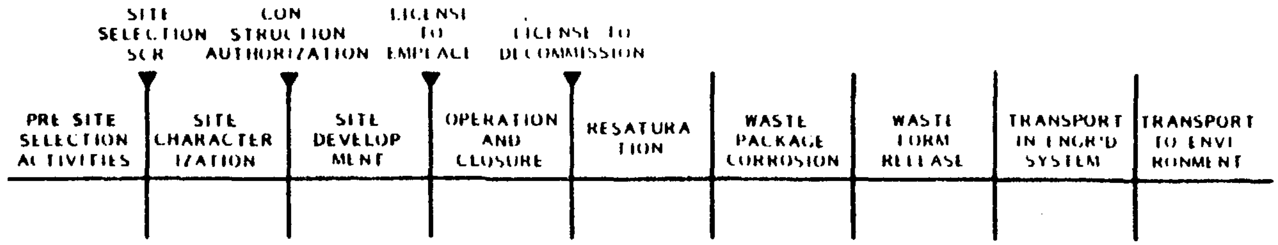


NEAR-TERM PERFORMANCE ASSESSMENT
SCR CONTENT

- CONSIDERATION OF REPOSITORY DEVELOPMENT AND OPERATIONAL SAFETY DEFERRED UNTIL CONCEPTUAL DESIGN COMPLETE

EVALUATION

- MITIGATION OF SURFACE RADIOACTIVE CONTAMINATION
- TRANSPORTATION BURDENS AND RISKS
  - CONSTRUCTION
  - WASTE
    - RADIOLOGICAL
    - NONRADIOLOGICAL
  - OPERATIONS

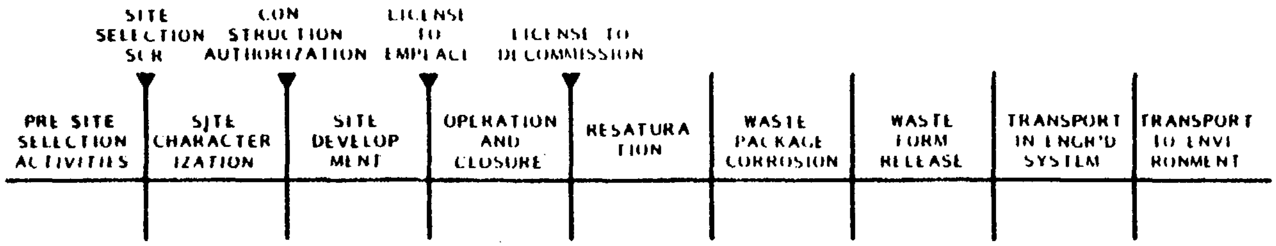


LONG-TERM PERFORMANCE ASSESSMENT SCR CONTENT

- PERFORMANCE ISSUES
  - EPA REQUIREMENTS
  - NRC REQUIREMENTS
    - TRAVEL TIME
    - PACKAGE LIFE
    - RELEASE RATE
- PERFORMANCE ASSESSMENT METHODS
  - MODELS
  - UNFAVORABLE RELEASE MECHANISMS
  - UNCERTAINTIES
- PERFORMANCE ANALYSIS RESULTS
  - PACKAGE LIFETIMES
  - LOW SOLUBILITIES
  - TRAVEL TIME VERY LONG

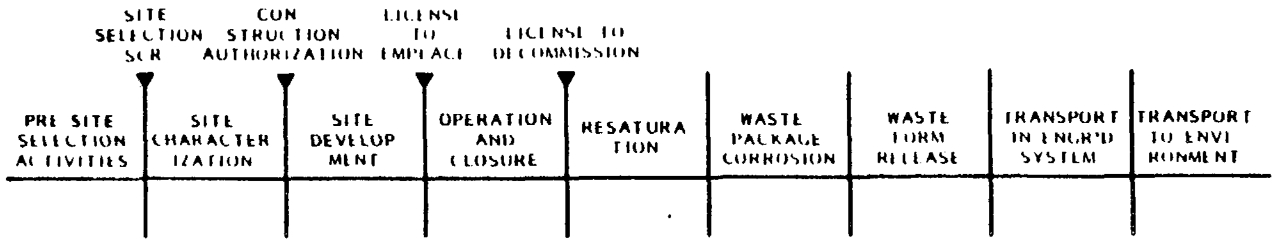
LONG-TERM PERFORMANCE ASSESSMENT

	RESATURATION	WASTE PACKAGE CORROSION	WASTE FORM RELEASE	TRANSPORT IN ENGR'D SYSTEM	TRANSPORT TO ENVIRONMENT
DOE ASSUMPTIONS AND/OR CALCULATIONS	• CALCULATED AT 2000 YEARS	• LIFETIME ASSUMED TO BE 1000 YEARS	• ASSERT SOLUBILITIES LOW	• NOT CONSIDERED	• TRAVEL TIME ESTIMATED TO BE 13,000 TO 7,000,000 YEARS
GAI EVALUATION	• HIGHLY UNCERTAIN • BEST CURRENT ESTIMATE 1 - 100 YEARS	• NO RELEVANT DATA • PACKAGE LIFETIME HIGHLY UNCERTAIN	• SOLUBILITIES HIGHLY UNCERTAIN • LEACH RATES UNCERTAIN	• POORLY DEFINED • NO SORPTION DATA • TRAVEL TIME UNCERTAIN	• GEOHYDROLOGY UNCERTAIN • TRAVEL TIMES ESTIMATED TO BE 100 TO 100,000 YEARS



LONG-TERM PERFORMANCE ASSESSMENT

- DOE CURRENTLY PLACES HIGH RELIANCE ON GEOLOGY AND HYDROLOGY
- GAI BELIEVES THERE ARE CURRENTLY LARGE UNCERTAINTIES IN GEOLOGY, HYDROLOGY, AND GEOCHEMISTRY, THUS LONG-TERM PERFORMANCE MUST PARTIALLY RELY ON ENGINEERED BARRIERS
- CURRENT DESIGNS AND PLANS DO NOT REFLECT THIS NEED
- PERFORMANCE OF HANFORD SITE CANNOT BE DEFENSIBLY PREDICTED AT THIS TIME



CONCLUSIONS

- DATA
  - VARIABILITY
  - UNCERTAINTY
  - METHODS
- DESIGN
  - PROCESS
  - ENGINEERED BARRIERS
  - RETRIEVAL
  - PERFORMANCE
- PERFORMANCE
  - UNCERTAINTY IN DATA
  - UNCERTAINTY IN MODELS
  - METHODOLOGY
- PLANS
  - DATA
  - DESIGN
  - PERFORMANCE CONFIRMATION