1292

ONWI-109
DRAFT

NNA.870407.0014

Evaluation of Area Studies of the U.S. Gulf Coast Salt Dome Basins

Technical Report

March 31, 1981

9003007015

Office of Nuclear Waste Isolation
Battelle Memorial Institute
505 King Avenue
Columbus, OH 43201

ONWI
Office of Nuclear Waste Isolation
Battelle

ONWI-109

DRAFT

Evaluation of Area Studies of the U.S. Gulf Coast Salt Dome Basins

Technical Report

March 31, 1981

Office of Nuclear Waste Isolation
Battelle Memorial Institute
505 King Avenue
Columbus, OH 43201

This report was prepared by Battelle Project Management Division Office of Nuclear Waste Isolation under Contract DE-AC06-76RLO1830-ONWI with the U.S. Department of Energy.

Department of Energy
National Waste Terminal
Storage Program Office
505 King Avenue
Columbus, Ohio 43201

March 26, 1981

To Distribution:

This report was prepared for the Department of Energy to provide a summary assessment of the Salt Dome evaluations conducted to date by Battelle Memorial Institute for the Department's National Waste Terminal Storage (NWTS) Program. The report does not constitute a final recommendation by the Department of Energy. The NWTS Program Office is providing this report of the contractor's conclusions to the States of Louisiana, Mississippi, and Texas for review and comment prior to any decision on the part of the Department.

This report evaluates eight salt domes which have been considered as potential repository sites: Rayburn's and Vacherie Domes in Louisiana, Cypress Creek, Lampton and Richton Domes in Mississippi; and Keechi, Oakwood and Palestine Domes in Texas. Four salt domes are found suitable for further study while the other four are recommended to be eliminated from further consideration as high-level nuclear waste repository sites. The four sites recommended for further study are Cypress Creek, Oakwood, Richton and Vacherie Domes; the three domes recommended to be eliminated from consideration are Lampton, Keechi and Rayburn's Domes. Palestine Dome was disqualified in 1980.

The Department intends to publish a final version of this document to reflect consideration of additional facts and interpretations brought to light in the comments of State agencies. The final publication will complete the area phase of characterization activities for the Gulf Interior Salt Domes.

After consulting with the States, the Department of Energy will continue evaluation of the domes determined to be most promising. These investigations would lead to identification of a single candidate dome to be considered along with one or more bedded salt site(s) for extensive at-depth testing. The Department currently plans to conduct such tests at three sites, one of which would be either a domed salt or a bedded salt site. Studies are being conducted at the Department of Energy's Hanford Site, Nevada Test Site, bedded salt regions of Utah and Texas and in several States with granitic formations.

The Department of Energy's NWTS Program Office has offered to plan the next phases of study jointly with officials from the States of Louisiana, Mississippi, and Texas. This office intends to incorporate the States' recommendations into the planning and implementation of subsequent phases of study.

The Department will consider comments received on this report prior to July, 1981. Comments should be addressed to me at the NWTS Program Office, U.S. Department of Energy, 505 King Avenue, Columbus, Ohio 43201.

Sincerely,

J. O. Neff

J. O. Neff
Program Manager
NWTS Program Office

ONWI
Office of Nuclear Waste Isolation
Battelle
505 King Avenue
Columbus, Ohio 43201
Telephone (614) 424-6424
Telex 24-5454

March 26, 1981

Mr. J. O. Neff
Program Manager
U.S. Department of Energy
National Waste Terminal
  Storage Program Office
505 King Avenue
Columbus, Ohio 43201

Dear Mr. Neff:

ONWI-109, "EVALUATION OF AREA STUDIES OF THE U.S. GULF COAST SALT DOME BASINS" TRANSMITTED TO NPO FOR FINAL REVIEW

This letter accompanies a draft report entitled "Evaluation of Area Studies of the U.S. Gulf Coast Salt Dome Basins". Seven volumes of supporting technical reports from Bechtel National, Incorporated, the Environmental Project Manager, and Law Engineering Testing Company, the Geologic Project Manager, have been transmitted previously. These reports document the phase of investigations on the Gulf Coast salt domes that is now being concluded.

This report is not intended to present the technical information gained on the salt domes that have been the subject of our investigations over the past 2 to 3 years. That information is contained in the three volumes of the Area Environmental Characterization Report prepared by Bechtel[1, 2, 3] and the four volumes of the Area Geologic Characterization Report[4, 5, 6, 7] prepared by Law Engineering. This report presents our recommendations for further work and the rationale by which we reached these recommendations, utilizing the technical information contained in the more voluminous technical volumes.

It is our intent that planning activities for the next phase of work, now under way, be concluded in the next few months and that the planning be followed by a resumption of field activities in the Gulf Coast Region. We anticipate that appropriate state officials in the states where field activities will occur will continue to participate in this planning, in addition to the technical organizations involved in the project on behalf of ONWI and DOE. The document [Site Characterization Plan (SCP)] that results

WBS 1.3.3.2.5

from this effort will lay out a precise plan of activities that need to be conducted and a schedule over which we would anticipate the work will be carried out. Also, it will identify technical organizations that will have the lead responsibility for each activity, and the technical report, results, and data that will be the end products of the investigations.

This and the supporting reports represent an appropriate and timely close to the area-level studies that have been conducted over the past 2 to 3 years. We believe the technical information utilized represents the best information that is currently available. We suggest that this report be made available to the public in a prompt manner for review.

Sincerely,

Neal E. Carter
General Manager

R. B. Laughon
Manager
Site Exploration

NEC/RBL:ne

Attachment

In Triplicate

Enclosure

REFERENCES

1. Bechtel National, Incorporated. 1980. Environmental Characterization Report for the Louisiana Study Area, Gulf Interior Region, ONWI-192, San Francisco, CA, Draft, November.

2. Bechtel National, Incorporated. 1980. Environmental Characterization Report for the Mississippi Study Area, Gulf Interior Region, ONWI-193, San Francisco, CA, Draft, November.

3. Bechtel National, Incorporated. 1980. Environmental Characterization Report for the Texas Study Area, Gulf Interior Region, ONWI-194, San Francisco, CA, Draft, November.

4. Law Engineering Testing Company. 1980. Area Characterization Report, Vol. I, Introduction, Background, and Summary, ONWI-117, Gulf Coast Salt Domes Project, Marietta, GA, Draft.

5. Law Engineering Testing Company. 1980. Area Characterization Report, Vol. II, East Texas Study Area, ONWI-118, Gulf Coast Salt Domes Project, Marietta, GA, Draft.

6. Law Engineering Testing Company. 1980. Area Characterization Report, Vol. III, North Louisiana Study Area, ONWI-119, Gulf Coast Salt Domes Project, Marietta, GA, Draft.

7. Law Engineering Testing Company. 1980. Area Characterization Report, Vol. IV, Mississippi Study Area, ONWI-120, Gulf Coast Salt Domes Project, Marietta, GA, Draft.

Bechtel National, Inc.
Engineers — Constructors

Fifty Beale Street
San Francisco, California
Mail Address: P. O. Box 3965, San Francisco, CA 94119

March 5, 1981

Dr. Neal E. Carter
General Manager
Battelle Memorial Institute
Project Management Division
Office of Nuclear Waste Isolation
505 King Avenue
Columbus, Ohio 43201

Dear Dr. Carter:

We have reviewed your Gulf Coast Dome Evaluation Document and are in agreement with the environmental data contained therein. This report accurately reflects the data that are contained in the Area Environmental Characterization reports prepared by our office.

Very truly yours,

Neil Norman

Neil A. Norman, P.E.
Project Manager

NAN/clo

LAW ENGINEERING TESTING COMPANY
geotechnical environmental & construction materials consultants
2749 DELK ROAD, S.E.
MARIETTA, GEORGIA 30067
(404) 952-9005

March 18, 1981

Battelle Memorial Institute
Project Management Division
Office of Nuclear Waste Isolation
505 King Avenue
Columbus, Ohio 43201

Attention: Mr. O. E. Swanson

Communication Number 1003

Dear Mr. Swanson:

Law Engineering Testing Company has received and reviewed the March 15, 1981 draft, "Recommendation of Preferred Salt Domes for Detailed Characterization in the Interior Basins of the Gulf Coast". It is our opinion that the geologic data presented is an accurate representation of the current state of knowledge for the subjects addressed.

Very truly yours,

LAW ENGINEERING TESTING COMPANY

D. E. Pauls, P.E.
Project Manager

C. O. Durham
Technical Director

DEP:COD:jfg

cc: R. K. Henricks

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

APPENDICES

LIST OF FIGURES

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

LIST OF TABLES

TABLE OF CONTENTS (continued)

ABSTRACT

Results of the evaluation of data from area studies in salt domes of the interior basins of the Gulf Coast region are presented, along with background information about salt domes, the site qualification process, and data collection and analysis methods; discussions of the geologic and environmental data obtained for the eight salt domes under investigation during area studies; and analysis of the data according to preestablished criteria. Applicable data are synthesized to differentiate among the domes.

Three recommendations are presented: (1) to eliminate one dome from further study because of a safety flaw; (2) to eliminate three domes from further study for failure to meet site performance criteria; and (3) to continue further studies at the four domes assessed as acceptable in meeting the site performance criteria.

This report and supporting technical documents form the basis for planning location studies at the domes to be further evaluated. Such studies involve all technical participants and the states and localities where the recommended domes are located.

The report was compiled for the U.S. Department of Energy (DOE) by the Office of Nuclear Waste Isolation (ONWI), managed by the Project Management Division of Battelle Memorial Institute in Columbus, Ohio.

SUMMARY

The U.S. Department of Energy's National Waste Terminal Storage (NWTS) program was established in 1976 to develop and implement a system for the permanent isolation of highly radioactive nuclear wastes. NWTS activities include providing the technology and facilities for permanent isolation. The concept being emphasized on an interim basis is disposal in deep underground geologic repositories.

An early step is initiation of a process to identify and qualify potential repository sites in various types of geologic formations. The site qualification process involves a series of increasingly more detailed studies of smaller geographic areas to obtain geologic and environmental data for potential sites. Throughout the process, data collected are analyzed and compared to predetermined technical and socioeconomic criteria.

One of the geologic media being considered is salt, specifically structural features designated as salt domes. Area* studies are complete for eight salt domes in the interior salt basins of the Gulf Coast region in the southeastern United States. These are Rayburn's and Vacherie domes in Louisiana; Cypress Creek, Lampton, and Richton domes in Mississippi; and Keechi, Oakwood, and Palestine domes in Texas.

This report presents results from the evaluation of data obtained during area studies of the domes and explains the method used to apply these results to differentiate among the domes. The evaluation draws conclusions. Four of the eight domes are acceptable for further study. The other four domes are recommended for elimination from further consideration.

Background sections describe in detail the site selection process being followed (Section 2.0), how data were collected and analyzed (Section 3.0), the origin of the Gulf Coast salt domes, and participants in the project (Section 4.0). The factors used to compare and differentiate among the domes are presented in Section 5.0. Domes were evaluated according to 10 differentiable factors: depth to host rock, lateral extent of the host rock, Quaternary faulting, geochemical regime, dissolution, surface hydrology, exploration history, environmental impact, land use conflicts, and socioeconomic impact. These factors are discussed in terms of significance to site qualification, level of data, data acquisition methods, and data adequacy.

Section 6.0 describes the evaluation process that resulted in the recommendations and conclusions of this document. The data for the 10 factors are discussed in terms of how they help differentiate among the domes. Dome evaluation is described in terms of acceptance (most favorable, more favorable, or less favorable) or non-acceptance (elimination).

---

*An area is defined as approximately 1,000 square miles (2,590 square kilometers).

Palestine dome was eliminated from further study at an earlier time because of failure to meet minimum site performance criteria. Evidence of prior dissolution at Palestine casts doubt on its integrity as a repository.

The conclusions of this report, as presented in Section 6.0, are:

- Elimination from further studies is recommended for three domes: Keechi, Lampton, and Rayburn's. Elimination is recommended for Keechi principally because of inadequate minimum depth and size, for Lampton because of inadequate size and land use conflict, and for Rayburn's because of inadequate minimum depth and size, resource potential, and dissolutioning uncertainties.

- Four domes are acceptable for further study: Richton, Vacherie, Cypress Creek, and Oakwood. The four recommended domes are described in the evaluation report as being more acceptable in meeting the site performance criteria than the four eliminated domes.

- Of the four acceptable domes, two (Richton and Vacherie) are assessed as being favorable. Richton is assessed as being more favorable.

The four recommended domes, while significantly more favorable in terms of the site performance criteria than those eliminated, have several less favorable characteristics to be investigated in more detail at the location study phase. The four domes, in order of most to least favorable, are listed below.

- Richton dome is considered most favorable because its size would allow a large buffer zone between the repository and surrounding strata. It is potentially less favorable because of land use and socioeconomic conflicts.

- Vacherie dome is acceptable but is ranked as less favorable than Richton because of technical uncertainties related to potential salt dissolution and surface water.

- Cypress Creek dome is acceptable but questions remain about dissolution, surface water, geochemical regime, and resource potential.

- Oakwood dome is acceptable in the context of this evaluation but is considered least favorable because of its resource potential, significant petroleum exploration, nearby Quaternary faulting, surface hydrology, and potential dissolution. It is anticipated that the exploration history and Quaternary faulting concerns will be formidable licensing issues and, ultimately, Oakwood may prove unlicensable.

After a period for public review and comment, this evaluation report and the supporting technical reports referenced will provide the basis for planning the next step--location studies--in the site qualification process in the Gulf Coast region. With input from and the assistance of appropriate state and local officials and technical participants, a location study plan will be prepared, schedules will be established for each activity, and necessary technical reports will be identified, as described in Section 7.0.

FOREWORD

The National Waste Terminal Storage (NWTS) program was established in 1976 by the Department of Energy's (DOE) predecessor agency, the Energy Research and Development Administration (ERDA), to develop the technology and provide the facilities for the safe, environmentally acceptable, permanent disposal of high-level nuclear waste (HLW). This includes spent fuel assemblies from commercial power reactors and the transuranic nuclear waste (TRU) for which the federal government is responsible. Although alternative concepts are being investigated (e.g., subseabed disposal), the interim strategy and principal emphasis are currently focused on disposal of these wastes by emplacement in mined repositories located in deep, stable geologic formations. The NWTS program is directed toward providing the nation with the first licensed, fully operational geologic repository within the 1997 to 2006 time period.

Management responsibility for all DOE nuclear programs is assigned to the Assistant Secretary for Nuclear Energy (ASNE), who reports to the DOE Under Secretary and Secretary. Under ASNE, the Office of Nuclear Waste Management is responsible for executing policy and managing all aspects of the national nuclear waste management program, including the NWTS effort. Responsibility for the day-to-day administration of the NWTS program within the guidelines established by the Office of Nuclear Waste Management resides with several DOE field offices. Work is carried out by appropriately qualified DOE prime contractors and their subcontractors that are selected and monitored by the field offices in accordance with the Office of Nuclear Waste Management approved program plans, schedules, and budgets. More than 2,000 highly skilled professional people are involved in the execution of the NWTS program.

The NWTS program will be carried out in five sequential activities: technology development, engineering development, construction, operations, and decommissioning.

The first activity, currently under way, focuses on identifying potential repository sites, using the systems approach, and developing the technologies and methodologies necessary to design, construct, license, operate, and safely decommission repositories in a way that will assure the wastes will remain isolated from the biosphere.

Throughout the repository siting and construction process, opportunities are provided for public and peer review and comment. DOE maintains an open information program for nuclear waste management activities and is committed to a policy of consultation and concurrence with state and local officials. Information is provided to both technical and nontechnical groups and to governmental officials through briefings, conferences, public forums, and the dissemination of printed material. Additional opportunities for public input will occur at public hearings and reviews that are part of the licensing process.

The second activity (engineering development) of the NWTS program will gradually be initiated as more detailed information about specific sites becomes available.

During the technology development activity, the work of the NWTS program is being accomplished by three coordinated project elements: (1) the Office of Nuclear Waste Isolation (ONWI), (2) the Basalt Waste Isolation Project (BWIP), and (3) the Nevada Nuclear Waste Storage Investigations (NNWSI). Each of these elements is conducting work on the general areas of site evaluation and technology development, facility design, and field testing specific to certain geologic systems. In addition, ONWI, the lead NWTS contractor, has program oversight responsibilities and is accountable for developing the criteria and technology which are generic to the design and safety assessment of geologic repositories. (Two conceptual designs, based on a hypothetical generic site, have been developed for repositories in salt, one for disposal of reprocessed high-level waste and the other for spent fuel. A conceptual design for a repository in basalt is being prepared.)

In the evaluation of potential repository sites, BWIP is investigating basalt formations underlying DOE's Hanford Reservation, NNWSI is investigating several different media (principally tuff, a naturally sintered volcanic ash) underlying DOE's Nevada Test Site (NTS), and ONWI is evaluating other geologic formations within the contiguous United States. The ONWI siting investigations, which had been historically focused on the potential of domes and bedded salt, have been expanded to include areas of granitic and other geologic systems.

Four documents provide policy and technical guidance in the definition and planning of the NWTS program:

(1) Report to the President by the Interagency Review Group on Nuclear Waste Management (IRG Report)[1]

(2) Final Generic Environmental Impact Statement, Management of Commercially Generated Radioactive Wastes (FEIS)[2]

(3) Earth Science Technical Plan for Mined Geologic Disposal of Radioactive Waste (ESTP)[3]

(4) Former President Carter's Policy Statement on the Implementation of a Comprehensive National Radioactive Waste Management Program, which was sent to the Congress on February 12, 1980.[4]

Both the IRG Report and the FEIS evaluate alternative waste disposal processes and conclude that mined geologic disposal will be the earliest one available. The IRG report recommends that near-term program activities should be predicated on the tentative assumption that the first disposal facilities will be geologic repositories. The FEIS provides a detailed evaluation of ten alternative methods for waste disposal and concludes that the technology for emplacement of radioactive wastes in geologic formations can likely be developed and applied with minimal environmental consequences. The ESTP, which is the product of a cooperative effort by DOE and the U.S. Geological Survey (USGS), furnishes detailed programmatic guidance for implementing research addressing specific earth science issues associated with geologic waste disposal.

Measurements in this report are given in both metric and English equivalents. Metric units are given, according to federal policy, for multidiscipline and international considerations. Conversion factors are listed in Appendix B. A glossary is also provided in Appendix D.

REFERENCES

1. Interagency Review Group on Nuclear Waste Management. 1979. Report to the President, TID-29442, Washington, D.C., March.

2. U.S. Department of Energy. 1980. Final Environmental Impact Statement -Management of Commercially Generated Waste, DOE/EIS-0046-F, October.

3. U.S. Department of Energy and U.S. Geological Survey. 1979. Earth Science Technical Plan for Mined Geologic Disposal of Radioactive Waste, TID-29018, Office of Nuclear Waste Management, draft, January.

4. Carter, J.E., U.S. President. 1980. President's Policy Statement on Comprehensive Radioactive Waste Management Program, February.

1.0 INTRODUCTION

This introduction discusses the purpose and organization of this document which evaluates Gulf Coast salt domes for detailed location* characterization.

1.1 PURPOSE OF DOCUMENT

This document presents the data, information, and methodology used to evaluate the eight Gulf Coast salt domes being investigated as possible nuclear waste repository sites. From those eight domes, four domes are identified as acceptable and recommended for consideration. Of these four, two are assessed as more favorable for additional study to qualify for a candidate repository site. Geologic and environmental field activities have been carried out. If a site is found suitable in the next step of the investigative process, it will be reserved for possible use or "banked"**. Later, this banked dome site will be evaluated and compared to other similarly banked sites in bedded salt and other geologic media, ultimately leading to selection of a site or sites for licensing as a nuclear waste repository(ies).

The document also describes the domes that are eliminated from consideration. These domes exhibit characteristics that cause a lack of reasonable assurance concerning their acceptability as repository sites or are perceived to pose major licensing difficulties.

---

*The meaning of "location" in this concept is discussed in Section 2.4.

**A site is banked when the participants in the siting process reach consensus on the technical, environmental, and institutional adequacy of the site and an interest is obtained in the land to preserve its integrity through the selection process.

2.0 NWTS SITE SELECTION PROCESS

This section describes how site characterization proceeds. The geologic system selected as a waste repository will need to accommodate a system of man-made engineered barriers consisting of the waste package, the repository facilities, and the sealing of all openings. The salt domes recommended for further investigation must have a high likelihood of meeting performance and functional requirements imposed on the eventual site and the isolation system, and the recommendation needs to be in accord with the current policy of consultation and concurrence with state and local officials.

The evaluations made in this document are a step in the national site characterization and selection process. Based on data and evaluations to date, the salt domes that are acceptable and appear to have the highest likelihood of safely isolating the waste, consistent with the requirements discussed in this section, are recommended for subsequent detailed studies leading to site banking.

2.1 GEOLOGIC ISOLATION SYSTEM

Conceptually, in the NWTS program the geologic repository is viewed as a waste isolation system made up of three functionally distinct but interacting subsystems which provide multiple natural and man-made barriers to the release of the contained waste into the biosphere. These subsystems are the waste package, the repository, and the site (Figures 2-1 and 2-2).

The waste package subsystem is an important part of the overall waste disposal system. During the repository operational phase, the waste package provides safe containment of the waste material during the handling and emplacement operations and helps ensure that the waste can be safely retrieved from the repository, if necessary. During the time there is fission product decay (400 to 600 years), the waste package provides containment for those highly radioactive isotopes. Beyond the thermal period, the waste package works in conjunction with the repository and the particular site subsystems to provide long-term waste isolation. The waste package includes the waste form itself and a system of engineered barriers consisting of a filler material (in the case of spent fuel), a canister, and one or more layers of protective materials selected to minimize interactions among the waste, the host rock, and any ground water that might enter the repository.

The repository subsystem (Figure 2-3) is much like a conventional mine. It incorporates man-made structures, which permit access to the underground facilities and enhance waste containment, and natural barriers such as the local host rock, to provide containment and isolation after closure. The design, construction, and operation of the repository will be carried out in a manner that preserves the desirable containment and isolation capabilities of the particular site.

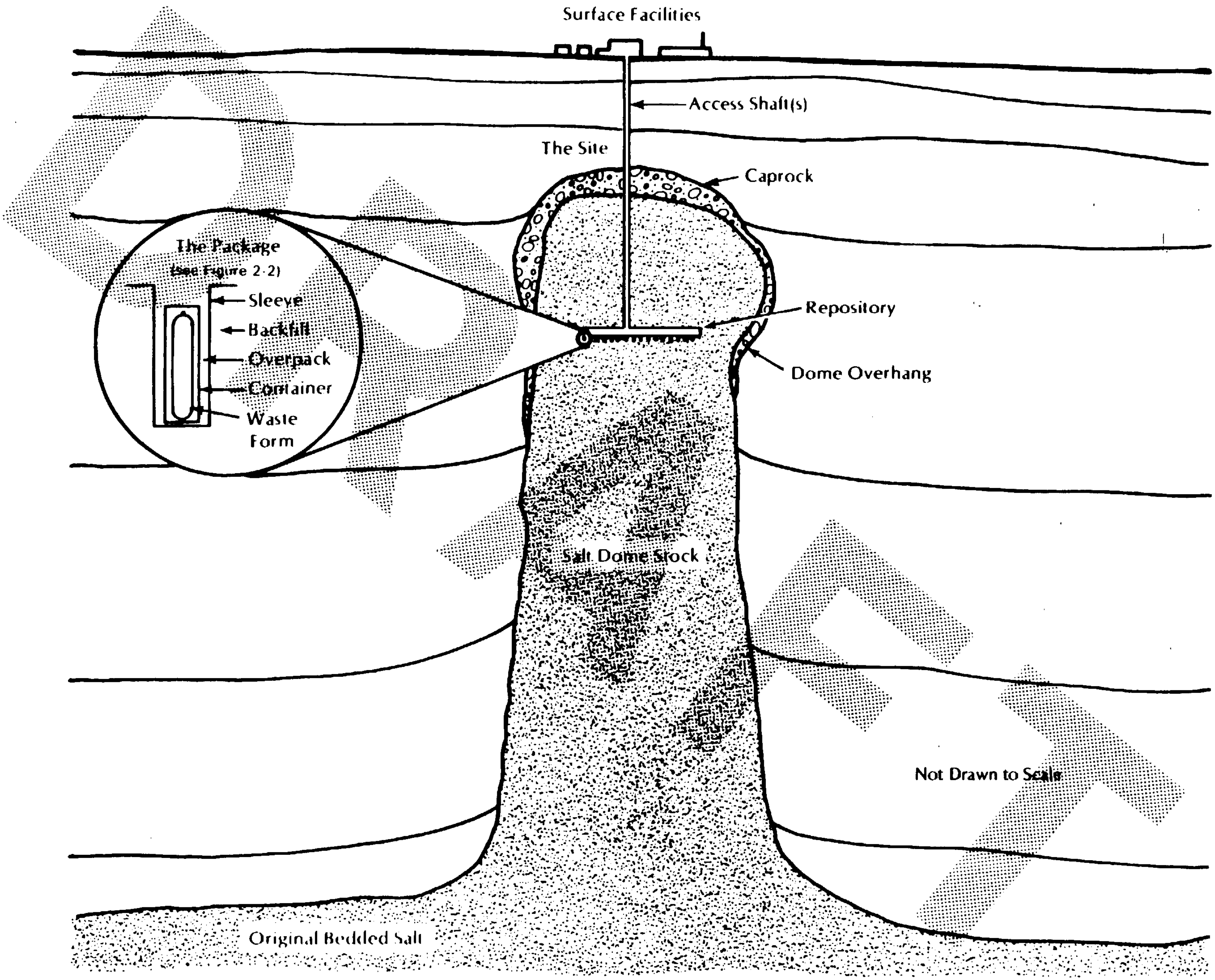

FIGURE 2-1. DOME CROSS SECTION AND ISOLATION SUBSYSTEMS

(See Appendix B for Metric Conversion)

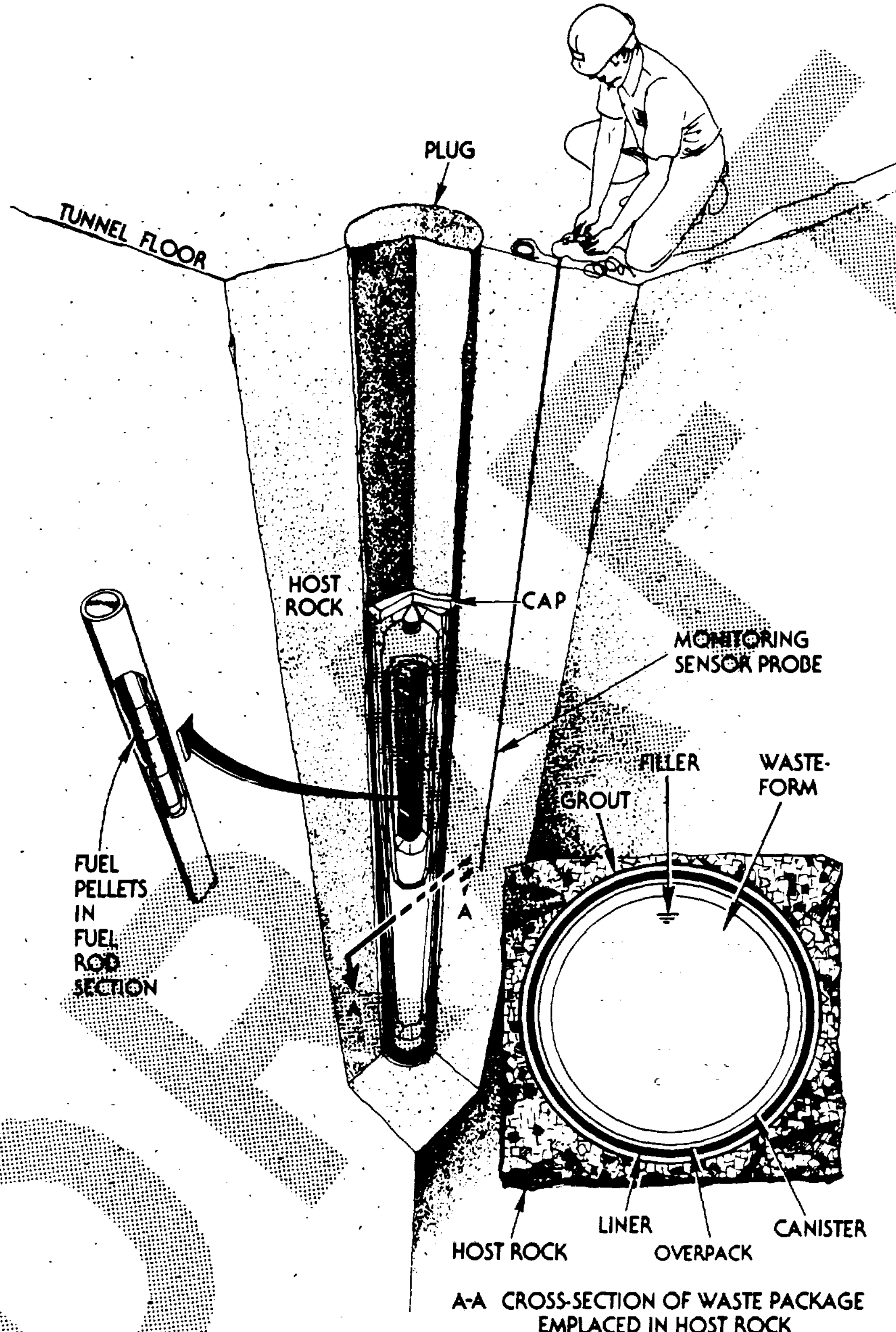

FIGURE 2-2. WASTE PACKAGE EMPLACED IN HOST ROCK

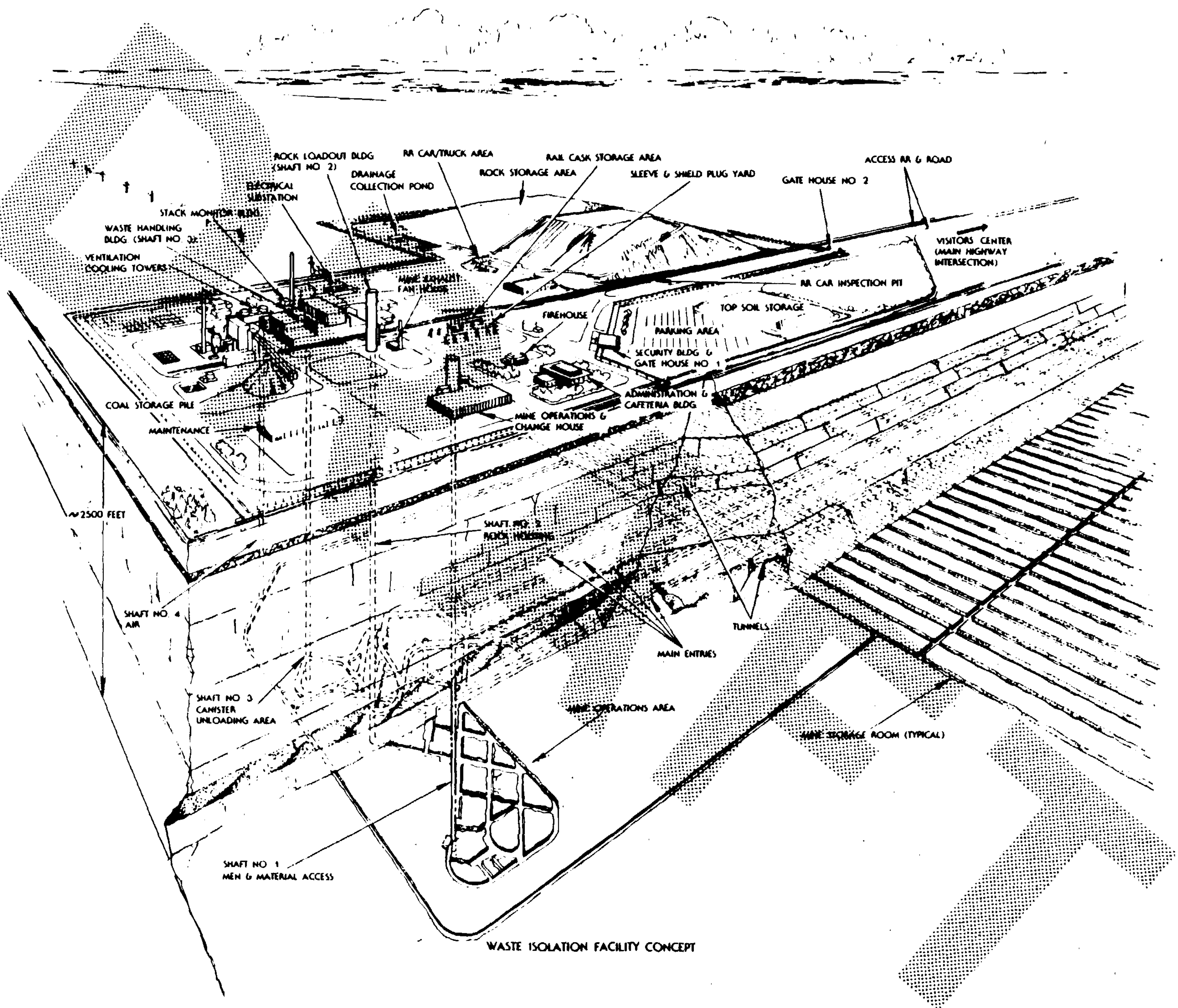

FIGURE 2-3. A TYPICAL REPOSITORY

Surface facilities will provide for waste receipt, preparation of the waste for emplacement, and transfer of the waste to the underground workings. The surface facilities will be similar to those that have been used to handle radioactive materials over the past several decades, as well as to industrial mining facilities, for which considerable engineering experience exists. The surface facilities will be required throughout the operational period of the repository.

Repository facilities at depth will include a receiving area for waste packages lowered down the shafts; transfer vehicles to move the waste packages to the disposal area and into the emplacement holes; and equipment to emplace auxiliary barriers, backfill, and other shielding as may be required.

The site subsystem includes natural barriers which provide for waste containment and isolation. These barriers will keep radionuclides from reaching man in unacceptable quantities, as discussed in Section 2.2.2.3.

2.2 REQUIREMENTS OF WASTE ISOLATION SYSTEM

2.2.1 General Performance Objectives

Pending the issuance of NRC and EPA guidance and regulations, DOE has defined seven specific general performance objectives for the waste isolation system.(1) These proposed objectives for safe and environmentally acceptable disposal are as follows:

Objective 1. Waste containment within the immediate vicinity of initial placement should be virtually complete during the period when radiation and thermal output are dominated by fission product decay. Any loss of containment should be a gradual process which results in very small fractional waste inventory release rates extending over very long release times, i.e., catastrophic losses of containment should not occur.

In the context of this objective:

Containment means confining the radioactive wastes within prescribed boundaries, within the waste package.

Objective 2. Disposal systems should provide reasonable assurance that waste will be isolated from the accessible environment for a period of at least 10,000 years with no prediction of significant decreases in isolation beyond that time.

In the context of this objective:

(a) Reasonable assurance means that the preponderance of available technical evidence as interpreted by objective experts in the field supports the conclusions drawn.

(b) Wastes will be considered to be isolated if long-term radiological consequences to the public due to the effects of any reasonably foreseeable events or processes are predicted to be within the range of variations experienced in background radiation. Releases with consequences of a few millirem to a few tens of millirem per year would be considered acceptable provided that the ALARA (as low as reasonably achievable) standard for man-made systems is met.

Objective 3. Risks during the operational phase of waste disposal systems should not be greater than those allowed for other nuclear fuel cycle facilities. Appropriate regulatory requirements established for other fuel cycle facilities of a like nature should be met.

In the context of this objective:

(a) Operational phase risks refer to radiological risks either to members of the public or to facility personnel.

(b) Appropriate regulatory requirements refer to safety standards which are derived for similar quantities of radioactive materials and/or systems subject to similar potential modes of failure and which can, with little or no modification, be applied to a high-level waste disposal facility.

Objective 4. The environmental impacts associated with waste disposal systems should be mitigated to the extent reasonably achievable.

In the context of this objective:

To the extent reasonably achievable means that which is shown to be reasonable considering the costs and benefits associated with potential mitigative measures and reasonable alternative courses of action in accordance with requirements set forth by the National Environmental Policy Act (NEPA) of 1969 and the Council of Environmental Quality (CEQ).

Objective 5. The waste disposal system design and the analytical methods used to develop and demonstrate system effectiveness should be sufficiently conservative to compensate for residual design, operational, and long-term predictive uncertainties of potential importance to system effectiveness, and should provide reasonable assurance that regulatory standards will be met.

In the context of this objective:

(a) Conservatism means taking a course of action in design, analysis, or operation which would tend to overestimate adverse consequences, underestimate mitigating factors, or otherwise provide large margins of safety against undesirable outcomes.

(b) Conservative measures might include:

   (i) A careful stepwise approach to design and operation

   (ii) Multiple containment and isolation barriers with sufficient independence and residual effectiveness to assure compliance with appropriate radiation standards over the range of credible failures

   (iii) Design and operating margins which safely limit the effects of system uncertainties.

Objective 6. Waste disposal systems selected for implementation should be based upon a level of technology that can be implemented within a reasonable period of time, should not depend upon scientific breakthroughs, should be able to be assessed with current capabilities, and should not require active maintenance or surveillance for unreasonable times into the future.

Objective 7. Waste disposal concepts selected for implementation should be independent of the size of the nuclear industry and of the resolution of specific fuel-cycle or reactor-design issues and should be compatible with national policies.

2.2.2 Program Policies and Criteria

In the implementation of the NWTS program, the DOE waste isolation system performance objectives just discussed are implemented in formal performance and functional criteria that are applied in the planning, execution, and evaluation of all program activities. These criteria are presented in the DOE/NWTS-33 series of documents. DOE/NWTS-33(1), General Program Policies and Criteria, is intended to provide direction for all NWTS efforts by (1) describing the program's objectives and key baseline requirements (policies) and (2) establishing general performance criteria for the waste isolation system and general functional criteria for the components (the waste package, repository, and site) of the system. These two points are discussed in the following subsections.

2.2.2.1 Program Policies

The ground rules in effect during the decision process are identified from the requirements imposed by national, regulatory, or DOE policy. Ground rules are needed because the policy environment in which the decisions are made affect which sites are eventually qualified and selected. If a ground rule changes, the effect on the decision process can be evaluated in a straightforward manner.

The policy statements that form the ground rules are restated here from DOE/NWTS-33(1)* and followed by their specific applicability to the area-to-location decision step, the subject of this document, as applied to Gulf Coast salt domes.

Waste Accommodation. Repositories, either individually or collectively, shall be capable of receiving and disposing of all commercial and defense high-level and transuranic (TRU) wastes in a safe manner regardless of the size of the nuclear industry and of the resolution of specific fuel cycle or reactor design issues. For design purposes, these wastes shall be assumed to be transported to the repository by rail and truck.

The domes being considered are of finite size. It is probable that no one dome will be capable of accommodating a facility for all the waste. A suitable dome together with disposal sites in other media and regions, however, would provide the capacity for whatever size the nuclear industry may evolve. The domes evaluated and selected should be large enough to accommodate a significant portion of the waste being generated.

Institutional and Societal Acceptability. The NWTS program will be conducted in a manner that will promote institutional and societal participation and acceptance of the program plans and activities.

Institutional and societal participation is possible throughout the NWTS program, through public information activities, state and local government involvement, peer review, and various steps in the licensing process. DOE's site characterization activities in the Gulf Coast region have provided and will continue to allow opportunities for participation, through briefings of public officials and news media representatives, regular distribution of technical and general information, public forums, and submission of technical reports for review and comment. This document itself is being distributed for peer, governmental, and public review.

---

*To be published.

900300745

Technical Conservatism. A policy of technical conservatism shall be applied throughout the NWTS program.

The mined geologic disposal system design and the analytical methods used to develop and demonstrate system effectiveness should be sufficiently conservative to compensate for residual design, operational, and long-term predictive uncertainties of potential importance to system effectiveness and should provide reasonable assurance that regulatory standards will be met.

The decision procedure identifies and evaluates factors for each dome that are important to isolation effectiveness. Where there was a lack of reasonable assurance about the isolation effectiveness, uncertainty about that site increased. For conservatism, locations ultimately preferred show evidence of long-term dome and regional stability, structural simplicity, unattractive resource potential, and easily resolved geologic or environmental features.

Multiple, Regional Repositories. The NWTS program shall develop multiple repositories addressing regional considerations. Features of the repositories shall be standardized to the extent practicable to facilitate safe and economical repository development.

This document describes the decision process being used to identify and characterize a location for a repository in the Gulf Coast salt dome region. Repository features that become standardized will likely have little effect on the decision process used or dome recommendations that will be made.

Risk to Future Generations. The disposal of radioactive wastes shall be conducted in a manner that limits potential risk to future generations to the extent reasonably achievable.

The mined geologic disposal system should provide reasonable assurance that waste will be isolated from the accessible environment for a period of at least 10,000 years with no predictable significant decreases in isolation beyond that time.

This policy statement requires that factors important to the performance of salt domes be evaluated for long-term isolation integrity against forces that can credibly be predicted to act on the site for periods significantly in excess of 10,000 years. Evidence used in dome characterization to support predictions of both the force-producing phenomena and isolation integrity will generally be based on the geologic record as interpreted by well-qualified scientists.

Effective Resource Utilization. The safe disposal and isolation of radioactive wastes shall be achieved in a manner that provides effective utilization of economic resources.

Safe placement of a repository in a salt dome may, itself, be an effective use of that economic resource. Much of the large amount of salt that is mined can be made available for distribution or use. Salt domes that would be easily accessible to conventional salt mining are less desirable than those less accessible for economical salt recovery. Salt domes that have little evidence of potential for oil or gas production are preferred to those which evidence indicates have economically recoverable reserves.

Use of Near-Term Technology. The mined geologic disposal system shall be developed based upon a level of technology that can be implemented within a reasonable period of time, shall not depend upon scientific breakthroughs, shall be able to be assessed with current capabilities and shall not require active maintenance or surveillance for unreasonable lengths of time into the future.

The methods of data collection and dome area characterization are based on current scientific knowledge. Old exploration techniques are being refined and new ones are being developed with current knowledge. This decision step was accomplished with exploration and characterization techniques currently available.

2.2.2.2 Performance Criteria

Performance criteria for long-term waste isolation have been defined for use in the NWTS program as described in General Program Policies and Criteria, DOE/NWTS-33(1). These criteria must be met by any nuclear waste disposal system to achieve the goals of containment and isolation of nuclear waste in a safe and environmentally acceptable manner.

The general performance criteria are the requirements placed on the mined geologic disposal system as a whole. These requirements must be satisfied to assure acceptable repository development and operation of the system. These requirements, which are independent of program policies, are discussed below. In identifying potential domes, either safety or environmental factors may be used to eliminate or defer further consideration of a given dome. Domes that are identified as viable candidates are compared using both the safety and environmental factors, with safety considerations judged more important than environmental ones.

System Performance Limits--Safety. The mined geologic disposal system shall meet all applicable standards and shall contain and isolate radioactive wastes to the extent necessary to assure that releases of radionuclides to the biosphere do not result in an unacceptably high incremental increase in doses to individuals and to the general population.

Safety during the operating phase of the mined geologic disposal system should be at least equal to that required for other nuclear fuel cycle facilities. Appropriate regulatory requirements established for other fuel cycle facilities of a like nature should be met.

The salt dome decision process is currently proceeding without standards promulgated by the NRC and EPA. Therefore, the NWTS program is using the qualification criteria discussed in Table 2-1 in evaluating whether a potential dome adequately provides for the safe disposal of radioactive waste.

The determination of whether the potential doses presented by a dome repository are unacceptably high will be based upon a comparison to increments in dose received from fluctuations in natural background radiation and the doses received from exposure to natural bodies of uranium ore. These two comparisons will lend perspective to the hazard imposed should a repository be located in a salt dome.

The dose received from natural background radiation varies with location in the United States and over time. The extent of this variation can be used as a comparison to the dose expected from waste repositories to judge whether the dose is acceptable.

The comparison to doses received from exposure to uranium ore bodies is pertinent in that the uranium must be removed from the ore body to create the waste and is then being replaced in the ground in a different form and location. Had the uranium not been removed, the ore bodies would have continued to impose a certain dose on the public. Therefore, in evaluating the performance of a repository, the dose imposed by the repository could be compared to that imposed by an ore body which contains the amount of uranium necessary to produce all the waste in the repository.

<u>Environmental Requirements. Siting of the mined geologic disposal system shall be conducted in a manner which preserves the quality of the environment to the extent reasonably achievable and complies with existing environmental legislation.</u>

The environmental impacts associated with the siting activity shall be mitigated to the extent reasonably achievable.

In selecting a dome and in developing and operating the disposal system, environmental impacts and existing environmental legislation are considered. This will involve the consideration of present land use conflicts, resource denial, and construction impacts, including impacts from surplus mined material handling, and complying with NEPA requirements.

2.2.2.3 General Functional Criteria--Site

The general functional criteria related to dome selection are applied to assure that the system as a whole will perform as required. The general functional criteria for the site are quoted below from DOE/NWTS-33(1) and then applied to the specific decision documented here.

Sites selected for nuclear waste disposal shall be capable of providing safe and environmentally and socioeconomically acceptable waste isolation.

Protection of the public health and safety is the key objective in the selection of candidate repository sites. The repository site must therefore provide natural barriers which ensure waste containment and isolation. These barriers should keep radionuclides from reaching man in unacceptable quantities by (1) maintaining the waste in its emplaced location for a given period of time (i.e., providing waste containment); (2) limiting radionuclide mobility through the geohydrologic environment to the biosphere (i.e., providing isolation); and (3) assisting in keeping man away from the waste (principally by making intrusion difficult, through depth below the surface). The site must contain a host rock suitable for construction of the repository and containment of the waste, as well as surrounding rock formations that can provide adequate isolation. Desirable hydrologic features include low groundwater flow rates, long path lengths to the biosphere, and evidence of long-term stability. The important natural attributes of the host rock include suitable thermal, mechanical, hydraulic, and chemical characteristics, which determine ground-water movement and chemistry, and the host rock's ability to withstand thermal effects.

Site selection must also be based on the protection of the environment and institutional and socioeconomic concerns. Selection of the repository site must take into consideration containment and isolation capabilities, as well as potential present and future environmental impacts; land use resource conflicts; and other potential social, political, and economic impacts on the communities affected by the repository.

The site must also be compatible with repository development and waste emplacement to ensure that these activities can be conducted without undue risk to the operating personnel and in a manner which preserves the capability of the site to contain and isolate the waste.

Because criteria may change during a long-lived project such as this, the decision procedure is designed so that the impact of modifications in performance criteria can also be evaluated. Any change that is made in the overall performance criteria may be a basis for reevaluating the siting decisions made prior to the change. Because the procedure is explicit, the steps affected can be readily identified and an updated evaluation made.

More specific functional criteria* are provided in DOE/NWTS-33(2)--*Site Performance Criteria*; DOE/NWTS-33(3)--*Repository Functional Design and Performance Criteria*; and DOE/NWTS-33(4)--*Waste Package Functional Criteria*. Each NWTS project (e.g., Basalt Waste Isolation Project, Nevada Nuclear Waste Storage Investigations, Office of Nuclear Waste Isolation) will develop specifications, technical requirements and methodologies specifically applicable to that particular project. Consistency of the project-specific information with that presented in the four documents mentioned above is

*To be published.

required. The site-specific standards can be considered as providing appendices to the four criteria documents. When consistency is attainable, NWTS-wide specifications will constitute a portion of the technical basis for preparation and submittal by the DOE of the formal licensing documents in support of license applications.

Specific criteria for site suitability which are applied in the decision process are the criteria of DOE and NRC [DOE/NWTS-33(2) and Draft 10 CFR 60]. These are described in Appendix C and are used as the standard against which the potential suitability of each dome is compared.

2.3 REQUIREMENTS OF A REPOSITORY SITE

2.3.1 DOE Site Qualification Criteria

The NWTS program repository site-qualification criteria form the guidance necessary to direct program activities toward its objective in a manner which protects the public health and safety, preserves the quality of the environment and is institutionally acceptable. Therefore, the criteria address all facets of waste isolation. Some criteria are directly relevant to anticipated radiological and nonradiological impacts that must be limited to acceptable levels. Other criteria address residual technical uncertainties that exist in the technology of geologic disposal. Still others address institutional issues such as public involvement and understanding of nuclear waste disposal and its technology options and licensing. Such criteria are necessary to identify repository sites in a technically defendable, timely, and economical manner. Applying the full range of such criteria supports the development of a repository in an institutionally acceptable manner.

The judgment as to what constitutes an acceptable repository from a regulatory viewpoint will ultimately be made by the responsible agencies (e.g., NRC and EPA) in consultation with state and local governments. These organizations will promulgate policies, criteria, and regulations for the development and operation of repositories. Specifically, the EPA will promulgate generally applicable environmental standards upon which the NRC will judge the performance of the repository. At the present time, however, final repository criteria have not been issued by the NRC and EPA. The criteria in this document have been developed to protect the health and safety of the public and the quality of the environment, and they are expected to be consistent with the anticipated regulatory standards.

These DOE criteria will be used on an interim basis to guide the site-qualification process, pending promulgation of NRC, EPA, and other applicable criteria, standards and guidelines. These criteria will be re-evaluated on a periodic basis to ensure that they remain consistent with national waste management policy and regulatory requirements. A final re-evaluation will be made when final criteria are promulgated by NRC and EPA.

Thus, it can be seen that the NWTS site-qualification criteria provide a means of assuring that the site-selection decision is reached in a manner consistent with the NWTS requirements for a waste isolation system as described in Section 2.2. These criteria are summarized in Table 2-1.

2.3.2 Proposed Regulatory Guidance

As has been discussed, the judgment of what constitutes an acceptable repository site will ultimately be made by the Nuclear Regulatory Commission with participation of state and local government agencies. The NRC is presently in the process of preparing the regulations and criteria for repository site selection and licensing.

On December 6, 1979, NRC published for comment in the Federal Register (44FR70408) proposed regulations for licensing geologic repositories for the disposal of high-level waste. This proposed rule contained only the procedural requirements for licensing concerning general provisions, licenses, and participation by state governments. This proposed rule was finalized and published in the Federal Register (Vol. 46, No. 37) on February 25, 1981, to be effective on March 27, 1981.

The proposed procedural rule was followed on May 13, 1980, by publication in the Federal Register (45FR31393) of an advance notice of rulemaking on the technical criteria intended for inclusion in 10 CFR Part 60, "Technical Criteria for Regulating Geologic Disposal of High-Level Radioactive Waste". The purpose of the advance notice is to inform the public and interested parties concerning the status of efforts related to the development of technical criteria, and to solicit comments for consideration in the preparation of a proposed rule. Thus, the criteria are in a preliminary and formative stage and the DOE is attempting to conform to the current thinking and technical positions of the Commission in this fluid situation.

The NRC's position regarding the advance notice is reflected in the following statement:

> "These criteria are a result of the efforts of the staff to accommodate and include the best thinking which has been available to the staff from technical experts in the form of technical points, suggestions and criticisms on previous drafts of technical criteria. However, these criteria do not necessarily represent staff positions with respect to rulemaking on this subject".

Although the technical criteria are preliminary and may not fully represent the regulatory positions that will be applicable during the formal review of an application for licensing, they provide the DOE with an insight into the present thinking of the regulatory staff as to what may constitute favorable or adverse site characteristics. These preliminary criteria are, therefore, being used as guidance in the site characterization and selection process. This guidance parallels the requirements of criteria developed by the DOE [DOE/NWTS-33(2)] for site qualification, and provides assurance that the decisions regarding the screening process leading to banking of sites will be acceptable when the final regulations become available.

The potentially adverse site conditions and favorable site characteristics, as delineated in "Siting Requirements", of the Advance Notice of Rulemaking, Code of Federal Regulations(2), are reproduced in Appendix C and related to the DOE criteria and subcriteria of Table 2-1.

TABLE 2-1. NWTS SITE QUALIFICATION CRITERIA*

Criterion I. Site Geometry
1. Minimum Depth
2. Thickness
3. Lateral Extent

Criterion II. Geohydrology
1. Geohydrological Regime/Aquifer Characterization
2. Hydrological Regime/Modeling/Surface-Subsurface
3. Geohydrological Regime/Shaft Seals/Flow Rates
4. Subsurface Dissolution Rates

Criterion III. Geochemistry
1. Chemical Interaction
2. Radionuclide Retardation

Criterion IV. Geologic Characteristics
1. Stratigraphy Characterization
2. Host Rock/Stress Phenomena
3. Rock Strength/Development, Operation, and Closure

Criterion V. Tectonic Environment
1. Tectonic Element Evaluation
2. Quaternary Faults
3. Quaternary Igneous Activity
4. Uplift/Subsidence
5. Seismicity/Ground Motion/Credible Earthquake

---

*These criteria were developed as the basis for DOE's determination of what site characteristics will provide protection of public health and safety and should be consistent with anticipated regulatory standards. Proposed Nuclear Regulatory Commission (NRC) criteria are contained in Appendix C.

TABLE 2-1. (Continued)

Criterion VI. Human Resources
1. Resources
2. Exploration History/Use
3. Land Ownership/Access

Criterion VII. Surface Characteristics
1. Surficial Hydrological System/Characteristics
2. Surface Topographic Features
3. Meteorological Phenomena
4. Industrial Transportation, Military Installation Effects

Criterion VIII. Demography
1. Population Density/Urban Proximity
2. Radioactive Waste Transportation Risk

Criterion IX. Environmental Protection
1. Potential Environmental Impacts
2. Air, Water, Land Use Conflicts
3. Consideration of Normal and Extreme Environmental Conditions

Criterion X. Socioeconomic Impacts
1. Social/Economic Impacts
2. Transportation, Access, Utility

2.4 THE SITE CHARACTERIZATION AND SELECTION PROCESS

National radioactive waste repository sites will be selected by a systematic process, taking into consideration all applicable factors. DOE's program leading to the selection of sites is carried out in four major steps:

(1) Site exploration and characterization
(2) Site banking
(3) Site recommendation
(4) Site selection.

2.4.1 Site Exploration and Characterization

The first of these major steps, the site exploration and characterization process, involves geologic and environmental studies to identify potential sites for mined geologic repositories and to obtain the technical data necessary to determine acceptability of these sites. Acceptability is determined by comparing the site characteristics, as defined during the exploration activities, to the NWTS program and site qualification criteria, as described in Sections 2.2 and 2.3. As the selection process narrows to more specific locations and sites, more data are developed, resulting in reinforced certainty that the criteria can be met and exceeded. Phases in the site exploration and characterization process are as follows:

1. National screening surveys

2. Determination of regions for further study [up to several states in extent]

3. Recommendation of areas for more detailed investigation [up to 1,000 square miles (2,590 square kilometers)]

4. Recommendation of specific locations for in-depth study [up to 30 square miles (78 square kilometers)]

5. Recommendation of preferred sites for banking as candidate repository sites with associated controlled zone [nominally 10 square miles (26 square kilometers)].

2.4.1.1 National Screening Survey

Site searches are initiated by national screening surveys. Starting with the contiguous United States, the initial step in site exploration and characterization is to identify places that have some potential for waste isolation. These places may be regions (up to several states in extent) or land areas having a particular suitability feature. As indicated below, national screening surveys have been structured in different ways, depending on the site suitability feature that is sought initially in process:

(1) A geologic approach begins with consideration of potentially suitable host rocks and identification of regions containing these formations. Early in the NWTS program, for example, rock salt was identified as a potentially suitable host medium. Thus, regions in the contiguous United States containing salt domes and bedded salt formations generally suitable for repository use were identified. The national effort is also evaluating the potential for repository development in regions containing granitic and argillaceous rocks, and recommendations on suitable regions are being developed.

(2) An approach considering current land use to identify regions for further studies would include the efforts being conducted at the Hanford Site and the Nevada Test Site. Both are large tracts of land owned by the federal government and currently used for nuclear activities. These government reservations would be classified as "areas" in the phases of the site characterization process. Investigations of both areas were initiated to determine whether geologic and hydrologic conditions, as well as other considerations, would allow use of these already dedicated lands for waste repositories.

(3) An approach based on screening of geohydrologic provinces can also be utilized to identify sites. In this approach, the contiguous United States is examined on a province-by-province basis considering geologic and hydrological characteristics. As screening narrows to smaller areas, those having more desirable geologic characteristics are also examined for compatibility with the other site qualification criteria.

Another screening approach is based on the consideration of all site qualification criteria simultaneously. This approach provides further assurance that otherwise unexamined regions having favorable repository characteristics will not be overlooked. This screening study is applying all criteria (geologic, hydrological, ecological, social, economic, political, and institutional) simultaneously to identify regions of potential use for repositories. This "systems approach" is expected to identify combinations of regional characteristics that might fulfill the criteria.

Whether the starting point of the site selection process is selection of regions according to rock type, land use, hydrology, or some combination of these factors, the subsequent phases in the screening process are similar. Upon completion of the national screening survey, regions are identified for further investigation. The process then continues through a series of increasingly detailed exploration activities, eventually developing detailed data on characteristics of areas, locations, and sites. These characteristics are evaluated at each phase of exploration, and geologic and environmental characterization reports are prepared.

2.4.1.2 Regional Studies

Regional studies investigate the region of interest to obtain further geologic and environmental information. Studies are based primarily on a review of existing data obtained through broad literature searches. Sources for geologic data include published scientific reports and geologic maps; drilling and production records from oil, gas, and mineral exploration programs; records of earthquake occurrences and intensities; and records of water well drilling. The regional studies result in designation of the areas most suitable for further study, while less promising areas are deferred.

2.4.1.3 Area Studies

Area studies are conducted to further characterize the areas of interest designated by the regional study or designated because of their current use as DOE reservations. Environmental, socioeconomic, and geologic factors are evaluated, but within a smaller area and in greater detail than in the regional studies. The objective is to narrow the scope of investigations to the most promising locations. A second objective is to build a data base toward the eventuality of licensing.

Geologic field work conducted in this phase includes drilling deep holes (possibly up to several thousand feet deep) to collect rock cores for laboratory tests of properties of the substrata; drilling to determine the characteristics of aquifers; and conducting geophysical surveys to assist in determining underlying rock structures. Environmental and socioeconomic studies are based on literature surveys of data available from local experts and institutions such as universities and local, state, and federal agencies. The scope of area environmental studies includes a description of the hydrosphere; atmosphere; demographic, socioeconomic, and land use characteristics; and ecosystems. Section 3.1, Data Collection and Development, deals with the data acquisition and evaluation of the area studies leading to the selection of domes for the more detailed location phase efforts.

2.4.1.4 Location Studies

Location studies further narrow the scope of the investigation to a site or sites. The objectives are to demonstrate the viability of the site or sites and develop the data base to support NEPA and to provide licensing application. Geologic data gathering at this stage includes more drilling, to obtain detailed geologic and hydrologic information, and additional testing of geologic and geochemical samples. Environmental studies during this phase include complete monitoring and sampling programs at the site(s) to obtain specific detailed information. Onsite meteorological data is collected, and physical surveys of plant and animal populations are taken. Activities planned in this subsequent phase for the Gulf Coast interior salt domes are discussed in Section 7.0 of this report. Socioeconomic studies conducted during this phase will address impacts of additional testing and potential impacts of a repository at each of the sites.

2.4.1.5 Detailed Site Characterization

The purpose of detailed site characterization is to collect all additional data that would be necessary if a license application were submitted for the potential site. Data gathering methods may include more extensive drilling to obtain geologic and hydrologic information, onsite and laboratory testing of rock and water samples, and more detailed geophysical surveys. The underlying rock structure will be characterized in sufficient detail to establish engineering and design envelopes and to confirm safety assessments and construction feasibility. Depending on the ability to adequately characterize the condition of the site, it may be necessary to proceed with an exploratory shaft and at-depth characterization activities at this time.

2.4.2 Site Banking

A candidate repository site is banked when the participants in the site selection process reach a consensus on the technical, environmental, and institutional adequacy of the site relative to established criteria, and an interest in the land has been obtained by the Department of Energy in order to maintain the integrity of the site through the remainder of the selection process. Obtaining interest in the land may involve interagency transfer of the land or an interagency agreement to reserve the land if it is owned by the federal government. If the land is privately owned, or owned by a state or local government entity, full ownership of the land is not necessary for site banking. It is only required that DOE be able to conduct its site characterization activities and that the land use be controlled until a decision is made on site selection. This use reservation may be accomplished through a lease with a purchase option or through outright purchase at site banking, depending on the circumstances.

2.4.3 Site Recommendation

During the site recommendation phase, socioeconomic, legal, political, and institutional factors will be combined with relevant technical data on the four or five sites banked at that time to determine which site or sites will be recommended for initial development as a mined geologic repository. This activity will lead to documentation of the decision in a Draft Environmental Impact Statement and Site Recommendation Report. These two reports will detail the comparison between the banked sites and the environmental impacts of proceeding toward development of a repository at the recommended site or sites. The legal status of the banked lands need not change at this point of the process.

2.4.4 Site Selection

The selection of a site or sites to be developed as a mined geologic repository is a decision of the Department of Energy. The site selection decision will be made following public review and comment on the Draft Environmental Impact Statement and the related Site Recommendation Report. Comments will also be requested from the appropriate federal and state agencies. As the site selection decision is made, a Final Environmental Impact Statement along with a Site Selection Report will be issued. Following site selection, full ownership of the site or sites selected must be secured by the Department of Energy, if not already held. The selected site or sites, if on federal land, will be formally transferred to the control of the Department. Clear ownership of private land will likewise be obtained. All land acquisition activities will be conducted according to appropriate statutes and agency procedures. In addition, some interest may be obtained in a buffer zone at the site of repository development. The extent of the buffer zone and the degree of land control are currently under evaluation.

REFERENCES

1. U.S. Nuclear Regulatory Commission. 1980. In the Matter of Proposed Rulemaking on the Storage and Disposal of Nuclear Waste (Waste Confidence Rulemaking), PR-50, 51 (44 FR 61372) - Statement of Position of the United States Department of Energy, DOE/NE-0007, Washington, D.C., April, II.A.1.3.

2. Office of the Federal Register. 1980. Code of Federal Regulations: Proposed Rules, 10 CFR 60, Government Printing Office, Washington, D.C., draft, May.

3.0 TECHNICAL APPROACH

The Gulf Coast salt dome exploration project, as described in Section 4.2, has the overall goal of identifying, characterizing, and eventually qualifying for banking one salt dome as one of the potential sites for a repository in the national radioactive waste isolation program. (There is a possibility no site will be acceptable if none of the sites meets the criteria.)

The exploration effort must identify a site that can meet the system requirements and performance objectives described in Sections 2.1 and 2.2. Also, the recommended site must meet the site qualification criteria listed in Section 2.3. The technical approach in the area phase is based on the NWTS site characterization and selection process, as described in Section 2.4.

The following section describes (1) the technical approach utilized in the area phase to characterize the eight Gulf Coast salt domes relative to the criteria, and (2) the decision process utilized to achieve the primary objective of the area phase--the selection of the most promising domes for further characterization in the location phase.

3.1 DATA COLLECTION AND DEVELOPMENT

The qualification of several potential repository sites in diverse geologic media is progressing with related efforts in dome and bedded salt, granitic rock, the basalt layers of the Hanford Reservation, and tuff at the Nevada Test Site. The investigation of the Gulf Coast salt dome basins is one of these site identification efforts. The data collection and development activities described in this section indicate the activities undertaken in the area phase to characterize the Gulf Coast salt domes of interest from both geological/hydrological and environmental standpoints.

3.1.1 Geologic Characterization

Geologic characterization in the area phase was planned to investigate those geologic and hydrologic factors that affect the present and projected characteristics of candidate domes. The investigations and studies were designed to provide the appropriate level of information in response to the pertinent issues for this phase of the decision process.

Studies have included compilation and evaluation of available data from oil and gas exploration and production operations, well logs, cuttings and cores, geophysical surveys, and review of state records of injection and disposal wells. Data were gathered using a number of methods including shallow and deep drill holes, gravity measurements, geologic mapping, surface and subsurface water quality sampling and analyses, and seismic surveys.

The area characterization activities have involved the preliminary evaluation of key geologic and hydrologic factors. Examples are discussed in the following seven subsections.

<u>3.1.1.1 Tectonic Stability</u>. Tectonic stability was evaluated through the use of available regional gravity data, seismic reflection profiles [from 150 to 215 linear miles (241 to 346 kilometers) of common depth point seismic data in each area], subsurface structural maps, remote sensing studies and the collection and interpretation of available well logs. The main objective of this evaluation was preparation of an inventory and the developmental history of major structures in the region and area surrounding the domes. An example of a major structure is the Mt. Enterprise fault system. There is tentative evidence that it may extend near Oakwood and Keechi domes in Texas.

<u>3.1.1.2 Lithology of the Sediments</u>. The lithology of sediments surrounding the upper section of the salt domes was evaluated by collecting extensive shallow boring samples, deep well, and borehole-geophysical data at Richton, Cypress Creek, Vacherie, Rayburn's and Oakwood domes. In addition, high-resolution seismic reflection data was obtained at Cypress Creek and Richton domes. This technique provides good definition of contacts between strata from near surface to about 4,000 feet (about 1,220 meters) deep. In addition, surface geologic mapping was conducted. These data were collected and interpreted at each dome in order that an evaluation and comparison of sedimentary lithologies could be made.

<u>3.1.1.3 Lateral Extent</u>. The lateral (cross-sectional) extent of the salt domes was evaluated by collecting detailed gravity, high resolution seismic reflection, and deep-well data. Gravity modeling was not done for Palestine dome, and high resolution seismic reflection data were obtained at Cypress Creek and Richton domes to confirm gravity data. These new data combined with available lithologic and geophysical logs from wells near each dome were modeled in order to develop reasonably accurate dome shapes, as well as to provide an indication of any anomalies.

<u>3.1.1.4 Mineral Resources</u>. The presence of significant mineral resources not presently being exploited in the immediate proximity of the domes was evaluated with the use of available data and reports by an expert consultant. A projection was made anticipating productive deep hydrocarbon strata and projecting them adjacent to each dome, if present. An analysis was completed of possible favorable trapping structures around each of the eight domes. This research allowed an evaluation of potential mineral resources that might be the target of future exploration, leading to the breach of the repository.

<u>3.1.1.5 Surface Hydrology</u>. The extent of flooding of the area overlying each salt dome was evaluated by using existing topographic maps and historical precipitation data. The probable maximum flood (PMF) was calculated for the areas over the domes. This evaluation allowed a comparison of the spatial arrangement and area available for surface facilities at each dome.

<u>3.1.1.6 Transport Time</u>. The length of time for ground water to flow from the repository level to the biosphere was evaluated by utilizing data collected from borehole-geophysical, aquifer pumping test, and deep-well data, including water samples for laboratory quality analysis.

Geologic cross sections were then developed for each dome using results of field and laboratory analysis. Literature values of permeability and porosity for confining beds of clay and limestone were utilized to prepare conservative, lower limit, bounding calculations of the transport time of water from the repository to the biosphere. The scenario assumed instantaneous transport of the waste from the repository through the salt buffer to the edge of the dome and through any sheath. The transport time vertically upward through confining strata to the salt-fresh water interface was calculated as the additive time for water to move through each of the more permeable aquifers. These calculations indicated that very long transport times exist for each dome even though the sorption of radionuclides in the multiple intervening confining beds was not considered. This sorption would have the effect of lengthening these already long travel times.

<u>3.1.1.7 Investigative Methods</u>. While the foregoing deals with the key geologic and hydrologic factors, other data were collected, analyzed, and stored for use in this decision or in later characterization phases and/or licensing.

<u>3.1.2 Environmental Characterization</u>

The operation of a repository may result in changes to the environment. It is important to select repository sites where such changes can be prevented or minimized. Effects or changes of concern include those directly affecting man and other aspects of the environment of immediate value to him (e.g., livestock, fisheries, agriculture). Also, indirect losses are considered, such as a reduction in the assimilative capacity of the environment for society's wastes (sewage, solid waste, etc.) and the destruction or contamination of resources (air, water).

The environmental aspects of site characterization include the ecological, socioeconomic, and land use factors which might be affected by the operation of the waste repository. Together these factors comprise segments of the biosphere. The purpose of the repository is to prevent, or delay until relatively harmless, the release of radionuclides into the biosphere.

In the area phase of characterizing the Gulf Coast salt domes, three broad environmental concerns were evaluated at an appropriate level to assist in the selection of a preferred dome for the in-depth location investigations. These are discussed in the following paragraphs.

3.1.2.1 Ecological Characterization

Ecological characterization includes analysis of climatological factors, background radiation, surface geological factors, soil properties, land forms, pollution factors, and specific habitats of flora and fauna. The overall objective is to have sufficient information by the time of site selection to alleviate or mitigate any adverse effects from waste materials generated during the construction or operation of the repository. Much of the necessary data were collected from existing studies.

Historic climatological data for the areas of interest were obtained from local National Weather Service reporting stations. Analyses were made of severe weather conditions which might affect repository operations or cause environmental impacts related to the disposal site. Background radiation data were collected from the available literature in the area study phase.

Land forms and surface geology were analyzed and described through the use of aerial photographs, topographic maps, and limited field reconnaisance.

The soils of the areas near the salt domes were characterized from soil survey maps to provide information by soil type on potential crop yields, woodland suitability, erosion potential, wildlife habitat, soil origin and depth, mechanical analysis, permeability, texture, slope, and use limitations.

Fauna and flora of the biological community were also evaluated. State and federal fish and game agencies provided data on game and nongame wildlife species. Published literature for the study areas was obtained through state forestry, wildlife, and natural resource agencies, as well as universities and private organizations.

Since the ultimate "sink" for airborne and surface contaminants is often an aquatic habitat, studies were conducted using aerial photographs of ephemeral and perennial aquatic habitats. Baseline measurements of water quality parameters, including chemical composition and stream flow, were gathered from existing data sources. Analysis of these data has provided the necessary information to make preliminary estimates of loading characteristics and potential impact to existing aquatic ecosystems.

A list of important species was compiled for both the aquatic and terrestrial environments. In the aquatic environment, an enumeration of all threatened and endangered species was made based on data from the U.S. Fish and Wildlife Service. Commercial and recreational species such as livestock, game, pollinating insects, farm crops, and timber are important in the terrestrial environment. Information was obtained from literature and interviews involving such sources as federal and state government agencies, timber companies, agricultural sources, and conservation organizations.

3.1.2.2 Socioeconomic Considerations

Socioeconomic analyses focus on regional and community social, economic, and institutional factors. Major topics covered include demography, housing, income, community services, labor force, employment, and finance. Baseline data on a number of socioeconomic variables were collected in order to profile the characteristics of the communities and regions of the Gulf Coast. Data on these concerns were obtained from federal, state, county, and local sources, such as the U.S. Census Bureau, state industrial directories, and reports of pertinent state planning agencies. Meetings were held with state officials to obtain up-to-date information on socioeconomic variables and comparative analysis with state and national data was accomplished.

3.1.2.3 Land Use Studies

Land use studies involve the compilation and mapping of land use data and the analysis of use patterns.

Major land use categories examined include agricultural, forest, transportation, residential, commercial, industrial, institutional, recreational, and open space. Baseline data on land use were obtained from several sources for the area phase evaluation of the Gulf Coast salt domes. Aerial photographs provided information on general land use over a wide area, allowing differentiation among agricultural, forested, and urban lands. Of particular concern was the transportation network both in terms of potential risk involved in the movement of nuclear waste and the relative ease of access to salt dome sites. Topographic maps, prepared by the U.S. Geological Survey, provided useful detailed information on land use near the domes of interest. Information from county agencies and regional planning commissions was also used to determine projected as well as current land uses. All domes were spot checked to verify published data.

Archaeological and historic resources on the domes of interest were researched and inventoried with regard to state and federal environmental legislation, including the Historic Preservation Act of 1966, the National Environmental Policy Act of 1969, Executive Order 11593 of 1971, and the latest NRC guidelines. A thorough literature review of known archaeological and historic sites was performed. Specific attention was given to listings in the National Register of Historic Places, and the appropriate state historic preservation officer was contacted for current information.

As the site characterization process proceeds, varying levels of land use characterization are required. In the area phase, a principal concern has been that potential repository locations be located away from areas of highly conflicting land uses such as large metropolitan areas, wild and scenic rivers, national parks, wilderness areas, and historic or archaeological sites.

3.1.2.4 Investigative Methods

Various investigative methods are used in the collection and development of environmental characterization data in the area phase of the process. Data are used in this present decision, as well as being acquired for subsequent characterization phases and eventual licensing.

3.2 DECISION PROCESS

This section describes the decision process used to provide a logical basis for recommending that the three areas (eight domes) under consideration be reduced to a smaller number of locations for subsequent detailed investigation. The objective of this decision process is to:

> Identify the location(s) for subsequent detailed characterization that exhibit favorable safety, social, and environmental characteristics coupled with low residual technical uncertainty based on consideration of all significant factors.

Due to the nature of salt dome geology, a "location" is necessarily synonymous with a specific salt dome.

In striving to complete the area phase, the decision process can yield results or "outcomes" which may include identification of:

- Dome(s) which are acceptable and preferred, should receive emphasis in the location characterization phase--acceptable domes to be characterized
- Dome(s) which are acceptable but not preferred, on which study should be deferred pending the results of further study of domes to be characterized--acceptable domes to be deferred
- Dome(s) which should be eliminated due to a significant safety flaw or technical uncertainty such as geometric inadequacy.

The decision process can be influenced by a number of considerations which are taken as boundary conditions.

1. A location that can potentially meet the siting criteria is acceptable and becomes a candidate location. The ranking of one location over another is an indication that one (or more)

location exhibits a higher degree of suitability* than the locations to which it is compared.

2. Domes which exhibit a lower degree of suitability may still be acceptable and will remain available for later selection should additional information render the preferred dome(s) undesirable.

3. The decision process can eliminate a dome based on a significant technical uncertainty that could make licensing difficult to impossible. Such an uncertainty is not necessarily considered as a safety inadequacy, but a dome with an uncertainty is avoided because DOE's NWTS program has other more attractive location options available.

4. Demonstrations of suitability will be developed in the detailed location study phase and subsequent licensing process that follows the location recommendation.

The discussion that follows describes the decision process.

3.2.1 General Process

This section describes the general process planned for progressing from one screening step to the next. The process forms the framework for identifying, developing, and using information to determine alternate courses of action a decision maker may choose.

The process may identify regions, areas, or locations, some better than others. If many appear favorable, some should nonetheless be deferred from further study. Further study of all but the more favorable land units identified in a screening step is unnecessary and would be prohibitively expensive. Study of less favorable land units is deferred indefinitely. Further studies, then, are focused on only as many favorable alternatives as reasonably necessary to (a) make it very likely that several alternative sites are identified and ultimately prove acceptable and (b) to satisfy the requirements for consideration of reasonable alternatives through each screening step.

Regions, areas, or locations may also be eliminated if there is a high likelihood that major siting criteria will not be met. In this situation, resources need not be expended to demonstrate site unsuitability. Screening decisions, then, are made to focus efforts on the more favorable appearing places.

---

*The word "suitable" is used to describe salt domes that have no obvious defects or major unresolvable uncertainties. A "lower degree of suitability" indicates a suitable dome that appears to be less well adapted for repository use than the preferred domes.

The general approach used for each screening step consists of several steps:

Step 1. Identify factors and supporting information needs thought to be important to the next screening decision

Step 2. Gather the required information in accordance with applicable consultation and concurrence procedures

Step 3. Identify possible alternatives

Step 4. Evaluate each possible alternative site according to previously identified factors

Step 5. Compare and recommend candidate alternatives

Step 6. Review the screening decisions in accordance with applicable consultation and concurrence procedures.

<u>Step 1. Identify Factors and Supporting Information Needs Thought to be Important to the Next Screening Decision</u>

At the end of each screening study a decision must be made concerning which of the land subunits (region, area, location) studied are deserving of a next phase of more intensive study. Factors identified at this time are those technical and institutional considerations that may significantly influence the decision outcomes. The actual contribution of each factor to the decision outcome will be evaluated in Step 4 after needed information is gathered. The geographic applicability of a factor is important to assessing when in the screening process it can be meaningfully evaluated. For example, tectonic stability is generally somewhat homogeneous across large geographic regions and generally will not discriminate among locations on the order of tens of square miles. Historic monuments, on the other hand, are generally very localized, and thus cannot be used to differentiate among large areas or regions.

The level of information needed to make a decision depends upon the nature of the decision and the factors that potentially influence that decision. For example, the information needed to select areas from regions is not sufficient to allow safety or environmental assessments of repository effects. The amount and depth of information needed to make the area selection decision is therefore much less than that required to support a site safety assessment. During screening, consideration will continue to be given to geographical units if no evidence is found to suggest a safety flaw. During licensing, however, suitability may not be presumed, but must be demonstrated with a high level of confidence by safety assessments and environmental analyses. The level of information needed is affected, in part, by the expanse of time (10,000 years or more) over which site integrity is required. Predictions of changes in the natural condition of a site that might affect its suitability must rely on the geologic record as presently interpreted and extrapolated by the scientific community. However, in geologic time 10,000 years is a very short period and significiant changes, especially in the lithosphere, are not likely in this time interval. The requirements for information to support screening decisions will be assessed by answering the question: "Will an incremental improvement of a screening decision be commensurate with the resources expended to obtain additional information?"

The requirements for information to support a demonstration of suitability will be assessed by answering the question: "Can we demonstrate with confidence that all significant uncertainties affecting site containment and isolation capabilities and safety have been uncovered, understood, and avoided or minimized by design?"

Question: What factors are significant and why?

- Factors are technical considerations that may significantly influence the decision outcomes.
- Factors are drawn from the site qualification criteria(1) and the draft NRC technical regulations(2). Site suitability will eventually be judged against final NRC regulations.
- The significance of each factor is defined in terms of its relevance to the safety, environmental, and confidence objectives.

Action:

- List all factors that are potentially significant to repository safety and environment. Define the significance of each factor. Define the geographic expression of the factor for this decision level. Tectonic stability, for example, is a factor that is considered across a large geographic region. Historic monuments, on the other hand, are generally quite localized.

Question: What information is needed?

- The level of data needed to make a decision depends upon the nature of the decision and the factors that potentially influence that decision. For example, area characterization does not demand the same degree of safety hazard or environmental impact assessment that repository construction requires. The amount and depth of information needed to make the location decision is therefore less. During siting, safety and environmental suitability can be presumed if no evidence is found to suggest a flaw in a particular geographic area. During licensing, suitability may not be presumed, but must be demonstrated to a high degree.
- The determination of the level of data needed for this type of facility is complicated by the expanse of time (10,000 years or more) over which site integrity is required. Predictions of changes that might affect the decision need to rely on the geologic record as presently interpreted and extrapolated by the scientific community.

- Tests for assuring that an adequate level of data is being applied to the decision will be satisfied by obtaining consensus on the answer to the question:

  · Will the incremental improvement in the decision that accrues from additional data be commensurate with the resources expended to obtain it?

<u>Action:</u>

- Define and list information needs for each factor.

<u>Step 2. Gather the Required Information in Accordance with Applicable Consultation and Concurrence Procedures</u>

During this step, information on each candidate alternative is obtained by methods described in Section 3.2.2. As the geographic area under investigation is reduced, the information gathered becomes more intensive and more detailed. Information is obtained from public files, published and unpublished records, the open literature, and by purchasing data from private sources, such as petroleum and mineral exploration companies. Field information is obtained by observation, remote sensing, direct measurement, and mapping.

Information gathering, particularly field investigations, will involve interactions with states and local representatives and can be a politically sensitive process. Emphasis will be placed on gathering data in strict accord with understandings developed with state, local, and tribal officials.

<u>Question:</u> What level of information is available and is it adequate?

- A broadly based information acquisition approach has been used to support decisions in the Gulf Coast salt dome region. As the geographic area under investigation was reduced from large regions to smaller areas, the information gathering became more intensive and more detailed. The area level investigations were more detailed than those at the region level, and the subsequent location phase characterization will be even more detailed than that at the area phase.

- Information is gathered by purchasing data from private sources such as oil companies and by searching public files, published and unpublished records, and the literature. Some boreholes are drilled in and around the domes. Field data are also obtained by observation, remote sensing, direct measurement, and mapping.

- In cases where some data have not been obtained, preliminary dome comparisons are made acknowledging these incomplete data. An evaluation is made as to whether having the additional data at this time would significantly change the decision. If not, the process proceeds. If the data are needed, they are obtained before decisions are finalized.

Action:

- Determine adequacy of available data.

Step 3. Identify Possible Alternatives

For each screening step, alternatives must be identified from which recommended candidates will be selected. Based on consultation with qualified technical and institutional experts, land units appearing to have a good chance of meeting site performance criteria upon subsequent study and evaluation are identified in a preliminary manner. Identification of alternatives will be based on a lack of obvious safety or environmental impediments and on the potential for obtaining adequate information to make a screening decision. Therefore, each alternative identified for comparison in Step 4 may contain acceptable sites.

In some surveys the geographic scale may make it impossible to meaningfully identify alternatives for the next screening step without first subdividing the geographic unit and identifying an intermediate set of alternatives.

Question: Do any domes have a safety or uncertainty flaw?

- A safety flaw is a significant condition that when viewed in the systems context would jeopardize the performance of the whole system and involves one or more of the following:
    - Compromises long-term host rock stability
    - Does not inhibit radionuclide movement
    - Unacceptably shortens travel time to the accessible environment
    - Does not provide required containment within the host rock under credible events and processes.

- A safety flaw is based on an obvious defect and would cause a salt dome to be eliminated from further consideration.

- An uncertainty flaw is a safety or environmental condition or other uncertainty that has the potential of creating licensing issues that cannot be completely understood due to inherent complexities. An uncertainty flaw will cause deferral of a dome. Domes with uncertainty flaws could be further investigated to thoroughly understand such problems.

- An uncertainty flaw is one which would prevent the dome in question from being a recommended site regardless of the other advantages it might possess, unless the condition is fully evaluated or uncertainties are resolved.

Action:

- Compare each dome against performance objectives of safety, confidence, and environment. Eliminate domes having safety flaws or defer domes with major technical uncertainty. Describe reasoning. List and label remaining domes as candidate domes.

Question: For each factor, which domes exhibit more favorable characteristics than other candidate domes?

- A rating for each candidate dome by factor is formulated from the appropriate data. Indicators of favorability are assigned by evaluating one dome against all others based on the information pertinent to each differentiating factor.

Action:

- Define method of assigning and indicating relative favorability of domes.

- Assign and list favorability indicators.

Question: What factors allow differentiation among candidate domes?

- Regardless of importance, factors for which available information indicates no significant differences between domes cannot be used to influence the decision outcomes.

Action:

- List differentiating factors. Display candidate domes versus differentiating factors.

Step 4. Evaluate Each Possible Alternative According to the Previously Identified Factors

This step involves analyzing the information gathered to determine, for each factor, how each alternative compares to the safety, environmental and institutional performance objectives. Each alternative will be systematically compared (e.g., "favorable", "less favorable", "more favorable", or "uncertain") by summarizing its expected performance with respect to all the factors considered at the given level of screening. It is not necessary, nor desirable, to maximize performance of an alternative with respect to each factor. Rather, the overall expected performance should be the basis for evaluating the suitability of candidate alternatives. The evaluation will then highlight the differences and similarities between the alternatives (locations). Only factors for which the information indicates substantive differences between alternatives are useful in the next step. These differentiating factors provide the basis for evaluating trade-offs and identifying the alternative(s) to be recommended.

Question: What is the importance of each factor relative to others?

- Focus attention on the differentiating factors that may exert a strong influence on the decision.

- The relative importance of one factor, such as tectonic stability, over another, such as urban proximity, can be assigned by group consensus or other techniques. The importances assigned represent the value the decision makers place on the contribution of that factor, assuming the performance criteria are met.

Action:

- Define the method for defining relative importance.

- List factors in order of importance.

- Define indicators used, if any, to designate relative importance of one factor to another.

Step 5. Compare and Recommend Candidate Alternatives (Locations)

At the end of each screening step, DOE must decide which, if any, of the favorably rated alternatives at a given screening phase should be selected for further study and evaluation. In so doing, DOE also may: (1) defer consideration of some favorable alternatives until such time as a recommended selected alternative(s) eventually proves unsuitable, (2) eliminate nonrecommended alternatives from further consideration, or (3) defer the decision until such time as additional information is available.

The decision of which alternatives to select will be made by comparing their key differences and weighing the relative importance of those key differences. Numerous techniques are available for making these comparisons.

The decision and the analytical basis for comparing alternatives will be documented, including an explicit description of assumptions, definitions, logic, information base, and uncertainties in the comparison process. The reasoning process for selecting, deferring, or eliminating each alternative will be explained. Significant, soundly based dissenting opinions, if any, within the recommending and decision-making bodies will be briefly summarized in decision documents.

Sensitivity analyses with respect to the importance of differentiating factors may also be performed. Such analyses widen the options for decision making by allowing, for example, either institutional or safety factors to dominate the analytical basis for ranking the suitability of alternatives. Such analyses, when properly described, also focus dialogue about geographic alternatives on the trade-offs that invariably will occur between individual safety objectives, e.g., long-term predictability versus current isolation qualities, as well as on trade-offs between long-term and operational safety, environmental concerns, institutional parochialism, and repository system costs.

Because different relative weightings of screening factors may result in different decisions, the sensitivity analyses will be carefully documented and the reasoning for assigning a given importance to each factor will be explicitly stated. In this manner the dialogue among parties concerned with repository siting can be focused on those issues most sensitive to administrative and technical opinion. This, in effect, provides a mechanism for identifying and separating siting issues into those for which consensus may be obtained based on technical, logical grounds and those for which expert and lay judgments are the basis of disagreement.

Question: How is a recommended dome(s) chosen?

Action:

- Define technique used for aggregation of favorability characteristics versus the relative importances of evaluation factors.
- Evaluate data for each factor to identify favorable dome(s) that have low uncertainty.
- Display dome and factor information and describe it in the text. Dissenting opinions that the decision makers believe may be valid are discussed along with the reasons decision makers chose not to be swayed by such opinions.

Step 6. Review the Screening Decisions in Accordance with Applicable Consultation and Concurrence Procedures

In order to construct and operate a repository at a site, the process used to find sites and the suitability of the sites eventually selected must be generally understood and accepted. This understanding will be sought by encouraging early review of the siting process by the technical community, governmental units, and the public. Some individuals or groups will review the plans for work, others will review the technical procedures and tests. Advisory committees have been formed to ensure representation of a broad field of experience and knowledge. Governmental units must exercise responsibility in providing places for disposal of the waste, including allowing the siting process and recognizing the safety of a disposal site. Active participation in the siting process by these governmental units and the people they represent will ensure an awareness of the whole isolation problem and what constitutes site suitability for geologic disposal. This participation will also ensure that public concerns are heard and considered in the decision process.

Appropriate technical, governmental, and public review of DOE-recommended decisions will be solicited. For screening activities on DOE lands, the individual DOE Field Operations Offices in the affected states will be primarily responsible for organizing and coordinating the review process consistent with NWTS program plans. The NWTS Program Office and ONWI will be primarily responsible for organizing the review process for activities on non-DOE lands.

Question: What is the sensitivity of the selection process to new information or reasonable changes in assignments of site advantages or disadvantages and relative factor importances?

Action:

- Describe the method used to check sensitivity. Describe any sensitivity checks performed.
- The selection of the recommended salt dome(s) is verified to establish the effect on the decision of different factor importance and dome rating assignments.
- In some situations the decision procedure does not yield a clearly preferred dome(s). If a clearly preferred dome is not apparent or if the preference does not "seem" right, the difficulty may relate to the real differences in the compared domes being small or to inadvertently leaving out some factor that is important to the decision process. The first situation indicates that there is no technical basis for selecting one candidate over another. In this case, the recommendation may be based on cost or on other institutional or social considerations. In the second situation, the process is repeated with appropriate consideration of the newly identified factor.

Question: Is there peer consensus on the decision procedure and result?

Action:

- Describe the peer consensus process, obtain consensus. Prepare recommendation for DOE.
- The consensus process used should be explicit and provide for a systematic evaluation of a number of interdependent factors relative to each other.
- Technical experts and managers need to participate at the program level. The technical experts explain the significance of various factors and judge data adequacy, while managers check the relevance of the information and logic of the evaluation being made.
- Peer groups and other review groups first evaluate the soundness of the stepwise procedure, then judge its application to the information and geographic areas being evaluated.

In summary, the six steps should be viewed as a complex system in which the steps may not follow in exact sequence and multiple "feedbacks" may occur even though a stepwise procedure is indicated. New alternatives may emerge at any time either from new information or policy changes. The key issues to be resolved may need redefinition as the analysis proceeds. Continuous data-gathering and refocusing of judgment occur through the entire process. Therefore, the process is characterized as a framework for making siting decisions rather than a serial procedure. The purpose of this framework is to focus the decision makers' and reviewers' reasoning and attention to relating the pertinent facts and thoughts in a rational pattern to converge on a consensus of elimination, deferral, or recommendation of the domes evaluated.

3.2.2 Screening Steps

As discussed above, the geographic screening planned by DOE consists of four possible steps. Each has been titled for reference as follows:

- National Survey (Nation to Region Screening)
- Regional Survey (Region to Area Screening)
- Area Survey (Area to Location Screening)
- Location Study (Location to Site Screening).

An additional step, Detailed Site Characterization, is not actually a screening step, but is a confirmatory step that continues after site banking, as detailed in Section 2.4.1.5.

3.2.3 Recommendation, Concurrence, and Implementation of the Decision

The acceptability of the decision process and the resulting decision will depend on the consensus obtained in the review process. An effort is being undertaken to provide the states in the Gulf Coast salt dome project area information on the DOE data gathering and evaluation activities in those states.

DOE will consult with the state and local governmental units on any proposed location recommendation before proceeding with location level studies at the recommended salt domes. Any dome recommended may later be dropped if warranted by evidence uncovered in a later detailed characterization phase. A reevaluation of the candidate domes not recommended would then be made to identify one or more new preferred domes, if such were the case.

REFERENCES

1. Office of Nuclear Waste Isolation. 1980. NWTS Criteria for the Geologic Disposal of Nuclear Wastes: Site Performance Criteria, DOE/NWTS-33(2), Battelle Memorial Institute, Columbus, OH, January.

2. Office of the Federal Register. 1980. Code of Federal Regulations: Proposed Rules, 10 CFR 60, Government Printing Office, Washington, D.C., draft, May.

4.0 BACKGROUND ON SALT DOMES

The salt domes of the interior basins in the Gulf Coast region are among locations in several regions that are being investigated as potential locations for a deep mined geologic repository for high-level radioactive wastes. This section gives the history of the salt domes site characterization efforts, objectives and organization of the project, area characterization activities, and a description of the domes under investigation.

4.1 HISTORY OF THE CHARACTERIZATION EFFORT

The effort to identify a suitable repository site in salt can be traced from 1954, when the U.S. Atomic Energy Commission (AEC) asked the National Academy of Sciences-National Research Council (NAS-NRC) to look at the problem and recommend a solution. After intensive study, that group recommended geologic disposal in salt formations as the best of the many options that they had considered.[1] This position has been reaffirmed in subsequent studies.[2]

Characteristics of salt deposits that are considered to be especially favorable for storage of high-level radioactive waste include the following.

(1) Many salt beds have remained undisturbed and dry for tens to hundreds of millions of years, indicative of their long-term integrity and nondissolution by hydrologic systems.

(2) Rock salt exhibits the ability to dissipate large quantities of heat (as would be generated by high-level wastes).

(3) Owing to its natural plasticity, salt is capable of "self-sealing" fractures which might develop in it, thus preventing access by fluids along zones of weakness.

(4) Rock salt appears to undergo only minor change due to exposure to radioactivity.

(5) Rock salt is comparable to concrete as a gamma-ray-shielding medium, and it has a compressive strength similar to that of concrete.

(6) Salt deposits that are sufficiently deep and thick to be considered as having potential are widespread in this country and generally occur in areas characterized by low levels of seismicity and tectonic activity; thus, the potential for damage to repository structures (shaft, surface plant) resulting from earthquakes is greatly reduced.

(7) Domestic salt resources are great enough so that if sites in several deposits were selected as repositories, there would be no adverse effect on the resource base; repository sites also could be selected far from existing mines so this would constitute no problem.

(8) Rock salt can be easily mined at relatively low cost, and the technology for the underground excavation of salt is well developed; underground rooms opened in salt have remained stable for long periods of time, provided adequate pillar size is incorporated into the mine design.

Characteristics of salt deposits that are considered unfavorable for storage of high-level radioactive waste include the following.

(1) Salt is soluble in unsaturated water; however, salt domes have remained, undissolved, for tens to hundreds of millions of years.

(2) Dome salt, a metamorphic rock, has the potential for mobility, allowing it to flow, and essentially "heal" itself.

(3) Rock salt has low shear strength.

In 1958, the U.S. Geological Survey undertook a study for the AEC to identify those salt deposits in the United States that might contain possible disposal sites.[3] Salt deposits that were identified with large volumes of salt at depths appropriate for construction of a repository included the Silurian salt deposits of the Salina group that underlie parts of New York, Pennsylvania, West Virginia, Ohio, and Michigan; salt domes in the Gulf Coast embayment in parts of Alabama, Louisiana, Mississippi, and Texas; salt deposits of the Permian Basin underlying parts of Kansas, Colorado, Oklahoma, Texas, and New Mexico; and those of the Paradox Basin in southeastern Utah and southwestern Colorado. This information was confirmed in a subsequent study by other investigators.[4]

Evaluation of the Gulf Coast region began in 1962, with the publication of a report on the geology and ground-water hydrology of the Atlantic and Gulf Coastal states as related to disposal of radioactive wastes.[5] The report is very generalized and does not contain information specific to salt dome geology and hydrology. At about the same time, the U.S. Bureau of Mines evaluated the Gulf Coast salt domes for the AEC as potential nuclear test sites.[6]

During the period 1963 to 1967, Oak Ridge National Laboratory conducted a series of research investigations to demonstrate the technical feasibility of the concept of mined geologic disposal in salt, using an abandoned mine near Lyons, Kansas, as a test site. This study, known as Project Salt Vault, concluded that disposal in bedded salt was feasible and that handling and emplacement equipment could be designed to safely transfer the wastes into a subsurface repository.[7]

Although Gulf Coast salt domes were discussed by Pierce and Rich[3], no effort was made to discriminate between either the several salt dome basins or individual domes in regard to their general suitability. The great thicknesses and purity of salt domes were cited, however, as favorable factors. Gera[8] also considered salt domes in his article about salt tectonics but did not specifically evaluate any Gulf Coast domes.

The Gulf Coast basin is one of the most significant salt dome provinces in the world.[9] More than 500 salt domes are present in the combined offshore and onshore Gulf Coast basin. Elsewhere throughout the Gulf of Mexico region, additional salt domes have been reported from Cuba and the Veracruz-Tabasco section of Mexico to the Sigsbee Deep within the central Gulf.[10] Salt-supported structures, mainly anticlinal, are also present in southern Arkansas[11] and in several provinces of both northeastern and southeastern Mexico.[10]

Of the more than 500 known or inferred salt domes of the Gulf Coast basin, some 263 are located onshore in three principal salt basins in east Texas, northern Louisiana, and southern Mississippi. Anderson and others[12] conducted the first assessment of onshore salt domes with regard to their general potential for waste disposal. Based upon the subsurface depth to the top of the salt in the domes and the degree of industrial usage, these investigators grouped the 263 known and suspected domes into two general categories: (1) any dome whose upper salt surface was deeper than approximately 1,900 feet (about 580 meters), or (2) for which petroleum production, cavern storage of hydrocarbons, salt or sulfur production, or a combination of these uses indicated appreciable development by industry, was considered less suitable and was not recommended for further study at that time. Of these 263 domes, 148 were too deep and 79 exhibited competing uses, leaving 36 domes that met the general considerations of Anderson and others.[12] These 36 domes are concentrated within the more northern interior basins of Texas, Louisiana, and Mississippi. The authors summarized the geology of the salt dome basins, inventoried the available geologic, geophysical, and hydrologic data, and recommended further studies on the 36 domes.

Ledbetter and others[13] also investigated Gulf Coast domes by means of some generalized approaches that included consideration of topography and surface-drainage features as well as subsurface hydrology. Although much of this work relied upon a review of the existing literature, three noteworthy considerations were that (1) heat from radioactive waste would not be expected to induce renewed tectonic movement in a dome, (2) domes sheathed by shale and below the level of local fresh-water aquifers might exhibit a reduced possibility of salt dissolution, and (3) the large vertical extent of salt domes could prove beneficial in terms of possible repository design. These investigators, like Anderson and others,[12] recommended further that additional data be acquired. Based upon their generalized study, Ledbetter and others[13] felt that domes within the interior basins offered more potential.

Martinez and others[14,15] extended these earlier studies by investigating 17 domes in the north Louisiana basin and nine domes in the northeast Texas basin for which they felt adequate data were available. They specifically studied salt movement through geologic time by analyzing rim-syncline development, the salt volumes involved, and regional stratigraphic relationships. Also studied was hydrologic stability by estimating saline groundwater plumes within fresh-water aquifers adjacent to salt domes and analyzing surface "salines" above certain domes. The potential for surface flooding was also considered. Other investigative approaches centered upon (1) the extent of past salt dissolution as shown by caprock features, especially the caprock/salt interface; (2) local and regional hydrology, using well-log analysis on existing borehole data, and several exploratory water wells; (3) determination of current tectonic movement or lack thereof through the use of instrumentation arrays, which include tiltmeters, precise-leveling stations, and microseismic monitors; and (4) the nature of Quaternary strata above domes to determine whether they have been affected by more recent salt movement. In the latter case, shallow geophysical profiles, borings, and a detailed logging served as the major evaluative techniques. These salt dome studies indicated no movement in the Quaternary.

Several domes within the northeast Texas basin were also studied by Netherland, Sewell, and Associates[16]. These workers analyzed the uplift-versus-time growth of these domes and attempted to evaluate hydrologic stability where available well-log data were adequate. Effort was made in their study to assess the current rate of salt dissolution on certain domes and to integrate existing geophysical data into an understanding of the basin and the salt domes of northeast Texas.

In 1976, ERDA announced the formation of the NWTS program, which had as one objective the identification of suitable sites for construction of one or more geologic repositories for radioactive wastes. As part of that program, Law Engineering Testing Company (LETCo) was selected by the Office of Waste Isolation (OWI) of Union Carbide Corporation to act as geologic project manager (GPM) for investigations in the Gulf Coast salt dome region. The role of the GPM at that time included the development of a technical plan for evaluating the salt domes and coordinating the research investigations of the many investigative teams studying the salt domes, as discussed in the next section. Simultaneously, Bechtel National, Inc. (BNI), was selected as regulatory project manager (RPM) to conduct environmental studies in parallel to those in geology and hydrology.

In 1978, draft reports were issued by LETCo[17] and BNI[18] which summarized the existing data and previous work in the region of interest containing the salt domes. These reports, as well as a Regional Summary Report prepared jointly by the GPM and RPM[19], formed the basis for a recommendation to DOE that eight domes be investigated further. These reports have been revised after extensive review and public comments and will be released in final form in the very near future. The selection of domes was based on criteria[20] and specifications[21] in existence at that time.

In 1978, responsibility for overall management of a large portion of the NWTS program was transferred to ONWI, operated by Battelle Memorial Institute.

4.2 ORGANIZATION OF SALT DOME PROJECT

DOE, through ONWI and its subcontractors, is charged with the task of identifying, characterizing, and, eventually, qualifying for banking, if justified, one salt dome as a potential site in in the NWTS program. This banked site will be considered along with others as the site for a nuclear waste repository.

4.2.1 Organization

As indicated in Figure 4-1, the Gulf Coast salt dome project is organized with two lead technical contractors to ONWI and two prime contractors to DOE, with an interagency agreement in place with USGS. This organization provides a means, in the geotechnical, environmental, and licensing fields, for data to be gathered, reduced, analyzed, and reported.

4.2.1.1 Bechtel National, Inc.

Bechtel National, Inc. (BNI), was selected in 1977 as the regulatory project manager (RPM). The RPM is responsible for environmental and regulatory activities as related to characterizing, banking, and the ultimate licensing of a repository site. Bechtel has conducted literature reviews and made contacts with state experts in the fields of ecology, meteorology, socioeconomics, land use, surface water hydrology, cultural and natural resources, archaeology, and background radiation to define the specific characteristics of the Gulf interior region, including the Louisiana, Mississippi, and Texas study areas. Environmental Research and Technology (ERT) is under subcontract to Bechtel to conduct field studies during the location characterization phase.

4.2.1.2 Law Engineering Testing Company

Law Engineering Testing Company (LETCo) of Marietta, Georgia, was selected in 1977 as the Gulf Coast geologic project manager (GPM). The LETCo effort is organized into data gathering (field operations and research), data analysis and reporting, and overall project management. Under LETCo's direction, field investigations and data/literature reviews have been conducted to define specific characteristics of Gulf Coast salt domes in Louisiana, Mississippi, and east Texas. Investigations include research on erosion and denudation, determination of the internal structure of salt domes, the preparation of salt diapirism models, salt dissolution studies, surface and subsurface hydrology and stream monitoring data collection, topographic mapping, field seismic refraction and reflection studies, remote sensing data collection and analyses, and assessment of the geologic structure and stratigraphy. These investigations include drilling of hydrologic test holes, core drilling, borehole geophysical logging, shallow exploratory borings, and geophysical gravity surveys. Subtasks include obtaining right-of-access to lands on which these studies will be performed and the necessary permits to conduct investigations in the study areas. LETCo has numerous consultants in a number of

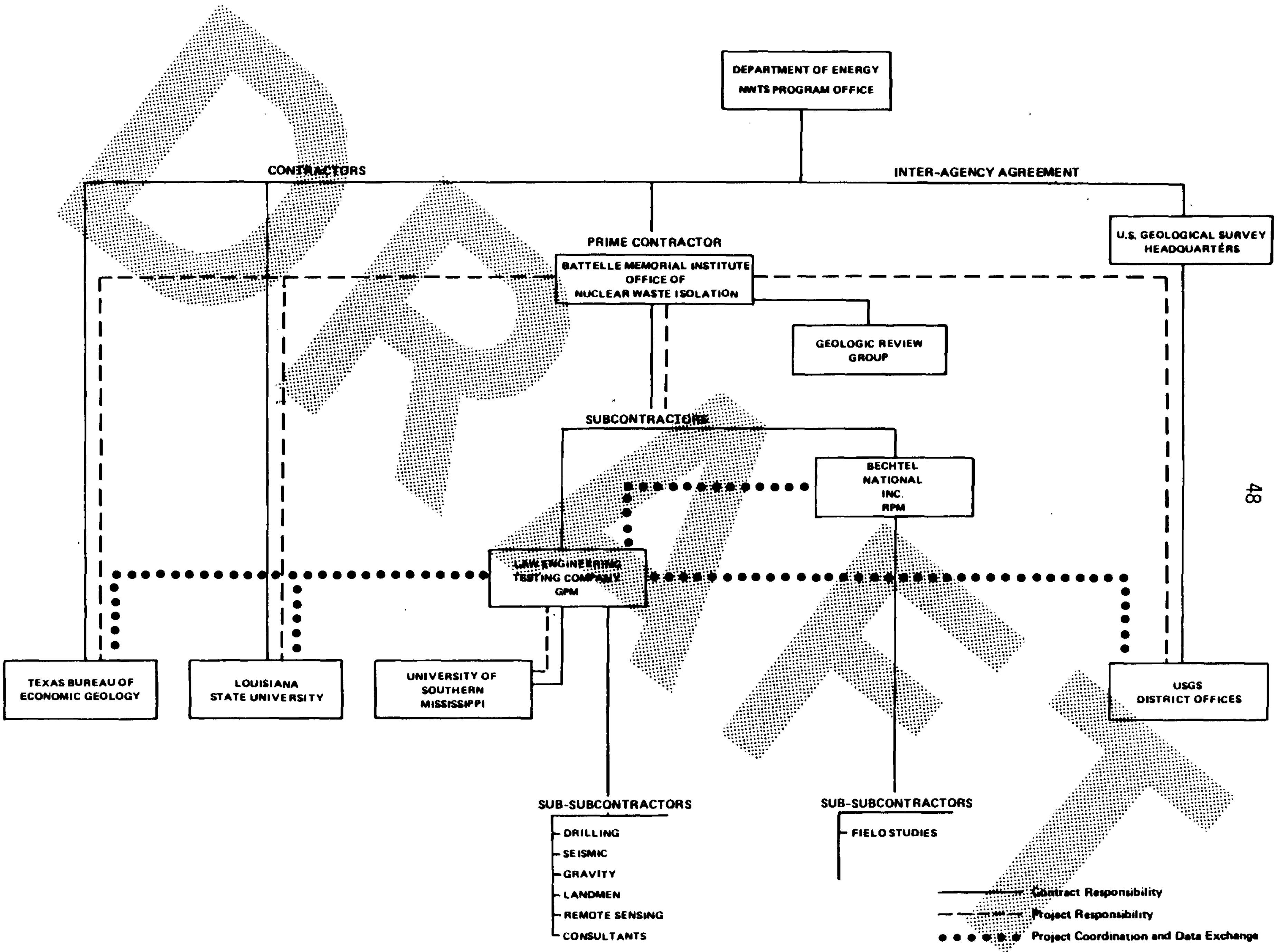

FIGURE 4-1. ORGANIZATION OF THE GULF COAST SALT DOME PROJECT

specialties such as hydrology, mineral resources, seismic, stratigraphy, petrology, geomorphology, structure, and general geology. LETCo also has numerous subcontractors engaged in drilling deep and shallow holes, site preparation and restoration, aquifer characteristic testing, geophysical surveys, and obtaining land access.

4.2.1.3 U.S. Geological Survey

The USGS--through its offices in Jackson, Mississippi, Austin and Houston, Texas, and Alexandria and Baton Rouge, Louisiana--has been responsible for evaluating the regional ground-water hydrology of the interior Gulf Coast salt domes in Mississippi and Louisiana and for geochemical characterization of surface water in east Texas. These data are incorporated in the appropriate characterization and summary reports.

4.2.1.4 Institute for Environmental Studies, Louisiana State University

The Institute for Environmental Studies (IES), located at Louisiana State University (LSU) in Baton Rouge, Louisiana, has been involved, since 1974, in the study of Louisiana salt domes. The IES has identified four main tasks related to salt domes in Louisiana: geomechanics, geohydrology, regional geology, and Quaternary geology. These studies are coordinated with LETCo and the USGS, and the data are incorporated into geologic characterizations and summary reports.

4.2.1.5 Bureau of Economic Geology

The Bureau of Economic Geology (BEG) of the University of Texas at Austin has been involved, since 1977, in the study of east Texas salt domes. The BEG has identified four tasks related to east Texas salt basins: areal surveys including surface and shallow subsurface mapping, remote sensing and interpretation, subsurface analyses, and hydrologic studies of regional and near-dome extent. These studies are also coordinated with LETCo and the USGS and are incorporated into geologic characterization and summary reports.

4.2.1.6 Department of Geology, University of Southern Mississippi

The Department of Geology of the University of Southern Mississippi (USM) has been involved in two tasks: evaluation of dome stability and mapping the geology of the areas over and adjacent to specified domes in Mississippi. These studies are coordinated with those of other groups and are incorporated into geologic characterization and summary reports.

4.2.1.7 Geologic Review Group

The Geologic Review Group (GRG) is a group of well-known, highly respected scientists from outside the NWTS program. They are retained by ONWI on a consulting basis, to provide an independent, critical, expert review of certain aspects of the geologic exploration program and give advice to ONWI management on the program. These individuals were selected because of their expertise in specialties critical to the geologic exploration program. Their work includes the periodic, systematic review of ongoing activities, work plans, technical reports, and other pertinent information; the issuance of periodic assessments of activities of ONWI subcontractors and other NWTS program participants within the group's area of expertise; monitoring the program and periodically preparing a technical commentary on the program; and recommending additions, deletions, or refinements to the program to improve it and make it more responsive to requirements of long-term safety and acceptable environmental impact.

4.2.1.8 ONWI Project Managers

Bechtel, LETCo, LSU-IES, BEG, USM, and the USGS with related subcontractors work closely with the assigned ONWI geologic and environmental project managers. These project managers are charged with coordinating the work effort, maintaining the quality of the data, and overseeing the processes undertaken to obtain, reduce, analyze, and report this data. They are responsible to maintain schedules and meet designated milestones within the overall NWTS program.

4.3 AREA CHARACTERIZATION PHASE

4.3.1 Objectives

The area characterization phase of the Gulf Coast exploration program has two objectives:

(1) To obtain adequate geologic and environmental data to select preferred salt domes for more detailed location characterization as candidate repository sites. (This screening of study areas to identify smaller locations is tantamount, in the case of salt domes, to a reduction in the number of domes since they are relatively finite in size and geographic position.)

(2) To continue building the data base for licensing application through the process of narrowing geographic focus with an accompanying increase in the depth of informational detail.

4.3.2 Activities Accomplished

Following the identification of the eight domes on which to continue work[19], project plans were developed for both the geologic and environmental area characterization. Some of these plans were published formally, after an appropriate period for public review and comment.

Environmental studies were begun in February, 1979, to evaluate potential impacts or risks of a waste repository on each salt dome. All factors of the total environment were considered, including geography, terrestrial and aquatic ecology, surface hydrology, meteorology, land and water resources, and land use and demography, as well as economic, historical, institutional, and societal factors.

Geologic field studies by participating organizations began in 1978 to investigate the general characteristics and features of the salt domes and the surrounding area. The evaluation considered stratigraphy, structure, ground-water, surface hydrology, erosion, tectonics, seismicity, and natural resources. The work entailed gathering and interpreting pertinent data from well logs, cuttings, and cores. Geophysical surveys were run at key locations. Hydrologic test holes were drilled and tests run to determine hydraulic parameters of important formations. The potential for oil, gas, and other natural resources was ascertained.

Details of the technical aspects of the area studies are in the geologic and environmental area characterization reports and are summarized in Section 3.1.

4.3.3 Project Status

The Gulf Coast salt dome project is in the final stages of data gathering for the area characterization studies, as described at the beginning of this section. This phase of the project began in late 1978, following completion of regional characterization studies and has involved the eight salt domes and surrounding areas described in Section 4.4. Draft area characterization reports, now available, contain the technical results of these studies.[22,23,24,25,26,27,28] The environmental characterization and geologic characterization reports have been submitted to the states in draft form for their review.

4.4 DESCRIPTION OF GULF COAST DOMES

Salt domes occur in three basins: east Texas, north Louisiana, and Mississippi (Figure 4-2). Salt domes are individual pillars of salt contained within the normal sedimentary sequence, and are generally one or more miles across, with tops ranging from near the surface to thousands of feet deep. The base of the domes is at the depth of the source or "mother" salt bed, which ranges from 15,000 to 30,000 feet (about 4,500 to 9,200 meters) below the surface in the interior basins. The Louann salt of the Mississippi basin is the deepest. Caprock of anhydrite, gypsum, and/or limestone generally tops the massive salt of the dome, often being several hundred feet thick (Figure 4-3).

The tops of the salt domes under investigation as possible nuclear waste repository sites are 1,600 feet (about 490 meters) or less in depth. At depths where a repository would be constructed, their lateral areas range from 1,100 to 5,800 acres (about 450 to 2,300 hectares). Eight domes were identified for study: three in Texas, two in Louisiana, and three in Mississippi. The origin and structure of these salt domes is discussed in the following paragraphs.

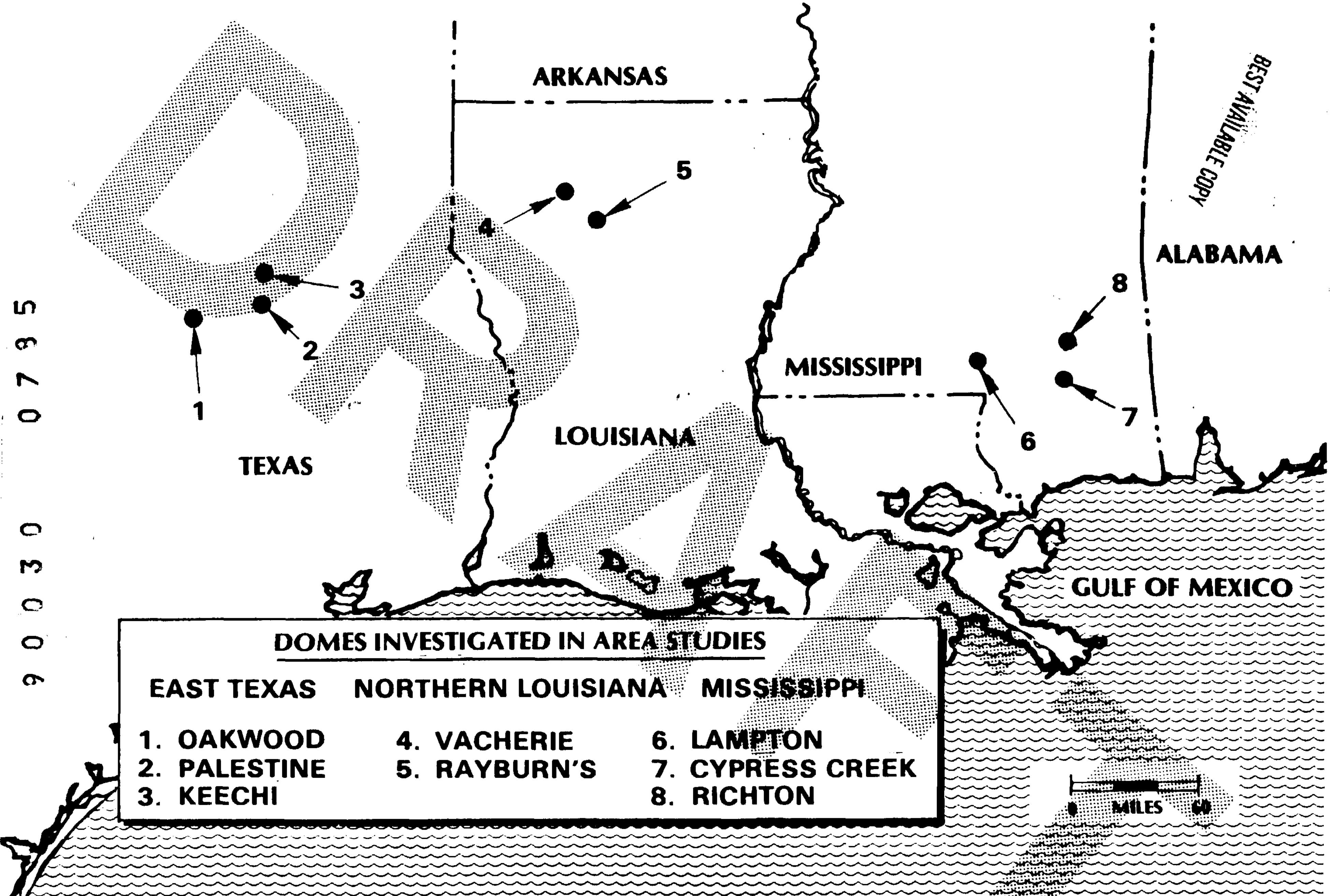

FIGURE 4-2. MAP OF GULF COAST EMBAYMENT SHOWING SALT DOMES OF INTEREST

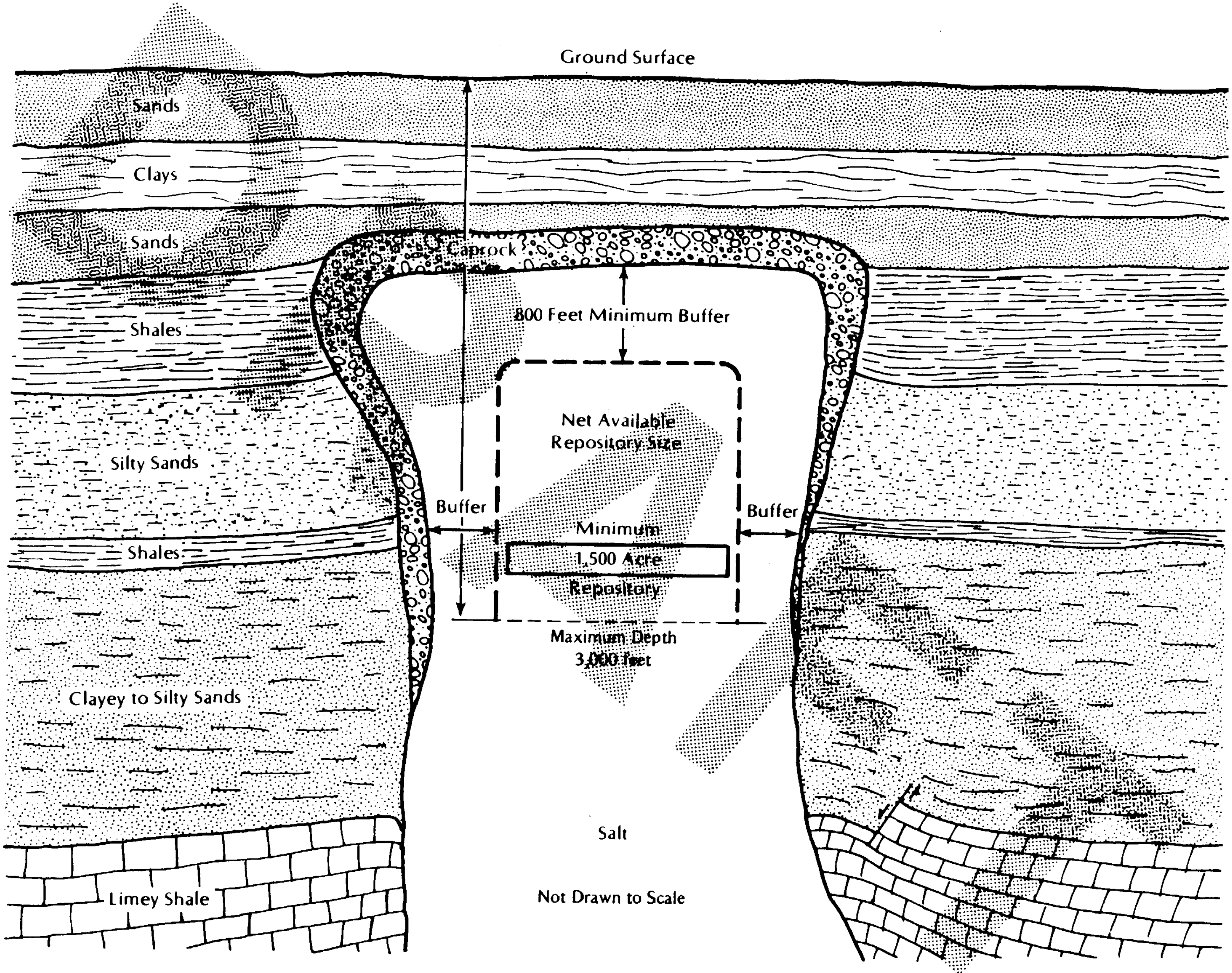

FIGURE 4-3. SITE GEOMETRY

(See Appendix B for Metric Conversion)

9003 0 0736

BEST AVAILABLE COPY

4.4.1 Origin and Stability of Salt Domes

Geologists generally agree on three points concerning the origin of salt structures:

- Salt domes have been derived from a sedimentary salt bed
- Plastic flow has created diapiric structures (domes)
- Density differences between the salt and the overlying sediments, plus down-building of sediments due to loading around the domes, are sufficient to cause dome development.

It is important to note that buoyancy and sediment-loading are nontectonic processes.

The Louann salt of late Triassic-early Jurassic age is the source or "mother" salt for dome formation. The salt presumably was deposited in an evaporating sea to a thickness of several thousand feet. From late Jurassic through Tertiary, a time span of 120 million years, virtually continuous sedimentation buried this layer to a depth of several miles. This sedimentary loading produced both lateral and vertical plastic movement of the salt, the initial mobilization possibly, but not necessarily, associated with tectonic activity. Initial salt movement produced pillows and ridges. During the Cretaceous, diapirs developed from the deeper pillows to form the salt domes of interest.

Because the mobile salt formed a substratum for overlying sedimentation, the salt movement affected the thickness and lithology of the overlying formations. Areas the salt evacuated to form these growing structures became structural basins and rim synclines. Rim synclines are structural depressions that partially or completely encircle most domes. Such a depression is thought to be caused by the sinking of the overlying sediment into the space left during the lateral flow of the salt into the dome. Hence, it is an indication of how large an area contributed salt to the dome. The rim synclines are thought to typically migrate inward and upward with time as the salt in the mother bed is depleted.

Hence, stratigraphic analysis permits the interpretation of patterns and volumes of salt movement through time as described by Kupfer[29] and Kumar[30:Y]. Interpretations of some domes, such as Hainesville in east Texas[31] and Minden in north Louisiana by Law Engineering Testing Company[32], demonstrate unroofing and loss of salt to the surface during Cretaceous time. These domes are characterized by pronounced rim synclines so that beds dip toward the domal peripheries. Kehle[33] considers such domes mature and incapable of reactivation because all of the salt in their original underlying pillows has been evacuated into or through the dome.

This method, as well as structural effects on the beds contiguous to the domes (e.g., their structural uplift, dip angles, and rate of fault growth), permit the upward movement of the salt in the domes to be computed. Unconformities that are localized above and adjacent to the salt dome also indicate when growth occurred. Each serves as a permanent record of the interval of relative uplift of the domal area with respect to adjacent sediments in the basin where deposition was continuous. Maximum rates of vertical movement generally occurred during the Mesozoic, but in some cases may have occurred in the early Tertiary.

Studies by Balk[34,35], Muehlberger[36,37], and Kupfer[29,38] in eight mines in Gulf Coast salt domes reveal vertical folds that are consistent with the foregoing description of lateral and then vertical salt movement that formed the domes. The bands are believed to represent original horizontal bedding of the Louann salt that were deformed in this fashion. Due to vertical movement of the salt during the dome-forming process, locally complex and highly folded structures with vertical axes that resemble the folds in window drapes were produced. Also from these studies, some domes are believed by some investigators to have developed as successive "spines" rather than as a single plug[29]. Vertical zones occur between the spines and contain clay, water, sand, gas, or other impurities. "Shear" or "anomalous" zones have been identified in several coastal salt domes. However, it has been suggested that the Gulf Coast interior domes may not have as complex a growth history as the coastal domes and that these zones may not be common or even present.[22]

Except for surficial alluvial deposits such as the flood plains and terraces of Quaternary age and, in Mississippi, the Plio-Pleistocene, Citronelle-Willis Formation, regional sedimentation ceased during the Eocene in east Texas and north Louisiana and during the Miocene in Mississippi. Cessation of regional sediment deposition eliminated a motive force for domal growth. Stabilization can be confirmed where appropriate Quaternary deposits exist over the domes. In such cases, as shown by Kolb[30:VI] at Vacherie, lack of deformation indicates lack of subsequent movement.

4.4.2 Characteristics of Salt Domes

Features associated with domes are the salt pillar, caprock, and stratigraphic and structural effects in the enclosing sediment.

The most notable feature of a salt dome is the salt pillar, which consists of a large column of salt extending from a deep source layer to varying depths below the present-day ground surface. The top of the salt may be flat, mushroomed, tapered, or irregular. The diameter of a salt pillar is usually at least 1 mile but may be less than or much greater than 1 mile (1.6 kilometers). A salt pillar may be circular, elliptical, or somewhat irregular. In a number of domes the upper portions of pillars bulge outward (mushroom) and are underlain by sediments. These overhangs usually occur within a few thousand feet of the surface.

Caprock composed of anhydrite, gypsum, and/or limestone occurs on all studied domes. The limestone is generally at the top of the caprock and anhydrite at the base, with gypsum, and some calcite in the middle. Anhydrite may also drape down the sides like a hood. Additionally, it forms overhangs and in some cases, extends beneath overhangs. The caprock may be absent but is normally 300 to 400 feet (about 90 to 120 meters) thick. However, it may be as much as 1,000 feet (about 300 meters) thick.[3] Commonly, it is thickest and most extensive over dome centers. Caprock is commonly brecciated or sheared and may contain fragments of adjacent strata, especially in the upper part of the caprock.

The current views on the mechanism of caprock formation support either the residual accumulation theory or the precipitation-in-place theory. Residual accumulation assumes that the caprock was formed at the top of the salt dome some time in the past as the salt dissolved by ground water, leaving less soluble materials (mainly anhydrite) behind. Such anhydrite comprises a small percentage of the original salt mass and is generally believed to have been deposited with the salt from sea water when the Louann salt beds were formed. An alternate explanation by Paulson[39] suggests that some of the caprock has been brought up along with the developing dome from evaporites originally beneath the salt bed in the evaporite basin. The second theory, precipitation-in-place, assumes that salt brine from deep saline aquifers rose along the salt dome stock and precipitated caprock on top of the dome when the dome top came into contact with a fresh-water aquifer.

The draping effect of caprock should not be confused with what some writers define as a "gouge" zone, sometimes present along the dome flanks. Normally, this sheath-like layer refers to a complex zone of material along the periphery of the dome. It consists of a mixture of limestone, shale, and sometimes anhydrite. This is believed to be the result of shearing and incorporation of sediments into the zone adjacent to the dome flanks as the sediments moved downward relative to the upward moving salt during dome development. This sheath sometimes forms an impermeable zone adjacent to the salt[23], as at Oakwood dome in Texas.

The piercement effect of salt domes on adjacent and superjacent sediment results in deformation and faulting of shallow over-dome sediment. Such faults may be radial or tangential to the flanks of the dome. In addition, a central graben fault-pattern is very common over salt domes created by tensional stresses. Experiments by Currie[40] showed that the formation of a graben can be the result of domal extension of the sediments over the core during sedimentation. Other theories of central graben formation suggest that it is due to collapse of the surface sediment after dissolution of the underlying salt by ground water.

Peripheral strata may dip gently toward domes that have pronounced rim synclines. In other cases beds dip away from the domes, often at high angles. Formations overlying domes are usually uplifted by arching and faulting to some extent.

The salt dome interiors are almost pure sodium chloride. The grain-size of the salt is coarse and distinctly crystalline, with prominent cubic cleavage. Most halite crystals range from 1/4- to 1/2-inch (about 1/2 to 1 centimeter) in diameter. However, fine- to very-fine-grained salt also occurs. Pods of extremely coarse-grained salt also occur with crystals 1 to 2 inches (about 2 1/2 to 5 centimeters) or more across, usually aligned parallel to the banding.

Minor amounts of anhydrite, commonly constituting 1 to 10 percent, are present in the salt either as finely disseminated crystals or in large fragments. A small amount of anhydrite results in a dark discoloration contrasting to white salt. This produces banding representing original depositional layers now deformed into vertical folds, as described previously.

Carbonates, sulfides, and sulfate minerals have also been reported. Minor amounts of potash appear in some domal salt. Inclusions of country rock, such as sandstone, occur in some domes.

Porosity and permeability of domal salt varies from low to virtually nonexistent. Inclusions of brine, oil, and gas are known from some domes. Minor seeps have been found in some salt mines, particularly those located near the edge or top of the shallow salt stocks located near or on the Gulf Coast. These anomalous features occur in localized vertical zones that also are the sites of occasional outbursts of material during mining. Kupfer[29] regards these as boundary zones between individual spines or along the exterior of the salt stock.

This section describes the eight domes studied.

Louisiana

- Rayburn's dome is located in southeastern Bienville Parish 6 miles (9.5 kilometers) northeast of Saline and 2 miles (about 3 kilometers) west of Friendship in northern Louisiana.
- Vacherie dome is located in southeastern Webster and northwestern Bienville Parishes, 2 miles (about 3 kilometers) east of Heflin in northern Louisiana.

Mississippi

- Cypress Creek dome is located in south central Perry County 4 miles (about 6.5 kilometers) southeast of New Augusta and partly within the boundaries of both Camp Shelby and the DeSoto National Forest in southeastern Mississippi.
- Lampton dome is located in east central Marion County 6 miles (about 9.5 kilometers) southeast of Columbia and 4.5 miles (7.2 kilometers) east of Lampton in southwestern Mississippi.
- Richton dome is located in northern Perry County, the dome center 2 miles (about 3 kilometers) west of Richton in southeastern Mississippi.

Texas

- Keechi dome is located in north central Anderson County 5 miles (about 8 kilometers) northwest of Palestine and 2.5 miles (about 4 kilometers) southeast of Montalba in eastern Texas.
- Oakwood dome is located on the Freestone-Leon county line 9 miles (about 14.5 kilometers) northeast of Buffalo and 1.5 miles (about 2.5 kilometers) northwest of Keechi in eastern Texas.
- Palestine dome is located in western Anderson County 4.5 miles (about 7 kilometers) west of Palestine in eastern Texas.

REFERENCES

1. National Academy of Sciences-National Research Council. 1957. The Disposal of Radioactive Waste on Land, Division of Earth Sciences, Committee on Waste Disposal, Report, Pub. 519, Washington, D.C.

2. National Academy of Sciences-National Research Council. 1970. Disposal of Solid Radioactive Waste in Bedded Salt Deposits, Committee on Radioactive Waste Management, Report, Washington D.C.

4. Johnson, K. S., and S. Gonzales. 1978. Salt Deposits in the U.S. and Regional Characteristics Important for Storage of Radioactive Waste, Y/OWI/SUB-741411, Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

5. LeGrand, H. E. 1962. Geology and Ground-Water Hydrology of the Atlantic and Gulf Coastal Plain as Related to Disposal of Radioactive Wastes, U.S. Geological Survey Open-File Report TEI-805.

6. U.S. Bureau of Mines. 1961. An Investigation of Salt Domes for Potential Nuclear Test Sites, U.S. Bureau of Mines Administration, Report.

7. Bradshaw, R. L., and W. C. McClain, eds. 1971. Project Salt Vault: A Demonstration of the Disposal of High Activity Wastes in Underground Salt Mines, ORNL-4555, Oak Ridge National Laboratory.

8. Gera, F. 1972. "Review of Salt Tectonics in Relation to the Disposal of Radioactive Wastes in Salt Formations", Geological Society of America Bulletin, Vol. 83, p. 3551-3574.

9. Halbouty, M. T. 1980. Salt Domes, Gulf Region, United States and Mexico, 2nd Edition. Gulf Publishing Company, Houston, TX.

10. Murray, G. E. 1968. "Salt Structures of Gulf of Mexico Basin--A Review", in Diapirism and Diapirs--A Symposium, American Association of Petroleum Geologists Memoir, Vol. 8, p. 99-121.

11. Bornhauser, M. 1958. "Gulf Coast Tectonics", AAPG Bulletin, V. 42, p. 339-370.

12. Anderson, R. E., D. H. Eargle, and R. O. Davis. 1973. Geologic and Hydrologic Summary of Salt Domes in Gulf Coast Region of Texas, Louisiana, Mississippi and Alabama, Open-File Report USGS-4339-2, U.S. Geological Survey.

13. Ledbetter, J. O., W. R. Kaiser, and E. A. Ripperger. "Radioactive Waste Management by Burial in Salt Domes", Unpublished Report, AEC Contract AT 40-1-4639, Engineering Mechanics Research Laboratory, University of Texas, Austin, TX, p. 82.

14. Martinez, J. D., D. H. Kupfer, R. L. Thomas, C. G. Smith, and C. R. Kolb. 1975. An Investigation of the Utility of Gulf Coast Salt Domes for the Storage or Disposal of Radioactive Waste, ORNL/SUB-4112/10, Institute for Environmental Studies, Louisiana State University, Baton Rouge, LA.

15. Martinez, J. D., R. L. Thomas, D. H. Kupfer, C. G. Smith, Jr., C. R. Kolb, E. J. Newchurch, R. E. Wilcox, T. A. Manning, Jr., M. Romberg, A. J. Lewis, and J. E. Rovik. 1976. An Investigation of the Utility of Gulf Coast Salt Domes for the Storage or Disposal of Radioactive Wastes, ORNL/SUB-4112/25, Institute for Environmental Studies, Louisiana State University, Baton Rouge, LA.

16. Netherland, Sewell and Associates, Inc. 1976. Geologic Study of the Interior Salt Domes of Northeast Texas Salt-Dome Basin to Investigate Their Suitability for Possible Storage of Radioactive Waste Material, Y/OWI/SUB-76-99939, Report to OWI, UCC Nuclear Division, Oak Ridge, TN, May.

17. Law Engineering Testing Company. 1978. Geologic Evaluation of Gulf Coast Salt Domes, National Waste Terminal Storage Program, ONWI LIB 0092, Marietta, GA, Draft, April.

18. Bechtel National, Inc. 1978. Regional Environmental Characterization Report for the Gulf Interior Region and Surrounding Territory, ONWI/SUB/78/512-01600-1, San Francisco, CA, Draft.

19. Battelle Project Management Division. 1979. Summary Characterization and Recommendation of Study Areas for the Gulf Interior Region, ONWI-18, EY-76-C-06-1830, for the U.S. Department of Energy, Final Draft, May.

20. Brunton, G. D., and W. D. McClain. 1977. Geological Criteria for Radioactive Waste Repositories, Y/OWI/TM-47, Office of Waste Isolation - Union Carbide Corporation, Nuclear Division.

21. Brunton, G. D., R. B. Laughon, and W. D. McClain. 1978. Screening Specifications for Gulf Coast Salt Domes, Y/OWI/TM-48, Oak Ridge National Laboratory, Oak Ridge, TN.

22. Law Engineering Testing Company. 1980. Area Characterization Report, Vol. I, Introduction, Background, and Summary, Gulf Coast Salt Domes Project, Marietta, GA, Draft.

23. Law Engineering Testing Company. 1980. Area Characterization Report, Vol. II, East Texas Study Area, Gulf Coast Salt Domes Project, Marietta, GA, Draft.

24. Law Engineering Testing Company. 1980. Area Characterization Report, Vol. III, North Louisiana Study Area. Gulf Coast Salt Domes Project, Marietta, GA, Draft.

25. Law Engineering Testing Company. 1980. Area Characterization Report, Vol. IV, Mississippi Area Study, Gulf Coast Salt Domes Project, Marietta, GA, Draft.

26. Bechtel National, Inc. 1980. Environmental Characterization Report for the Louisiana Study Area; Gulf Coast Interior Region, ONWI-192, San Francisco, CA, Draft, November.

27. Bechtel National, Inc. 1980. Environmental Characterization Report for the Mississippi Study Area; Gulf Interior Region, ONWI-193, San Francisco, CA, Draft, November.

28. Bechtel National, Inc. 1980. Environmental Characterization Report for the Texas Study Area; Gulf Interior Region, ONWI-194, San Francisco, CA, Draft, November.

29. Kupfer, D. H. 1976. "Shear Zones Inside Gulf Coast Salt Stocks Help to Delineate Spines of Movement", AAPG Bulletin, Vol. 60, No. 9, pp. 1434-1447.

30. Martinez, J. D., R. L. Thoms, C. G. Smith, Jr., C. R. Kolb, E. J. Newchurch, and R. E. Wilcox. 1977. An Investigation of the Utility of Gulf Coast Salt Domes for the Storage or Disposal of Radioactive Wastes, Y/OWI/SUB-4112/37, Institute for Environmental Studies, Louisiana State University, Baton Rouge, LA.

31. Loocke, J. E. 1978. "Growth History of the Hainesville Salt Dome, Wood County, Texas", University of Texas Thesis, Austin, TX.

32. Law Engineering Testing Company. 1978. "Minden Salt Dome Geology and Growth History", Gulf Coast Salt Dome Project, LETCo Job. No. MV7670.01, Marietta, GA.

33. Kehle, R. O. 1978. Identifying Suitable Piercement Salt Domes for Nuclear Waste Storage Sites, Report by Turk, Kehle and Associates, Austin, Texas, for Law Engineering Testing Company, Marietta, GA.

34. Balk, R. 1949. "Structure of Grand Saline Salt Dome, Van Zandt County, Texas", AAPG Bulletin, Vol. 33, pp. 1791-1829.

35. Balk, R. 1953. "Salt Structure of Jefferson Island Salt Dome, Iberia and Vermillion Parishes, Louisiana", AAPG Bulletin, Vol. 37, pp. 2455-2474.

36. Muehlberger, W. R. 1959. Internal Structure of the Grand Saline Salt Dome, Van Zandt County, Texas, RI 38, Bureau of Economic Geology, University of Texas, Austin, TX.

37. Muehlberger, W. R. 1968. Internal Structures and Mode of Uplift of Texas and Louisiana Domes, GSA Special Paper 88, pp. 359-364.

38. Kupfer, D. H. 1970. "Conflicting Strain Pattern in the Salt of Gulf Coast Salt Domes and Their Genetic Implications", Third Symposium on Salt, pp. 271-281.

39. Paulson, O. L., Jr. 1977. "Sub-Salt Origin of Salt Dome Caprock", Transactions of the Gulf Coast Association Geological Society, Vol. 27, pp. 134-138.

40. Currie, J. D. 1956. "Role of Concurrent Deposition and Deformation of Sediments in Development of Salt-Dome Graben Structures", AAPG Bulletin, Vol. 40, No. 1, pp. 1-16.

5.0 DESCRIPTION OF FACTORS

This section discusses the factors considered potentially important in the decision. Factors are discussed in terms of (1) significance, (2) level and scope of data required, (3) data acquisition methods, and (4) adequacy of available data. Hence, this section accounts for the first step of the decision procedure. The remainder of the decision procedure and the recommendation of the preferred Gulf Coast salt domes are discussed in Section 6.0.

5.1 THE DECISION PROCESS

The screening process will identify locations (domes), some better than others. If many appear favorable, some should nonetheless be deferred from further study. Further study of all but the most favorable locations identified in this screening step is unnecessary and would be prohibitively expensive. Study of less favorable locations can be eliminated. Further studies, then, are focused on only as many favorable locations as reasonably necessary to (a) ensure that several locations are identified and ultimately prove acceptable and (b) to satisfy the requirements for consideration of reasonable alternatives through each screening step.

Locations (domes) may also be eliminated if there is a high likelihood that major siting criteria will not be met. In this situation, resources need not be expended to demonstrate site unsuitability. Screening decisions, then, are made to focus efforts on the most favorable and acceptable location (dome).

The general approach used for screening consists of several steps as follows:

Step 1. Identify factors (criteria and subcriteria) and supporting information needs important to the screening decision

Step 2. Gather the required information in accord with applicable consultation and concurrence procedures

Step 3. Identify candidate locations (domes)

Step 4. Evaluate each candidate location (dome) according to previously identified factors

Step 5. Compare and recommend candidate locations (domes)

Step 6. Review the screening decisions in accord with applicable consultation and concurrence procedures.

5.2 FACTORS CONSIDERED

Regional characterization studies identified eight domes as candidates for area characterization studies.[1] These eight domes were (1) Texas: Oakwood, Keechi, and Palestine, (2) Louisiana: Vacherie and Rayburn's, and (3) Mississippi: Lampton, Richton, and Cypress Creek. Early studies in Texas brought about the elimination of Palestine dome due to an extensive history of brining operations and subsequent collapse of overdome strata. This dome elimination was reported in ONWI-78[2] in 1979, leaving a total of seven domes studied during the remainder of the area characterization phase. The criterion and subcriterion utilized in the decision process, summarized in Section 3.2, are presented factor-by-factor in the following subsections.

5.2.1 Site Geometry

The following criterion is the basis for consideration of the site geometry in the repository selection process:

The site shall be located in a geologic environment that physically separates the radioactive wastes from the biosphere and that has geometry adequate for repository placement.

5.2.1.1 Depth to Host Rock

The following subcriterion is the basis and requirement for consideration of the depth of host rock (distance from ground surface to top of host rock) in the site selection process:

The minimum depth of the repository waste emplacement area shall be such that credible human activities and natural processes acting at the surface will not unacceptably affect system performance.

In order to establish this depth, erosion and denudation rates and other phenomena must be evaluated.

5.2.1.1.1 Significance. This factor is important for locations where the host rock is erodible and/or soluble. Removal of the overburden by natural phenomena could expose the host rock to the environment and subject it to further erosion or dissolution.

Natural phenomena that could cause removal of the overburden and exposure of the host rock are significant changes in the extent of continental glaciation and meteor impact at the repository site.

These events are not likely to occur, but they provide an extreme case for assessing the vulnerability of the overburden to major climatic changes. Geomorphologic studies[3] indicate there could be a possible rise of sea level of from approximately 270 feet (about 82 meters)[4,5] to approximately 360 feet (about 110 meters), assuming a total melting of the world's ice. Rises in sea level would not provide a mechanism by which the overburden would be directly removed and the host rock exposed, but could cause the repository site to be inundated.

A large sea level drop has been proposed[6] for the Illinoian Glacial Stage (of approximately 525 feet or about 160 meters), based on the area and thickness of the Illinoian ice sheet. However, this remains unconfirmed by any substantial subsea evidence of shoreline features. Landward leveling of the coast to this depth by headward stream erosion and cliff retreat is an event that is considered improbable.[3] The process may require more time than the intended 10,000-year period of waste isolation specified for emphasis for prediction of changes in natural conditions and the performance of the geologic repository in the draft regulations, 10 CFR 60.[7] In addition, cliff retreat of this magnitude is unknown for previous sea level lowering. Postulated from this improbable scenario is that Rayburn's and Keechi domes be exposed and possibly breached. All other domes would maintain more than 100 feet (more than 30 meters) of existing overburden cover. In separate studies, Kolb[8] and Alford[9] concluded that the maximum erosion in northern Louisiana in the next quarter of a million years will be approximately 120 feet (about 37 meters), 70 feet (about 21 meters) of which would be due to regional uplift and 50 feet (about 15 meters) due to scour during a hypothetical glacial period. Based on the above, the worst-case credible erosion limits may be established as 425 feet (129 meters) for Texas domes and 275 feet (84 meters) for Mississippi domes. For Louisiana, the full 525 feet (160 meters) are used in this analysis for the erosion limit.

A repository site being breached by a meteorite is discussed in the <u>Final Environmental Impact Statement--Management of Commercially Generated Radioactive Waste</u>.[10] The probabilities of a 25-meter meteorite striking a repository site is assessed as 2×10^{-13} per year.[11]

<u>5.2.1.1.2 Level of Data</u>. At the area characterization stage, it is sufficient to know three types of data: (1) the description of the nominal dome depth, including depths to caprock and salt; (2) the general description of supradome topographic relief; and (3) the calculated rate of future erosion based on credible natural events.

<u>5.2.1.1.3 Data Acquisition Methods</u>. At this stage of investigations, data from one or two drill holes that penetrate the caprock and the salt are sufficient. The information obtained from the drill holes is augmented by data from gravity and seismic surveys, both shallow high resolution and deep common depth point (CDP).

<u>5.2.1.1.4 Adequacy of Data</u>. The available data are adequate because drill holes exist to determine dome overburden depth. Core holes and gravity/seismic surveys exist to determine the top of the salt and caprock. Topographic relief was determined on topographic maps. The climatological and glaciological work of a number of researchers was also used.

5.2.1.2 Thickness of Host Rock

The following subcriterion is the basis and requirement for consideration of the thickness of host-rock units in the repository site selection process:

> The thickness and lateral extent of the geologic system surrounding the waste emplacement area shall be sufficient to accommodate the repository and a buffer zone and to ensure that impacts induced by construction of the repository and by waste emplacement will not unacceptably affect system performance.
>
> Consideration of these impacts will include evaluation of induced stresses, heat, and radiation generated by the waste.

5.2.1.2.1 Significance. The host rock should contain sufficient thickness to contain repository workings, with a buffer zone of sufficient dimensions to protect the dome from dissolution.

According to the draft of NRC's 10 CFR 60,(7) the DOE shall select the site so that, to the extent practicable, the geologic setting:

> "possesses a geologic framework...that permits excavation of a stable subsurface opening and the emplacement of waste at a minimum depth of 300 meters from the ground surface."
>
> This minimum depth includes the host rock as well as overburden.

5.2.1.2.2 Level of Data. At the area characterization phase it is adequate to know the size and shape of a salt dome from gravity modeling, aided by data from deep drill holes into the caprock or salt stock. Gravity and borehole data can be augmented by information obtained by high resolution seismic lines to better delineate the shoulder zone of the dome and the dome's configuration.

5.2.1.2.3 Data Acquisition Methods. Gravity and/or seismic data supported by a few drill holes will be required. At the area characterization stage, only a general understanding of dome morphology and genesis is required. This can be obtained by examining the general stratigraphic record around and over the dome, as outlined in Table 5-1, and incorporating any available structural information into the analysis.

TABLE 5-1. DESIRED FIELD DATA
(See Appendix B for metric conversion)

Technique	Number	Location
Deep drill holes	one	Over dome; to caprock or into salt
Gravity	Several hundred stations	Over dome, near dome
Seismic	3 lines/dome of 2-5 miles each	Dome periphery outward

5.2.1.2.4 Adequacy of Data. Gravity data are available for all domes: Oakwood, Keechi, Cypress Creek, Lampton (limited number of data stations), Richton, Vacherie, and Rayburn's. Seismic data are available for all domes. Deep drill holes have penetrated the Oakwood, Cypress Creek, Richton, Vacherie, and Rayburn's domes. Exploratory drill-hole data are available for all domes. High resolution seismic data are available for Cypress Creek, Richton, and Keechi. The gravity and seismic data show the approximate size and shape of each dome; the drill-hole data support and confirm computer models developed for each dome, including thickness and distribution of caprock. The data are considered adequate for all domes except Lampton. Access to Lampton dome has been denied by the Mississippi State Wildlife Commission[12,13] and access to Vacherie and Rayburn's for high resolution seismic surveys was not obtained in time to allow results to be included in this Area Characterization Report; however, sufficient CDP data have been obtained to obviate the need for high resolution seismic surveys at the area characterization phase.

5.2.1.3 Lateral Extent of Host Rock

The following subcriterion is the basis and requirement for consideration of the lateral extent of the host rock:

> The thickness and lateral extent of the geologic system surrounding the waste emplacement area shall be sufficient to accommodate the repository and a buffer zone and to ensure that impacts induced by construction of the repository and by waste emplacement will not unacceptably affect system performance.
>
> Consideration of these impacts will include evaluation of induced stresses, the waste's thermal output, and the existence of a buffer zone.

5.2.1.3.1 Significance. The host rock should provide the necessary containment for the first 1,000 years after decommissioning of the geologic repository operations area and as long thereafter as is reasonably achievable[7] by maintaining nuclear waste in its original emplaced position and condition. To accomplish this, the host rock unit at the repository horizon must have adequate thickness and lateral extent (1) to accommodate the repository workings plus buffer zones and (2) to ensure that impacts induced by repository construction and waste emplacement do not adversely affect repository performance.

The repository workings within the host rock are comprised of access and service tunnels, rooms, and possible subfloor drill holes, for waste emplacement and a portion of the access and service shafts.

The space required for the repository workings can be calculated for a given quantity of nuclear waste to be disposed of in a single repository, for a conservative thermal loading determined to yield near-field temperatures well below the decrepitation temperature of salt, and far-field deformations that would not degrade the containment and isolation capabilities.

Around the extremities of the repository workings, a buffer zone of adequate dimension should be provided to allow for:

(1) Uncertainties in characterization and mapping of the actual location of the dome flank

(2) Compensation for local and minor anomalies that may exist but have not been detected within the peripheral zone of the dome

(3) Local or general dissolutioning of the salt adjacent to the dome periphery

(4) Dissipation of the heat at the repository horizon, to preclude an unacceptable increase in ground-water temperature that might lead to an increased dissolution rate and degradation of the edge of the dome due to thermal induced deformations

(5) A conservative margin to assure that breaching of the buffer zone will not occur; such a breach could result in formation of pathways for ground water to reach the repository workings and the emplaced waste.

Based on these considerations the area required to provide an adequate buffer zone is calculated and added to the area of the repository workings. This determines the minimum gross area that domes must provide, at an elevation between approximately 1,000 feet and 3,000 feet (between approximately 300 meters and 900 meters) below surface.

Domes that do not provide the minimum area are eliminated since they will not accommodate the quantity of anticipated waste or will not provide the minimum buffer zone required for assured containment, or both.

Domes that provide at least the minimum area are re-examined to calculate the actual width of the available buffer zone.

The buffer zone is a vital natural barrier to assure waste containment and isolation. All other factors being equal, the dome or domes with buffer zones larger than the acceptable minimum would be favored since they provide additional conservatism. Domes meeting the minimum buffer zone requirements would thus be ranked to reflect that additional conservatism.

The importance of the containment function of the host rock and surrounding strata is reflected in the NRC advance notice for rulemaking[7]:

> "(9) The Department (DOE) shall determine by appropriate analyses the extent of the volume of rock within which the geologic framework, ground-water flow, ground-water chemistry, or geomechanical properties are anticipated to be significantly affected by construction of the geologic repository or by the presence of the emplaced wastes, with emphasis on the thermal loading of the latter."

Neither construction nor thermal loading is expected to significantly affect the host rock. The buffer zone around the repository workings will provide assurance that if there were any effects they would remain within the limits of the host rock and not degrade the isolation provided by the surrounding geosphere.

An adequate buffer zone, approximately 800 feet (about 245 meters) in width, will limit the increase in surrounding aquifer temperature to approximately 10 F (about 5.6 C) and provide ample assurance that construction activities have no effect on the surrounding strata. The 800-foot (245-meter) buffer figure is based on conservative extrapolations from standard mining practices and estimates of temperature dissipation in a lateral direction.[14] This is more adequately developed in Section 5.2.1.3.2 below.

<u>5.2.1.3.2 Level of Data.</u> The data required to evaluate the adequacy of the lateral extent (area size) of the host rock are:

(1) Configuration and dimensions of the dome at different depths from 1,000 feet to approximately 3,000 feet (about 300 meters to 900 meters).

The configuration and size of the domes are needed to determine the adequacy of each dome and to evaluate the buffer zone provided for a given size of repository. Gravity survey data, calibrated by at least one boring to salt on an appropriate grid, are adequate at this stage of the investigations. Grid size is dependent on the areal size of the dome and the accuracy desired. The number of stations at each dome may vary from 300 to 600 for a typical survey at this stage of investigations. High resolution seismic survey confirmations are available at this stage of investigations only for Cypress Creek, Keechi, and Richton domes.

(2) The areal extent (size and configuration) of the repository depends on the establishment of a minimum limit on the inventory of waste to be disposed of and a maximum limit on the thermal loading at which the waste

will be placed in the repository. The amount of waste will depend on the geographic region to be served by the repository, the projected number of operating reactors within the service region, and the number of years during which waste will be received.

The number of repositories to be constructed in a region will depend upon environmental impacts that multiple installations would create and the economics of disposal. For example, available data indicate that the unit cost of disposal in a 1,200-acre repository is 65 percent higher than that in a 2,000-acre (about 810-hectare) repository, while the unit cost of disposal decreases by only 23 percent when the size of repository is increased from 2,000 acres to 2,800 acres (about 1,130 hectares).[15:Table III-5]

Although specific information on service regions needed for determining the inventory of waste is not presently available, a repository whose working size is 1,500 acres (about 600 hectares) could accommodate approximately 75,000 metric tons uranium (MTU) of spent fuel at a thermal loading of 60 kilowatts (KW) per acre. If the growth of nuclear power in the United States is limited to 160 gigawatts (electric) (GWe) by the year 2000, the total inventory of spent fuel to be disposed of during the lifetime of the operating reactors would be approximately 187,000 MTU. The 160 GWe total represents the capacity of presently operating reactors (59 GWe) plus those under construction and in NRC review for construction permits. This projection does not assume that any new applications for construction will be submitted by the utilities. Assuming that 40 percent of this generating capacity would be located in the southeastern quadrant of the United States and that the service region to be established will cover an equivalent area, then the repository serving the southeast should, at the minimum, have the capacity to accommodate 40 percent of 187,000 MTU or 75,000 MTU of spent fuel.[16]

As stated above, a 1,500-acre (about 600-hectare) (net repository: acreage is defined as total acreage available less buffer zone) repository could accommodate an inventory of spent fuel of this size. In earlier studies[17, 18] a size of 1,000 acres (about 400 hectares) was used for screening of domes. It is apparent that a dome that can provide a repository area of only 1,000 acres (about 400 hectares) would be very limited in size, thus requiring multiple repositories in a given region. Also, if any unforeseen anomolous zones are discovered in the development phase of the mine, the available space would be reduced further. For these reasons it is prudent that domes which cannot provide a net repository area of 1,500 acres (about 600 hectares) be eliminated from further consideration in the location phase of the investigations.

If the nuclear electrical generation is more than 160 GWe or if the thermal loading is kept below 60 KW/acre to achieve additional conservatism, an additional repository will have to be constructed to serve the region (provided the first site can accommodate only the assumed minimum of 75,000 MTU of spent fuel).

The assumed thermal loading of 60 KW/acre will yield maximum host rock temperatures of less than 140 C,[19] which is below the lower bound of decrepitation temperature of 260 C for salt.

A rule commonly used on minimum buffer zones in five salt mines in the Gulf Coast region (Weeks Island, Avery Island, Jefferson Island, Belle Isle, and Cote Blanche) was to develop the extremities of the mine no closer than 300 feet (about 90 meters) of the dome flank. When adhered to, this buffer zone distance has generally provided adequate compensation for uncertainties, such as existence of undetected anomalies and inaccuracies in locating the flank of the dome. In the case of salt domes being studied for repositories, additional considerations such as long-term dissolutioning and effects caused by temperature increase must be included in allowing an adequate buffer zone. A bounding calculation on dome dissolution indicates that approximately 1.3 million years would be required to breach 800 feet (about 245 meters) of buffer zone.[14:4-11 to 4-17] In addition, the temperature at the flank of a dome at the repository horizon, with an 800-foot (245-meter) buffer zone, is expected to increase approximately 13 F (about 7 C) for 75 KW/acre loading.[20] For 60 KW/acre loading, the increase would be approximately 10 F (about 6 C). An increase of 10 F (about 6 C) at the dome flank will result in a temperature increase of less than 10 F (about 6 C) in the surrounding aquifer. However, the actual temperature depends on the site and must be verified for the dome selected for further studies. On the basis of these observations, a minimum buffer zone width of 800 feet (about 2,454 meters) was selected as conservative and a reference value for assessing the adequacy of dome sizes.

<u>5.2.1.3.3 Data Acquisition Methods.</u> The shape and dimensions of the dome are determined by conducting gravity and seismic surveys and by examining drill-hole logs. In conducting gravity surveys, a grid of adequate spacing is laid out providing the required number of stations.

The drill-hole data are examined to verify the limits (flanks and top) of salt and caprock for each dome to calibrate the gravity data.

<u>5.2.1.3.4 Adequacy of Data.</u> The first source of information on actual sizes of the domes was data from previous explorations conducted by others. Where applicable, drilling data as well as geophysical data were acquired and utilized. Gravity data obtained by others were purchased for Oakwood and Keechi domes. Existing and project drilling data were examined as confirmation of the size and shape of Oakwood dome.

Field activities to assess the sizes and configurations on certain domes included gravity surveys and in some cases high resolution seismic surveys. Gravity and high resolution seismic surveys were conducted at Richton, Keechi, and Cypress Creek. Purchased common depth point (CDP) seismic data were sufficient for Oakwood and Vacherie domes. Gravity surveys were conducted at Rayburn's.

Approximately half of Lampton dome lies beneath a wildlife refuge managed by the Mississippi Wildlife Management Commission. The Commission will not grant access permits to conduct gravity surveys. Where access to the dome was available, a limited amount of gravity survey work was conducted. With the data available from previous surveys conducted by others and limited surveys conducted under this program, the lateral extent of Lampton dome was determined. Further efforts to gain access to Lampton dome have not been pursued, in accordance with DOE's policy of consultation and concurrence with local and state authorities. The accuracy of existing data on the areal extent of Lampton dome is judged to be plus or minus 40 percent, meaning the calculated acreage could vary by a maximum of 200 acres (about 80 hectares), thus making the available acreage no more than 700 acres (280 hectares). Even if this larger size were proven, Lampton's status would not change.

Where gravity survey results were confirmed by seismic surveys and drill hole data, uncertainties in the sizes and shapes of the domes are decreased. Conversely, at the sites where only gravity survey data were available, the accuracy of the size determinations is less.

Using available data, the decision can be made to (1) eliminate certain domes from further consideration because of their inadequacy to provide the assumed required space, (2) to maintain certain domes as viable candidates, and (3) to evaluate the buffer zone size with respect to a given repository loading and thus assess their containment capability. The accuracy of the data regarding the size and shape of the domes varies with the type of investigations made at the site. However, it is not expected that the inaccuracies would be great enough to alter the recommendation. The domes are evaluated for assessment of the buffer zone that would be provided if 1,500 acres (607 hectares), concentrically located, is used for the repository (see Table 6-3).

5.2.2 Geohydrology

The following criterion is the basis for consideration of the geohydrologic regime in the repository selection process.

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

5.2.2.1 Geohydrologic Regime/Flow

The following subcriterion is the basis and requirement for consideration of ground-water flow in the repository site selection process:

The site shall be located so that the present and probable future geohydrological regime will minimize contact between ground water and wastes and will prevent radionuclide migration or transport from the repository to the accessible environment in unacceptable amounts.

The evaluation of the geohydrological regime will include characterization of ground-water residence times, travel times, recharge rates, potentiometric surfaces, and path lengths and orientations. These factors must be assessed to show that path lengths are long enough and transport times are slow enough under present and probable future conditions to constitute effective barriers to radionuclide transport.

5.2.2.1.1 Significance. The geologic formations at the repository site, the surrounding strata, and the characteristics and flow of ground water could have an impact on the containment and isolation of the waste from man's accessible environment and the biosphere in general. Moving ground water provides, by far, the most significant mechanism by which radionuclides could be transported from the repository to the biosphere. Such transport is most likely if ingress and egress to waste emplacement areas exist that allow ground water to reach the waste. The potential for and impact of this transport must be evaluated. The host rock provides the necessary containment by minimizing the likelihood that circulating ground water will contact the waste package.

Early in the site selection process, when several alternative sites are under investigation, a comparative assessment of the isolation qualities of the various sites can be accomplished by calculating the ground-water travel times via the shortest path from the repository to the biosphere. Such calculations yield conservatively low results because the sorptive capacities of the flow path formations have not been taken into consideration. If these calculations indicate travel times will be longer than limits cited in the criteria, it is assured that the site will more than meet isolation requirements when sorptive capacities are included in the calculations.

In assessing the isolation qualities of a site selected for construction of a repository, ground-water travel times and the capacity for radionuclide sorption will be considered by calculating transport times for each of the radionuclides in the waste inventory. These calculations will be used to evaluate radionuclide concentrations at the biosphere, which in turn will be compared with the limits set by the regulatory agencies (See Section 5.2.3).

The NRC criteria[7] for the hydrologic regime were used as guidance in assessing and comparing the Gulf Interior domes.

The document cites the following favorable site characteristics:

"(i) [Site] Exhibits demonstrable surface and subsurface geologic, geochemical, tectonic, and hydrologic stability since the beginning of the Quaternary period.

(ii) [Site] Contains a host rock and confining units that provide:

(a) Long ground-water residence times and long flow paths between the repository and the accessible environment.

(b) Inactive ground-water circulation within the host rock and surrounding confining units, and little hydraulic communication with adjacent hydrogeologic units due to formation characteristics, such as low intrinsic permeability and low fracture permeability of the rock mass.

(iii) [Site] Possesses ground-water flow characteristics that:

(a) Result in a host rock with very low water content.

(b) Prevent ground-water intrusion or circulation of ground-water in the host rock.

(c) Prevent significant upward ground-water flow between hydrogeologic units and along shafts, drifts, and boreholes.

(d) Result in low hydraulic gradients in the host rock and surrounding confining units.

(e) Result in horizontal or downward hydraulic gradients in the host rock and surrounding confining units.

(f) Result in ground-water residence times under ambient conditions, between the repository and the accessible environment, that exceed 1,000 years..."

DOE has used a more conservative ground-water residence time between the repository and accessible environment than 1,000 years. General Performance Objective No. 2 of the Proposed Rulemaking on the Storage and Disposal of Nuclear Waste--Statement of Position of the United States Department of Energy[15] used as guidance in its place, states:

"Disposal systems should provide reasonable assurance that wastes will be isolated from the accessible environment for a period of at least 10,000 years with no prediction of significant decreases in isolation beyond that time".

The DOE position, as stated in the Proposed Rulemaking on the Storage and Disposal of Nuclear Waste--Statement of Position of the United States Department of Energy[15] is that ground-water residence time and sorption, in combination, should provide a time barrier of 10,000 years to migration of radionuclides. Whereas the NRC specification refers to ground-water residence time alone, the number adopted by DOE addresses the more important question of radionuclide retention. If it can be shown that ground-water residence time alone exceeds 10,000 years, then the more difficult question of sorption need not be addressed at this stage of the investigations.

In addition to the favorable characteristics, the NRC's proposed regulations delineate certain potentially adverse natural conditions relating to the hydrologic regime. Those pertaining to subsurface hydrology are:

(i) There is potential for significant changes in hydrologic conditions including hydraulic gradient, average pore velocity, storativity, permeability, natural recharge, piezometric level, and discharge points.

(iii) There is reasonable potential for natural phenomena such as landslides, subsidence, or volcanic activity to create large scale impoundments that may affect the regional ground-water flow system.

(iv) There is a fault or fracture zone, irrespective of age of last movement, which has a horizontal length of more than a few hundreds of meters.

5.2.2.1.2 Level of Data. The level of data required at the area-to-location phase of the evaluation of the eight domes should be adequate to make the following findings:

(1) The isolation capability provided by the hydrologic/geochemical regime appears to meet the minimum requirements cited in the criteria. If the results of a conservative, bounding, lower limit travel time calculation indicate that the hydrologic travel time is 10,000 years or more, then the data needed at this stage may be limited to hydrologic considerations only. The geochemical data for assessment of sorptive characteristics and detailed hydrologic models will be prepared in the subsequent phase.

(2) A basis for comparison of the isolation capabilities provided by the sites under consideration may or may not exist. If the hydrologic travel times for all of the sites under investigation are significantly different, with some being close to the 10,000 year minimum, then a basis for comparison exists. The sites exhibiting lower travel times would have to be reexamined if the radionuclide transport times would be appreciably larger than the hydrologic travel times, due to sorptive characteristics of the surrounding strata. In this case, geochemical data will have to be obtained during the location phase investigations.

To formulate a matrix for differentiating among the domes under consideration, the following information should be obtained:

(a) The lithologic characteristics of the stratigraphic units to at least the first unit below the depth of the hypothetical repository horizon should be defined. These characteristics should include the thickness, position, nature of material (sand, clay, etc.), porosity, permeability, mineralogy, and some indication of physical properties. It is especially important to define the number, thickness, and nature of confining beds.

(b) The lithologic section should be utilized to determine those aquifers that conceivably could be the starting point of a flow path that radionuclides might take to the biosphere if a repository is breached.

(c) Aquifer properties should be obtained. These would include, for each aquifer, potentiometric head data (preferably sufficient data to define a potentiometric surface), transmissivity, hydraulic conductivity, storage coefficient, and the water chemistry and density distributions.

(d) From the potentiometric surface defined for each aquifer the direction of flow and probable discharge areas should be determined. Probable path lengths from potential repository location to the biosphere should be delineated. Additionally, such things as path orientation, the effect of existing pumping and recharge centers, and potential effect of hypothetical future pumping and recharge centers could also be analyzed if there appears to be a need. If the necessary aquifer and confining bed properties are known, travel times can be calculated from flow paths.

(e) An evaluation of the importance of vertical flows between aquifers can be obtained by analyses of the differential heads between aquifers, and by integrating the data from the confining beds.

<u>5.2.2.1.3 Data Acquisition Methods</u>. For the salt dome investigation, test holes were drilled both in the immediate vicinity of the domes under consideration and away from the domes. Holes were also drilled through the caprock and into the salt. Aquifer properties were determined for each significant aquifer to a depth approximating that of a hypothetical repository horizon. Caprock was also tested. Water samples were taken for water chemistry determinations. Piezometric surfaces and flow paths were determined from the resulting information. Existing aquifer data and characteristics were obtained through an exhaustive literature search of published and unpublished material.

<u>5.2.2.1.4 Adequacy of Available Data</u>. Presently, adequate data exist to show the direction and magnitude of ground-water movement within each basin and for each dome at least to a first approximation. Data are more than adequate for Cypress Creek and Richton domes. Data are adequate for Keechi, Oakwood, Rayburn's, and Vacherie domes. Information on the shallow aquifer systems is available at Rayburn's and Vacherie domes from earlier drilling. A considerable amount of data was obtained from the earlier extensive oil and gas exploratory drilling in the vicinity of Vacherie and both of the Texas domes (especially Oakwood). Data are marginal at Lampton dome.

With currently available data, current ground-water travel times were either calculated or qualitatively evaluated for the domes.[13,21,22] The level of studies depended on whether a particular dome looked promising for further studies. For example, Palestine dome was not included in these studies, and considerations on Lampton and Rayburn's were limited.

Three cases were assessed for determining isolation capability:

(1) Horizontal travel of water from the repository site to the accessible environment along a pathway coinciding with an aquifer. This assessment was a qualitative one and consisted of reviewing the ground-water flow paths around the domes.

Ground-water flow around the domes in deep saline aquifers, near proposed repository elevations, generally follows the dip of the sediments. The sediments dip down and thicken toward the Gulf of Mexico.

Ground-water discharge areas for the deep saline aquifers have not yet been identified. These areas, however, must be down dip from the domes indicating that travel times to the biosphere must be greater than vertical travel times computed from the flanks of the domes.

(2) Travel of water in a vertical direction has been calculated from the flank of the dome at the repository level to the accessible environment. These calculations were based on a number of assumptions as follows:

(a) The salt dome is assumed to be breached by an undefined mechanism.

(b) The starting point for the travel time analysis is in the geologic unit opposite the elevation of the repository.

(c) There are no effects due to variations in fluid density.

(d) The shortest path (vertical from the assumed starting point to the biosphere) is appropriate for the analysis.

(e) Steady, one-dimensional flow exists through a layered porous media system, flow is normal to the layered units and each lithologic layer is homogeneous and isotropic.

(f) Flow is within the range for which Darcy's Law is applicable.

(g) The base of the accessible environment coincides with the base of fresh water (total dissolved solids equal to 1,000 ppm).

(h) No short-circuiting paths for ground-water flow exist. Faults and their relation to ground-water flow paths will be studied in location and site characterization studies. Similarly, caprock and the interface between the salt and caprock will be characterized and analyzed during the qualification of a particular dome as a site.

The length of time for ground-water to flow vertically from the repository level to the biosphere was evaluated by collecting borehole-geophysical, aquifer test, and deep-well data, including water samples for laboratory analysis.

Geologic cross sections were developed for each dome using results of field and laboratory analysis. Literature values of permeability and porosity for confining beds of clay and limestone were utilized to prepare conservative, lower limit, bounding calculations of the transport time of water from the repository to the biosphere through the sedimentary section flanking the domes. The scenario assumed instantaneous transport of the waste from the repository through the salt buffer zone to the dome's periphery.

Computed travel times were greater than 250,000 years for all domes for which the calculations were made.(12,13,21,22) This is many times in excess of the 1,000-year period cited in the NRC draft criteria and the 10,000-year period adopted for this study. This, of course, is the result of the very thick and impermeable confining beds that surround the various domes, although the bounding calculations were performed utilizing generalized permeabilities for the confining media. A variation of one order of magnitude in the calculated travel times will not affect the acceptability of the domes, nor will it become a differentiating factor for comparison of domes.

(3) Travel times from repository level along the periphery of shaft seals to the top of the dome and from there vertically to the accessible environment were qualitatively determined. The initiating assumption for this scenario is that a future exploratory boring penetrates the salt dome at its flank and connects the repository to an adjacent, high pressure aquifer with a six-inch, uncased borehole. (Current data do not indicate the presence of this hydrostatic pressure differential. The assumption was made to compare the response of the dome systems in a postulated worst case scenario.) It is further assumed that the backfill salt has not been consolidated, allowing water to enter the repository and move past the waste and up the repository access shafts and through the annulus and around the cement plug in the caprock shaft holes and into the aquifer above the dome. This study was limited to the most promising four domes when all other factors were considered.

As a result of the hypothetical calculations, the travel times for all domes from repository workings to the top of the dome were in excess of 10,000 years: approximately 12,000 years for Cypress Creek, Richton, and Keechi, and 24,000 years for Vacherie.

The estimates of water travel time from the top of the domes to the base of fresh water (less than 1,000 ppm dissolved solids) were difficult because of the complexity of the strata overlying the domes. Travel times so obtained for Cypress Creek, Richton, and Keechi were negligible. The lower bound value for Vacherie was calculated as 52,000 years, based on the assumption that a thick clay layer uniformly covers the top of this dome. The geology above Vacherie is complex and this assumption may not be valid. A qualitative assessment of the sorptive characteristics of the surrounding strata was also made. The conclusion was that Vacherie exhibits the best characteristics, and Richton is next with about two-thirds of the value estimated for Vacherie. Cypress Creek and Keechi show much less, about one-twentieth that of Richton in sorptive potential. These evaluations were not refined, since the data for full characterization of overdome stratification were limited. More accurate calculations will be made for the final dome selected for banking.

The cumulative travel time in this scenario, using the assumptions discussed above, is therefore 12,000 years for Cypress Creek, Richton, and Keechi, and 76,000 years for Vacherie.

The time required to fill the backfilled repository workings with water and the impeding effects of hydraulic and salinity gradients in the sealed shafts, as well as viscosity and density effects at depth, would considerably lengthen the travel time for this scenario. However, these were not included in this analysis.

In the latter two cases of vertical flow of ground water, one adjacent to the dome and the other through the sealed shafts and strata above, the accessible environment was defined as being above the base of fresh water where the dissolved solids are 1,000 ppm or less. The tops of the domes evaluated were all lower than the freshwater/salt water interface line of 1,000 ppm. Only the strata between the top of the dome and the interface line were considered in evaluating the travel time and presumed sorptive characteristics.

5.2.2.2 Hydrological Regime/Modeling

The following subcriterion is the basis and requirement for consideration of modeling in the repository site selection process:

> The site shall be located so that the hydrological regime can be sufficiently characterized to permit modeling to show that present and probable future conditions have no unacceptable impact on repository performance.
>
> Evaluation of the geohydrologic regime shall include consideration of surface conditions or features such as impoundments or glaciers, and changes in subsurface conditions induced, for example, by aquifer pumpage or injection, or thermally-induced ground-water flow.

5.2.2.2.1 Significance. Modeling represents an approach that can aid in evaluating the adequacy of the data base for describing the hydrological regime. Early modeling efforts and sensitivity analyses will identify the data that are most important to the models and areas where added data would need to be collected to improve the data base.

Models that are calibrated and verified using the data base are valuable aids for predicting the consequences of natural or induced changes in the hydrological regime.

Models that cannot be fully calibrated and verified can be valuable aids for estimating the range of consequences that might reasonably be expected as a result of natural or induced changes in the hydrological regime.

5.2.2.2.2 Level of Data. At the area characterization phase it is sufficient to be able to define in general terms the ground-water flow systems around the domes. The ground-water flow systems around Richton, Cypress Creek, Lampton, Keechi, Oakwood, Vacherie, and Rayburns domes have been defined to varying degrees, but of sufficient levels of effort to facilitate decision making.

5.2.2.2.3 Data Aquisition Methods. Test holes were drilled in the immediate vicinity of the domes and in areas away from the domes. Hydraulic properties and water levels were determined for significant water transmitting formations to a depth approximating that of the proposed repository horizon. Water samples were obtained from test holes taken for chemical analyses. Geophysical logs were run in selected test holes and sidewall core samples were taken for laboratory analyses.

5.2.2.2.4 Adequacy of Data. Sufficient geologic, hydrologic, and water chemistry data are available for Richton and Cypress Creek domes to begin ground-water flow modeling efforts at these sites. Ground-water flow modeling around Oakwood and Vacherie domes is already under way.

Insufficient data are available at the dome sites to address surface- and ground-water interrelationships at this phase of the investigations but will be obtained during the location phase.

5.2.2.3 Geohydrologic Regime/Shaft Construction

The following subcriterion is the basis and requirement for consideration of shaft construction in the repository site selection process:

The site shall be located so that the geohydrological regime allows construction of repository shafts and maintenance of shaft liners and seals.

Existing aquifer systems, particularly in strata between the repository level and the land surface, must be isolated from the repository workings. Evaluations must include anticipated aquifer flow rates, reliability and effectiveness of sealing technique, and geohydrological perturbations of the aquifers induced by shaft construction and liner emplacement.

5.2.2.3.1 Significance. In addition to having an effect on the cost and feasibility of shaft construction, the surface water regime and the hydrologic properties of those rocks above the salt through which the shafts must be sunk will affect the integrity of the mined opening during the period of construction and operation. Abundant flowing ground water can make shaft construction difficult, expensive, and impractical. Even after shaft construction is complete, an imperfect seal could allow the passage of water downward along the shaft, increasing the potential for flooding the mine chamber. A shaft failure that occurred in a salt mine in a dome in modern times was related to an abundance of ground water in the porous rock units overlying the salt, coupled with inadequate design and construction.[23]

Although the draft NRC regulations do not specifically address the question of the hydrologic regime as related to shaft construction, they do address the question of the overall geologic framework. The draft regulations cite as favorable characteristics--that the volume of rock (for the repository) shall possess a geologic framework that permits effective sealing of shafts, drifts, and boreholes, and that permits excavation of a stable subsurface opening, and the emplacement of waste at a minimum depth of 300 meters from the ground surface.[7:122,c,2,ii] The draft regulations state that DOE, to the extent practicable, shall select such a site.

The boundary of acceptability cannot be defined at this time. The stratigraphic units, thickness, physical, and hydrologic properties of rocks overlying and adjacent to the salt domes under consideration are extremely similar to those at several domes where mines in salt already exist and where exploratory and production shafts were constructed using state-of-the-art techniques.

5.2.2.3.2 Level of Data. To fully evaluate this factor, it is necessary to know the nature and physical and hydrologic properties of all sedimentary units above host rock (dome salt), of rock units overlying the salt, including the caprock. Information required would include porosity, permeability, unconfined compressive strength, shear strength, consolidation, etc., a complete suite of soil and rock mechanics information. Also, and especially, the properties of any aquifers that may overlie the salt dome must be known. Aquifer yield, direction of flow, and flow rate must be determined using aquifer testing techniques.

At the area characterization phase, it is adequate to know the thicknesses, total and relative, of sedimentary units with differing hydrologic properties (aquifers versus confining units) over the domes of interest, and whether or not there are gross inequalities in these properties among the domes.

5.2.2.3.3 Data Acquisition Methods. Information can be obtained by drilling one or more holes, hydrologic testing of appropriate units, and downhole geophysical logging. One test hole through the caprock, although inadequate to define the areal variations in properties that are no doubt present, will allow the gross definition that is needed at this stage. Properties of the flanking sediments can also be determined from geophysical logs in holes adjacent to the dome itself.

5.2.2.3.4 Adequacy of Data. Thicknesses, rock types, and properties of caprock and overdome rock units have been obtained from drilling, hydrologic testing, and geophysical logging on all domes except Lampton and Keechi. Existing information was evaluated in addition to new data obtained expressly for this program. Absolute and relative thicknesses of rock types with differing hydrologic characteristics have been determined. Data are considered to be adequate for this phase for all domes except Lampton and Keechi.

5.2.2.4 Dissolution

The following subcriterion is the basis and requirement for consideration of subsurface rock dissolution in the repository site selection process:

> The site shall be located so that subsurface rock dissolution that may be occurring, or is likely to occur, can be shown to have no unacceptable impact on system performance.
>
> Existing solution features must be analyzed to identify the rate of dissolution. The effects of further dissolution or of new dissolution features on system performance must be evaluated.

5.2.2.4.1 Significance. Dissolution of salt represents a possible method of breaching the host rock or of reducing the buffer zone within the host rock. Evidence of dissolution, no matter how slight, represents a complexity that will be an issue in licensing and will increase the amount of effort required in the characterization process. For safety considerations, dissolution rates that would violate the integrity of the host rock over a period of thousands or possibly tens of thousands of years should be avoided. However, salt domes have existed in their present state for tens of millions of years indicating long-term stability. This indicates that dissolution is a resolvable technical issue.

In the draft regulations, the NRC has recognized the importance of dissolution, citing as a potentially adverse condition any evidence of dissolutioning, such as karst features, breccia pipes, or insoluble residues.[7]

Caprock represents material left and concentrated when more soluble material was removed assuming formation by residual accumulation. All salt domes containing caprock have undergone a considerable amount of dissolution in the past. The caprock formation, however, is thought to be coincident with dome movement. While the offshore domes in the Gulf Coast are still in the formative stage, the interior domes are thought to be stable; this was one of the criteria applied early in the screening process.[18]

Evidence of dissolution currently or in the immediate past, or the presence of conditions that could give rise to dissolution in the immediate future are items of concern. The boundary of acceptability depends on both the rate of dissolution that might be occurring or anticipated and the thickness of buffer zones that would be susceptible to dissolution before the dissolution front contacted the radioactive material. The absolute requirement is that radioactive material not be allowed to reach the biosphere in amounts that exceed standards yet to be established by the Environmental Protection Agency. Bounding calculations indicate dissolution of 800 feet (245 meters) of dome salt will require greater than 1 million years, assuming impingement of fresh-water flow around a dome (see Section 5.2.1.3.2).

5.2.2.4.2 Level of Data. At the area characterization phase, water chemistry data should be available for aquifers at several depths in the vicinity of the salt domes and for the area as a whole. This will allow a comparison of salinities; dissolution may be indicated by the presence of anomalously high salinity values immediately down gradient from the salt domes. General ground-water flow rates and salinity values within the basin will indicate the potential for dissolution, whether or not there is surface evidence of such activity at the present time. Significant amounts of dissolution in the immediate geologic past would probably be evident from displacement of recent sediments and geomorphological features, as well as disruption of normal drainage patterns.

At the area characterization phase, it is adequate to know whether or not there are significant differences in ground-water chemistry (salinities) between the sediments in the immediate vicinity of the salt domes and in the basin as a whole. A fair understanding of the geologic history of each dome for the Quaternary period should also be obtained by profiling of Quaternary terraces, where present, examination of Quaternary sediments, if any, and geomorphic analysis. The objective is not to provide a full characterization of dissolution or Quaternary history, but rather to allow a differentiation to be made among the domes on the basis of this factor when and if possible.

5.2.2.4.3 Data Acquisition Methods. Water samples have been obtained from aquifers to a depth approximating a repository, both in the vicinity of the salt domes under investigation and elsewhere in the basin, and chemical analyses run. All existing water quality data have been assembled and examined for evidence of current or past dissolution.

5.2.2.4.4 Adequacy of Data. Water quality data are available from water samples taken from drilled holes at Cypress Creek, Richton, and Oakwood domes as well as within their respective basins but away from the domes. Results of water chemistry analyses and determination of the base of fresh water (contouring of salinities) has been accomplished. Considerable data existed from the uppermost shallow aquifers in all three basins and these have been examined.

Adequate data exist to make a rough comparison among the domes under consideration. More detailed information might change the present interpretation for this factor. However, gaining additional information probably would not change the present interpretation drastically or establish a degree of superiority or inferiority totally overriding the other characteristics used in this analysis. Significant analysis was undertaken at Palestine dome, prior to the time of elimination. Palestine dome is unique among the domes under consideration because of the previous history of solution mining.

5.2.3 Geochemistry

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

The site shall be located so that the chemical interactions between radionuclides, rock, ground water, or engineered components will not unacceptably affect system performance.

The evaluation of the geochemical regime shall include characterization of factors that contribute to slowing or preventing radionuclide transport, such as solubilities, sorption, dissolution, precipitation, environment, and pH. The evaluation of the geochemical regime shall consider any factors that may adversely affect the radionuclide containment capabilities provided by the waste package, or geologic system.

Discussion of the geochemical aspects of site characterization is done under two subheadings: (1) chemical interactions and (2) radionuclide retardation. The chemical reactions that occur in the repository between ground water, waste packages, radionuclides, and host rocks will be discussed in Section 5.2.3.1, Chemical Interactions. The chemical and physical interactions that occur between radionuclides and the geological environment outside the repository are discussed in Section 5.2.3.2, Radionuclide Retardation.

5.2.3.1 Chemical Interaction

5.2.3.1.1 Significance. Moving ground water provides by far the most significant mechanism by which radionuclides could be transported away from the repository. But first, the ground water must enter the repository, penetrate the engineered barriers, dissolve some of the nuclear waste, again penetrate the engineered barriers and then exit the repository. There are many chemical reactions that can occur during this process. The extent and course of these reactions will be at least somewhat different if the breach occurs during the thermal period because the higher temperatures will increase reaction rates and shift equilibria. The probability, sequence, extent, and consequences of these reactions depend heavily on the geochemical (and hydrological) properties of the site, as well as the components of the waste package. These properties may be geochemical processes, past or present, or the results of these processes. Knowledge of these properties is essential to assessing the suitability of a candidate site, to the design of potential waste packages, the choice of waste packages, and to assessing the long-term performance of the repository.

The geochemical properties of the host rock and the ground water contained in it can be described, for example, in terms of the pH and redox environment of the ground water, the solubility of radionuclides in the ground water, the sorption of radionuclides by the host rock, solubility of minerals in the host rock, shifts in equilibria between host rock and ground water when temperature is increased, etc.

For candidate repositories in salt there are two specific considerations that differ significantly from those for candidate repository sites in other types of host rocks. They are dissolution of the salt by ground water that intrudes the salt deposit and migration of brine inclusions in the salt toward the emplaced nuclear waste. All salt domes have presumably undergone at least some dissolution at some time in their history. The important question is whether the salt, and/or the caprock and sheath are currently undergoing dissolution at an adverse rate or have done so in the recent geologic past. Answering this question requires identification of dissolution features and estimates of the time during which this dissolution occurred and, if appropriate, its rate today. The salt, in salt domes, contains very little water (generally less than 0.5 and 0.01 and often less than 0.001 percent by weight) and hence low total volumes of brine inclusions, except perhaps in potential anomalous zones. Information about the source of water in the brine inclusions is relevant to the past dissolution history of the salt dome. Information about the amount of water in salt, the size distribution of the brine inclusions, the average migration rate and direction of the brine inclusions in a thermal gradient are all items of information that are essential for the design of waste packages and assessment of their performance.

5.2.3.1.2 Level of Data. At the area characterization stage, it is sufficient to know (1) an indication of the the general purity of the salt, (2) an average concentration of water in the salt, (3) petrographic descriptions of caprock, and (4) evidence indicating the presence or absence of salinity plumes located down the flow path from the salt domes and possibly the fraction of the salinity that is contributed by Na^+ and Cl^-.

5.2.3.1.3 Data Acquisition Methods. At the area characterization stage it is sufficient to (1) observe the visual purity of the salt obtained in drill cores, (2) determine the maximum water concentration of such salt samples, (3) allow visual examination of core material from caprocks for evidence of dissolution, such as macroporosity, vugs, etc., (4) allow examination of thin sections from different depths in the caprock for petrographic evidence of dissolution, (5) obtain resistivity logs of wells drilled outside of the dome and of the caprock and superjacent strata that are cored when exploratory holes are drilled into the salt dome, and (6) prepare water quality analyses of ground waters encountered at various depths in both the meteoric and saline aquifers.

5.2.3.1.4 Adequacy of Data. The data available are adequate for the area characterization phase and for initial planning of the subsequent phase. Substantial amounts of currently nonexistent geochemical data will have to be acquired for subsequent phases.

5.2.3.2 Radionuclide Retardation

5.2.3.2.1 Significance. Before it can enter the biosphere, any ground water leaving the repository must flow through the rocks, sediments, and/or soils that separate the repository from the biosphere. The hydrology of the site gives the minimum travel times from the repository to the biosphere. Very few, perhaps none, of the radionuclides dissolved in the ground water will travel at the same velocity as the ground water. Instead, they will travel at a slower velocity because their movement away from the repository will be retarded by chemical and physical interaction with the materials through which the water flows. This retardation substantially increases the intrinsic ability of the site to isolate the radionuclides in nuclear waste from the biosphere. The geochemical environment in which these interactions occur will be little influenced by chemical perturbations caused by the repository because of distance from the repository, solubility limitations on the amount of repository material that can be dissolved in the ground water, and the small volumes of material in the repository relative to that in the surrounding earth. The geochemical processes that occur are those that would have occurred had the repository not been built. Given the requirements of geologic stability, these processes are those that are occurring today, those that have occurred during at least recent geological times, and those that are expected to continue during the short period of geologic time during which the repository must isolate nuclear waste from the biosphere.

Therefore, evaluation of the nuclide retardation potential of the rock, sediment, and soil located between the repository and the biosphere consists of two parts: (1) understanding the past and present changes in ground water chemistry that occur along the ground-water flow paths that are potential paths for radionuclide migration between the repository and the biosphere and (2) assessing the fate, in this environment, of radionuclides dissolved from the nuclear waste in the repository. In the case of a repository in salt, there is an additional factor that must be considered, that is, that breaching of the repository will increase the Na^+ and Cl^- concentrations in the ground water. This will have at least some effect on the sorption properties of the materials through which the ground water flows and probably lesser effects on other mechanisms of nuclide retardation. One way to evaluate this factor in site characterization is to characterize the geochemistry of the saline aquifers in the vicinity of the site and quantify the geochemical processes that determine the potential for radionuclide retardation in saline aquifers.

5.2.3.2.2 Level of Data. At the area characterization stage, it would have been sufficient to know the following data: (1) the general variations in the chemical composition of material dissolved in the ground water and the pH of the ground water, (2) the correlations of the above noted chemical variations with age of the ground water, aquifers, position in the flow regime, and relationship to major geologic features, such as salt domes, and (3) the general mineralogy of the sediments through which the ground water flows.

5.2.3.2.3 Data Acquisition Methods. At this stage of investigations, it is adequate to acquire ground-water samples from wells drilled and screened in specific aquifers, and to obtain "water quality" analyses of these ground-water samples for pH and/or the major cations and anions dissolved in the water. Information from drillers' logs is an adequate supplement to the general knowledge of the mineralogy of the sediments surrounding the dome.

5.2.3.2.4 Adequacy of Data. The available data are adequate for the area characterization phase. There is adequate coverage of drill holes and wells from which ground-water data and samples have been obtained and analyzed. Literature knowledge of the mineralogy in the sediments surrounding the salt domes is also adequate for current purposes.

5.2.4 Geologic Characteristics

The following criterion is the basis for consideration of the geologic characteristics in the repository selection process:

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

5.2.4.1 Stratigraphy

The following subcriterion is the basis and requirement for consideration of stratigraphy in the repository site selection process:

> The site shall be located so that the subsurface setting can be sufficiently characterized to permit identification and evaluation of conditions that are potentially adverse or favorable to waste containment, isolation, and retrieval.
>
> Characterization of the subsurface setting will include all pertinent physical, structural, mineralogical, and geochemical features of the rock units. The geologic conditions shall be shown to not unacceptably affect system performance.

5.2.4.1.1 Significance. Stratigraphy in the vicinity of the repository must be evaluated in order to determine its adequacy with regard to repository performance, because it will provide one or more of the key barriers to radionuclide migration in the unlikely event of breach in the containment provided by the host rock. Detailed knowledge of the stratigraphy is also the key to understanding the geologic history. Stratigraphic information permits evaluation of resource potential, ground water potential, and tectonic stability. To be acceptable, stratigraphy would be sufficiently simple and continuous to be defined with assurance and would permit identification of discontinuities. All things being equal, simple stratigraphy is preferred to complex stratigraphy; such simplicity reduces uncertainties in the knowledge of geologic history and greatly facilitates modeling.

The NRC has recognized the importance of stratigraphic setting in its draft of regulations. The NRC points out[7:122,a,1] that the site and environs should not be so complex as to preclude thorough investigation and evaluation of site characteristics. The NRC goes on to explain that data required for this should include knowledge of the pattern, distribution, and origin of fractures, discontinuities, and heterogeneities in the host rock and surrounding confining units. Identification of the presence of potential pathways such as fractures, discontinuities, solution features, etc., in the host rock and surrounding confining units is also required.[12:122,a,9,i,ii] The draft regulation states that, at a minimum, investigations must evaluate a volume of rock which extends to a depth of one kilometer below the limits of the repository excavation.[7:122,a,9] All of these concerns are directly related to knowledge of the stratigraphic setting.

<u>5.2.4.1.2 Level of Data</u>. At the area characterization stage, it is sufficient to know that stratigraphy within the area is definable and reasonably continuous, allowing an estimation of the types of sediment and rock present, their characteristics, and their distribution.

<u>5.2.4.1.3 Data Acquisition Methods</u>. Data have been acquired on the basis of reviews of existing literature, evaluation of previously drilled oil and gas exploratory wells, examination of existing and newly obtained seismic reflection lines, and by drilling and evaluating numerous additional exploratory wells.

<u>5.2.4.1.4 Adequacy of Data</u>. Abundant data are available in the three Gulf Coast salt basins on the stratigraphy around the candidate domes. A bibliography of existing literature which was reviewed for this study is available in Volumes I, II, III, and IV of the <u>Area Characterization Report</u>.[12,13,21,22] Evaluation of previously drilled oil and gas exploratory wells considered the following numbers of wells within 5 miles (about 8 kilometers) of the candidate domes: Keechi (88), Oakwood (74), Vacherie (168), Rayburn's (66), Lampton (20), Cypress Creek (13), Richton (49). Other previously existing wells were also evaluated for each of the salt dome subbasins. Altogether, 1,611 existing wells were reviewed throughout the study areas. CDP and high resolution seismic-reflection profiles were reviewed; 536 line-miles of previously existing CDP seismic reflection were purchased. Seismic lines are as follows: Oakwood (purchased), Vacherie (purchased), Rayburn's (purchased), Lampton (purchased), Keechi [4 miles (6.4 kilometers) newly run], Cypress Creek [6 miles (9.7 kilometers) newly run], and Richton [8 miles (12.9 kilometers) newly run]. New exploratory wells were drilled in each state: 7 in Texas, 16 in Louisiana, and 41 in Mississippi.

<u>5.2.4.2 Host Rock</u>

The following subcriterion is the basis and requirement for consideration of host-rock characteristics in the repository site selection process:

The site shall provide a geologic system which can be shown to accommodate anticipated geomechanical, chemical, thermal, and radiological stresses caused by waste/rock interactions.

Phenomena such as thermally induced fractures, hydration and dehydration of mineral components, brine migration, or other physical, chemical, or radiological phenomena must be evaluated to show that they would not unacceptably affect system performance.

5.2.4.2.1 Significance. Host-rock characteristics of importance are inherent strength sufficient to permit an engineered structure to be excavated and maintained, thermal properties that will allow adequate dissipation of heat, low moisture content, and chemical properties compatible with, or that will enhance, repository performance. Rock with inadequate inherent strength could prevent, or make excessively hazardous, construction of the repository. Unacceptable thermal properties that could lead to heat buildup that might result in fracturing are not anticipated in dome salt. Decrepitation/fracturing does not occur in dome salt until temperatures approach the range of 260 to 400 C. Inappropriate chemistry could result in long-term changes in host rock characteristics that could be detrimental to repository performance.

5.2.4.2.2 Level of Data. At the area characterization stage, it is sufficient to know the range of variability in the host rock's physical properties at the sites of interest. Information has been collected on rock salt's mechanical, thermal, and chemical characteristics over many years.(24) Because of the uniformity of the values obtained, few additional data, confined to confirmatory information, are required at the area characterization stage.

5.2.4.2.3 Data Acquisition Methods. Salt samples have been taken from drill cores. These samples were submitted for thermal, chemical, and mechanical laboratory tests to determine their properties.

5.2.4.2.4 Adequacy of Data. Each accessible dome has been cored. At the present time, salt samples exist from five of the seven domes which remain under consideration: Oakwood, Vacherie, Rayburn's, Cypress Creek, and Richton. Access to Lampton and Keechi domes has not been obtained.

5.2.4.3 Rock Strength

The following subcriterion is the basis for consideration of the strength of the geologic media housing the repository and subsurface support facilities.

The site shall be located so that development, operation, and closure of underground areas can be accomplished without undue hazard to repository personnel.

Sites with subsurface conditions that preclude or make excessively difficult design and construction of the repository using practical procedures shall be avoided.

5.2.4.3.1 Significance. The strength of the host rock, caprock, and the sediment overlying the dome must be evaluated in order to determine dome adequacy with regard to the design, constructibility and safety of the repository system. Detailed knowledge of rock strength is necessary for design and determination of construction methods for the repository and surface access shafts. To be acceptable, the rock strength should be sufficient for the system to be designed with factors of safety adequate for development, operation, and closure of the system without undue hazard to personnel. Also, the design should be such that it allows construction of the system using state-of-the-art techniques.

5.2.4.3.2 Level of Data. At the area characterization stage, it is sufficient to know some of the strength characteristics of the host rock and caprock so that their strength can be estimated. The strength of the overlying sediments, which is dependent on their lithologic characteristics, will be determined as their stratigraphic variation is being defined.

5.2.4.3.3 Data Acquisition Methods. Data from the literature concerning design and construction of salt mines and salt mine access shafts have been augmented by literature which deals with the strength characteristics of salt. Additional data have been obtained from laboratory analyses of caprock and salt core from five of the seven candidate domes and from geophysical log analyses in deep exploratory wells and borings.

5.2.4.3.4 Adequacy of Data. At the area characterization phase, it is sufficient to obtain data from salt core analysis to demonstrate little to no variation among domes. Additional rock strength and rock mechanic testing and analysis will be accomplished in greater detail on a fewer number of domes in the location phase.

5.2.5 Tectonic Environment

The following criterion is the basis for consideration of the tectonic environment in the repository selection process:

The site shall be located such that credible tectonic phenomena will not degrade system performance below acceptable limits.

5.2.5.1 Tectonic Elements

The following subcriterion is the basis and requirement for consideration of tectonic elements in the repository site selection process:

The site shall be located so that its tectonic environment can be evaluated with a high degree of confidence to identify tectonic elements and their impact on system performance.

Potentially hazardous geologic elements including faults of any age, volcanoes, and anomalous geothermal gradients, must be sufficiently investigated to allow determination of their potential effects on system performance and to show that these effects will not unacceptably affect system performance.

5.2.5.1.1 Significance. Broad uplift and subsidence of the Earth's crust (epeirogeny) are tectonic phenomena that must be evaluated generally in terms of their potential effects on the repository horizon or erosion. Denudation, or the general lowering of the land's surface by erosion, is not a threat to waste containment or isolation in a deep repository in domes other than Keechi and Rayburn. Anomalous tectonic phenomena, such as epeirogenic and halokinetic events, could possibly cause containment breach, or overdome faulting. The draft NRC regulations indicate that there should be no evidence of active processes in the candidate area that could result in structural deformation in the volume of rock such as uplift, diapirism, subsidence, folding, faulting, or fracture zones.(7:122,b,2,III)

The potential for vertical incision and lateral erosion due to rapid uplift has been evaluated for each area to determine if erosion rates will threaten repository locations. In such regions where rapid uplift rates are present, the minimum distance from repository to major rivers and steep scarps is calculable, which is sufficient to determine potential breaching of the system.(15:II-D.2, p. II-79)

5.2.5.1.2 Level of Data. At the area characterization phase, it is sufficient to know that no anomalous tectonic phenomena (elements) have been identified. If any had been identified, each would have been evaluated on a case-by-case basis at the area phase and would be evaluated in greater detail at the location phase.

5.2.5.1.3 Data Acquisition Methods. Anomalous tectonic phenomena were sought through an extensive regional literature search, evaluation of remote sensing imagery, by geophysical means such as seismic reflection and by data from deep borings.

5.2.5.1.4 Adequacy of Data. The regional literature search conducted in conjunction with the fault and igneous activity investigation is adequate for area level studies.

5.2.5.2 Quaternary Faults

The following subcriterion is the basis and requirement for consideration of Quaternary faults in the repository site selection process:

> The site shall be located so that Quaternary faults can be identified and shown to have no unacceptable impact on system performance.
>
> The evaluation of Quaternary faults will emphasize the determination of the potential for rupture in or adjacent to the site but will include evaluation of the likelihood and consequence of earthquake generation and plausible impacts on the regional hydrology.

5.2.5.2.1 Significance. Movement in the form of surface rupture (vertical and/or horizontal deformation) could cause damage to the repository horizon and cause displacement to the stratigraphic make-up of the geosphere. Damage to the surface structures would pose a safety issue for personnel within the facilities. Displacements within the geosphere could hypothetically cause a short-circuit, or by-pass, of the flow path of radionuclides to the biosphere. Tectonic faults or faults associated with crustal structures and potentially significant earthquake activity are of major interest. Non-tectonic, overdome faulting associated with salt movement could affect facility construction and underground operations by causing higher engineering and construction costs.

The NRC has historically been concerned about all faults and their histories in the proximity of nuclear facilities.(25:100, Appendix A) This concern is reflected in NRC's proposed regulations for repository licensing as follows:

> The geologic repository operations area should not be located within the near field of a fault that has been active since the start of the Quaternary period.(7:122,b,3,IV)

5.2.5.2.2 Level of Data. Considered during the area phase for identification, study, and assessment of faults are:

- Distance from dome to fault
- Fault orientation, sense of movement, total offset, length of rupture, total projected length
- Age of latest movement, age of other movements, and, if applicable, dating techniques.

5.2.5.2.3 Data Acquisition Methods. A detailed literature search utilizing federal, state, and local agencies, and academic and commercial data sources is used, along with a regional study of all available remote imagery, to provide identification of faults located within 100 kilometers of the areas in question. Suspected fault traces are assessed by reconnaissance mapping of identified or suspected fault traces within 8 kilometers of the area. Field surveys, consisting of drilling and trenching, and geophysical and hydrological programs, were conducted.

5.2.5.2.4 Adequacy of Data. Quaternary tectonic faulting within the Gulf Coast salt dome study areas has been addressed in Geologic Area Characterization Reports for Texas,[21] Louisiana,[22] and Mississippi.[13] It has been tentatively concluded that there are no active Quaternary tectonic faults in Louisiana or Mississippi. The Texas Bureau of Economic Geology has concluded that there may have been faulting of Trinity River terrace deposits associated with salt movement, 15 miles (24 kilometers) north-northeast of Oakwood dome and 14 miles south (22.5 kilometers) of Keechi dome during the Quaternary period. Overdome nontectonic faults related to dome formation are present on most, if not all, of the domes.

5.2.5.3 Quaternary Igneous Activity

The following subcriterion is the basis and requirement for consideration of Quaternary igneous activity in the repository site selection process:

> The site shall be located so that the centers of Quaternary igneous activity can be identified and shown to have no unacceptable impact on system performance.
>
> The evaluation of the likelihood and impact of igneous activity on the disposal system will include thorough evaluations of the region's igneous history, with particular attention given to temporal and spatial distribution of activity, character of activity, and analysis of the possibility of migration or expansion of areas of active volcanism.

5.2.5.3.1 Significance. A newly formed, migrated, or previously unknown magma-related chamber could suddenly breach the repository and displace the contents, or it could cover the surface overlying the repository with thin to thick flows of volcanic material. The presence of Quaternary igneous activity within 100 kilometers of the areas of concern indicates greater likelihood of renewed activity of this type in the future.

The regulatory concern for this factor is expressed in the NRC draft regulations: "The geologic repository should not be located in an area in which there is evidence of intrusive activity since the start of the Quaternary period".(7:122,b,2,VI)

5.2.5.3.2 Level of Data. At the area characterization phase, it is sufficient to know whether or not there is evidence of Quaternary igneous activity within 100 kilometers of the Gulf Coast salt dome project area. Evidence of such activity would justify detailed study and assessment.

5.2.5.3.3 Data Acquisition Methods. Quaternary igneous activity is identifiable through regional literature searches of federal, state, and local agency records, academic and commercial sources, geophysical surveys, and review of remote imagery.

5.2.5.3.4 Adequacy of Data. The regional literature search for Quaternary igneous activity has been accomplished in the Gulf Coast region. Collected data have been assessed and Quaternary and older igneous activity addressed in the area characterization reports.(12,13,21,22)

5.2.5.4 Uplift/Subsidence

The following subcriterion is the basis and requirement for consideration of uplift and subsidence in the site selection process:

> The site shall be located so that long-term, continuing uplift or subsidence rates can be shown to have no unacceptable impact on system performance.
>
> Evaluation of the rates of uplift or subsidence is required so that effects of such movement can be shown to cause no unacceptable reduction in repository performance.

5.2.5.4.1 Significance. While extremely unlikely, rapid rates (geologically) of uplift of domes could increase the potential for exposure of the host rock, i.e., salt domes, and possibly deform or damage the repository or surface facilities, or create "short circuited" radionuclide pathways to the biosphere. Rapid rates of local uplift or subsidence may create shear zones within the salt dome host rock, the surrounding strata, and the over-dome strata through differential movement within the salt, between the salt and surrounding and/or overlying strata, or between the overlying and/or the surrounding strata. Rapid rates of regional uplift or subsidence could increase the potential for host rock exposure or burial through changes in stream base level.

The occurrence of rapid rates of uplift or subsidence could lead to an increased risk to repository containment. Movement since the start of the Quaternary, through uplift of domes or subsidence of over-dome strata, could be a licensing issue and may substantially increase the time and effort required to address the issue. The draft NRC technical requirements direct that there should be no evidence of processes which could result in structural deformation in the volume of rock such as uplift, diapirism, subsidence, folding, faulting, or fracture zones.(7:122,b,2,II)

5.2.5.4.2 Level of Data. At the area characterization phase, it is adequate to have determined if uplift, subsidence, or diapirism has occurred or is in the process of occurring. An analysis of structural and stratigraphic data must be accomplished to determine pre-Quaternary and/or Quaternary dome growth, regional uplift/ subsidence, and the effects anticipated

9 0 0 3 0 0 8 2 6

should glacial activity reoccur. Evidence for renewed sedimentation is sought, since this would be a mechanism to precipitate renewed dome movement. The onshore portion of the Gulf Coast region, however, is currently in an erosion cycle. Available first order level data exist for the Gulf Coast region. No reasonable interpretation of regional uplift or subsidence exists. Geomorphic evidence indicates that no significant local uplift or subsidence is occurring.[26]

5.2.5.4.3 Data Acquisition Methods. Uplift and subsidence data collection methods included regional literature searches, terrace mapping, identification of variations in Quaternary unit thicknesses, precise leveling surveys, remote imagery evaluations, seismic profiling, and, to some extent, gravity modeling. These methods would detect uplift or subsidence in the over-dome strata at the area characterization level. Shallow borings substantiate surface geomorphic mapping.

5.2.5.4.4 Adequacy of Data. The data are adequate to estimate current and past rates of uplift and subsidence. The geologic record indicates stability during Quaternary time within at least 100 kilometers of all areas of concern.

5.2.5.5 Seismicity

The following subcriterion is the basis and requirement for consideration of ground motion in the repository site selection process:

> The site shall be located so that ground motion associated with the maximum credible earthquake will not have unacceptable impact on system performance.
>
> The evaluation of seismic effects on the disposal system requires state-of-the-art definition of (1) regional historical seismicity (both instrumental and preinstrumental), (2) maximum-credible earthquake, and (3) related seismic-design parameters such as the level of vibratory ground motion, that can be accommodated at the site by practical design measures. The seismic evaluation must be performed considering the ground motions that can be accommodated by design.

5.2.5.5.1 Significance. Principal issues are the design of surface facilities to withstand earthquakes and potential long-term effects on waste isolated below the surface. Accordingly, primary concerns relate to long-term radiological effects and to mine and surface facility designs that minimize hazards from structural failures should an earthquake occur. Available information suggests that vibratory motion from earthquakes is lower at repository depths than at the Earth's surface. The effects of ground motion on the natural containment and isolation system are expected to be minimal.[15:II-D,3,p.II-78] Seismically active zones will generally have higher engineering and construction costs.

The NRC concern about ground motion is expressed in the draft 10 CFR 60 which states that potentially adverse conditions exist when the seismicity of a candidate area is high relative to the surrounding region, or there are indications, based on correlations of earthquakes with tectonic processes and features, that an area's seismicity may increase in the future.(7:122,b,2V)

5.2.5.5.2 Level of Data. Area data collection will sufficiently identify local and regional seismicity from preinstrumental and instrumental records to determine historical seismicity. Maximum credible earthquake and related seismic design parameters will be determined during the site characterization phase.

5.2.5.5.3 Data Acquisition Methods. Local and regional seismicity data are available from published and unpublished literature. This literature is contained in federal, state, and, to some extent, local agency publications and records, and from academic and commercial sources.

5.2.5.5.4 Adequacy of Data. The regional literature search for historical seismicity has been well coordinated. Adequate data are available from instrumental and preinstrumental records of seismicity at the area characterization phase in east Texas, northern Louisiana, and eastern Mississippi. A modified Mercalli intensity of VI maximum has been reported in historical records[12] in the three salt basins of the Gulf Coast.

5.2.6 Human Intrusion

The following criterion is the basis for consideration of the human intrusion potential in the repository selection process:

The site shall be located to reduce the likelihood that past or future human activities would cause unacceptable impacts on system performance.

5.2.6.1 Resources

The following subcriterion is the basis and requirement for consideration of economic resources in the repository site selection process:

> The level of evaluation necessary to assess the likelihood of human intrusion will increase with the value of and the proximity of the site to exploitable features or resources such as water, thermal energy, petroleum, or minerals.

5.2.6.1.1 Significance. Resource potential is significant for two reasons: (1) known resources could be a target for future exploration, which might lead to a breach of the repository, and (2) resources in the vicinity of a repository site might have to be indefinitely withdrawn from use. Certainly, resource exploration will continue for the foreseeable future; therefore, the problem is one of evaluating the potential for future penetration and of speculating on the value and amounts of resources in the vicinity of each candidate dome. The future-penetration problem suggests that sites should be located to avoid areas containing large amounts of valuable resources, given today's conditions. The resource-withdrawal or potential storage value problem must be dealt with on a case-by-case basis, since the economic trade-off between the value and necessity of a repository versus the withdrawn resources or storage value will be determined legislatively, based on national policy and needs.

Draft NRC regulations indicate that resource assessment must include both known and undiscovered deposits of all resources within the geologic province of the candidate site, that either have been or are being exploited or have not been exploited but are exploitable given current technological and market conditions.[7:122,a,8] An assessment of the resource value, development, extraction, and marketing costs must be made in determining the net value of the resource.[7:122,b,1,iv] The draft regulation goes on to say that two resource-related conditions are considered to be potentially adverse. These conditions are:

- Resources which are economically exploitable using existing technology under present market conditions,
- Resources that have higher gross or net value than the average for other areas of similar size in the region in which the repository is located, based on a resource assessment.[7:122,b,1,iii,iv]

<u>5.2.6.1.2 Level of Data</u>. At the area characterization phase, it is adequate to know what resources are present, which have been exploited, where they are located, how much has been extracted, how much remains, current market conditions, and the prognosis for future extraction.

<u>5.2.6.1.3 Data Acquisition Methods</u>. Resource potential in the regions surrounding salt domes is evaluated on the basis of existing literature and other available information. This evaluation is best done by an expert in mineral economics who is familiar in detail with the area under consideration.

<u>5.2.6.1.4 Adequacy of Data</u>. Dr. Grover Murray of Texas Technical University analyzed resource potential in the vicinity of the seven candidate domes. A bibliography of literature which he reviewed is contained in Volume I of the <u>Area Characterization Report</u>.[12]

On the basis of Dr. Murray's resource evaluation and the inventory of previous exploratory activities, it is concluded that all available information has been reviewed and this information permits comparison of the resource potential of the domes.

5.2.6.2 Exploration History

The following subcriterion is the basis and requirement for consideration of exploration history in the repository site selection process:

> The site shall be located so that the exploration history or relevant past use of the site or adjacent areas can be determined and can be shown to have no unacceptable impact on system performance.

5.2.6.2.1 Significance. Subsurface penetrations may threaten the integrity of the repository; at least, they represent evidence of some interest in a potentially exploitable resource. Conversely, lack of exploration in the vicinity of a repository suggests that there may be no resource potential in the vicinity. The presence of subsurface penetrations reflect (1) a licensing issue which will have to be addressed, and (2) a potential short-circuit pathway to the accessible environment.

The draft of proposed NRC regulations, 10 CFR 60, identifies previous exploration as a potentially adverse human activity. The regulations are particularly concerned with places where there has been conventional or in situ subsurface mining for resources and where there has been drilling, for whatever purposes to depths below the lower limit of the accessible environment.[7:122,b,ii,iii]

The past use of the site is significant because past human activities such as mineral resource exploration and exploitation may have unacceptably affected the repository system. Examples of this would be hydrocarbon and sulphur exploration and production wells which penetrate the salt stock. The success of past mineral resource exploration is also a key factor in assessing the potential of future penetrations.

5.2.6.2.2 Levels of Data. At the area characterization stage, it is sufficient to know the location and character of prior subsurface penetrations of any type. Evaluation of the exploration history in the vicinity of each of the seven domes has identified all known exploration activity within a 5-mile (8-kilometer) radius. The NRC's draft regulation concerns itself with a 2-kilometer radius.

5.2.6.2.3 Data Acquisition. A search of the literature and other available information from agencies which regulate mineral exploration and brine injection was conducted to identify the location and character of all prior subsurface penetrations.

5.2.6.2.4 Data Adequacy. The survey of exploration history at each dome is summarized in Table 6-9.

A detailed examination has been made of prior exploration history in the vicinity of the seven domes. The data recorded are considered adequate for the area characterization stage.

5.2.6.3 Land Ownership/Control

The following subcriterion is the basis and requirement for consideration of ownership and control in the repository site selection process:

The site shall be located on land for which the federal government can obtain ownership, control access, and obtain all surface and subsurface rights necessary to ensure that surface and subsurface activities at the site will not cause unacceptable impact on system performance.

5.2.6.3.1 Significance. Ownership is significant because obtaining access for exploration may affect scheduling. It is not significant in terms of the actual construction and operation, because the federal government can obtain land held privately or owned by other federal agencies or by state or local governments.

5.2.6.3.2 Level of Data. Data must be acquired to determine ownership and control, including any mineral or mining rights. At the area phase, all that is necessary is a general knowledge of the ownership of the area and knowledge of where specific access is required to accommodate field programs.

5.2.6.3.3 Data Acquisition Methods. Commercially available property ownership maps were purchased and reviewed. For locations where specific access was required, records available at the county courthouses were searched to determine ownership, liens, leases (surface and subsurface), and other items influencing the control of the property.

5.2.6.3.4 Adequacy of Data. The data are adequate because the ownership of the domes has been established. Property ownership maps indicate the ownership of the domes. When access was required to lands within the area, ownership was verified by searching court and other records.

5.2.7 Surface Characteristics

The following criterion is the basis for consideration of the surface characteristics in the repository site selection process:

The site and its surrounding area shall be such that surface characteristics or conditions can be accommodated by engineering measures and can be shown to have no unacceptable impacts on repository operation and system performance.

5.2.7.1 Surficial Hydrologic System

The following subcriterion is the basis and requirement for consideration of the surface hydrology in the repository selection process:

The repository site shall be located so that the surficial hydrological system, both during anticipated climatic cycles and during extreme natural phenomena, will not cause unacceptable impact on repository performance.

The repository shall be located so that nearby surface water bodies, embayments, streams, flood plains, runoff, or drainage under present or future climatological conditions can be shown to present no unacceptable adverse impact on repository performance.

Consideration of the impact of such features must include evaluation of the impact on surface and subsurface facilities and on site access corridors during both the operational phase and the long-term isolation phase of the repository.

5.2.7.1.1 Significance. The surficial hydrologic regime on or near the supradomal areas has engineering significance to the dome evaluation process. Understanding the location and impacts of man-made alterations to the surface water environment may be important to the subsurface conditions in or adjacent to a repository. An understanding of the surface water characteristics is necessary to anticipate what effect natural-caused alterations might have on the subsurface water environment.

The NRC cites the following natural hydrologic conditions as potentially adverse to repository safety:

(1) There is potential for significant changes in hydrologic conditions including hydraulic gradient, pore water velocity, storativity, permeability, natural recharge, piezometric level, and discharge points.

(2) The geologic repository operations area is located where there would be long-term and short-term adverse impacts associated with the occupancy and modification of the flood plains. (In fact, Executive Order 11988 discourages the siting of federal facilities in a 100-year flood plain.)

(3) There is reasonable potential for natural phenomena such as landslides, subsidence, or volcanic activity to create large-scale impoundments that may affect regional ground-water flow systems.

The repository will be located and designed so the changes in the above conditions that are predicted to occur will not unacceptably affect repository performance over the long term. When a choice of conditions between domes is being made, domes that exhibit a low potential for change are more favorable, other factors being equal.

The above parameters can be changed by long-term erosion, glacial leveling, and filling or emptying of natural or man-made impoundments (whether inadvertent or intentional). The significance of long-term erosion and glacial loading (and unloading) is discussed in Section 5.2.1.1. Impoundments may affect the areal ground-water system, such as ground-water flow, direction, and hydraulic gradients. Such impoundments may also affect areal stress fields in the dome vicinity by changing pore water pressure at depth. Earthquakes can be induced by or in association with such large impoundments. According to the NRC staff support for the 10 CFR 60 draft regulations, the presence of a large dam near a repository makes the assessment and performance more complex in several ways. It complicates the definition of natural ambient conditions. Second, in analyzing effects over the long term, one must assume for whatever reason the dam is removed. Third, the presence of a dam on a river today may imply that other dams may be built and again change ambient conditions. Fourth, the presence of the dam implies the possible presence of other human activities, which can lead to many complex and uncertain scenarios for long-term performance. Therefore, a site is presumed adversely affected if prior to decommissioning there is a reasonable potential for the repository area to be affected by natural or human impoundments. The draft regulation will make siting a repository near or downstream from a significant impoundment undesirable.

Consideration of flooding and flood plains is potentially significant to repository siting, operation, and performance. Executive Order 11988 discourages the siting of federal facilities in a 100-year flood plain. Flood waters from dam failures or excessive precipitation need to be prevented from having unacceptable impacts on the repository. This is accomplished by designing against flood waters and streams, or by avoiding sites that are downstream from existing or potential future impoundments. Flood protection by design can be accomplished by filling low areas, raising the grade of the surface facilities, or diking and rechanneling of potential flood waters. The placement of repository shafts depends in large part on the lateral extent at repository depth. The grade of the surface facilities needs to be such that the shaft openings are above the probable maximum flood (PMF) level predicted for each dome.

The surface facility will be in existence only during the operational period* which has been assumed to be less than 100 years. The PMF represents a worst extreme natural phenomenon that might occur during the operational period. The PMF is defined as the most severe flood considered reasonably possible to occur. It is estimated from the probable maximum precipitation (PMP), defined as the reasonable maximization of the meteorological factors that operate to produce a maximum storm. PMP is usually derived

*The time when the repository is open and waste can be emplaced or retrieved. This period is defined to include the construction and backfilling (sealing) of the repository.

by (1) taking the results of depth-areas-duration analyses of precipitation in major storms that have or could have occurred in the area of interest, (2) adjusting them for maximum moisture charge and rate of moisture inflow, and (3) enveloping the adjusted values for all storms to obtain the depth-area-duration curves of PMP. PMP is an extraordinary event, and it does not necessarily follow that it will occur when all other conditions are favorable for maximizing the peak.[27,28] During the operational period man-induced changes in the surficial hydrologic system should not cause a detrimental effect to the surface facility.

5.2.7.1.2 Level of Data. The information necessary to evaluate surface hydrology for this decision step includes:

- Location of the domes with respect to the drainage areas in which they are located
- Regional ground-water basins and flow
- The proximity of domes to existing impoundments
- The potential for man-made or naturally formed impoundments occurring in the future
- Dome proximity to flood plains and flood levels.

5.2.7.1.3 Data Acquisition Methods. Local and regional hydrologic data are available from the published and unpublished literature. This literature is contained in federal, state, and to some extent, local agency publications and records, and from academic and commercial sources. A comprehensive list of information sources is included in the environmental and geologic area characterization reports.[12,13,20,21,29,30,31,32]

5.2.7.1.4 Adequacy of Data. The regional and area literature searches of surface hydrology have been well coordinated and adequate data are available as described in the regional and area characterization reports. The domes have been located with respect to their watersheds. Probable Maximum Flood (PMF) levels have been established. Consideration of the feasibility of future impoundments has been made. Preliminary estimates of the areal extent of the regional ground-water basins have been made.

5.2.7.2 Surface Topography

The following subcriterion is the basis and requirement for consideration of surface features in the repository site selection process:

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

Sites in which road and rail access routes encounter steep grades, sharp switchbacks, slope instability, or other potential sources of hazard to incoming waste shipments should be avoided.

5.2.7.2.1 Significance. This factor is significant in siting nuclear waste repositories to prevent hazards during transportation of the waste through high-relief terrain to the repository. Additionally, although of less significance, the complexity and cost of repository surface facilities can be influenced by surface features.

5.2.7.2.2 Level of Data. At the area characterization phase, it is adequate to know that areas of high topographic relief either are not present or can be avoided by judicious placement of surface structures and access corridors.

5.2.7.2.3 Data Acquisition Methods. Appropriate data are publicly available from the topographic maps prepared by the USGS for the area around each of the candidate salt domes. Topographic maps are prepared by using mapping and remote sensing survey techniques.

5.2.7.2.4 Adequacy of Data. Existing data are adequate to identify the location and magnitude of areas of high-relief terrain.

5.2.7.3 Meteorological Phenomena

The following subcriterion is the basis and requirement for consideration of meteorological phenomena in the site selection process:

The site shall be located where meteorological phenomena can be accommodated by engineering measures and can be shown to have no unacceptable effect on repository operation.

5.2.7.3.1 Significance. The evaluation of such meteorological phenomena as high winds, floods, tornadoes, and heavy rainfall is important for assessing impacts on repository operation and system performance in order that the potential inputs can be accommodated by engineering measures.

5.2.7.3.2 Level of Data. The information needed on meteorological phenomena is frequency and intensity of tornadoes, severe thunderstorms with high winds, hurricanes with intense winds and potential for flooding, and heavy rainfall.

5.2.7.3.3 Data Acquisition Methods. The required data were obtained from reviewing historical regional and area meteorological data from the National Weather Service.

5.2.7.3.4 Adequacy of Data. Required historical regional and area meteorological data, as described above, were obtained, analyzed, and are reported in the environmental area characterization reports.(30,31,32)

5.2.7.4 Industrial, Transportation, and Military Installations

The following subcriterion is the basis and requirement for consideration of industrial, transportation, and military installations in the site selection process:

> The site shall be located where present and projected effects from nearby industrial, transportation, and military installations and operations can be accommodated by engineering measures and can be shown to have no unacceptable impacts on repository operations.

5.2.7.4.1 Significance. Evaluation of external risks to the facility from the presence of hazardous materials (e.g. explosives, chemicals, or radioactive materials), flying and falling objects, and hazardous activities are important. This information is needed to accommodate, by engineering measures, any potential external risks.

5.2.7.4.2 Level of Data. The data needed to evaluate external risks are: (1) location of nearby installations that manufacture or store hazardous materials and the identity and quantity of the materials; (2) effluents from nearby installations that may cause some risk to the repository; (3) location of major airports or flight corridors within the study areas; (4) location of nearby military installations, operations, and targets; and (5) location of transportation routes of hazardous materials in the study areas.

5.2.7.4.3 Data Acquisition Methods. The required information was obtained from chambers of commerce maps, regional planning maps, Environmental Protection Agency permits, Federal Aviation Administration maps and statistics, the Department of Defense, and the Department of Transportation.

5.2.7.4.4 Adequacy of Data. Required data, as described above, were obtained, analyzed, and reported in the environmental area characterization reports.(30,31,32)

5.2.8 Demography

The following criterion is the basis for consideration of demography in the site selection process:

The site shall be located to minimize the potential risk to and potential conflict with the population.

5.2.8.1 Population Density/Urban Areas

The following subcriterion is the basis and requirement for consideration of population density and urban areas in the site selection process:

The site shall be located in an area of low population density and at a distance away from population concentrations and urban areas.

5.2.8.1.1 Significance. It is standard practice to site nuclear power plants in areas of lower population due to the potential risk from radiation exposure. However, calculations for a repository show that accidental radionuclide releases to the surface would be very low.[10] Radionuclide releases below the surface are expected to be low and far into the future when the population distribution cannot be projected accurately. Thus, population distribution and density are not considered to be important factors in the current stage of the selection process. This subcriterion is discussed primarily to respond to expected regulations.

The proposed 10 CFR 60 regulations[7] require that a repository be located in an area with a low population density and that the population distribution be such as to assure that a radiological exposure of the population is within the limits of 10 CFR 20.[25] Calculations have shown that an operating repository will have no trouble meeting the limits of 10 CFR 20 for any population distribution. Population doses were predicted between 0.03 and 0.003 percent of background.[15:II-291,33:3-9] In reactor siting, precedence has been established for using 500 people per square mile and below as a low population density.[34]

Used in siting most other nuclear facilities, 10 CFR 100.11[25] criteria determines the distance the facility must be located away from population centers. This regulation requires that individuals residing in a nearby population center, defined as 25,000 residents, not receive a total radiation dose to the whole body in excess of 25 rem or to the thyroid in excess of 300 rem from iodine exposure during the most severe upper limit accident.[35]

Calculations in the Final Environmental Impact Statement[10] show that the dose to an individual located on the edge of the exclusion area at the repository would receive a 70-year committed dose of 0.035 mrem* to the whole body, which is a factor of 700 thousand below the 10 CFR 100 limits. Controlled areas surrounding the repository will be established to prevent adverse human actions that could affect the ability of the natural or engineered barriers to isolate the waste material from the accessible environment.

Dose calculations from accident and routine releases show that, when compared with natural background radiation doses to the population, the potential risk to the population from radiation exposure becomes insignificant[10,15,33].

The final consideration under the urban proximity subcriterion is the effect of a possible evacuation. Credible technical reasons for an evacuation are difficult to postulate. However, the precedent set by regulatory and public interest groups for an evacuation for whatever reason demands that this contingency be considered. The number of people who can be safely evacuated is a consideration.

5.2.8.1.2 Level of Data. Two factors are needed to evaluate demography: (1) the population density as suggested by 10 CFR 60; and (2) the number of people residing within 5 miles (8 kilometers) of a potential site, which can be used for evaluating effects of an evacuation and for comparing the domes.

5.2.8.1.3 Data Acquisition Methods. The location of towns and cities, cumulative population, and population density were obtained from maps, aerial photographs, and published and unpublished literature.

5.2.8.1.4 Adequacy of Data. Available demographic data are sufficient for determining the population densities for this phase of study. Population figures taken from the 1970 U.S. Census are reported in the area characterization reports.[30,31,32]

5.2.8.2 Radioactive Waste Transportation Risk

The following subcriterion is the basis and requirement for consideration of transportation risk in the site selection process:

The site shall be located such that risk to the population from transportation of radioactive wastes and from repository operation

---

*A millirem (mrem) is one thousandth of a rem (roentgen equivalent in man). The radiation dose equivalence in rems is numerically equal to the absorbed dose in rads multiplied by the quality factor, the distribution factor, and any other necessary modifying factors.

can be reduced below acceptable levels to the extent reasonably achievable.

"To the extent reasonably achievable" implies an evaluation must be made that takes". . . into account the state of technology, and the economics of improvements in relation to benefits to the public health and safety and other societal and socio-economic consideration. . ." [10 CFR 20.34(a)].(25)

5.2.8.2.1 Significance. Dose commitment to the population from one year's shipment of spent fuel from existing and planned reactors to a repository located in a particular region is a factor that can be used to compare transportation risks among the domes. The calculated population dose commitments from spent fuel shipments can be compared with background radiation dose to the population to determine the significance of this risk.

The greatest risk in transportation involves accidents. Accident scenario analyses will be done on a site-specific basis in the location phase.

5.2.8.2.2 Level of Data. To calculate population dose commitments from spent fuel shipments, the following information is needed: (1) the most probable rail and truck transportation routes and corresponding distances from all existing and planned reactors within the region of interest; (2) the number of shipments planned per year; and (3) the population densities along the routes. These data are used in conjunction with an assumed travel time and the Department of Transportation dose-rate limit for the shipping cask to calculate dose commitment to the population.

5.2.8.2.3 Data Acquisition Methods. The data required for these calculations were obtained from maps and a literature search. Transportation routes and distances were obtained from Oak Ridge National Laboratory. Population densities were estimated using U.S. Bureau of the Census and Rand McNally data.

5.2.8.2.4 Adequacy of Data. Available data were used to estimate dose commitments to the population from the transportation of nuclear waste and are considered sufficient for this phase. This calculation is sufficient for determining the significance of transportation risk and for comparing the domes.

5.2.9 Environmental Protection

The following criterion is the basis for consideration of the environment in the site selection process:

The site shall be located with due consideration to: potential environmental impacts; air, water, and land use; and ambient environmental conditions.

5.2.9.1 Environmental Impact

The following subcriterion is the basis and requirement for consideration of environmental impact in the site selection process:

> The site shall be located with due consideration to potential environmental impacts.
>
> The evaluation of such impacts will include assessment of air, water, land, aesthetic, ecological, noise, resource, and historical factors appropriate to repository construction, operation, and isolation.

5.2.9.1.1 Significance. The existence of threatened or endangered species, unique sensitive habitats, wetlands, and wild and scenic rivers is the important factor for this subcriterion. The impact of a repository on any of these areas could be significant. Therefore, these areas should be avoided where possible. The overall impact on the terrestrial and aquatic habitats is also of consideration. Assessments of noise and aesthetic factors will be considered in the location place. Consideration of air quality and historical factors is in the next section.

5.2.9.1.2 Level of Data. Knowledge of (1) the existence of any sensitive habitats, wetlands, and wild and scenic rivers; (2) the potential for threatened or endangered species; and (3) a characterization of the existing terrestrial and aquatic habitats are required during the area characterization phase in order to select locations.

5.2.9.1.3 Data Acquisition Methods. A literature search was used to determine the existence of wetlands and wild and scenic rivers, and to characterize the existing terrestrial and aquatic habitats. A literature search and contacts with state experts were used to determine the potential for threatened or endangered species and sensitive habitats. If evidence of possible threatened or endangered species is found, field confirmation is required. Further investigation of a sensitive habitat would be required during the location phase.

5.2.9.1.4 Adequacy of Data. The data obtained from published and unpublished literature, state experts, and site confirmation are adequate for determining the existence of any sensitive and unique areas and for characterizing the existing habitats. This information is reported in the area characterization reports.(30,31,32)

5.2.9.2 Air, Water, and Land Use Conflicts

The following subcriterion is the basis and requirement for consideration of air, water, and land use conflicts in the site selection process:

The site shall be located to reduce the likelihood or consequence of air, water, and land use conflicts.

The consideration of air, water, and land use must include both surface use, subsurface use and resource denial as currently regulated by local, state, and federal legislation. Current legislation and executive orders to be addressed include:

- National Environmental Policy Act of 1969
- The Wilderness Act of 1964
- The Wild-and-Scenic Rivers Act of 1968
- Wildlife Preservation Act of 1966
- Endangered Species Act of 1973
- National Wildlife Refuge Act of 1966
- National Park Service Lands
- National Historic Preservation Act of 1974
- National Heritage Program
- Noise Control Act of 1972
- Resource Conservation and Recovery Act of 1976
- Clean Air Act, Amended 1977
- Clean Water Act, Amended 1977
- The Land Policy and Management Act of 1976
- Floodplain Management, Executive Order 11988
- Protection of Wetlands, Executive Order 11990, 1977
- Prime or Unique Farmlands U.S.D.A 101(b)4.

Consideration of sites covered by these and other applicable acts, orders, or legislation will include evaluation of mitigating measures that could be undertaken to allow repository construction and operation. Such mitigating measures might include removal or exploitation of articles covered by the acts, or shifting location of repository surface systems to avoid such articles. Evaluation of subsurface resources will include assessment of the impact of the denial of mineral, geothermal energy, water, or petroleum resources and the archaeological value of the site. Consideration will be given to whether or not these resources or articles of value can be exploited or removed to allow siting.

5.2.9.2.1 Significance. Lands legally dedicated to uses that are incompatible with a repository should be avoided, unless appropriate changes or exceptions to the laws are enacted. This includes such land uses as national park systems and wilderness areas. Other types of land uses--such as parklands, monuments, scenic views, agricultural uses, existing structures, and cultural places--should also be considered even if they are not protected by law. In some cases, such as historical or archaeological sites, the legally dedicated lands in an area are so small that they are more appropriately considered in the location phase.

Considerations that are environmentally sensitive, such as wild and scenic rivers and wetlands (water uses) and endangered species, were covered previously under the environmental impact subcriterion.

Ambient air quality is an important factor in selecting locations for further study. This subcriterion includes identification of "Class I" areas* and determination of "nonattainment" areas.** Siting a new facility near a Class I area can create air quality licensing problems and require nonstandard construction techniques if the atmospheric emissions from construction intrude into the Class I area in significantly measurable amounts. Siting a new facility in a nonattainment area can also create difficult air quality licensing problems; such problems could even preclude construction.

The proposed 10 CFR 60 regulations[7] require that a repository site possess meteorological characteristics to assure that a radiological exposure of the population is within limits of 10 CFR 20.[26] Calculations have shown that an operating repository will have no trouble meeting the limits of 10 CFR 20 under any meteorological conditions.[15,33]

<u>5.2.9.2.2 Level of Data</u>. Current land uses on and adjacent to the proposed location, including areas legally dedicated to uses that are incompatible with a repository, are required to be identified during the area characterization phase in order to select locations.

The data needed to determine potential siting problems caused by ambient air quality conditions are the locations of Class I and nonattainment areas. The meteorological data needed are mixing heights and wind speeds.

<u>5.2.9.2.3 Data Acquisition Methods</u>. A search of maps, photographs, and literature, and contacts with state experts were used to determine potential land use conflicts. A literature search was performed to identify Class I and nonattainment areas and obtain meteorological data in the area of interest.

---

*Class I means that increases in baseline air quality with respect to ambient sulfur dioxide or particulate matter must be restricted to very low percentages of the corresponding National Ambient Air Quality Standards (NAAQS).

**An attainment area is an area judged by the Environmental Protection Agency (EPA) to be equal to or better than the primary or secondary NAAQS. Primary standards limit levels of air quality the EPA judges necessary to protect the public health, while secondary standards restrict levels of air quality judged necessary to protect the public welfare from any known or anticipated adverse effects of a pollutant.

5.2.9.2.4 Adequacy of Data. The data obtained from maps, photographs, published and unpublished literature, and state experts are sufficient for determining current and planned land uses in the area characterization phase. All Class I areas and nonattainment areas were identified and a history of the meteorological data was obtained.

5.2.9.3 Normal and Extreme Environmental Conditions

The following subcriterion is the basis and requirement for consideration of normal and extreme environmental conditions in the site selection process:

The site shall be located with due consideration to normal and extreme environmental conditions.

5.2.9.3.1 Significance. The evaluation of such items as high winds, tornadoes, rainfall, flooding, and normal meteorological conditions must be included to ensure that environmental impacts that would result from construction runoff, spoil-pile erosion, and other repository-related activities are mitigated or eliminated to the extent practicable.

5.2.9.3.2 Level of Data. The information needed on extreme environmental conditions is frequency and intensity of tornadoes, severe thunderstorms with high winds, hurricanes, floods, and heavy rainfall. The normal meteorological data needed are mixing heights and wind speeds.

5.2.9.3.3 Data Acquisition Methods. The required data are obtained from reviewing historical area meteorological data from the National Weather Service.

5.2.9.3.4 Adequacy of Data. All required historical-meteorological data were obtained and reported in the environmental area characterization reports.(30,31,32)

5.2.10 Social/Economic Impact

The following criterion is the basis for consideration of social, political, and economic factors in the site selection process:

The repository shall be sited with due consideration to social, political, and economic impacts on communities affected by the repository.

5.2.10.1 Social/Economic Impacts

The following subcriterion is the basis and requirement for consideration of socioeconomic impacts in the site selection process:

> The repository site shall be located so that social (including economic and political) impacts resulting from repository construction and operation can be managed by mitigation and/or compensation strategies.
>
> Social and economic impacts include both positive and negative effects on individuals, communities, and institutions, such as: the influx of new workers into a town, the effect of population growth on housing markets and community services, the fiscal burden on the local government, the impacts on governmental processes, and changes in land use patterns. Some impacts may remain for which compensation or mitigation may be necessary.

5.2.10.1.1 Significance. The size of the local population and the proximity to an urban center are important in determining potential settlement patterns of in-migrants. Labor in-migration is directly related to pressures on community facilities and services. The availability of appropriately skilled labor in sufficient quantity and within commuting distance has implications for labor migration and consequent demand on community services. If the skilled labor necessary for repository construction and operation can be drawn primarily from the region and nearby urban centers rather than from outside this area, there will be fewer demands on the local community. A large increase in population growth could strain the local infrastructure and lead to inadequate services and housing facilities.

A sudden increase in the need for local wholesale and retail goods for construction purposes may result in localized shortages and price increases.

Residents may experience increases in personal cost of living. Coupled with possible wage rate differentials between skilled in-migrants and the local population, financial difficulties may arise for long-term residents on fixed incomes.

There is an important trade-off to consider. Proximity to urban areas may provide a skilled labor force for the repository and necessary services for workers and their families. At the same time, however, the intensity of land use and population density may conflict with the desirability of minimizing the number of people in the vicinity of the site. Thus, the local socioeconomic and political concerns become a trade-off with the concern for nearby population centers. Since all the sites under consideration are within a 50-mile (80.5-kilometer) commuting range from an urban center, those sites which best balance the needs of nearby population centers and the repository community would be the more desirable.

Local land use considerations are also important in the site selection process. Existing land use (e.g., agricultural, recreational, residential), local zoning restrictions, and land use plans may be affected by the placement of a repository. The political and legal ramifications of land use conflict will be experienced in varying degrees among sites under consideration for intense evaluation.

5.2.10.1.2 Level of Data. An assessment of local and regional population density of potential site communities is required to project population increase and socioeconomic effects. Wage rate differentials based on local income and project-labor wage rates are also needed. Finally, information concerning local zoning regulations and land use plans is required.

5.2.10.1.3 Data Acquisition Methods. Data may be acquired by searching literature, such as regional planning documents, and by contacting relevant state and regional agencies. Most information will be secondary-level data that have already been compiled by federal, state, and county agencies.

Draft environmental characterization reports on the Texas, Mississippi, and Louisiana study areas provide useful information for a socioeconomic impact assessment.[29,30,31,32] For example, data on population density and proximity of urban centers to the potential site community are provided. Unemployment rates, employment by category (occupation), and per capita income are presented for each county within the three study areas. These figures--supplemented by census data, information from federal, state, and local agencies, and site visits--will be useful in assessing the need for in-migrant workers and for projecting the impact on local communities. Information on per capita income and the percentage of persons below the poverty line will be useful in assessing potential wage rate differentials.

The Final Environmental Impact Statement[10] forecasts the total number of workers needed during the construction and operation phases of a repository. This information is provided on a regional level, as is project-induced (secondary) employment. Socioeconomic data from other large-scale energy-related projects will be useful in assessing expected and actual effects of increased population on the local community.

5.2.10.1.4 Adequacy of Data. Regional population data, population densities, local land use plans, and wage rate differentials are available and are adequate for comparative purposes during this phase.

5.2.10.2 Transportation, Access, and Utility*

The following subcriterion is the basis and requirement for consideration of transportation requirements in the site selection process:

> The site shall be located so that adequate access and utility capability required for the repository either exists or can be provided without unacceptable impact on affected communities.

> The movement of construction equipment and supplies, and of waste to the repository during operation, can create burdens on highway and rail systems. Both systems need to be adequate to carry these loads, or may need to be upgraded if current capability is not adequate. Utility services must have the capacity to expand to meet the demands of growth.

5.2.10.2.1 Significance. Transportation facilities and the availability of utility services within the region are an important consideration when planning for the mitigation of adverse socioeconomic impacts. Facets of transportation such as comparative costs, accident risks, public perception, and increased public use must be considered before site construction. Shipping distance on a regional basis (cost and safety) and population density (urban proximity) are the primary considerations associated with transportation. Existing highway, rail, and water transportation facilities are differentiating factors. The movement of construction equipment and supplies and the increased use during repository operation can create burdens on highways, railways, and waterways. These systems need to be adequate to carry the anticipated loads or to be upgraded if inadequate. Utilities must have the capacity to provide services such as electricity, water, and, in some cases, natural gas to meet the demands of growth. Location of a repository may affect the costs of distributing these services if new distribution systems are required.

5.2.10.2.2 Level of Data. Accurate and comprehensive data are needed concerning highway, railway, and water systems. Distances from the potential repository site to urbanized areas and the quality of the transportation systems are the primary considerations. At this phase, data are needed on major and secondary highways, rail carriers, and waterway facilities and capabilities. Information is needed on the availability of utilities in relation to potential sites.

---

*The draft NWTS Criteria for the Geologic Disposal of Nuclear Waste: Site-Qualification Criteria [DOE/NWTS-33(2)] contains a subcriterion that states that the repository site shall avoid conflicts with the existing legal requirements and be accepted by the established processes of affected governments. This proposed subcriterion will be appropriately applied during the decision process, which will follow the issuance of this report.

5.2.10.2.3 Data Acquisition Methods. Necessary data are acquired from maps, aerial photographs, utility and transportation officials, ONWI subcontractors' reports(29,30,31,32) and other literature.

5.2.10.2.4 Adequacy Data. The necessary data are available and are adequate for comparative purposes during this phase.

REFERENCES

1. Office of Nuclear Waste Isolation. 1980. Summary Characterization and Recommendation of Study Areas for the Gulf Interior Region, ONWI-18, prepared by Battelle Project Management Division for U.S. Department of Energy, Contract EY-76-C-06-1830, November.

2. Office of Nuclear Waste Isolation. 1979. Tabulation of Waste Isolation Computer Models: Final Report, Science Applications, Inc., ONWI-78, Battelle Memorial Institute, Columbus, OH, December.

3. Aronow, S. 1980. "Maximum Potential for Erosion and Sedimentation in the Future", in Area Characterization Report, Vol. 1, Introduction, Background, and Summary, Gulf Coast Salt Domes Project, by Law Engineering Testing Company, Marietta, GA, draft.

4. Lamb, H. H. 1971. Climate: Present, Past and Future, Vol. 1, Climate Fundamentals and Climate Now, Metheun, London, England.

5. Lamb, H. H. 1977. Climate: Present, Past and Future, Vol. 2, Climate History and the Future, Metheun, London, England.

6. Donn, W. L., W. E. Farrand, and M. Ewing. 1963. "Pleistocene Ice Volumes and Sea-Level Lowering", in Journal of Geology, Vol. 70, p. 206-214.

7. Office of the Federal Register. 1980. Code of Federal Regulations: Proposed Rules, 10 CFR 60, Government Printing Office, Washington, DC, draft, May.

8. Kolb, C. R. 1978. "Supplementary Quaternary Studies", in An Investigation of the Utility of Gulf Coast Domes for the Storage or Disposal of Radioactive Wastes, Vol. 2, EW-78-C-05-5941/53, by J. D. Martinez, R. L. Thoms, C. R. Kolb, M. B. Kumar, R. E. Wilcox, and E. J. Newchurch, Institute of Environmental Studies, Louisiana State University, Baton Rouge, LA.

9. Alford, J. 1977. Erosion Rates at Vacherie Dome for the Next 250,000 Years, Institute of Environmental Studies, Louisiana State University, Baton Rouge, LA.

10. U.S. Department of Energy. 1980. Final Environmental Impact Statement--Management of Commercially Generated Waste, DOE/EIS-0046-F, Washington, DC, October.

11. Claiborne, H. C., and F. Gera. 1974. Potential Containment Failure Mechanisms and Their Consequences at a Radioactive Waste Repository in Bedded Salt in New Mexico, ORNL/TM-4639, Oak Ridge National Laboratory, Oak Ridge, TN.

12. Law Engineering Testing Company. 1980. Area Characterization Report, Vol. 1, Introduction, Background, and Summary, Gulf Coast Salt Domes Project, Marietta, GA, draft.

13. Law Engineering Testing Company. 1980. Area Characterization Report, Vol. IV, Mississippi Study Area, Gulf Coast Salt Domes Project, Marietta, GA, draft.

14. Pacific Northwest Laboratory. 1979. Reference Site Initial Assessment for a Salt Dome Repository, Vol. 1, PNL-2955, Richland, WA.

15. U.S. Nuclear Regulatory Commission. 1980. In the Matter of Proposed Rulemaking on the Storage and Disposal of Nuclear Waste (Waste Confidence Rulemaking), PR-50,51 (44 FR 61372)--Statement of Position of the United States Department of Energy, DOE/NE-0007, Washington, DC, draft, April.

16. Joy, D. 1981. Regional Repositories Spent Fuel Logistics Characterization Report, ONWI-124, ORNL, Oak Ridge, TN, March.

17. Brunton, G. D., and W. D. McClain. 1977. Geological Criteria for Radioactive Waste Repositories, Y/OWI/TM-47, Office of Waste Isolation, Union Carbide Corporation, Nuclear Division.

18. Law Engineering Testing Company. 1978. Geologic Evaluation of Gulf Coast Salt Domes: Site Selection Program Plan, prepared for Office of Waste Isolation, Union Carbide Corporation Nuclear Division.

19. Claiborne, H. C., L. D. Rickertsen, and R. F. Graham. 1980 Expected Environments in a Nuclear Waste/Spent Fuel Repository in Salt, ORNL/TM-7201, Oak Ridge National Laboratory, Oak Ridge, TN, August.

20. Callahan, G. D., and L. Ratigan. 1977. Thermoelastic Analyses of Spent Fuel Repositories in Bedded and Dome Salts, Y/OWI/SUB-77/22303/4, prepared by RE/SPEC, Inc. for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

21. Law Engineering Testing Company. 1980. Area Characterization Report, Vol. II, East Texas Study Area, Gulf Coast Salt Domes Project, Marietta, GA, draft.

22. Law Engineering Testing Company. 1980. Area Characterization Report, Vol. III, North Louisiana Study Area, Gulf Coast Salt Domes Project, Marietta, GA, draft.

23. Belchic, H. C. 1960. The Winnfield Salt Dome Field Trip Guide Book, Winn Parish, LA, p. 29-47.

24. Dames & Moore. 1977. Baseline Rock Properties--Salt, Technical Report DM-2A, prepared for Office of Waste Isolation by Union Carbide Corporation under subcontract No. 62Y-45701C.

25. Office of the Federal Register. 1980. Code of Federal Regulations: 10, Energy, Parts 0 to 199, 10 CFR 20, 50 and 100, Government Printing Office, Washington, DC.

26. Holdahl, Sandford R., and N. L. Morrison. 1974. "Regional Investigations of Vertical Crustal Movements in the U.S. Using Precise Relevelings and Mareograph Data", Tectonophysics, Vol. 23, p. 373-390.

27. Viessman, W., T. E. Harbaugh, and J. W. Knapp. 1972. Introduction to Hydrology, Intext Educational Publishers, NY.

28. Linsley, R. K., M. A. Kohler, and J.L.H. Paulhus. 1975. Hydrology for Engineers, McGraw Hill, Inc., NY.

29. Bechtel National, Inc. 1980. Regional Environmental Characterization Report for the Gulf Interior Region and Surrounding Territory, ONWI-67, San Francisco, CA, November.

30. Bechtel National, Inc. 1980. Environmental Characterization Report for the Louisiana Study Area: Gulf Interior Region, ONWI-192, San Francisco, CA, draft, November.

31. Bechtel National, Inc. 1980. Environmental Characterization Report for the Mississippi Study Area: Gulf Interior Region, ONWI-193, San Francisco, CA, draft, November.

32. Bechtel National, Inc. 1980. Environmental Characterization Report for the Texas Study Area: Gulf Interior Region, ONWI-194, San Francisco, CA, draft, November.

33. U.S. Department of Energy. 1980. Waste Isolation Pilot Plant: Environmental Impact Statement, DOE/EIS-0026, Washington, DC, October.

34. U.S. Nuclear Regulatory Commission. 1975. Regulatory Guide 4.7, Washington, DC, November, p. 9.

35. U.S. Atomic Energy Commission. 1974. Regulatory Guide 3.24, Washington, DC, December, p. 9.

6.0 EVALUATION OF DOMES

In this section, the salt domes are evaluated to identify potential locations. The evaluation examines the relative favorableness of each acceptable dome with regard to the differentiable factors and determines the relative importance of these differences.

6.1 SALT DOME CONSIDERATIONS

The salt dome evaluation results in the recommendation for further investigation of four Gulf Coast salt domes: Richton and Cypress Creek in Mississippi, Oakwood in Texas, and Vacherie in Louisiana. One dome, Palestine in Texas, was eliminated earlier due to a potential safety flaw (see Section 6.1.2). Lampton dome in Mississippi, Rayburn's dome in Louisiana, and Keechi dome in Texas are assessed as not acceptable (eliminated) because of inadequacy in meeting site geometry requirements.

6.1.1 Application of Criteria

An evaluation of the data in Section 5.0 indicated that Gulf Coast salt domes under consideration could be differentiated by applying the site performance criteria. These criteria have different weights of significance in the siting process, as analyzed in Section 5.0. In Section 6.0 these criteria and subcriteria are applied to data for each dome in the same numbering format as in Section 5.0. For example, the evaluation of each dome with respect to the depth to host rock subcriterion is numbered 6.2.1.1, and that subcriterion was stated and its significance analyzed in Section 5.2.1.1.

6.1.2 Consideration of Safety

Of the domes studied in the area characterization phase, one was dropped when it failed to meet site performance criteria. During the area phase of investigating the eight candidate domes, data indicated that Palestine dome in Texas is unsuitable for use as a repository. The data showed dissolution of the dome due to salt brining operations, which have now ceased. The subsurface cavities created by these operations have caused significant collapses observed at the surface. For example, the most recent collapse, in 1972, measured 36 feet (11 meters) in diameter, while earlier ones ranged from 27 to 105 feet (about 8 to 32 meters) in diameter with some of them in excess of 15 feet (5 meters) in depth.(1)

A report by the Texas Bureau of Economic Geology(2) describes the brining operations as follows:

"A critical problem for Palestine dome is potential subsidence from the abandoned brine operations over the dome. The Palestine Salt and Coal Company produced brine from at least 15 brine wells from 1904 to 1930. Saline brine water from beneath the caprock and above the salt was allowed to drain into dome salt cavities, become saturated and then (was) pumped out... Well depth ranged from 150 feet [45 meters] to a maximum of 500 feet [150 meters]..."

It is highly probable that the brine operations may have altered the hydrology and increased the rate of salt solution at Palestine dome. The collapses that have already taken place may have created pathways for water to circulate between the caprock and the salt. Such circulation of water could result in additional dissolution and future collapses of the strata overlying the dome. Due to this condition, the following two significant concerns related to safety arise:

(1) Can there be assurance that the host rock will maintain its integrity through a period of 10,000 years or more?

(2) Can surface structures for the repository be constructed with assurance that no significant subsidence will occur due to the possible collapse of strata underlying their foundations?

Of these concerns, the Texas Bureau of Economic Geology report concludes:

"There are serious doubts about the suitability of Palestine salt dome for a repository to isolate nuclear waste because of the abandoned salt brine operations. The random geographic and spatial occurrence of collapse sinks over the dome may prevent safe construction of the necessary surface installations for a repository. The dissolution of salt between the caprock and dome may permit increased rates of salt dissolution long into future geologic time."

Hence, there is considered opinion that this type of dissolutioning may be a major problem. In the draft technical criteria (10 CFR 60), NRC defines evidence of dissolutioning as a potentially adverse natural geologic condition. The collapses that have occurred at this dome provide indications of the potential adverse condition addressed in the NRC criteria.

The decision process discussed in Section 3.2 of this report includes non-acceptance (elimination) of a site being investigated if a condition is identified which will compromise the long-term stability of the host rock or the hydrologic characteristics around the dome cannot be assured. For this reason, Palestine dome has been excluded from further consideration as a potential site.

Considerations of the appropriate information did not reveal any unacceptable safety conditions at the other seven domes. Hence, Cypress Creek, Richton, Lampton, Vacherie, Rayburn's, Oakwood, and Keechi domes were considered potential locations for further evaluation during area characterization studies.

6.2 CONSIDERATION OF CRITERIA

6.2.1 Site Geometry

6.2.1.1 Depth to Host Rock

Depth to host rock, which is a differentiating and eliminating factor, considers the vulnerability of the host rock (salt dome) to exposure to the environment. Such exposure could occur due to removal of the overlying strata by major climatic changes or meteor impact.

Under extreme conditions associated with glacial activity, the tops of Rayburn's dome in Louisiana and Keechi in Texas could be exposed as a result of overburden removal. Because of the vulnerability of these domes to the above natural effects, it is recommended that they be eliminated from further consideration and not continue as candidate repository sites at this time. Other domes are not affected by consideration of these extreme climatic changes or by consideration of moderate-sized meteor impacts and are considered acceptable for this factor.

Status. Table 6-1 presents data on the remaining seven domes under study regarding the depth of the host rock under consideration and potential erosion and inundation scenarios.

The table indicates that dome depth and erosion potential are quite variable. Of the seven domes investigated, Rayburn's would be breached either by erosion of the land above and around it or by impact of a moderate size meteorite. Keechi would be breached if lowering of sea level occurred during a major glaciation and the major streams were regraded to the new sea level.

6.2.1.2 Thickness of Host Rock

The thickness of the host rock, which considers the adequacy of the host rock for construction of a repository with an adequate buffer zone, is not a differentiating factor. All domes by definition exceed the 800-foot (244-meter) buffer zone for vertical host-rock thickness. The 800-foot (244-meter) buffer is based on technical conservatism, standard mining practice, the practice adapted to European waste management programs, and criteria used in the Strategic Reserve Program. The salt stock is essentially unlimited vertically, with depth to the Louann salt layer as much as 15,000 to 30,000 feet (4,572 to 9,144 meters) below the surface. The requirement selected is for the repository to be located from 1,000 to 3,000 feet (305 to 914 meters) below surface grade, and this can be accomplished for all the domes.

Status. All domes have adequate vertical thickness (see Table 6-2), although the vertical and lateral thickness at Lampton (and Palestine) can only be estimated, based on generalized geophysical data and geological deduction.

TABLE 6-1. DEPTH OF HOST ROCK CONSIDERATIONS

(See Appendix B for metric conversion)

Dome	Approximate Elevation Range (ft)* of Supradomal Surface Within ± 3000 ft Structure Contour	Elevation of Top of Salt Below Sea Level (ft)	Minimum** Depth from Surface to Top of Salt(ft)	Scenario 1 Melting of Ice Sheets: Possible Inundation From 270 ft Sea Level Rise	Scenario 1 Melting of Ice Sheets: Possible Inundation From 360 ft Sea Level Rise	Scenario 2 Lowering of Sea Level: Regarded Erosion*** Overburden Thickness Remaining (ft)
Oakwood	300-500	-811	1163	None	Partial	Adequate
Keechi	340-480	-85	435	None	Partial	None, breached
Vacherie	180-320	-560	777	Partial	Total	Adequate
Rayburn's	180-300	+90	115	Partial	Total	None, breached
Richton	160-290	-508	722	Partial	Total	Adequate
Lampton	190-370	-1360	1646	Partial	Partial	Adequate
Cypress Creek	180-270	-1037	1271	Total	Total	Adequate

* Determined from USGS Quadrangle Maps and interpolated to nearest 10 feet.

** Minimum depth is not the algebraic difference of the minimum ground surface elevation and the elevation to the top of salt because the locations of these measurements are not coincident.

*** Landward leveling considered to be not credible. Erosion limits utilized are 275 feet for domes in Mississippi, 425 feet for domes in Texas, and 525 feet for Louisiana domes.

TABLE 6-2. VERTICAL THICKNESS OF DOMES
(See Appendix B for metric conversion)

Dome	Host Rock Vertical Thickness*	Assumed Repository Depth**
Oakwood	1,780	2,800
Keechi	2,260	2,700
Cypress Creek	1,020	2,400
Richton	1,050	1,900
Lampton	850	2,500
Vacherie	1,000	2,600
Rayburn's	1,750	2,000

*From probable repository depth to the bottom of caprock in feet.

**Depth from surface level in feet. Repository horizon opposite a confining layer. This depth may change as further studies establish more definitive physical and engineering depth limits.

6.2.1.3 Lateral Extent of Host Rock

The lateral extent of host rock, which is a differentiating factor, considers the adequacy of the areal extent of the domes under investigation to accommodate the repository workings and provide an adequate buffer zone surrounding it. The reference repository workings area is 1,500 net acres (600 hectares). This can contain 75,000 MTU of spent fuel at a thermal loading of 60 KW/acre, with a minimum buffer zone of 800 feet (245 meters).

Rayburn's, Keechi, and Lampton domes are too small to meet the reference repository size. Therefore, it is recommended that they be eliminated from further considerations.

Cypress Creek, Oakwood, and Vacherie provide buffer zones of 1,680, 1,400, and 1,150 feet (512, 425, and 350 meters), respectively, for the reference repository workings. Therefore, they remain on the list of potential domes for this purpose with acceptable ratings for this factor.

Richton is most favorable, because the largest buffer zone [2,900 feet (885 meters)] would be realized by placing the reference repository in a concentric configuration in this dome. This dome also provides the flexibility of placement of the repository workings, accommodating a reduction in the thermal loading, or avoiding gas or brine pocket areas that may have been too small to be detected before repository development.

Status. Table 6-3 evaluates dome sizes on a 1,500-acre (600-hectare) (75,000 MTU at 60 KW/acre) repository.

TABLE 6-3. EVALUATION OF DOME SIZES
(See Appendix B for metric conversion)

Dome	Net Acreage Available at Repository Depth*	Buffer Zone (Feet)	MTU Accommodated with 800' buffer	Buffer Zone Provided for 75,000 MTU (Feet)
Richton	3,760 (1)	800	188,000	2,900
Cypress Creek	2,130 (1)	800	106,500	1,680
Oakwood	1,940 (3)	800	97,000	1,400
Vacherie	1,760 (2)	800	88,000	1,150
Rayburn's	924 (2)	800	46,000	None
Keechi	990 (1)	800	49,500	None
Lampton	500**	800	25,000	None

* Available dome area minus 800-foot buffer zone.
** See discussion on accuracy of data in Section 5.2.1.3.
(1) ± 10%: supported by high resolution seismic, gravity
(2) ± 10%: supported by purchased overdome seismic, gravity
(3) ± 30%: supported by purchased deep (CDP) seismic and gravity

6.2.2 Geohydrology

6.2.2.1 Geohydrologic Regime/Flow

At the area characterization phase the ground-water flow regime has been evaluated as a nondifferentiating factor by bounding calculations on travel times through the aquifers and confining layers surrounding the domes.

The regional and near-dome ground-water flow regimes were evaluated from the results of the area characterization field program and existing hydrologic data. Sufficient data were available at the end of area characterization to define regional ground-water flow directions in fresh-water aquifers in the vicinity of all domes. Additionally, adequate data were available to construct preliminary potentiometric surface maps for saline-water aquifers in the Mississippi study area (Richton, Cypress Creek, and Lampton domes).

Status. The conclusions with regard to the geohydrological regime provide the perspective that (1) no dome can be eliminated at this time due to hydrologic deficiencies and (2) all domes have good potential for satisfactory hydrologic transport times. It is not likely that more detailed data would change the calculated ground-water flow times significantly enough to disqualify any of the domes.

Test holes will be drilled during the next phase of characterization to define discharge areas for deep saline aquifers that might transport radionuclides away from the domes. Cores of both aquifers and confining units will be obtained to aid in the evaluation.

Additional test holes will be cored and drilled at the domes to investigate the potential for transport of radionuclides by "short circuiting" flow through caprock or fractures.

6.2.2.2 Hydrologic Regime/Modeling

Hydrologic modeling is not a differentiating factor. The existing data and models are insufficient to prove that the present and probable future conditions of the hydrological regime have no unacceptable impact on repository performance. However, no significant problems associated with the existing flow conditions were detected from the quantitative and qualitative analysis.

Status. The area characterization data are sufficient to generate conceptual ground-water flow models of the study areas from which preliminary estimates of regional ground-water flows were established. Potentiometric surface maps and cross-sectional views were used to develop the conceptual models. A one-dimensional analytical model was used to obtain a preliminary estimate of the ground-water flow time in the vertical direction at the domes.

6.2.2.3 Geohydrologic Regime/Shaft Construction

Insufficient data are available to differentiate among the domes on the basis of this factor. Since shaft sinking is not in the current phase, this factor is not appropriately considered until selected domes are chosen. Working shafts have, with very few exceptions, been placed in Gulf Coast salt domes without problems. Avery Island, Weeks Island, Jefferson Island, and others have had shafts emplaced for many years without failures. However a shaft at Belle Isle mine did fail due to unchecked water leakage along the outer periphery of the shaft. These shafts were constructed using standard mining and construction techniques with off-the-shelf materials and equipment.

Only a single data point exists for several of the domes under consideration: that of the hole drilled into salt. A considerable number of additional data points will be required for a comparative evaluation of geohydrologic characteristics of stratified units over the domes.

There is currently no evidence that the general geohydrologic regime over any of the domes will prohibit construction or the sealing of shafts, drifts and boreholes; however, the amount of water that represents an engineering threshold to construction has not been determined.

Status. Palestine dome, in addition to having a lake over it, has a number of collapses related to a previous brining operation as discussed. Brine cavities within the upper portion of the salt have caused collapse of overlying caprock and sediments. The indeterminate location and extent of cavities within the upper portion of the salt make it currently impossible to fully characterize these conditions.

A recent mine accident occurred at the Diamond Crystal salt mine in a dome at Jefferson Island, Louisiana. A lake situated over the dome and connected by canal to the Gulf of Mexico drained into and caused complete flooding of the mine. The origin of this accident is presently under investigation. The impact of this type of accident is being assessed.

Hydrologic conditions related to shaft construction are more favorable at the other domes. Due to variations in the overlying stratigraphy and amount/nature of caprock, some differences among the domes may exist. At Rayburn's dome, all sedimentary units are saturated from about 3 feet (about 1 meter) below the surface. The water is brackish, with the water table varying seasonally from 2 to 6 feet (0.6 to 1.8 meters) deep. For other domes, hydrologic properties are directly related to the total thickness of rocks above the dome and the sand/clay ratio of those rocks. Table 6-4 summarizes the total thickness of sand and clay in the rock units overlying the domes under consideration. As a general rule, the higher the amount of sand, the greater the potential for hydrologic problems associated with shaft construction and maintenance of shaft liners.

TABLE 6-4. TOTAL THICKNESS OF SAND/CLAY OVERLYING DOMES*
(See Appendix B for metric conversion)

	Clay (ft)	Sand (ft)
Cypress Creek	743	424
Richton	394	156
Lampton	875	595
Vacherie	190	340
Rayburn's	(**)	(**)
Oakwood	184	516
Keechie	150	350

*These thicknesses are based on calculations from top of caprock to surface.

**Dome almost crops out; virtually no overlying sedimentary units; clay and sand content variable.

6.2.2.4 Dissolution

The future dissolution potential of the salt domes was evaluated from past history and the occurrence of saline anomalies. As indicated previously, Palestine dome was eliminated at an early stage of consideration because of dissolutioning associated with a brining operation, which was discontinued some years ago. Minor saline anomalies have been identified from various evidence by members of the area characterization team and mapped near several of the domes, including Oakwood, Vacherie, Cypress Creek, and Richton. These anomalies are based on sparse data points. The anomalies have not been identified to result from dissolution of salt from beneath the caprock and are not considered serious enough to warrant being considered less favorable.

At Vacherie and Rayburn's domes, other lines of evidence indicate that present day and/or Quaternary dissolutioning of the salt domes is occurring. Both exhibit some evidence for dissolutioning at the dome top during the Quaternary. Rayburn's dome has shallow porous caprock, with a past history of brining operations. A topographic depression directly over the dome is indicative of dissolution. Vacherie appears to have undergone extensive dissolutioning in the past with attendant collapse of pre-Quaternary age materials which is expressed as a complex system of over-dome faulting. There is, however, no evidence of collapse due to Quaternary dissolution at Vacherie. The base level of Quaternary terraces which are not offset suggests stability. Cypress Creek has a swamp over the dome which preliminary studies indicate might be related to domal dissolution and over-dome strata subsidence.

Cypress Creek, Oakwood, Vacherie, and Rayburn's, with dissolutioning features, were considered less favorable. The lines of evidence for dissolution at Richton are much weaker than at Lampton and Keechi. All three domes are considered acceptable.

Status. The unsuitability of Palestine dome has been addressed in a previous report.[1] The conclusion of an extensive examination on the abandoned salt "brining" operations was that the random locations and spatial occurrence of one to five collapse "sinks" over the dome may prevent safe construction of the necessary surface installations for a repository. The dissolution of salt between the caprock and the dome from at least 15 brine wells up to 500 feet (150 meters) deep might permit increased rates of salt dissolution long into future geologic time. It was concluded that the induced subsurface dissolution is occurring at a rate difficult, if not impossible, to assess or to calculate. It cannot be shown that this dissolution rate is insignificant to the integrity of a future repository or to ancillary features The most recent significant collapse was 36 feet (11 meters) in diameter and occured in 1972. Other collapses have ranged from 27 to 105 feet (8 to 32 meters) in diameter and from 1-1/2 to more than 15 feet (1/2 to 4 1/2 meters) deep.

Additionally, there is some evidence of salinity anomalies in the vicinity of Oakwood,[3] Cypress Creek, and Vacherie domes[4] and weaker lines of evidence near Richton dome. These anomalies may indicate minor current dissolution (Oakwood) or may represent relict high salinities that have not yet been flushed out (Richton, Cypress Creek, Vacherie), due to the very slow movement of ground water in the basins.

On the basis of geomorphology, domes in Louisiana exhibit some evidence of dissolution at the dome top prior to the Quaternary period.[5] This is most pronounced at Rayburn's dome, which occupies a circular depression that is almost exactly coincident with the underground outline of the dome and which disrupts the normal drainage pattern. In addition, Rayburn's dome has some early history of brine production. Although this brining operation is thought to be minor, it represents a serious licensing issue because of the lack of documentation. No records were kept on hole locations, numbers of holes, and amount of salt removed.

The southern portion of Cypress Creek dome is overlain by a swamp, which might be interpreted as a result of recent and/or ongoing dissolution at the top. Also, the apparent down dropping of the base of alluvium, and the base of the Cittronelle formation appears to indicate dissolution/subsidence during the Quaternary. The apparent lack of datable terrace surfaces allows the Quaternary interpretation.

6.2.3 Geochemistry

6.2.3.1 Chemical Interaction

Existing or probable chemical interaction data obtained during area characterization studies provides no reason to differentiate among salt domes. The level of information is adequate to proceed to the next phase. Future use of chemical interaction as a differentiating factor may depend as much on the status of waste package design and development as on additional information from site characterization. The geochemical processes, past or present, and the materials and consequences of these processes, are important in assessing the suitability of a candidate site because they bear directly on the design of potential waste packages, the choice of waste package and assessment of long-term performance of the repository. The suitability of a given dome depends, in part, on the nature and rate of geochemical processes that are acting to increase or decrease the rate at which that dome is or may undergo dissolution by ingressing ground water.

Status. The data bearing on chemical interaction are discussed under two subheadings: Brine Migration and Dissolution/Ingress of Ground Water.

Brine Migration. Brine migration is worthy of concern because the small (<1.0mm) inclusions of brine in natural salt can migrate up the thermal gradients produced by the emplaced nuclear waste, creating a chemical condition that must be dealt with in the design of the waste packages. The amount of water in natural salt in salt domes is commonly much less than 0.5 wt% and often less than 0.001 wt%[6,7]. The rate at which brine inclusions can migrate is dependent on the size of the inclusions and various other parameters[8,9]. The rates of migration of inclusions in salt from Rayburn's and Vacherie domes are in the same range as those obtained for equivalent-sized inclusions in salt from the Waste Isolation Pilot Plant site[9]. Under expected repository environments for salt[10], the amount of brine accumulating in each hole containing a canister of nuclear waste is less than 10 liters for an average initial concentration of brine inclusions of 0.5 volume %, which is a factor of 2 to 10 higher than salt in salt domes.

The research behind the above noted calculations of brine inflow to a waste package was largely done on salt by petrographic analysis from sources other than the domes considered in this report. Visual and petrographic examination of salt cores from the domes considered in this report finds the salt in all domes to be high purity NaCl with stringers of anhydrite[11,12,13,14] and similar in average properties to the salt used in the above noted research.

Dissolution/Ingress of Ground Water. The very existence of salt domes in the Gulf interior region requires that each dome be surrounded by a material of low permeability that has greatly reduced the rate at which ground water is and has dissolved the salt stock. The exterior of this protective material is in contact with ground water and possibly/potentially subject to degradation by reaction with the ground water. Dissolution of the caprock or sheath could result in increased permeability which, in turn, could result in increased dissolution rates of the salt stocks.

The caprock over five domes has been drilled with partial recovery of cores. Four of the five domes, Vacherie, Cypress Creek, Richton and Oakwood have over 100 feet (over 30 meters) of massive anhydrite capping the salt stocks[11,12,15,16]. Rayburn has at least three feet of massive anhydrite caprock and about 30 total feet (about 9 total meters) of caprock. The thick anhydrite sections of the caprocks commonly have discrete bands and zones of gypsum and the upper part may have gypsum cement between the grains of anhydrite. The hydration of anhydrite ($CaSo_4$) to gypsum ($CaSo_4 \cdot 2H_2O$) shows that at some time in the dome's history water penetrated the caprock. This may have been long ago and be completely inactive today. For the current level of investigation, it is adequate to note that this has not resulted in any obvious increases in porosity of the massive anhydrite portion of the caprock. Increases in the porosity of the upper part of the caprock, where it contacts meteoric ground water, are common and may have been produced by either growth or dissolution of the caprock. Determination of the growth and/or dissolution rates of different parts of the caprock will be addressed in future work.

Preservation and/or augmentation of the caprock and sheath may occur, or have occurred, by upward migration of reducing gasses and/or reducing saline waters from depth. Carbon isotopic evidence[16] indicates that much of the carbon in the calcite portion of the caprock at Oakwood dome came from thermogenic methane, which must have migrated up from depth. Such upward-migrating, reducing fluids also enhance the isolation ability of the dome itself, especially if they migrate upward along the boundary between the salt stock and the sheath. This is because the long lived component of the nuclear waste consists very largely of elements that are precipitated in reducing environments.

Information about dome dissolution can be sought in the salinity values of ground water surrounding the domes. Resisitivity logs of drill holes can be interpreted to give total salinity. Chemical analyses of the ground waters show what portion of the total salinity is $Na^+ + Cl^-$, hence, potential for dissolution of the salt in the dome. High concentrations of Na^+ and Cl^- alone are not indicative of dome dissolution because they could result from upward leakage of deep, saline water along faults or from sampling areas where low permeability has resulted in extensive chemical evolution of the ground water or to incomplete flushing of saline "connate" water. Areas of high salinity have been sampled and some of them have high Na^+ and Cl^- concentrations, but none can presently be shown to conclusively be the result of dissolution of the salt in one of the domes considered in this report.[17,18,19]

6.2.3.2 Radionuclide Retardation.

There is nothing in the present level of information concerning radionuclide retardation to differentiate among the seven salt domes.

The hydrology of the confining and water bearing units surrounding the domes give the minimum travel times from the repository to the biosphere. Because of various chemical and physical effects, very few, perhaps none, of the radionuclides dissolved in the ground water will travel at the same velocity as the ground water.[20]

Status. The information bearing on radionuclide retardation will be discussed under the subheadings Reducing Environment and Sorption/Ion Exchange.

Reducing Environment. Long-lived radionuclides are those most likely to escape a repository emplaced in a salt dome and have a chance to contaminate aquifers adjacent to a dome. Many of these radionuclides are extremely insoluble in the reducing environments that exist in the sediment outside the domes. The importance of such reducing environments is illustrated by a brief sketch of the conditions of uranium ore formation in sedimentary wedges along the Texas Gulf Coastal plain. These sedimentary wedges are very similar in internal structure and geochemistry[17,18,19,21] to the sedimentary wedges through which the salt domes have penetrated. In the formation of these uranium ores, the uranium is leached out of the source material by meteoric water and transported down flow in a confined aquifer in sandy portions of the sediments. The meteoric water reacts with the sediments, oxidizing them and becoming increasingly reduced itself. When conditions in the ground water become sufficiently reducing, the U^{+6} is reduced to U^{+4}, precipitates, and becomes an integral part of the ore body. With time, the uranium ore body migrates very slowly down flow as uranium is oxidized, transported and reduced again. In the case of a repository being breached by meteoric water (or other oxidizing water) which then exits through the breach in the dome, a similar sequence of oxidation, followed by reduction and immobilization, will occur.

Sorption and Ion Exchange. The term "sorption" has different meanings for different people. It is often used in the NWTS program to denote all processes and mechanisms that remove dissolved material from ground water. Here, it is used to denote processes other than precipitation and ion exchange.

In sediment such as that surrounding salt domes, ion exchange on clays plays a major role in removing divalent cations such as Ca^{+2} and Mg^{+2} from the ground water and replacing them with Na^{+}, resulting in waters whose dissolved material is essentially Na^{+} and HCO_3^{-}[17,18,19,22,23]. This ion exchange occurs over hundreds to thousands of years and will also reduce the concentrations of Sr^{90}, and probably to a lesser extent, that of Ra^{226} in ground water exiting a breached repository.

In addition to clays, other important sinks for trace elements (including radionuclides) are oxides of iron and manganese, organic matter, sulfides and carbonates[20]. These are abundantly present in the sediments surrounding the salt domes.

6.2.4 Geologic Characterization

6.2.4.1 Stratigraphy

Stratigraphy, which considers whether the subsurface setting in the vicinity of the repository system is definable and continuous, is not a differentiating factor. Stratigraphy directly over the domes is more complicated than that surrounding the domes because emplacement-related faults formed during the final stages of dome growth. These nontectonic structures complicate the stratigraphic setting; however, this local complexity is characteristic of all salt domes and cannot be used to differentiate one dome from another at the area characterization stage. The stratigraphy of the selected dome will, of course, be characterized in great detail during the site-specific exploration program.

Status. Detailed stratigraphic descriptions can be found in Volumes II, III, and IV of the Area Characterization Report.[17,18,19] All of these data have been evaluated in characterizing the stratigraphy of the Gulf Coast salt domes. Numerous stratigraphic cross sections make it clear that the stratigraphy in the environs of the Gulf Coast salt domes is definable and continuous in a large area surrounding each of the domes. The stratigraphy is sufficiently well known to be able to identify the variety of rock types and to identify discontinuities, such as faults in the Gulf Coast salt basins. Surrounding each dome are thousands of feet of sediments distributed more or less in "layer-cake" fashion.

6.2.4.2 Host Rock

Host rock characteristics, which consider existing fracture orientation and potential thermally induced fractures, water content, hydration and dehydration of mineral components, brine migration, and other phenomena are not differentiating factors.

Status. Important host rock characteristics have been determined for each of the candidate domes where access is available. Analyses have been made in order to compare the characteristics of each dome's salt with previously existing information on rock salt characteristics. Comparison of data from the candidate domes with the world-wide body of data on rock salt characteristics indicates that relevant characteristics of the salt at the candidate domes fall within the range of values to be expected from previous investigations.[24]

The U.S. Geological Survey has investigated moisture content of salt recovered from Rayburn's and Vacherie domes.[25] USGS reports indicate moisture contents as high as 0.1 to 0.5 percent, but predominantly in the range 0.01 percent to less than 0.001 percent by weight. This predominant range is less than has been reported from other salt domes not involved in this program.[26]

6.2.4.3 Rock Strength

Rock strength, which considers geologic characteristics which preclude, or make excessively difficult, repository design and construction, is not a differentiating factor.

Status. Studies in the literature indicate similar strengths for dome salt. Additional detailed studies of salt characteristics will be performed in later phases of the program.

6.2.5 Tectonic Environment

6.2.5.1 Tectonic Element

The study of tectonic elements considers the impact of faults, regional uplift and subsidence, and anomalous geothermal gradients on the repository system. Anomalous tectonic phenomena such as epeirogenic or kalokinetic events are not differentiating factors among domes at the area level of investigation.

Status. There is no evidence of anomalous tectonic phenomena in the Gulf Coast salt dome area identified at the regional or area characterization level.

However, Richton dome is located 5 miles (8 kilometers) west of the Phillips fault system, which is postulated by Oxley and others[27] to be a fault manifested by the presence of the Heidelberg-Sandhill Salt Ridge[19:p.12-57] Seismic evidence discussed by Morgan [28] indicates that the faulting in the system is minor and the loss of section is due to rapid thinning and up-dip convergence of beds.

Another fault, F-7, is adjacent to the west flank of the Richton salt stock and is thought to be related to salt movement, not regional tectonic forces[19:p.12-67]

6.2.5.2 Quaternary Faulting

Quaternary faulting within 5 miles (8 kilometers) of the subject salt domes is considered a potential containment/isolation issue and is a differentiating factor. At the area characterization level, information indicates that the domes located in the east Texas salt basin are near reported offset Quaternary Terrace deposits. This area, located 15 miles (24 kilometers) north-northwest of Oakwood dome and 14 miles (22 kilometers) south of Keechi dome, is the only area in the Gulf Coast where possible Quaternary faulting has been reported.[2]

The presence of this suspected fault caused the Oakwood and Keechi domes to be considered conservatively as less favorable. Additional investigation would be required to prove or disprove the relationship of this suspected surface fault to the Mt. Enterprise system. The domes in Louisiana and Mississippi are considered acceptable for this factor, because there are no known faults of known tectonic origin within 45 miles (72 kilometers) of any of the domes.

Status. Exposed surface faults and evidence of nonexposed faults have been identified and described in the literature (see Table 6-5). No known Quaternary faults lie within the near field [3 to 5 miles (5 to 8 kilometers)] studied and assessed in the area characterization phase. However, possible Quaternary movement has been described on the Mt. Enterprise fault zone, which is the nearest regional fault system to any of the domes of interest.

The offset Trinity River terrace deposits near Oakwood and Keechi domes are the only reported or suspected Quaternary fault activity in the Gulf Coast salt dome project areas.

TABLE 6-5. DISTANCE TO NEAREST MAJOR REGIONAL FAULT
(See Appendix B for metric conversion)

	Miles
Lampton	75
Rayburn's	70
Richton	45
Cypress Creek	56
Vacherie	50
Keechi	14
Oakwood	15

6.2.5.3 Quaternary Igneous Activity

The study of Quaternary igneous activity, which is not a differentiating factor, considers the likelihood and impact of igneous activity on the repository system. There has been no Quaternary igneous activity recorded in any of the areas in the Gulf Coast salt dome region.

Status. There is no recorded or observed indication that Quaternary igneous activity has occurred within the region as indicated in Table 6-6. This determination for regional and area characterization will also be adequate for site characterization.[24]

TABLE 6-6. IGNEOUS ACTIVITY

Area	Record of Quaternary Igneous Activity	Distance from Area(s) to Recorded Activity
Eastern Texas	No	N/A
Northern Louisiana	No	N/A
Eastern Mississippi	No	N/A

6.2.5.4 Uplift and Subsidence

The study of uplift and subsidence, which are not differentiating factors, consider whether domal movement will affect the performance of the repository system. Areas are neither being uplifted nor subsiding but appear to be very stable.

Status. Regional uplift and/or subsidence has been evaluated by existing first order level surveys across the U.S., and histories and current geomorphic evidence in the study areas and may approach 2 to 4 millimeters per year.(19). At present, the first order level survey data is being re-evaluated at Cornell University. Geomorphic evidence indicates that the Gulf Interior salt basin region has been stable for at least the past several million years. Domal uplift and/or subsidence (see Table 6-7) within the areas of interest are at a rate below detection limits and pose no safety problem.(24) At Cypress Creek deeply incised stream beds and the possibility that the base of the Cittronelle formation is entrenched deeper at the southern end than at the northern end may indicate dissolution/ subsidence at the southern portion of the dome. This potential dissolution effect and the pre-Quaternary dissolution/subsidence are manifestations of dissolution and are addressed in Section 6.2.3.1.

TABLE 6-7. UPLIFT/SUBSIDENCE

Texas	Keechi	See note below
	Oakwood	See note below.
Louisiana	Vacherie	See note below. Undisturbed Quaternary terraces indicate long-term stability; however, overdome faults caused by pre-Quaternary dissolutioning and subsidence are present.

TABLE 6-7. (Continued)

	Rayburn's	See note below. Undisturbed Quaternary terraces indicate long-term stability. Topographic depression over dome.
Mississippi	Richton	See note below.
	Cypress Creek	Potential for Quaternary dissolution/subsidence. Topographic depression over dome.
	Lampton	See note below.

Note: Area has no known uplift/subsidence in Quaternary time. The Gulf Coast salt dome project region is in an erosion cycle, and no known force, such as sedimentation, is occurring to cause such movement.

6.2.5.5 Seismicity

The study of seismicity considers the effects of vibratory ground motion on the design and performance of the repository system. Ground-surface acceleration cannot be used as a differentiating factor for any of the domes within this area since the values for all are low and fall below the level of significance (0.2 g).

Status. All areas within the Gulf Coast salt dome project region have been assessed to be the same. That is, there is no difference between tectonic structures and plotted epicenters within the region. The earthquake potential in the study area has a maximum horizontal ground-surface acceleration of 0.06 gravity[24] based on the 1811 New Madrid earthquake, as shown in Table 6-8.

TABLE 6-8. SEISMICITY

	Modified Mercalli	Ground Acceleration (g)
Eastern Texas	VI	0.06
Northern Louisiana	VI	0.06
Eastern Mississippi	VI	0.06

Low values of ground acceleration, i.e., less than 0.2 g (9.8 meters per second^2), are insignificant when related to design, engineering, and construction capabilities. Moderate values, between 0.2 and 0.5 g, pose a design, engineering, and construction feasibility and cost problem. High values, greater than 0.5 g at the surface, pose a grave problem related to the seismic risk associated with design, engineering, and construction and project cost.

6.2.6 Human Intrusion

6.2.6.1 Resources

The study of resource potential, which is a differentiating factor, considers the likelihood of future human intrusion in the search for or exploitation of any resources including salt from the domes. Based on all available data, and with implementation of the best possible estimation techniques, four domes can be assessed as unfavorable for total mineral resource potential. These four domes are, in ascending order, Rayburn's, Keechi, Oakwood and Cypress Creek. However, there is little to recommend any of the domes for future mineral exploration. On the basis of Dr. Murray's report, even Oakwood and Cypress Creek domes, ranked highest among the seven, have very minimal potential. The four domes, Rayburn's, Keechi, Cypress Creek and Oakwood are assessed as less favorable for resource potential.(17)

Status. Potential resources do exist in the vicinity of the domes, and their future development may be desirable. Data presently available do not, however, indicate the worth of any uniquely valuable resource. Higher quality resources exist in other parts of the country in much greater quantities than in the areas of the domes. Development of any of the resources around the domes would be of low priority.

The economic practicality of attempting to exploit the known resources of the candidate domes is low in comparison with other known deposits. Removing them from the usable domain would not jeopardize the national, regional, or local welfare for the foreseeable future.

In reaching this conclusion, the following types of potential resources were evaluated: asphaltic rock, bentonite and other volcanic materials, brines and salt, cement materials, construction and road materials, geopressured and geothermal resources, heavy minerals, iron ore, lignite, oil, natural gas, and unusual gases.

Oil and gas are currently produced from Jurassic, Cretaceous, and Tertiary aged strata of the interior salt basins of the northern Gulf Coast. The structures of the seven domes indicate that major hydrocarbon resources, excluding existing production of Oakwood and Cypress Creek domes, are unlikely to exist within 2 miles (3 kilometers) of any of them and certainly not within one mile of them. Based on all available data, the seven study domes can be ranked for potential hydrocarbon exploitability as follows: Rayburn's, Lampton, and Richton--speculative to poor; Keechi, Vacherie, Oakwood, and Cypress Creek--poor.(24:p.2-162)

Lignite coal has become an important resource in the Texas and Louisiana study areas; however, there are no known resources near the domes. Other potential mineral resources exist in the northern Gulf Coastal provinces, but all are considered to be nonproductive or nonexploitable to negligible or speculative.(24:pp. 2-154 to 2-182)

In addition to Dr. Murray's investigation, an inventory was made of all existing exploration holes in the vicinity of each of the seven domes. All exploratory borings within 5 miles (8 kilometers) of the candidate domes were identified. This information is discussed in Section 6.2.6.2, Exploration History.

6.2.6.2 Exploration History.

The study of exploration history, which is a differentiating factor for Oakwood and Rayburn's domes, considers the impact of past human intrusion on the performance of the repository system. Table 6-9 lists the domes in descending order of suitability on the basis of exploration over the domes and within 2 kilometers and 5 miles (8 kilometers), respectively. The extensive borings at and near Oakwood are most unfavorable for this dome from a licensing standpoint. It should also be noted that the closeness of Rayburn's dome to the surface represents potential for use of the salt and is also an unfavorable factor.

TABLE 6-9. EXPLORATION HISTORY

	Number of Borings			
	Over Dome		Vicinity	
	Into Salt	Into Caprock	2 Km	5 miles (8 Km)
Cypress Creek	7	7	9	22
Lampton	1	8	16	39
Rayburn's	4	8	12	66
Keechi	9	9	25	88
Vacherie	9	10	26	168
Richton	9	31	39	85
Oakwood	36	36	38	74

The Gulf Coast salt dome region is associated with active oil exploration in the states of Mississippi, Louisiana, and Texas. There has been some oil exploration in the immediate vicinity of Cypress Creek and Oakwood domes, including borings which penetrated caprock and salt. The nature and density of such exploration have been fully characterized, and the domes have been evaluated relative to the type and density of borings to caprock, into the salt, into the salt to repository level, and in the general vicinity of the domes.

Approximately 36 holes have penetrated the salt at Oakwood dome, some at the repository level, and many of the penetrations have been further whipstocked below the salt overhang. Therefore, Oakwood was assessed as most unfavorable based on its exploration history. Locations of these deep boreholes are not well documented and borehole sealing of whipstocked holes has technical uncertainties associated with it. The NRC clearly states that evidence of previous drilling within the disturbed zone is considered a potentially adverse condition and as such may preclude licensing at Oakwood dome.

The salt penetrations that exist at the other domes are few in number and are sufficiently documented. Borehole plugging can be considered viable at all domes other than Oakwood.

It was also concluded that Rayburn's shallow depth offered a unique opportunity for salt recovery operations by even a primitive society, and Rayburn's was assessed as unfavorable because of this human intrusion potential. The remainder of the domes were judged acceptable with regard to exploration history.

Status. The exploration history of each of the domes has been evaluated in detail. The ranking on both the 2-kilometer and 5-mile (8-kilometer) bases is indicated in Table 6-9. Oakwood is unique in that the record shows that many early salt penetrations were made, but their locations are not given.

6.2.6.3 Land Ownership

Land ownership, which is not a differentiating factor, considers the ability of the federal government to obtain ownership of and control access to the repository site. Land privately owned or owned by state governments or another federal agency can be obtained by various legal mechanisms. Any differentiation is in the land use, not the ownership.

Status. Lampton Dome: Approximately half of the dome is overlain by the Marion County Wildlife Management Area. This public game preserve is owned by the Mississippi Department of Wildlife Conservation (formerly the Mississippi Game and Fish Commission).

Richton Dome: Land on the dome is privately owned.

Cypress Creek Dome: The entire dome lies within the boundaries of DeSoto National Forest. A portion of the land is owned by the U.S. government and managed by the U.S. Forest Service. The Forest Service, in turn, has granted use to the Mississippi National Guard under a special use permit. Section 16 and some adjoining parcels are owned by the state of Mississippi. Section 16 lands are typically managed for the benefit of schools within the state.

Vacherie Dome: Land on the dome is privately owned.

Rayburn's Dome: Land on the dome is privately owned.

Keechi Dome: Land on the dome is privately owned.

Oakwood Dome: Land on the dome is privately owned.

6.2.7 Surface Characteristics

6.2.7.1 Surficial Hydrologic System

The surface hydrology associated with each of the domes is important to repository safety.

Surface flooding considerations influence whether substantial flood protection is necessary for optimum shaft placement. No domes were eliminated because an engineering solution for flood protection exists for the design of all the surface facilities. Assuming that vertical shafts will be used, the projection of the salt perimeter at proposed repository depth up to the surface was used to estimate the location most likely for placement of shafts. These locations are judged against the areas inundated by a Probable Maximum Flood (PMF). All domes have some percentage of their area inundated by a PMF. As shown in Table 6-11, these areas range from 9 percent at Oakwood to 29 percent at Cypress Creek. Construction of a repository at any one of the domes would involve some earth work. The domes that do not have significant stream drainage through their areas will probably need only engineered fill to protect against a PMF flood. Keechi, Vacherie, Oakwood, and Cypress Creek domes may also require dikes for flood protection or to divert drainage. These dikes would likely be categorized as safety-related. Keechi, Vacherie, Oakwood, and Cypress Creek domes are judged less favorable due to these surface hydrological considerations.

Surface impoundments in the supradomal area may influence the site selection, design of surface facility, and ground-water regime adjacent to the shafts. Surface impoundments as far away as the outcrop areas of the hydrogeologic units surrounding the dome at repository level and lower may influence the ground-water regime of interest.

No domes were eliminated due to this hydrologic consideration. Palestine and Lampton were assessed slightly less favorably because of existing water bodies over the supradomal area. Lake Bill Waller, a new man-made impoundment is at the Lampton site and Duggeys Lake is at Palestine. The existence of these two lakes is considered to be minor because the detrimental effects are limited to the site planning and construction phase of the surface facilities.

TABLE 6-10 PROXIMITY TO REGIONAL OR AREAL DRAINAGE

Dome	Drainage Patterns
Keechi	Minor stream drainage of Keechi Creek through the dome area. Ten miles from major drainage divide of Trinity River Basin and Neches River Basin.
Oakwood	Drainage of minor watershed of Alligator Creek runs through dome area.
Vacherie	Dome area drained by Bashaway Creek. Dome is adjacent to drainage divide between Boggy Bayou and Black Lake Bayou, subbasins of the Red River.
Rayburn's	Dome area drained by Fouse Creek. Dome is adjacent to drainage divide between Saline Bayou and Dugdemona River.
Richton	Minor drainage by several creeks in all directions from north central point of dome area. Dome area is in the interior of Leaf River drainage area.
Cypress Creek	Minor stream drainage of Cypress Creek through dome area. Dome area is adjacent to drainage divide between Black Creek and Leaf River.
Lampton	Drainage by several creeks is away from dome area center. Dome is adjacent to upper Little Creek.

TABLE 6-11. FLOODS AND FLOOD PROTECTION
(See Appendix B for metric conversion)

Dome	Probable Maximum Flood Coverage, %	Earthwork Needed
Keechi	17	Yes, fill, divert drainage, no net fill needed
Oakwood	9	Yes, divert drainage, nominal fill needed
Vacherie	18	Yes, divert drainage, nominal fill needed
Rayburn's	20	Yes, nominal net fill needed
Richton	12	Yes, nominal net fill needed
Cypress Creek	44	Yes, drain swamp, nominal net fill needed
Lampton	10	Yes, drain lake, no net fill needed

TABLE 6-12. EXISTING AND FUTURE IMPOUNDMENTS
(See Appendix B for metric conversion)

Dome	Significant Future Impoundments, Feasible, Close	Proximity of Dome to Existing Impoundments
Keechi	No	15 miles to Coon Creek Lake (small, outside study area), 20 miles to Lake Palestine (large)
Oakwood	No	15 miles to Fairfield Lake (small)
Vacherie	No	7 miles to Lake Bistineau, man-made (17,200 acres), 7 miles to Kepter Creek Lake, man-made (small)
Rayburn's	No	7 miles to Kepter Creek Lake, man-made (small)
Richton	No	3.9 miles to unnamed reservoir
Cypress Creek	No	5.6 miles to Perry Lake (30 acres), 13 miles to Lake Shelby
Lampton	No	175-acre man-made lake on dome, Lake Bill Waller

<u>Status</u>. The surface hydrologic data have been evaluated to detect each dome's susceptibility to the probable maximum flood (PMF) and the type of earthworks, if any, that are likely to be needed as protection against such a flood. The data are summarized in Tables 6-10 and 6-11.

Because of the gentle slopes, low topographic relief, and low seismicity of the region, failures of stream banks are unlikely to cause flooding that would compromise the safety of any of the domes including the surface facilities during the operation period. More definite calculations will be made in the next study phase of preferred locations. There are no impoundments whose failure would affect the safety of any of the dome areas, including the surface facilities during the operation period.

The surface hydrologic data have been evaluated for both the short-term operational phase and the long-term isolational phase. There are no impoundments whose failure would unacceptably affect the safety of any of the dome areas.

Future man-made or natural impoundments as far away as the outcrop areas of the hydrogeologic units surrounding the domes at repository elevation, and lower, can affect the regional ground-water circulation patterns of interest. The occurrence of such events would not produce significant detrimental effects and thus would not affect the safety of the domes. In addition, such occurrences are judged to be "equally likely" events for all seven domes and thus cannot be considered differentiating factors.

Sea level changes would produce changes in the ground-water regime, but these changes would likely be of the same order of magnitude at all seven domes and cannot be considered a differentiating factor.

Proximity to existing impoundments is also provided along with a judgment as to whether future impoundments of significant size could be feasibly located adjacent to or close enough to influence the regional ground-water regime adjacent to each dome. The data are summarized in Table 6-12.

6.2.7.2 Surface Topography

The study of surface topography considers the impact of natural and cultural hazards to the safe transportation of nuclear waste to the repository. Uniformly benign topographic relief exists in the Gulf Coast region. This factor does not allow differentiation among the seven salt domes.

Status. In the Gulf Coast region, high-relief terrain does not occur and there are no hazards associated with transportation of materials over or through such terrain.

6.2.7.3 Meteorological Phenomena

The three study areas experience little difference in meteorological phenomena. The meteorological phenomena subcriterion is not a differentiating factor and is considered for assessing impacts on repository operation.

Status. All study areas experience hurricanes, tornadoes, and severe thunderstorms. Table 6-13 gives historical meteorological phenomena data for the three study areas.

TABLE 6-13. METEOROLOGICAL PHENOMENA

Study Area	Maximum Rainfall*	Hurricanes** (Winds > 33 m/s)	Hurricanes** (Winds > 56 m/s)	Tornadoes***	Annual Extreme Windspeed
Louisiana	25.4 cm	44	9	36	32 m/s
Mississippi	26.7 cm	24	-	40	38 m/s
Texas	27.9 cm	49	18	12	35 m/s

* 100-year recurrence.
** 1886 to 1970.
*** 1955 to 1967.

6.2.7.4 Industrial, Transportation, and Military Installations.

This subcriterion includes interactive land and air uses that could conflict with the construction and operation of a repository. None of these installations would preclude the siting of a repository in any of the three study areas. Since all three areas contain potential conflicts, this subcriterion is not considered to be a differentiating factor.

Status. In the Louisiana study area, there are several types of air and land uses that could conflict with the construction and operation of a repository. These uses include small airports, low altitude training routes, nuclear facilities/activities, and large industrial complexes. There are no nuclear or industrial facilities in the Mississippi study area; however, there are small airports, restricted airspaces, and a military operations area. The Texas study area contains several small airports and two electrical generating facilities.

6.2.8 Demography

This criterion includes population density, urban areas, and transportation risk.

6.2.8.1 Population Density and Urban Areas

There are no significant differences in the population densities at the domes. The population within 5 miles (8 kilometers) of Palestine and Keechi domes is significantly higher, but urban proximity is not considered to be differentiating.

Status. Table 6-14 presents the demography at each of the eight domes.[29,30,31:2,6] All domes are located in areas of low population density (much less than 500 people per square mile). The population within 5 miles (8 kilometers) of all domes is considered low enough to allow for evacuations.

TABLE 6-14. DEMOGRAPHY OF DOMES
(See Appendix B for metric conversion)

	Towns/Cities Within 5 miles of dome	Town/City Population	Population Density* (people per square mile)
Lampton	None	rural population only**	42
Richton	Richton	1,110	14
Cypress Creek	Beaumont and New Augusta	1,572	14

*Population density for counties where domes are located.
**Unincorporated, sparsely populated areas.

TABLE 6-14. (Continued)

	Towns/Cities Within 5 miles of dome	Town/City Population	Population Density* (people per square mile)
Oakwood	None	rural population only**	13 and 8
Keechi	Palestine	14,525	26
Palestine	Palestine	14,525	26
Rayburn's	None	rural population only	19
Vacherie	Heflin	314	19 and 65

*Population density for counties where domes are located.
**Unincorporated, sparsely populated areas.

6.2.8.2 Radioactive Waste Transportation Risk

This subcriterion considers risk to the population from transport of radioactive waste. The differences in the calculated population doses from transportation of nuclear waste are not considered to be differentiating. If the dose calculations were expanded to include all reactors in the U.S., the differences among the domes would be even less. Thus, transportation risk is not a differentiating factor.

Status. Relative population dose commitments were calculated for seven domes using the existing and planned reactors in the southern U.S. as sources. The results are given in Table 6-15.

TABLE 6-15. POPULATION DOSE COMMITMENTS FOR DOMES*

	Population Dose, person-rem/year
Lampton	52
Richton	49
Cypress Creek	50
Oakwood	79
Keechi	78
Palestine	Not Calculated
Rayburn's	66
Vacherie	66

*These doses are less than 0.005 percent of that received from background radiation, thus insignificant. All of the domes meet the subcriterion of reduced risks from transportation.

6.2.9 Environmental Protection

This criterion includes environmental impact, air/land/water conflicts, and extreme/normal meteorological conditions.

6.2.9.1 Environmental Impact

Environmental factors pertaining to the siting of a nuclear waste repository must be considered in the area to location decision.* This subcriterion is considered to be less favorable for Lampton dome. All of the candidate dome sites are covered by a mix of forested and agricultural land. There are potential habitats of threatened or endangered species at all domes, but field surveys have not confirmed the existence of such species at any of the domes. Wild and scenic rivers near Vacherie and Rayburn's domes are not considered close enough to indicate a less favorable condition. Likewise, the intermittent wetlands over Cypress Creek are not unique to the area and are not judged a disadvantage. The wildlife preserve maintained by the state of Mississippi at Lampton dome was perceived as a definite environmental issue. The evaluation is that Lampton is less favorable for this consideration. The other domes were considered equally acceptable.

Status. Table 6-16 compares the domes on potential environmental impacts.[29,30,31:Section 2] No unique sensitive habitats are located on or near the domes. During the winter months, much of Cypress Creek dome is flooded. During the summer, marsh areas are much more limited. This intermittent wetland is not considered to be unique. No threatened or endangered species have been sighted. The wild and scenic rivers near Rayburn's dome and Vacherie dome should not be affected. A game reserve is located above Lampton dome.

TABLE 6-16. POTENTIAL ENVIRONMENTAL IMPACTS
(See Appendix B for metric conversion)

Domes	Habitat	Endangered Species[a]	Other Considerations
Lampton	75% Forest, Lake	Possible	Game Reserve
Richton	50% Forest, Ponds 50% Agriculture	Possible	None

[a]All domes are located in counties that contain endangered species. However, no actual sightings at any of the domes have been verified. A comprehensive field survey will be made during location studies.

*An environmental assessment, which will accompany the final decision document, will determine whether these and other impacts should be considered in an environmental impact statement at this stage of the site characterization process.

TABLE 6-16. (Continued)

Domes	Habitat	Endangered Species[a]	Other Considerations
Cypress Creek	20% Clear Cut, 80% Forest	Possible	Intermittent wetland
Oakwood	75% Forest	Possible	None
Keechi	50% Forest; 50% Open	Possible	None
Palestine	53% Forest, Lake; 47% Open	Possible	None
Rayburn's	10% Clear Cut; 80% Forest, Marsh	Possible	Wild and scenic river (Saline Bayou), 2 miles west
Vacherie	90% Forest	Possible	Wild and scenic river (Black Lake Bayou), 1 mile east

[a]All domes are located in counties that contain endangered species. However, no actual sightings at any of the domes have been verified. A comprehensive field survey will be made during location studies.

6.2.9.2 Air, Water, and Land Use Conflicts

This subcriterion is considered to be differentiating for land use conflicts. The federal use of the national forest over Cypress Creek for military operations was viewed as more favorable land use relative to the consideration of this factor. In addition, only three buildings are located on land over the dome. The location of the town of Richton near Richton dome and the wildlife preserve at Lampton were categorized as less favorable from a land use standpoint. The other domes were viewed as acceptable with primarily agricultural and forestry land usage. Air use is not considered to be differentiating among the domes. Water use was included under environmental impacts.

Status. Table 6-17 presents the important land use conflict considerations for the eight domes.(29,30,31) No wilderness areas, proposed wilderness areas, or prime or unique farmland exist on or near the eight domes. DeSoto National Forest and Camp Shelby Military Reservation are located on Cypress Creek dome. The Marion County Wildlife Management Area and an existing small cemetery are located on Lampton dome. A prehistoric site is located 1 mile (1.6 kilometers) east of Vacherie dome and a cemetery is located on the dome. The town of Richton is located adjacent to Richton dome. Lands over the domes contain existing buildings.

TABLE 6-17. LAND USE CONFLICT CONSIDERATIONS
(See Appendix B for metric conversion)

	Buildings on Domes	Agriculture	Other
Lampton	<15	6 dairies in 4 miles	Wildlife refuge, existing cemetery
Richton	<20	50% cultivated/pasture	Adjacent town
Cypress Creek	3	None	National forest, military reservation
Oakwood	<15	5,800 cattle in 3 miles	None
Keechi	<15	11,500 cattle in 3 miles	None
Palestine	<15	13,500 cattle in vicinity	None
Rayburn's	<30	1,500 cattle in 4 miles	None
Vacherie	<35	125 cattle in 4 miles	Prehistoric site 1 mile east, existing cemetery

All eight domes are in Class II areas and are considered by the EPA to be attainment areas. The closest Class I area to any of the domes is about 90 miles (145 kilometers).[29,30,31] At this distance air quality is not considered to be of importance in siting a repository.[29,30,31] The mixing heights and wind speeds for the three study areas are given in Table 6-18.[29,30,31]

TABLE 6-18. ANNUAL AVERAGE METEOROLOGICAL DATA

Study Area	Mixing Heights (m) AM	Mixing Heights (m) PM	Wind Speed (m/s) AM	Wind Speed (m/s) PM
Louisiana	497	1452	5.7	6.0
Mississippi	402	1299	5.3	7.2
Texas	650	1450	6.5	7.0

Atmospheric diffusion estimates at all domes will be equal to other interior locations of the U.S. Diffusion is not limited by mixing heights or wind speed. There are no unique characteristics at any of the domes that would cause a potential air quality problem or result in any differences in the diffusion factors.

6.2.9.3 Normal and Extreme Environmental Conditions

This is not a differentiating factor since there are no significant differences among the eight domes under this subcriterion.

Status. Information on normal and extreme environmental conditions was given in Sections 6.2.9.2 and 6.2.7.3, respectively.

6.2.10 Socioeconomic Impacts

The following is an evaluation of socioeconomic impacts for domes under consideration during this phase.

6.2.10.1 Social/Economic

The socioeconomic impacts on the town of Richton, located in the control zone if a repository were sited in Richton dome, are considered less favorable, and should be given detailed consideration during the next phase and be included in the environmental impact statement.

Possible differentiating factors include existing land uses, local land use plans, and the requirement for in-migrant workers, which includes the population density within 10 miles (16 kilometers) of the dome and regional population figures. These factors vary somewhat between potential sites.

Status. Table 6-19 presents regional population within a 50-mile (80-kilometer) range as one indicator of the potential labor supply. Table 6-20 lists population densities within 10 miles (16 kilometers) of each dome.

TABLE 6-19. REGIONAL POPULATION*

	Total Population Within 50 mi (80 km) of Dome
Rayburn's	657,900
Oakwood	540,000
Richton	1,177,000
Cypress Creek	1,177,000
Vacherie	684,000
Lampton	1,177,000
Keechi	540,000

*1970 census data.

TABLE 6-20. POPULATION DENSITIES WITHIN 10 MILES*
(See Appendix B for metric conversion)

		Persons/Square Mile**
Rayburn's	- Bienville Parish, Louisiana	19.3
Oakwood	- Freestone County, Texas	12.9
	- Leon County, Texas	7.9
Richton	- Perry County, Mississippi	13.9
Cypress Creek	- Perry County, Mississippi	13.9
Vacherie	- Webster Parish, Louisiana	64.9
	- Bienville Parish, Louisiana	19.3
Lampton	- Marion County, Mississippi	41.6
Keechi	- Anderson County, Texas	25.9

*1970 census data.
**Persons/square mile in the United States, 57.7.

Areas immediately surrounding the domes are sparsely populated. The population densities within 5 miles (8 kilometers) of the centers of Keechi, Lampton, Oakwood, and Rayburn's domes are very low. Such low densities will minimize the number of households relocated because of proximity to the dome. Because of the lower populations in these areas, there will be a need for a greater influx of workers, which will cause other socioeconomic impacts.

Comprehensive regional land use plans either exist or are under consideration for Rayburn's, Oakwood, Vacherie, and Keechi domes. Local land use plans are available for some municipal areas near Richton, Cypress, Lampton, Palestine, and Keechi domes. Counties in Mississippi where the domes are located have no comprehensive land use plans.

A comparison of local income in affected counties versus the national average indicates possible wage rate differentials. The national average is almost two times greater than the county per capita income for Rayburn's, Richton, Lampton, and Vacherie and 1-1/4 times the local average for the other domes.

6.2.10.2 Transportation, Access, Utility

No dome is sufficiently different in terms of access or potential access to transportation and utility systems to be deemed less favorable as a potential site.

Status. Potential repository sites in Texas, Louisiana, and Mississippi have the following transportation and utility service characteristics:

- Less than a 5-mile (8-kilometer) distance to the nearest U.S. or state highway

- Less than a 9-mile (14.5-kilometer) distance to a Class I railroad system (except for Rayburn's which has a 2-mile (3.2-kilometer) distance to a Class II railroad system)

- Less than a 35-mile (56-kilometer) distance to a waterway in Texas and Louisiana; no relevant waterway system in Mississippi

- Potential accessibility to electric power, phone, and other utilities.

Table 6-21 summarizes data concerning existing transportation facilities and urban proximity of the dome sites in Texas, Louisiana, and Mississippi.

6.3 RECOMMENDATION OF DOMES

The deliberations discussed above establish the acceptance (relative favorableness) or non-acceptance (elimination) of the domes with regard to differentiable factors. This discussion resulted in elimination, based on conservative uncertainty considerations, of Lampton, Rayburn's, and Keechi domes. Acceptable are Richton, Vacherie, Cypress Creek, and Oakwood domes.

As shown in Table 6-22, Richton, Vacherie, Cypress Creek, and Oakwood remain as acceptable locations following the establishment of the relative favorability of domes and the importance of factors. The choice among these candidates and the future exploration activities at these locations are discussed below and in Section 7.0.

6.3.1 Eliminated Domes

One dome, Palestine, was eliminated in 1979 since it was found to have a significant safety flaw associated with prior dissolution processes. Strong implications concerning the safety of a repository result from the impact of this past dissolutioning.

Three domes were eliminated because they did not meet minimum site geometry requirements. These domes are:

<u>Keechi Dome</u>. This dome was eliminated because of inadequate lateral extent with regard to a reference repository loading. This loading could not be accommodated in Keechi dome with an adequate buffer. The dome would also be eliminated for being at an inadequate minimal depth. In addition, the dome has the uncertainty of the presence of Quaternary faulting and less favorable geochemical regime, mineral resources, and surficial hydrologic system. Keechi dome is recommended for elimination as a candidate repository location because of the inadequate lateral extent and minimum depth.

TABLE 6-21. EXISTING TRANSPORTATION FACILITIES AND SOURCE POINT PROXIMITY(30,31,32)

(See Appendix B for metric conversion)

	Nearest US/State Highway	Class I Railroad	Class II Railroad	Waterway
Texas				
Oakwood	U.S. 79 bisects dome U.S. 45 within 8 miles	1 mile S. 9 miles S.E.		Trinity River 14 miles E.
Keechi	State 19 bisects dome, State 287 within 3 miles	9 miles S.E.		Trinity River 20 miles W.
Louisiana				
Rayburn's	State Hwys 4 and 155 bisect dome		2 miles E.	Red River 35 miles W.
Vacherie	U.S. Interstate 20 8 miles N., State 516 3 miles S.	2 miles W. 5 miles N.		Red River 35 miles W.
Mississippi				
Lampton	State Hwy 13 within 3 miles	6 miles		
Richton	State 42 bisects dome State 15 within 3 miles	1 mile		
Cypress Creek	U.S. 98 within 4 miles	3 miles		

BEST AVAILABLE COPY

TABLE 6-22. EVALUATION OF DOMES CONSIDERING DIFFERENTIATING FACTORS

Criteria	Reference Numbers*: DOE/NWTS 33(2)	Section 5	Section 6	Relative Favorableness of Domes: Richton	Vacherie	Cypress Creek	Oakwood	Keechi	Rayburn's	Lampton
1.0 Site Geometry										
Minimum Depth	1.1	5.2.1.1	6.2.1.1					Eliminated	Eliminated	
Thickness	1.2	5.2.1.2	6.2.1.2							
Lateral Extent (with 800 ft buffer zone)	1.3	5.2.1.3	6.2.1.3	★				Eliminated	Eliminated	Eliminated
2.0 Geohydrology										
Geohydrological Regime, Aquifer Characterization	2.1	5.2.2.1	6.2.2.1							
Hydrological Regime, Modeling, Surface Subsurface	2.2	5.2.2.3	6.2.2.3							
Geohydrological Regime, Shaftseal-Flow Rates	2.3	5.2.2.4	6.2.2.4							
Subsurface Dissolution Rates	2.4	5.2.2.5	6.2.2.5		Less Favorable	Less Favorable	Less Favorable		Less Favorable	
3.0 Geochemistry										
Chemical Interaction of Waste/Rock/Ground Water	3.1	5.2.3.1	6.2.3.1							
Radionuclide Retardation	3.2	5.2.3.2	6.2.3.2							
4.0 Geologic Characterization										
Stratigraphy	4.1	5.2.4.1	6.2.4.1							
Host Rock Stress Phenomena	4.2	5.2.4.2	6.2.4.2							
Rock Strength — Development, Operation and Closure	4.3	5.2.4.3	6.2.4.3							
5.0 Tectonic Environment										
Tectonic Element	5.1	5.2.5.1	6.2.5.1							
Quaternary Faults	5.2	5.2.5.2	6.2.5.2				Less Favorable	Less Favorable		
Quaternary Igneous Activity	5.3	5.2.5.3	6.2.5.3							
Uplift, Subsidence	5.4	5.2.5.4	6.2.5.4							
Seismicity, Ground Motion, Credible Earthquake	5.5	5.2.5.5	6.2.5.5							
6.0 Human Resources										
Resources	6.1	5.2.6.1	6.2.6.1			Less Favorable	Less Favorable	Less Favorable	Less Favorable	
Exploration History	6.2	5.2.6.2	6.2.6.2				Less Favorable		Less Favorable	
Land Ownership, Access	6.3	5.2.6.3	6.2.6.3							
7.0 Surface Characteristics										
Surficial Hydrological System	7.1	5.2.7.1	6.2.7.1		Less Favorable	Less Favorable	Less Favorable	Less Favorable		Less Favorable
Surface Topographic Features	7.3	5.2.7.3	6.2.7.3							
Meteorological Phenomena	7.4	5.2.7.4	6.2.7.4							
Industrial, Transportation, Military Installation Effects	7.5	5.2.7.5	6.2.7.5							
8.0 Demography										
Population Density, Urban Proximity	8.1	5.2.8.1	6.2.8.1							
Radioactive Waste Transportation Risk	8.2	5.2.8.2	6.2.8.2							
9.0 Environmental Protection										
Potential Environmental Impacts	9.1	5.2.9.1	6.2.9.1							Less Favorable
Air, Water and Land Use Conflicts	9.2	5.2.9.2	6.2.9.2	Less Favorable		★				Less Favorable
[illegible] Environmental Conditions	9.3	5.2.9.3	6.2.9.3							
10.0 Socioeconomic Impacts										
Social Economic Impacts	10.1	5.2.10.1	6.2.10.1	Less Favorable						
Transportation, Access, Utility	10.2	5.2.10.2	6.2.10.2							

★ = More Favorable; (blank box) = Acceptable; (hatched box) = Less Favorable; (black box) = Eliminated

* The first column of numbers refers to the NWTS Program Criteria for Mined Geologic Disposal of Nuclear Wastes: Site Performance Criteria (DOE/NWTS-33(2)). Numbers in the second and third columns are for Sections 5.0 and 6.0 of this report.

90030 0834

Lampton Dome. This dome was also found to have inadequate lateral extent with regard to the reference loading. In addition, the dome has a significant disadvantage due to the over dome water body, land use conflict, and environmental issues associated with the game reserve over the site. Lampton dome is recommended for elimination because of the inadequate lateral extent.

Rayburn's Dome. This dome was found to have inadequate minimum depth and inadequate lateral extent. In addition, the dome has unfavorable dissolutioning uncertainties, resource potential, and exploration history related to the surface proximity of the dome. Any one of these considerations alone would have been sufficient to defer the dome. The existence of these several concerns and the inadequate lateral extent indicates that Rayburn's dome be eliminated.

In the case of the dome determined to have a safety flaw and those with site geometry inadequacies, it was clear that none of these domes would be considered as the first choice for a repository from among the original eight candidates available. The remaining four domes, Cypress Creek, Oakwood, Richton, and Vacherie, are significantly more acceptable than those eliminated.

6.3.2 Acceptable Domes

Domes to be considered for detailed characterization in the location phase are, from most to least favorable (see Table 6-22):

Richton Dome. This dome is acceptable and most favorable because of its large lateral extent, which would provide for a very large buffer zone and technically conservative repository loadings. However, it is potentially less favorable due to a land use and socioeconomic conflict, i.e., the location of the town of Richton within a potential control zone for the repository site.

Vacherie Dome. This dome is acceptable although it has no significant advantages and is ranked somewhat less favorable due to the apparent dissolution of the host rock and surface hydrology.

Cypress Creek Dome. This dome is acceptable and although one factor is more favorable (existing land use), it has been assessed less favorable due to its resources, geochemical regime, potential dissolution, and surface hydrology.

Oakwood Dome. This dome, although acceptable for the purpose of this evaluation, has been assessed as much less favorable due to its exploration history and significant petroleum exploration. Approximately 36 holes have penetrated the salt, some to repository level, and many have been further whipstocked beneath the salt overhang. The NRC concerns are strong in considering this an "adverse condition". This issue may preclude licensing of

Oakwood. In addition, the proximity of potential Quaternary faulting, dissolution, and the surface hydrology conditions are assessed less favorable.

6.3.3 Conclusion

The evaluations based on the decision process described herein conclude that Richton, Vacherie, Cypress Creek, and Oakwood have met the minimum NWTS requirements established as screening criteria, and are acceptable for further characterization. These same requirements were not met by Lampton, Keechi, and Rayburn's; therefore, they were eliminated from any future study program. Palestine was eliminated earlier.

Although Oakwood is deemed acceptable for further consideration for the purposes of this report, it has serious licensing uncertainties associated with salt penetrating borings and nearby reported Quaternary faulting. Cypress Creek also is assessed less favorable. Thus Richton and Vacherie are deemed the more favorable of the four domes. Between those two, Richton is assessed as the more favorable.

6.4 SENSITIVITY AND UNCERTAINTY ANALYSES

6.4.1 Introduction

This section describes the uncertainties involved in deciding relative dome favorability and identifies the factors to which dome recommendation decisions are most sensitive.

Uncertainties arise from three primary sources:

- Data
- Assumptions
- Analyses (ability to adequately describe or predict potentially significant phenomena or conditions).

The uncertainties in data may arise from lack of precision in measurements and the inability of experiments or observations to precisely measure the needed geologic data without altering the rock system in the process. Uncertainties also arise from assumptions of which factors are more important than others and from inadequate understanding of phenomena or conditions being modeled or evaluated.

Against this background, testing the "correctness" of the choice of recommended domes involves an evaluation of how sensitive the choice is to the uncertainties present in the formation used. Large uncertainties in the data, assumptions, or analyses used to evaluate each factor may be unimportant, if the decision being made is insensitive to such uncertainties. Similarly, small uncertainties in the evaluation of some factors may be quite significant, if the choice is sensitive to changes in data, assumptions, or analyses used to evaluate those factors.

Any analysis of uncertainty or sensitivity needs to be performed in the context of the decision being supported by such analysis. The area-to-location step is made based on a "presumption" rather than a "demonstration" of safety, and the choices are based on the relative favorability of one alternative over another. At this step a dome is "presumed" safe if unacceptable conditions or features are not found. One dome is more favorable than another if, other things being equal, it appears to come closer to meeting the site performance criteria described in Section 2.0 than the other domes. A demonstration of safety and a finding of dome suitability result only after detailed site investigations are performed in a later siting phase.

The analysis is approached in two ways depending on whether the "uncertainty" question or the "sensitivity" question is considered first:

> Is the decision sensitive or insensitive to reasonable changes (within the range of uncertainty) in data, analyses, or assumptions? Only sensitive factors are evaluated because the degree of uncertainty of insensitive factors has little effect on the outcome.

> Are the uncertainties small or large and does that make any difference to the decision outcome? . . .The large uncertainties are evaluated for their potential effect on the outcome.

Therefore, the dome recommendation is valid unless large uncertainty remains regarding a factor to which the decision is sensitive. The key question is: are there any real data or reasonable weighting uncertainties that could change the decision outcome?

6.4.2 Analysis

The uncertainties and sensitivities associated with each differentiating factor are evaluated in this section. The summary of the analysis performed to answer the above questions is presented in Table 6-23. Nondifferentiating factors are not included in the analysis. By definition, a factor is nondifferentiating because the uncertainty ranges evaluated are overlapping and do not provide a basis for differentiation among domes. These nondifferentiating factors may still be significant to the eventual demonstration of dome suitability. The data and analysis, however, provide no significantly favorable or unfavorable evidence for any of the nondifferentiating factors at this point. In other words, each dome still being considered is judged acceptable for each nondifferentiating factor. Table 6-23 indicates that the uncertainties in the evaluation of host rock depth, geochemical regime, resources, surface hydrology, and environmental impact provide insufficient cause to defer further study of the acceptable domes (Richton, Vacherie, Cypress Creek, and Oakwood). The uncertainties associated with licensing issues are sufficient to cause Oakwood dome to appear much more unfavorable than the other acceptable domes.

TABLE 6-23. SUMMARY OF UNCERTAINTIES AND SENSITIVITIES IN SALT DOME RECOMMENDATION DECISIONS

Differentiating Factors	Nature of Uncertainty or Minimum Uncertainty Needed to Change Dome Evaluation	Approximate Uncertainty	Recommendation?[1]	Potential Effect on Recommended Domes for Differentiating Factor
Depth to host rock (Table 6-1)	±250 ft	±20 ft	No	None, based on present data
Lateral extent of host rock (Table 6-3)	±180 acres	+30%[3] ±10%[4]	Yes	Possible, but unlikely, that Oakwood dome would be larger than Cypress Creek dome (for +30%) and smaller than Vacherie (for -30%)
Dissolution of host rock (Section 6.2.2.5)	Evidence of dissolutioning that would unacceptably affect repository performance	Are the mechanisms for dissolutioning active or could they be reactivated?	Yes	Dissolution at Richton, Vacherie, Cypress Creek, and Oakwood domes could render these domes less favorable
Geochemical regime (Section 6.2.3.1)	Travel time predictions	Not estimated	No	None, based on present data
Quaternary faulting (Section 6.2.5.2)	Hypothesized near-dome capable faulting less than 2 million years old[2]	Capability of offset Trinity River terrace deposits	Yes	Licensing issue could adversely affect Oakwood dome favorability
Resources (Section 6.2.6.1)	Declining petroleum production	Amount of recoverable resources	No	None, based on present data
Exploration history (Section 6.2.6.2)	Presence of unrecorded boreholes	Not estimated	Yes	Licensing issue could adversely affect Oakwood dome favorability
Surface hydrology (Section 6.2.7.1)	Feasibility of engineered protection against probable maximum flood	Not significant	No	Recommendation of Cypress Creek dome could be changed based on feasibility of extensive engineered fill
Environmental impact (Section 6.2.9.1)	Impact prediction	Not significant	No	None, based on present data
Air, water, land use conflict (Section 6.2.9.2)	Displacement of residents	Not estimated	Yes	Mitigative measure would need to be negotiated with local officials and affected residents of town of Richton
Socioeconomic impact (Section 6.2.10.1)	Alteration of utilities, services and infrastructure of town of Richton	Not estimated	Yes	Mitigative measure would need to be negotiated with local officials and affected residents of town of Richton

(1) Could any recommended dome lose favorability? Or, could the uncertainties cause any eliminated domes to be recommended? "Yes" answers are discussed in Section 6.4.

(2) Collins, E. W., et al, *Quaternary Faulting in East Texas*, Bureau of Economic Geology, Geologic Circular 80-1.

(3) Oakwood.

(4) Cypress Creek, Richton, and Vacherie.

The uncertainties associated with the remaining factors in Table 6-23 (lateral extent, Quaternary faulting, dissolution, exploration history, land use conflict, and socioeconomic impact) require some discussion before recommendation (acceptance) of the four domes is considered valid.

6.4.2.1 Lateral Extent

The uncertainty in measurement and estimation of the lateral extent of domes is on the order of + 10 percent, for all domes, except for Oakwood and Lampton domes estimations, which are + 30 and + 40 respectively. This amount of uncertainty is insufficient to consider Cypress Creek, Richton, or Vacherie less favorable than indicated by the study results. If the Oakwood dome size were 30 percent low and the Cypress Creek dome size estimate (at repository level) were 10 percent high, a possible but unlikely situation, then Oakwood would be larger than Cypress Creek. The possible difference is of little importance because Oakwood dome has other characteristics (possible Quaternary faulting and extensive exploration history) that are considered more significant and outweigh the possibility of relatively minor differences in dome size with Cypress Creek. If the size estimate for Oakwood dome was too high, Oakwood could possibly be smaller than Vacherie, but the relative ranking of the four domes would not be changed.

Similar evaluation of size differences leads to a conclusion that it is unlikely that any of the eliminated domes would provide as large a repository buffer zone area as the recommended domes. Uncertainties in estimated dome sizes do not, therefore, provide a basis to change the dome recommendations.

6.4.2.2 Dissolution of Host Rock

Acceptable domes Cypress Creek, Oakwood, and Vacherie are less favorable for the dissolution factor than is Richton. The evidence suggesting dissolutioning of Vacherie, Cypress Creek, and Oakwood domes is not considered strong enough to defer them from further investigation, however. The presence of dissolutioning may not be severe when viewed against evidence that the domes have been relatively stable over the past several tens to hundreds of millions of years. The impact of possible dissolutioning at these domes on repository performance will be more thoroughly evaluated in the next stage of investigation.

Dissolutioning at Rayburn's dome is not the sole reason for recommending its elimination. The recommendation is based on size, depth, geochemical regime, and exploration history--less than favorable conditions that were not present at Cypress Creek or Vacherie--which combined to make Rayburn's dome a less likely choice for a repository.

The relative uncertainties associated with other factors listed in Table 6-22 for which Lampton and Keechi domes were rated less favorable or eliminated are considered more important than uncertainties associated with dissolutioning at Vacherie, Cypress Creek, and Oakwood domes. These three domes should, therefore, remain candidates for the investigation.

6.4.2.3 Quaternary Faulting

Oakwood dome is the only remaining dome for which an uncertainty exists relative to Quaternary faulting. This uncertainty is raised by the existence of a Texas Bureau of Economic Geology report "Quaternary Faulting in East Texas"(32) that postulates Quaternary faulting in east Texas near Oakwood and Keechi domes. Removal of the Quaternary fault uncertainty would not cause Keechi dome to be considered acceptable; it was eliminated due to insufficient size. Oakwood was not eliminated for this factor, but further study of the postulated structures and a "negative finding" would be necessary to rank Oakwood dome over Richton, Cypress Creek, or Vacherie domes. A "positive finding" of Quaternary fault existence near Oakwood dome could create extreme licensing uncertainties and effectively eliminate it from further consideration.

6.4.2.4 Exploration History

Drilling or other exploratory activities are known to have occurred at all domes considered in this evaluation. The quantity, dome proximity, depth of drilling penetrations, and existence of exploration documentation are factors in this evaluation. Oakwood dome is known to have been explored, more extensively than the other three acceptable domes, and many of the penetrations in and around the dome were not recorded. This lack of documentation poses a potentially intractable licensing issue, not present at Richton, Vacherie, and Cypress Creek domes. The important of this lack of documentation was not considered sufficient to eliminate Oakwood dome from further consideration, but it does cause Oakwood dome to be considered the least favorable of the domes judged acceptable. If a higher importance is assigned to the lack of exploration documentation in the vicinity of Oakwood dome, Oakwood could be dropped into the range of unacceptability. No reasonable change in the relative importance of this factor could be made that would cause Oakwood dome to be judged more favorable than Richton, Vacherie, or Cypress Creek domes for the exploration history factor.

6.4.2.5 Land Use Conflict and Socioeconomic Impact

The land use and socioeconomic factors for Richton were reviewed against factors that caused three domes to be eliminated to ascertain whether uncertainties in the present data could cause Richton to be assessed as less favorable or replaced by another dome not having the same "less favorable" characteristic (Table 6-23).

The Richton recommendation is supported by two considerations. First, any uncertainties associated with geologic factors that contribute to or detract from radionuclide containment and isolation are safety related and are, therefore, considered more severe than uncertainties associated with socioeconomic impact or land use conflicts. For example, Keechi dome cannot be made larger, but the conflicts and impacts at Richton may be amenable to mitigation. Additional investigation of Keechi dome may provide evidence to indicate an increase in dome size at the repository horizon, but this would still be insufficient to accommodate a 75,000 MTU repository even considering uncertainties in size estimates. The impacts of locating a repository adjacent to Richton are not all negative and are amenable to mitigation. The socioeconomic impact and land use conflict apparent at Richton are considered less severe than:

- The lateral extent disadvantage at Lampton, Rayburn's and Keechi domes
- The minimum depth disadvantages at Keechi and Rayburn's domes, or
- The exploration history disadvantages at Rayburn's and Oakwood domes (see Table 6-22).

Based on these considerations, Lampton, Rayburn's, Keechi, and Oakwood domes cannot be considered equal to or better than Richton dome.

Secondly, when Richton dome is compared with the other recommended domes, the "less favorable" land use and socioeconomic characteristics at Richton do not warrant changing the recommendation to only Cypress Creek, Vacherie, and Oakwood domes at this phase of the study. Richton dome, unlike the other three, is either "acceptable" or "more favorable" for all containment and isolation factors (Table 6-22). The uncertainties associated with dissolutioning at Vacherie, Cypress Creek and Oakwood domes are more severe than the land use and socioeconomic uncertainties associated with Richton dome, because containment and isolation factors are considered more important to site suitability than environmental and socioeconomic factors. On the other hand, Vacherie, Cypress Creek and Oakwood domes (Table 6-22) have no "less favorable" characteristics for the environmental, socioeconomic and land use factors, whereas Richton dome does. The uncertainties associated with each of these four domes at least partially overlap and do not provide a basis for recommending one dome as undisputably superior to the others. Therefore, it is recommended that all four domes remain available for continued study.

6.4.3 Conclusion

In conclusion:

- Richton, Vacherie, Cypress Creek, and Oakwood domes should remain available for further study.
- Richton dome has a significant, but potentially resolvable, land use and socioeconomic conflict that deserves further study, but which does not outweigh its favorable safety provided by containment and isolation capabilities.
- Cypress Creek and Oakwood dome have containment, isolation, and safety uncertainties that may be expensive to study and resolve and perhaps pose formidable licensing questions.
- No reasonable changes in the importance of the differentiating factors could cause any of the four eliminated domes to be considered acceptable based on present data.

The recommendation for continued study of four domes appears valid but will be reassessed as new information for these domes becomes available in subsequent exploration steps.

6.5 CONSENSUS GROUP

This section describes the groups within ONWI which were charged with evaluating the appropriate data and formulating the recommendation of Gulf Coast salt domes for further characterization. Also discussed are the interactions to date with other technical participants, peer groups, and state officials.

6.5.1 Preliminary Evaluations

In August, 1979, a Gulf Coast Site Evaluation Committee (SEC) was formed by ONWI management. This group consisted of key ONWI staff, as well as personnel from Law Engineering Testing Company, the Gulf Coast geologic project manager; Bechtel National, Inc., the Gulf Coast regulatory project manager; and Battelle's Pacific Northwest Laboratories, which is involved in far-field safety analyses. This group was given the reponsibility of evaluating the available data on the Gulf Coast salt domes and examining methods for arriving at a recommendation of a more limited number of domes for detailed subsequent characterization.

The Site Evaluation Committee held four meetings during the remainder of 1979. In this period, site qualification criteria and subcriteria were related to the available data in a matrix format. Data deficiencies were determined and methods explored for screening the domes to be recommended and selecting the domes for further in-depth investigation.

The work of the Site Evaluation Committee was discussed in a series of meetings with participants in the Gulf Coast effort during January and February, 1980. Participants included the Texas Bureau of Economic Geology, the Institute for Environmental Studies of Louisiana State University, the Geology Department of the University of Southern Mississippi, and the U.S. Geological Survey. This culminated in a three-day seminar on the Gulf Coast salt dome for all participants in late February, 1980.

In April, 1980, the Geologic Review Group, an ONWI peer review committee, examined the proposed recommendation process and the data then available. Their conclusions, although not documented, appear to parallel those reported in this document.

Through appropriate DOE channels, the available technical information and the salt dome screening and recommendation process were discussed with Mississippi state officials in late May and again in early September, 1980. In addition, appropriate state officials and agencies in Texas and Louisiana were briefed during this period.

Concurrently, in the spring and summer of 1980, additional field data were obtained and analyses were completed to realize the level of information adequate to this recommendation process.

6.5.2 Gulf Coast Salt Dome Evaluation Team

In June, 1980, the general manager of ONWI created the Gulf Coast Salt Dome Evaluation Team to complete work started by the SEC and formulate the recommendations presented in this document. This section describes how the group arrived at its recommendation and the composition of that team.

6.5.2.1 Recommendation Process

It should be emphasized that this team did not make a decision to further investigate Richton, Vacherie, Cypress Creek, and Oakwood domes. DOE will decide which domes, if any, to study, after consultation with state and local officials and technical peer review. However, the evaluation team did spend several months (June to October, 1980) (1) reviewing characterization data, (2) developing a step-by-step approach to deciding which domes to recommend for further study, (3) defining the significance of the various site suitability factors, (4) requesting new information or analyses to reinforce the data base, (5) comparing dome favorabilities, and (6) evaluating or postulating the consequences of uncertain future events, before making the recommendations reported here.

The group did not use formal decision analysis, majority rule, or poll-taking to decide the key issues and how to address them. Rather, team members individually assessed facts and expert opinion to identify features or conditions that were judged to enhance or diminish the ability of a given dome to perform as required by the performance objectives and criteria. Many differences of opinion were raised and the ensuing debates were fully heard. This led to a better understanding by each team member of the effect of various factors on both the area-to-location recommendation, and an eventual dome suitability determination. The general agreement reached on the significance of the various factors to the eventual dome suitability determination is as described in this document. Thus, the result is a "group consensus" by the evaluation team.

6.5.2.2 Composition of the Salt Dome Evaluation Team

Evaluation team members possess the educational qualifications and experience indicated below:

- ONWI General Manager's Office

  Nuclear Engineer--radioactive waste management-siting and technology development, research management, engineering sciences, nuclear physics, nuclear safety, nuclear waste management safety, and systems analysis.

  Professional Civil Engineer--radioactive waste repository and nuclear reactor siting; reactor standards development, design, and licensing; and construction of nuclear facilities.

- ONWI Site Exploration Functional Area

  Geologist--repository siting, geologic exploration and characterization of host rock media, mineralogy and petrology, geologic teaching and research.

  Environmental and Radiological Health Engineer--repository siting, environmental exploration and characterization, environmental pathway analysis, radiation dose analysis, and applied health physics.

  Professional Geologist and Engineering Geologist--radioactive waste repository and nuclear reactor siting, military facility siting, and hydrologic and geotechnical studies for major industrial facilities.

- NWTS Site Program Office

  Professional Geologist--radioactive waste repository and nuclear reactor siting, siting criteria development, geologic hazards analysis, and geologic teaching and research.

  Professional Civil Engineer--radioactive waste repository and nuclear reactor siting, siting criteria development, environmental impact assessment, and geotechnical studies for nuclear facilities.

- Other Key Staff

  Systems Department--Sociologist--radioactive waste repository sociological and socioeconomic impact and mitigation analysis, public participation, agricultural economics, rural and developmental sociology, and teaching and research.

  Legal Department--Attorney--environmental, administrative, nuclear and energy law; radioactive waste repository siting; power reactor siting litigation; NEPA implementation; assistant attorney general (Ohio), and public participation workshops.

  NWTS Programs Functional Area--Computational and Systems Analyst--radioactive waste repository planning, research administration, computing, and information processing.

All team members are employees of the Battelle Office of Nuclear Waste Isolation. Consultants, subcontractors, and other ONWI staff members supported the deliberations of the group by providing expert technical opinion and the data on which the recommendations are based.

This recommendation document in its final form may include additional evaluations of the four recommended domes and will incorporate, as appropriate, comments made and concerns expressed during the review process. These reviews will contribute to general acceptance of the recommendation or may cause reevaluations to be made. If general consensus is obtained, DOE will implement the decision by initiating further study of recommended domes in consultation with the affected states and localities, as discussed in Section 7.0.

REFERENCES

1. Patchick, P. F. 1980. The Suitability of Palestine Salt Dome, Anderson County, Texas, for Disposal of High-Level Radioactive Waste, ONWI-74, Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

2. Kreitler, C. W., E. G. Wermund, E. H. Geuvera, A. Giles, and G. Fogg. 1978. Preliminary Evaluation of Salt Domes in East Texas, prepared for NWTS Program by Bureau of Economic Geology, University of Texas at Austin.

3. Kreitler, C. W. 1978. Evaluating the Potential of East Texas Salt Domes for Isolation of Nuclear Waste, Annual Report for Period January 1 to September 30, 1978, Bureau of Economic Geology, University of Texas, Austin, TX.

4. Martinez, J. D., D. H. Kupfer, R. L. Thoms, C. G. Smith, and C. R. Kolb. 1975. An Investigation of the Utility of Gulf Coast Salt Domes for the Storage or Disposal of Radioactive Wastes, ORNL/SUB-4112-10, Institute for Environmental Studies, Louisiana State University, Baton Rouge, LA, p. 204.

5. Bloom, A. L. 1980. Summary Report: ONWI Geologic Review Group Meeting, January 23-25, 1980, April, p. 3.

6. Gwontman, L. H., ed. 1981. Handbook of Rock Salt Properties Data, Monograph 167, U.S. Department of Commerce, National Bureau of Standards.

7. Knauth, L. P., and M. B. Kumar. 1981. Trace Water Content of Salt in Louisiana Salt Domes, Institute for Environmental Studies, Louisiana State University, Baton Rouge, LA, submitted for publication.

8. Jenks, G. H. 1979. Effects of Temperature, Temperature Gradients, Stress and Irradiations of Brine Inclusions in a Salt Repository, ORNL-5526.

9. Roedder, E., and H. E. Belkin. 1979. Fluid Inclusions in Salt from the Rayburn and Vacherie Domes, Louisiana, USGS Open File Report 79-1675.

10. The Reference Repository Conditions Interface Working Group. 1980. Interim Reference Repository Conditions for Commercial and Defense High-Level Nuclear Waste and Spent Fuel Repositories in Salt, RRC IWG.

11. Nance, D., and R. E. Wilcox. 1979. Lithology of the Rayburn's Dome Salt Core, Topical Report E511-02500-3, Institute for Environmental Studies, Louisiana State University, Baton Rouge, LA.

12. Nance, D., J. Ruvik, and R. E. Wilcox. 1979. Lithology of the Vacherie Salt Dome Core, Topical Report E511-02500-5, Institute for Environmental Studies, Louisiana State University, Baton Rouge, LA.

13. Kreitler, C. W., O. K. Agagu, J. M. Basciano, E. W. Collins, O. Dix, S. P. Dutton, G. E. Fogg, A. B. Giles, E. H. Guevara, D. W. Harris, D. K. Hobday, A. B. Giles, M. K. McGowen, D. Pass, and D. H. Wood. 1980. Geology and Geohydrology of the East Texas Basin, Geology Circular 80-12, Bureau of Economic Geology, University of Texas, Austin, TX.

14. Dix, O. R., and M.T.A. Jackson. 1981. Lithology of Oakwood Salt Core: Annual Report 1980; Geology and Geohydrology of the East Texas Basin, Texas Bureau of Economic Geology, University of Texas, Austin, TX.

15. Law Engineering Testings Company. 1981. Petrographic/Chemical Characteristics of the Cypress Creek Salt Core, Gulf Coast Salt Domes Project, Marietta, GA, draft.

16. Kreitler, C. W., and S. P. Dutton. 1981. Preliminary Report on Oakwood Dome Caprock: Milestone Report, DOE Contract DE-AC97-80ET46617.

17. Law Engineering Testing Company. 1980. Area Characterization Report, Vol. II, East Texas Study Area, Gulf Coast Salt Domes Project, Marietta, GA, draft.

18. Law Engineering Testing Company. 1980. Area Characterization Report, Vol. III, North Louisiana Study Area, Gulf Coast Salt Domes Project, Marietta, GA, draft.

19. Law Engineering Testing Company. 1980. Area Characterization Report, Vol. IV, Mississippi Study Area, Gulf Coast Salt Domes Project, Marietta, GA, draft.

20. Jenne, E. A. 1977. "Trace Element Sorption by Sediments and Soils - Sites and Processes" Symposium on Molybdenum in the Environment, Vol. 2. W. Chappell and K. Peterson, ed., M. Dekker, Inc., NY.

21. Galloway, W. E., C. W. Kreitler, and J. H. McGowen. 1979. Depositional and Ground-Water Flow Systems in the Exploration for Uranium, Bureau of Economic Geology, University of Texas, Austin, TX.

22. Freeze, A. R., and J. A. Cherry. 1979. Ground Water, Prentice-Hall, Inc., Englewood Cliffs, NJ.

23. Kreitler, C. W., E. Guevara, G. Granata, and D. McKalips. 1977. Hydrogeology of Gulf Coast Aquifers: Houston-Galveston Area, Gulf Coast Association of Geological Society Transcripts, Vol. 27.

24. Law Engineering Testing Company. 1980. Area Characterization Report, Vol. I, Introduction, Background, and Summary, Gulf Coast Salt Domes Project, Marietta, GA, draft.

25. Roedder, E., and H. E. Belkin. 1980. Fluid Inclusions in Salt from the Rayburn and Vacherie Domes, Louisiana, USGS Open File Report 74-1675.

26. Hansen, F. D. 1977. Case History Rock Mechanics Examination of the Jefferson Island Salt Mine: II. Laboratory Evaluation of Strength and Creep Deformation Characteristics of Dome Salt Under Confining Pressure, Y/OWI/SUB-77/22303/5.

27. Oxley, M. L., E. Minihan, and J. M. Ridgeway. 1968. "A Study of Jurassic Sediments in a Portion of Mississippi and Alabama", Jurassic Stratigraphy of Mississippi, T. H. Dinkens, Jr., et al, ed., Mississippi Geological Society Bulletin 109, p. 39-77.

28. Morgan, J. K. 1970 "Central Mississippi Uplift", Gulf Coast Association of the Geological Society Transactions, Vol. 20, p. 91-109.

29. Bechtel National, Inc. 1980. Environmental Characterization Report for the Louisiana Study Area: Gulf Interior Region. ONWI-192, San Francisco, CA, draft, November.

30. Bechtel National, Inc. 1980. Gulf Interior Study Areas: Mississippi Study Area, ONWI-193, San Francisco, CA, draft, November.

31. Bechtel National, Inc. 1980. Gulf Interior Study Areas: Texas Study Area, ONWI-194, San Francisco, CA, draft, November.

32. Collins, E. W., Hobday, D. K., and Kreitler, C. W. 1980. "Quaternary Faulting in East Texas", Texas Bureau of Economic Geology, Circular 80-1.

7.0 FUTURE PLANS

As outlined in DOE's statement of position for the Confidence Rulemaking activity of the NRC[1], the activities that have led to the preparation of this document represent the second of a sequence of four steps that will be required before a salt dome can be considered as one possible site out of four or five in several geologic media from which a selection will be made for the nation's first repository.

Following a period of public review of this document and the technical reports that provide the basis for the recommendations contained herein, it is expected that there will be a period of planning for the technical activities that will be conducted during the next phase of technical investigations. It is anticipated that appropriate state representatives will assist in the preparation of these plans, as well as the participants in the technical program. These activities will result in a precise plan of activities to be conducted, a schedule over which they will be carried out, identification of organizations that will have the lead responsibility for each activity, and identification of technical reports, results, and data that will be the products of the studies. These plans will be documented in a report which should be transmitted to DOE about one month after the plans are finalized and to the states for public review shortly thereafter.

It is already clear that a number of activities are very important to the next phase of work and will be included in the plans that will be developed. Among these activities are added hydrologic investigations, both on a regional basis to provide the baseline against which site-specific data can be compared, and specific to the domes in question to more thoroughly address the question of dissolution and hydrologic stability. Core samples of the stratigraphic units flanking the domes must be obtained to determine the nature and quantity of sorptive material within these units, so that the important question of retention of radionuclides due to these processes can be addressed. Dome-specific seismic information must be obtained by utilization of a microseismic net, and a better definition of the structure of the domes and the flanking sedimentary units must be obtained by additional seismic surveys. Other investigations to be conducted will be determined during the planning period discussed in the preceding paragraph.

It is not anticipated that the next phase of activities will necessarily result in an equal amount of data on the domes that are acceptable, or that exactly the same activities will be conducted for each of the domes. This occurs because the questions that need to be addressed at the domes are not exactly the same. The most significant questions at one dome are not exactly the same as those for a second dome. It is also anticipated that information gained during the next phase will allow a further narrowing of the program.

REFERENCES

(1) U.S. Nuclear Regulatory Commission. 1980. In the Matter of Proposed Rulemaking on the Storage and Disposal of Nuclear Waste (Waste Confidence Rulemaking), PR-50, 51 (44 FR 61372) - Statement of Position of the United States Department of Energy, DOE/NE-0007, Washington, D.C., April, II.A.1.3.

APPENDIX A. SALT DOME DATA SUMMARY

Data in this appendix will be updated as additional information is obtained in the next phase of investigations.

	Rayburn's, Louisiana	Vacherie, Louisiana	Cypress Creek, Mississippi	Lampton, Mississippi	Richton, Mississippi	Keechi, Texas	Oakwood, Texas
I. Site Geometry							
1. Minimum Depth (to salt)	115 ft (35 m) Surface elevation over dome 180 to 300 ft (55 to 91 m)	777 ft (237 m) Surface elevation over dome 180 to 320 ft (55 to 98 m)	1271 ft (387 m) Surface elevation over dome 180 to 270 ft (55 to 82 m)	1646 ft (502 m) Surface elevation over dome 190 to 370 ft (58 to 113 m)	722 ft (220 m) Surface elevation over dome 160 to 290 ft (49 to 88 m)	435 ft (133 m) Surface elevation over dome 340 to 480 ft (104 to 146 m)	1163 ft (354 m) Surface elevation over dome 300 to 550 ft (92 to 168 m)
2. Thickness	1750 ft (533 m)	1000 ft (305 m)	1020 ft (311 m) max.	850 ft (260 m)	1050 ft (320 m) min.	2260 ft (689 m)	1780 ft (543 m)
3. Lateral Extent (with 800 ft buffer zone)	924 acres (374 ha) (See Figure A-1)	1760 acres (712 ha) (See Figure A-6)	2130 acres (826 ha) (See Figure A-10)	500 acres (202 ha) ±40% (See Figure A-14)	3760 acres (1522 ha) (See Figure A-18)	990 acres (401 ha) (See Figure A-22)	1940 acres (785 ha) (See Figure A-26)
II. Geohydrology							
1. Geohydrological Regime, Aquifer Characterization	Adequate data for area phase; additional data to be obtained in next phase						
2. Hydrological Regime, Modeling, Surface-Subsurface	Adequate data for area phase; additional data to be obtained in next phase						
3. Geohydrological Regime, Shaftseal-Flow Rates	Clay 5 to 15 ft (1.5 to 4.6 m) thick	Clay 190 ft (58 m) thick	Clay 743 ft (226 m) thick	Clay 875 ft (267 m) thick	Clay 394 ft (120 m) thick	Clay 150 ft (46 m) thick	Clay 184 ft (56 m) thick
4. Subsurface Dissolution Rates	Topographic depression may indicate some dissolutioning	Possible saline anomaly, origin unknown	Swamp over dome may indicate dissolution	No evidence of dissolution	Saline anomaly near dome, cause yet to be determined	No evidence of dissolution	Possible saline anomaly, source and consequences unknown
III. Geochemistry							
1. Chemical Interaction of Waste/Rock/Ground Water	Adequate data for area phase; additional data to be obtained in next phase						
2. Radionuclide Retardation	Area phase data indicates adequate retardation at all domes. Additional data to be obtained in next phase						

APPENDIX A. SALT DOME DATA SUMMARY (Continued)

	Rayburn's, Louisiana	Vacherie, Louisiana	Cypress Creek, Mississippi	Lampton, Mississippi	Richton, Mississippi	Keechi, Texas	Oakwood, Texas
IV. Geologic Characterization							
1. Stratigraphy	(See Figure A-2)	(See Figure A-7)	(See Figure A-11)	(See Figure A-15)	(See Figure A-19)	(See Figure A-23)	(See Figure A-27)
2. Host Rock Characteristics	Analysis indicates very low moisture content; additional data to be obtained in next phase						
3. Rock Strength: Development, Operation and Closure	Analysis of available core indicates strength within previously observed limits. Additional data to be obtained in next phase						
V. Tectonic Environment							
1. Tectonic Element	No evidence of anomalous tectonic phenomena; additional data to be obtained in next phase						
2. Quaternary Faults	None observed to date	None observed to date; undisturbed Quaternary terraces over dome	None observed to date	None observed to date	None observed to date	Possible Quaternary fault 14 mi	Possible Quaternary fault 15 mi
3. Quaternary Igneous Activity	No activity recorded						
4. Uplift, Subsidence	No known uplift/subsidence in Quaternary period						
5. Seismicity, Ground Motion, Credible Earthquake	Intensity: VI min; 0.6 g (See Tables A-1 and A-2; Figure A-3)						
VI. Human Resources							
1. Resources	Poor hydrocarbon potential. Closeness to surface represents opportunity for exploration of salt and caprock; also sand and limestone	Poor. Little hydrocarbon (gas) production	3 active oil/gas wells. Future potential poor	No oil production in 5 mi (8 km). Possibility of brining or underground storage	No hydrocarbon production. Low potential for hydrocarbon production	Some asphaltic rock and tarry seepage; little commercial potential	Cumulative oil production since 1958, 2,115,715 barrels. Future potential poor

APPENDIX A. SALT DOME DATA SUMMARY (Continued)

	Rayburn's, Louisiana	Vacherie, Louisiana	Cypress Creek, Mississippi	Lampton, Mississippi	Richton, Mississippi	Keechi, Texas	Oakwood, Texas
VI. Human Resources (Continued)							
2. Exploration History	1 deep boring between -2000 and -3000 ft (-610 and -914 m) MSL 60 deep borings in 5-mi (8-km) radius	1 deep boring in salt between -2000 and -3000 ft (-610 and -914 m) MSL 168 deep borings in 5-mi (8-km) radius	6 boreholes in salt between -2000 and -3000 ft (-610 and -914 m) MSL 13 deep borings in 5-mi (8-km) radius	0 borings into -2000 ft (-610 m) MSL 20 deep borings in 5-mi (8-km) radius	0 borings penetrate -2000 ft (-610 m) MSL 19 deep borings in 5-mi (8-km) radius	3 deep borings penetrate between -2000 and -3000 ft (-610 and -914 m) MSL 88 borings in 5-mi (8-km) radius	26 boreholes in salt between -2000 and -3000 ft (-610 and -914 m) MSL. 74 boreholes in 5-mi (8-km) radius In addition, 34 whipstocked producing 77 holes in sediments below the overhang
3. Land Ownership, Access	Private	Private	State and federal government	50% private 50% state wildlife management area, public game reserve	Private	Private	Private
VII. Surface Characteristics							
1. Surficial Hydrological System	Drained by Fouse Creek (See Figure A-4 and A-5)	Drained by Bashaway Creek (See Figures A-8 and A-9)	Minor drainage of Cypress Creek (See Figures A-12 and A-13)	Drained by Upper Little Creek and Lower Little Creek (See Figures A-16 and A-17)	Dome between Bogue Homo and Thompson Creek (See Figures A-20 and A-21)	Minor drainage of Keechi Creek (See Figures A-24 and A-25)	Drained by Alligator Creek (See Figures A-28 and A-29)
2. Surface Topographic Features	Central depression surrounded by hills (See Figure A-5)	Central depression (See Figure A-9)	Depression (swamp) (See Figure A-13)	Lake and flat-topped ridge with 180 ft relief (See Figure A-17)	Topographic high over dome (See Figure A-21)	Benign topographic relief (See Figure A-25)	Irregular ridge of low, rolling hills (See Figure A-29)
3. Meteorological Phenomena	Adequate data for area phase; additional data to be obtained in next phase						
4. Industrial, Transportation, Military Installation Effects	Louisiana – small airports, some industrial complexes, nuclear facilities/activities in area		Mississippi – small airports, military installation in area			Texas – small airports, two electrical generating facilities	

APPENDIX A. SALT DOME DATA SUMMARY (Continued)

	Rayburn's, Louisiana	Vacherie, Louisiana	Cypress Creek, Mississippi	Lampton, Mississippi	Richton, Mississippi	Keechi, Texas	Oakwood, Texas
VIII. Demography							
1. Population Density, Urban Proximity	19 persons/sq mi Friendship, 2 mi (3 km) Saline, 6 mi (10 km) 30 bldgs. on dome	65 persons/sq mi (Webster County) 49 persons/sq mi (Bienville County) Freyburg, 3.8 mi (6.1 km) Gibsland, 9.8 mi (15.8 km) Dubberly, 5 mi (8 km) Sibley, 7 mi (11 km)	14 persons/sq mi Columbus, 6 mi (10 km) 25 bldgs. on dome	42 persons/sq mi Columbia, 6 mi (10 km) 156 bldgs. on dome	13.9 persons/sq mi Richton, on edge of dome	25.9 persons/sq mi Palestine, 5 mi (8 km) Montalba, 2.5 mi (4 km)	12.9 persons/sq mi (Freestone County) 7.9 persons/sq mi (Leon County)
2. Radioactive Waste Transportation Risk	66 person-rem/yr	66 person-rem/yr	50 person-rem/yr	32 person-rem/yr	49 person-rem/yr	78 person-rem/yr	79 person-rem/yr
IX. Environmental Protection							
1. Potential Environmental Impacts	Wild and scenic river Saline Bayou	Wild and scenic river, Black Lake Bayou, 1 mi (1.6 km) east	DeSoto National Forest	Game preserve on dome	None	None	None
2. Air, Water, and Land Use Conflicts	80% forest with some timber harvesting Some agriculture and grazing	Prehistoric site, 1 mi (1.6 km) east	Camp Selby Military Reservation	Game preserve	Town on edge of dome	50% forest and grazing	Grazing
3. Normal and Extreme Environmental Conditions	Adequate data for area phase; additional data to be obtained in next phase						
X. Socioeconomic Impacts							
1. Social/Economic Impacts	Grazing and timber use over dome	90% forest Some farming	Military reservation	Game preserve	Town of 1100	Two towns within 5 mi (8 km)	Farming and grazing over dome 75% forest
2. Transportation, Access, Utility	St. hwys. 4 and 156 cross dome RR 2 mi (3 km) east	U.S. Interstate 20 within 8 mi (13 km) RR 2 mi (3 km) west RR 5 mi (8 km) north	St. rt. 29 over dome RR 2.5 mi (4 km) U.S. hwy. 98 within 4 mi (6.4 km)	St. hwy. 13 within 3 mi (4.8 km) RR 6 mi (10 km)	St. hwy. 45 over dome RR 1 mi (1.6 km)	St. rt. 19 over dome RR 9 mi (14.5 km)	U.S. hwy. 79 over dome RR 1 mi (1.6 km) south