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Task 2 – Criteria Development

Volume II – First Draft

February, 1979

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Prepared for Rockwell Hanford Operations,
a Prime Contractor to U.S. Department of Energy,
Under Contract EY–77–C–06–1030 Service Agreement SA–846

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SUMMARY

This report ~~is the second in a series of six reports that will~~ describe the ~~results of the Repository Site Identification Study of the Basalt Waste Isolation Program (Reference SA-846)~~. It presents the results of Task 2 (Criteria Development). Two parallel site identification studies utilizing the same criteria will be carried out: 1) the Columbia River Basalt area except Hanford (abbreviated CORBEH in this report); and 2) the Hanford area (abbreviated Hanford in this report).

Task 2 is divided into three major subtasks: 1) identify and develop the baseline information for siting criteria development, 2) develop the siting criteria and 3) develop a framework for sensitivity analysis.

1) A necessary part of developing siting criteria for the site identification study is the identification and selection of basic information that establishes baseline conditions describing the proposed radioactive waste repository. These baseline conditions provide quantitative and qualitative physical and facility performance information which are used as a basis for establishing numerical crtieria in the site identification study. The primary categories of the basic information are: facility description, waste description, repository host rock characteristics, performance characteristics, legal and licensing issues, system economics, environmental and socioeconomic conditions and national defense and security. Fixing a basic description of the proposed project prior to criteria development is a necessary requirement to establishing numerical screening and ranking siting criteria. In addition, changes to the baseline information can impact the criteria and their use in the study.

2) The screening and ranking criteria used in the site identification study are developed through a process that begins by identifying key assumptions concerning the description and performance characteristics of the proposed repository and the legal and licensing issues pertaining to nuclear facilities. The overall goal of identifying a suitable site meeting the objectives of maximizing public health and safety, minimizing environmental impacts and minimizing system costs, is used to identify and establish values which measure the achievement of these objectives. The results of this process are two sets of criteria, one for identifying sites and another for ranking sites. Sites identified by the first set of criteria can be shown to meet minimum levels of achievement of the siting objectives; sites ranked by the second set of criteria can be compared in terms of specific differential achievement of the siting objectives. This approach meets anticipated regulatory agency requirements for an objective and systematic site selection method and provides a mechanism for traceability and documentation in the project record. The criteria developed through this process are preliminary and will be subject to a test application on a portion of the study area prior to their use in screening and ranking sites in entire area.

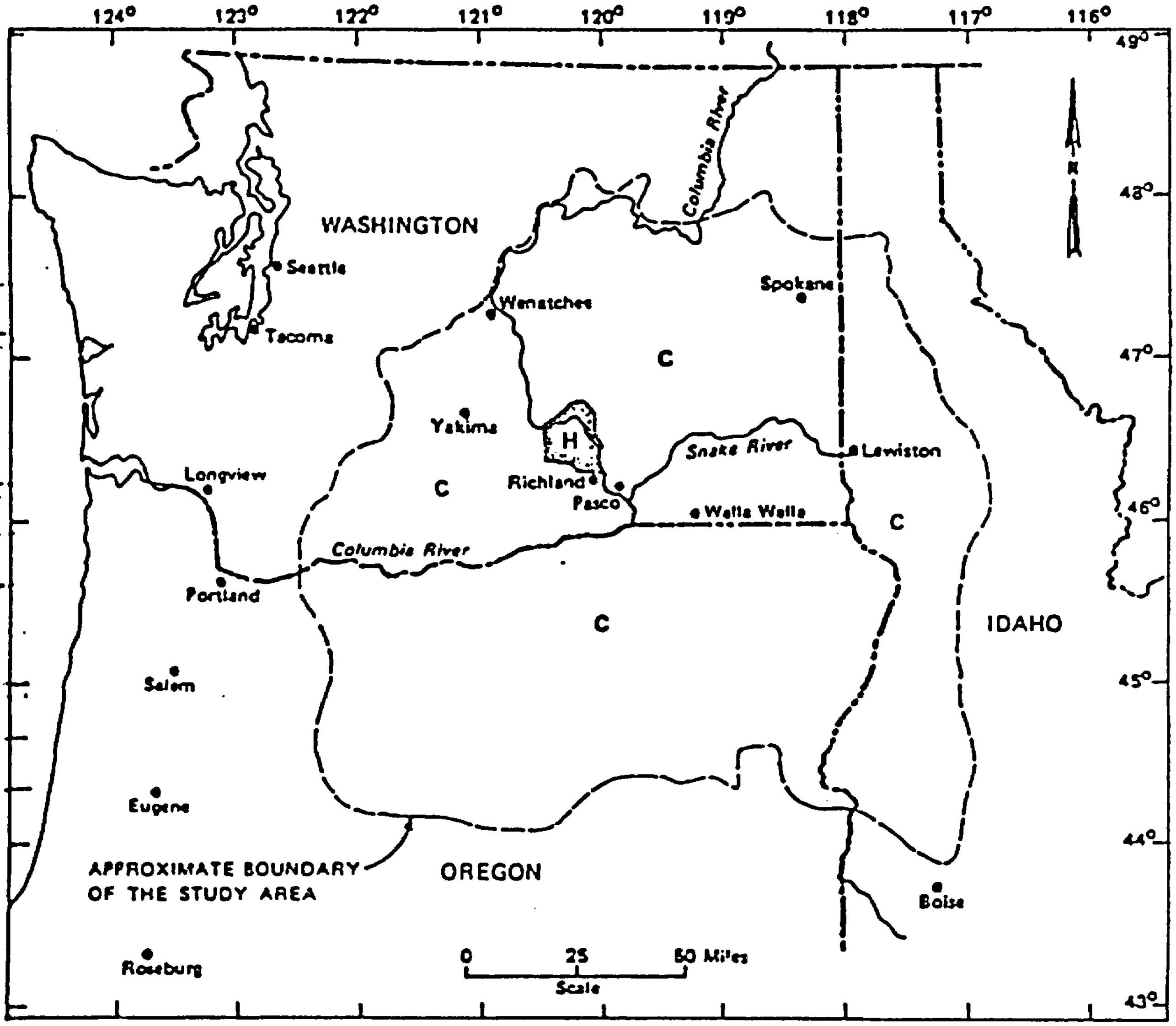
3) The results of the site identification process can be influenced by changes in the numerical values used in the study and in the relationships used for site evaluations. The effects of these potential changes can be assessed through a sensitivity analysis. A framework for sensitivity analysis is provided which will evaluate the impacts of changes in baseline conditions, changes in the regulatory framework, changes in the screening and ranking criteria on results of the screening and ranking processes and acquisition of additional data. A sensitivity analysis provides useful insights into the relative influence of various parameters and enables one to identify the dominant parameters which could significanly influence the results of the site identification process. The results of a sensitivity analysis can be utilized to identify geographic areas where additional work may be necessary or to identify the need for acquisition of additional data or for refining assumptions.

I. INTRODUCTION

1. PROJECT DEFINITION

This report is the second in a series of six reports that will describe the work done on the site identification study for a repository for radioactive waste in basalt. Under Prime Contract EY-77-C-06-1030 to the U.S. Department of Energy (abbreviated DOE in this report), Rockwell, is investigating the concept of radioactive waste storage in basalt. As one part of the investigation, a site identification study is being conducted to identify, rank, and recommend candidate repository sites in the Columbia River Basalt area which extends over a region of approximately 46,300 sq mi (120,000 sq km) in eastern Washington, eastern Oregon, and western Idaho (see Figure I-1). Two parallel studies are ~~proposed by Rockwell~~: (1) a site identification study for the Columbia ~~River Basalts~~ excluding Hanford (abbreviated in this report as CORBEH), and (2) a site identification study for the Hanford area (abbreviated in this report as Hanford).

To accomplish the site identification process for the two study areas, six tasks are used. The relationship between these tasks is illustrated in Figure I-2. Task 1 has been completed and consisted of the preparation of an overall site identification study work plan, a review of the existing licensing framework, and site suitability criteria. ~~prepared by Rockwell and others.~~ Task 2, the subject of this report, presents the screening and ranking siting criteria to be used in the site identification process and discusses the development of the criteria. The hierarchy of terms used in the study are illustrated in Figure I-3. Task 3 will consist of a review of the engineering and geotechnical studies scheduled during fiscal years 1979 through 1981 for the Basalt Waste Isolation Program. The impact of the various studies on the site identification, evaluation, and licensing process will be evaluated. Task 4 will consist of the acquisition, evaluation, and compilation of geotechnical, engineering, and environmental characteristics of the areas for which the two site identification studies will be carried out. Task 5 will consist of a screening process in which the siting criteria can be applied to focus attention on progressively smaller areas that have a higher potential for containing suitable sites than the areas excluded from the study. Task 6 will consist of ranking selected candidate sites identified by the screening process. ~~Based on the results of the ranking process, sites may be selected for verification.~~ Future steps in the site identification process ~~should consist of site verification,~~ design, licensing, and construction of a repository. For the purpose of the site identification study, the repository is generally considered to consist of surface facilities which would be capable of receiving daily rail and/or truck shipments of radioactive waste contained in shielded shipping casks, removing the waste from the shipping cask, and transferring of the waste



C CO~~R~~PBEH (Columbia ~~River~~ Plateau Basalt Except Hanford)

H HANFORD

FIGURE I-1

THE STUDY REGION SHOWING AREAS FOR THE TWO SITING STUDIES

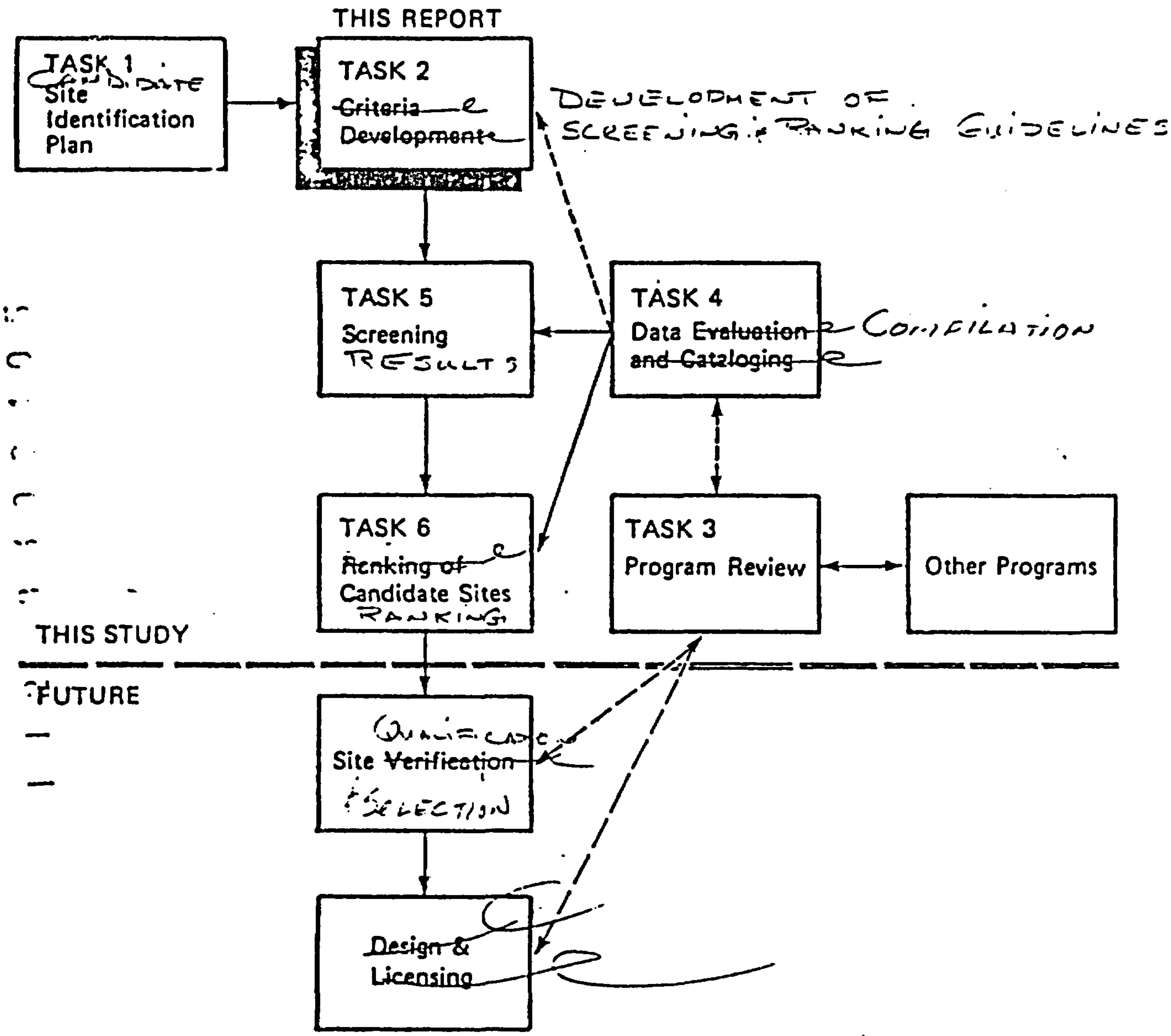


FIGURE I-2

RELATIONSHIP BETWEEN TASKS OF THE STUDY

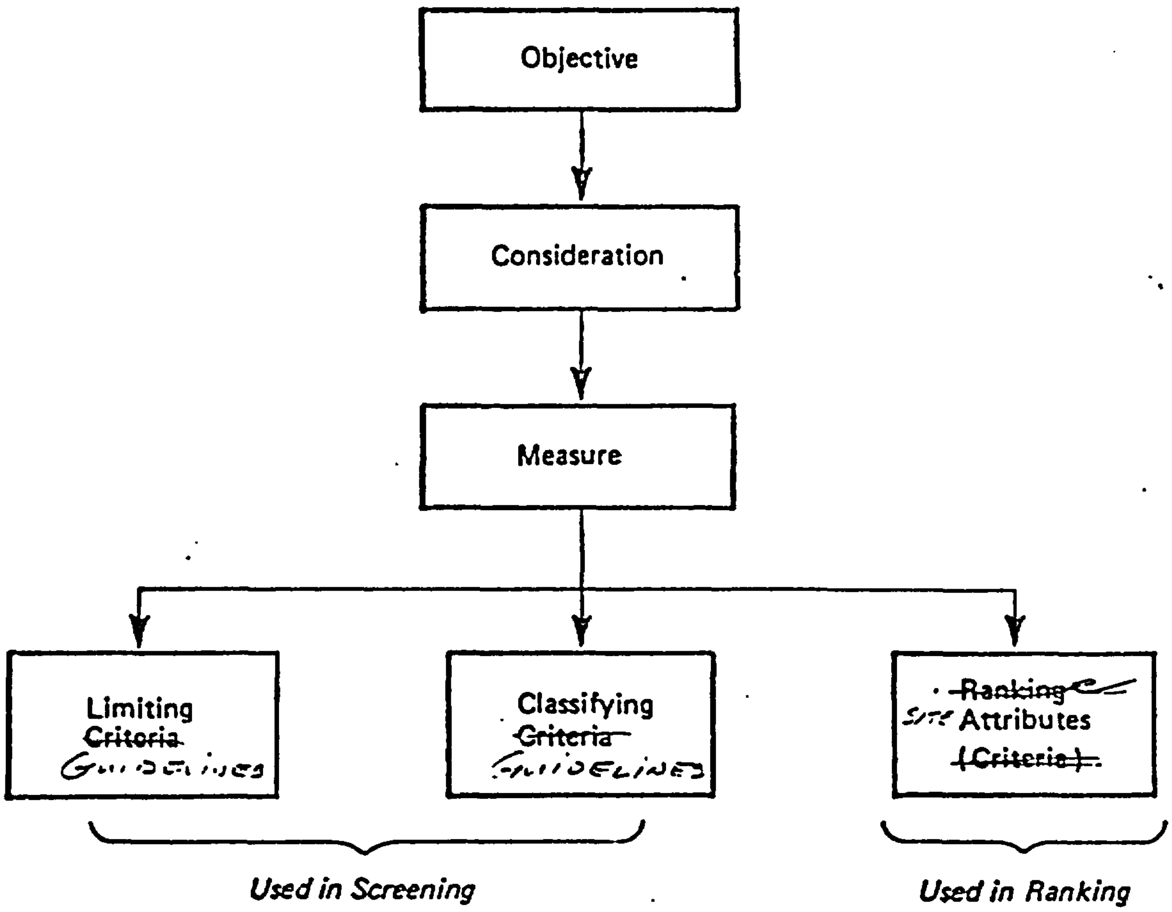


FIGURE I – 3

RELATIONSHIP OF TERMS USED
IN SCREENING AND RANKING

into a transport shaft or tunnel. The shaft or tunnel would provide access to the underground repository where placement of the waste would most likely be in specially prepared boreholes.

The sites identified from the siting study, ideally should, be capable of accommodating, as a, facility for the packaging of high-, intermediate-, and low-level waste and a facility for lag storage of radioactive waste prior to packaging, possibly consisting of water basins similar to those in use at light water reactor plants. ~~In addition to the facilities just described, the site should also have sufficient area to~~ permit inclusion of a waste reprocessing facility in the event that such an option is exercised in the future.

2. TASK GOALS

The overall goal of the site identification process is to identify sites in the CORBEH and Hanford areas which are suitable for nuclear waste repositor~~ies~~. Working objectives associated with this overall goal are: to minimize adverse conditions affecting public health and safety, to minimize adverse environmental impacts, and to minimize the costs associated with the development and construction of such a repository. Corollaries to these objectives are that the identified sites should be capable of meeting the desired performance characteristics of a repository and that these sites are suitable within the regulatory, legislative, and public acceptance framework. These objectives and their corollaries provide the basis for the development of the siting criteria.

The goal of Task 2, Criteria Development, as documented in this report, is to establish ~~criteria that~~ are usable in a screening and ranking process and that meet the goal of identifying suitable nuclear waste repository sites.

3. APPROACH

The overall approach to the development of siting criteria in Task 2 consisted of the following steps, which are illustrated in Figure I-4:

1) Identify and evaluate the baseline or existing given information which describes the proposed nuclear waste repository, its physical characteristics and properties and its expected performance characteristics. This baseline information provides the basis for the development of criteria.

2) Develop the criteria using the baseline information~~, as a basis~~. These criteria are developed to meet the objectives of maximizing public health and safety, minimizing adverse environmental impacts, and minimizing system costs. In addition, they are based on the existing licensing and regulatory framework for nuclear

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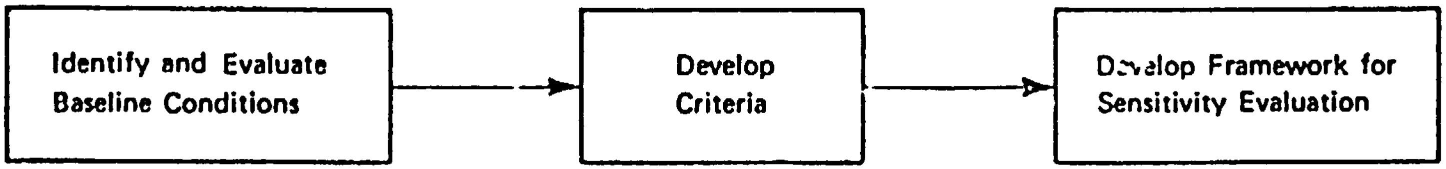


FIGURE I – 4

TASK 2 FLOW DIAGRAM

plants and the anticipated framework for nuclear waste repositories. These siting criteria are preliminary and will undergo a test application of the screening process on a portion of the study area. Revised siting criteria will then be used in screening and ranking (Tasks 5 and 6, respectively) to identify candidate sites.

3) Develop the framework for evaluating the sensitivity of the siting criteria and site identification study to changes in the baseline information, to changes in the regulatory framework, and to additional data.

4. ORGANIZATION OF THE REPORT

The Task 2 report presents the results of the criteria development beginning with an introduction (Section I) which provides a general project definition, goals of the site identification study and general approach to Task 2. Section II lists and discusses the baseline information or key assumptions used in the development of the criteria. Section III presents the screening and ranking criteria with a detailed discussion of the approach and methodology used in the criteria development and also includes an example of the hypothetical application of the criteria in a site identification process. Section IV presents a discussion of the framework for the evaluation of the sensitivity of the criteria to changes in basic information or key assumptions of the site identification study.

II. BASELINE CONDITIONS USED IN CRITERIA DEVELOPMENT

1. GENERAL

An essential part of the development of siting criteria is the identification and selection of basic information or data that establish baseline conditions describing the proposed nuclear waste repository. This information is necessary because it provides qualitative and quantitative physical and facility performance information which provide a basis for establishing numerical criteria in a site identification process. For example, the size or acreage of a desired facility must be a known, fixed quantity otherwise sites might be identified which are physically too small to contain the proposed facility. Table II-1 presents a summary of the basic information describing the physical and performance characteristics of the nuclear waste repository considered for the Columbia River Basalt. This information provided the basic data for the formulation of the siting criteria discussed in Section III and described in Appendix A.

2. DISCUSSION

The basic information in Table II-1 was derived in two ways: (1) by examining existing Rockwell documents which describe the proposed repository and performance characteristics of the repository and waste, and (2) through evaluations by the WCC project team which were used to fill gaps in the existing available information. The following discussions briefly describe the categories of information contained in Table II-1 and the derivation of the baseline information in each category.

2.1 Facility Description

The majority of the information under this category deals with the physical dimensions, geometry, and types of facilities that are expected or planned for the surface and underground components of the nuclear waste repository. The majority of the data in this category are derived from Rockwell documents. This information is significant to criteria development in that it provides basic data needed to develop screening and ranking criteria dealing with radiation releases, system costs, and environmental impacts. For example, the size of the surface facility will affect how criteria are developed to assess site preparation costs where topography, access, and usable land area are important.

TABLE II-1

BASIC INFORMATION USED IN CRITERIA DEVELOPMENT

Category	Item	Value or Condition Used in This Study	Source or Basis*
Facility Description	Type of Facility	Reprocessing facility is considered.	Rockwell, 1978a
		Reprocessing lag storage and packing facilities will be or will have Cat. 1 components.	Rockwell, 1978b and WCC
Surface Facility	Area: total	1700 acres	Rockwell, 1978a
	packing facil.	200 acres	Rockwell, 1978a
	lag storage	200 acres	Rockwell, 1978a
	~~reprocessing~~	~~300 acres~~	Rockwell, 1978a
	rock spoil	1000 acres	WCC
	Surface	1300 acres	
	Configuration	Square approx. 1.6 mi/side	WCC
	Volume of Rock Spoil	38×10^6 to $61 \times 10^6 yd^3$	WCC
	Power Supply	Dedicated	Rockwell, 1978b
	Water Supply	On-site wells, with cooling towers	Rockwell, 1978b
Subsurface Facility (Repository)	Depth	2000 to 4000 ft	Rockwell, 1978a
	Area	3200 ~~to 5200 acres~~	Rockwell, 1978a and WCC
	Configuration	One level approx. 2.25 to 2.80 mi/side	WCC
	Dimension of Shaft	25 x 25 ft	WCC
	Dimension of Tunnels	Arch construction 25 ft, center height 25 ft, floor width	WCC
	Canister Placement (SURF)	Vertical, with excavation up to 25 ft below tunnel floor	WCC

Category	Item	Value or Condition Used in This Study	Source or Basis*
Facility Description (cont.)	Repository Expansion	Expansion of repository is probable in future.	Rockwell, 1978b
	Design Basis Earthquake	Facilities will have SSE/ OBE evaluation and reviews.	WCC
Waste Description	Type of Waste	SURF, LL-TRU, IL-TRU, HLW,CW	Rockwell, 1978b
	Waste Form	Solid	Rockwell, 1978b
	Total Time Period of Waste to be Stored	1973 to and including ~~including~~ 2010	Rockwell, 1978b
	Period of Waste Aging	5 years minimum	Rockwell, 1978b
	Number of Waste Canisters	SURF = 527,864 LL-TRU = 38,502 (as of 2010)	Rockwell, 1978b
	Volume of Stored Canisters (SURF and LL-TRU)	SURF = 13,635, 187 ft^3 LL-TRU = 310, 426 ft^3 (as of 2010)	Rockwell, 1978b and WCC
	Number of Canisters/Acre	approx. 100	WCC
	Thermal Loading	153 kilowatts/acre	Rockwell, 1978b
	Retrievability of Waste	Up to 25 years after receipt of last canister (i.e., 2040) e.g.	Rockwell, 1978b

accompanying note? page

Category	Item	Value or Condition Used in This Study	Source or Basis*
Repository Host Rock Characteristics	Type	Columbia River Basalt	Rockwell, 1978a, & b
	Flow Thickness	100 ft minimum	Rockwell, 1978a & b
	Flow Dip	Less than 5° is optimum condition	WCC
	Strata Continuity	Major flows (>100 ft thickness) of formations within Columbia River Basalt are relatively continuous over extent of the given formation.	WCC
	Engineering Properties	Density = 2.87 gm/cm^3 Young's Modulus = 77 GPa Poisson's Ratio = 0.25 Uniaxial Compressive Strength = 284 MPa Friction = 55° Tensile Strength = 21 MPa	Rockwell, 1978c " " " " " " " " " "
	Thermo-mechanical Properties	Thermal Conductivity = 3.6 x 10^{-3} cal/cm-sec-°C Specific Heat = 0.35 cal/gm-°C Thermal Expansion Coefficient = 6.6 x 10^{-6}/°C	" " " " " "
Performance Characteristics	Time Frame	Operational Phase, 60 years Isolation Phase, 10,000 used for criteria development (range to 100,000 years for sensitivity analysis)	WCC
	Radiation Releases	Within 10CFR100, 10CFR20 during operational phase. No releases to atmosph re during isolation phase.	Rockwell, 1978b and WCC
	Waste Volume	The ideal repository will be able to safely and adequately handle the volume of waste generated in the U.S.	WCC

need explain of where 60 years come from + logic

+ 60 = 2050

Category	Item	Value or Condition Used in This Study	Source or Basis*
	Natural and Man-made Barriers	Sealing and plugging works and existing (drilled) boreholes ~~do~~ not penetrate repository. Natural ~~isolation~~ barriers effective ~~work~~ over the isolation period (≈ 10,000 years)	WCC
	Climate	Climate remains essentially the same as today's during isolation period	WCC
	Geologic and Tectonic Conditions	The geologic and tectonic processes, patterns and conditions existing at the present in the Columbia Plateau region are likely to be similar over the next 10,000 years. Regional tectonic movements are uniform throughout study area and affect potential sites equally.	WCC
Legal and Licensing Issues	Licensing Authority State Sanction	The repository will be licensed by and under the authority of the NRC ~~Existing Oregon~~ State laws prohibiting nuclear waste storage ~~is~~ not considered for the technical purposes of this study.	WCC and Rockwell
System Economics	Total Cost	~~Maj~~or cost components are: construction and site preparation costs, site acquistion costs, facility costs for design against natural and man-made hazards, cost of mitigation of impacts, and operating costs.	WCC
Environmental and Socioeconomic Conditions	Administrative Control	Considered to be similar to the present framework ~~up to 100 years~~ thru operational phase	WCC

Category	Item	Value or Condition Used in This Study	Source or Basis*
National Defense and Security	Security and Defensibility	All potential sites in the Columbia Plateau area are equal with respect to national defense and security	WCC

may not be entirely true - how close to river or existing facilities could present an attractive nuisance.

Delete if referenced

*Source or Basis:

Rockwell, 1978a, Repository Site Selection Study Contract with WCC

Rockwell, 1978b, Waste Isolation Program, Basalt Repository, Preconceptual Design Guidelines: Rockwell Hanford Operations Report RHO-BWI-CD-2.

Rockwell, 1978c, Basalt Waste Isolation Program Annual Report - Fiscal Year 1978: Rockwell Hanford Operations Report RHO-BWI-78-100.

Woodward-Clyde Consultants, Values based on WCC files or established by WCC project team.

2.2 Waste Description

The data listed under waste description ~~again~~ are derived primarily from Rockwell ~~documents~~. They deal mainly with the type of waste, age of waste, and projected volumes of the waste to be stored in the repository. These data are significant to criteria development in providing information for the calculation and verification of estimated potential radiation releases from repository facilities. Because of the uncertainties regarding types of wastes, types of facilities ~~(reprocessing plant option vs. non-option)~~ and amounts of emissions as compared to existing nuclear facilities (i.e., nuclear power plants), ~~it was felt that~~ an evaluation of nuclear wastes and estimated emissions from the repository facilities ~~was~~ needed. ~~This~~ verification ~~was~~ necessary because it impacts the setback distance from population centers, ~~which is~~ an important siting ~~criterion~~ guideline developed and utilized in the site identification study. The result of this verification is that the emissions are similar, thus the siting ~~criteria~~ concerning operational radiation releases from a repository ~~are~~ the same as for a nuclear power plant.

2.3 Repository Host Rock Characteristics

The baseline ~~information~~ conditions in this category provides information or assumptions concerning the stratigraphic, engineering, and thermomechanical properties of the proposed repository in basalt. These data are significant to criteria development because they provide limits around which the criteria can be built. For example, stating that the host rock is within the Columbia River Basalt provides a stratigraphic limit around which criteria can be developed. Likewise, a minimum flow thickness of 100 feet provides another stratigraphic limit.

2.4 Performance Characteristics

The majority of the baseline information in the performance characteristics category resulted from evaluations made by the WCC project team. The information in this category includes assumptions concerning the time frame of the repository, radiation releases, and the long-~~time~~ term stability of the repository and its environment.

A significant baseline condition which impacts criteria development is the time ~~frame~~. It is particularly important in selecting criteria concerned with long-term geologic stability because the time period over which stability is considered must be known. ~~Thus, the evaluation and establishment of a repository time frame is a necessary baseline condition.~~

Various proposals ~~estimates~~ for the long-term isolation period (isolation phase) have ranged from a few hundred years to 100,000 years (National Academy of Science, 1978). Obviously this wide range can seriously affect criteria development. To arrive at a reasonable estimate for the isolation period time frame, ~~an evaluation was made of~~ the types of wastes expected to be stored in the repository and their decay rates. Tables II-2 and II-3 presents the ~~results of this evaluation~~. These ~~results~~ suggest that the radioactivity of the wastes decreases by approximately five orders of magnitude in the period of 3,000 to 10,000 years. ~~In addition,~~ similar ~~results~~ have been reported by Cohen (1977). Because of the uncertainty in the relative decay of the radioactivity, 10,000 years appeared to be reasonable for the isolation phase time frame.

2.5 Other Categories

The remaining categories of Table II-1 are concerned with legal, economic, socioeconomic, and security conditions of the proposed repository and/or environment. A ~~significant~~ item is the condition that ~~the existing Oregon~~ state laws prohibiting nuclear waste repositories will not be considered in this study. This is done to preserve the technical and generic continuity of the site identification study in Columbia River Basalt.

3. INFORMATION CONSIDERED BUT NOT USED

In addition to developing the basic information for use in criteria development, certain considerations regarding geologic stability, rock mechanics, natural hazards, etc., were found to be not applicable to the formulation of siting criteria. These considerations are generally either too broad in scope and cannot be used to differentiate one area from another (an important concept necessary for siting criteria) or are too detailed such that the data do not exist with which to differentiate areas. Table II-4 lists several examples of specific considerations which were examined for use in criteria development but were found to be not applicable, or could not be utilized.

~~4. CONCLUSIONS~~

An integral part of the development of siting criteria is the establishment of the baseline conditions for the project facility, physical description, and expected performance characteristics. Unless it is known what is desired in terms of physical description and expected performance of the proposed facility, it is impossible to locate sites which meet the needs of the repository. An undefined project description would then result in undefinable sites.

Another result of compiling and listing the basic information for criteria development is the potential impact, to the siting criteria and ultimately

TABLE II-2

FISSION PRODUCTS AND ACTINIDES IN SPENT FUEL AND HIGH-LEVEL WASTE[1]

		90 days	160 days	1.0 years	1.4 years	10 years	10.4 years	100 years	1000 years	3000 years
Spent Fuel										
Fission Products	Ci/MTHM	6.0E6[2]	4.2E6	2.1E6		2.5E5		2.7E4	1.8E1	1.7E1
Actinides	"	8.4E4	8.1E4	7.5E4		4.8E4		4.2E3	1.2E3	6.1E2
Total	"	6.0E6	4.2E6	2.1E6		3.0E5		3.1E4	1.2E3	6.3E2
Thermal Radiation	W/MTHM	2.7E4	1.9E4	9.2E3		8.6E2		1.9E2	3.8E1	1.9E1
High-Level Waste										
Fission Products	Ci/MTHM		4.2E6		1.5E5		2.4E5	2.7E4	1.8E1	1.7E1
Actinides	Ci/MTHM		8.0E3		2.5E3		7.7E2	1.5E2	3.9E1	1.5E1
Total	Ci/MTHM		4.2E6		1.5E5		2.4E5	2.7E4	5.7E1	3.2E1
Thermal Radiation	W/MTHM		1.8E4		6.4E3		7.4E2	8.0E1	1.1E0	4.0E-1

Source = ERDA-76-43 Tables 2.17 and 2.19

1 Basis: 25 GWd/MTHM, 35 MW/MTHM, initial ^{235}U content = 3.3%

2 Read 1.0E6 as 1.0 X 10^6

1 1 2 3 3 7 0 4 1 9

TABLE II-3

RADIOACTIVITY IN FUEL-ASSEMBLY METAL WASTE

	120 days	1 year	10 years	100 years	1,000 years	3,000 years	10,000 years
Fission Products							
Ci/MT hulls	8.4E3[1]	3.2E2	3.7E2	2.0E1	2.7E-2	2.6E-2	2.6E-2
Ci/MT fuel	2.7E3	1.0E2	1.2E2	1.3E1	8.9E-3	8.5E-3	8.3E-3
Activation Products							
Ci/MT hulls	2.7E5	1.1E5	1.2E4	3.8E2	7.9E0	6.9E0	5.6E0
Ci/MTHM fuel	8.8E4	3.6E4	3.9E3	1.2E2	2.6E0	2.2E0	1.8E0
Actinides							
Ci/MT hulls	5.4E2	4.7E2	2.9E2	2.4E1	5.4E0	2.3E0	1.3E0
Ci/MTHM fuel	1.8E2	1.5E2	9.4E1	7.9E0	1.8E0	7.4E-1	4.3E-1
Gross Total							
Ci/MT hulls	2.8E5	1.1E5	1.3E5	4.4E2	1.3E1	9.2E0	6.9E0
Ci/MTHM fuel	9.1E4	3.6E4	4.2E3	1.4E2	4.4E0	3.0E0	2.2E0
Heat Generation							
W/MT hulls	1.5E3	6.0E2	8.9E1				
W/MTHM fuel	5.0E2	2.0E2	2.9E1				

Source = ERDA-76-43, Tables 2.15 and 2.16

Calculations based on "reference" LWR fuel assembly, 25 GWd/MTHM burnup, 35 MW/MTHM specific power and on residual fuel in cladding of 0.05%

[1] Read 1.0E6 as 1.0×10^6

TABLE II-4

EXAMPLES OF CONSIDERATIONS EXAMINED FOR CRITERIA DEVELOPMENT BUT NOT USED

Consideration	Remarks
Future climatic changes	Future climatic changes were considered to affect all areas of the Columbia River plateau equally such ~~that one~~ area could not reasonably ~~be differentiated~~ relative from another area.
Continental glaciation	Continental glaciation was considered to have a low probability of occurring and to have a low probability of affecting the Columbia plateau during the 10,000 year isolation period.
Catastrophic flooding	Catastrophic flooding similar to the Spokane floods of the Columbia plateau were considered to have a low probability of occurring during the 10,000 year isolation period. It is believed that more than 10,000 years would be necessary for continental glaciation to occur and to create the circumstances necessary to produce such floods.
Meteorite impact	Meteorite impact is considered to have the same probability throughout the Columbia plateau and cannot be used to differentiate areas.
Severe weather	Severe weather, to the point of affecting repository facilities, was considered to be undifferentiable throughout the study area.
National defense and security	National defense and security was not used because no reasonable way could be found to differentiate between areas within the study area.
Mechanical, chemical, and physical interactions between waste and rock	Information on these considerations will not generally be available in enough detail to differentiate areas on the basis of these properties and interactions.
Future socio-economic development	Adequate information does not exist to predict and assess future socio-economic development in the Columbia plateau and to adequately differentiate between areas.

NAS 3.3.3 not sure this could be defended - might want to consider as classifying

meteorology on top of RS much worse than 200 areas

proximity to other facilities may be a relevant issue

true for isolation phase but not true for operational phase

also may be able to some classifying based on soil types, etc. identification of regeneration ... nuclear parks.

to the results of the siting study, that changes in the basic information can cause. For example, extending the isolation phase time frame beyond 10,000 years ~~can significantly~~ affect the criteria dealing with tectonic stability. The sensitivity to the siting study of such changes of the basic information is discussed in Section IV.

III. METHODOLOGY AND RESULTS OF CRITERIA DEVELOPMENT

1. GENERAL

The purposes of this section ~~are~~ to describe the methodology used to develop site identification criteria and to present the results. The word "criteria", as used here, means a set of rules chosen to guide the site identification process through screening and ranking. Some criteria are said to be "limiting", meaning they are used to limit or reduce the area under consideration in the study. Other criteria are said to be "classifying", meaning they are used to classify or characterize smaller areas as an aid to evaluation. "Ranking criteria" are neither limiting nor classifying; they are rules for describing differences between sites identified in the screening process.

This section consists of a description of the general approach used to develop site identification criteria, a review of the implementation of this approach, a presentation of results (the criteria), and a discussion of how criteria ~~are~~ applied in the screening and ranking steps of the site identification proces

2. APPROACH

This subsection presents ~~the~~ background information and key assumptions that figured ~~in~~ the development of criteria, followed by a description of each ~~of~~ steps in the criteria development process.

The basic logic of the approach begins with ~~the~~ articulation of objectives of the repository siting decision, and proceeds systematically to refine these objectives and identify means of measuring achievement of the objectives. The results of this process are two sets of criteria, one for identifying sites and another for ranking sites. Sites identified by the first set of criteria can be shown to meet minimum levels of achievement of the siting objectives; sites ranked by the second set of criteria can be compared in terms of specific differential achievement of the siting objectives. The steps in the approach are shown schematically in Figure III-1. This approach was selected to meet anticipated regulatory agency requirements for an objective and systematic site selection method and to provide a mechanism for traceability and documentation in the project record. For example, any site identified and ranked on the basis of these criteria may be discussed and evaluated ~~conclusively~~ in terms of the siting objectives set forth at the outset of the study; and the decision to include or remove any area, locality, or site may be traced through the criteria to systematically applied rules that are directly related to siting objectives.

1 1 2 . 3 3 1 2 4 2 3

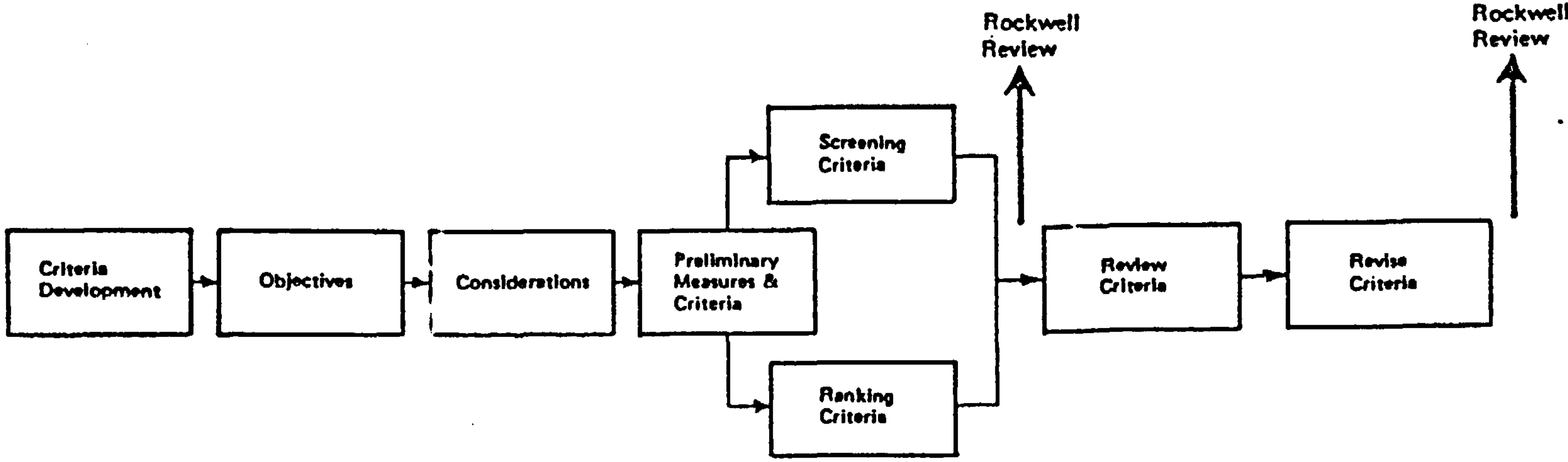


FIGURE III – 1

STEPS IN CRITERIA DEVELOPMENT

2.1 Background and Assumptions

The approach described here conforms to Task 2, as presented in the site identification work plan report. Task In that report, the key assumptions guiding the siting study were said to be:

- The repository will require licensing involving the NRC, other federal agencies, and possibly state and local entities;
- The design and operation of most surface facilities will be governed by existing safety and environmental licensing requirements, and the licensing requirements for the underground facilitiy will be similar or more stringent;
- The pre conceptual design and performance characteristics of the repository are known; these are discussed as given basic information in Section II of this report;
- The long-term, safety-related characteristics of host rock ~~basalt~~ can be estimated and used in the selection of criteria. Similarly, appropriate judgments can be made regarding long-term social, economic, and political considerations applicable to repository siting;
- The repository will be designed for two time frames, a relatively short emplacement and retrieval phase, and a much longer isolation phase;
- The site identification study will be based on available data; site identification criteria will be based on currently available technology.

It is further assumed that forthcoming repository licensing requirements will be written by, or adapted in the style of, the NRC. In the interim, existing NRC regulations pertaining to other nuclear fuel cycle facilities (mining, enrichment, fuel fabrication, power reactors, fuel reprocessing and fuel handling, and storage) provide a reasonable basis for estimating the scope of siting considerations and the degree of conservatism appropriate to repository licensing.

The overall site identification study will consist~~s~~ of two parallel efforts to identify and rank sites; one effort examines the area within the Hanford Reservation while the other examines the area associated with the extent of the Columbia River Basalts except Hanford (abbreviated as the CORBEH area). For objectivity, a single set of criteria will be developed to identify sites in both the Hanford and CORBEH areas. There may, however, be differences in the way in which classifying criteria are applied in the two areas. Limiting criteria will be applied consistently in both areas. However, some classifying criteria aimed at differentiating between area characteristics in the large CORBEH region may not discriminate within the smaller Hanford area and, hence, may not contribute to a decision to reduce the area under consideration at Hanford.

2.2 Objectives

The first step in the approach to develop criteria is the establishment of objectives for the siting decision. The overall objective is to identify "suitable" sites for a deep geologic repository and its associated surface facilities.

Existing and anticipated regulations, national and state environmental legislation, and principles of sound engineering practice provide basic guidance for the interpretation of the word "suitable" and, hence, for the articulation of more precise siting objectives. Each objective derived from this initial interpretation may be serially refined and restated in increasingly greater detail to reflect specific characteristics of the repository facilities, as well as conditions and concerns within the study area. The hierarchy of objectives thus established provides the framework for choosing and applying criteria to identify sites.

2.3 Considerations and Measures

For each of the general objectives established in the above step, one or more "considerations", or technical matters of concern, can be identified to describe the subject matter that must be addressed to orient the siting study toward achievement of the objectives.

The considerations reflect characteristics, conditions, or processes in the study area that may affect suitability of a repository site. An example of a consideration related to a safety objective is fault rupture; this is a technical matter that must be addressed in the siting study to assure achievement of the safety objective.

For each consideration, a measure is selected or developed to allow differentiation between areas, localities, or sites in terms of the consideration. Using the fault rupture example, the measure is distance from capable faults and those interpreted to be capable. This measure provides a means of assessing the degree to which a repository at any location in the study area can achieve the objective of maximizing safety in relation to fault rupture. For some considerations, a specific level of achievement is required or implied by statute, regulation, technological limitations, or gross economic considerations. In these cases, a limit can be established for the appropriate measure and used to identify locations that meet the minimum requirements for that consideration. In the fault rupture example, it is generally accepted that most effects of fault rupture (surface rupture, lurching, severe deformation, etc.) occur within 5 miles of the capable structure and cannot be compensated by design. The NRC holds that sites for nuclear power plants (and presumably for repositories) within 5 miles of a capable fault are not generally acceptable. Hence, a limit can be set on the measure of the fault rupture consideration; in this case, locations within 5 miles of capable faults would be removed from consideration in the siting study because they fail to meet the minimum level of achievement of the safety objective, as expressed in relation to the fault rupture consideration.

Considerations for which no specific minimum level of achievement is required are used to characterize and classify areas and sites within portions of the study area that attain minimum levels of achievement on other considerations.

2.4 Establishment of Criteria

For considerations for which a specific level of achievement is required, the value of the measure at which the limit is set is a limiting criterion. In the fault rupture example, the limiting criterion is "include areas farther than 5 miles from capable faults". For considerations for which no specific level of achievement is required, the measure itself, or a non-prescriptive classificatory interpretation of it, is the criterion and is used to characterize or classify areas, localities, and sites. If the criterion is used to identify groups of areas or localities with similar characteristics, it is called a "classifying criterion". If the criterion is used to characterize sites for comparative purposes, it is called a "ranking criterion" or a "ranking attribute".

All of the measures selected for the many considerations developed in the process described above may not be assessed meaningfully at the same level of detail or on maps of the same scale. For this reason, it is often necessary to repeat the measurement of some considerations at several steps of the screening process. For example, if a limiting criterion is "include areas outside of protected ecological reserves", and if such reserves could vary in size from a few acres to several tens of thousands of acres, it may be necessary to restate this criterion in terms appropriate to the several scales of maps character"istically used in a screening process. Thus, in the first step of screening, using small-scale maps, the criterion might be "include areas outside of protected ecolocial reserves larger than 18,000 acres" (an area which is readily discernible on maps of 1:500,000 scale). In subsequent steps of screening, the criterion should be restated to consider smaller and smaller ecological reserves.

The complete hierachy of criteria can be shown then in tabular form in relation to considerations and objective; the table can also specify the steps in the siting study at which the criteria are used.

2.5 Review and Revision of Criteria

The final step in criteria development is to review the set of established criteria for completeness, appropriateness, responsiveness to governmental regulations and guidelines, consistency, and practicality in application. Modifications suggested by this review are made, and a revised set of criteria is issued. It is important to note that this review and revision process can take place at any time in the future. The siting methodology and the criteria development task within it are structured to allow accommodation of new or revised information; the effect of a changed -tive, a technological advance, or a new or revised regulation can be iso.. 1 within the rigorously defined heirarchy of criteria and played out in the corresponding steps of screening or ranking. At the outset of the siting study, however, the emphasis on criteria review are on: consistency within the set of criteria, compatibility with emerging repository design concepts and repository systems development, compliance with regulations, completeness and reasonableness in comparison to previous or concurrent repository siting criteria development efforts, and "mapability". This review is accomplished through a review of pertinent literature, comparison with successfully applied sets of criteria used to site similar large facilities, meetings with the engineering and geologic design team, and test applications of selected criteria on different scale maps of the study area.

3. IMPLEMENTATION AND RESULTS

This section describes the manner in which each of the steps of the approach was carried out and presents the outcome of steps leading to a preliminary set of site identification criteria.

3.1 Objectives

The overall objective of the site identification study is to find suitable sites for a deep geologic repository for high-level radioactive waste. It is given that the repository will be licensed and that the NRC is the most likely licensing agency. In a November 1978 Proposed General Statement of Policy for licensing requirements for a repository, the NRC indicated that the proposed repository application would require a site safety review and would be required to comply with NEPA. From these conditions and from past siting and licensing experience with the NRC, it is deduced that for a repository site to be accepted by the NRC as suitable, the site must meet the following objectives:

- Maximize public health and safety;
- Minimize adverse environmental and socioeconomic impacts;

- Attain and maintain feasibility of operation as a repository throughout the emplacement and retrieval phases;

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

The overriding concern for safety is the possibility that through an accident or routine operation, unacceptably high levels of radioactivity will be released to the biosphere. The objective of maximizing public health and safety can then be restated to bear on conditions or events that could be associated with the causes or consequences of radiation releases from a repository. These conditions or events may be grouped into natural hazards, man-made hazards or events, and repository-induced events. The safety objective can then be particularized to state:

- Maximize public health and safety in relation to:

  natural hazards;
  man-made hazards and events;
  repository-induced events.

It is implied that achievement of this objective is related to the prevention or minimization of the possibility or consequence of radiation releases to the biosphere. ref

The environmental objective is derived from NEPA, which requires the pertaining federal agency (in this case the NRC) to account for environmental factors in its decision-making process and to align its decisions reasonably with national environmental policy guidelines. In practice, this means that the site identification process pursued by an applicant for a NRC license must demonstrate avoidance and minimization of conflict with environmental values and that the site submitted for NRC review must be defendable in terms of a balance between environmental impacts and other siting considerations. ? "Environment" as used here refers to both the natural and built environments. The time frame covered by an NRC environmental review covers all phases of repository development, use, and decommissioning. Therefore, the environmental objective can be particularized as:

adverse

- Minimize environmental and socioeconomic impacts related to:

  construction;
  operation;
  closure and surveillance.

The feasibility objective may be considered to be corollary to the cost objective; feasibility of a site to function as a repository is a basic condition of design. The cost objective is derived from NEPA and the associated NRC regulations, which require an exposition of cost-benefit relationships and the manner in which they are considered in evaluating alternative sites. The cost objective may be particularized by stage of repository development:

- Minimize system costs related to:

  construction and mitigation;
  operation and maintenance;
  closure, decommissioning, and surveillance.

The three major objectives (safety, environmental, and cost) are considered to embrace the totality of concerns pertinent to a siting decision. Two major practical objectives of a siting decision are: maximize licensibility of the proposed facility and maximize public acceptance. Both of these objectives are inherent in the safety, environmental, and cost objectives; that is to say, a site that achieves highly on all objectives should be licensible, and the siting decision should be acceptable to the public. Table III-1 summarizes the objectives developed to guide repository site identification.

3.2 Considerations and Measures

For each of the objectives described above, a set of considerations and the means to measure them was developed. The selection of considerations was based on the given repository design and performance characteristics, the pertinent regulatory guidance, and assessment of the natural and man-made characteristics of the study area. In addition, the set of considerations was limited to those considerations that might be expected to differ from one location to another. If a consideration was estimated to have an equal probability of occurrence or an equal manifestation or significance at all locations in the study area, it was not included in the set. For example, meteorite impact was estimated to have an equal probability of occurrence at all locations in the study area and was not included as a siting consideration. Likewise, if a condition or event was not known or expected to occur in the study area, it was not included as a siting consideration. For example, seismic sea waves are natural hazards that could affect the safety of operation of a repository, but they do not occur in or affect any portion of the study area. The identification of considerations took into account both the short-term operating time frame and the long-term isolation time frame. Thus, for the safety-related consideration of volcanic effects, the potential for future volcanic activity throughout the isolation phase was included as an additional consideration.

The choice of measures for the considerations was based on prior NRC licensing experience and relevant regulatory positions, on the availability of data, and on the need to portray as many of the measures as possible on maps. In many cases, the measure was used in a proxy for the siting consideration or its associated effects. For example, the

TABLE III-1

REPOSITORY SITE IDENTIFICATION OBJECTIVES

OBJECTIVE	DERIVATION
1. Maximize Public Health and Safety in relation to: • natural hazards • man-made hazards and events , repository induced events	NRC Policy Statement[1] 10 CFR 100 10 CFR 20 10 CFR 60[2]
2. Minimize Adverse Environmental and Socioeconomic impacts related to: mitigation • construction and maintenance • operation decommissioning • closure, and surveillance	NRC Policy Statement NEPA[3] Reg. Guide 4.2
3. Mimimize System Cost Related to: • construction and mitigation • operation and maintenance • closure, decommissioning, and surveillance	NRC Policy Statement NEPA Reg. Guide 4.2

1 U.S. Nuclear Regulatory Commission, Proposed General Statement of Policy for Licensing Procedures for Deep Geologic Repositories for High-Level Radioactive Wastes, November 17, 1978. FR 78-53869 et. seq.

2 10 CFR 60, in preparation, will contain site suitability criteria for nuclear waste repositories.

3 42 U.S.C. 4341

ground motion consideration is measured in miles; the motion itself is traditionally measured in terms of acceleration. In this study, the range of acceleration levels is inferred from a magnitude-acceleration attenuation relationship, and the magnitude is estimated from a fault rupture length-magnitude relationship. On a map, this consideration is portrayed as a distance in miles from faults of different lengths, the distance representing a range of acceleration levels.

The considerations and measures selected appear in Table III-2 and are further explained in Appendix A.

3.3 Establishment of Criteria

The set of considerations and measures was reviewed to identify those considerations for which a specific level of achievement is required. Guidance for this determination consisted of imposed statutory or regulatory limits, technological limits, and limits implied by prior regulatory experience. An example of a statutory limit is the prohibition on industrial development in Federal wilderness areas. An example of a technological limit is the current inability to design a ~~repository~~ to withstand fault rupture. An example of an implied regulatory limit is the requirement for detailed risk analysis for nearby hazardous facilities. The analysis and the possibility of an adverse finding can be minimized by setting a limit on the permissable proximity to such facilities; suggested limits are present in the regulatory literature.

The considerations for which no specific level of achievement is required were designated as classifying or ranking criteria. Ranking criteria (also called attributes) are non-limited measures that are site specific and impact-oriented.

Table III-2 presents the preliminary criteria selected for site identification. Each criterion is identified as limiting or classifying and is shown in relation to the pertinent objective, consideration, and measure. Table III-3 presents the preliminary ranking attributes.

3.4 Review and Revision

The criteria shown in Table III-2 were compared to repository site identification and site suitability criteria proposed in previous studies. The criteria were reviewed with respect to existing regulations and draft regulations or policy statements. The preliminary criteria were discussed with Rockwell at a project meeting. Modifications to these criteria suggested by the review will be incorporated in future drafts. Previous experience in siting studies was used to guide the evaluation of practical applicability (whether the measures could be effectively mapped); for measures that had not been mapped in previous studies, a test application

1 1 2 . 3 ? ? ? ? 3 ?

TABLE III-2

PROPOSED CRITERIA FOR SCREENING – ? both surface and subsurface

OBJECTIVE: MAXIMIZE PUBLIC HEALTH AND SAFETY

Consideration	Measure	Criterion	Type	Possible Use To Obtain	Time Frame (1) (2)
A. Natural Hazards					
1. Fault Rupture	a) Horizontal and vertical distance from capable faults and faults interpreted to be potentially capable	Include areas >5 mi, horizontally and vertically, from capable faults, faults interpreted to be capable and faults of unknown capability and their logical projections	Limiting	Candidate Area Sub-area Site Locality Candidate Site	0 and I
deep microearthquake – probabil-ity – How are they treated	b) Distance from noncapable faults and zones of intense fracturing or jointing	Include areas >1/2 mi from noncapable faults and zones of fracturing or jointing	Limiting	Site Locality	0 and I
2. Generation of New Faults	Location with respect to future potentially capable tectonic structures	Include areas >5 mi from anticlines interpreted to be capable of forming new faults	Limiting	Candidate Area Site Locality	0 and I
3. Ground Motion	Location with respect to earthquake sources and levels of ground motion	a) Include areas that may be subject to less than 40% g peak surface acceleration from known and interpreted earthquake sources – ? with what recurrence probability	Limiting	Candidate Area	0

(1) 0 – Operational Phase (0 to 60 years); I – Isolation Phase (up to 100,00 years)
(2) Criteria applicable to the underground repository are for both Operational and Isolation Phases.

III-11

RHO-BWI-C-

		b) Proximity to historical seismicity based on felt reports and instrumental data	Classifying	Site Locality Candidate Site	0 and I
		c) Proximity to microearthquake activity	Classifying	Site Locality Candidate Site	0 and I
4. Tectonic Movement	a) Location with respect to potential bedrock folding	a) Include areas >3 mi from axes of large folds (>300 ft fold amplitude and/or >10 mi length)	Limiting	Sub-area Site Locality	I
eliminate inside mountain systems i.e. RSH	not sure there is enough data to effectively apply.	b) Include areas >1 mi from axes of small folds (<300 ft fold amplitude and/or <10 mi length)	Limiting	Site Locality Candidate Site	I
	b) Location with respect to bedrock folds and fold systems	Evaluate areas and their locations with respect to spacing and orientation of folds and fold systems	Classifying	Site Locality Candidate Site	I
5. Groundwater Contamination	Location with respect to natural and man-made discharge areas	Evaluate areas on basis of distance from discharge ? intake areas and interpreted containment travel time time time?	Classifying	Site Locality Candidate Site	0 and I
6. Surface Flooding	Height above selected flood level	a) Include areas outside of primary floodplains ~~of rivers~~	Limiting	Sub-area Site Locality	0 and I
		b) Evaluate areas on basis of height above primary floodplains ~~of rivers~~ and estimated PMF levels	Classifying	Site Locality	I

7. Volcanic Effects	Distance from volcanic sources and their effects	a) Include areas >5 mi from Quaternary volcanic center or volcanic flow	Limiting	Candidate Area Site Locality	0
		b) Areas are classified on basis of exposure: A - no expected volcanic effects B - area near volcanic center but no expected effects C - volcanic effects may approach area	Classifying	Site Locality Candidate Site	0
		c) Areas are classified on basis of exposure to tephra fall: A - >100 mi to source B - 40-100 mi to source C - <40 mi to source	Classifying	Site Locality Candidate Site	0
8. Future Volcanic Activity	Location with respect to probability of new volcanic sources	Evaluate areas on basis of probability of what? — relative to dikes? - fissures that are not faults? - microearthquake swarms?	Classifying	Site Locality Candidate Site	1
9. Ground Failure	a) Location with respect to landslides and potential landslides	a) Include areas not on mapped landslides	Limiting	Site Locality	0
		b) Evaluate areas on basis of probability of landsliding:	Classifying	Site Locality Candidate Site	0

1 1 2 [illegible] 4 3 5

		A - low			
		B - slight			
		C - higher			
	b) Characteristics of foundation conditions	Evaluate general foundation conditions:	Classifying	Site Locality Candidate Site	O
	basalt or Ringold or both	A - bedrock area (0-20 ft overburden)			
		B - shallow alluvial (20-100 ft overburden) area			
		C - deep alluvial area (>100 ft overburden)			
10. Erosion/ Denudation	Location with respect to potential areas of erosion or denudation	a) Include areas >1/2-mile from steep-walled slopes or canyons	Limiting	Site Locality	I
		b) Evaluate areas on basis of height above base level:	Classifying	Site Locality Candidate Site	I
		A - repository elevation below base level			
		B - repository elevation above base level			
11. Stratigraphic Characteristics	a) Total basalt thickness	a) Include areas where total basalt thickness >1000 ft — includes or excludes interbeds?	Limiting	Candidate Area	I

1 1 2 3 3 9 0 4 3 5

	b) Evaluate areas on basis of total basalt thickness: A - >3000 ft B - 1000 - 3000 ft	Classifying	Candidate Site	I
Does this conflict with 9(b) — b) Depth to basalt surface	Include areas where depth to basalt <1000 ft	Limiting	Candidate Area Site Locality	0 and I
c) Bedrock dip will not have any data to apply this criteria except on folds which have already been determined by other means	Evaluate areas on basis of bedrock dip: A - 0^0 - 5^0 B - 5^0 - 10^0 C - >10^0	Classifying	Site Locality Candidate Site	0.
d) Presence of suitable stratigraphic characteristics ? should this be 100'	Include areas where basalt flows with desirable interval flow structure, density, porosity, extent, continuity, etc., are >1000 ft thick within the proposed repository depth zone	Limiting and Classifying	Site Locality Candidate Site	0 and I
e) Thickness of underlying basalt	Include areas where thickness of underlying basalt at the repository depth is >500 ft	Limiting	Site Locality Candidate Site	0 and I

1 1 2 3 1 0 2 4 3 7

B. Man-made Hazards

1. Aircraft Impact	a) Distance from airports	a) 5 mi from airports shown on state airport plans, accommodating aircraft $\geq$12,500 lbs g.w., or any military airport	Limiting	Candidate Area	0
		b) For airports with >12,500 operations, but less than 50,000, d miles from airport, $d = \sqrt{.002\ (\text{operations})}$		Sub-area	0
		c) For airports with 50,000 to 100,000 operations, 10 miles from airport. For airports with >100,000 operations, d miles from airport, $d = \sqrt{.001\ (\text{operations})}$		Sub-area Site Locality	0
	b) Location with respect to commercial jet routes and military training	Evaluate areas with respect to proximity to high-frequency routes	Classifying	Sub-area	0
2. Hazardous Facilities	a) Location with respect to hazardous facilities	Include areas away from facilities occupying 18,000 acres or more	Limiting	Candidate Area	0
	b) Distance from possible missile generators	Include areas greater than 1 mile from facilities with potential explosion, fire, missile hazards	Limiting	Sub-area	0

are nuclear power plants considered hazardous?

1 1 2 3 5 1 . 4 3 3

200 areas

	c) Distance from possible vapor sources	Include areas greater than 1 mile from potential sources of noxious or flammable vapors	Limiting	Site Locality	0
3. Transportation	Distance from transportation corridors	Include areas greater than 1/2 mile from U.S. highways, 1 mile from interstate highways, railroads and navigable waterways	Limiting	Site Locality	0
4. Induced Seismicity	Location with respect to sources of induced seismicity and potential future earthquake sources	a) Include areas >5 mi from existing reservoirs >100 ft deep	Limiting	Sub-area	0 and I
		b) Evaluate areas on basis of proximity to future reservoirs and interpreted sources of induced seismicity A - >5 miles B - 0 to 5 miles	Classifying	Site Locality Candidate Site	0 and I
5. Subsurface Mineral Exploration and Extraction	Location with respect to existing and potential future mineral exploration and extraction	a) Include areas away from existing subsurface mineral exploration or extraction	Limiting	Site Locality	0 and I
		b) Evaluate areas on basis of proximity to potential future mineral exploration or extraction	Classifying	Candidate Site	I

Takes out 100 areas
Pasco Basin unless i-
some hard evidence there
produced that shows potential for
is no economic potential for
minerals within or under
basalts - within interbeds - those looking
for uranium in interbeds -
below - those looking
oil and gas.

112.3310439

C. Repository Induced Events

1. Thermomechanical Effects	Thickness of host rock flow and general rock characteristics	Evaluate flow thicknesses and characteristics of potential host rock	Classifying	Candidate Site	0 and I
2. Operational Radiation Release	Distance from population	Include areas >3 mi from populations (>2500) — might afford to be more conservative and use ... of incorporated community.	Limiting	Candidate Area	0

OBJECTIVE: MINIMIZE ADVERSE ENVIRONMENTAL IMPACTS

1. Protected Ecological Areas	Location with respect to protected ecological areas — How is the NLE project to be treated?	Include areas outside of designated protected ecological areas of:			
		>18,000 acres	Limiting	Candidate Area	0
		5-18,000 acres	Limiting	Sub-area	0
		<5,000 acres	Limiting	Candidate Site	0
2. Culturally Important Areas	a) Location with respect to designated scenic areas	Include areas greater than a calculated distance based on height of spoil	Limiting	Candidate Area/ Sub-area	0
Indian Reservations, Parks, Monuments, Wilderness, Primitive Areas, Roadless Area of NF, BLM Roadless, Recreation Area, ONL, ONA, Archeological Sites (acronym list.)	b) Location with respect to all designated areas	Include areas outside of designated culturally important areas of:			
		>18,000 acres	Limiting	Candidate Area	0
		5-18,000 acres	Limiting	Sub-area	0
		<5,000 acres	Limiting	Candidate Site	0

1 1 2 ' . 3 ' ? ? ' 4 ?

How about man?

ALE - again

3. Rare and Endangered	Location with respect to rare and endangered species	Include areas outside of known locations of rare and endangered species	Limiting	Candidate Site	0
4. Biologically Important Areas	Location with respect to biologically important areas	Evaluate areas based on proximity to biologically important areas	Classifying	Site Locality	0
5. Existing Significant, Specialty, or Incompatible Land Uses	Location with respect to significant, specialty or incompatible land uses	Include areas outside of mapped extent of specialty agriculture, irrigated agriculture, incompatible facilities, or other land uses which are locally limited and regionally significant	Limiting	Site Locality	0
6. Potential Significant or Incompatible Land Uses	Location with respect to potential future significant or incompatible land uses	Evaluate areas with respect to potential future uses; the evaluation will focus on agriculture: Potentially Irrigable Lands Arable Soils Marginal Soils Sub-Marginal Soils	Classifying	Candidate Zone Candidate Sub-area	I

<u>OBJECTIVE</u>: MINIMIZE SYSTEM COSTS

1. Site Preparation (Surface)	Terrain ruggedness	Subjective evaluation for terrain characteristics (ie, topography, slope, relief, and degree of dissection)	Limiting	Sub-area	0

	Usable land area	Evaluate available land area for dominant site preparation costs, slope, local relief, degree of dissection, size of area, location and juxtaposition of relatively level areas, water supply, access, and amount of excavation and fill necessary to fit 1700 acres of surface facilities	Classifying	Candidate Zone, Site Locality, and Candidate Site	0
2. Site Preparation (Subsurface)	Mining and excavation costs	Evaluate areas on basis of thickness of overburden, depth of shafts, host rock characteristics, configuration and length of tunnels (spoil etc.), excavated volume, etc.	Classifying	Candidate Site	0

TABLE III-3

RANKING CRITERIA

OBJECTIVE: MAXIMIZE PUBLIC HEALTH AND SAFETY

Consideration	Attribute
1. Potential Radiation Exposure	Site population factor
2. Groundwater Contamination (tentative)	Distance in miles to source of discharge area

OBJECTIVE: MINIMIZE ADVERSE ENVIRONMENTAL IMPACTS

Consideration	Attribute
1. Ecological Impacts at a Site	Subjective scale
2. Air Quality (tentative)	Calculated non-radioactive pollutant concentration mg/m^3
3. Effects on Aquatic Species (Cooling Tower)	Number of individuals affected, annual escapement of stream
4. Socioeconomic Effects of Construction	Subjective scale

OBJECTIVE: MINIMIZE SYSTEM COSTS

Consideration	Attribute
1. Site Acquisition, Design, Development, Construction, Operating, and Closure Costs	Differential site costs (in dollars)

X

studies, a test application was made on maps of the study area. The criteria presented in Table III-2 incorporate all revisions accepted to date. The ranking attributes presented in Table III-3 will be reviewed following the identification of candidate sites. Each of the criteria appearing in Table III-2 are discussed in greater detail in Appendix A.

4. APPLICATION OF CRITERIA

This section describes the application of criteria presented in Tables III-2 and III-3. Examples of a screening criterion and a ranking attribute are presented.

Most of the data used in screening will be mapped. In general, this involves preparation of a base map, preparation or collection of source data maps, interpretaion of these source data according to the criteria and preparation of an interpretive overlay to the base map, and superimposition of interpretive maps to yield a composite overlay. The composite overlay is a graphic display of all areas interpreted to meet criteria related to a set of considerations studied in a single step of screening. Each step in screening corresponds to a change in map scale or a change in the evaluation technique as the study focuses on smaller and smaller areas with progressively higher likelihoods of containing candidate sites. At the end of each step of screening, the result is mapped. In steps where limiting criteria are applied, the criteria are mapped and then evaluated in a tabular or matrix format and the result (a classification of areas) is mapped. The steps in screening are:

- Identification of candidate areas;
- Identification of subareas;
- Identification of site localities;
- Identification of candidate sites.

For each of the criteria shown in Table III-2, the step in screening at which the criterion will be applied is shown. All ranking criteria (Table III-3) are applied following the identification of candidate sites. Table III-4 contains definitions of the area designations used in screening.

To illustrate the manner in which criteria are applied in the site identification study, two examples have been prepared. The first example describes the consideration of volcanic effects as an impact to screening. The second example describes the consideration of population exposure to radiation as an input to ranking.

<u>Example 1</u> - Screening Criteria. The consideration of volcanic effects has been selected to illustrate the screening process of the siting study. It is a useful illustration because it involves the application of both limiting and classifying criteria at several levels during the progress of the study. A discussion of the consideration of volcanic effects and the

may want to use the Pub 66 Spring volcanic criteria as a model.

TABLE III-4

AREA DESIGNATIONS USED IN SCREENING

Study Area: The area covered by this repository site identification study. The total study area (CORBEH) covers approximately 50,000 square miles, including portions of the states of Washington, Oregon, and Idaho. The Hanford study area is approximately 600 square miles.

Candidate Area: Portions of the study area that have a higher potential of containing suitable sites for a waste repository than the rest of the study area. (Typically, a candidate area covers several hundred square miles and is derived by the application of limiting criteria.)

Subarea: Portions of candidate areas that have a higher potential of containing sites than other portions. The subarea is typically defined on a larger scale map than that used to identify candidate areas and is derived by the application of limiting criteria. Subareas represent refinements of candidate areas and are still measured in hundreds of square miles. Following subarea identification, several interim classification steps are pursued. These involve subdivision of the subarea into smaller areas (called zones) and may include evaluation and preferential selection of a number of zones (these would be called candidate zones.)

Site Locality: Portions of subareas or candidate zones that have a higher potential of containing suitable sites for a waste repository than the rest of the subarea or candidate zone. (Typically, a site locality covers an area of 6 to 20 square miles.) The site locality is intended to be a potential location where a repository facility might be located but requires field observation and more detailed study before a site center and approximate site boundary can be established.

Candidate Site: A specific location within a site locality considered to be suitable for locating a repository. Not all site localities will contain candidate sites; this determination is made on field visits to site localities. (Typically, a candidate site covers an area of 3,000 to 10,000 acres.)

development of the criteria which describe it are presented in Appendix A. Table III-2 summarizes the criteria.

The consideration of volcanic effects is utilized at three significant levels in the siting study, and criteria are applied to obtain: candidate areas, site localities, and candidate sites. Prior to the application of the criteria, however, an evaluation is made of Quaternary volcanic sources, with the result that the volcanism in and near the study area is of two general types: basaltic and andesitic.

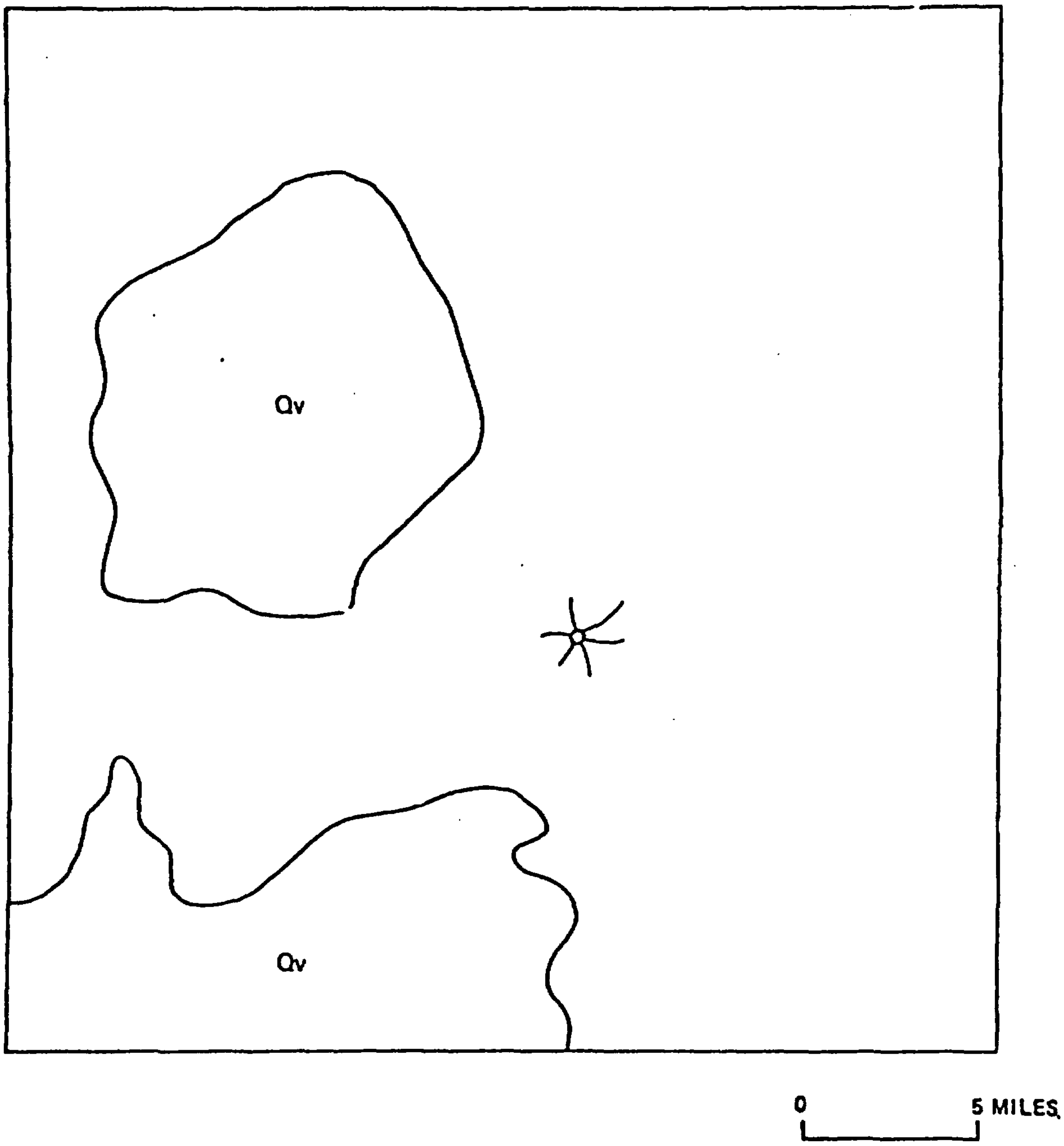
The eruptive characteristics of these two types of volcanism are quite different. Basaltic volcanism is characterized by shield volcanoes, such as Newberry Crater in Oregon, and by small isolated flows and cinder cones, such as those near Goldendale, Washington. Eruptions from this type of volcano are generally less violent, and explosive activity is generally confined to lava fountains. The primary volcanic effect from an eruption of this type is lava flow. The lava may be fluid and may cover large areas.

Andesitic volcanism is characterized by the high stratovolcanoes of the Cascade Range, such as Mt. Rainier and Mt. St. Helens. Eruptions from this type of volcano can be violent. The effects of eruptions from this type of volcano include:

- Eruption of large volumes of viscous lava and pyroclastic material;
- Explosions and eruptions which deposit a blanket of ash over a very large area;
- Mud flows and debris avalanches that are confined to the valleys which originate on the large stratovolcanoes;
- Volcanic earthquakes;
- Air blast and base surge.

An examination and evaluation of the geologic literature suggests that, except for widespread ashfall, most of the effects of andesitic volcanism occur within 12 miles of the stratovolcano. Since the Cascade stratovolcanoes lie beyond 12 miles from the study area, only ashfall is considered in this siting study.

Using this information, the first application of the criteria is made. This involves the use of the limiting criterion, which includes, for further study, areas greater than 5 miles from a Quaternary volcanic center or lava flow. To accomplish this, all Quaternary volcanic deposits within the study area are identified on an overlay of the 1:500,000 base map of the CORBEH study area. (There are no Quaternary volcanic deposits in the Hanford area.) This overlay becomes the data map depicting Quaternary volcanic deposits (Figure III-2). The data map is then



Qv — Quaternary volcanic deposit

— Quaternary volcanic center (cinder cone)

FIGURE III – 2

SCHEMATIC DRAWING OF DATA MAP FOR VOLCANIC EFFECTS overlaid again, and lines are drawn representing the limiting criteria setback of 5 miles from Quaternary volcanic sources and flows. The resulting map is the screening overlay for volcanic effects applied in the first step of screening (Figure III-3). When this map is overlaid with the other screening maps used in step one, the resulting areas outside of the composite overlays are designated candidate areas.

Following the application of limiting criteria (such as for volcanic effects) to obtain candidate areas, other limiting criteria and evaluations are utilized to successively reduce the study area so that either subareas and/or candidate zones remain. The next use of the consideration of volcanic effects involves the application of two classification criteria to the evaluation of subareas/candidate zones to obtain site localities.

Using detailed geologic information available for the subareas/candidate zones, Quaternary volcanic deposits, if any, are again identified. This includes identifying potential sources of volcanic effects which lie outside the subareas/candidate zones but which may still have affects within. Quaternary andesitic stratovolcanoes within 100 miles of any subarea/candidate zone are also identified. Prevailing wind direction?

Using this information, each subarea/candidate zone is evaluated and classified as to its exposure to Quaternary volcanic effects and distance from a potential source of ash fall; i.e., distance from a Quaternary stratovolcano (refer to Table III-2 for the classification criteria). For example, part of a subarea/candidate zone may straddle a drainage coming from a Quaternary volcanic center which lies greater than 5 miles away. The evaluation may suggest that the drainage should be classified C--volcanic effects may approach near the area. The slopes above the drainage might be classified B--area near volcanic center but no expected effects. Finally, the nearest major potential source of ash fall might lie 85 miles away; thus, the subarea/zone would be classified B for ash fall. An example of the application of these criteria to a subarea/candidate zone is illustrated in Figure III-4.

After the classifications are applied, the results are combined with the results of the application of other classifying as well as limiting criteria. The areas remaining following the application of all limiting criteria are evaluated, and site localities are preferentially identified in areas of the subarea/candidate zones which have the most favorable characteristics. For example, using only the consideration of volcanic effects, site localities may be identified as shown on Figure III-4 because these areas offer the most favorable characteristics in the subarea/candidate zone regarding potential volcanic hazards.

The final application of the consideration of volcanic effects involves the subjective evaluation of the site localities regarding their exposure to volcanic effects. In this step, candidate sites are identified through the comparison of the site localities and their respective relative

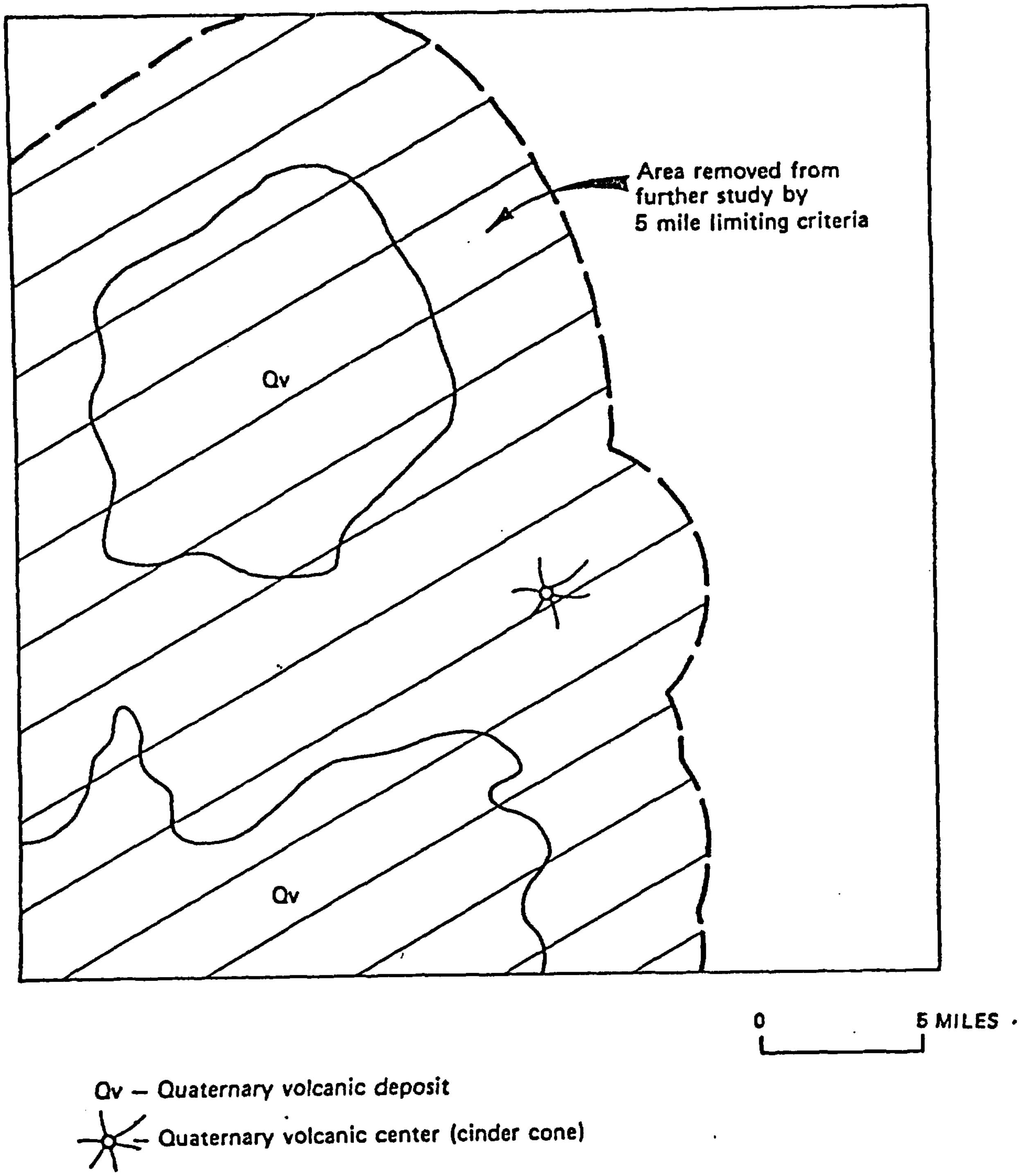


FIGURE III – 3

SCHEMATIC DRAWING OF APPLICATION OF LIMITING CRITERIA FOR VOLCANIC EFFECTS

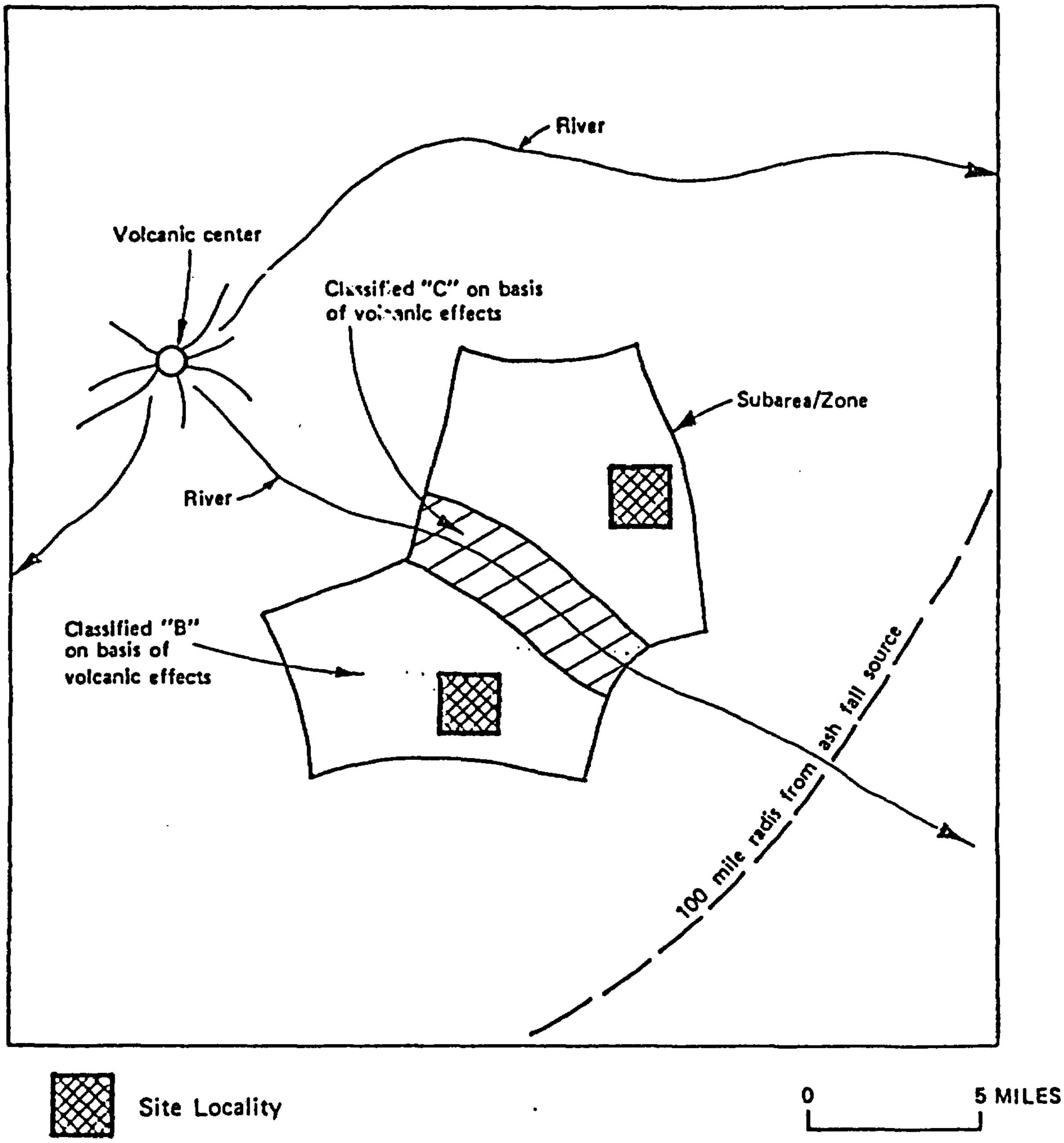


FIGURE III – 4

SCHEMATIC DRAWING OF THE APPLICATION OF CLASSIFYING CRITERIA FOR VOLCANIC EFFECTS exposure to volcanic effects. One site locality that is higher above a drainage, coming from a Quaternary volcano, than another site locality and is also further away from an ash fall source might be identified as a candidate site and recommended for ranking.

Example 2 - Ranking Attribute. One of the measures to be used to compare and rank candidate sites is concerned with potential radiation exposure to populations residing in the site vicinity. Routine or accidental releases of radioactivity from a repository may lead to two types of public exposure: direct exposure and exposure through pathways. Ideally one would use radiation exposure in man-rems/year under routine or accident scenarios as an attribute of this consideration. However, it is extremely difficult to estimate probabilities, magnitudes, and directions of radiation release at each of the candidate sites. The NRC recognized this difficulty and proposed the site population factor (SPF) as a reasonable proxy variable for use in selecting a site for nuclear power plants (Kohler et al, 1974; AEC, 1974). The use of a site population factor in site selection for the repository also appears to be appropriate.

I could not find reference where this has been accepted in site hearings
- [illegible]
- [illegible]
- [illegible]
- [illegible]?

The SPF is a numerical index that considers both the number of people and their proximity to a candidate site and is used as a proxy variable to represent potential radiation exposure to man. The SPF is defined by the formula:

$$SPF = \frac{\sum_{r_j} r_j^{-1.5} P_j}{\sum_{r_j} r_j^{-1.5} Q_j}$$

r_j = distance in miles from site
P_j = population between r_{j-1} and r_j
Q_j = population between r_{j-1} and r_j for a uniform population of 1,000 per square mile

Examination of the formula reveals that the SPF is a weighted average considering both population and distance from the site. The distance from the site, r_j, enters as an exponential decay with power -1.5. Therefore, a given number of people living near the site are assigned a higher weight than if the same population were located a greater distance from the site. This decay function is based on average diffusion of gaseous radioactive emissions from plants licensed by the NRC. The numerator of equation represents the sum of the actual population living in the site locale, weighted by their distance from the site. The denominator is a normalizing constant calculated assuming an evenly distributed population of 1,000 per square mile for all distances from the site. Thus, an SPF = 0.2 represents a site that is equivalent to a hypothetical situation with an evenly distributed population of 200 per square mile. This population density roughly corresponds to an area characterized by 10-acre farms.

1 mi² = 640 ac
640/200 = 3.2
640/100 = 6.4

The SPF factor for each site will be determined considering a maximum distance of 50 miles from a site (the NRC convention) and using distances of r_j = 1, 2, 3, 4, 5, 7, 10, 15, 20, 30, 40 and 50 miles. These distances define the radii of circles, and the population located between each is determined using 1970 U.S. Census data, more current estimates, available projections, and linear or exponential extrapolations to the 60th year of repository operation.

3.2 acres/person
× 4.2 persons
≈ 13.5

For each candidate site, the concentric annuli are plotted with the site at the center in the fashion of a "bullseye". For distances from 5 to 50 miles, the population estimate is computed by summing the populations of towns and cities lying within each annulus (if a town or city lies on the boundary of two annuli, the entire population of the town is counted in the annulus closest to the site). The population of unincorporated areas is assumed to be clustered about the incorporated places in direct proportion to size of the incorporated place; thus a fraction of the unincorporated area population is added to the population of each incorporated place. For annuli between 0 and 5 miles of a site, the residential structures are counted directly from maps, aerial photographs, and field observations. The pertinent county population per household is used as a multiplier to estimate the number of persons residing in structures. This estimation technique is more likely to overestimate than underestimate the actual population living near a site. This manual approach to estimation is used instead of commercially available computer-based techniques (these services access U.S. Census tapes and interpret them through a geographic grid) because experience has shown the computer estimates to be wholly unreliable in the sparsely populated rural areas characteristically surrounding candidate sites for nuclear facilities.

The total populations estimated by? to reside in each annulus are then projected to the 60th year and input to a computer program that computes the SPF. Transient populations are not considered by this index. If a significant basis for differentiating between candidate sites in terms of transient population can be established, the SPF function can be adjusted or a separate population factor can be developed. The numerical value of the SPF is used directly as an input to ranking.

Further steps of the ranking process are described briefly below. A detailed discussion for each attribute will be presented in ~~Volume~~ VI. Task VI? separate? The consequences of choosing a site are composed of various impacts, each represented by a specific measure; for example, the SPF for public exposure ~~to the public~~.

Each impact has an associated uncertainty which is site-dependent. Therefore, a relationship between probability and the levels of a specific measure are developed for each site. The levels of impact and their

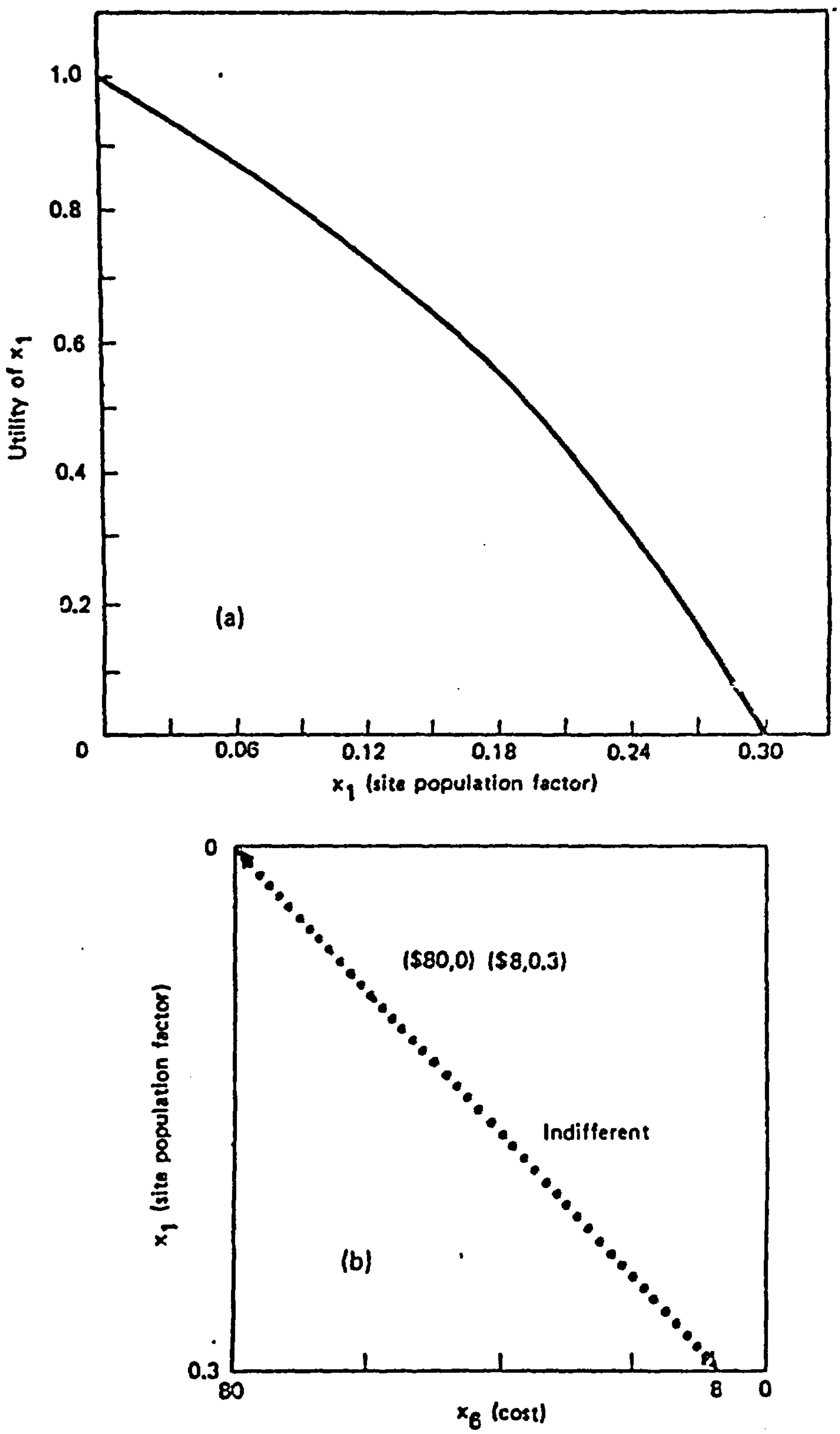
very important question!

associated probabilities are assessed on the basis of existing or new data and the specialized knowledge of scientists, engineers, and economists.

The next step consists of establishing the preference structure. Persons and groups involved in the site identification prefer some consequences over others. These preferences are measured using concepts of utility theory. *need reference at footnote* A utility function is developed by assigning a numerical value on an arbitrary scale (e.g., 0 to 1) to every level of an impact. In general, this value is not directly proportional to the magnitude of the impact. *As* ~~For~~ example, Figure III-5(a) shows the relationship between the site population factor and the associated utility function.

Since selecting a site has multiple impacts, a multiattribute utility function which combines the utility functions of individual impacts is ~~developed~~ *utilized*. The multiattribute utility function accounts for the relative importance of the individual functions. This relative importance ~~was~~ *is* measured by a series of trade-off constants determined by assessing from *a* ~~the~~ decision-maker how much of one impact he would be willing to trade for another within the range of the ~~possible~~ *probable* impacts. Figure III-5(b) shows a typical *trade-off* relationship between site population factor and system cost.

Finally, for each site the probability associated with various consequences is determined using the probabilities estimated as described above. The utility of the consequences is determined using the individual utility functions and the computed trade-off constants. The expected utility is evaluated by multiplying the probability of the consequence by its utility. The sites are then ranked in order of the *relative* magnitude of expected utility *for that (a) decision maker*.



might want to show utility curve for cost and also say some words about differential cost within total cost.

FIGURE III – 5

EXAMPLE OF (a) UTILITY FUNCTION AND
(b) EVALUATION AND TRADEOFFS FOR RANKING

IV. FRAMEWORK FOR SENSITIVITY ANALYSIS

1. GENERAL

The ~~objective~~ purpose of this section is to present results of a preliminary examination of the sensitivity of the results of the site identification process to various parameters. The site identification process described in Section III of this report is a step-by-step process which utilizes information derived from analytical and judgmental evaluations. These evaluations are based, in turn, on a number of parameters established either on the basis of available data, regulatory stipulations, or by professional judgment. Obviously the results of the site identification process can be influenced by changes in either the numerical values of the parameters used and/or in the relationships utilized in the evaluations. A sensitivity analysis enhances the utility of the site identification process because it provides useful insights into the relative influence of various parameters and enables one to identify the dominant parameters which could influence the results of the process in a significant manner. The results of a sensitivity analysis can then be utilized for identifying geographic areas where additional work may be necessary or for identifying need for acquisition of additional data or for refining the assumptions.

The site identification process is basically accomplished in three phases: (1) identifying baseline conditions (Section II), (2) establishing and applying screening criteria to identify a number (say, 10 to 20) of candidate sites, and (3) establishing and applying ranking criteria to preferentially order the candidate sites. The criteria ~~are~~ have been defined based on the regulatory framework and available data. When additional data are acquired, a review of the criteria and results may become appropriate.

The discussion below attempts to address parameters that may influence the results of each one of these phases. Figure IV-1 is a flow diagram showing the topics to which a sensitivity analysis may be applied.

2. SCOPE

The scope of the sensitivity analyses ~~may be~~ is defined as follows:

1) To evaluate the effect of change in baseline conditions;

2) To evaluate the effect of change in the regulatory framework;

3) To evaluate the effect of change in the screening criteria on the results of the screening process;

4) To evaluate the effect of change in the ranking criteria on the results of the ranking process;

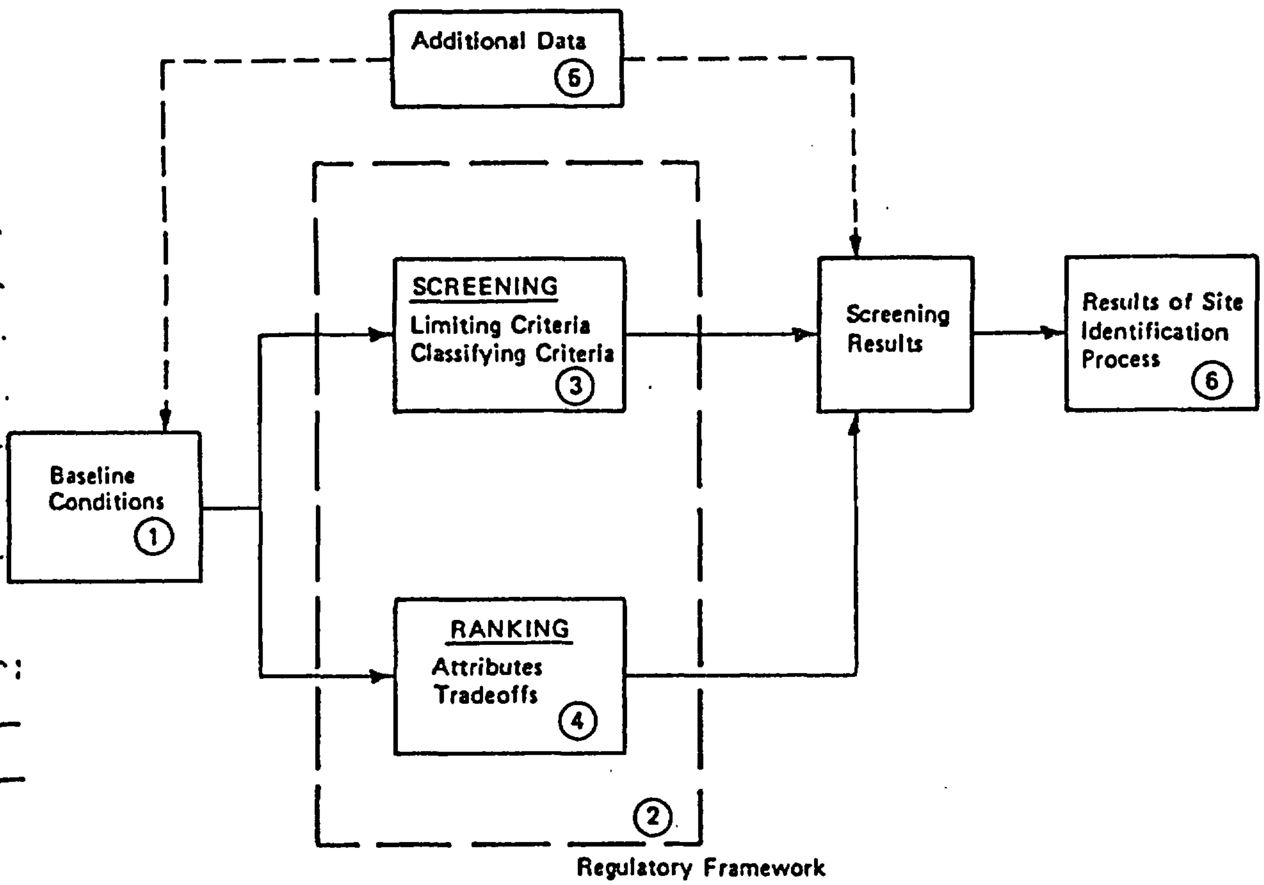


FIGURE IV – 1

SCOPE OF SENSITIVITY ANALYSIS

5) To evaluate the effect of acquisition of additional data on items 1, 3, and 4 above;

6) To identify dominant parameters that influence the results of a site identification process.

The numbers in various boxes in Figure IV-1 correspond to the numbers of the items listed above. The following discussion establishes a framework for the ~~sensitivity~~ analyses. Results ~~of~~ actual analyses will be presented in Volume V, Screening, and Volume VI, Ranking.

Task V? Task VI?

3. FRAMEWORK FOR ANALYSIS

3.1 Change in Baseline Characteristics

A set of baseline conditions was defined in Section II and summarized in Table II-1 of this report. These conditions include numerical values of parameters defining the location and geometry of the repository, description of the type and volume of waste, and a set of parameters that define the desired performance characteristics for the repository system. A variation in any of these parameters could influence the results of a site identification study. For example, a variation in the time frames for the operational and isolation phases ~~can~~ could affect the results of a number of steps in the screening and ranking processes. These changes are discussed in greater detail in Sections 3.3 and 3.4 below.

A change in the number of canisters expected to be emplaced within the repository, the rate of emplacement, and the period of aging before which the canisters arrive at the repository site would influence the calculation of the areas of underground tunnels, the volume of spoil piles, the amount of potential releases from the repository, and the thermal loads that the surrounding rock may be subjected to during the operational and isolation phases. For example, available information suggests that the number of canisters expected by the year 2015 is in the order of approximately 700,000 canisters. If a thermal load of 100 kilowatts per acre is assumed, then a 3200-acre repository would be able to accommodate approximately 320,000 canisters. If, therefore, the above number of canisters has to be accommodated, it would be necessary to enlarge the underground area of the repository or restrict the number of canisters. If a previously identified site does not have the enlarged area, it may become unsuitable. ?

Changes in the number of canisters or assumptions regarding the amount of releases would require an adjustment in the calculated doses and the population setback distances required for locating the repository.

Changes in repository host rock characteristics such as thermomechanical properties and groundwater permeability would change the expected thermal effects or the expected travel time of radionuclides due to groundwater transport, respectively. These calculated changes viewed in conjunction with the regulatory stipulations may result in a change in the suitability or rank order of sites.

3.2 Regulatory Framework

The numerical values of a number of screening criteria and ranking attributes are based on the minimum levels of safety and environmental effects specified by regulatory agencies such as the NRC and EPA. A change in the specified limits by regulatory agencies would automatically result in a change in the criteria. For example, the NRC has specified limits for the allowable population densities within different distances from a nuclear facility such as a nuclear power plant. If these limits are changed, or the projected population is relevant for certain areas the setback distances for various population centers from a proposed nuclear facility would change, thereby altering the sizes and boundaries of the candidate areas, subareas, zones, etc., identified in the screening process.

Similarly, the identification of capable faults that could influence a nuclear facility such as a nuclear plant is currently based upon the presence or lack of multiple movements on the fault for a period greater than 500,000 years. If this value is changed to another time period (e.g., to one million years, as suggested by the National Academy of Sciences, 1978), then the number and location of faults identified as being capable would change, resulting in a change in the boundaries of screening areas based on the criterion which states that a site should be located at distances greater than a selected value (e.g., 5 miles) from a capable fault.

Yet another example may consist of the acceptable probability of hazard to a surface nuclear facility due to aircraft impact. The present NRC regulations call for demonstrating that the probability of unacceptable radiation releases due to an accident resulting from aircraft impact be less than 10^{-7}. If this level of acceptable probability is changed, setback distances based on a number of aircraft operations would be altered.

Another aspect of the regulatory framework concerns the status of evolving regulations or laws whose applicability has not been clearly established. An example is a current Oregon law (see Section III, Volume I), which in effect "prohibits the storage of radioactive wastes in the state of Oregon". If the law is to be interpreted as a complete prohibition of the siting of a radioactive waste repository, areas in Oregon may not be included in the screening process.

- If you back off on this issue - it would be an open invitation to other states including Washington and Idaho to enact similar legislation - Dixy and Cecil Andrus aren't going to be around much longer. - Suggest - this be dropped - and don't worry about it unless the environmental statement shows there is an "obviously" superior site other than Hanford.

3.3 Effect of Change in the Screening Criteria

The screening process utilizes a number of limiting or classifying criteria. There criteria are established on the basis of existing ~~the~~ regulatory framework and the desired baseline conditions discussed in Sections 3.1 and 3.2 above. Any change in the baseline conditions or in the regulatory framework could ~~will~~ require a change in the limiting or classifying screening criteria. ~~A major~~ example of the change in baseline conditions is a change in the time frames corresponding to the operational and isolation phases. Most screening criteria, described in Appendix A and summarized in Table III-2, are based on an isolation phase of 10,000 years. If the isolation phase is changed or extended to 100,000 or one million years, some criteria may require revision. In Table III-2 the criterion related to tectonic movement states that areas of potential bedrock folding should not be included in the screening process. In general, the probability of the occurrence of differential tectonic movement and deformation along existing or new rupture zones increases as the time frame is increased by one or two orders of magnitude. In case of a typical nuclear facility, such as a nuclear power plant, for which a lifetime is in the order of approximately 30 to 40 years, the probability of deformation along a given fold may be small and, therefore, not significant. If the isolation time frame for a repository is assumed to be several hundred thousand years, as suggested by certain workers, ~~some~~ consideration ~~may have to~~ should be given to siting in areas of bedrock folds. Where the assumed isolation period is assumed to extend over 100,000 to one million years, it would appear desirable that siting on areas of such folds should be avoided.

A similar example may lie in the estimation of possible effects of erosion and denudation. Where erosion rates are uniform and small, such as 3 millimeters per year, a time frame lasting over a few hundred years may not be significant to a repository which is located at depths of approximately 2,000 feet. If the time frame is incresed to 10,000 years, the expected erosion may be in the order of 100 feet and the possible effects should be reviewed, although it may still not be significant to a repository emplaced at a depth of 2,000 feet. If the time frame is expanded to 100,000 years or greater, the expected erosion may exceed 1,000 feet, which is certainly a significant factor in evaluating the safety of the repository. Also, in case the isolation time frame goes beyond 100,000 years, it is likely that the environment under which erosion is occurring and the forces contributing to erosion may undergo substantial change requiring additional evaluations.

Changes in the time frames can also cause changes in the probability of man-made hazards such as drilling, construction of new reservoirs, and change in the land use patterns that could result in increased potential for induced seismicity or adverse changes in the groundwater conditions in the vicinity of the repository.

Changes in the classification criteria, particularly if the criteria are based on considerations of cost (e.g., the distance from waterways, the distance to sources of water or land access, or the land preparation costs as a percentage of the total cost) could change the relative preferences with respect to candidate sites and zones.

3.4 Effect of Change in the Ranking Attributes

The ranking process requires the identification of attributes pertaining to the fulfillment of the objectives. For each ranking attribute, analyses are carried out to estimate the probability of occurrence of various levels of impacts, and utility functions are established to assess the value of the impacts and tradeoffs between various values of attributes based on the preferences of the decision-makers. Changes in the estimated probabilities, estimated levels of impact, and tradeoffs between different attributes can influence the results of the ranking process; that is, the rank order of candidate sites. For example, the estimation of the adverse socioeconomic impact during the operation and early isolation phase may require estimation of ~~the~~ land use patterns, the number of people inhabiting the affected areas, and the negative value of the impacts generated by the repository in the isolation phase. These evaluations will require assumptions regarding the number of people, the type of land use, and the value of impacts. Variation in the values selected for analyses ~~would~~ could result in a change in the calculated value of the impact. In the case of ~~the~~ evaluation ~~of~~ tradeoffs, a typical assessment may require the evaluation of the number of dollars ~~the~~ a decision-maker is willing to spend in additional system cost to mitigate a particular impact, such as the preemption of a desirable land use or the preservation of the habitat of a rare and endangered species.

3.5 Influence of Additional Data

A site identification study is a dynamic process. It is based on a number of parameters and is generally carried out utilizing available data. One of the desirable features of a site identification process is the flexibility to accommodate and accept additional information. It is anticipated that additional information will become available both during the course of this study and after it. This additional information may ~~primarily~~ consist of data on the geologic, tectonic, and groundwater conditions or on the socioeconomic conditions within the study areas. Use of the additional information could lead to a modification in the boundaries of areas established in various steps of the site identification process, such as candidate areas, subareas, zones, and candidate sites.

3.6 Implementation of Sensitivity Analysis

As described above, sensitivity analyses will be carried out for appropriate ranges of selected parameters utilized in various steps of the site identification process. The results and a discussion ~~of the~~ significance of the sensitivity ~~analyses~~ would be presented in ~~Volume~~ V for the screening process and Volume VI ~~for~~ the ranking process. Task (V)? Task (VI).

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APPENDIX A
CRITERIA AND RATIONALE

A.1 INTRODUCTION

This appendix presents a detailed discussion of the various considerations and siting criteria to be used in the repository siting study and the rationale utilized to select each criterion. The criteria and the considerations from which they were derived are organized under the objectives of: maximize public health and safety, minimize environmental impacts and minimize system costs. The anticipated approach for the use of each criterion is discussed as well as its relevance to the siting of a nuclear waste repository. A summary of the siting criteria is presented in Table III-2.

A.2 PUBLIC HEALTH AND SAFETY

The considerations and criteria developed to meet the objective of maximizing public health and safety deal with hazards, effects or events which fall into three general categories: natural hazards, man-made hazards or events and repository induced events.

A.2.1 Natural Hazards

A.2.1.1 Fault Rupture

The potential for fault rupture is studied to describe the locations, orientations, and lengths of capable faults, faults of potential capability, faults of unknown capability and noncapable faults in the study area. This serves to determine areas of high potential for fault rupture, which are relatively less desirable for nuclear waste repository.

Relevance to Siting. Active fault movement through the subsurface repository and/or through surface ~~repository~~ facilities may affect the safety of a potential site. In addition, because licensing will be under the authority of the U.S. Nuclear Regulatory Commission (NRC) and will most likely ~~be similar~~ if not more stringent than for nuclear power plants, ~~then capable~~ faults will need to be evaluated. The present NRC position on capable faults for nuclear power plants states (Appendix A to 10 CFR Part 100): (1) sites that include capable faults are not suitable for nuclear power stations, and (2) sites within approximately 5 miles of a surface capable fault (greater than 1000 feet in length) are generally not suitable for a nuclear power station.

In addition to capable faulting, potential repositories located on or near noncapable faults or fractured zones may be relatively less desirable because of the potential for increased pathways to the biosphere and poorer bedrock foundation conditions.

Measure. Two sets of measures are derived to describe the fault rupture consideration. The first set is for capable faulting where the horizontal as well as vertical distance from capable faults and faults interpreted to be potentially capable is important. The second set considers the distance from noncapable faults and/or distance from intense fracturing/jointing.

Criteria. Two sets of limiting criteria, and one classifying criteria corresponding to the three sets of measures, are used. The criteria applicable to capable faults, faults of potential capability, and faults of unknown capabilities are:

- Include areas to within 5 miles (8km) (horizontally and vertically) of capable faults and logical projections of capable faults;
- Include areas to within 5 miles (vertically and horizontally) of faults interpreted to be potentially capable or of unknown capability and to within 5 miles of logical projections of these faults.

The criteria applicable to noncapable faults and fractures are:

- Include areas to within one-half mile of faults interpreted to be noncapable and to within one-half mile of zones of intense fracturing or jointing.

Rationale. The potential for fault rupture is considered in the NRC review process for nuclear power plants. In this review, capable faults or faults interpreted to be capable that are greater than 1000 feet in length and are located within 5 miles of the power plant must have detailed studies to determine the possibility for fault rupture. These studies are conducted within an area called the "zone requiring detailed faulting investigations". Nuclear power plants may not be located within such a zone unless detailed studies demonstrate that the need to design for the effects of surface faulting has been properly determined.

Because a nuclear waste repository will likely be subject to similar or more stringent site suitability criteria for fault rupture, the 5-mile setback from capable and potentially capable faults ~~was~~ is considered to reasonably satisfy the present and future NRC regulatory position concerning fault rupture. In addition, if a fault cannot reasonably be proven to be noncapable, it ~~must~~ should be considered capable. Due to the difficulty of proving capability and resultant licensing delays, faults of unknown capability are subjected to the same criteria as capable faults.

Siting to within one-half mile of noncapable faults and fractures is based primarily upon the desire to avoid siting on any fault that may provide pathways to the biosphere.

Approach. The capable fault criteria are applied at all steps in the screening process because of the importance to siting of these criteria. The areas limited in each step by these criteria are based on the level of detail of the data for each step in the screening process. Thus the criteria are reapplied at each step as the level and detail of the data increases. The noncapable fault criteria are applied to obtain candidate site localities.

The approach ~~used in applying these fault rupture criteria is~~ described: All mapped faults are identified and subjected to the limiting criteria. Areas delineated on the basis of the limiting criteria are plotted on overlay maps for the particular screening step and removed from further consideration.

All mapped faults are classified into three groups:

- Capable faults or faults interpreted as capable according to the definition ~~of a capable fault~~ in 10 CFR 100, Appendix A;
- Noncapable faults or faults interpreted as noncapable based on local stratigraphy and the tectonic history of the area;
- Faults for which the capability could not be determined from the presently available ~~maps and literature.~~

Geologic maps of particular areas under study and literature on the geologic structure, tectonics, seismicity, and geologic history of the zones are used to identify capable faults and faults interpreted as being capable. If a particular fault is shown to displace sediments younger than 500,000 years, has historic seismicity associated with it, or can be shown to be structurally associated with a capable fault, it is classified as capable.

Noncapable faults or faults interpreted as being noncapable are identified from evidence indicating that undeformed sediments 500,000 years old or less ovelie the fault.

Faults are identified as of unknown capability when there is no definite geologic evidence to determine whether movement on the fault is older or younger than 500,000 years. The majority of the faults classified are of unknown capability.

Following identification and classification of the faults and/or fractures, the limiting criteria are applied and the areas meeting the criteria are included for further study.

Definition of Terms. "Capable fault": capable fault as defined by the NRC (10 CFR 100) is a tectonic fault which has exhibited one or more of the following characteristics:

1) Movement at or near the ground surface at least once within the past 35,000 years or movement of a recurring nature within the past 500,000 years;

2) Macro-seismicity instrumentally determined with records of sufficient precision to demonstrate a direct relationship with the fault;

3) A structural relationship to a capable fault according to characteristics (1) or (2) of this paragraph such that movement on one could be reasonably expected to be accompanied by movement on the other.

In some cases, the geologic evidence of past activity at or near the ground surface along a particular fault may be obscured at a particular site. This might occur, for example, at a site having a deep overburden. For these cases, evidence may exist elsewhere along the fault from which an evaluation of its characteristics in the vicinity of the site can be reasonably based. Such evidence shall be used in determining whether the fault is a capable fault within this definition.

Notwithstanding the foregoing paragraphs (1), (2), and (3), structural association of a fault with geologic structural features which are geologically old (at least pre-Quaternary), such as many of those found in the eastern region of the United States, shall, in the absence of conflicting evidence, demonstrate that the fault is not a capable fault within this definition.

A.2.1.2 Generation of New Faults

Because of the long time frame proposed for the repository isolation period (10,000 years), the potential generation of new faults is studied to delineate areas having a lower potential of new fault rupture. These areas thus have a higher likelihood of containing suitable nuclear waste repository sites.

Relevance to Siting. The relevance to siting of the generation of new faults is the same as for fault rupture (Section A.2.1.1). This consideration becomes more important during the isolation period because fault rupture during the operational period is most likely to occur on existing faults.

Measure. The measure selected to represent the generation of new faults is location with respect to future potentially capable tectonic structures. How does this differ from unknown capability?

Criterion. Locations within the study interpreted as having a potential for the generation of new faults are areas within 5 miles of anticlines interpreted as being capable of forming new faults. This criterion is applied to obtain candidate site localities and to obtain and preferentially select candidate sites.

Rationale. Based on a review of geologic, structural geologic and tectonic data for the Columbia Plateau area, the major faulting appears to be associated with and concentrated near the axes of bedrock folds, particularly anticlines. Any future new faulting is also likely to occur along or near anticlinal axes. The 5-mile setback is based on the NRC regulatory position concerning capable faults (see Section A.2.1.1).

Why not preclude also — what basis is there to assume that anticlines don't have faults.

Approach. The approach used in applying this criterion consists of identifying and locating anticlinal folds in the study area and defining those interpreted to be capable of forming new faults. This process is done at two screening steps: to obtain candidate areas and also to obtain candidate site localities. Each step uses data at significantly different levels of detail.

To obtain candidate areas, regional scale data are used to identify and locate anticlines within the study area. The anticlines are examined and evaluated on the basis of the age of deformation, degree and intensity of deformation, rate of movement and regional and local tectonic framework. Based on this evaluation, the anticlines believed to be capable of generating new faults are identified, and areas greater than 5 miles from the axes of the folds are included for further study. The same process is used to obtain candidate site localities; however, the data used are more detailed.

Definition of Terms. "Anticline": a fold, the core of which contains the stratigraphically older rocks; it is convex upward.

"Capable fault": (See Section A.2.1.1).

A.2.1.3 Ground Motion

Ground motion is studied in order to describe the potential for seismic ground shaking ~~at the surface~~ in the study area. Although there will be facilities underground as well as on the surface, results of a preliminary literature review indicate that vibratory ground motion at depth in a rock environment would be less than at the surface. The location of historical seismicity as well as the level of potential ground motion is used to define a relative level of potential hazard to the surface facilities and

more references would be desirable to preclude questions later.

below ground repository galleries and tunnels. In this manner, the relative desirability of an area for repository siting is defined.

Relevance to Siting. The response of the site to potential ground motion, over the operational lifetime of the facility, can affect both the safety and design costs of surface and subsurface facilities. Additionally, a requirement of baseline seismic monitoring can cause delays in licensing.

Measure. The estimated level of ground motion (horizontal acceleration) and the location of a site away from close proximity to historical earthquake activity were the measures used in applying the criteria for the consideration of ground motion. The estimates of horizontal acceleration are based on identifying potentially capable faults and applying applicable empirical relationships between length of fault rupture, earthquake magnitude, and horizontal base rock acceleration.

Criteria. Three criteria define the consideration of ground motion. The first is a limiting criterion where portions of the study area considered to have a high likelihood of experiencing moderate to low horizontal accelerations (<0.40 g) are included for further study. This criterion is used to obtain candidate areas. The remaining two criteria are classifying criteria dealing with proximity to historic macro- and microearthquake activity. One evaluates areas based on proximity to concentrations of earthquake epicenters located from instrumental data and felt reports. The other evaluates areas based on proximity to microearthquake epicenters. Both classifying criteria are used to preferentially identify and evaluate areas to obtain candidate site localities and candidate sites.

Rationale. A potential horizontal acceleration of moderate to low severity (0.40 g or less) is considered to be an acceptable characteristic for above-ground and below-ground facilities of a waste repository. Major manufacturers of Nuclear Steam Supply System (NSSS) components for nuclear power plants generally design for acceleration of 0.25 g as a minimum, and designs for higher accelerations up to .75 have been completed ~~are possible~~. Potential accelerations of up to 0.40 g would, probably not require significant additional expenditures for either seismic design or cause ~~require~~ delays related to additional seismic investigations; however, designs in excess of 0.40 g are significantly more expensive and may cause licensing delays. (except in the case of Hanford where .25 g has been accepted and if WCC comes up with anything more - we all have problem)

It is not desirable, in the siting of the repository and its underground components, to site the facilities in close proximity to reported locations of historical seismicity. Recognizing that the uncertainty and variation of the detection threshold of historical seismicity changes with time, population distribution, and seismographic instrument coverage, the two classifying criteria for the inclusion of portions of the study area are judged as acceptable.

Approach. The approach used in applying the limiting criterion for ground motion, "include areas with horizontal acceleration (<0.40 g)" consisted of several steps. In the first step two interpretive maps are developed: a fault map of the study area and an earthquake epicenter map. The fault map is based on available regional geologic, structural geologic and tectonic data. The earthquake epicenter map is prepared with the following requirements:

1) Include instrumental data for all earthquakes of ~~Richter~~ magnitude greater than zero; -(microearthquakes are all Coda length - nothing below zero.)

2) Include all earthquakes based on epicentral felt reports;

3) When data sources site more than one epicentral location, available data on felt effects and/or instrument coverage will be analyzed in order to select the most probable location. (already done? for BWIP SS)

In the second step, the fault and earthquake epicenter maps are evaluated to identify potential earthquake sources. The faults are classified into three categories: capable and potentially capable faults, noncapable faults, and faults of unknown capability. Capable faults are those which meet the criteria for capable faults specified by the NRC in 10 CFR 100, Appendix A. Faults of unknown capability are those on which the age of the last movement cannot be ascertained from the available data. Only capable faults and lineaments and faults of unknown capability longer than 12 miles are considered as potential earthquake sources in evaluating the ground motion potential. Faults of smaller length are considered for the consideration of fault rupture (see Section A.2.1.1) or are evaluated during the later stages of the screening process. In addition, concentrations of seismicity (both micro and macro?) are compared to geologic structure to locate and interpret potential earthquake sources.

The third step consists of using empirical relations relating earthquake sources to horizontal ground acceleration at the surface. Potential earthquake sources identified in step two are assigned a Richter magnitude based on using an accurate earthquake magnitude-fault rupture length empirical correlation. (½ or ⅔ ?) The probability of occurrence of the assigned magnitude earthquake is considered to be the same everywhere along a capable or potentially capable fault. Next, peak horizontal acceleration on rock is estimated for the given earthquake magnitude. Setback distances based on earthquake magnitude and peak horizontal acceleration are estimated from the faults. Setback distances are those distances for which, given the length of fault rupture, are estimated to generate 0.40 g or less peak horizontal acceleration on rock at the surface.

Length in Miles of Structure	Distance in Miles Setback
12-24	5
25-60	10
> 60	15

Lines are drawn around the potential earthquake sources at the appropriate setback distances. Areas outside these enclosures are considered to have a higher likelihood of experiencing moderate or low acceleration from earthquake ground shaking. Concentration of earthquakes interpreted to be potential earthquake sources (identified in step two) are delineated and areas outside of these concentrations are considered to have a higher likelihood of experiencing moderate to low accelerations.

The approach used in applying the classifying criteria pertaining to historic seismicity consists of estimating the various uncertainties associated with locations for instrumental epicenters and felt reports. A map of the study area is prepared which delineates uncertainties in the recorded location of earthquake epicenters. Radii of uncertainty are drawn about the plotted earthquake locations as follows:

- 12 miles for felt reports of Modified Mercalli Intensity V or greater; (How will you treat 1872 at White Bluffs MM VII or 1918 Corfu)
- 6 miles for instrumental earthquakes with magnitude > 3.0;
- 1.2 miles for instrumental earthquakes with magnitude < 3.0. - may wish to omit [illegible] project.

This map is examined to preferentially identify and evaluate candidate site localities and candidate sites.

Definition of Terms. "Capable fault": See Section A.2.1.1

"Epicenter": the point on the earth's surface that is directly above the focus of an earthquake.

"Microearthquake": for the purposes of this study, an earthquake having a Richter magnitude of 3 or less.

"Macroearthquake": for the purposes of this study, an earthquake having a Richter magnitude of 3 or greater.

A.2.1.4 Tectonic Movement

Tectonic movement is used to define areas of potential differential tectonic movement (as opposed to uniform regional movement) which may occur during the isolation period of the repository. The level or potential for differential tectonic movement defines areas of relative desirability for locating a nuclear waste repository.

Relevance to Siting. Potential differential tectonic movements localized at or near a repository site can affect the safety of the site through local uplift/subsidence, changes in the local stress regime which may initiate new patterns or modify existing patterns of geologic structure (eg., fractures, joints), or through potential changes in the local groundwater regime. Avoiding areas of existing and potential future tectonic movement can not only increase the suitability of the repository site but also decrease the potential for delays in licensing.

Measure. Past differential tectonic movement in the Columbia Plateau has been concentrated on or near bedrock folds (anticlines, synclines and monoclines) and future differential tectonic movement is likely to occur along existing folds. Thus the measure used for this consideration is location with respect to potential bedrock folding (including anticlines, synclines and monoclines).

Criteria. Two sets of criteria are developed to describe the potential for differential tectonic movement. The first set includes limiting critiera which are used to obtain candidate subareas as well as candidate site localities:

- Include areas > 3 miles from the axes of large folds (those folds with > 300 ft fold amplitude and/or > 10 miles fold length); where is the fold amplitude measured from?
- Include areas > 1 mile from axes of small folds (those folds with < 300 foot fold amplitude and/or < 10 mile fold length).

The second set is a subjective classification of potential siting areas based on distance away from mapped folds. This nonlimiting classification is used to preferentially identify and evaluate candidate site localities and candidate sites. Same criteria

Rationale. Based on a review of detailed geologic and structural geologic studies in the basalt of the Columbia Plateau, the limiting criteria of 3 miles and 1 mile for large and small folds, respectively, are considered to reasonably represent the area over which future folding may have an effect. The available data suggest that bedrock folding in the Columbia Plateau basalts was ~~initiated~~ continued as late as the Ringold Formation (Plio-Pleistocene) and is probably an ongoing process. Because of the relative recency of bedrock folding and the need for a stable geologic environment for the repository, it is felt that avoidance of areas of past tectonic movement will result in the location of sites which have a higher likelihood of being suitable for nuclear waste repositories.

Approach. The approach used for employing the limiting criteria involves an examination and evaluation of structural geologic maps for the study areas. Mapped folds are identified and categorized as large or small, and the limiting criteria are applied to the folds such that areas meeting the criteria are included for further study.

The categorization of the folds into large and small, although having definite description, may be adjusted from one to the other if overriding data suggest such an adjustment. For example, a fold with greater than 300 foot amplitude and 10 mile length may exhibit evidence of no movement in the past 1 million years. This could possibly change its classification to a "small" fold for the purposes of this study.

The approach used for the c. .ssifying criteria involves an examination and evaluation of mapped folds to preferentially identify candidate site localities (away from sources of differential tectonic movement) and to evaluate and select candidate sites.

Definition of Terms: "Tectonics": branch of geology dealing with the broad structures of the upper part of the earth's crust; their origins, mutual relationships and evolution.

"Fold": a curve or a bend of rock strata, usually a product of tectonic deformation. Types of folds are:

anticline: see Section A.2.1.2;

syncline: a fold, the core of which contains the stratigraphically younger rocks; it is concave upward;

monocline: a unit of strata that dips or flexes from the horizontal in one direction only and is not part of an anticline or syncline; generally a large feature of gentle dip.

A.2.1.5 Groundwater Contamination

The groundwater flow system is studied with regard to the potential for radionuclide transport to natural and man-made surface discharge areas. This allows an assessment of the relative desirability of an area for repository siting.

Relevance to Siting. Groundwater flow direction and velocity in formations adjacent to the repository host rock affect the degree to which long-term isolation from the biosphere can be achieved.

Measure. The measure selected to represent groundwater contamination is location with respect to natural and man-made discharge areas. Adequate groundwater data are lacking in the Columbia Plateau region to support a more rigorous application of the groundwater consideration.

Criteria. The criterion used to define the potential for groundwater contamination is a non-limiting classifying criterion based on proximity to natural and man-made discharge areas. It involves an evaluation of discharge areas and the groundwater characteristics of the region to preferentially select one area over another.

How are Recharge areas considered?

Both the Hanford and CORBEH study areas have locations that have a high likelihood of containing natural or man-made groundwater discharge points which may be hydraulically interconnected to some degree with deep aquifer systems. In addition, these same locations are characterized by relatively high apparent (composite) horizontal hydraulic gradients. Such localities most likely occur along the Columbia/Snake River drainage systems and in areas containing a high density of irrigation wells.

Thus, areas such as the above are avoided in siting the repository. In addition, because the subsurface migration distance of radionuclides in groundwater increases the travel time and hence also increases the decay, diffusion, dilution, and absorption potential between the subsurface repository and the biosphere, the farther away a repository site is selected from these discharge areas, the better. Thus, the classification criterion is used to preferentially identify and evaluate site localities and candidate sites.

Rationale. Because subsurface hydrologic test data are not available in sufficient detail to reliably quantify the vertical and horizontal hydraulic gradients and permeabilities, porosities, dispersion, and absorption, of the proposed repository formation or the formations immediately above and below it, it ~~is~~ may be difficult to reliably estimate the velocity of radionuclide transport throughout the study region. Thus, no numerical limiting criteria have been specified. Rather, by using general hydrogeologic concepts regarding the hydrodynamics of the region, site localities and sites will be evaluated and classified based on their distance from groundwater discharge areas.

Approach. The first step of applying this classifying criteria is to obtain maps of groundwater level and water well locations within the study areas. The second step is to prepare an overlay map of apparent natural and man-made groundwater discharge areas. The areas are then classified using these overlay maps according to the principle that site localities and candidate sites farther away from discharge areas are better.

A.2.1.6 Surface Flooding

Surface water hydrology and river flood plain geomorphology are studied to delineate areas that have a low potential for flooding and thus have a higher likelihood of containing suitable repository sites.

Relevance to Siting. Flooding may affect the safety of a repository's surface facility. It is reasonable to assume that the NRC position regarding nuclear power plant sites would probably also apply to nuclear repository sites ~~if and~~ when such a position on repository sites is promulgated.

The NRC position states that sites located in river valleys, in flood plains, or along coastlines where there is a potential for flooding will not be evaluated for site suitability until the studies outlined in Regulatory Guide 1.59 have been made. These factors make flooding potential relevant to repository siting.

missed point that flooding of repository will occur through access shaft.

Measure. The measure used in applying this consideration to the siting study is height above a selected flood level. This measure can be depicted on maps of the study areas and also reasonably represents the concern of potential surface flooding of repository facilities.

Criteria. Locations within the study area having a high potential for flooding are interpreted as being within primary flood plains from topographic and geologic maps. They occur adjacent to the Columbia, Snake, Yakima Rivers, and other rivers in the study area. These high flood potential areas, plotted on an overlap map, are not retained for further consideration. Areas above the primary flood plains are classified on the basis that higher elevations above the flood plain are more suitable for the surface access to ~~nuclear waste repository~~ sites.

Cold Creek Syncline?

Rationale. Because floods which have occurred throughout Quaternary and Holocene times have been largely responsible for forming the primary flood plain, it is reasonable that areas outside the primary flood plain will have a significantly lower potential for flooding in the future.

covered all the Pasco Basin.

Approach. Overlay maps delineating the primary flood plains of the rivers in the study area are prepared. The primary flood plains are removed from further consideration. Site localities with higher elevations above the primary flood plain are classified as being more favorable with regard to flooding potential.

Definition of Terms. "Flooding potential": areas susceptible to flooding by precipitation, wind, or seismically induced floods (i.e., those resulting from dam failure, river blockage or diversion, or distantly or locally generated waves) are considered to have a flooding potential.

A.2.1.7 Volcanic Effects

The type and intensity of potential volcanic effects are used to define the relative potential hazards to repository facilities. The distribution of potential volcanic hazards is used to define the relative desirability of an area for repository siting.

all?

Relevance to Siting. Quaternary volcanic activity is common within and along the borders of the Columbia Plateau, particularly in and near the Cascade Mountains. Renewed volcanic activity may have a large range of effects including mud flows, debris avalanches, lava flows, hot ash flows, and ash fall. Because of the active nature of some of the volcanoes within and near the study area and the magnitude of effects possible from a large eruption, volcanic effects are considered to be a safety-related factor in site identification.

Measure. The measure selected to represent the consideration of volcanic effects is the distance to a potential volcanic source or its effects. Since the sources and limits of volcanic effects can be defined from maps and available data, then the measure becomes a mappable quantity adequate to depict the consideration.

Criteria and Approach. Three sets of criteria are used to describe the range of volcanic effects which could affect the siting of a repository. In the first set a limiting criterion is used to delineate areas considered to have a probability of experiencing potential volcanic effects. The limiting criterion includes, for further study, areas greater than 5 miles from a Quaternary volcanic center or from a Quaternary volcanic lava flow. This criterion generally encompasses the following severe volcanic effects: mud flows, debris avalanches, lava flows, hot ash flow and ash fall.

The second set of criteria are non-limiting classifying criteria used to evaluate areas not directly affected by the volcanic effects limited above. These classifying criteria include:

A - None of the above volcanic effects is near or expected to come near the area.

B - The area is located on a drainage from a Quaternary volcanic center; however, there is no evidence to suggest that it would be subject to any of the above effects.

C - There is evidence that one or more of the above volcanic effects is very near or may come very near the area.

The third set of criteria are also classifying and are used to assess the effects of potential volcanic ash fall (from the eruption of a Cascade stratovolcano) on the repository site.

The potential thickness of ash fall in a zone is estimated on the basis of a model developed around a geologically recent eruptive event at Mt. St. Helens. The probability of an ash fall occurring with a great enough thickness that could affect the safety of repository facilities (and thus limit areas) is considered to be low, since the closest stratovolcano is at least 12 miles from the study area. From the model, however,

Mt. Adams and Glacier Peak are closer! Mt. Hood has to be considered as source for Pebble Springs classifications for potential thickness of ash fall are established on the basis of distance from potential sources of ash:

A - > 100 miles to source;
B - 40 to 100 miles to source;
C - < 40 miles to source.

The nonlimiting classifications for potential ash fall and other volcanic effects are used in the preferential selection of site localities and in the identification and evaluation of candidate sites.

Rationale. Based on an examination and evaluation of geologic data dealing with volcanic eruptions from Quaternary basaltic volcanoes in the Pacific Northwest and the world, the 5-mile limiting criterion around volcanic centers or flows appears to be a reasonable value which encompasses the range of intense volcanic effects (i.e., lava flows, ash flows, thick ash fall, volcanic earthquakes, base surge, mud flows, etc.). An examination of volcanic effects from Quaternary andesite stratovolcanoes suggests that these effects are concentrated within 12 miles of the volcano. Since the Quaternary stratovolcanoes are greater than 12 miles from the study area, no limiting criterion is used.

Beyond the 5-mile limiting criterion, the volcanic effects, if present, are generally confined to drainage systems; thus, the classifying criteria for volcanic effects beyond the 5-mile limit.

Mt. St. Helens is used as the model for ash fall because it has produced the largest volumes of ash fall of the stratovolcanoes near the study area. The model ash fall (Ash Fall Y) has produced the greatest thicknesses downwind of the volcano, and the data for that ash fall are used to classify areas. It is believed that for distances less than 40 miles ash fall will have maximum effect on repository facilities and may affect facility design; for distances beyond 100 miles the effects will be minimal, and will probably not affect facility design. - ? How about intake air systems - coolant pumps - elevator hoists and other mechanical equipment needed to insure access and safety

A.2.1.8 Future Volcanic Activity

Future volcanic activity is studied to describe the potential for future new eruptions within the study area and thus to define the relative desirability of an area for a nuclear waste repository.

Relevance to Siting. Because of the long time frame (10,000 years) of the isolation period and the need to maintain a stable geologic environment for that period, the potential for future volcanic activity breaching or affecting the repository becomes important. This is particularly true when siting of the repository occurs within a thick volcanic sequence in an area of extensive past volcanic activity (i.e., the Columbia Plateau and Cascade Range).

<u>Measure</u>. The measure selected to represent future volcanic activity is the location of an area with respect to areas which may have a potential for future volcanic activity.

<u>Criteria and Approach</u>. A nonlimiting, classifying criterion is used to define the probability of future volcanic activity and its affect on areas of the siting study. The basis for this is an evaluation of available geologic, tectonic and geophysical data for the study area to ascertain past patterns of volcanic activity. These data are used to estimate future patterns of volcanic activity within and near the Columbia Plateau and those areas which may have a probability of future eruption. This evaluation is thus used to preferentially identify site localities and evaluate candidate sites.

A.2.1.9 Ground Failure

Ground failure is used to describe areas of existing ground instability as well as to delineate areas that may have a potential for ground failure. It serves to define areas that are more desirable for the siting of nuclear waste repository facilities (particularly surface or near surface facilities).

<u>Relevance to Siting</u>. Siting on ~~existing~~ ? unstable ground or in an area [illegible] with a high potential for ground failure may affect the safety of a [illegible] nuclear waste repository. In addition, extensive foundation and slope [illegible] stability investigations may cause delays in licensing and could also add to the cost of design and construction of repository facilities.

<u>Measure</u>. Two measures are developed to describe the major concerns for the consideration of ground failure. One is location with respect to existing landslides or potential landslides which deals essentially with slope stability. The other is characteristics of foundation conditions which deal with foundation stability. Both measures can be adequately applied to maps to successively reduce areas for further study.

<u>Criteria and Approach</u>. The approach used to define the consideration of ground failure involves the used of both limiting and classifying criteria. In general, those areas of mapped landslides or interpreted to be landslides are identified and removed from further consideration. The remaining areas are evaluated for potential ground failure as manifested in any of the following phenomena: landslides, liquefaction, subsidence, or differential settlement. The areas are then classified as to the probability of such failure.

Specifically, areas that are mapped as landslides or interpreted to be landslides are outlined and plotted on overlay maps and are not considered further. The limiting criterion is used to obtain site localities. The areas remaining are classified by two sets of non-limiting criteria:

- Potential for landslides:
  A - low probability of a landslide;
  B - slight probability of a landslide;
  C - higher probability of a landslide.

- General foundation characteristics:
  A - bedrock area (0 to 20 feet of unconsolidated material);
  B - shallow alluvial area (20 to 100 feet unconsolidated material);
  C - deep alluvial area (more than 100 feet unconsolidated material).

The bases for the evaluation of the potential for landslides are the lithologic descriptions of formations from available geologic maps (including all mapped landslides), the history of landslides within each formation, and the presence of mass movement topography as determined from geologic hazard maps and topographic maps. From the above data, landslides are delineated and the remaining areas evaluated as to their potential for landslides (categories A through C above).

The bases for evaluation for other types of potential ground failure include the lithologic descriptions and determinations or estimates of the depth of unconsolidated material throughout the area. The thickness of unconsolidated material in each area is determined or estimated from the available literature on geology. Each area is then classified as to its general foundation characteristics (categories A through C above).

These two classifications are used in the preferential selection of site localities and the evaluation of candidate sites.

Rationale. Areas of actual mapped landslides or unstable topography (mass movement topography) and areas that are interpreted to be landslides may affect the safety of repository facilities. Experience has shown that delays in licensing can occur when nuclear facilities are located on or near existing or potential landslides. The potential for landslides and mass movement of the topography can be estimated through a geologic evaluation of the data in the site localities.

Similarly, the thickness of unconsolidated material can affect the safety of a thermal power station in that under seismic stress the materials may be subject to liquefaction. Therefore, the thickness of such materials determines the ease and cost of excavations to reach a stable foundation. Experience has shown that the difficulty and cost of excavation increases sharply when the thickness of unconsolidated material exceeds 100 feet, and that thicknesses of 0 to 20 feet are better since they approximate bedrock conditions. From this evaluation, areas more closely approximating bedrock conditions are delineated.

Definition of Terms. Landslide: general term covering a varity of mass movement land forms and processes involving the moderately rapid to rapid (on the order of 1 foot per year or greater) downslope transport of soil and rock material en masse by means of gravitational body stresses.

Unconsolidated Material: clay, silt, sand, gravel, or similar detrital material deposited during comparatively recent geologic time (i.e., late Pleistocene to Recent).

A.2.1.10 Erosion/Denudation

Erosion or denudation of the landscape is studied to describe the potential for exposing the repository to the biosphere during the isolation period. The relative potential for erosion or denudation affecting or breaching the repository is used to define the relative desirability of an area for containing a nuclear waste repository.

Relevance to Siting. The potential for erosion or denudation may affect the safety of a repository site. Erosion or denudation during the isolation period could expose the repository to the biosphere either by breaching the host rock containment or by shortening the pathways to the biosphere. Location of potential repository sites in areas with lower erosion/denudation potential would increase the likelihood of finding safety and licensible repositories.

Criteria should be that the repository must be some distance below sea level

Measure. The measure selected to represent erosion or denudation is the location of potential repository sites, with respect to areas of potential erosion of denudation. This measure can be depicted as a map distance or judged subjectively.

Criteria. Two sets of criteria are used to describe the potential for erosion/denudation. The first set is a limiting criterion used to obtain candidate site loc~~alities. It~~ includes, for further study, areas greater than 1/2 mile from steep-walled canyons. The second set of criteria are non-limiting classifying criteria used in the preferential identificaton and evaluation of both candidate site localities and candidate sites. These non-limiting criteria classify the study area into the following:

- A - Those areas where the proposed repository level would be below sea level (base level for erosion);
- B - Those areas where the proposed repository level would be above sea level (base level for erosion).

Rationale: The limiting value, of 1/2 mile from steep-walled canyons, for the consideration of erosion/denudation is based on an evaluation of ~~regional denudation rates~~ in the Columbia Plateau area. Hunt (1974) and Judson and Ritter (1964) suggest regional rates of denudation (regional lowering) for the Columbia Plateau, which range from 0.6 inches/1000 years

refer

to 1.5 inches/1000 years (1.5 to 3.75 centimeters/1000 years). Over a 10,000-year isolation period, the plateau would be lowered on a regional basis 6 to 15 inches (15 to 37.5 centimeters). However, erosion would proceed more rapidly in areas with steeper slopes by factors of 10 to 20 times (Hunt, 1974). Thus, along steeper slopes, the amount of erosion over 10,000 years could range from 60 to 300 inches (150 to 750 centimeters). Because these values are averages and because of the uncertainty of the data, a 1/2-mile setback from steep-walled canyons is used as the limiting criterion.

The classification criteria, based on elevation above sea level (base level for erosion), were derived from an evaluation of long-term erosional/denudation processes and ~~were~~ are based on professional judgment. Although regional lowering of the Columbia Plateau is proceeding at a slow rate, it would be better for a repository to be located below the present base level for erosion (sea level) due to uncertainties in erosion rates and also sea level predictions for the next 10,000 years. The higher the repository is above base level, the faster the erosion rate will generally be.

Approach. The approach used for the limiting criteria involves an examination of the detailed topographic maps of candidate zones. Steep-walled canyons and valleys are identified, and the areas within 1/2 mile of the edge of the canyon are delineated and limited from further study.

The approach used for the classifying criteria also involves an examination of the detailed topographic maps of candidate zones and an evaluation of the elevations of potential repositories. Those areas where the repositories lie below sea level would be classed in the A group, and those above sea level would be in the B group. The classification of the areas would then be used to preferentially identify candidate site localities and to evaluate and select candidate sites.

using what depth below surface?

Definition of Terms. Erosion: the general process whereby the earthy and rocky materials of the earth's crust are loosened, dissolved, or worn away and removed from one place to another.

Denudaton: the sum of the processes that result in the wearing away or the progressive lowering of the earth's surface through weathering, erosion, mass-wasting and transportation.

Base Level: the theoretical limit or lowest level toward which erosion of the earth's surface constantly progresses; but its bed, the general ultimate base level for land surface, is sea level.

A.2.1.11 Stratigraphic Characteristics

The rock housing the nuclear waste repository will probably be ~~the~~ a major containment barrier. The study of the stratigraphic characteristics of ~~this rock is used to describe~~ favorable rock characteristics and, thus, areas of relative desirability for a nuclear waste repository.

Relevance to Siting. The physical dimensions, geometry, position and internal characteristics and properties of the rock housing the repository are important stratigraphic characteristics which ~~can affect~~ determine the ~~integrity~~ degree of the natural containment and, thus, safety of the repository.

Measure. Five measures are used to define the consideration of stratigraphic characteristics:

1) total basalt thickness; includes interbeds?
2) depth to basalt surface;
3) bedrock dip;
4) presence of suitable stratigraphic characteristics;
5) thickness of underlying basalt. - how do you know its all basalt

how will they be composited

Criteria. The criteria developed to quantify or qualify these measures are both limiting and classifying:

1) Total basalt thickness:

   a) Include for further study those areas where the total basalt thickness exceeds 1000 feet. This limiting criterion in used to obtain candidate area.

   b) Evaluate areas on the basis of total basalt thickness. This criterion preferentially classifies areas into two groups: those with total basalt thickness from 1000 to 3000 feet and those with greater than 3000 feet thickness. The criterion is used to evaluate and identify candidate sites.

2) Depth to the basalt surface: This limiting criterion includes for further study those areas where the depth to the basalt surface is less than 1000 feet or conversely where the overburden is less than 1000 feet thick.

3) Bedrock dip: This classifying criterion divides potential repository strata into three groups on the basis of dip: 0 to 5 degrees, 5 to 10 degrees, and greater than 10 degrees.

4) Presence of suitable stratigraphy: This limiting and classifying criterion essentially states that suitable rock for repository containment must exist at the proposed repository depth and that it must have acceptable thickness, structure and internal strength

and mechanical properties. Areas are evaluated for these suitable characteristics to obtain site localities and preferentially identify candidate sites.

5) Thickness of underlying basalt: This limiting criterion includes areas where the thickness of basalt underlying the proposed repository is at least 500 feet. why not other volcanic rock.

Rationale. The limiting and classifying criteria for total basalt thickness are ~~derived~~ based on the need to must you isolate the proposed repository from surface geologic processes and to also insure that sufficient host rock exists for the placement of the repository. In addition, basic data (Section II) ~~requires~~ makes that the repository ideally be in the depth range of 2000 to 4000 feet. Since the Columbia River basalt exists at or near the surface over much of the study area, then the limiting criterion of at least 1000 feet basalt thickness seems reasonable to avoid areas lacking sufficient basalt and to include areas where, despite uncertainties in the data, sufficient thickness is believed to occur. The classifying criterion are useful because, given the uncertainties in the data, the thicker the basalt sequence, the higher the probaility of locating a suitable site.

The limiting criteria of 1000 feet for the depth to the basalt surface reasonably maintains at least 1000 feet of basalt over any repository. This insures that the repository will be reasonably surrounded by the rock for which it was designed. not necessarily

The classifying criterion of bedrock dip applies primarily to the development, construction, and operating costs of the repository. The bracketed ranges in dip reflect the relative ease of construction and operation, and thus cost of potential repositories which must be located in definite stratigraphic and depth intervals. The greater the dip, the more difficult and costly it becomes.

The limiting and classifying criteria concerning the presence of suitable stratigraphic characteristics is based on the ~~requirement that~~ idea that at least one basalt flow of greater than 100 feet thickness ~~must~~ should ideally occur at the proposed repository depth of 2000 to 4000 feet. In addition, unless this flow meets the minimum or estimated minimum, structural, strength, mechanical, density, porosity, extent, continuity, etc., requirements for the repository, it ~~is~~ may be not suitable. This criterion becomes a classifying criterion if more than one suitable flow is present within the repository depth range. That is, more repository options are available at a site with more suitable flows; thus, such a site becomes more desirable.

The limiting criterion for the thickness of underlying basalts stems from the need to insure that the repository is isolated in rock for which information exists and for which it ~~is~~ will probably be designed. The 500-foot-thick limit appears to be reasonable and fits the level of detail of the available data on basalt thickness.

Approach. The total basalt thickness limiting criterion is applied to the study area to obtain candidate areas. An isopach map of basalt thickness will be ~~is~~ developed for the study area, and an overlay of areas with greater than 1000 feet of basalt thickness defines area for further study. The classifying criterion uses the thickness data developed for the limiting criterion as well as detailed information collected during later steps in screening to evaluate site localities and preferentially identify candidate sites.

The limiting criterion for depth to basalt surface (overburden thickness) is applied to the study area to obtain candidate areas. If detailed information collected at later stages of the screening process indicates more areas with overburden greater than 1000 feet thick, these are removed from further consideration to identify site localities.

Detailed geologic data concerning basalt thickness, flow thickness, geologic ~~structure, internal~~ flow characteristics and stratigraphic characteristics are collected for the subareas and/or candidate zones. These data are used to develop overlays for the limiting criteria of stratigraphic characteristics and thickness of underlying basalt, as well as for the evaluation of areas to preferentially identify site localities and candidate sites using the classifying criteria of bedrock dip and suitable stratigraphic characteristics.

A.2.2 Man-Made Hazards

A.2.2.1 Aircraft Impact

Areas with potentially high volumes of low altitude aircraft traffic are considered to be unsuitable for repository siting and are removed from further study.

Relevance to Siting. The NRC review process will very likely consider the potential hazard to the safety of repository surface structures (and a reprocessing plant if developed at the site) resulting from aircraft collision with such structures. In addition, segregating airports and air traffic patterns from land uses with potentially hazardous emissions is a generally accepted principle of land-use management.

Measure. The potential hazard of aircraft impact is measured in miles from airports and designated aviation routes. This measure is a proxy for probability of impact, the assumption being that probability of impact decreases with distance from high traffic areas.

Criteria. Areas within 5 miles of airports shown on state airport plans as accommodating aircraft of 12,500 pounds gross weight and areas within 5 miles of any military airport will not be included for further study. In addition, the present (and if available, projected) volume of air traffic at airports will be considered and used to define a setback distance. For airports with more than 12,500 operations per year and fewer than 50,000 operations (an operation is a takeoff or landing; a touch-and-go movement is two operations), the setback distance in miles is equal to the square root of .002 (total operations). For airports with 50,000 to 100,000 operations, the setback is 10 miles. For airports with more than 100,000 operations per year, the setback in miles is equal to the square root of .001 (total operations). The distance in miles from designated commercial jet lanes and designated military training routes is used as a classifying criterion.

Rationale. The NRC regulatory positions on accident analysis, aircraft considerations, and nearby hazardous facilities as they apply to nuclear power stations are considered to be representative of the degree of conservatism that will attend to a repository siting safety review. This position is stated in Regulatory Guides 1.70 and 4.7, in NUREG 75/087, and in documentation of AEC Project 385 "Aircraft Considerations: Preapplication Site Review in the Matter of.... the Boardman Nuclear Plant". The following language is taken from Reg. Guide 4.7:

> A special analysis of such factors as frequency and type of aircraft movement, flight patterns, local meteorology, and topography should be performed for (1) sites located within 5 miles of any existing or projected commercial or military airport, (2) sites located between 5 and 10 miles from any existing or projected commercial or military airport with more than approximately 500 d^2 (where d is in miles) aircraft movements per year, and (3) sites located at distances greater than 10 miles from an airport with more than approximately 1000 d^2 aircraft movements per year. The analysis should demonstrate that the probability of any potential aircraft affecting the plant in such a way as to cause the release of radioactive materials in excess of the guidelines of 10 CFR Part 100 is less than about 10^{-7} per year. If the probability is on the order of 10^{-7} per year or greater, aircraft impact should be considered in the design of the facility.

The setback criteria given above are direct translations or numerical conversions of these NRC review formulas. The criteria are applied to minimize the probability that aircraft could impact at a repository site and to avoid the requirement to perform multiple, detailed risk analyses for sites proximitous to airports.

The classifying criteria to consider the distance to designated commercial jet lanes and designated military training routes recognizes the generally low probability of an accident along such routes when compared to fixed point sources of traffic. The precedent for consideration of these routes in nuclear siting reviews is AEC Project 385 (1974), which considered a site at Boardman, Oregon (within the study area) and resulted in suggested design modification to surface facilities and ultimately in relocation of the plant site.

Approach. The 5-mile setback from airports is applied to small-scale maps of the study area. Airports are identified on state airport plans, located on study area maps, and circumscribed with a 5-mile radius. The additional setbacks that correspond to the volume of operations are applied in a similar fashion to larger-scale maps of candidate areas. Operation volumes are obtained from state airport plans, the Federal Aviation Administration, and from direct contacts to airport traffic managers.

The classifying criterion is applied to zones. All or portions of a zone are described in terms of air miles to the ground locations of commercial and military routes. This information is used in the preferential selection of zones, and in the selection of site localities.

Definition of Terms. State airport plans are officially prepared descriptions of present and projected aviation facilities. A common categorization of airports is by gross weight of aircraft accommodated. Airports accommodating aircraft weighing less than 12,500 pounds generally have few or no facilities. FAA control is generally not provided for such airstrips.

How about oil gas fields - other nuclear facilities - any classif. weapons storage

A.2.2.2 Hazardous Facilities

Areas currently in a land use are interpreted as presenting a potential hazard to the safety of operation of a repository and its associated facilities, and areas close to and potentially affected by such hazardous uses are not considered to be suitable for siting.

Relevance to Siting. The NRC review process for a proposed repository is likely to consider the effects of accidents or potentially hazardous operations at facilities that handle explosive, corrosive or flammable materials that could generate missiles, fire, shock waves or vapor clouds.

Measure. The location of potentially hazardous facilities and distance to certain facilities in miles are used as proxies for the potential hazard associated with such facilities.

Criteria. Large, potentially hazardous facilities (> 18,000 acres in size) are identified and removed from further consideration. Such facilities may include bombing and gunnery ranges, major ordnance depots, and large transportation or transshipment centers. Facilities which are possible missile or noxious vapor cloud generators (of any size) are further limited by a 1-mile setback, if they have not been removed by application of the first criterion. The large area criterion is applied to obtain candidate area; potential missile generators are considered at the subarea stage of screening, and vapor cloud sources are considered in the identification of site localities.

Rationale: NRC safety review procedures on nearby hazardous facilities as they apply to nuclear power plants, reprocessing plants, and other fuel cycles installations are considered to be representative of the concerns and degree of conservatism that will attend to a repository siting review. The NRC position on hazardous and potential accidents used in developing these criteria is stated in Regulatory Guides 1.70 and 4.7 and NUREG 75/087. An example of the language appearing in these guides is (taken from 4.7):

Potentially hazardous facilities and activities within 5 miles of a proposed site must be identified. If a preliminary evaluation of potential accidents of these facilities indicates that the potential hazards from shock waves and missiles approach or exceed those of the design-basis tornado for the region (the design-basis tornado is described in Regulatory Guide 1.76), or potential hazards, such as flammable vapor clouds, toxic chemicals or incendiary fragments exist, the suitability of the site can only be determined by detailed evaluation of the potential hazard.

Areas which are presently occupied or used for hazardous facilities or operations (like a bombing range) are not considered suitable for siting. More specific review criteria for sites near sources of missiles, shock waves or vapor clouds generally require detailed risk analysis if the hazardous facilities in question are closer than a specified distance, ranging in most cases, from 350 to 1000 meters. The 1-mile setback proposed above bounds the range of these distances and would thereby alleviate the need for detailed study of most potentially hazardous facilities. The 18,000 acre minimum limit on large areas is chosen as a practical matter related to the size of areas discernible on small-scale maps. For most of these large areas, additional setbacks will not be required, since the boundaries of many such areas are established to include a safety zone. Facilities capable of generating noxious vapor clouds are considered later in screening than other facilities, since vapor cloud sources can be very small operations (such as a fertilizer plant, or an LPG storage facility), which are not well known or easily discernible, except by field observation or on large-scale maps.

Approach. Large hazardous facilities are identified and plotted on small-scale maps of the study area, and removed from further consideration. Potential sources of missiles and shock waves are identified within Candidate Areas, and a 1-mile setback is circumscribed. This step may be repeated as smaller areas are identified on larger-scale maps. Sources of noxious vapor clouds are identified at the site locality level, plotted on maps of zones, and circumscribed with a 1-mile setback. Candidate site descriptions will include a discussion of all potentially hazardous facilities within 5 miles of any site.

Definition of Terms. Missiles are generally considered to be any objects flying through the air with sufficient mass and velocity to present signficiant hazard to persons or structures.

A.2.2.3 Transportation

Areas close to highways, railroads, and navigable waterways are not considered to be suitable for siting.

Relevance to Siting. Areas close to major transportation routes (other than airways) are considered to be subject to potential accidents that affect the safety of operation of a repository; in addition, some transportation routes (highways) are considered to be signficant transient population generators that should be considered in terms of potential public exposure to radioactivity associated with the repository facilities.

Measure. The distance in miles from linear transportation routes is used as a proxy for both potential hazard to a repository from accidents along such routes and potential exposure to radiation of persons using such routes.

Criteria. Areas within 1/2 mile from U. S. Highways and 1 mile from interstate highways, railroads and navigable waterways are not included for further consideration. These criteria are applied to subareas or zones and are used to identify site localities.

Rationale. The 1-mile setback from interstate highways, railroads and navigable waterways is consistent with the criterion applied to potential generators of missiles and noxious vapor clouds (see Section A.2.2.2 above). The 1/2-mile setback around U. S. highways reflects the smaller volume of traffic and lighter duty classification of these routes. These criteria would not apply to controlled access routes.

A.2.2.4 Induced Seismicity

Induced seismicity caused by man's activities is studied to describe the potential for seismic shaking in the study area. The level of potential ground motion is used to define the relative desirability of an area for a nuclear waste repository.

Relevance to Siting. Although the ground motion potential due to earthquakes associated with the release of regional tectonic stresses has been discussed in Section A.2.1.3, induced seismicity caused by man's activities ~~must~~ would also be considered. This mechanism of generation of seismic events is not as well understood as that of earthquakes generated mainly from release of tectonic stress and represents an additional safety consideration.

Measure. The measure selected to represent this consideration is location with respect to existing and future potential sources of induced seismicity. The location of the planned repository away from present and future areas of potential induced seismicity is important.

Criteria. Two criteria are used to describe the potential effects of induced seismicity. A limiting criterion is used to define potential areas of ground motion associated with potential existing sources of induced seismicity: include those areas greater than 5 miles from existing man-made reservoirs greater than 100 feet deep. This recognizes that the primary source of induced seismicity is most likely from man-made reservoirs. This limiting criterion is used to obtain subareas.

The second criterion classifies areas on the basis of proximity to planned future reservoirs and interpreted sources of induced seismicity in the following manner:

A - > 5 miles;
B - 0 to 5 miles.

This criterion is used to preferentially identify site localities and evaluate candidate sites.

Rationale. Locating the repository site away from present reservoirs is a limiting criterion to be used at the subarea level because of the potential for moderate to large magnitude earthquake generation from reservoirs with at least 100 feet depth. The issue of the maximum magnitude earthquake that can be reservoir induced remains a topic of research, and no definitive results are available at present. Therefore, for the purposes of this analysis, the setback distance from present reservoirs has been selected as 5 miles. This is consistent with the minimum setback distance given in Section A.2.1.3, from a capable fault 12 to 24 miles, and the associated moderate to low horizontal acceleration of 0.40 g.

The classifying criterion was selected because it recognizes both the need to consider future sources of induced seismicity and the uncertainty whether planned reservoirs will ever be constructed. Again, the break at 5 miles is related to the minimum setback established for ground motion in Section A.2.1.3.

Approach. A map is prepared for candidate areas indicating locations of existing and planned reservoirs. An overlay with a setback of 5 miles is drawn for each existing reservoir greater than 100 feet deep. These areas are removed from further consideration.

The data developed for planned or future reservoirs is used to evaluate subareas and/or candidate zones for the purpose of preferentially identifying site localities, then candidate sites.

A.2.2.5 Subsurface Mineral Exploration and Extraction

If any part of potential area [illegible] – would the entire area be excluded?

Subsurface mineral exploration and extraction is used to describe the potential for possible breach of the repository through existing and future mining activities. A site with a relatively lower potential for exploration and/or exploitation is considered more suitable for a nuclear waste repository.

Relevance to Siting. Existing drill holes and future exploratory programs could cause a breach of containment in the repository, resulting in pathways to the biosphere. Areas which are attractive to future mineral exploration or are already being exploited are generally undesirable for nuclear waste repositories.

Measure. The measure used to describe this consideration is location with respect to existing and potential future areas of mineral exploration and extraction.

Criteria and Approach. Both a limiting criterion and classifying criterion are used to describe the measure. The limiting criterion includes, for further study, those areas outside of the limits of existing subsurface mineral extraction and/or exploration. The approach used to apply this criterion consists of: (1) identifying the areas of existing (and past) mining activities; (2) identifying areas of extensive subsurface exploration; and (3) preparing on overlay delineating these areas. Areas outside of the limits of these areas are considered for further study.

The classifying criterion deals with the potential for future mineral exploration and extraction. It is based on an evaluation of the probability of future mining activity to preferentially identify and evaluate candidate sites. To accomplish this, geologic data concerned with mineral resources exploration and mineral production are evaluated to identify areas judged to have a relatively higher likelihood for future exploration and/or exploitation. This information is then used in the classification of areas.

Rationale. Because of the need to avoid all possible sources of repository breaching, it is reasonble to avoid areas where mining activities are currently concentrated. Given the uncertainties and vagaries of future developments in the mineral industry, it seems reasonable to classify areas on the basis of perceived future exploration and exploitation.

Definition of Terms. Mineral resource: In the context of this study, a mineral resource include metallic and non-metallic ores, petroleum resources, and groundwater.

A.2.3 Repository Induced Events

A.2.3.1 Thermomechanical Effects

Thermomechanical effects are studied to evaluate the effect of repository operation on the stability of the host rock. Repository locations with desirable thermomechanical properties are considered to be suitable for nuclear waste repositories.

Relevance to Siting. The thermomechanical properties of the repository rock are significant to the performance of the repository in maintaining adequate containment. If one area is marginally adequate in terms of these properties compared to another area, then the relative suitabilities as potential repositories can be assessed.

Measure. Although the thermomechanical properties of any rock are measured by using numerous parameters, the flow thickness appears to be a reasonable measure to apply for the purposes of the siting study. In addition to the thermomechanical properties, general engineering properties are also examined.

Criteria and Approach. Based on an examination of the geology, stratigraphy, rock properties, and available laboratory data for the site localities, a subjective evaluation is made to identify candidate sites. This evaluation is based primarily on flow thickness with the assumption that, given equal and desirable internal flow characteristics, the thicker the flow, the more suitable will be the thermomechanical properties.

Rationale. Because of the lack of detailed data concerning rock properties over much of the study area, the use of flow thickness as a measure of the thermomechanical properties appears to be reasonable. In general, a thicker flow will perform better under thermal loading; and, in general, a thicker flow will have better mechanical properties because of the greater thickness of homogeneous rock.

A.2.3.2 Operational Radiation Releases

Populated areas are not considered to be suitable for repository siting. Areas of current and projected moderate or greater population density and urbanized places are removed from consideration, along with a setback distance based on calculated concentrations of gaseous radioactive emissions expected from operation of the repository and associated facilities.

Relevance to Siting. The segregation of major industrial facilities from concentrated residential and commercial areas is a widely accepted principle of land-use management. In addition, the population distribution around nuclear facilities is considered as a safety-related site characteristic by the USNRC. Densely populated areas are generally considered to be unacceptable for siting.

Measure. The measure used is distance from populated areas, based on calculated concentrations of gaseous radioactive emissions from a repository and its associated facilities.

Criteria. Areas within 3 miles of populated places with a present or projected population greater than 2500 and within 1 mile of populated places with smaller population are removed from further consideration. Specific cumulative population distribution and density around candidate sites will be considered in ranking.

Rationale. Regulatory limits on volumes and concentrations of operational radiation releases and associated doses to the public are set in 10CFR20, 10CFR100 and 40CFR190. Using concentrations calculated on the basis of gaseous emission estimates from a repository (see Table II-2), the minimum setback from emission sources at a repository site is tentatively calculated to be at least 1 kilometer. This is extended to 1 mile for conservatism and to be consistent with measures used for other considerations. Sites within 1 mile of any populated place are not considered to be suitable. The 3-mile setback for places greater than 2500 population is a density consideration. As a rule of thumb, population densities greater than 200 persons per square mile close to sources of significant radioactive emissions will require detailed analysis and justification before the NRC. At 3 miles, this density would imply a total population of about 5600. If one town of 2500 is located within 3 miles, it is reasonable to assume that an equivalent population could be living in all other portions of a 3-mile circle surrounding the site (such an assumption corresponds to a region of 20-acre forms). Therefore, sites within 3 miles of a population center of 2500 persons would be at or in excess of the threshold densities generally considered acceptable by the NRC. The 3-mile setback is commonly used in nuclear power plant siting and is considered reasonable by the NRC as a first approximation population exclusion.

one, two or more ... ?

ep see III-30

Approach. Using the latest U. S. census population estimates available, cities and towns with current populations of 2500 or more are identified and circumscribed with a 3-mile setback. These areas are shown on maps of the study area and are used to identify candidate areas. Smaller populations are considered in subsequent screening steps as appropriate to their size and the scale of maps and aerial photographs available. At the zone stage of screening, projected populations are considered. Available projections, current population estimates and historical population are used as the basis for an extrapolated linear or exponential estimate at the 60th year of operation of the repository. As a check, the projected area and extent of urban areas will also be estimated. The 3-mile setback will be applied to towns projected to be 2500 or larger in the 60th year, measured from the projected limits of the urbanized area. The 1-mile setback for smaller towns will be applied in a similar fashion. For conservatism, a projected decline in population below the 2500 population limit will be treated as a static future population, and the 3-mile setback will be applied to the current urban limits. Populations projected in this manner will be used as the basis for cumulative population distribution and density considerations used in screening.

A.3 ENVIRONMENTAL IMPACTS

The considerations and criteria developed to meet the objective of minimizing adverse environmental impacts are concerned primarily with avoiding designated or legislated cultural and ecological areas and reducing impacts associated with the preemption of use of a large track of land such as a repository. These considerations are primarily concerned with the surface facilities of the repository during the operational time period.

A.3.1 Protected Ecological Areas

ALE project: how will it get ...?

Land areas that are of particular ecological value and for which binding land restrictions have been established are considered unsuitable for repository siting. Areas which are considered ecologically important and sensitive, but for which there are no legally defined boundaries on statutory prohibitions, are not considered in the screening steps. The larger of the areas are identified in the screening steps and not considered further.

Relevance to Siting. Each of the ecological areas considered is protected by statutory prohibitions against any development or by permit regulations and permit procedures which are likely to result in delays in the licensing process.

Measure. The measure is the location of the protected area as defined by its legal boundaries. No setback from the boundary is considered in the screening steps unless there is a known requirement for such a setback.

Criteria and Approach. Areas that have been formally designated by a public agency to be of ecological value and for which binding restrictions on land use affecting repository siting have been established are identified; the public agency placing restrictions on these areas, the types of restrictions, and the reason for protection are described. These areas are plotted and shaded on the appropriate overlay map of the study area. The shaded portions of the study area are considered to be unsuitable for repository siting and are not included for further study.

Protected ecological areas are limiting criteria considered in three screening steps, specifically:

Screening Steps	Criterion
Candidate Areas	outside areas of > 18,000 acres
Subareas/Zones	outside areas of 5,000 to 18,000 acres
Candidate Site(s)	outside areas of < 5,000 acres

Rationale. Major developments, including repository siting, within the boundaries of these areas is either prohibited or restricted by statutory authority. The decision to examine different size areas in subsequent screening steps is based on the map scale used at the particular step.

Definitions. Protected ecological areas: those areas which are protected by binding restrictions on the basis of a particular ecological attribute; they could include critical habitat or threatened or endangered species.

Dave Rice archeologic survey - Hanford?

A.3.2 Culturally Important Areas

Areas that are interpreted as being important because of certain values that society may have placed on them (scenic, historical, recreational, or cultural) are considered to be unsuitable for repository siting and are not retained for further consideration.

Relevance to Siting. Scenic, historical, recreational, and cultural areas that have been formally designated by public agencies and for which restrictions have been established to preserve or enhance the cultural values are judged to have a high potential for delays in licensing. These areas are considered to be unsuitable for repository siting.

Measure. The location of culturally important areas is the principal measure. For areas that have been set aside for scenic values, a visual setback distance, measured in miles, is used. This setback distance is a proxy for the degree of visual intrusion into scenic areas that could be associated with such an obstruction as a 200-meter stack at a site. The distance is calculated on the basis of rationale presented below.

Criteria. Different size areas are considered at different steps in screening, dependent on the scale of maps in use at each step. Areas greater than 18,000 acres are considered on maps of the study area; smaller areas (5 to 18,000 acres and less than 5,000 acres) are considered in identifying subareas and candidate sites.

The areas considered include Indian reservations, parks (national, state, and local), monuments, wilderness areas, primitive areas, roadless areas of National Forests, BLM roadless areas, wilderness study areas, wild and scenic rivers, national shorelines, national recreation areas, outstanding natural landmarks, outstanding natural areas (designated), and archaeological sites. The functions, uses, and values associated with these types of areas vary widely; therefore, different criteria are employed for different types of culturally important areas. A zone of influence is circumscribed around certain areas using the following criteria:

- Include areas farther than 6.5 miles from designated scenic areas, trails, wilderness areas, national parks, recreational areas, and designated and proposed wild and scenic rivers;

- Do not consider locating sites within areas which have been interpreted as being "culturally important" on the basis of values other than scenic or recreational values.

Rationale. The areas identified in this step are restricted in use and are considered to be unsuitable for further consideration. The decision to examine areas of different sizes is based on the map scale used in each step. The zones of influence drawn around scenic areas were selected to limit the visibility of major structures, such as a stack, from the location or boundary of scenic areas. For example, at a distance of 6.5 miles with no intervening vegetation and on level ground, a 200-meter stack would subtend an angle of 1 degree on the horizon. The 1-degree angle is judged to provide a "far background" visible effect which would not compromise the scenic values of the designated areas. This approach and the 1-degree value are suggested as an appropriate screening technique for nuclear power plant siting by the NRC staff (Jan Norris, Directorate of Licensing, Environmental Review staff, 1974).

Approach. The designated culturally important areas are plotted on maps of the appropriate scale, and the visual setbacks are applied to the appropriate areas. All areas affected by application of this criteria are removed from further consideration.

A.3.3 Threatened or Endangered Species

Areas that are known to be important for the breeding, nesting or feeding activities, or general survival of individuals or populations of threatened or endnageered species are considered unsuitable for siting a repository. In many cases, the area has not been officially designated as Critical Habitat, but the regulatory restrictions and public opposition are likely to cause significant delays in licensing.

Relevance to Siting. The potential for any major development such as a repository to jeopardize the survival of a threatened or endangered species will be closely scrutinized by the NRC in the site review process. Any indication that the individuals or populations of the species might be jeopardized is likely to result in delay or denial of the application for license.

Measure. The measure is the location of habitats or specific geographic areas known to be important to the survival of the threatened or endangered species. These locations will be defined as precisely as possible on 1:24,000-scale topographic maps. No setback from the boundary is considered unless one has been specifically recommended by a recognized authority or agency of concern.

Criteria. Areas will be identified on a 1:24,000-scale topographic map in the site identification step, and these areas will not be included for further consideration.

Rationale. General range maps depicting historical or possible distribution of the species and/or its important habitats will not be used to identify the areas of concern. These range maps are not precise enough and would result in large areas being dropped from consideration even though the species never has occupied or will occupy much of the area removed. At the site identification step, known areas can be plotted as precisely as the habitat requirements and, thus, boundaries of the species are known.

Definitions. Threatened or endangered species: those plants and animals officially listed in the Federal Register by the U.S. Fish and Wildlife Service. However, species listed by the states as rare, threatened, or endangered are not included (unless they are also on the Federal list) because they are not officially recognized by the NRC.

A.3.4 Biologically Important Areas

Portions of subareas/zones that were interpreted to be biologically important and highly sensitive to the short- or long-term effects of repository construction or operation are not considered suitable for siting. These areas were removed from further cnsidertion.

Relevance to Siting. The potential effect of the construction or operation of a repository on habitats of important species is considered in the NRC site review process. Such habitats include breeding, nesting, spawning, nursery, feeding, resting, wintering, or seasonal concentration areas and migration routes. Other areas may be considered biologically important because of their high biological productivity or commerical value, and attempts to site in these areas could delay licenisng.

Take out the 230 acres [illegible] [illegible] swamps.

Measure. The measure is the location of the biologically important area as precisely as it can be defined from features on the appropriate topographic maps or from published information. No setback from the boundary is considered.

Criteria and Approach. Biologically important areas are identified on 1:62,500- and 1:24,000-scale maps of candidate zones. Ecological features considered to be biologically important include freshwater marshes and bogs, "potholes" and other small freshwater ponds, and lowland riparian communities. These areas are plotted on transparent overlay maps. These biologically important areas are used to classify zones or sites according to a subjective scale of relative importance. The scale will be determined after data on the zones and sites are reviewed and biologically important areas identified.

Rationale. The above areas are considered to be important for the following reasons:

- Freshwater marshes and bogs are high primary productivity, feeding-resting-nesting areas for numerous kinds of birds;
- Lowland riparian communities have relatively high primary productivity, essential to the maintenance of water quality and quantity in streams and rivers, hence important to the maintenance of habitats for salmonids and other important aquatic species.

The NRC states:

"Important habitats are those that are essential to maintaining the reproductive capacity and vitality of populations of important species or the harvestable crop of economically important species..."

In general, the NRC staff will require detailed justification when the destruction or significant alteration of more than a few percent of important habitat types is proposed.

The reproductive capacity of populations of important species and the harvestable crop of economically important populations must be maintained unless justification for proposed or probable changes can be provided.

A.3.5 Existing Land Uses

Existing significant, specialty, or incompatible land uses are not considered to be suitable for repository siting and are removed from further consideration.

Relevance to Siting. The following general land-use considerations are evaluated in the NRC site review process: compatibility with existing land uses in the site vicinity, the potential effect of facility construction or operation on the productivity of specailty or prime crop land, and the potential visual or physical impact of a site on established or prospective public amenity areas.

Measure. The mapped or observed locations of certain land uses are considered.

Criteria. Based on an examination of large scale maps and available county or regional land-use plans, the existing land uses in each zone are evaluated. The evaluation considers the type, extent, and intensity of major land uses and includes an identification of land uses considered to be incompatible with a repository facility. These uses include restricted use areas, specialty and irrigated agriculture, urbanization, recreational and tourist areas, and major industrial facilities. These uses are plotted on maps of the zones, and removed from further consideration. This criterion is used to identify site localities.

Rationale. The segregation of major industrial facilities from incompatible land uses is an accepted principle of land-use management. The evaluation of present land use will be based on the professional judgment of an experienced land-use planner in consideration of regulatory positions of the NRC The land uses considered are characteristically the focus of specific NRC review in licensing proceedings. The NRC position on specialty agriculture is that sites that preempt the use of unusually productive land which is locally limited and regionally significant, or regionally limited and nationally significant, may not be suitable. Irrigated farmland, while more extensive than specialty cropland, may be interpreted as limited and regionally significant. Also, much of the new irrigation water in the study area is produced from wells; a continuation or extension of groundwater development at or adjacent to a repository site is considered to be an incompatible use. Certain nearby industrial facilities will be judged to be incompatible with a repository site, considering plume interaction with repository emission streams. A special case of this consideration is a nearby nuclear power plant, for which a minimum setback distance would be observed on the basis of radiological concentration limits.

Approach. Land uses such as those described above will be identified from large-scale maps, aerial photographs and field observation, plotted on maps of candidate zones and removed from further consideration.

A.3.6 Potential Significant or Incompatible Land Uses

Proposed or potential land uses of the types discussed in Section A.3.5 will be used as a basis for evaluating zones. This is a classifying criterion.

Relevance to Siting. See Section A.3.5.

Criteria. The evaluation will focus on agriculture. Non-agricultural uses that are proposed or planned and included in a public document will also be considered. For potential agricultural lands, four categories will be identified:

1) Potentially irrigable lands;
2) Arable soils;
3) Marginal soils;
4) Submarginal soils.

Submarginal soils will be considered to be more suitable for repository siting, followed by marginal soils, arable soils, and potentially irrigated lands (least suitable). The thrust of this classification system is to encourage sites to be selected away from areas that might be developed for agriculture in the future.

Rationale. See Section A.3.5. The heirarchy of land and soils types is used as a classifying criterion (rather than limiting) since it is inappropriate to predict the precise locations of agricultural uses far into the future. The criterion presents a range of siting choices, with emphasis on areas least likely to undergo cultivation in the future, and thereby least likely to be penetrated by wells developed for irrigtion purposes.

Approach. This criterion is applied on maps of sub-areas. Potentially irrigable lands will be identified from state university reports and maps describing the irrigation and groundwater development potential of the Columbia Plateau. Soil classifications will be taken from maps and reports of the Soil Conservation Service and state university departments of agronomy and soils. Land classifications will be mapped on overlays of sub-area maps; the mapped limits and the proportion of a zone occupied by a land classification will be used in the zone evaluations.

A.4 SYSTEM ECONOMICS

The considerations and criteria developed to meet the objective of minimizing system costs deal primarily with site preparation, both for the surface and in the subsurface. These considerations are either mappable or can be evaluated with the use of maps and, thus, lend themselves to the screening process.

A.4.1 Site Preparation Costs - Surface

A.4.1.1 Terrain Ruggedness

Areas characterized by predominantly rugged terrain are considered to have a relatively lower likelihood of containing suitable repository sites. Areas so identified are not retained for further study.

Relevance to Siting. The ruggedness of terrain at and around a site can materially affect the cost of site development. Areas with very steep slope and/or highly dissected topography are generally difficult to work in and develop. Such areas have a greater potential for extensive earthwork in site preparation, potentially difficult access for heavy equipment, potential difficulty in developing rail and road access to the site, and relatively higher potential for poor meteorological dispersion characteristics. High slope, high relief, and a high degree of dissection are considered to limit flexibity in choosing facility configurations.

Measure. The measure is a subjective assessment of terrain ruggedness, as judged from topographic maps of candidate areas.

Criteria. The topography of candidate areas are examined subjectively on relief maps and remote sensing imagery. Those portions of the study area showing a high degree of terrain ruggedness (high mountains, steep canyons, and highly dissected lands) will be judged to have a low potential of containing acceptable repository sites and will not be retained for further study.

Rationale. The identification of predominantly rugged areas will be based on professional judgment. The intent of such judgment is to define those areas which appear to have a relatively low potential of containing acceptable sites because of potential problems with site preparation, access, and meteorological dispersion.

Approach. Candidate areas will be examined on 1:250,000-scale maps; those portions judged to be excessively rugged will be outlined on overlay maps and removed form further consideration. As appropriate, guidelines for making this determination (such as maximum slope or gross elevation change per unit of distance) will be developed and used.

A.4.1.2 Usable Area

Sub-areas, candidate zones, and site localities are subjectively examined to delineate portions that have sufficient land area for a repository facility and that meet the kinds of subjective topographic criteria described above in Section A.4.1.1.

Relevance to Siting. Development of a repository is a major construction project, the economics and enviromental impact of which are sensitive to the amount and nature of earthwork required to prepare the site for mining activities and facilities placement. To the extent that it is practical to identify areas that require a mimimum of complicated preparation while possessing other generally desirable surface and subsurface characteristics, such areas should be preferred in evaluating sub-areas, candidate zones, and site localities.

Measure. The measure is a subjective assessment of topography, as judged from maps and direct field observation.

Criteria and Approach. Usable area is a classifying criterion, used to identify zones, site localities, and sites. Maps of sub-areas and zones will be examined subjectively, considering the relative effort and dominant cost factors that would be associated with slope, local relief, degree of dissection, size of available level and non-dissected areas, location and juxtapositon of such areas, potential sources of and distances to water supply and power, access, and the relative amount of excavation and fill that would be necessary to fit 1700 acres of surface facilities on the landscape. Portions of sub-areas and zones that appear from examination of maps to be highly favorable from the standpoint of these considerations will be delineated on overlay maps. Similar delineations will be made for modertely favorable and unfavorable areas. These areas are evaluated and enter into the identification of specific candidate sites and proposed configurations for surface facilities. In every case where delineations are made, a written description of the judgments and observations leading to the classifications are included in the project documentation.

Rationale. See Section A.4.1.1.

A.4.2 Site Preparation Costs - Subsurface

The subsurface preparation of the repository is studied to evaluate the relative ease and/or cost of site preparation and thus its suitability as a site.

Relevance to Siting. Excavation and mining at a proposed repository can significantly affect the overall cost of the repository. It is preferable to identify sites that tend to reduce the mining and excavation costs.

Measure. The measure selected to represent subsurface site preparation is a subjective evaluation of mining and excavation costs.

Criteria and Approach. Site localities are examined on the basis of thickness of overburden, depth of shafts, configuration and length of tunnels, excavated volume, etc. A subjective evaluation or classification is made of the site localities in terms of these parameters and candidate sites are preferentially identified.

Rationale. Because the data are general and the uncertainties in the data are high, a rigorous comparison of areas is not feasible. The subjective evaluation of subsurface site preparation costs, based on professional judgment, appears to be reasonable in light of the available data.

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Data Cataloging
First Draft

SITE LOCALITY IDENTIFICATION STUDY: HANFORD RESERVATION

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SUMMARY

Data compilation and cataloging for the candidate site locality identification study was accomplished through efforts in Task 4 in order to provide a retrieveable data cataloging system for the present siting study and future site evaluation and licensing processes. This task occurred concurrently with and also independently from the other tasks of the candidate site locality identification study. Work in Task 4 provided the data utilized primarily in the development and application of screening and ranking processes to identify candidate site localities on the Hanford Reservation.

The overall approach to Task 4 included two steps: data acquisition and screening and data compilation and cataloging. Data acquisition and screening formed the basis for preliminary review of data sources with respect to their probable utilization in the candidate site locality identification study and review with respect to the level of completness and detail of the data. The important working assumption was that the data to be used in the study be based on existing and available published and unpublished literature.

The data compilation and cataloging provided the basic product of Task 4: a retrievable data cataloging system in the form of an annotated reference list and key word index and an index of compiled data. The annotated reference list and key word index are cross-referenced and can be used to trace and retrieve the data sources utilized in the candidate site locality site identification study.

I. INTRODUCTION

1. GENERAL

Task 4 was formed as a concurrent but relatively independent task within the overall site identification study with the objective of providing a retrievable data cataloging system for the candidate site locality identification study and for future site evaluation and licensing processes. In particular, this consisted of the collection review and cataloging of existing data sources dealing with geology, seismology, tectonics, geotechnical engineering, ecology, land use, socioeconomics and so on for the Pasco Basin area and surrounding region. These existing data sources were utilized in part or entirely in the candidate site locality identification study and the collection and review of the data were geared to the data's usefullness to the siting study. The following report includes the approach and methodology used to compile and catalog the data sources as well as the results of the cataloging system. As an independent task in the site identification study Task 4 primarily provided input to Task 2, Developement of Screening and Ranking Guidelines, Task 5, Screening and Task 6, Ranking. In general, the data were collected as needed for each task and efforts in Task 4 occurred concurrently with the other tasks in the study. In addition, Task 4 provided a minor source of data for other tasks in the study. In addition, Task 4 provided a minor source of data for Task 3 Program Review. The relationship of Task 4 to other tasks is illustrated in Figure I-1.

For Task 2, the data acquired and compiled in Task 4 were used to develop the screening guidelines and provide preliminary information for development of possible ranking attributes for use in Task 6. Such data, dealing with geology, tectonics, geotechnical engineering and environmental science, were used to develop the consideration under the working objectives of the candidate site locality identification study. For each consideration, measures were developed and guidelines, or numerical values representing the measures, were formulated for use in screening. Examination and evaluation of the data collected in Task 4 provided the basis for the formulation of the numerical guidelines.

For Task 5, the data from Task 4 were used to apply the guidelines, developed in Task 2, to the screening maps and overlays. This involved compiling data maps, interpretative data maps and data compilation maps to which the guidelines were applied.

For Task 6, the Task 4 data were the primary source for developing and examining the issues and concerns under study for ranking and for finalizing the set of ranking attributes to be used. In addition, these data provided the basis for differentiating between the ranked set of candidate site localities.

2. KEY ASSUMPTIONS

Three key assumptions were used to direct the efforts in Task 4 and dealt with data availability, utilization and detail.

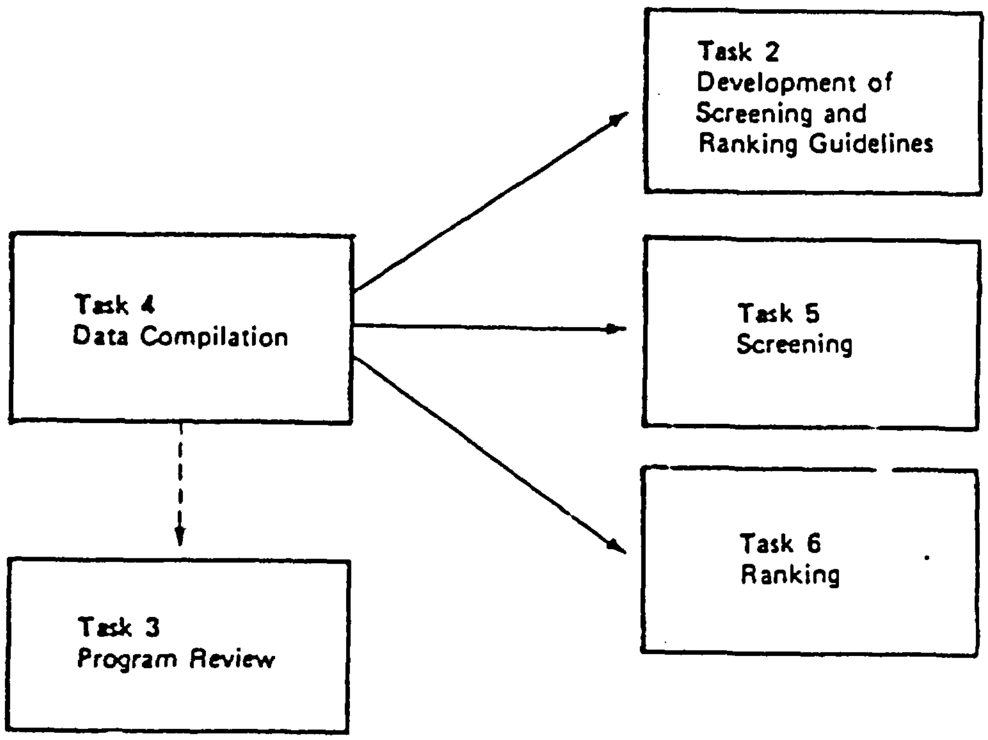

FIGURE I-1

RELATIONSHIP OF TASK 4 TO OTHER
TASKS IN THE SITE IDENTIFICATION STUDY

- The data to be collected, reviewed and cataloged in this task consist of readily available published and unpublished literature generated to the present date;

- The compilation and cataloging of the data will be primarily from the standpoint of their probable utilization in the siting process with the application of present-day technology;

- The coverage and detail of the data could vary depending upon the size of the area under study. The data utilized for a more regional assessment may not be the same as those used for assessing smaller areas such as candidate site localities.

3. OVERALL APPROACH

The overall approach to Task 4, Data Compilation, consisted of two basic steps: 1) data acquisition and screening and 2) data compilation and cataloging. However, prior to these basic steps, the basis for data acquisition, compilation and cataloging was formulated. It involved a preliminary examination of the amount, type and detail of the available data and provided information needed to scope the work in further steps in Task 4. The overall approach is illustrated in Figure I-2.

In the first step, existing bibliographies were examined to locate data sources considered useful to the site identification study. These sources were collected then screened to extract the data considered significant to the siting process. In addition, data not readily available from the literature were developed, through special studies involving limited analyses and literature evaluation for use in the site identification study.

In the second step, the data sources were compiled and cataloged in a retrievable cataloging system. Data compilations included data summaries and data map compilations which were used in the site identification process. The retrievable cataloging system includes an annotated reference list, a key word index and an index of compiled data which were also used in the study to provide for data traceability.

4. ORGANIZATION OF REPORT

This report presents the results of data compilation and cataloging beginning with Section I which includes the key assumptions, general approach and relationship of Task 4 to other tasks of the candidate site locality identification study. The approach and methodology for data acquisition and screening are discussed in Section II. Section III includes a description of the data compilation and cataloging systems used for data storage and retrieval. Appendixes A, B, C, and D include the annotated references, key word index, index of compiled data and a discussion of special studies respectively.

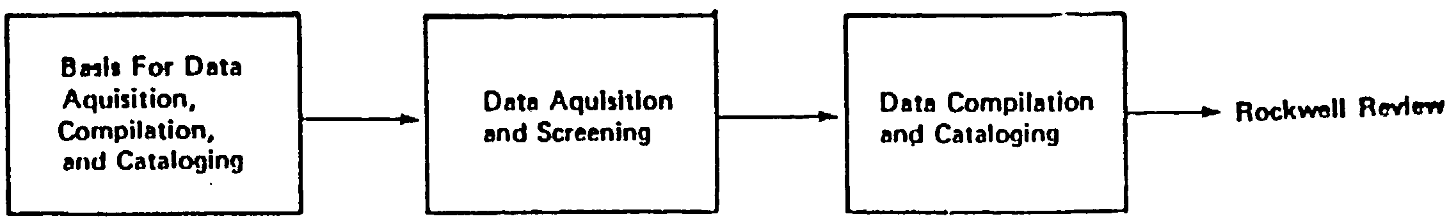

FIGURE I-2

OVERALL APPROACH TO TASK 4

II. DATA ACQUISITION AND SCREENING

1. GENERAL

The first step in Task 4 was data acquisition and screening. Using the key assumptions stated previously (Section I), the objectives of this step were to locate, acquire and screen those sources of data concerning geology, tectonics engineering, socioeconomics, enviromental science and so on based on their probably utilization in the siting process and also based on readily available published and unpublished literature. To achieve this purpose, bibliographies of available literature were scanned for promising articles which were collected. Literature was screened for its significance to the site identification study and pertinent articles were obtained or copied for the project library. Literature screening forms were filed in a notebook for later use in identifying candidate repository site localities and in developing a key word index and an annotated reference list.

2. APPROACH AND METHODOLOGY TO DATA ACQUISITION AND SCREENING

Three substeps were utilized in the approach and methodology to data acquisition and screening for the Pasco Basin and surrounding region:

- o Initial review of bibliographies to identify promising sources of data for utilization in the site identification study;
- o Secondary review of bibliographies and data sources to locate and obtain promising literature sources for utilization in the siting process;
- o Screening of the data sources to review and extract the information considered to be significant to the site identification study.

The initial review of bibliographies consisted of an examination of several bibliographies dealing with geology, geophysics, tectonics and other topics of the Pasco Basin and surrounding region of the Columbia Plateau (Summers and Schwab, 1978,Tucker and Rigby, 1978, Roberts, 1970, Roberts and others, 1973, Tucker, 1978, Reichert, 1969). These bibliographies, some of which contain map indexes, were scanned to compile an initial list of articles and maps to be gathered and reviewed (Figure II-1). Reference lists from pertinent literature were also checked. Using titles as the major guide, literature which appeared significant was ordered or borrowed from libraries.

The secondary review of the literature consisted of a visual examination of the data sources identified in the initial step, to determine whether the information contained within was applicable to the site identification study or could be utilized in the various tasks of the siting study. Those literature sources which appeared to be promising were retained for further use and placed in the project files. In both the initial and secondary review of the literature, extensive use was made of the libraries and associated reports available from Rockwell, Battelle and WPPSS.

Page from Tucker and Rigby, 1978

Bond, J. C., 1962, Geology of the Clearwater embayment in Idaho:
? Univ. of Washington, Ph.D. thesis.

Brown, R. E.; Brown, D. J., 1958, Surface of the basalt series in the
\+ Pasco Basin, Washington: (abs.) Bull. Geol. Soc. Am. v. 69, no. 12, pt. 2, p. 1677.

Coe, R. S.; Bogue, S.; Myers, C. W., 1978, Paleomagnetism of the Grande Ronde (Lower Yakima) Basalt exposed at Sentinel Gap: potential
\+ use for stratigraphic correlation: Rockwell-Hanford Operations Rept. RHO-BWI-ST-2, 24 p.

Culver, H. E.; Kirkham, V. R. D., 1927, General geology of eastern
— Washington and northern Idaho: Northwest Sci., v. 1, p. 25-30, map, 1:500,000.

Hubbard, P. S., 1968, Geology of the Saddle Butte quadrangle, Washington:
— Univ. of Hawaii, M.S. thesis.

Piper, C. V., 1905, The basalt mounds of the Columbia Lava: Science,
— new series 21, p. 824-825.

Portland General Electric Co., 1974, Pebble Springs Nuclear Plant Units 1 and 2, License Application, PSAR, section 2.5 - geology
✓ + and seismology, section 2.6 - references.

Reidel, S. P., 1978, The stratigraphy and petrogenesis of the Grande
? Ronde Basalt in the lower Salmon and adjacent Snake River canyons: Washington State Univ. Ph.D. thesis.

Shannon and Wilson, 1973, Geologic studies of the Columbia River Basalt and age of deformation, the Dalles - Umatilla region,
\+ Washington and Oregon, The Boardman Nuclear Project: Report to Portland General Electric Co., Portland, Oregon.

Steen-McIntyre, Virginia, 1977, A manual for tephrochronology-collection, preparation, petrographic description and approximate dating
— of tephra (volcanic ash): Published by the author, Box 1167, Idaho Springs, Colorado, 80452, 167 p.

Thayer, T. P.; Wagner, N. S., 1969, Geology of the Blue Mountain region:
? Oregon Dept. of Geol. & Min. Ind., Bull. 64, p. 68-74.

"?" may be useful

"+" marks possibly relevant article to be collected

"✓" article already in project files

"—" article does not appear to be useful

FIGURE II-1

EXAMPLE OF SCANNED BIBLIOGRAPHY PAGE

Screening of the data sources involved the development of a literature screening form for use in reviewing the significant data sources and summarizing the pertinent data. Two general forms were developed: one for geologic/tectonic and geotechnical purposes and one for environmental science purposes. The forms contain spaces to fill in the reference information, location of the study being described, relevance to the project, key words and a summary of the article. In addition, the forms for geologic studies contain space for specific information on stratigraphy, structure, hydrology and economic geology. A sample of how this form was used is illustrated in Figure II-2. The purpose of the forms was to summarize the type of data available, the amount of detail in each article or map and to provide a mechanism to trace data sources used in the site identification study. The literature screening forms are maintained in the project files and are continously updated as data is acquired.

A. Sample Screening Form

REPOSITORY SITING PROJECT ROCKWELL HANFORD Literature Screening Form	Area: Region ______ Reservation ____ Investigator: Date/Initial __________ Significant: Yes/No/Maybe __________

NOTE: Do not attempt to extract all relevant data - List the type and value of data the paper presents:

Author(s)/Date: ....

Title: ....

Publication/Report: ....

1. Regional Location (location map on page ___) ....
2. Key words: disciplines, groups or formations, and locations): ....
3. Stratigraphic data, maps, pages _____, cross sections, pages _____. (list key groups, formations and age dates, etc.) ....
4. Tectonics/structure/geophysics: maps, pages _____, cross sections, pages _____ (active faults, folds, volcanoes, etc.) ....
5. Hydrology: basin or aquifer maps, pages _____, logs/cross sections, pages _____. (surface runoff data, dams, gauging) ....
6. Economic geology: location map, page _____, cross section or log, page _____, mines, dollar value, gravel pit, wells, etc. mentioned on pages, ...
7. Summary: ....

B. Sample of Completed Form

REPOSITORY SITING PROJECT ROCKWELL HANFORD Literature Screening Form	Area: Region [illegible] Reservation [illegible] Investigator: Date/Initial [illegible] Significant: Yes/No/Maybe [illegible]

NOTE: Do not attempt to extract all relevant data - List the type and value of data the paper presents:

Author(s)/Date: Bretz, J H, Smith, Neff 1956

Title: Channeled Scabland of Washington: New Data and Interpretations

Publication/Report: G S A Bull., v 67, p. 957-1049

1. Regional Location (location map on page 962) [illegible] northeastern Columbia Plateau
2. Key words: disciplines, groups or formations, and locations): geomorphology glaciofluvial dep. Channeled Scablands surficial deposits Pasco Basin
3. Stratigraphic data: maps, pages many, cross sections, pages _____. (list key groups, formations and age dates, etc.) maps and descriptions of effects of glacial flood [illegible]
4. Tectonics/structure/geophysics: maps, pages _____, cross sections, pages _____ (active faults, folds, volcanoes, etc.) Pasco and Quincy Basins as enclosed structural depressions [illegible]
5. Hydrology: basin or aquifer maps, pages _____, logs/cross sections, pages _____. (surface runoff data, dams, gauging) many maps of channels surface drainage
6. Economic geology: location map, page _____, cross section or log, page _____, mines, dollar value, gravel pit, wells, etc. mentioned on pages, several economic gravel pits
7. Summary: [illegible] arguments against his theories. [illegible] maps and photos showing [illegible] of scabland features

FIGURE II-2

EXAMPLE OF USE OF LITERATURE SCREENING FORM

III. DATA COMPILATION AND CATALOGING

1. GENERAL

The data compilation and cataloging step provided the primary product of Task 4 work in the site identification study: a retrievable cataloging system useable during the siting study as well as through subsequent phases of the siting process. Basically, two types of data sources were utilized in the site locality identification study and included published and unpublished literature and compiled data summaries and data maps. To accomodate the available published and unpublished literature and catalog it in a retrievable manner two systems were utilized: an annotated list of references and a key word index. The annotated references (Appendix A) include all published and unpublished literature screened for use in the siting study. The key word index (Appendix B) was developoed to provide a cross-reference to the annotated reference list and to provide an additional method to enter the data cataloging system.

Data summaries and data compilation maps evolved from the review and evaluation of the available data sources. This information was used directly or indirectly in the various tasks of the candidate site locality identification study. In addition, where specific information could not be compiled from the existing data sources special studies were undertaken to develop data that could be utilized in the siting study. Appendix C includes an index of compiled data while Appendix D is a discussion of two special studies used to develop data.

2. DATA CATALOGING

2.1 Annotated References

The annotated reference list present in Appendix A, evolved as the need for data developed in each of Tasks 2, 5, and 6. As such the reference list was being continously updated throughout the site identification study. The annotations for each reference are based on the information extracted from the data screening forms discussed in Section II and are generally limited to the pertinent data utilized in the site identification study. Thus it is likely that other information may also be present in a given source of data but it was not considered to be significant to the present siting study. The numbers assigned to each reference in Appendix A were developed for cross-reference with the key word index and provide for reference list expansion by the use of decimal numbering.

The annotated reference list was designed to provide a system to trace the use of available published and unpublished data in the site identification study and retrieve a summary of the pertinent information. In addition, when used in conjunction with the filed literature screening forms, more detailed data can be retrieved.

2.2 Key Word Index

All the key words listed on the literature screening forms were compiled into a master list. The list was organized by topic into a preliminary key word list which was reviewed and evaluated for completeness and to eliminate possible redundancies. The preliminary key word index was finalized and resulted in the list presented in Appendix B. All available published and unpublished data sources (Appendix A) are listed by number in the key word index (Appendix B) under each key word used on the data screening form or an equivalent key word.

The key word index was designed to provide an additional source of entry into the annotated reference list and thus provide an additional method of tracing and retrieving sources of data. Using the key word index, a general topic and/or a known key word can be located and the appropriate or pertinent data sources can be traced. An example of how the key word index can be used is shown in Figure III-1.

2.3 Data Summaries And Compilations

Data from available, existing literature that could be mapped and used in the screening of Pasco Basin for Task 3 was compiled on overlays of the study area. Other maps were compiled to show where surface mapping had been done and where subsurface data existed. In addition, where information was needed, though not necessarily mapped information (eg: lithology, stratigraphic descriptions), notebooks and small scale maps were developed to organize and summarize the pertinent data on the Pasco Basin and region. The data compilations are placed on file and accompanied by references to sources, data summaries, working drafts and so on. Appendix C contains an index of the compiled data placed on file and used in to date in the screening of the Pasco Basin.

3. SPECIAL STUDIES

When neither the existing data sources nor the compiled data could provide necessary information for the various tasks of the siting study, special studies involving analyses and evaluations of the data were undertaken to obtain such information. These studies generally involved a review of existing literature plus the development of assumptions and subsequent analyses to reach conclusions necessary to provide the required information. Two such special studies undertaken were to 1) characterize estimated operational radiation releases from nuclear waste repositories and 2) characterize underground earthquake ground motion. Adequate information does not exist to characterize either of these subjects although they are of particular interest to the siting study in terms of the development of screening and ranking guidelines. Appendix D includes detailed discussions of the approaches and methodologies to the particular special studies of repository operational releases and underground earthquake ground motion.

1. SAMPLE TOPIC:
   Internal structures of basalt flows

2. LOCATE THE MOST APPROPRIATE KEY WORD.
   Key words are arranged in outline format under major subject headings.

3. ENTRY IN KEY WORD INDEX:

Intrabasalt structures 143 150 184 201 283 447

4. TURN TO APPENDIX A – ANNOTATED REFERENCES, AND LOCATE THE REFERENCES WITH THE NUMBERS ON THE KEY WORD INDEX.

Example from references

143. Hodges, C. A., 1978, Basaltic ring structures of the Columbia Plateau: Geological Society of America Bulletin, v. 89, p. 1281-1289.
The ring structure found in the Roza Member near Odessa is described and features are related to rising ground water as thick flows cooled over a topographic low.

150. Hoyt, C. L., 1961, The Hammond Sill-An intrusion in the Yakima Basalt near Wenatchee, Washington: Northwest Science, v. 35, no. 2, p. 58-64.
The basalt structures in western Douglas County are discussed. The Hammond Sill is an invasive sill with subsidiary dikes within the Rock Island interbed.

184. Long, P. E., 1978, Characterization and recognition of intraflow structures, Grande Ronde Basalt: Rockwell International, Informal Report RHO-BWI-LD-10, prepared for the U.S. Department of Energy, Contract EY-77-C-06-1030.
This report describes various intraflow structures in the Grande Ronde flows and their usefulness in correlating drill hole data.

201. McKee, B., and Stradling, D., 1970, The sag flowout: a newly described volcanic structure: Geological Society of America Bulletin, v. 81, p. 2035-2044.
This article describes the ring structures occurring in the Roza Member near Odessa, Washington. They were formed by fluid lava escaping along concentric dikes in the partly solidified flow.

283. Ryan, M. P., and Sammis, C. G., 1978, Cyclic fracture mechanisms in cooling basalt: Geological Society of America Bulletin, v. 89, p. 1295-1308.
This paper addresses the question of how hexagonal polyhedra are found and how vertical joints grow longer (crack tip deformation) in cooling basalts.

447. Waters, A. C., 1960a, Determining direction of flow in basalts: American Journal of Science, v. 258-A, p. 350-366.
A determination of flow direction using columnar joints, spiracles, pipe vesicles and cylinders, and primary foreset bedding in palagonite.

FIGURE III-1

EXAMPLE OF USE OF KEY WORD INDEX AND ANNOTATED REFERENCES

ANNOTATED REFERENCES

The following list of over 470 annotated references is the primary product of Table 4, Data Cataloging. The type and variety of the list reflects the data needs for the various tasks of the site locality identification study for the Pasco basin and surrounding region. The annotations for each reference are based on the information extracted from the literature screening forms (discussed in Section III) and as such are geared to present a summary of the information considered pertinent to the present siting study. Appendix A together with Appendix B (key word index), provide a cross-referenced cataloging system for the available published and unpublished literature used or condidered for use in the site locality identification.

1. Adam, J.A., and Rogers, V.L., 1978, A classification system for radioactive waste disposal--what waste goes where?: U.S. Nuclear Regulatory Commission, NUREG-0456.

This classification system is based on the premise that characteristics of radioactive waste should determine the waste disposal method employed.

2. The Aerospace Corporation, 1973a, Washington State Airport System Plan. Prepared for the Washington State Aeronautics Commission and the Federal Aviation Administration, ATR-73(7273)-1, v. 1.

This plan describes aviation facility needs in the State of Washington for the next 20 years. An inventory of aviation facilities identifies land use patterns in the vicinity of the state's airports.

3. The Aerospace Corporation, 1973b, Washington State Airport System Plan: Technical Supplement. Prepared for the Washington State Aeronautics Commission and the Federal Aviation Administration, ATR-73(7273)-1, v. 2, Part 1.

This report presents the planning study information that was developed during the preparation of the Washington State Airport System Plan. It identifies the procedures followed during development of information and presents data, plans and guidelines directed to county and local planners.

4. The Aerospace Corporation, 1973c, Washington State Airport System Plan: Technical Supplement, Prepared for the Washington State Aeronautics Commission and the Federal Aviation Administration, ATR-73(7273)-1, v. 2, Part 2.

This report describes the analyses performed during the planning study and the techniques employed in making the various forecasts. Appendices include the 1972 state aviation facility survey and description of data files.

5. Agapito, J.F., Hardy, M.P., and St. Laurent, D.R., 1977, Geo-engineering review and proposed program outline for the structural design of a radioactive waste repository in Columbia River basalts: Rockwell International report RHO-ST-6.

This geological engineering review program is for a proposed radioactive waste repository in Columbia Plateau basalts.

6. American Nuclear Society, Inc., 1978, Waste management: Nuclear News, v. 21, n. 11, p. 119-130.

A news article summarizing a public hearing on radioactive waste by an interagency task force. Federal proposals are briefly explained by legislators.

7. Anderson, J.V., and others, 1973, Correlation of Columbia River Basalt by geophysical techniques (abstract): Geological Society of America, abstracts with programs, v. 5, no. 1, p. 3.

Stratigraphic correlations, based on TiO_2 analysis, gamma and neutron logs, and driller's logs, were performed on the upper 500 feet of basalt in Horse Heaven plateau. Correlations were made for Wanapum and Saddle Mountains.

7.5. Armstrong, B.H., 1969, Acoustic emission prior to rockbursts and earthquakes: Bulletin of the Seismological Society of America, v. 59, no. 3, p. 1259-1279.

The acoustic emissions prior to earthquakes and rockbursts were examined. Transmission effects and the effect of anelastic absorption (Q-values) are considered. Indications are that highly stressed areas of mine workings may be identified through the monitoring of acoustics and earthquakes of the mined area.

8. Armstrong, R.L., Taubeneck, W.H., and Hales, P.A., 1977, Rb-Sr and K-Ar geochronometry of Mesozoic granitic rocks and their Sr isotopic composition, Oregon, Washington, and Idaho: Geological Society of America Bulletin, v. 88, p. 397-411.

Orogenic events occurred in the basement complex during Late Triassic to Early Jurassic (200 to 217 m.y.a.) in western Idaho; Late Jurassic (140 to 160 m.y.a.) in Oregon; and Late Cretaceous (70 to 100 m.y.a.) in the Idaho batholith.

9. Atlantic Richfield Hanford Company Staff, 1972, Bibliography of reports related to earthquake studies at Hanford, with synopses of individual reports: Atlantic Richfield Hanford Company, 77 p.

An annotated bibliography to earthquake studies performed at Hanford.

10. Atlantic Richfield Hanford Company, 1976, Preliminary feasibility study on storage of radioactive wastes in Columbia River Basalts: Document No. ARH-ST-137, v. 1 and v. 2, Richland, Washington.

The geologic, hydrologic, heat transfer and rock-waste compatability studies that were used in evaluating radioactive waste disposal sites in Columbia River Basalt are discussed. Stratigraphic correlations, degree of aquifer isolation, assessment of tectonism, heat transfer from radwastes, and geochemistry were studied.

11. Atomic Industrial Forum's Study Group on Waste Management, 1978, Spent fuel and nuclear waste: Atomic Industrial Forum, Inc., Washington, D.C.

A policy statement on storing spent nuclear fuels on a short term basis.

12. Baker, V.R., 1978, The Spokane flood controversy and the Martian outflow channels: Science, v. 202, p. 1249-1256.

The hypothesis regarding the Spokane flood and the development of the Scablands topography of the Columbia Plateau is presented, and the development of the Scablands is compared to the Martian outflow channels morphologic development.

13. Baker, V.R., and Nummedal, D., eds., 1978, The Channeled Scablands: Guide prepared by the National Aeronautics and Space Administration for the Comparative Planetary Geology Field Conference, June 5-8, 1978.

This is a compilation of papers on the Channeled Scablands physiographic region of eastern Washington. The geomorphology is thoroughly described and its inferred origin, including the hydrodynamics of high-velocity flood erosion, is discussed.

14. Baksi, A.K., and Watkins, N.D., 1973, Volcanic production rates: Comparison of oceanic ridges, islands, and the Columbia Plateau Basalts: Science, v. 180, p. 493-496.

Volcanic production rates for the Colulmbia River Basalts were two to three times that of volcanic island (oceanic) basalts. Lithospheric plate motions elsewhere along the North American Pacific plate margin is suggested to have triggered the event.

15. Baldwin, E.M., 1966, Geology of the Columbia River gorge: Northwest Science, v. 40, no. 4, p. 121-128.

This article discusses the Tertiary stratigraphy in the Columbia River gorge , specifically the Goble and Skamania Volcanics, Eagle Creek Formation, the Columbia River Basalts, Troutdale Formation, Sandy River Mudstone and the Dalles Formation.

16. Battelle Pacific Northwest Laboratory, 1967, Nuclear power plant siting in the Pacific Northwest: Report for the Bonneville Power Administration, Contract No. 14-03-67868, 50 p.

The general characteristics of Pacific Northwest areas selected as potential nuclear power plant sites are presented.

17. Battelle Pacific Northwest Laboratory, 1971, Bibliography of geological publications supported by the AEC, related to the Columbia River Thermal Effects Studies: BPNL, document no. BNWL-1543-VC-48.

These papers and publications deal almost exclusively with Salmonids, mainly regarding thermal effects and related topics. Most entries are from 1966 to 1970, but the bibliography covers the period of 1950 to 1970.

18. Battelle Pacific Northwest Laboratory, 1977, The Hanford 6-7 series, a volume of atmospheric field diffusion measurements: BNPL document no. PNL-2433.

Meteorological data obtained by taking atmospheric diffusion measurements in the Hanford Reservation area are presented.

19. Battelle Pacific Northwest Laboratory, 1979, Defense programmatic environmental impact statement for high-level waste: Release Scenario Analysis (Draft): Prepared for Rockwell Hanford Operations, Richland, Washington.

This draft report analyzes Rockwell Hanford Operations' disruptive release scenarios for high-level waste, as well as presenting additional scenarios.

20. Battelle Seattle Research Center, 1978, Tectonics and seismicity of the Columbia Plateau workshop: Battelle Tectonics Symposium, February 14-16, 1978, Basalt Waste Isolation Program - Rockwell Hanford Operations, Seattle, Washington.

This report summarizes the present knowledge on the Columbia River basalts and their tectonic setting, past and present.

21. Beaulieu, J.D., ed., 1972, Geologic formations of eastern Oregon: Oregon Department of Geology and Mineral Industries, Bulletin 73, 80 p.

A descriptive index of lithologies and mapping of formations in eastern Oregon is provided. (No geologic map is included.)

22. Beaulieu, J.D., ed., 1973, Geologic field trips in northern Oregon and southern Washington: Oregon Department of Geology and Mineral Industries, Bulletin 77, 206 p.

Pre-Columbia River Basalt formations in Oregon are discussed, including limited stratigraphic information on the Columbia River Plateau.

23. Beaulieu, J.D., 1978, Surficial geologic hazard concepts for Oregon: The Oregon Bin, v. 40, no. 3, p. 41-56.

Various types of surfical geological hazards are discussed with (non-referenced) examples.

24. Beck, M.E., Jr., 1978, Summary of tectonic models for the origin of the Columbia River Plateau: Paper presented at Battelle Tectonics Symposium, February 14-16, 1978, Seattle, Washington, 8 p.

This paper discusses several tectonic models and theories for the origin of the Columbia River Basalt.

25. Becraft, G.E., and Weis, P.L., 1957, Preliminary geologic map of part of the Turtle Lake quadrangle, Lincoln and Stevens Counties, Washington: U.S. Geological Survey, Mineral Inventory Field Studies, Map MF-135.

This map shows basement rock formations and surficial deposits. Very little of the Columbia River Basalt is exposed. No direct correlation of flows is given.

26. Becraft, G.E., and Weis, P.L., 1963, Geology and mineral deposits of the Turtle Lake quadrangle, Washington: U.S. Geological Survey, Bulletin 1131, 73 p.

This bulletin describes the structure, stratigraphy and mineral deposits in Lincoln and Stevens Counties on the northern edge of the Columbia Plateau. There are sparse exposures of the Columbia River Basalt and no direct correlations of the flows are made, however, there is data on basement and surficial deposits.

27. Beeson, M.H., and others, 1976, Preliminary correlation of Lower Yakima Basalt flows in western Oregon with the type area in central Washington (abstract): Geological Society of America Abstracts with programs, v. 8, no. 3, p. 353-354.

This abstract discusses the possible correlation of some Grande Ronde Basalt flows between central Washington and the Portland area.

28. Benson, L.V., 1978, Secondary minerals, oxidation potentials, pressure and temperature gradients in the Pasco Basin of Washington State: Topical Report No. 1: Lawrence Berkeley Laboratory, University of California at Berkeley, Contract No. EY-77-C-06-1030.

This report presents the lithostatic pressure-temperature versus depth gradients, oxidation potential measurements and interpretations, and a review of secondary mineralization phases present at depth in the Pasco Basin.

29. Bentley, R.D., 1977, Stratigraphy of the Yakima Basalts and structural evolution of the Yakima ridges in the western Columbia Plateau (Field Trip no. 12), in Geological Excursions in the Pacific Northwest, Geological Society of America 1977 Annual Meeting, Seattle, Washington, p. 339-389.

Stratigraphic and structural cross sections, field locations with descriptions, photographs and geologic maps of the western Columbia Plateau are provided.

30. Benton, Franklin, and Walla Walla County Air Pollution Control Board Staff, 1973, Regulation II - Air Quality Standards: Benton, Franklin, and Walla Walla County Air Pollution Control Board, Washington.

This document contains a listing of official air quality standards as of 1973 for Benton, Franklin, and Walla Walla counties, Washington.

31. Bierschenk, W.H., 1957, Hydraulic characteristics of Hanford aquifers: Hanford Atomic Products Operation, General Electric, Richland, Washington.

Three analytical techniques are applied to aquifer test data at Hanford: (1) non-equilibrium "type-curve" method, (2) non-equilibrium "straight-line" method, (3) "image well" technique. These techniques are described and discussed as they apply to the Hanford area aquifers.

32. Bingham, J.W., and Grolier, M.J., 1966, The Yakima Basalt and Ellensburg Formation of south-central Washington: U.S. Geological Survey Bulletin 1224-G, 15 p.

Type locations and a bibliography of measured stratigraphic sections are given for: (1) Saddle Mountain Basalt, (2) Roza member, (3) Sentinal Gap member, and (4) Frenchman Springs member. Basement rock is found at 4,600 feet near Odessa, Washington.

33. Bingham, J.W., Londquist, C.J., and Baltz, E.H., 1970, Geologic investigation of faulting in the Hanford region, Washington: U.S. Geological Survey, Open-File Report, 103 p.

The report states that the block gliding on the Smyrna bench last occurred at least 12,000 y.a. Gable Mountain fault is at least 40,000 years old and probably more than 100,000 years old, and the Wallula Gap fault is probably active.

34. Bingham, J.W., and Walters, K.L., 1965, Stratigraphy of the upper part of the Yakima basalt in Whitman and eastern Franklin Counties, Washington: U.S. Geological Survey Professional Paper 525c, p. C87-C90.

This paper discusses the stratigraphy of the Yakima Basalt and contains cross sections, tables and maps correlating flow members.

35. Bishop, W.P., and others, 1978a, Proposed goals for radioactive waste management: U.S. Nuclear Regulatory Commission, NUREG-0300.

For policy development, the goals for radioactive waste management are set forth with respect to time of nuclear use, management and permanent isolation, government organizations, costs, technical problems, health and safety.

36. Bishop, W.P., and others, 1978b, Essays on issues relevant to the regulation of radioactive waste management: U.S. Nuclear Regulatory Commission, NUREG-0412.

Essays discuss the history of radioactive waste management, credulity, methods, managerial errors, public participation, problems, and goals of radioactive waste management.

37. Blume, John A., and Associates, 1971a, A summary report, seismic evaluation and development of ground acceleration and response spectra for FFTF site. Report prepared for WADCO, Richland, Washington.

This summary report indicates a maximum credible earthquake on Rattlesnake-Wallula fault at M6.8 and acceleration of 0.25 g.

38. Blume, John A., and Associates, 1971b, Supplementary geologic investigations for seismic evaluation of the FFTF site near Richland, Washington. Report prepared for WADCO, Richland, Washington.

This summary geologic investigation report for the Hanford reservation evaluates seismicity hazards of the Fast Flux Test Facility (FFTF) site, geology and surface faulting.

39. Board, M.P., 1978, Rock mechanics methods and in situ heater tests for design of a nuclear waste repository in basalt: Rockwell Hanford Operations report RHO-Bull-LD-2, 49 p.

A discussion on how <u>in situ</u> data from the near surface test facility will be integrated into the overall Waste Isolation Program. The rock mechanics program is discussed.

40. Bond, J.G., 1962, Geology of the Clearwater Embayment in Idaho: Ph.D. thesis, University of Washington, Seattle, 193 p.

The tectonic development of the area is discussed, and stratigrahic information for the eastern Columbia Plateau and pre-basalt flow geology and topography are provided.

41. Bonini, W.E., Hughes, D.W., Danes, Z.F., 1974, Complete Bouguer gravity anomaly map of Washington: Washington Division of Geology and Earth Resources, map GM-11.

This gravity map has a 10 mgal contour interval showing 50 mgal readings near the Hanford area.

41.2. Boore, D.M., 1977, Strong-motion recordings of the California earthquake of April 1906: Bulletin of the Seismological Society of America, v. 67, no. 3, p. 561-577.

The values of inexpensive techniques to simulate ground motion are illustrated, and the importance of directivity and rupture velocity to the sensitivity of ground motion are shown.

41.4. Brekke, T.L., and Glass, C.E., 1973, Some considerations related to underground siting of nuclear power plants in rock. Department of Civil Engineering, University of California, Berkeley.

The importance of expansive coupling of system structures to floor, walls or roof of rock cavities are examined.

42. Bretz, J.H., 1933, The Channeled Scabland: Guidebook 22, Excursion C-2, International Geological Congress, 16th Session, U.S. Government Printing Office, 16 p.

A field guide to the glacial features and deposits of the Scablands, Columbia River Plateau.

43. Bretz, J.H., 1959, Washington's Channeled Scabland: Washington Division of Mineralogy and Geology, Bulletin no. 45, 57 p.

This bulletin describes the various flood features of the Channeled Scabland, discharge routes, and rates of discharge of the Channeled Scabland physiographic area.

44. Bretz, J.H., and others, 1956, Channeled Scabland of Washington: New data and interpretations: Geological Society of America Bulletin, v. 67, p. 957-1049.

This bulletin discusses several geomorphic features relating to Pasco and Quincy Basins and the overall Scabland physiographic area. Many maps and photographs that show outcrops in support of the catastrophic flooding theory are provided.

45. Brock, M.R., and Grolier, M.J., 1973, Chemical analysis of 305 basalt samples from the Columbia River Plateau, Washington, Oregon, and Idaho: U.S. Geological Survey, Open-File Report No. 1889.

A computer printout of geochemical data on Columbia River Basalt samples. Sample location listings are provided.

46. Brooks, W.E., Jr., 1974, Stratigraphy and structure of the Columbia River Basalt in t. : vicinity of Gable Mountain, Benton County, Washington: M.S. thesis, University of Washington, Seattle.

Data on the stratigraphy and structural geology of the Columbia River Basalt in the vicinity of Gable Mountain are presented.

47. Brown, C.E., and Thayer, T.P., 1966, Geologic map of the Canyon City quadrangle, northeastern Oregon: U.S. Geological Survey Miscellaneous Geologic Investigations, Map I-447.

This map shows Columbia River Basalt geology and general basement geology. A description of map units and the tectonics of the area are also presented.

48. Brown, D.J., 1965, Correlation of sediments overlying the Columbia River Basalt in southeastern Washington (abstract): Geological Society of America, Special Paper no. 82, p. 321.

This abstract discusses Late Tertiary and Quaternary sedimentation.

49. Brown, J.C., 1978, Discussion of geology and ground-water hydrology of the Columbia Plateau, with specific analysis of the Horse Heaven, Sagebrush Flat, and Odessa-Lind areas, Washington: Washington State University, College of Engineering, Research Report no. 78/15-23.

This report mainly discusses relationships of geologic units and structures to hydrology of the areas.

50. Brown, R.E., 1960, The use of geophysics and geochemistry to confirm geological interpretations of the Hanford works of the Atomic Energy Commission, U.S.A.: Twenty-first International Geological Congress, Copenhagen, part 2, p. 75-82.

A study of geohydrology at Hanford is provided for use in planning waste disposal.

51. Brown, R.E., 1965, Problems associated with the extension of the stratigraphic units of south-central Washington, Part 1: The late basalt flows, Ellensburg and Lower Ringold Formations: Presentation at Annual Meeting of the Northwest Scientific Association, Portland, Oregon, 11 p.

The geologic report provides information on stratigraphy of the Saddle Mountains Basalt, the Ellensburg Formation and lowest part of the Ringold Formation.

52. Brown, R.E., 1966, The stratigraphy of the uppermost part of the basalt sequence and its implications: Battelle Pacific Northwest Laboratory, BNWL-235, v. 3, p. 1-4.

This report provides some information on the near surface hydrology in the Beverly member of the Ellensburg Formation and the sequence of Tertiary-Quarternary folds in the Hanford area.

53. Brown, R.E., 1968a, The incidence of earthquakes at Hanford as deduced from geological features: Battelle Pacific Northwest Laboratory, BNWL-481, v. 3, p. 3-5.

This report discusses earthquakes, landslides and faulting. It is noted that major faulting occurs, and landslides are probably not triggered by earthquakes.

54. Brown, R.E., 1968b, The Yakima Basalt Formation and its relationships to the Columbia River in aquifer development: Battelle Pacific Northwest Laboratories, BNWL-481, v. 3, p. 1-2.

The influence of basalt flow advancement on the flow regime of the Columbia River is discussed. Due to basining, the former river course would return to the east, having been previously diverted to the west by advancing basalt flows.

55. Brown, R.E., 1968c, Reported faulting in the Pasco Basin: Battelle Pacific Northwest Laboratory, BNWL-SA-1704, 14 p.

This summary report emphasizes the role of active faulting and the role of folding of basalt in Pasco Basin. The role of faulting between Wallula Gap and Rattlesnake Hills is de-emphasized. The conclusion is made that faults associated with folds are aseismic.

56. Brown, R.E., 1968d, A study of reported faulting in the Pasco Basin: Battelle Pacific Northwest Laboratory, BNWL-662.

Faulting is secondary to folding, with maximum 500-foot offsets. Evidence for the Olympic-Wallowa Lineament or of very recent faulting was not found.

57. Brown, R.E., 1969, Hydrologic inter-area relationships as indicated by rising heads in confined acquifers, Pasco Basin, Washington: Battelle Pacific Northwest Laboratory, BNWL-SA-686.

This report contains diagrams of the complex hydrologic flow system with cross-sections showing changes in the configur-ation of anticlines and synclines during the period of deposition of the Saddle Mountains Basalt.

58. Brown, R.E., 1970a, Interrelationships of geologic formations and processess affecting ecology as exposed at Rattlesnake Springs, Hanford Project: Battelle-Pacific Northwest Labor-atory, BNWL-B-29, 39 p.

This report disagrees with other authors on previously hypothesized faults. It contains a description of drainage patterns, faults and other structural features.

59. Brown, R.E., 1970b, Some effects of irrigation in the Pasco Basin, Washington (abstract): Geological Society of America, abstract with programs, v. 2, no. 5, p. 326-327.

This abstract discusses some geological hazards (landslides, local flooding) resulting from irrigation in the Pasco Basin.

60. Brown, R.E., and McConiga, M.W., 1960, Some contributions to the stratigraphy and indicated deformation of the Ringold Formation: Northwest Science, v. 34, no. 2, p. 43-54.

The stratigraphy and structure of the Ringold Formation indicates gentle Quaternary folding towards the Pasco Syncline and post depositional warping of the Ringold and underlying basalt. Possible continuation of warping is suggested.

61. Brown, R.E., and Raymond, J.R., 1963, A geophysical seismic evaluation study of the Hanford Works, Washington: General Electric Co., Hanford Atomic Products Operation, report no. HW-SA-3280, 17 p.

This feasibility study tested the value of seismic methods for data compilation and correlation purposes. Results show the surface of the basalt and the Ringold Formation.

62. Brunton, G.D., and McClain, W.C., 1977, Geological criteria for radioactive waste repositories.

Listing of geological criteria and factors that can be used to derive specifications that will be applied to each step of a geological evaluation process.

63. Bush, J.H., and Siems, B.A., 1973, Basalt stratigraphy of the Jamestown Lake area, Douglas County, Washington (abstract): Geological Society of America, Abstracts with Programs, v. 5, no. 1, p. 19.

The stratigraphy of seven Columbia River Basalt flows (757 feet total thickness) is discussed in this abstract.

64. Bush, J.H., Jr., and others, 1972, Test-observation well near Mansfield, Washington, description, stratigraphic relationships and preliminary results: Washington State University, College of Engineering Research Report No. 72/11-128, Project No. 3811-1184.

Aquifer and stratigraphic data obtained in T27N, R26E Section 25 and nearby areas are presented.

65. Bush, J.H., Jr., and others, 1973, Test-observation well near Walla Walla, Washington: Description, stratigraphic relationships and preliminary results: Washington State University, College of Engineering Research Division, Research Report No. 73/15-66, Project No. 3811-1184.

This is a report describing aquifer data obtained in T6N, R35E, S18.

66. Byerly, G., and Swanson, D., 1978, Invasive Columbia River Basalt flows along the northwestern margin of the Columbia Plateau, north-central Washington: Geological Society of America, abstracts with programs, 1978, v. 10, p. 98.

Indicates invasive sills can be traced to surface flows showing gradational changes.

68. Camp, V.E., 1976, Petrochemical stratigraphy and structure of the Columbia River Basalt, Lewiston Basin area, Idaho-Washington: Ph.D. thesis, Washington State University, Pullman, 201 p.

Data on the stratigraphy and petrochemical correlation of Columbia River Basalts in the Lewiston Basin are presented. A generalized geologic map and discussion of the tectonic development of the area are also provided.

69. Campbell, N.P., 1975, A geologic road log over Chinook, White Pass and Ellensburg to Yakima highways: Washington Division of Geology and Earth Resources, Information Circular 54, 79 p.

This road log contains photographs and drawings of the western edge of the Basalt plateau and underlying formations.

70. Campbell, N.P., 1976, Geologic map of the Yakima area: Washington State Department of Natural Resources, Division of Geology and Earth Resources, map no. OF 76-11.

This large-scale geologic map of the Yakima area portrays geologic structures and stratigraphic units from the Grande Ronde Basalt to deposits of Quaternary age.

71. Carrell, D.J., and Jones, G.L., 1978, Proposed format and content of environmental report for deep geologic terminal repositories for radioactive material: Rockwell International-Hanford Document RHO-BWI-CD-18.

This document is Rockwell's proposed guide for preparation of environmental reports and is to be used as a basis for discussions with the NRC to develop a 4.2-type document for repositories.

72. Carter, L.J., 1978, Nuclear wastes. The science of geologic disposal seen as weak: Science, v. 200, pp. 1135-1137.

This article questions the scientific feasibility of disposing radioactive waste in geologic formations, especially salt formations.

73. Cline, D.R., 1969, Groundwater resources and related geology north central Spokane and southeastern Stevens Counties: State of Washington, Department of Water Resources, Bulletin No. 27.

The ground-water resources, primarily in unconsolidated Quaternary deposits in parts of Spokane and Stevens Counties, are discussed.

74. Cline, D.R., 1976, Reconnaissance of the water resources of the upper Klickitat River basin, Yakima Indian Reservation, Washington: U.S. Geological Survey, open-file report.

Well water data and general water resource information for the area are presented.

75. Coe, R.S., Bogue, S., and Myers, C.W., 1978, Paleomagnetism of the Grande Ronde (Lower Yakima) Basalt exposed at Sentinel Gap: Potential use for stratigraphic correlation: Prepared for U. S. Department of Energy, under contract EY-77-C-06-1030, Atomics International Division, Rockwell International-Hanford Operations Report RHO-BWI-ST-2.

This report describes the potential for age dating of basalt flows in the Columbia Plateau by paleomagnetic correlation.

76. Cohen, B.L., 1977, The disposal of radioactive wastes from fission reactors: Scientific American, v. 236, no. 6, p. 21-31.

This article describes the nature of radioactive wastes produced by reactors, evaluates their environmental impact, and outlines current plans for disposal in subsurface repositories.

77. Columbia Basin Interagency Committee, 1965, Bibliography of published climatological data, Columbia Basin states: Columbia Basin Interagency Committee, Portland.

This bibliography lists sources of published climatalogical data for the states of Washington, Idaho and Oregon.

78. Columbia-North Pacific Technical Staff, 1970a, Appendix IV: Land and mineral resources, comprehensive framework study: Submitted by Pacific Northwest River Basins Commission, Vancouver, Washington, 2 volumes.

In this report, climate, ground water, and surface water in the Columbia Plateau area are discussed.

79. Columbia-North Pacific Technical Staff, 1970b, Appendix V: Water resources, comprehensive framework study: Submitted by Pacific Northwest River Basins Commission, Vancouver, Washington, 2 volumes.

This report contains maps, charts, and tables describing land and mineral resources of the Columbia Plateau region.

80. Columbia-North Pacific Technical Staff, 1971a, Appendix IX: Irrigation, comprehensive framework study: Submitted by Pacific Northwest River Basins Commission, Vancouver, Washington.

This report summarizes the present status of, and future needs for irrigation in the Columbia drainage area. It includes detailed information regarding present and projected available water supplies, acreages under irrigation, and crop yields.

82. Columbia-North Pacific Technical Staff, 1971b, Appendix XII: Water Quality and Pollution Control, comprehensive framework study: Submitted by Pacific Northwest River Basins Commission, Vancouver, Washington.

This document describes existing water quality in the Columbia River-North Pacific area, the means for satisfying future water needs, flow requirements, treatment costs, and management practices.

83. Columbia-North Pacific Technical Staff, 1971c, Appendix XIV: Fish and wildlife, comprehensive framework study: Submitted by Pacific Northwest River Basins Commission, Vancouver, Washington.

This document describes freshwater wildlife species in the Columbia River-North Pacific region, the extent and quality of available habitats, and the demand for wildlife resources.

84. Committee on Radioactive Waste Management, 1978a, Geological criteria for repositories for high-level radioactive wastes: Panel on Geological Site Criteria from the Committee on Radioactive Waste Management, National Academy of Sciences, Washington, D.C., 19 p.

This report summarizes geologic, tectonic, hydrologic, geochemical and economic criteria for assessig the suitability of sites for storage or disposal of high-level radioactive wastes.

85. Committee on Radioactive Waste Management, 1978b, Radioactive wastes at the Hanford Reservation: A technical review: National Academy of Sciences, Washington, D.C., 269 p.

This document is a review of technological aspects of radioactive waste management at Hanford.

86. Cook, N.G., 1977, An appraisal of hard rock for potential underground repositories of radioactive wastes: prepared for the U. S. Department of Energy, Contract W-7405-ENG-48, University of California, Lawrence Berkeley Laboratory.

Potential engineering stress and stability factors, interaction between adjacent excavations, and the consequences of thermal loading are examined with respect to underground radioactive waste disposal in hard rock.

87. Cornwall, H.R., 1966, Nickel deposits of North America: U.S. Geological Survey Bulletin 1223.

This report contains descriptions of two small nickel deposits near Cle Elum and Winesap at the western edge of the Columbia Plateau.

87.5. Crosby, J.W., and Mellott, J.C., 1973, Physical characteristics of basalt aquifers: Completion report for OWRR project no. A-C21-WASH, Washington State University Water Research Center.

This report summarizes a research project which was conducted to ascertain the physical characteristics of basalts which influence transmission and storage of ground water.

88. Culver, H.E., and Lupher, R.L., 1937, The bearing of post-Paleozoic sedimentary record on the occurrence of gas in the Rattlesnake gas field, Washington: Northwest Science, v. 11, no. 3, p. 71-74.

This report discusses the occurrence and source of oil and gas in porous basalt near Wenatchee, Washington.

89. Cushing, C.E., and Watson, D.G., 1973, Aquatic studies of Gable Mountain Pond: Battelle Pacific Northwest Laboratory, BNWL-1884 UC-48.

Radiation levels were measured in fish, ducks, and other organisms at a Hanford Reservation cooling pond to assess ecosystem uptake of radioactive materials.

90. Danehy, E.A., and others, 1976, Structural elements of the Pasco Basin, south-central Washington (abstract): Geological Society of America, Abstracts with Programs, v. 8, no. 3, p. 366-367.

In the geologic structures in the Pasco Basin, minor faults were found, but no evidence of the reported Olympic-Wallowa lineament was cited.

91. Davis, N.F., 1947, Relief features of southern British Columbia, in Freeman, O.W., and Martin, H.H., eds., The Pacific Northwest: John Wiley and Sons, Inc., New York, p. 97-103.

A map and descriptions of physiographic features in southern British Columbia and a summary of the geologic history of the region are presented.

92. DeBuchananne, G.D., 1974, Geohydrologic considerations in the management of radioactive waste: Nuclear Technology, v. 24, p. 356-361.

This article discusses geohydrologic considerations for managing radioactive waste, including water's importance in transporting radioactive materials, considerations for near-surface and deep disposal, and uniformitarianism as a method for evaluating the geohydrologic suitability of waste disposal sites.

92.5. Deju, R.A., 1976, Feasibility of storing radioactive waste in Columbia River basalts: Atlantic Richfield Hanford Company, prepared for the U.S. Energy Research and Development Administration under contract EY-76-C-06-2130, No. ARH-SA-281.

This paper summarizes the results of an incomplete study that was conducted by the Atlantic Richfield Hanford Company to assess the feasibility of storing radioactive wastes in deep caverns constructed in the Columbia River Basalt.

93. Deju, R.A., 1977, Environmental assessment of near-surface test facility: Rockwell International-Hanford Operations, Letter Report R77-540A.

A brief description of the ecology at the near-surface test facility at Hanford is presented.

94. Deju, R.A., 1978, Evaluation of basalt flows as a waste isolation medium: Presented at 1979 Annual Meeting of the American Nuclear Society, Atlanta, Georgia, Rockwell International-Hanford Operations, report RHO-BWI-SA-16-A.

This paper briefly describes the Basalt Waste Isolation Program within Rockwell Hanford Operations and includes studies of geology, hydrology, systems integration, engineered barriers, engineering testing, and the construction of a near-surface test facility.

95. Deju, R.A., and others, 1977, Environmental factors needed to establish the geotechnical feasibility of storing radioactive waste in Columbia River Basalt: Rockwell International-Hanford Operations, Report RHO-ST-8.

The geologic and hydrologic factors that must be considered to assess the feasibility of storing radioactive waste in Columbia River Basalt are discussed. An extensive bibliography with several hundred entries is provided.

96. Deju, R.A., and others, 1978, Structural considerations in the design of a repository to store radioactive waste in basalt formations: Rockwell International-Hanford Operations, Report RHO-SA-10, 17 p.

Structural design considerations for radioactive waste repositories in basalt are discussed and the structural and thermo-mechanical properties of basalt are summarized.

97. deLaguna, W., 1962, Engineering geology of radioactive waste disposal: Reviews in Engineering Geology I, Geological Society of America, p. 129-160.

This paper contains one of the early literature discussions of the geologic requirements of a waste repository. An assumption of zero defects was implied, and a case was made for storage in salt formations, suposedly a "water-tight" media.

98. Diery, H.P., and McKee, B., 1969, Stratigraphy of the Yakima Basalt in the type area: Northwest Science, v. 43, no. 2, p. 47.

The geologic map and stratigraphic sections, covering the Ellensburg-Roza area, correlate many of the lower Yakima Basalt flows on the basis of lithologic and petrographic features.

99. Durrani, S.A., 1975, Nuclear reactor in the jungle: Nature, v. 256, no. 5515, p. 264.

The geologic environment, which concentrated a natural reactor fuel and caused a naturally moderated nuclear reactor to function, was briefly described. A change in concentration of nuclides in the Oklo mine lead to the discovery of the reactor. Since most fission products

remained in place for over 1.5 to 5 billion years, the phenomena has relevance to waste disposal problems: the plutonium generated by the reactor has hardly m

100. Easterbrook, D.J., Baker, V.R., and Waite, R., 1977, Glaciation and catastrophic flooding of the Columbia Plateau, Washington, (Field Trip No. 13), in Geological Excursions in the Pacific Northwest: Geologic Society of America, 1977 Annual Meeting, Seattle, p. 390-414.

This is a field guide to locations and descriptions of glacial and glacio-fluvial features on the Columbia River Plateau.

101. Eddy, P.A., 1970, Geology and ground-water availability, Selah area, Washington: State of Washington, Department of Ecology, Olympia, Washington.

The Ellensburg Formation is shown to provide the major portion of the ground water to the Selah area.

102. Eddy, P.A., 1976, Description, preliminary results, and pumping tests of test-observation well #13 near George, Washington: State of Washington Department of Ecology, Olympia, Washington, 43 p.

The hydrologic, stratigraphic and structural relations obtained from test well results are presented.

103. Farkas, S.E., 1971, Stratigraphic and structural analysis of Columbia River Basalt flows, Umtanum Ridge, Yakima and Benton counties, Washington (abstract): Geologic Society of America, Abstracts with Programs, v. 3, no. 6, p. 380.

The Umtanum flow is assessed to be greater than 400 feet near the base of Umtanum Ridge, and northward thrusting imbricate sheets are indicated on the ridge.

104. Farkas, S.E., 1972, Structural relationships of folds and faults in Yakima Basalt and Ellensburg Formation, central Washington (abstract): Geological Society of America, Abstracts with Programs, v. 4, no. 6, p. 375-376.

The variation in the number of flows in the Frenchman Springs member over the plateau area is discussed. From one to nine flows exist in various localities over the area. Normal faulting is shown in fold and thrust belts of the Wanapum Basalt and in the Ellensburg Formation.

106. Farooqui, S.M., and others, 1976, Structural implications of the Yakima Basalt in north central Oregon and south central Washington (abstract): Geological Society of America Abstracts with Programs, v. 8, no. 3, p. 372-373.

This abstract indicates the predominance of east-west and northwest structural trends, minor pre-Roza member deformation, minor pre-Selah member deformation and major post Elephant Mountain member deformation.

107. Federal Aviation Administration, 1978, Airport Statistics Handbook for 1977, Tower-Operated Airports: Advanced Technology, Inc., Report No. FAA-AVP-78-10.

A handbook of computerized listings of specific air traffic statistics including means, standard deviations, and peak occurrences computed for individual and multiple airport groupings. Histograms and time curves are presented for FAA towered airports.

108. Fenix and Scisson, Inc., 1978, Hole History of Rotary Hole DC-5, Hanford, Washington: report submitted to Rockwell Internatinal-Hanford (RHO-BWI-C-7).

This drilling and test boring report summarizes stratigraphic section intersected by boring DC-5: Top of the basalt at approximately 600 feet. The Vantage member is at approximately 2,600 feet. Total depth is 3,990 feet, in the Grande Ronde Basalt.

109. Fisher, R.V., 1967, Early Tertiary deformation in north-central Oregon: American Association of Petroleum Geologists Bulletin, v. 51, no. 1, p. 111-123.

Rock formations deposited prior to the Columbia River Basalt are presented in a structural framework.

110. Fitzner, R.E., and Price, K.A., 1973, The use of Hanford waste ponds by waterfowl and other birds: Battelle Northwest Laboratory, Special Distribution Report BNWL-1738.

Graphs and charts showing weekly and seasonal species counts are provided with summaries, lists and references of species.

111. Forrester, J.D., 1947, Rocky Mountain Province, in Freeman, O.W., and Martin, H.H., eds., The Pacific Northwest: John Wiley and Sons, Inc., New York, p. 80-96.

This outline summary of physiographic groupings or subprovinces within the Rocky Mountain physiographic province includes the Okanogan Highlands.

112. Foster, R.J., 1958, The Teanaway Dike Swarm of Central Washington: American Journal of Sciences, v. 256, p. 644-653.

Data on the pre-Columbia River Basalt tectonic setting of the western edge of the Columbia Plateau are provided.

113. Foxworthy, B.L., 1962, Geology and Groundwater Resources of the Ahtanum Valley, Yakima County Washington: U.S.Geological Society, Water Supply Paper 1598.

This hydrogeologic report discusses aquifers in the Ahtanum Valley.

114. Foxworthy, B.L., and Washburn, R.L., 1963, Ground Water in the Pullman area, Whitman County, Washington: U.S. Geological Survey Water-Supply Paper 1655.

Maps and cross sections of the Pullman area of Whitman County, Washington are provided.

115. Franklin, J.F., and others, 1972, Rattlesnake Hills Research Natural Area, separate from Federal Research Natural Areas in Oregon and Washington - A Guidebook for Scientists and Educators: Pacific Northwest Forest and Range Experiment Station, Portland, Oregon, 18 p.

The Rattlesnake Hills Research Natural Area was established for research and educational purposes. This area is ecologically significant because it is the last piece of natural shrubsteppe vegetation of this size in the Pacific Northwest.

116. Freeman, O.W., 1947, Columbia lava basins and plateaus, in Freeman, O.W., and Martin, H.H., eds., The Pacific Northwest: John Wiley and Sons Inc., New York, p. 59-79.

This is a simplified source reference for physiographical and geomorphological provinces, with a short geologic history, and a summation of regional geology.

117. Frutchter, J.S., and Baldwin, S.F., 1975, Correlations between dikes of the Monument Swarm, central Oregon, and Picture Gorge Basalt flows: Geological Society of America Bulletin, v. 86, p. 514-416.

A chemical analysis of dike swarms, many having composition similar to the Picture Gorge Basalt flows is presented. Tables and chemical data are also included.

118. Fryxell, R., 1962, A radiocarbon limiting date for Scabland flooding: Northwest Science, v. 36, no. 4, pp. 113-119.

A date of 31,600 ± 900 y.b.p. was obtained from peat deposits in glacial debris near Vantage. This debris was not from the most recent glacial flood.

119. Gard, L.M., and Waldron, H.H., 1954, Geologic map of the Starbuck Quadrangle, Washington: U.S. Geological Survey Map GQ-38.

This map shows Palouse soil and Columbia River Basalt.

120. Geological Society of America, 1977, Geological excursions in the Pacific Northwest: 1977 GSA Annual Meeting, Seattle, Field trips nos. 12 and 13.

This is a geologic field trip guidebook for northern Oregon and southern Washington.

121. Gibson, I.L., 1966a, Crustal flexures and flood basalts: Tectonophysics, v. 3, no. 5, p. 447-456.

The tectonics of the Columbia River Basalt in Southwest Idaho is discussed, and cross sections of flexures associated with volcanism and faulting are presented. Much of this information is out of date.

122. Gibson, I.L., 1966b, Grande Ronde dike swarm and its relation to the Columbia River Basalts (abstract): Geological Society of America, Special Paper 87, p. 204.

A swarm of 40 dikes, each approximately 35 feet thick, that cut the Columbia River Basalt may be feeder dikes to some lava flows.

123. Gilmour, E.H., and Stradling, D., eds., 1969, Proceedings of the Second Columbia River Basalt Symposium: Eastern Washington State College, Cheney, Washington, EWSC Press, 333 p.

This compilation of papers covers petrology, mineralogy, geochemistry, palynology and tectonics relating to the Columbia River Basalt.

124. Glass, C.E., 1977, Remote sensing analysis of the Columbia Plateau: Washington Public Power Supply System, Amendment 23, WPPSS Nuclear Projects 1 and 4, Appendix 2RK.

This is a final report discussing a three-part study utilizing remote sensing techniques in assessing the potential for earthquakes along active faults within the Columbia Plateau.

124.5. Goldstein, P., Hultgen, G.O., and Nelson, R.W., 1978, A model of contaminant diffusion from a finite line source in a dense basalt stratum to an overlying permeable interbed: Rockwell International-Hanford Operations report RHO-BWI-C-3, prepared by BCS Richland, Inc., Richland, Washington.

This report presents a mathematical model for the diffusion of radioactive wastes located in dense rock stratum bounded above and below by permeable interbeds.

125. Gray, D.A., and others, 1976, Disposal of highly-active, solid radioactive wastes into geological formations--relevant geological criteria for the United Kingdom: Republic Institute Geological Science, v. 76, no. 12, 4 p.

This series of _a priori_ criteria applies to the selection of areas containing formations suitable for the disposal of high level wastes within the United Kingdom.

126. Gray, J., and Kittleman, L.R., 1967, Geochronometry of the Columbia River Basalt and associated floras of eastern Washington and western Idaho: American Journal of Science, v. 265, p. 257-291.

Age dating and stratigraphic relations of the Latah Formation, Picture George Basalt, Columbia River Basalt, Ellensburg Formation and many unnamed flows in eastern Washington and western Idaho are discussed.

127. Greensfelder, R.W., 1976, Maximum probable earthquake acceleration on bedrock in the State of Idaho: Idaho Division of Highways Research project no. 79.

This summary report of Late Quaternary faulting in Idaho provides discussion of regional seismicity and levels of maximum probable accelerations.

128. Gregg, D.O., and Laird, L.B., 1975, A general outline of the water resources of the Toppenish Creek Basin, Yakima Indian Reservation: U.S. Geological Survey, Open File Report 75-19.

This report broadly summarizes the water resources and includes a water budget scheme and summary of the geology of the area.

129. Gregg, D.O., and Lum, W.E., II, 1973, Dry creek exploration test well: U.S. Geological Survey Open File Report, prepared in cooperation with the Confederated Tribes and Bands of the Yakima Indian Nation, 9 p.

This hydrogeologic report of the Dry Creek Basin is based on test well data. The drilling of the 700-foot test well revealed dense basalt flows and less dense interflow acquifer layers.

130. Griggs, A.B., 1973, Geologic map of the Spokane Quadrangle: U.S. Geological Survey, Miscellaneous Geologic Investigations Map I-768.

This map represents the geology of the Spokane area.

131. Griggs, A.B., 1976, The Columbia River Basalt Group in the Spokane Quadrangle, Washington, Idaho, and Montana: U.S. Geological Survey, Bulletin 1413, 39 p.

A series of cross sections show basalt thickness and underlying formations, and contains well log data and outcrop data of the area. Petrographic and geochemical analyses may be useful for flow correlations.

132. Grolier, M.J., and Bingham, J.W., 1969, Geology and ground-water condtions in parts of Grant, Adams and Franklin counties, Washington: U.S. Geological Survey, Professional Paper, with a section on chemical quality of the groundwater by A.S. VanDenburgh.

The authors discuss the geology and hydrology of the Ellensburg Formation, Wanapum Basalt, Saddle Mountains Basalt and the Ringold Formation.

133. Grolier, M.J., and Bingham, J.W., 1971, Geologic map and sections of parts of Grant, Adams and Franklin counties, Washington: U.S. Geological Survey Miscellaneious Geologic Investigations Map I-589.

Hydrologic, structural, and geologic data on the Columbia River Basalt, the Ringold and Ellensburg Formations are shown on this map.

134. Grolier, M.J., and Bingham, J.W., 1978, Geology of parts of Grant, Adams and Franklin Counties, east-central Washington: Washington Division of Geology and Earth Reserves Bulletin no. 71, 91 p.

This bulletin is the text to accompany Grolier and Bingham's 1971, U.S. Geological Survey Map I-589. It contains descriptions of stratigraphic units and structures.

135. Grolier, M.J., and Foxworthy, F.L., 1961, Geology of the Moses Lake north quadrangle, Washington: U.S. Geological Survey, Miscellaneous Geologic Investigations, Map I-330.

This geohydrologic map shows Quaternary stratigraphy, ground-water development data, and structure of the area.

136. Hamilton, W., 1962, Late Cenozoic structure of west-central Idaho: Geological Society of America Bulletin, v. 73, p. 511-516.

Possible tectonic creep on faults near Seven Devils Mountains (southeast border of the Columbia River Plateau) are inventoried. In the Columbia River plateau province normal faults strike west to northwest and some may indicate movement in the Quaternary period.

137. Hamilton, W., and Myers, W.B., 1966, Cenozoic tectonics of the Western United States: Reviews of Geophysics, v. 4, no. 4, p. 509-549.

This review presents very little data with respect to the Columbia River Plateau. The authors suggest that the western part of the plateau is underlain by oceanic crust.

137.5. Hardy, H.R., 1977, Some current applications of microseismic techniques: Proceedings of Dynamic Methods in Soil and Rock Mechanics (DMSR) 77/Karlsruhe, September 5-16, 1977, v. 3, p. 173-199.

Some techniques and applications of acoustic emission/microseismic activity to geomechanics for mining and other underground cavity excavations.

138. Hardy, M.P., St. John, C.M., and Hocking, G., 1978, Numerical modelling of rock stresses within a basaltic nuclear waste repository: Final report submitted to Rockwell International-Hanford Operations, Atomic International Division, Prime Contract EY-77-C-06-1030, Department of Energy.

This report summarizes the numerical modelling of rock stresses within a basalt rock nuclear repository for the Rockwell Hanford Operations. The types of thermo-mechanical problems analyzed using numerical models are identified and discussed.

139. Hedlund, J.D., and Rogers, L.E., 1976, Characterization of small mammal population inhabiting the B-C cribs environs: Battelle Northwest Laboratory, BNWL-2181-VC-11.

This is a bibliography of small mammal population studies on the Hanford reservation.

140. Hill, D.P., 1972, Crustal and Upper Mantle structure of the Columbia Plateau from long range seismic-refraction measurements: Geological Society of America Bulletin, v. 83, p. 1639-1648.

Previous seismic studies of the Columbia Plateau are compared to present study data.

141. Hinds, W.T., and Thorp, J.M., 1971, Annual summaries of microclimatological data from the Arid Lands Ecology Reserve, 1968-1970: Battelle Northwest Laboratory, Special Report BNWL-1629.

Air quality data tabulation of precipitation and temperature ranges on the Hanford reservation are presented.

143. Hodges, C.A., 1978, Basaltic ring structures of the Columbia Plateau: Geological Society of America Bulletin, v. 89, p. 1281-1289.

The ring structures found in the Roza Member near Odessa are described and features are related to rising ground water as thick flows cooled over topographic lows.

144. Hoffer, J.M., 1967, The Rock Creek Flow of the Columbia River Basalt: Northwest Science, v. 41, no. 1, p. 23-31.

A detailed report covers the physical and petrographic properties of the Rock Creek Member of the Grande Ronde Basalt. No correlation is made with other flows in the area.

145. Hogenson, G.M., 1964, Geology and ground-water of the Umatilla River Basin, Oregon: U.S. Geological Survey, Water Supply Paper no. 1620.

Basic well log and geologic data are provided, and structural relations of the basalt are described.

146. Holden, G.S., and Hooper, P.R., 1976, Petrology and chemistry of a Columbia River Basalt section, Rocky Canyon, west-central Idaho: Geological Society of America Bulletin, v. 87, p. 215-225.

The geochemistry and petrography of the Imnaha Basalt, and Columbia River Basalt are described.

147. Holmgren, D.A., 1969a, Columbia River basalt patterns from central Washington to northern Oregon: Ph.D. thesis, University of Washington, Seattle.

A multiple-criteria comparison of Columbia River Basalt near Yakima, Central Washington, and The Dalles, Northern Oregon is provided, and their successional identity is demonstrated.

148. Holmgren, D.A., 1969b, Columbia River Basalt stratigraphic pattern near Yakima and Columbia Gorge areas, Washington and Oregon (abstract): Geological Society of America Abstracts with Programs, v. 2, no. 3, p. 26.

The flow succession and magnetism near Yakima and The Dalles is summarized. Thickness was measured to be between 2,000 and 2,750 feet.

149. Hooper, P.R., and others, 1976, Magnetic polarity and stratigraphy of the southeastern part of the Columbia River Basalt Plateau (abstract): Geological Society of America Abstract with Programs, v. 8, no. 3, p. 383.

Paleomagnetic and stratigraphic data on the Columbia River Basalt of Southeastern Washington showed 9 polarity intervals thicknesses greater than 1,500 m of exposed basalt were indicated in the Snake River Canyon and Salmon River Canyon, and greater than 450 m of Imnaha Basalt.

150. Hoyt, C.L., 1961, The Hammond Sill-An intrusion in the Yakima Basalt near Wenatchee, Washington: Northwest Science, v. 35, no. 2, p. 58-64.

The basalt structures in western Douglas County are discussed. The Hammond Sill is an invasive sill with subsidiary dikes within the Rock Island interbed.

151. Hunt, C.B., 1974, Natural regions of the United States and Canada: W.H. Freeman and Company, 725 p.

The physiography, geology, stratigraphy, tectonics, and Quaternary geologic processes of the Columbia Plateau are summarized and the Spokane floods and regional erosion rates are discussed.

152. Huntting, M.T., 1949, Perlite and other volcanic glass occurrences in Washington: State of Washington, Department of Conservation and Development, Report of Investigations No. 17.

This is a report on perlite and other volcanic glasses occurring on the Columbia River Plateau.

153. Huntting, M.T., 1956, Inventory of Washington minerals, Part I: Metallic minerals: State of Washington, Department of Conservation and Development, Division of Mines and Geology, Bulletin no. 37, v. 1-Text, v. 2-Maps.

This report shows a deposit of gold and silver near Prosser. No other metallic minerals are shown on the Plateau.

155. Huntting, M.T., and others, 1961, Geologic map of Washington (1:500,000): Washington Department of Conservation, sheets 1 and 2, Division of Mines and Geology.

This map depicts and describes the geologic formations of this State of Washington.

156. Idaho Department of Highways, 1974, Official Highway Map.

This is the official Idaho state road map.

157. Idaho Department of Parks and Recreation, undated, Idaho State Parks and Recreation.

This map shows the locations of Idaho State Parks and provides information on specific parks.

158. Jackson, D.B., 1975, Description of the geoelectric section, Rattlesnake Hills Unit 1 well, Washington: Journal of Research, U.S. Geological Survey, v. 3, no. 6, p. 665-669.

The interpretive discussion of basalt stratigraphy is derived from electric log data. A major change in rocktype occurs between 4,000 and 7,000 feet in the Rattlesnake Hills well.

159. Jahns, R.H., 1967, Geologic factors relating to engineering seismology in the Hanford area, Washington: Prepared for Douglas United Nuclear, Inc., Richland, Washington, Report DUN-1300.

The recent seismicity in Saddle Mountains and Wallula Gap area is discussed. Evidence of recent faulting was examined. The report is essentially a rebuttal to Jones and Deacon, 1966.

160. Jones, F.O., and Deacon, R.J., 1966, Geology and tectonic history of the Hanford area and its relation to the geology and tectonic history of the State of Washington and the active seismic zones of western Washington and western Montana: Douglas United Nuclear, Inc., Richland, Washington, under consultant agreement CA-00056.

This literature review summarizes the geologic history, tectonics and seismicity of the Hanford area and provides structural cross sections and water and gas well data.

161. Jones, M.G, and Landon, R.D., 1978, Geology of the Nine Canyon map area: Rockwell International Informal Report RHO-BSI-LD-6, prepared for the U.S. Department of Energy, Contract EY-77-C-06-1030.

This is a detailed study of part of the southern Pasco Basin. Stratigraphy and structural geology of the Priest Rapids Member, Saddle Mountain Basalt, Ellensburg Formation, Quaternary deposits, and as well as the Rattlesnake Hills-Wallula Gap lineament and other folds and faults in the vicinity are discussed.

162. Jones, R.W., and Ross, S.H., 1972, Moscow Basin ground water studies (abstract): Idaho Bureau of Mines and Geology, Pamphlet no. 153.

163. Judson, S., and Ritter, D.F., 1964, Rates of regional denudation in the United States: Journal of Geophysical Research, v. 69 no. 16, p. 3395-3401.

This is a summary article of various regional rates of erosion or denudation throughout the United States. Included is the rate calculated for the Columbia Plateau, based on stream sediment calculations.

163.2. Kanai, K., Tanaka, T., and Yoshizawa, S., 1959, Comparative studies of earthquake motions on the ground and underground (multiple reflection problem): Bulletin of the Earthquake Research Institute, v. 37, p. 53-87.

Spectral analyses were carried out on seismograms of earthquakes recorded underground and at the surface of two mines. These analyses indicated that the amplitude on the ground increased relative to depth due to multiple reflection in the surface layer.

163.4. Kanai, K., and others, 1966, Comparative studies of earthquake motions on the ground and underground, II, Bulletin of the Earthquake Research Institute, v. 44, p. 609-643.

Empirical relations for strong motions in bedrock are compared to empirical data from recorded motions of 22 earthquakes. Velocity and acceleration apectra are shown for recordings from four stations.

163.6. Kaufman, S.K., Reuben, P.A., and Wyss, M., 1978, Focal mechanism and stress drops for mining-induced microearthquakes in Idaho (abstract): 74th Annual Meeting of the Seismological Society of America, October-December, 1978, v. 49, no. 4.

Focal mechanisms and stress drops have been determined for earthquakes occuring in an Idaho mine. Stress fields around the mine are compared to the regional field.

164. Keeney, R.L., and Nair, K., 1977, Evaluating potential nuclear power plant sites in the Pacific Northwest using decision analysis: Energy Policy, v. 5, no. 1.

The use of decision analysis in the selection and ranking of suitable future sites for nuclear power generating facilities in the Pacific Northwest is described.

165. Kienle, C.F., Jr. 1972, The Yakima Basalt in western Oregon and Washington (abstract): Geological Society of America, Abstracts with Programs, v. 4, no. 7, p. 561-562.

This paper discusses paleomagnetism, geochemistry, petrography and geomorphology as methods of stratigraphic correlation of the Columbia River Basalt.

166. Kienle, C.F., Jr., Bentley, R.B., and Anderson, J.L., 1977, Geologic reconnaissance of the Cle Elum-Wallula lineament and related structures: Shannon and Wilson, Inc., Portland, Oregon, Report no. WNP-1/4, 33 p.

Each structural feature along the CLEW is described, and detailed mapping of several areas in the Yakima Ridges area is provided. A model for structural deformation is discussed.

167. Kienle, C.F., Jr., and others, 1978, Western Columbia Plateaus tectonic structures and their age of deformation: Paper presented at Battelle Tectonics Symposium, February 14-16, 1978, Seattle, Washington.

Tectonic features of the plateau are described and the ages of deformation are approximated using dated volcanics and sedimentary deposits.

168. Kohler, J.E., Kennecke, A.P., and Grimes, B.K., 1974, Population distribution considerations in nuclear plant siting: American Nuclear Society Conference, August 1974.

A method for calculating a site population factor, which measures cumulative population distribution around nuclear power plant sites, is presented. A distance decay function that simulates average atmospheric diffusion of radionuclides released from power reactors is used in this method.

169. Kuno, H., 1969, Plateau Basalts, in Hart, P.J., ed., Earth's Crust and Upper Mantle: American Geophysical Union, Washington, D.C., p. 495-501.

The tectonics of the Plateau Basalts are discussed along with a proposed mechanism for slow and continuous magma genesis of the Columbia River Plateau Basalts.

170. Laubscher, H.P., 1977, Structural analysis of post-Yakima deformation, Columbia Plateau, Washington (draft): Geological Institute, University of Basel, Basel, Switzerland.

This draft report develops a model to explain the post-Miocene deformational style of the Columbia Plateau.

171. Laval, W.N., 1956, Stratigraphy and structural geology of portions of south-central Washington: Ph.D. thesis, University of Washington, Seattle, 208 p.

Mapping, measured sections, and correlations of middle and upper basalt in the Horse Heaven Hills area are presented.

172. Laval, W.N., 1957, Primary structures of the Columbia River Basalt flows, south-central Washington (abstract): Geological Society of America Bulletin, v. 68, p. 1867.

The flow structures in Wanapum and Saddle Mountains basalt are discussed.

173. Laval, W.N., 1958, Anticlines of the southwestern Columbia Basin (abstract): Geological Society of America Bulletin v. 69, no. 12, pt. 2, p. 1734.

The structural geology and history of the southwestern Columbia Basin are discussed.

174. Lawrence Livermore Laboratory, 1978, Draft environmental impact statement, high-level waste repository site suitability criteria: Prepared by Tera Corporation, Berkeley, California.

This report discusses the various types of environmental impacts of a high-level waste repository. It includes draft site suitability criteria.

175. Ledgerwood, R.K., and Deju, R.A., 1976, Hydrogeology of the uppermost confined aquifers underlying the Hanford Reservation: Atlantic Richfield Hanford Company, ARH-SA-253, 27 p.

This comprehensive hydrogeology report contains tables of transmissibility and conductivity and well log data and structural interpretations on the upper confining aquifers underlying the Hanford Reservation.

176. Ledgerwood, R.K., Myers, C.W., and Cross, R.W., 1978, Pasco Basin stratigraphic nomenclature: Rockwell International-Hanford Operations, RHO-BWI-LD-1.

This chart and discussion of the stratigraphic nomenclature and age dating parameters of the Columbia River Basalt and younger units in the Pasco Basin uses the most current data available.

178. Ledgerwood, R.K., and others, 1973, Identification of Yakima Basalt flows in the Pasco Basin: Atlantic Richfield Hanford Co., Report no. ARH-2768.

This report discusses techniques used in correlating stratigraphy of the Yakima Basalt flow members in the Pasco Basin. Drill cores, geophysical logs and geochemical data were analyzed. Cross sections across the Pasco Basin summarize the flow stratigraphy.

179. Lillie, J.T., and Richard, B.H., 1977, An analysis of selected gravity profiles on the Hanford Reservation, Richland, Washington: Rockwell International-hanford Operations, Report RHO-BWI-C-6.

Two dimensional models were constructed using gravity values. Indications of buried valleys cut into bedrock were found; however, distinguishing these valleys from sedimentary contacts would be difficult.

180. Lillie, J.T., Tallman, A.M., and Caggiano, J.A., 1978, Preliminary geologic map of the Late Cenozoic sediments of the western half of the Pasco Basin: Rockwell International, Informal Report RHO-BWI-LD-8, prepared for the U.S. Department of Energy under Contract EY-7¯-C-06-1030.

This is a detailed (1 mile to 1 inch) map of Quaternary deposits in the Pasco Basin.

181. Lindsley, D.H., 1960, Geology of the Spray Quadrangle, Oregon: Ph.D. thesis, Johns Hopkins University, Cleveland, Ohio, 235. p.

This thesis primarily discusses the stratigraphy and petrography of the Picture Gorge Basalt and its magnetic properties and the stratigraphy of the early Tertiary Clarno and John Day Formations.

182. Livingston, T., 1978, Origin of the Grand Coulee and Dry Falls: Washington Geologic Newsletter, v. 6, no. 3.

The geology and geomorphic processes relating to the development of some of the structures in the Columbia Plateau are discussed.

184. Long, P.E., 1978, Characterization and recognition of intraflow structures, Grande Ronde Basalt: Rockwell International, Informal Report RHO-BWI-LD-10, prepared for the U.S. Department of Energy, Contract EY-77-C-06-1030.

This report describes various intraflow structures in the Grande Ronde flows and their usefulness in correlating drill hole data.

185. Lowry, W.D., and Baldwin, E.M., 1952, Late Cenozoic geology of the Columbia River Valley, Oregon and Washington: Geological Society of America, Bulletin, v. 63, p. 1-24.

This bulletin focuses only on the westernmost portion of the Columbia Plateau and summarizes the Late Cenozoic geologic history of the area.

186. Luzier, J.E., 1969, Ground water occurrence in the Goldendale area, Klickitat County, Washington: U.S. Geological Survey, Hydrologic Investigations Atlas HA-313.

This is a general geologic map and a water level contour map. Well logs of the Goldendale area are included.

187. Luzier, J.E., Bingham, J.W., and Burt, R.J., 1969, Ground water survey, Odessa-Lind area, Washington: Washington State Department of Water Resources, Water Supply Bulletin No. 36.

This bulletin presents generalized hydrogeologic data from the Odessa-Lind area, Washington.

188. Luzier, J.E., and Burt, R.J., 1974, Hydrology of basalt aquifers and depletion of ground water in east-central Washington: U.S. Geological Survey, Water Supply Bulletin No. 33.

This bulletin presents hydrologic characteristics of the basalt aquifers in east-central Washington, the variability of heads in different aquifers, and recharge-discharge rates. Ground-water barriers may be related to tectonic structures.

189. Mackin, J.H., 1961, A stratigraphic section in the Yakima Basalt and the Ellensburg Formation in south-central Washington: Washington Division of Mines and Geology, Report of Investigations, no. 19, 45 p.

A stratigraphic history is presented of the Wanapum Basalt and Ellensburg Formation within the area bounded at corners by Yakima, Ellensburg, Vantage, and Priest Rapids.

190. Maddox, George and Associates, Inc., 1978, Groundwater hydrology and proposed water management policy--Quincy and Odessa subareas: Report (Job no. 77-08101) prepared by George Maddox and Associates, Inc., Yakima, Washington, for Eastern Big Bend Resources.

The discovery of hydraulically discontinuous structural aquifers invalidates water management policies promulgated by the State of Washington.

191. Maddox, G.E., and Fox, F.M., and Associates, Inc., 1976, A proposed structural control of surface and groundwater in the eastern portion of the Columbia River Basalt: Geological Society of America, Abstracts with Programs, v. 8, no. 3.

Markedly different transmissibility values on each side of a hypothesized lineament may be indicative of structurally controlled groundwater flow.

192. Malde, H.E., 1968, The catastrophic Late Pleistocene Bonneville flood in the Snake River Plain, Idaho: U.S. Geological Survey Professional Paper 596, 52 p.

The glacial flood deposits and paths along the Snake River in Idaho are discussed.

193. Matsuda, T., 1976, Empirical rules on sense and rate of recent crustal movements: Journal of the Geodetic Society of Japan, v. 22, no. 4, p. 252-263.

This article compares geologic evidence of Quaternary rates of uplift, folding, and horizontal strain with geodetic data of recent crustal movements in Japan. Sample calculations are made for the rate of anticlinal folding.

194. Mattinson, J.M., 1972, Ages of zircons from the northern Cascade Mountains, Washington: Geological Society of America Bulletin, v. 83, p. 3769-3784.

Two metamorphic events that occurred in the Northern Cascades during the middle Paleozoic (approximately 415 m.y.a.) and in the Late Cretaceous period are examined. The rock formations remained deeply buried into the Eocene epoch and some may be as old as 2 billion years.

195. Maynard, W.S., and others, 1976, Public values associated with nuclear waste disposal: Battelle Memorial Institute, Human Affairs Research Centers, Seattle, Washington, Document No. BNWL-1997.

This report summarizes public response to a questionnaire on nuclear waste disposal issues, such as, long and short term safety, accident detection/recovery, and cost factors.

196. McCarthy, G.J., and Grutzeck, M.W., 1978, Preliminary evaluation of the characteristics of nuclear wastes relevant to geologic isolation in basalt:

This report reviews and discusses physical and chemical characteristics of radioactive waste. This information has bearing on the concept of geologic storage in basalt.

197. McCarthy, G.J., and others, 1978, Hydrothermal stability of spent fuel and high-level waste ceramics in the geologic repository and environment: Rockwell International-Hanford Operations, Report RHO-BWI-SA-12A.

This abstract focuses on waste-rock hydrothermal interaction and closed system waste-water reaction in basalts and shales.

198. McDougall, I., 1976, Geochemistry and origin of basalt of the Columbia River Group, Oregon and Washington: Geological Society of America Bulletin, v. 87, p. 777-792.

The strontium ratios of coeval coastal basalts and Columbia Plateau basalts are the same; different parent magmas gave rise to the Picture Gorge and the Grand Ronde and Wanapum basalts.

198.2. McGarr, A., 1971, Violent deformation of rock near deep-level: Tabular excavations-seismic events, Bulletin of the Seismological Society of America, v.F 61, no. 5, p. 1453-1466.

Modeling that uses two-edge dislocations are presented for elastic deformation of the rock near the edges of thin tabular excavations (stopes) of deep-level mines. The results compare favprably to energies released during observed tremors.

198.4. McGarr, A.M., and Wiebols, G.A., 1977, Influence of mine geometry and closure volume on seismicity in a deep-level mine (abstract): International Journal of Rock Mechanics, Mineral Sciences and Geomechanics, v. 14, p. 139-145.

Seismicity and volume of closure relationships are studied in three mines. Indications are that by planning mine geometrics, problems associated with large tremors can be kept to a predictable level by controlling the convergence.

198.6. McGarr, A.M, Green, R.W., and Spottiswoodie, S.M, 1978, Strong ground motion of tremors recorded in a deep mine (abstract): 74th Annual Meeting of the Seismological Society of America, October-December, 1978, v. 49, no. 4.

Accelerogram recordings were analyzed for event location, peak acceleration, stress drop and magnitude.

199. McGhan, V.L., Myers, D.A., and Damschen, D.W., 1976, Hanford wells: Battelle Pacific Northwest Laboratories, prepared for the U.S. Energy Research and Development Administration, Contract E(45-1):1830, Report BNW1-1981.

General information on wells drilled on the Hanford reservation is provided; however, data from wells, such as depth to basalt or purpose of well, are not included.

201. McKee, B., and Stradling, D., 1970, The sag flowout: a newly described volcanic structure: Geological Society of America Bulletin, v. 81, p. 2035-2044.

This article describes the ring structures occurring in the Roza member near Odessa, Washington. They were formed by fluid lava escaping along concentric dikes from the partly solidified flow.

202. Mercer, J.W., and Orr, B.R., 1977, Review and analysis of hydrogeologic conditions near the site of a potential nuclear-waste repository, Eddy and Lea Counties, New Mexico: U.S. Geological Survey, Open-File Report 77-123, 35 p.

This report focuses on hydrology, salt beds and radioactive waste management in southeast New Mexico; it provides no relevant information on Basalt.

203. Miller, F.K., and Engels, J.C., 1975, Distribution and trends of discordant ages of the plutonic rocks of northeastern Washington and northern Idaho: Geological Society of America Bulletin, v. 86, p. [illegible]7-528.

This report contains information on four episodes of intrusion during the Mesozoic and Cenozoic eras. The major events occurred during mid-Cretaceous and early Eocene. Useful information is provided regarding pre-basalt tectonic setting.

204. Milne, P.C., and Walker, C.W., 1978, Directory of Washington mining operations for 1977: State of Washington, Department of Natural Resources, Division of Geology and Earth Resources. Information Circular No. 63.

This directory summarizes and identifies metallic and non-metallic mining operations in the State of Washington, by name of operator, product, and property (mine) location.

204.5. Milne, C., and Vonheeder, E.R., 1979, Metallic and nonmetallic mineral exploration and mining highlights, 1978: Washington Geologic Newsletter, v. 7, no. 1, Washington Department of Natural Resources.

This publication summarizes metallic and nonmetallic mineral exploration, including a discussion of energy exploration, in the State of Washington.

205. Moen, W.S., 1978, Mineral resource maps of Washington: Washington Department of Natural Resources, Division of Geology and Earth Resources, Map GM-22.

This publication contains several location maps and provides up-to-date information. Few economic mineral deposits are on the Columbia Plateau except sand, gravel, rock and diatomite.

206. Molenaar, D., 1968, A geohydrologic reconnaissance of northwestern Walla Walla County, Washington: Washington Department of Water Resources, Monograph No. 1.

A reconnaissance map of Eureka Falt and vicinity, Washington, showing locations and hydrologic data.

207. Molenaar, D., 1977, Outline of the Water Resources of the Satus Creek Basin, Yakima Indian Reservations, Washington: U.S.Geological Survey, Open File Report 76-808.

The general hydrology and a water budget analysis of the area are presented.

208. Monahan, C.J., 1962, John Day lock and dam: Foundation investigations: Journal of the Power Division Proceedings of the Society of Civil Engineers, v. 3344, no. 4, p. 29-45.

Engineering and geology studies of foundation conditions are described for a 5-mile section of the lower Columbia River, near the western edge of the Columbia River Plateau.

209. Monahan, C.J., 1969, Reservoirs in volcanic terrain: Association of Engineering Geologists Bulletin, v. 6, no. 1, p. 53-60.

Requirements of and guidelines for investigating reservoirs, including lava flow characteristics and their effects on structural permeability, are discussed.

210. Myers, C.W., 1973, Yakima Basalt flows near Vantage and from core holes in the Pasco Basin, Washington: Ph.D. thesis, University of California, Santa Cruz.

This thesis provides detailed stratigraphic, petrographic, and chemical information on the Grande Ronde and Wanapum Basalt, including the Museum Basalt, Frenchman Springs Basalt, Roza Basalt, Ginko, Sand Hollow, and Sentinal Gap flows and/or members.

211. Myers, D.A., 1972, Test-observation well near Davenport, Washington, description and preliminary results: U.S. Geological Survey, Open-File Report, 23 p.

This well description contains very little stratigraphic information, but identifies several aquifers.

212. Nair, K., and others, 1975, An approach to the siting of nuclear power plants in siting of nuclear facilities: International Atomic Energy Agency.

This report describes a regional approach to nuclear power plant siting by using exclusionary criteria (i.e., active faults, population centers) to eliminate areas from consideration and identify likely candidate areas. Candidate sites are then ranked by decision analysis methods.

213. National Academy of Sciences, 1978, Radioactive wastes at the Hanford reservation; A technical review: Document No. ISBN 0-309-02745-3, Washington, D.C., 269 p.

The radioactive wastes at Hanford are briefly characterized, and storage facilities, equipment and methods are summarized. This report suggests that a deep repository in basalt may be preferable to the present methods of surface storage.

214. National Geographic Society, 1977, Wild and Scenic Rivers Map of the United States: Supplement to National Geographic, July 1977, v. 152, no. 1--Wild and Scenic Rivers of the United States, p. 2a.

This is a series of schematic location maps of national and state wild and scenic rivers (designated and proposed).

215. National Oceanic and Atmospheric Administration, 1979, Seattle Sectional Aeronautical Chart, 1:500,000 scale: U.S. Department of Commerce.

Airports, jet routes and restricted airspace of the Pacific Northwest are shown on this map.

216. National Research Council, 1978, Geologic criteria for repositories for high-level radioactive wastes: National Academy of Sciences pamphlet, Wasnington, D.C.

Criteria for high-level radioactive waste disposal sites are presented. The factors considered were related to host-rock geometry, long-term stability, hydrology, geochemistry and economics.

217. Newcomb, R.C., 1951, Preliminary report on the ground-water resources of the Walla Walla Basin, Washington-Oregon: U.S. Geological Survey, Open-File Report.

This report contains basic well inventory, well log and water level data from the Walla Walla Basin.

218. Newcomb, R.C., 1958, Ringold Formation of Pleistocene age in type locality, the White Bluffs, Washington: Washington Division of Mineralogy and Geology, reprint no. 1 (from American Journal of Science, v. 256, p. 328-340).

This report describes the Quaternary stratigraphy and geology of the Ringold Formation.

219. Newcomb, R.C., 1961a, Structural barrier reservoirs of ground water in the Columbia River Basalt: U.S. Geological Survey Professional Paper 424-B, p. B213-B215.

The upper Cold Creek Valley, Walla Walla Valley at College Place structural ground water barriers are discussed.

220. Newcomb, R.C.b, 1961, Age of the Palouse Formation in the Walla Walla and Umatilla River Basins, Oregon and Washington: Northwest Science, v. 35, no. 4, p. 122-127.

The Palouse Formation is differentiated from younger loess. It is of Middle to Late Pleistocene age, and closely follows the Ringold deposition and pre-Wisconsin glacial stage.

221. Newcomb, R.C., 1961c, Storage of ground water behind subsurface dams in the Columbia River Basalt, Washington, Oregon, and Idaho: U.S. Geological Survey, Professional Paper 383-A, 15 p.

This is a good general paper on the permeability of faults, structural ground-water reservoirs, and fault barriers in synclinal basins of the Columbia River Basalt.

222. Newcomb, R.C., 1965, Geology and ground-water resources of the Walla Walla River Basin, Washington-Oregon: Washington Division of Water Resources, Water Supply Bulletin no. 21.

This is a hydrogeologic bulletin of the Walla Walla River Basin. Well inventories and stratigraphic descriptions of the Columbia River Basalt, Pleistocene clays and gravels, and Ringold and Palouse Formations are provided.

223. Newcomb, R.C., 1966, Lithology and eastward extension of the Dalles Formation, Oregon and Washington, U.S. Geological Survey, Professional Paper 550-D, p. 59-63.

This paper correlates the Dalles Formation to parts of the Arlington Lake Beds, Shutler Formation and Pliocene fanglomerates, suggesting an Early to Middle (?) Pliocene age for the Dalles Formation.

224. Newcomb, R.C., 1967, The Dalles-Umatilla syncline, Oregon and Washington: U.S. Geological Survey, Professional Paper 575-B, p. B88-B93.

This paper describes the structure of the Dalles-Umatilla syncline and the stratigraphy of the area.

225. Newcomb, R.C., 1969, Effect of tectonic structure on the occurrence of groundwater in the basalt of the Columbia River Group of the Dalles area, Oregon and Washington: U.S. Geological Survey, Professional Paper 383-C, 33 p.

The geohydrology of the Columbia River Group and general tectonics which influence ground-water parameters in the Dalles area are described. The mapped area includes White Salmon, the Dalles and Wishram Quadrangles. Many maps and cross sections are provided.

226. Newcomb, R.C., 1970, Tectonic structure of the main part of the basalt of the Columbia River Group, Washington, Oregon, and Idaho: U.S. Geological Survey, Miscellaneous Geological Investigations Map I-587.

This is a tectonic map showing fold axes, faults, Quaternary basins of deposition and extent of the Columbia River Basalt.

226.5. Newcomb, R.C., 1971, Geologic map of the proposed Paterson Ridge pumped-storage reservoir, south-central Washington: U.S. Geological Survey, Miscellaneous Geological Investigations Map I-653.

This is a geologic map of the resrvoir area with a general description of the geology and a discussion of the stratigraphic and petrographic characteristics of the bedrock.

227. Newcomb, R.C., 1972, Quality of the ground water of the Columbia River group, Washington, Oregon and Idaho: U.S. Geological Survey, Water Supply Paper 1999-N, p. N1-N71.

This regional ground-water quality investigation has implications on transit time, transit path, location and mechanism of recharge for the Columbia River Basalt group.

228. Newcomb, R.C., Strand, J.R., and Frank, F.J., 1972, Geology and ground-water characteristics of the Hanford Reservation of the U.S. Atomic Energy Commission, Wasnington: U.S. Geological Survey, Professional Paper 717, 78 p.

This paper describes the geologic and hydrologic characteristics of the Hanford Reservation. Geologic structures and stratigraphy are correlated with ground-water characteristics. Maps, including cross sections, are provided.

229. Newcomb, R.C., and others, 1953, Seismic cross sections across the Spokane River Valley and Hillyard trough, Idaho and Washington: U.S. Geological Survey, Water Research Division, Tacoma, Washington, Open-File Report.

Basic seismic data, showing profiles and velocities of valley fill, Latah Formation, glaciofluvial deposits, and basement rock of the area, are presented.

230. Norris, J.A., 1974, Selected environmental considerations and their measuring parameters: Paper presented to the American Nuclear Society, Portland, Oregon.

This paper provides a general discussion of selected environmental considerations, (ecology, land use, aesthetics, water supply, meteorology) with regard to nuclear power plant siting.

231. Northwest Energy Policy Project, 1978, Energy Futures Northwest, Northwest Energy Policy Project: Final report, sponsored by Pacific Northwest Regional Commission, Vancouver, Washington.

An overview of energy policy options, available to the Pacific Northwest states, that might influence future patterns of energy production and consumption in the region.

233. Oak Ridge National Laboratory, 1972, Federal waste repository, site selection factors and criteria: Internal Report, central file number 72-3-4. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Problems concerning "criteria" for construction of radioactive waste repositories in salt are discussed in this report.

234. Office of Waste Isolation, Union Carbide Corporation, 1976, National waste terminal storage program information meeting: Union Carbide Corp., Office of Waste Isolation, Oak Ridge, Tennessee, v. I, Y/OWI/TM-11/1.

This booklet contains a short discussion of Union Carbide Corporation's (UCC) project to find repositories in various rock formations. It also contains abstracts or copies of view-graph slides relating to early in-house and subcontracted investigations administered by OWI (a branch of UCC). Much of the emphasis is on repositories in salt or shale formations.

235. Office of Waste Isolation, Union Carbide Corporation, 1977, Conceptual design criteria for facilities for geologic disposal of radioactive waste in salt formations: (Y/OWI/TM-9), Union Carbide Corporation, NP Engineering, Oak Ridge, Tennessee, Document No. X-OE-17 (Y/OWI/TM-9).

This document contains both general and specific criteria for the facilities and systems for a repository built in salt.

236. Olson, T.M., 1975, Geology and groundwater resources of part of Harryman and Marshall Creek drainage basins: M.S. thesis, Eastern Washington State College, Cheney, Washington.

Approximately 1000 existing wells provide yields of several hundred gallons per minute from basalt rock in Spokane County. Less than 25 gallons per minute are provided from wells tapping overlying sediments.

237. Oregon Department of Transportation, 1974b, Oregon Parks Map: Travel Information Section, Oregon Department of Transportation, Salem, Oregon.

This map shows the general locations of federal, state and county parks and land areas of inherent scenic, historic, recreational and economic quality.

238. Oregon Department of Transportation, 1974a, Official Highway Map of Oregon, State Shighway Division, Oregon Department of Transportation, Salem, Oregon.

This highway map shows culturally important and land use areas such as highways, airports, and state parks.

239. Oregon Department of Transportation, 1974c, Summary of Oregon aviation system plan: Oregon Department of Transportation and Oregon Aeronautics Division, Salem, Oregon.

This is a listing of specific air traffic statistics for airports grouped in Oregon.

240. Packer, D.R., 1978, Review of paleomagnetic studies of the Columbia Plateau Basalts: Paper presented at Battelle Tectonics Symposium, February 14-16, 1978, Seattle, Washington.

Various paleomagnetic studies that have been conducted on the Columbia Plateau Basalts are discussed and reviewed.

241. Patton, P.C., and Baker, V.R., 1978, New evidence for pre-Wisconsin flooding in the channeled scabland of eastern Washington: Geology, v. 6, p. 567-571.

This paper presents stratigraphic evidence for the pre-Wisconsin flood history of the chanelled scabland in the eastern portion of the State of Washington.

242. Patwardhan, A.S., Tocher, D., and Savage, E.D., 1975, Relationships between earthquake magnitude and length of fault rupture surface based on aftershock zones (abstract): Geological Society of America Abstracts with Programs, v. 7, no. 3, p. 419.

This paper presents empirical data from aftershock zones, relating fault rupture length and rupture surface to earthquake magnitude.

243. Pearson, H.E., 1973, Test-observation well near Paterson, Washington, description and preliminary results: U.S. Geological Survey, Water Resources Investigations 9-73, 23 p.

Information presented includes data on aquifer characteristics and water quality obtained from a test-observation well in Benton County, Washington.

244. Pearson, R.C., and Obradovich, J.D., 1977, Eocene rocks in northeastern Washington - radiometric ages and correlation: U.S. Geological Survey, Bulletin 1433, 41 p.

This article describes the Eocene basement rocks in the Okanogan Highlands region of northeastern Washington.

245. Peck, D.L., 1961, Geologic map of Oregon west of the 121st meridian: U.S. Geological Survey, Miscellaneous geologic investigations Map I-325.

This is a regional geologic map of Oregon, west of the 121st meridian, and includes cross sections.

246. Pitt, A.M., 1972, Seismic activity in the Hanford region, Washington, March 23, 1969 to June 30, 1971: U.S. Geological Survey, Open-File Report 72-298.

This report contains the preliminary results from the U.S. Geological Survey seismograph network for the Hanford area during time period March 23, 1969 to June 30, 1971. Distribution, number, and magnitude of earthquakes are discussed, and events are listed.

247. Portland General Electric Company, 1974, Pebble Springs nuclear plant: Preliminary Safety Analysis Report, v 2.

This volume contains detailed maps and geologic information on the study area for the Pebble Springs Nuclear Plant in Oregon.

248. Pratt, H.R., Hustrulid, W.A., and Stephenson, D.E., 1978, Earthquake damage to underground facilities: Prepared by DuPont-Savannah River Laboratory, Aiken, S. Carolina for U.S. Department of Energy, Report AT(07-2)-1.

The use of ground motion measurements of nuclear explosions are discussed to provide constrainsts on parameters important for siting an underground nuclear waste repository. Seismological data (primarily from Japan) on ground motions (underground relative to above ground) are examined.

249. Price, C.E., 1961, Artificial recharge through a well tapping basalt aquifers, Walla Walla area, Washington: U.S. Geological Survey, WSP 1594-A.

This paper provides a general stratigraphic description of the Walla Walla valley in Washington. The transmissivity of the local basalts and the effects of artificial recharge on the Columbia River Basalts are discussed.

250. Price, D., Hart, D.H., and Foxworthy, B.L., 1962, Artificial recharge in Oregon and Washington: U.S. Geological Survey, WSP 1594-C.

This article provides a brief description of artificial recharge operations in Oregon and Washington.

251. Price, S.A., 1977, An evaluation of dike-flow correlations indicated by geochemistry, Chief Joseph Swarm, Columbia River Basalt: Ph.D. thesis, University of Idaho, Moscow.

This thesis presents the results of a detailed study of geochemical correlation of basalt flows and dikes in the eastern Columbia Plateau, Oregon. Stratigraphic information on basalt flows within the formations and information on tectonic development of the area are provided.

252. Price, W.H., and Fecht, K.R., 1976a, Geology of the 241-AX Tank Farm: Atlantic Richfield Hanford Company, document no. ARH-LD-128, Prepared for the U.S. Energy Research and Development Administration Under Contract E(45-1)-2130.

This is an informal geologic report with accompanying maps of the 241-AX Tank Farm on the Hanford Reservation, Washington.

253. Price, W.H., and Fecht, K.R., 1976b, Geology of the 241-B Tank Farm: No. ARH-LD-129, Prepared for the U.S. Energy Research and Development Administration Under Contract E(45-1)-2130.

This is an informal geologic report with accompanying maps of the 241-B Tank Farm on the Hanford Reservation, Washington.

254. Price, W.H., and Fecht, K.R., 1976c, Geology of the 241-BX Tank Farm: No. ARH-LD-130, Prepared for the U.S. Energy Research and Development Administration, Contract E(45-1)-2130.

This is an informal geologic report with accompanying maps of the 241-BX Tank Farm on the Hanford Reservation, Washington.

255. Price, W.H., and Fecht, K.R., 1976d, Geology of the 241-BY Tank Farm: No. ARH-LD-131, Prepared for the U.S. Energy Research and Development Administration Under Contract E(45-1)-2130.

This is an informal geologic report with accompanying maps of the 241 BY Tank Farm on the Hanford Reservation, Washington.

256. Raiffa, H., 1968, Decision Analysis, Introductory Lectures on Choices Under Uncertainty: Addison-Wesley Publishing Co., Reading, Massachusetts.

This is a textbook on decision analysis methods and applications.

257. Raisz, E., 1945, The Olympic-Wallowa lineament: American Journal of Science, v. 243A, p. 479-485.

This article presents surface evidence for the Olympic-Wallowa lineament in the State of Washington, and traces its course on a physiographic map.

258. Raymond, J.R., 1957, A pumping system for ground-water aquifer evaluation tests: Hanford Laboratories Operation, General Electric Company, Richland, Washington, Report No. HW-51171.

This report describes pumping and related equipment chosen for quick and accurate performance tests for determining aquifer characteristics at the Hanford Reservation.

259. Raymond, J.R., 1978, Hydrologic support to Department of Waste Isolation, RHO-completion report for subtask 2: Battelle Pacific Northwest Laboratory, Seattle, Washington.

This report contains Landsat enhanced imagery that would be useful for differentiating land use types. Structural and hydrologic data on Kittitas County are also provided.

260. Raymond, J.R., and Tillson, D.D., 1968, Evaluation of a thick basalt sequence in south central Washington--geophysical and hydrological exploration of the Rattlesnake Hills deep stratigraphic test well: Battelle Pacific Northwest Laboratory, Seattle, Washington Report BNWL-776.

This report presents the data, findings, and interpretations of a detailed geophysical and hydrological exploratory study of the Rattlesnake Hills deep stratigraphic test well in south-central Washington.

261. Reichert, S.O., and Fenimore, J.W., 1964, Lithology and hydrology of radioactive waste-disposal sites, Savannah River Plant, South Carolina, in Engineering Geology Case Histories 1-5, Geological Society of America, p. 295-316.

This article discusses the techniques used to determine and map the lithology, structure, and hydrology of the areas chosen for radioactive waste disposal at the Savannah River Plant, South Carolina. Results obtained from using the techniques and conclusions regarding the radiological safety are also included.

262. Reichert, W.H., 1969, Compilation of geologic mapping in Washington through 1968: Open file report prepared by the Washington Department of Natural Resources, Geology and Earth Sciences Division, Olympia, Washington.

This is an index to geologic maps for the State of Washington (through 1968).

263. Reidel, S.P., 1978a, Geology of the Saddle Mountains between Sentinel Gap and 119o30 Longitude: Rockwell International, Informal Report RHO-BWI-LD-4, prepared for the U.S. Department of Energy, Contract EY-77-C-06-1030.

This report presents the results of a detailed study of the structure, stratigraphy, and geochemistry of the Saddle Mountains area.

264. Reidel, S.P., 1978b, The stratigraphy and petrogenesis of the Grande Ronde Basalt in the lower Salmon and adjacent Snake River Canyons: Ph.D. thesis, Washington State University, Pullman.

This thesis deals primarily with the petrology, petrochemistry, and petrogenesis of Grande Ronde Basalt. Data on stratigraphy and flow correlations are prepared.

265. Richard, B.H., and Deju, R.A., 1977, Three-dimensional gravity investigation of the Hanford Reservation; Rockwell International-Hanford Operations, Report RHO-BWI-C-5, 112 p.

This report presents the results of a gravity study conducted at the Hanford Reservation and provides mapped locations of anticlines and synclines in the area.

266. Richard, B.H., Lillie, J.T., and Deju, R.A., 1977, Gravity studies of the Hanford Reservation, Richland, Washington: A report prepared for Rockwell International-Hanford Operations, Report RHO-BWI-C-4, contract EY-77-C-06-1030.

In this report Cold Creek snycline is remapped to the west of a previously mapped location at the south end of the reservation. The Umtanum anticline is mapped as being continuous to Richland. The Pasco syncline is not shown.

267. Rigby, J., and Tucker, G., 1978, Basalt [NUCLEAR] waste isolation program: Washington Geologic Newsletter, Department of National Resources, Division of Geology and Earth Resources, v. 6, no. 2.

This report provides a brief summary of the U.S. Department of Energy's Basalt Nuclear Waste Isolation Program. In particular, the study and mapping efforts of the Quaternary deposits of the Columbia Basin (except Pasco Basin) are summarized through July 1979.

268. Rigg, G.B., 1958, Peat resources of Washington: State of Washington, Department of Conservation, Division of Mines and Geology, Bulletin No. 44.

This article discusses peat resources in Grant, Lincoln, and Spokane Counties, Washington, that exist as deposits found in former scabland lake beds.

269. Ringe, D., 1970, Sub-loess basalt topography in the Palouse Hills, southeastern Washington: Geological Society of America Bulletin, v. 81, p. 3049-3060.

This article discusses the structural relief of sub-loess basalt in the Palouse Hills area of southeastern Washington.

270. Roberts, M., 1973, Bibliography of the geology and mineral resources of Oregon (fourth supplement): Oregon Department of Geology and Mineral Industries, Bulletin no. 67.

This bibliographical index of publications, theses, open-file reports, and unpublished materials focuses on the geology and mineral resources of Oregon for years 1956-1960.

271. Roberts, M.S., and Steere, M.L., and Brookhyser, C.S., 1973, Bibliography of the geology and mineral resources of Oregon (fifth supplement): Oregon Department of Geology and Mineral Resources, Bulletin no. 78.

This bibliographical index of publications, theses, open-file reports focuses on the geology and mineral resources of Oregon for years 1961-1970.

272. Robinson, C.F., 1966, Stratigraphy and structural geology of Antanum Ridge, Yakima, Washington: M.S. thesis, University of Washington, Seattle.

This thesis discusses the stratigraphy and structure of the Antanum Ridge, which is on the western portion of the Columbia River Plateau. General descriptions of units and structure, and nomenclature of flows are included.

273. Robison, J.H., 1971, Hydrology of basalt aquifers in the Hermiston-Ordance Area, Umatilla and Morrow Counties, Oregon: U.S. Geological Survey Atlas, HA-387 (2 sheets).

Hydrological data on the basalt aquifers in the Hermiston-Ordance area of Oregon are provided. Data on transmissivity, specific capacities and yields, and water quality are also included.

274. Rochlin, G.I., 1977, Nuclear waste disposal, two social criteria: Science, Jan. 7, 1977, v. 195, p. 23-29.

Rochlin points out that a zero defect repository is impossible. Therefore, decisions should be based on acceptable or defined risks. After a predicted period of administrative control, there is no guarantee that the repository could or would be repaired if it is breached. Therefore, the repository should be put in a geologically uninteresting area surrounded by a wide zone of similar terrain to minimize any accidental breach by future investigators. A second criteria would be honesty in our approach to locating a repository. Any and all possible adverse impacts on future generations should be declared by

the responsible agency.

275. Rockwell International (R.A. Deju), 1977a, Summary of siting criteria for geological repositories of nuclear waste: Report RHO-BWI-CD-9, draft, 5 p.

This paper provides criteria for the siting of nuclear waste repositories in geologic settings.

276. Rockwell International, 1977b, The basalt storage program: Rockwell International, Department of Waste Isolation Research and Engineering, Report RHO-SA-11, 34 p.

This report provides a general description of Rockwell's basalt storage program for radioactive wastes at Hanford.

277. Rockwell International, 1978, Basalt waste isolation program annual report--Fiscal year 1978: Prepared for the U.S. Department of Energy, Contract EY-77-C-06-1030.

This report summarizes the status of the basalt waste isolation program for fiscal year 1978.

279. Rogers, L.E., and Rickard, W.H., 1977, Ecology of the 200 area plateau waste management environs. A status report: Battelle Pacific Northwest Laboratory Report PNL-2253 VC-11.

This report provides descriptions of the biological communities occuring in the 200 area of the Hanford Reservation. A partial bibliography (for years 1943-1977) of biological field studies on radioactivity in biota of the Hanford area is also included.

280. Rosenmeier, F.J., 1968, Stratigraphy and structure of the Table Mountain-Mission Peak area in the Wenatchee Mountains, central Washington: M.S. thesis, University of Washington, Seattle.

This thesis presents the results of modal analyses of an 85-square-mile study area located at the edge of the Columbia Plateau, central Washington. Members of the Grande Ronde basalt are named.

281. Ross, M.E., 1975, The structure of Yakima Basalts in a portion of the Grande Ronde River region of northeastern Oregon and southeastern Washington (abstract): Geological Society of America Abstracts with Programs, v. 7, no. 5, p. 638-639.

The tectonics and structure of the Grande Ronde Basalt are discussed for part of the Grande Ronde River region of northeastern Oregon and southeastern Washington.

282. Rothe, G.H., 1978, Earthquake swarms in the Columbia River Basalts: Addendum to Annual Technical Report 1968, Earthquake monitoring of the Hanford region., Ph.D. thesis, University of Washington, Seattle, 181 p.

This thesis discusses earthquake swarms in the Columbia River Basalts and attempts to correlate earthquake activity with geologic structures in the area of Wooded Island.

283. Ryan, M.P, and Sammies, C.G., 1978, Cyclic fracture mechanisms in cooling basalt: Geological Society of America Bulletin, v. 89, p. 1295-1308.

This paper addresses the question of how hexagonal polyhedra are found and how vertical joints grow longer (crack tip deformation) in cooling basalts.

284. Sandia Laboratories, 1978, Environmental impact statement for the waste isolation pilot plan: Working draft for review.

This report addresses short and long term environmental impacts of operating a high-level radioactive waste repository at the WIPP site on the Hanford Reservation. Environmental considerations include: health and safety, wildlife, land use, and pre-emption of resources.

285. Schlumberger Well Surveying Corporation, 1958, Well logs for Rattlesnake Hills Unit #1, Benton, Washington: Standard Oil Company of California: Reproduced by Rocky Mountain Well Log Service.

This compilation of geophysical well logs (gamma, neutron, S-P, resistivity) is from 600 to 10,600 feet below the surface for the Rattlesnake Hills area.

286. Schlumberger Well Surveying Corporation, 1960, Well logs for Basalt Explorer #1, Lincoln Washington: Development Associates: Reproduced by Rocky Mountain Well Log Service, Denver, Colorado.

This series of geophysical well logs (S-P, resistivity) is for the Explorer #1 boring, in eastern Washington.

287. Schmincke, H.U., 1967, Stratigraphy and petrography of four Upper Yakima Basalt flows in south-central Washington: Geological Society of America Bulletin, v. 78, p. 1385-1422.

This article presents stratigraphic and petrographic data on the four upper flows (Umatilla, Pomona, Ward Gap, and Elephant Mountain) of the Saddle Mountains Basalt.

288. Schuster, J.E., 1973, Directory of Washington mining operations, 1971-1972: State of Washington, Department of Natural Resources, Information Circular No. 48.

Directory of the State of Washington mining operations (years 1971-1972) covers metallic and non-metallic minerals and contains maps and information on mining company holdings and operations.

289. Science Applications, Inc., 1978a, Technical support for GEIS: Radioactive waste isolation in geologic formations; Volume 23. Environmental effluent analyses: Prepared for the U.S. Department of Energy, Contract W-7405 eng 26, Y/OWI/TM-36/23.

Radioactive and non-radioactive releases to the environment from facility construction and waste handling operations, and releases arising from operational accidents are discussed.

290. Science Applications, Inc., 1978b, Technical support for GEIS: Radioactive waste isolation in geologic formations; Volume 1. Executive Summary: Prepared for the U.S. Department of Energy, Contract W-7405 eng 26, Y/OWI/TM-36/1.

This volume briefly presents the Alternate Repository Preconceptual Design Studies that led to the generic repository designs, and the determination of resource requirements for repositories.

291. Science Applications, Inc., 1978, Hydrologic testing in borehole DC-2: Prepared for U.S. Department of Energy, Contracts no. EY-77-C-06-1030 and no. EY-76-C-06-2175.

This is a summary report on packer (hydraulic conductivity) testing at Borehole DC-2 on the Hanford Reservation, as conducted by Science Applications, Inc. The data are used to evaluate flow systems and ground-water aquifers for radionuclide movement in the biosphere.

292. Seattle, Walla Walla and Portland Districts; U.S. Army Corps of Engineers, and State of Washington Department of Ecology, 1974, Flood plain information reports and special flood hazards information reports for Washington State.

Annotated index to informational reports concerning locations and characteristics of flood plains in the State of Washington. Also contains an index map of flood control zones in the State of Washington.

293. Shannon & Wilson, Inc., 1973a, Regional geologic and seismic investigations, Boardman Nuclear Project: Report no. 0-618D, prepared for Portland General Electric Company, Portland, Oregon, 43 p.

This report presents the results of detailed fault and earthquake studies conducted for the Boardman Nuclear Project.

294. Shannon & Wilson, Inc., 1973b, Geologic studies of Columbia River Basalt structures and age of deformation, the Dalles-Umatilla Region, Washington and Oregon, Boardman Nuclear Project: Report no. 0-618E, prepared for Portland General Electric Company, Portland, Oregon, 52 p.

This report contains information on faulting, folding and volcanism in the Dalles-Umatilla region of Washington and Oregon. Information on ages of deformation within basalt, as determined from studies of past fault movement, is presented.

295. Shannon & Wilson, 1976, Volcanic hazard study potential for volcanic ashfall, Pebble Springs nuclear plant site, Gilliam County, Oregon: Prepared for Portland General Electric Company

This report provides a summary of world-wide thickness, geochemistry, rates of accumulation, and physical properties of volcanic ashfall. Of particular importance are the data on cascade volcanoes, which show downwind ashfall thickness, grain size, water acidity, and dissolved solids content.

296. Shaw, H.R., and Swanson, D.A., 1969, Eruption and flow rates of flood basalts: Proceedings of the Second Columbia River Basalt Symposium, March, 1969, Eastern Washington State College, Cheney, Washington, p. 271-299.

This report discusses basalt eruption, flow rates and gradients, and feeder dike characteristics of the flood basalts.

297. Sheppard, R.A., 1964, Geologic map of the Husum quadrangle, Washington: U.S. Geological Survey Mineral Investigation Field Study, Map MF-280.

This is a basic geologic map with cross sections of the Husum quadrangle.

298. Siems, B.A., 1973, Surface to subsurface correlation of Columbia River Basalt, using geophysical data, in parts of Adams and Franklin Counties, Washington: Washington State University, College of Engineering, Pullman, Bulletin 331, 63 p.

Stratigraphic and geophysical data on the portion of the Columbia Plateau north of the Hanford Reservation are provided.

299. Siems, B.A., 1974, Stratigraphic identification and correlation of basalt aquifers using geophysical and chemical techniques: Washington State University, College of Engineering, Research Report no. 74/15-90, 33 p.

This report presents the results of a preliminary study relating stratigraphic units to physical features through the use of geophysical logs and chemical techniques.

300. Siems, B.A., Bush, J.H., and Crosby, J.W., 1974a, TiO_2 and geophysical logging criteria for Yakima basalt correlation, Columbia Plateau: Geological Society of American Bulletin, v. 85, p. 1061-1068.

This article addresses methods of correlation for identifying basalt flow sequences from borehole data.

301. Siems, B.A., and others, 1974b, Geophysical investigation of Washington's groundwater resources: State of Washington Department of Ecology, Technical Report no. 73-034, 45 p.

This report presents the results of a geophysical investigation of selected ground-water resources in the State of Washington.

302. Silar, J., 1969, Ground-water structures and ages in the eastern Columbia River Basin, Washington: Washington State University, College of Engineering Research Division, Bulletin 315, Project No. 141-01-11B-3998-2201.

The hydrologic significance of ground-water structures in the eastern Columbia River Basin are discussed. Available data (through 1969) regarding age of water in shallow aquifers are summarized.

303. Skehan, J.W., 1965, The Olympic-Wallowa lineament: A major deep-seated tectonic feature of the Pacific Northwest (abstract): EOS (American Geophysical Union Transactions) v. 46, no. 1, p. 71.

The Olympic-Wallowa lineament is hypothesized to be a transition between the continental and oceanic crusts, and may be a fault.

304. Smith, W.D., 1947, Physical framework of the Pacific Northwest, in The Pacific Northwest: John Wiley & Sons Inc., New York, p. 44-58.

This is a reference to the physiographic provinces of the Pacific Northwest.

304.5. Smith, R.B., and others 1974, Source mechanics of microearthquakes associated with underground mines in eastern Utah: Bulletin of the Seismological Society of America, v. 64, no. 4, p. 1295-1317.

The relationship between earthquakes and coal mining, based on information obtained from a microseismic survey is discussed. And data on the frequency of events and results of spectral analysis and source mechanism determination are presented.

305. Snavely, P.D., Macleod, N.S., and Wagner, H.C., 1973, Miocene tholeiitic basalts of coastal Oregon and Washington and their relations to coeval basalts of the Columbia Plateau: Geological Society of America Bulletin, v. 84, p. 387-424.

Three theories about the coeval and cosanguinous basalts of the Columbia River Plateau and coastal regions of Oregon and Washington are addressed. A considerable amount of chemical data and other information regarding the basalts are provided.

306. Sonnicksen, J.C., and others, 1970, Dispersion characteristics of the Columbia River between river miles 383 and 355: Battelle Northwest Laboratory, Report BNWL-1477 VC-70.

Meteorological data and interpretations for the K-Area of the Handford Reservation are presented.

307. Staatz, M.H., and Morris, R.H., 1976, Resume of the regional geology of the Grand Coulee Area, Washington: U.S. Geological Survey, Open-File Report 76-782.

This report describes the structural geologic features of lower rock units of the Grand Coulee Area.

308. Starr, W.A., and others, 1971, Study A: Potential rate of development of irrigation in eastern Washington: State of Washington Water Research Center, Washington State University and the University of Washington, Report No. 3A, 80 p.

This report presents a gross examination of the distribution of irrigable lands in eastern Washington and analyzes different methods of irrigation development.

308.5. Stevens, P.R., 1977, A review of the effects of earthquakes on underground mines, U.S. Geological Survey, Open-File Report 77-313.

This report summarizes a literature search performed to assess subsurface damage from earthquakes. Mines in the epicentral region of large earthquakes can be damaged by transecting activated faults. Underground damage is generally less than above ground damage from earthquakes.

309. Stone, W.A., Jenne, D.E., and Thorp, J.M., 1972, Climatography of the Hanford Area: Battelle Pacific Northwest Laboratory, Report BNWL-1605 UC-53.

A wide variety of meteorological and climatological data on the Hanford Reservation is provided.

310. Summers, W.K., and Schawb, G.E., 1978, Bibliography of the geology and groundwater of the basalts of the Pasco Basin, Washington: Prepared for Rockwell International-Hanford Operations, Report no. RHO-BWI-C-15.

This is an annotated bibliographic index to publications dealing with the geologic and hydrologic characteristics of the basalts in the Pasco Basin.

311. Summers, W.K., and Weber, P.A., 1978, Data for well penetration basalt in the Pasco Basin area, Washington: Prepared for Rockwell International-Hanford Operations, Report no. RHO-BWI-C-19.

Hydrologic data, most of which is from driller's logs are presented on the Pasco Basin.

311.5. Swanger, H.J., and Boore, D.M., 1978, Simulation of strong-motion displacements using surface-wave modal superposition: Bulletin of the Seismological Society of America, v. 88, no. 4, p. 907-922.

In this paper, a surface-wave modeling technique indicates that displacements of surface waves in sedimentary basins can be dominant for only a few focal depths. Both point sources and propagating sources are used in the analysis.

312. Swanson, D.A., 1967, Yakima Basalt of the Tieton River area, south-central Washington: Geological Society of America Bulletin, v. 78, p. 1077-1110.

This article discusses the geologic history, structure, stratigraphy, petrography, and hydrology of the northwest section of the Columbia Basin, Washington.

313. Swanson, D.A., 1969, Reconnaissance geologic map of the east half of the Bend quadrangle, Crook, Wheeler, Jefferson, Wasco, and Deschutes Counties, Oregon: U.S. Geological Survey, Miscellaneous Geologic Investigations, Map I-568.

This detailed geologic map shows the structure and stratigraphy of areas in Oregon.

314. Swanson, D.A., and Wright, T.L., 1973, Extent, source and structure of the Roza Member of the Yakima Basalt in southeast Washington (abstract): Geological Society of America, Abstracts with Programs, v. 5, no. 1, p. 113-114.

This abstract describes the source vents, flow thicknesses,and the number of flows, of the Roza Member of the Wanapum Basalt in southeast Washington.

315. Swanson, D.A., and Wright, T.L., 1978, Some important facts and inferences concerning the Columbia River Basalt group: Paper presented at Battelle Tectonics Symposium, February 14-16, 1978, Seattle, Washington.

The authors compare the different Columbia River Basalt types in terms of formation, structure, and stratigraphy.

316. Swanson, D.A., Wright, T.L., and Helz, R.T., 1975, Linear Vent Systems and estimated rates of magma production and eruption for the Yakima Basalt of the Columbia Plateau: American Journal of Science, v. 275, p. 877-905.

This paper describes the north-northwest trending vent systems and outcrops of Roza, Ice Harbor, Dodge and Uniontown flows of the Yakima Basalt group.

317. Swanson, D.A., and others, 1972, Revisions in stratigraphic nomenclature of the Columbia River Basalt group: U.S. Geological Survey, Bulletin 1457.

Revised stratigrahic nomenclature and descriptions of formations, members, and flows for the Columbia River Basalt group are provided.

318. Swanson, D.A., and others, 1976, Geologic interpretation of an aeromagnetic map of the west central Columbia Plateau, Washington and Oregon: U.S. Geological Survey, Open-File Report no. 76-51.

This report contains an aeromagnetic map, accompanied by interpretive discussions.

319. Swanson, D.A., and others, 1977, Geologic reconnaissance map of the Columbia River Basalt group, Pullman and Walla Walla quadrangles, southeast Washington and adjacent Idaho: U.S. Geological Survey, Open-File Report no. 77-100.

This map shows the extent of ind' idual flows in the Grande Ronde, Wanapum, and Saddle M .ins Basalt and folds and faults not previously mapped.

320. Sylvester, K.J., 1978, Geophysical investigations of the hydrogeology of the Goldendale-Centerville areas, Washington: M.S. thesis, College of Engineering, Washington State University, Pullman.

This thesis provides stratigraphic and hydrogeologic data for an area in the western portion of the Columbia Plateau. Locations of structural features and age of deformation are also provided.

321. Tabor, R.W., and others, 1977, Preliminary map of the Wenatchee 1:100,000 quadrangle, Washington: U.S. Geological Survey, Open File Map 77-531.

Compilation and correlation of mapping prepared by a variety of sources. The stratigraphy of basement units and Columbia River Basalts of the Wenatchee area are described.

322. Tanaka, H.H., and Wildrick, L., 1978, Hydrologic bibliography of the Columbia River Basalts in Washington. Washington State Department of Ecology for Rockwell International-Hanford Operations, Report RHO-BWI-C-14.

A hydrologic bibliography contains some articles not included in other bibliographies. Majority of articles are from the late 1940, 1950 and 1960 decades. Very few articles are from after 1973.

323. T.A.P., Inc., 197?, Summary to the Idaho State airport system plan: Submitted to Idaho Department of Aeronautics, Boise, Idaho.

This document provides a summary of the Idaho airport system plan. Included are airport locations, airport categories, and projected airport usage.

324. Taubeneck, W.H., 1966, An evaluation of tectonic rotation in the Pacific Northwest. Journal of Geophysical Research, v. 71, no. 8, pp. 113-212.

The Nevadan Orogeny and the Olympic-Wallowa Lineament as a non-hazardous tectonic feature are discussed. The Columbia River Basalt feeder dikes in eastern Oregon and Washington are very well described.

325. Taylor, G.C., 1948, Groundwater in the Quincy Basin, Wahluke Slope and Pasco Slope subareas of the Columbia Basin Project, Washington. U.S. Geological Survey, Open-File Report, 182 p.

This is a description of geologic units and ground water aquifers, well logs and spring data.

326. Tera Corporation, 1978, High-level waste repository site suitability criteria: Draft Environmental Impact Statement submitted to Lawrence Livermore Laboratory, Livermore, California.

This is an evaluation of environmental impacts associated with the issuance of prospective roles regarding the siting of nuclear waste repositories. Also contains a discussion of alternative actions as well as overall assessment costs and benefits of the licensing procedure.

327. Thayer, T.P., and Brown, C.E., 1964, Pre-Tertiary orogenic and plutonic intrusive activity in central and northeastern Oregon: Geological Society of America, Bulletin, v. 75, p. 1255-1262.

The pre-basalt tectonics in the Blue Mountains and the Mesozoic intrusives in northeast Oregon are discussed.

328. Tillson, D.D., 1970, Analysis of crustal changes in the Columbia Plateau area from contemporary triangulation and leveling measurements: Battelle Pacific Northwest Laboratory, Richland, Washington, 59 p.

This is an analysis of geodetic data on the Columbia Plateau in southeastern Washington and northeastern Oregon, as part of an effort to determine seismicity of the Hanford area.

329. Tillson, D.D., Brown, D.J., and Raymond, J.R., 1969, River water ground water relationships along a section of the Columbia River valley: ASCE Annual Meeting and National Meeting on Water Resources Engineering, New Orleans, La, February 3-7, 1969, Meeting Preprint 823.

Information on bank storage, ground-water levels, hydrographs and areas influenced by changes in river water level in the Hanford area is provided with a summary chart.

331. Tocher, D., and Patwardhan, A.S., 1975, Attenuation of peak acceleration in earthquakes (abstract): Geological Society of America, Abstracts with Programs, v. 7, no. 3, p. 426.

This paper presents compiled world-wide data on earthquake acceleration attentuation versus distance, and estimated peak acceleration versus distance.

332. Tucker, G.B., 1978, Compilation of columnar, cross, and type sections in the Columbia Basin and surrounding areas of Washington: CA/W2G4, Appendix C to Open-File Report 78-3.

This is a tabular compilation of maps, cross-sections and references on geology, hydrology and petrology of the Columbia Plateau in Washington.

333. Tucker, G.B., and Rigby, J.B., 1978, Bibliography of the geology of the Columbia Basin and surrounding areas of Washington with selected references to Columbia Basin geology of Idaho and Oregon: Washington State Department of Natural Resources, Division of Geology and Earth Resources, Report RHO-BWI-C-10.

Published, unpublished, and open-file references on the geology and geophysics of the Columbia Basin of eastern Washington are contained in this bibliography.

334. Union Carbide Corporation, Nuclear Engineering Division, 1977, Conceptual design criteria for facilities for geologic disposal of radioactive wastes in salt formations: Prepared for U.S. Energy Research and Development Administration, Office of Waste Isolation, Oak Ridge, Tennessee, Document no. X-OE-17.

This document provides conceptual design criteria for terminal waste storage disposal facilities in rock salt.

335. University of Washington, 1978, Earthquake monitoring of the Hanford region, eastern Washington: University of Washington, Geophysics Program, Annual Technical Report 1968, including Quarterly Technical Report 78-B.

This report lists seismograph stations and earthquakes recorded during the periods from January to June 1975 and April to June 1978. Theses by Sheng-Shang Boi and George Rothe are included.

336. U.S. Army Corps of Engineers, 1975, Report of the Chief Engineers on the national programs of inspection of dams.

This listing of dams provides data on the dams' physical characteristics and condition.

337. U.S. Atomic Energy Commission, 1974a, Population density around nuclear power plant sites: Report T-160.

Rules and regulations regarding the population density around nuclear power plants are discussed.

338. U.S. Atomic Energy Commission, 1974b, Draft Environmental Statement, Waste Management Operations, Hanford Reservation, Richland, Washington: Report Wash-1538, v. 1.

The Hanford facilities, waste management operations, environmental setting, endangered species, and impact on environment are described.

339. U.S. Atomic Energy Commission, 1974c, Draft Environmental Statement, Waste Management Operations, Hanford Reservation, Richland, Washington: Report Wash-1538, v. 2, appendices.

Geologic maps of Hanford, environmental setting of Hanford and vicinity, and water, animal, vegetation, weather, and seismological data are provided.

339.5. U.S. Atomic Energy Commission, 1974d, Environmental statement related to construction and operation of Barnwell Nuclear Fuel Plant, Document no. 50-332.

This is the only written environmental statement for a nuclear fuel processing plant. Information on the radioactive releases from such a processing plant is provided.

340. U.S. Bureau of Reclamation, 1974, Geologic and seismic evaluation of Grand Coulee Dam and forebay, Columbia Basin Project, Washington: U.S. Bureau of Reclamation, Division of Design, Denver, Colorado, 77 p.

Information on geologic structure of the northern Columbia Plateau area and on the age of faulting are discussed. Maximum probable earthquakes and possible ground motions are estimated.

341. U.S. Committee, International Committee on Large Dams, 1958, 1963, 1968: World Register of Dams, v. 2.

This listing of dams provides data such as dam height, reservoir capacity, and discharge rates.

342. U.S. Department of Agriculture, 1964, Soils of the western United States: A Joint Regional Publication by Agricultural Experiment Stations of Western States Land-Grant Universities and Colleges and by the Soil Conservation Service of U.S. Department of Agriculture, 69 p.

Soils, climate and vecetation, and possible land uses for the western United States are described.

343. U.S. Department of Commerce, Bureau of the Census, 1977, Population estimates and projections: Current Population Reports Series P-25, no. 660, 680, 695.

These reports contains demographic data for the States of Idaho, Oregon, and Washington for the years 1970, 1973, and 1975.

344. U.S. Department of Commerce, Bureau of the Census, 1978, Bibliography: Directory of Federal Statistics of Local Areas, Washington.

This is a bibliography of federal statistics on socioeconomic land uses and demographic impacts for Washington State.

345. U.S. Department of Commerce, 1979, Seattle sectional aeronautical chart: 1:1,500,000 scale.

All airports, low altitude airways, navigational aids, controlled airspace, topography and geography are depicted on this map covering the Columbia Plateau area.

346. U.S. Department of Defense, Mapping Agency, 1979a, Area Planning AP/1B Chart, Military Training Routes, Western Routes: U.S. Defense Mapping Agency Aerospace Center, St. Louis, Missouri.

The map (scale of 1 inch = 30 nautical inches) shows military VFR and IFR training routes for the western U.S., including the Columbia River area.

347. U.S. Department of Defense, Mapping Agency, 1979b, Area Planning training routes, North and South America: Department of Defense, Flight Information Publication AP/1B.

Flight information on military training routes in North and South America are presented.

348. U.S. Department of Energy, 1978a, Report of task force for review of nuclear waste management: Draft report, DOE/ER-0004/D, 165 p.

This is an assessment of current nuclear waste managment programs, issues, and courses of action for formulating an administrative policy.

349. U.S. Department of Energy, 1978b, Environmental assessment - National Waste Terminal Storage Program - Near Surface Test Facility, Hanford Reservation: Report DOE/EA-0052.

This is a compilation of test data obtained from conducting electrical heater tests and spent fuel tests for determining the suitability of basalt as a repository medium. The Near Surface Test Facility at Gable Mountain is described.

350. U.S. Department of Energy, 1978c, Proposed format and content of license applications for deep geologic terminal repositories for radioactive material: Rockwell International-Hanford Operations, Richland, Washington.

This report provides basic guidelines for license applications for geologic radioactive waste repositories.

352. U.S. Department of Energy, 1978d, Environmental assessment--National Waste Terminal Storage Program (NWTSP)--Exploratory Borehole Drilling Program, wells ARH-DC-4,-5,-6,-7,-8, DOE/EA-2048: ERDA document control no. EIA/WPR/77-3, Appendix of ARH-DC-2.

The drilling procedures used to obtain geologic and hydrologic data for assessing the environmental feasibility of a nuclear waste repository in the Columbia River Basalt are provided.

353. U.S. Department of Energy, 1978e, Commercial waste forms, packaging and projections for preconceptual design studies: Technical support for GEIS - radioactive waste isolation in geologic formations, v. 2. Prepared by Science

Applications, Inc., Report no. Y/OWI/TM-36/2.

This volume contains data bases for waste forms, packaging and projections for commercial waste as defined by the Office of Waste Isolation and Battelle Pacific Northwest Laboratories.

354. U.S. Department of Energy, 1978f, Stratigraphies of salt, granite, shale, and basalt: Technical support for GEIS - Radioactive waste isolation in geologic formations, v. 3. Prepared by Dames and Moore, Report no. Y/OWI/TM36/3.

This volume contains general stratigraphic information on salt, granite, shale, and basalt geologic formations for evaluating their suitability as repositories.

355. U.S. Department of Energy, 1978g, Baseline rock properties - granite: Technical support for GEIS - radioactive waste isolation in geologic formations, v. 5. Prepared by Dames and Moore, Report no. Y/OWI/TM-36/5.

This volume discusses the geology, hydrology, and rock properties of granite as a possible medium for locating a radioactive waste repository.

356. U.S. Department of Energy, 1978h, Baseline rock properties - shale: Technical support for GEIS - radioactive waste isolation in geologic formations, v. 6, prepared by Dames and Moore, Report no. Y/OWI/TM-36/6.

This volume reviews the properties of shale, and discusses in detail the shales from four different parts of the U.S. These four shales were considered to be most suitable as host rock for a nuclear waste repository.

357. U.S. Department of Energy, 1978i, Baseline rock properties - basalt: Technical support for GEIS - radioactive waste isolation in geologic formations v. 7. Prepared by Dames and Moore, Report no. Y/OWI/TM-36/7.

This volume discusses properties of basalt as a possible medium for the location of a nuclear waste repository.

358. U.S. Department of Energy, 1978j, Repository preconceptual design studies - salt: Technical support for GEIS - radioactive waste isolation in geologic formations, v. 8. Prepared by Parsons Brinckerhoff Quade and Douglas, Inc., Report no. Y/OWI/TM-36/8.

This volume presents a preconceptual design for a nuclear waste storage facility in salt.

359. U.S. Department of Energy, 1978k, Repository preconceptual design studies - granite: Technical support for GEIS - radioactive waste isolation in geologic formations, v. 10. Prepared by Parsons Brinckerhoff Quade and Douglas, Inc., Report no. Y/OWI-/TM-36/10.

This volume presents a preconceptual design for a nuclear waste storage facility in granite.

360. U.S. Department of Energy, 1978L, Repository preconceptual design studies - shale: Technical support for GEIS - radioactive waste isolation in geologic formations, v. 12. Prepared by Parsons Brinckerhoff Quade and Douglas, Inc., Report no. Y/OWI/TM-36/12.

This volume presents a preconceptual design for a nuclear waste storage facility in shale.

361. U.S. Department of Energy, 1978m, Repository preconceptual design studies - BNPL waste forms in salt: Technical support for GEIS - radioactive waste isolation in geologic formations, v. 16. Prepared by Parsons Brinckerhoff Quade and Douglas, Inc., Report no. Y/OWI/TM-36/16.

This volume describes a preconceptual design for a nuclear waste storage facility in salt, for various forms of radioactive waste.

362. U.S. Department of Energy, 1978n, Thermal analysis: Technical support for GEIS - radioactive waste isolation in geologic formations, v. 19. Prepared by Science Applications, Inc., Report no. Y/OWI/TM-36/19.

This volume discusses the effects of thermo-nuclear waste heat generation on the waste matrix, the protective cansiters, and the geologic formation.

363. U.S. Department of Energy, 1978o, Groundwater movement and nuclide transport: Technical support for GEIS - radioactive waste isolation in geologic formations, v. 21. Prepared by Dames and Moore, Report no. Y/OWI/TM-36/21.

This volume discusses the effects of repository construction and consequent heat generation (thermal loading) on the movement of ground water in granite, shale, and basalt.

364. U.S. Department of Energy, 1978p, Nuclear considerations for repository design: Technical support for GEIS - radioactive waste isolation in geologic formations, v. 22. Prepared by Science Applications, Inc., Report no. Y/OWI/TM-36/22.

This volume presents baseline design considerations, such as decay levels, characteristics of containers, shielding, and health and safety.

365. U.S. Department of Energy, 1978q, Environmental effluent analysis: Technical support for GEIS - radioactive waste isolation in geologic formations, v. 23. Prepared by Science Applications, Inc., Report no. Y/OWI/TM-36/23.

This volume discusses the releases of radioactive and non-radioactive materials to the environment during construction, waste handling, and operational accidents.

366. U.S. Department of Interior, 1972, The mineral industry of Washington: Bureau of Mines Minerals Yearbook.

This description of the mineral industry provides information on numerous sand, gravel, rock quarries, and diatomite, clay, and lime deposits on the Columbia River Basalt Plateau.

368. U.S. Energy Research and Development Administration, 1976a, Evaluation and impact of potential flooding criteria on the Hanford Project: Prepared by U.S. Energy Research and Development Administration, Richlands Operation Office, Richland, Washington.

A brief discussion, prepared with a series of maps and data, describes the historic, geographic, hydrographic, and programmatic relationships of hypothetical floods on the Columbia River, particularly as these floods would affect Hanford.

368.5. U.S. Energy Research and Development Administration, 1976b, Alternatives for managing wastes from reactors and post-fission operations in the LWR fuel cycle, ERDA-76-43.

Alternatives are examined in considerable detail. Information on the 3H and85KR content of fuel assemblies after 5 years decay is provided.

369. U.S. Environmental Protection Agency, 1977, EPA radiation protection programs; Environmental radiation protection standards for nuclear power operations: Federal Register, v. 43, no. 195.

This document sets forth environmental radiation standards for nuclear power plant operations.

370. U.S. Environmental Protection Agency, 1978a, State hazardous waste programs; Proposed guidelines: Federal Register, v. 43, no. 22.

These guidelines prescribe procedures by which states may apply for authorization; and procedures by which such authorization may be withdrawn from hazardous waste management programs. This program is not for radioactive waste.

371. U.S. Environmental Protection Agency, 1978b, Criteria for radioactive wastes--Recommendations for Federal Radiation Guidance: Federal Register, v. 43, no. 221.

These recommended criteria for federal radiation guidance include basic management principles and guidelines for development of generally applicable standards for radioactive waste sources.

372. U.S. Fish and Wildlife Service, 1965, Map of McNary National Wildlife Refuge.

This detailed map shows the location and boundaries of McNary National Wildlife Refuge.

373. U.S. Fish and Wildlife Service, 1974, Map of Columbia National Wildlife Refuge.

This detailed map shows location and boundaries of Columbia National Wildlife Refuge. Seven accompanying maps show land ownership within the Columbia National Wildlife Refuge.

374. U.S. Fish and Wildlife Service, 1976a, Map of Saddle Mountain National Wildlife Refuge.

This detailed map shows location and boundaries of Saddle Mountain National Wildlife Refuge.

375. U.S. Fish and Wildlife Service, 1976b, Map of Turnbull National Wildlife Refuge.

This detailed map shows location and boundaries of Turnbull National Wildlife Refuge.

376. U.S. Fish and Wildlife Service, 1976c, National fish hatcheries and wildlife refuges - Washington.

This small scale, schematic map shows general locations and boundaries of national wildlife refuges.

377. U.S. Fish and Wildlife Service, 1978a, National fish hatcheries and wildlife refuges - Idaho.

This map shows general locations of national wildlife refuges and hatcheries.

378. U.S. Fish and Wildlife Service, 1978b, National fish hatcheries and wildlife refuges - Oregon.

This is a general location reference map for national fish hatcheries and wildlife refuges in Oregon.

379. U.S. Forest Service, 1966, National forests and national grasslands - Region 1 map.

This is a small scale map showing general locations and boundaries of national forests and national grasslands.

380. U.S. Forest Service, 1976a, National forest wildernesses of the Pacific Northwest region.

The small scale and schematic format limits the usefulness of this map which shows general locations of national forests and wilderness areas.

381. U.S. Forest Service, 1976b, National Forests of Region 6.

This map shows the locations and boundaries of national forests, national parks, national monuments, and national grasslands.

382. U.S. Forest Service, 1977a, Roadless and undeveloped area evaluation II map - Oregon.

Locations and boundaries are shown on a detailed map of the Rare II areas, new wilderness study areas, and national forests.

383. U.S. Forest Service, 1977b, Roadless and undeveloped area evaluation II map - Idaho.

Locations and boundaries for Rare II areas, new wilderness study areas, and national forests are shown.

384. U.S. Geological Survey, Topographic map of Canyon City: 1:250,000 scale.

This topographic map covers 44°-45° latitude, and 118°-120° longitude.

385. U.S. Geological Survey, Topographic map of The Dalles: 1:250,000 scale.

This topographic map covers 45°-46° latitude,and 120°-122° longitude.

386. U.S. Geological Survey, Topographic map of Grangeville: 1:250,000 scale.

This topographic map covers 45°-46° latitude, and 116°-118° longitude.

386.5. U.S. Geological Survey, Topographic Map of Pendleton: 1:250,000 scale.

This topographic map covers 45°-46° latitude, and 118°-120° longitude.

387. U.S. Geological Survey, Topographic map of Pullman: 1:250,000 scale.

This topographic map covers 46°-47° latitude, and 116°-118° longitude.

388. U.S. Geological Survey, Topographic map of Ritzville: 1:250,000 scale.

This topographic map covers 47°-48° latitude,and 118°-120 longitude.

389. U.S. Geological Survey, Topographic map of Spokane: 1:250,000 scale.

This topographic map covers 47°-48° latitude, and 116°-118° longitude.

390. U.S. Geological Survey, Topographic map of Walla Walla: 1:250,000 scale.

This topographic map covers 46°-47° latitude,and 118°-120° longitude.

391. U.S. Geological Survey, Topographic map of Wenatchee: 1:250,000 scale.

This topographic map covers 47°-48° latitude, and 120°-122° longitude.

392. U.S. Geological Survey, Topographic map of Yakima: 1:250,000 scale.

This topographic map covers 46°-47° latitude, and 120°-122° longitude.

393. U.S. Geologic Survey, 1969, The geologic setting of the John Day country: USGS Informational Pamphlet. 69-10 (R.-4).

The basic geology of the John Day and Monument, Oregon vicinity are presented with structural views showing faulting and folding. General description of rock units include road logs of area.

394. U.S. Geologic Survey, 1972, Water resources investigations in Washington: Map A-30, Water Resources Division.

These maps and references, and hydrologic data include precipitation, runoff, and river discharge in the State of Washington.

395. U.S. Geological Survey, 1974, The Channeled Scablands of Eastern Washington: USGS Informational Pamphlet 72-2(R-1).

This pamphlet describes the Spokane flood and the formation of the Channeled Scablands in eastern Washington, including present drainage in areas of deep scour.

397. U.S. Nuclear Regulatory Commission, 1975a, Standard format and content of safety analysis reports for fuel reprocessing plants: USNRC Regulatory Guide 3.26, 110 p.

This report discusses the geography, hydrology, meteorology, geology and seismology in describing site characteristics for Safety Analysis Reports (SARs). This standard format and content are identified.

398. U.S. Nuclear Regulatory Commission, 1975b, Environmental statement related to operation of Davis-Besse Nuclear Power Station Unit 1, proposed by Toledo Edison Company: Office of Nuclear Reactor Regulation, Docket No. 50-346, NUREG-75/097.

This is a summary environmental impact statement presenting an evaluation and the NRC position on licensing of the Davis-Besse Nuclear Power Station Unit 1 of the Toledo Edison Company, Ohio.

399. U.S. Nuclear Regulatory Commission, 1976a, Preparation of environmental reports for nuclear power stations: Regulatory Guide 4.2, Revision 2, NUREG-0099.

This USNRC guide to the preparation of environmental reports for nuclear power stations, delineates techniques and provides guidance on regulatory standards development.

400. U.S. Nuclear Regulatory Commission, 1976b, Rules and regulations; Part 20. Standards for protection against radiation: Code of Federal Regulations - Energy, Title 10, Chap. 1, p. 20.1-20.18.

These rules and regulations cover the areas of permissible doses, precautionary procedures, waste disposal, notification requirements, and enforcement policies regarding health and safety aspects of radiation.

401.2. U.S. Nuclear Regulatory Commission, 1976c, Environmental survey of the reprocessing and waste management portions of the LWR fuel cycle. A task force report: National Technical Information Service Publication no. PB-258-316.

This is a preliminary, generic environmental discussion of waste management. Some of the various problems and possible means of finding solutions are discussed.

401.3. U.S. Nuclear Regulatory Commission, 1976d, Final generic environmental statement on the use of recycled plutonium in mixed oxide fuel in light water-cooled reactors (GESMO), NUREG-002.

This multi-volume generic environmental statement includes a comprehensive treatment of many aspects of the nuclear fuel cycle. This reference was used in this analysis to obtain estimates of annual releases from nuclear power reactors and the surface facilities associated with nuclear waste repositories and to calculate a preliminary does for 85Kr released from a repository.

402. U.S. Nuclear Regulatory Commission, 1977, Safety evaluation report, Pebble Springs Nuclear Plant Units 1 and 2: NUREG-0013, Supplement No. 3, Docket Nos. 50-514, 50-515, p. 2-1 to 2-3.

Section 2.5 of the Safety Evaluation Report Supplement provides for the Nuclear Regulatory Commission policy decision of the ashfall model to be used at Pebble Springs Nuclear Plant, near Arlington, Oregon, on the Columbia River. Safety analysis also involved volcanic hazards.

403. U.S. Nuclear Regulatory Commission, 1978a, Workshops for state review of site suitability criteria for high-level radioactive waste repositories, analysis and recommendations: NUREG-0354, v. 1.

This volume presents the views and recommendations of state officials regarding the preliminary site suitability criteria for high-level radioactive waste repositories.

404. U.S. Nuclear Regulatory Commission, 1978b, Rules and regulations--reactor site criteria: Title 10, Chapter 1, Code of Federal Regulations--Energy, Part 100.

This description of reactor site criteria is used in evaluating the suitability of stationary reactor sites. Seismic and geologic criteria for nuclear power plants are provided.

405. U.S. Nuclear Regulatory Commission, 1978c, Licensing and regulatory policy and procedures for environmental protection: Title 10, Chapter 1, Code of Federal Regulations--Energy.

This code establishes the policy and procedures for processing environmental impact statements and related documents in connection with the NRC's licensing and regulatory activities.

406. U.S. Nuclear Regulatory Commission, 1978d, Storage of spent fuel in an independent spent fuel storage installation (ISFSI)--Proposed licensing requirements: Federal Register, v. 43, no. 195; 10 CFR, Part 72.

These regulations specify procedures and requirements for issuance of licenses to store spent fuel in an independent spent fuel storage installation (ISFSI). Requirements for siting, general design criteria, and certain operational aspects of such an activity are presented.

407. U.S. Nuclear Regulatory Commission, 1978e, Workshops for state review of site suitability criteria for high-level radioactive waste repositories, analysis and recommendations: NUREG-0354, v. 2.

A series of seminars on repositories was held with state and local government representatives to discuss the division of responsibility between federal and state agencies. The reactions of participants to various geologic, engineering, operational, and administrative problems were discussed. Comparison were made concerning reactions in various geographic areas.

408. U.S. Nuclear Regulatory Commission, 1978, Licensing procedures for geologic repositories for high-level radioactive wastes: Federal Register, v. 43, no. 223, pp.53869-53872, plus addendum.

The responsibilities and interaction between various government bodies and repository operating agencies were proposed for discussion and comment. The general tone of the discussion indicated that the NRC would become involved in a decision making/decision approving capacity for any radioactive repository constructred or operated by or for the U.S. Department of Energy.

409. Valentine, G.M., 1960a, Inventory of Washington Minerals, Part 1--Nonmetallic minerals: (Second Edition), State of Washington, Department of Conservation, Division of Mines and Geology, v. 1 - Text.

This report summarizes nonmetallic mineral resources and mining operations in the State of Washington, as of 1960.

410. Valentine, G.M., 1960b, Inventory of Washington Minerals, Part 1--Nonmetallic minerals: (Second Edition), State of Washington, Department of Conservation, Division of Mines and Geology, v. 2--Maps.

The economic minerals on the Columbia Plateau are clays, shales, minor coal, peat, diatomite, some common gemstones and fire opal, soda compounds, grinding pebbles, rock, sand, gravel, and poor quality silica sand.

411. Vance, J.A., 1978, The Pre-Yakima basement of the Washington Cascades: Paper presented at Battelle Tectonics Symposium, Seattle, Washington, February 14-16, 1978.

The known events and deposits, pre-Columbia River Basalt, Northwest of the plateau, including pre-Miocene faulting, subduction, and volcansim, are summarized.

412. Van Denburgh, A.S. and Santos, J.F., 1965, Ground water in Washington: Its chemical and physical quality: State of Washington, Department of Conservation, Division of Water Resources, Water Supply Bulletin No. 24.

The chemical characteristics of Washington's ground water are described. Charts and maps are included.

413. Van Houten, F.B., 1961, Maps of Cenozoic depositional provinces, western United States: American Journal of Science, v. 259, p. 612-621.

General description of locations of deposition at various times during the Cenozoic, but out-of-date and pre-plate tectonics theory.

414. Von Neumann, J., and Morgenstern, O., 1947, Theory of Games and Economic behavior: Princeton University Press, Princeton, New Jersey.

This is a textbook on game theory and its applications to economic behavior.

415. Wagner, N.S., 1954, Preliminary report on the geology of the southern half of Umatilla County, Oregon: The Ore-Bin, v. 16, no. 3, p. 13-17.

The pre-Tertiary basement of northeastern Oregon is discussed. This report is too old and lacking in detail to be useful.

416. Wagner, N.S., 1955, Summary of Wallowa Mountains geology: The Ore-Bin, v. 17, no. 5, p. 31-35.

The pre-Tertiary basement of Wallowa Mountains is discussed. No detail is provided except for the Columbia River Basalt in Minam Canyon which is a maximum thickness of 3,000 to 4,000 feet.

417. Waite, D.A., and Newcomb, W.E., 1979, Integrated geological and environmental site-qualification criteria: Prepared for the U.S. Department of Energy, Contract No. EY-76-C-06-1830

This draft report was prepared to guide site qualification investigations until the Nuclear Regulatory Commission establishes its criteria for radioactive waste repositories. Siting criteria for health/safety, environmental/socioeconomic, and engineering/economic considerations are listed and discussed.

418. Waitt, R.B., 1977, Guidebook to Quaternary geology of the Columbia, Wenatchee, Peshastin, and upper Yakima Valleys, west-central Washington: U.S. Geological Survey Open-File Report 77-753, 25 p.

Glacial deposits in the river valleys are discussed and a road guide is provided. Table of Quaternary deposits in this vicinity and their ages are presented.

419. Waitt, R.B., Jr., 1978, Post-Miocene stratigraphy and tectonism of parts of the Great Columbia Plain and adjacent Cascades, Washington: Paper presented at Battelle Tectonics Symposium, Seattle, Washington, February 14-16, 1978.

Post-Miocene events are summarized, beginning with a discussion of glacial, then Ringold, and then pre-Ringold structures. The development of present drainage with respect to rising structures is analyzed.

419.5. Waitt, R.B., Jr., 1979, Late Cenozoic deposits, land forms, stratigrphy and tectonism in Kittitas Valley, Washington: U.S. Geological Survey, Professional Paper no. 1127, 18 p.

This paper discusses the stratigraphy of the Columbia River Basalts, and the Quaternary stratigraphy in the Kittitas Valley. Tectonic deformation of this stratigraphy is also discussed.

420. Walker, G.W., 1973a, Contrasting compositions of the youngest Columbia River Basalt flows in Union and Wallowa Counties, northeastern Oregon: Geological Society of America Bulletin, v. 84, p. 425-430.

A 900-meter-thick section correlative to Wanapum and Saddle Mountains Basalts and Ellensburg Formation is described.

421. Walker, G.W., 1973b, Reconnaissance geologic map of the Pendleton Quadrangle, Oregon and Washington: U.S. Geological Survey, Miscellaneous Geologic Investigation Map I-727.

This 1:250,000 scale geologic reconnaissance map of the Pendleton quadrangle presents mineral and water resources, geology, and engineering features of some lithologic units.

422. Walker, G.W., 1973c, Preliminary tectonic map of Oregon east of the 121st meridian: U.S. Geological Survey, Miscellaneous Field Studies Map MF-495.

This is a preliminary tectonic map of eastern Oregon.

423. Walker, G.W., 1977, Geologic map of Oregon east of the 121st meridian: U.S. Geological Survey, Miscellaneous Investigations Map I-902.

This is a geologic map of eastern Oregon with separate tectonic and geomorphic map inserts.

424. Walker, G.W., and others, 1974, Index to potassium-argon ages of Cenozoic volcanic rocks of Oregon: U.S. Geological Survey, Miscellaneous Field Studies Map MF-569.

This is an index map showing locations and K-Ar ages of Rhyolitic, intermediate and Basaltic Cenozoic volcanic domes, sills and other intrusive bodies and some associated sediments.

425. Walters, K.L., 1972, Test-observation well near Almira, Washington: Description and preliminary results: U.S. Geological Survey Open-File Report, 20 p.

A test-well in basalt approximately 10 miles south of Almira, Washington showed a specific capacity of 92 gpm/ft to 546 feet, and 96 gpm/ft to 750 feet depth. No stratigraphic interpretations are provided.

426. Walters, K.L., and Glancy, P.A., 1969, Reconnaissance of geology of ground-water occurrence in Whitman County, Washington: U.S. Geological Survey, Water Supply Bulletin No. 26.

These geologic maps identify the Roza flow and gross areal geology. The regional dip is evident, but very little tectonic structure is shown.

427. Walters, K.L., Cline, D.R., and Luzier, J.E., 1972, Test-observation well near Odessa, Washington: Description and preliminary results: U.S. Geological Survey, Open-File Report, 25 p.

Piezometer data from wells in seven individual aquifers is discussed.

428. Walters K.L. and Grolier, M.J., 1960, Geology and ground water resources of the Columbia Basin Project Area, Washington: State of Washington, Department of Conservation, Division of Water Resources, Water Supply Bulletin no. 8, v. 1.

This report consists of approximately 500 pages of well records, drillers' logs, and hydrographs. Brief descriptions are given of the Ringold Formaion, Palouse Formation and Columbia River Basalt.

429. Warnic, C.C., and others, 1973, Regional problem analysis in the Pacific Northwest; Part B: Basalt groundwater aquifers: Washington State Water Research Center, Office of Water Research and Technology, Pullman, Washington.

Differences (confined versus unconfined) in the Columbia River Plateau and Snake River Plain basalt aquifers are compared. The Snake River Plain is more permeable with higher transmisivity.

430. Washington Department of Natural Resources, 1973, Washington's major public lands.

This is a map showing public land ownership in Washington State.

431. Washington Department of Natural Resources, Geology and Earth Resources Division, 1969, Placer gold.

Placer gold has been found on sandbars along the Columbia and Snake Rivers.

431.5. Washington Department of Parks and Recreation, 1977, Washington State Outdoor Recreation Guide: Northwest Experience, Moscow, Idaho.

This list of maps of Washington State Parks shows culturally important areas.

432. Washington Public Interest Research Group, 1978, Nuclear waste, a national waste repository at Hanford: considerations for Washington State: University of Washington, Energy Research Group, Seattle, Washington, 50 p.

This study draws negative conclusions about the feasibility of safely transporting and disposing of nuclear wastes at Hanford. A moratorium is recommended on plant licensing, feasibility studies on basalt, various legislation for safety. Costs for decommissioning and disposal of wastes should be included by power companies.

434. Washington Public Power Supply System, 1974, Preliminary Safety analysis Report, Amendment 9, for WPPSS Nuclear Projects No. 1 and 4.

This PSAR contains regional and site specific geologic information for the Hanford Reservation area including the results of literature review for stratigrapny, aerial photo interpretation of faulting and borehole drillings.

435. Washington Public Power Supply System, 1977, Preliminary Safety Analysis Report, Amendment 23 for WPPSS Nuclear Project No. 1 and 4 vols. 2A, 2B.

This Preliminary Safety Analysis Report for WPPSS Nuclear Project No. 1 and 4 deals specifically with the 1872 earthquake.

439. Washington, State of, 1975, Water quality assessmentreport: Report 75-8, v. 1 and 2.

Volume 1 assesses present water quality and outlines the programs and goals of water quality management. Volume 2 contains maps (scale of 1:750,000) of Washington showing bacterial densities, water temperatures, turbidity levels, and dissolved oxygen. Classification and monitoring sites for all rivers in Washington are included.

441. Washington State Game Department, 1975, Columbia Basin recreation areas: Pamphlet-map prepared by the Washington State Game Department in conjunction with the U.S. Bureau of Reclamation.

This pamphlet contains a schematic map showing wildlife recreation areas, national wildlife refuges, and state parks in the Columbia Basin region of eastern Washington.

442. Washington State Game Department, 1976, Wildlife recreation areas: Pamphlet-map.

These maps, at various scales, show the boundaries of all the Wildlife Recreation Areas (Regions I-VI) in the State of Washington.

443. Washington State Game Department, (undated), Wildlife recreation areas: Map-Pamphlet.

This schematic map of Wildlife Recreation Areas in the State of Washington provides short descriptions of each area: L.T. Murray, (north and south segments), Oak Creek (two segments), Quilomene, Rattlesnake Slope, and Wahluke.

444. Washington State Highway Commission, 1973, Washington State Highways Road Map.

General locations, some with boundaries of highways, national parks, and state parks, are shown. This map is of limited usefulness because of schematic format.

445. Washington State University, 1972, Irrigation development potential and economic impacts related to water use for the Yakima River Basin: Report submitted to the Yakima Valley Natural Resources Development Association, Washington State University, Agricultural Research Center, Pullman, Washington.

Land use, soils, hydrology and ecology are addressed in this report.

446. Waters, A.C., 1955, Volcanic rocks and the tectonic cycle: Geological Society of America, Special Paper 62, p. 703-722.

Tectonics and volcanism in the Columbia River Basin are discussed on the basis of differentiation. The material is out-of-date.

447. Waters, A.C., 1960a, Determining direction of flow in basalts: American Journal of Science, v. 258-A, p. 350-366.

Flow direction is determined by using columnar joints, spiracles, pipe vesicles and cylinders, and primary foreset bedding in palagonite.

448. Waters, A.C., 1960b, Two-fold division of the Columbia River Basalt (abstract): Geological Society of America Bulletin, v. 71, p. 2082.

Petrographic and stratigraphic correlations were made on 28 stratigraphic sections of the Columbia River Basalt. The basalts are products of separate magmatic hearths, and are not differentiates of a hypothetical uniform parent magma.

449. Waters, A.C., 1961a, Keechelus problem, Cascade Mountains, Washington: Northwest Science, v. 35, no. 2, p. 39-57.

The pre-Columbia River Basalt geology near Mount Rainier is discussed. The Fife's Peak and Steven's Ridge Formations are differentiated.

450. Waters, A.C., 1961b, Stratigraphic and lithologic variations in the Columbia River Basalt: American Journal of Science, v. 259, p. 583-611.

This article notes the distinct chemical differences between Picture Gorge Basalt and Yakima Basalt Subgroup. Tables and variation diagrams are included. These are good observations and discussions, but the stratigraphy is now obsolete, as the author had predicted.

451. Waters, A.C., 1973, Problems of basalt correlation (abstract): Geological Society of America, Abstract with Programs, v. 5, no. 1, p. 120.

An important correlation problem is the recognition of a sequence of flows in stratigraphic order. Especially helpful is Kuno's solidification index in petrography.

452. Watkins, N.D., 1964, Structural implications of paleomagnetism in Miocene lavas of north-eastern Oregon, south-eastern Washington and west-central Idaho: Nature, v. 203, p.830-832.

Inconclusive results show evidence of oroclinal rotation of Miocene lavas or crustal spreading during the Miocene.

453. Watkins, N.D., 1965, Paleomagnetism of the Columbia Plateaus: Journal of Geophysical Research, v. 70, no. 6, p. 1379-1406.

Evidence of tectonic rotation of the Columbia River Basalts is shown to be compatible with the "orocline" hypothesis for the Pacific Northwest.

454. Watkins, N.D., and Baksi, A.K., 1974, Magnetostratigraphy and oroclinal folding of the Columbia River, Steens and Owyhee Basalts in Oregon, Washington and Idaho: American Journal of Science, v. 274, p. 148-189.

This review of previous literature on rotation contains considerable paleomagnetic work, charts, maps, and correlations with K/Ar dates.

455. Weis, P.L., 1968, Geologic map of the Greenacres quadrangle, Washington and Idaho: U.S. Geological Survey, Map GQ-734.

This geologic map depicts basic bedrock geology and describes information on the clay and glacial deposits and related features of the area.

456. Weis, P.L., and Richmond, G.M., 1965, Maximum extent of Late Pleistocene Cordilleran glaciation in northeastern Washington: U.S. Geological Survey, Professional Paper 525-C, p. C126-C132.

Maximum southern ice extension is placed farther north than by previous authors.

457. Weissenborn, A.E., 1969, Geologic map of Washington: U.S. Geological Survey, Miscellaneous Geologic Investigations Map I-583.

This is a basic, large-scale geologic map of the State of Washington.

457.5. Wiggins, R.A., and others, 1978, Simulations of earthquake ground motions: Proceedings, Seminar-Workshop on Strong Ground Motions, Rancho Santa Fe, New Mexico.

Computer codes have been developed to simulte ground motions near a strike-slip fault for frequencies in the range of 1 to 20 Hz. This is useful for engineering design of response spectra for structures.

458. Williams, J.F., 1960(?), Well report--Basalt explorer, Number 1: Development Associates, Inc., Spokane, Wash.

The base of the Columbia River Basalt is near 4,300 feet below surface. Beneath it are 300 of sediments named the "Irby shale" and "Odessa sand". Descriptions of rotary samples and cores are included. The basalt is well bottomed in granitic bedrock.

460. Woodward-Clyde Consultants (San Francisco), 1975, Final Siting Report, v. 1 and 2: Prepared for the Washington Public Power Supply System.

This report summarizes an investigative approach and findings identifying and recommending sites suitable for nuclear or fossil fuel electric generating stations in the Pacific Northwest.

461. Woodward-Clyde Consultants (San Francisco), 1976, Preliminary draft report Seismicity listing for the Pacific Northwest: Prepared for Washington Public Power Supply, Washington.

This is a catalogue of earthquakes that have occurred between latitudes 44° and 54° north and longitude 110° and 128° west. Tables list earthquakes chronologically and by location.

462. Woodward-Clyde Consultants (San Francisco), 1977a, Draft report: Preliminary site selection factors for the NWTS program: Prepared for Union Carbide Corporation (Nuclear Division), under contract to U.S. Energy Research and Development Administration, 32 p.

Site selection factors, such as geologic events, repository-induced processes, impact of construction, and location, are listed and described with reference to possible effects on a repository site.

463. Woodward-Clyde Consultants (San Francisco), 1978a, 1872 earthquake studies: Washington Public Power Supply System Nuclear Project No. 1 and 4. [Straight Creek Fault Zone Study; Microearthquake Study]

The Straight Creek Fault Zone Study presents maps and a detailed examination of Quaternary faulting along the Mesozoic Straight Creek fault zone in the Northern Cascades, Washington. The microearthquake study presents the results obtained from a microseismic network in Washington. An evaluation of the data is included.

464. Woodward-Clyde Consultants (San Francisco), 1978b, Evaluation of residual risk for earthquake risk management and mitigation by public and private organizations: Research proposal submitted to the National Science Foundation, Division of Problem-Focused Research Applications.

This report contains a program proposal for development and verification of methodology for the evaluation of residual risks from earthquakes.

465. Woodward-Clyde Consultants (San Francisco), 1978c, Culturally important areas composite data map: Woodward-Clyde Consultants' working project file (WPPSS, 3D-1C).

This map shows locations and boundaries of culturally important areas of the Pacific Northwest, including wild and scenic rivers, wilderness areas, primitive areas, scenic areas. Plots are accurate for entire study area.

466. Woodward-Clyde Consultants, 1978, Annotated wild and scenic rivers under study data map: Woodward-Clyde Consultants' working project file (WPPSS, 3E-3a)

This map shows locations of wild and scenic rivers. The coverage is incomplete.

467. Woodward-Clyde Consultants (San Francisco), 1978e, Culturally important areas data and interpretive map(s): Woodward-Clyde Consultants' working project file (WPPSS, 3F-4) (scale 1:250,000).

These maps show locations and boundaries of state parks, state wild and scenic rivers, and federally designated culturally important areas (5000 acres) in the Pacific Northwest. Coverage of the study area is incomplete.

468. Woodward-Clyde Consultants (San Francisco), 1978f, Protected ecological areas data map(s): Woodward-Clyde Consultants' working project file (WPPSS, 3F-3), (scale 1:250,000).

These maps shows locations and boundaries of national and state wildlife refuges, and wildlife recreation areas. Coverage is incomplete and graphically schematic for some areas.

469. Woodward-Clyde Consultants (San Francisco), 1978g, Project quality assurance manual, Repository site selection study: Prepared for Rockwell International-Hanford Operations.

This document describes the project quality assurance program,including project organization, audit procedures, project documenation, and control and project procedures.

470. Woodward-Clyde Consultants (San Francisco), 1979, Siting study technical report, Candidate sites for coal-fired power plants: Prepared for Washington Public Power Supply System.

The subjects of this study are: geology, hydrology, topography, demography, land use, ecologically important areas, culturally important areas, air quality, and potentially hazardous areas. This report presents the investigative approach and findings of a study conducted to identify candidate sites for coal-fired power plants in the Pacific Northwest. The report describes the methodology used in the screening process, and graphically portrays the results of applying various criteria to the study area. Specific data are not included.

471. Yates, R.G., and others, 1966, Tectonic framework of northeastern Washington, northern Idaho, and northwestern Montana: Canadian Institute of Mining & Metallurgy Special, v. 8.

Rock types and provinces north of the Columbia Plateau are generally described. Several small scale geologic maps are included.

APPENDIX B - KEY WORD INDEX

The following key word index was developed to provide an additional access into the annotated references listed in Appendix A. The numbers under each key word or topic refer to the numerical listing of the annotated references in Appendix A. Thus, by referring to those numbered references under a particular key word in which one might be interested and then referring to Appendix A, one can locate the significant literature pertinent to the key word and also a summary of the article. The key words listed were developed from the literature screening forms used in Task 4 and, in general, reflect the data needs, concerns, and considerations of the site locality identification study.

APPENDIX C
INDEX OF COMPILED DATA

The following index of compiled data is a reproduction of the file index for use in the site identification study for the Hanford Reservation. It includes primarily data maps, compiled data maps and screening overlays developed to date for the screening process in the Pasco Basin and Hanford Reservation.

4310 Geology

4311 Structure - field notes

4311.1 Structure overlays of region 1:500,000 scale map
4311.5 Structure overlay of Hanford 1:62,500 scale map

4313 Stratigraphy

4313.1 Stratigraphy notebook
4313.2 Grande Ronde basalt notebook and 1:1,000,000 scale overlay showing location of measured sections
4313.3 Subsurface data overlay of regional 1:500,000 scale map
4313.3.1 Hanford deep well logs field notes
4313.4 Quaternary stratigraphy, field notes
4313.4.1 Regional Quaternary stratigraphy overlay 1:500,000 scale
4313.4.2 Hanford Quaternary stratigraphy 1:62,500 scale overlay
4313.5 Surficial deposit thickenss, field notes
4313.5.1 Regional surficial deposit thickness 1:500,000 scale overlay
4313.5.2 Hanford Surficial deposit thickness 1:62,500 scale overlay
4313.6 Total baslt thickness - regional 1:600,000 scale overlay and field notes
4313.7 Cross-sections 1:250,000 and field notes

4316 Geologic history - Tectonics , pre-mid Miocene, Columbia Plateau region set of overlays at 1:1,000,000 scale and field notes

4340 Environment

4341 Demography and airports - field notes

4341.1 Population data map, regional 1:500,000 scale
4341.2 Population data overlay - Hanford 1:62,500 scale
4341.3 Airports data map, regional 1:500,000 scale

4342 Biology/Ecology - field notes

- 4342.1 Protected ecological areas, regional 1:500,000 scale overlay
- 4342.2 Protected ecological areas, Hanford 1:62,500 scale overlay
- 4342.3 Culturally important areas - regional 1:500,000 scale overlay

5510 Hanford 1:250,000 base map and field notes for selection of candidate areas

- 5510.1 Generation of new faults and fault rupture screen
- 5510.2 Terrain ruggedness screen
- 5510.3 Transportation screen
- 5510.4 Aircraft impact screen
- 5510.5 Operational radiation release screen
- 5510.6 Protected ecological areas screen
- 5510.9 Ground motion screen
  Compilation of candidate area screens

5520 Hanford 1:62,500 scale maps and filed notes for screening of subareas

- 5520.1 Priest Rapids 15' quadrangle
  - 5520.1.1 Flooding
  - 5520.1.2 Terrain
  - 5520.1.3 Erosion idenuation
  - 5520.1.4 Fault rupture
  - 5520.1.9 Compilation of subarea screens
- 5520.2 Coyote Rapids 15' quadrangle
  - 5520.2.1 Hazardous facilities
  - 5520.2.2 Flooding
  - 5520.2.3 Terrain ruggedness
  - 5520.2.4 Fault rupture
  - 5520.2.9 Compilation of subarea screens
- 5530.3 Hanford 15' quadrangle
  - 5530.3.1 Landslides
  - 5530.3.2 Flooding
  - 5530.3.3 Terrain ruggedness
  - 5530.3.4 Erosion/denudation
  - 5530.3.5 Fault rupture
  - 5530.3.9 Compilation of subarea screens
- 5520.4 Mesa 15' quadrangle
  - 5520.4.1 Terrain ruggedness
  - 5520.4.2 Erosion/denudation
  - 5520.4.9 Compilation of subarea screens
- 5520.5 Corral Cayon
  - 5520.5.9 (on same sheet as base)
- 5520.6 Richland 15' quadrangle
  - 5520.6.1 Hazardous facilities
  - 5520.6.2 Flooding

5520.6.3 Terrain ruggedness
5520.6.4 Erosion/denudation
5520.6.5 Induced seismicity
5520.6.9 Compilation of subarea screens
5520.7 Eltopia 15' quadrangle
5520.7.1 Terrain ruggedness
5520.7.2 Erosion/denudation
5520.7.3 Induced seismicity
5520.7.9 Compilation of subarea screens

5530 Hanford site locality selection
5530.1 Overlays showing site localities on Hanford
5530.2 Notes, forms, files, etc., used in selection of site localities

APPENDIX D - SPECIAL STUDIES

Special studies, to develop information needed for the various tasks of the site locality identification study, were undertaken when the existing available literature lacked the necessary specific data. These special studies generally involved an extensive review of the existing literature to extract the needed data. They also involved the development of assumptions and subsequent data analyses to reach conclusions to provide the specific information needed for use in the siting study. The following two examples of special studies deal with an evaluation of operational radiation releases from a repository and a preliminary evaluation of earthquake ground motion in the subsurface.

D.1 EVALUATION OF OPERATIONAL RADIATION RELEASES

Safety-related radiological studies figure prominently in the licensing of all nuclear facilities. Accordingly, radiological considerations typically appear in methodologies for site identification studies that may lead to the selection and application for licensing of a nuclear facility. In the present case of a site identification study for a deep geologic repository for high level radioactive wastes in basalt, an evaluation was conducted to estimate the nature and magnitude of operational radiation releases from a repository. The results of this study were applied to the development of guidelines for the identification of candidate repository site.

D.1.1 Structuring the Problem

The objective of the radiological study was to develop a guideline for site identification that considered potential human exposure to operational releases of radiation from a repository. A comparable and analogous model for such guidelines is available from nuclear power plant identification studies. In these studies a minimum distance from population concentrations is frequently used to limit the area under consideration for sites. Such population setback guidelines, while often applied as conservative "rules of thumb", are based on an anticipated amount of radiation release, an average atmospheric diffusion potential (to account for dispersion of releases), and on Nuclear Regulatory Commission (NRC) positions on acceptable radionuclide concentrations, population doses, and population densities around nuclear power reactors. The phenomenon under study has several important features: a fixed source of radioactive emissions with a known emission rate operating over a known area and a knowable population density. Since these features are the same for rectors, repositories and other nuclear facilities, an approach for developing a repository siting guideline modeled after reactor siting guidelines was selected.

The steps in the approach were:

1. Estimate the maximum annual emmissions expected from a repository during its operating phase.

2. Based on calculated diffusion of expected emissions, estimate the distance

from a repository at which radionuclide concentrations would fall within established standards, both for environmental radiation and population dose.

3. Compare these results with NRC guidelines for popultion distribution around reactors (generally, a low population zone of about three miles radius is acceptable).

4. Select a conservative population setback distance for use in screening.

The greatest uncertainty in this approach occurs in the first step: estimating the operational releases at a repository site. At the time this evaluation was initiated, the size of the repository (its radioactive inventory) and the engineering characteristics of the repository were largely unknown; in addition, a spent fuel reprocessing facility has been dropped from consideration in the site identification study.)

The estimate of the emissions from a repository was based on assumptions regarding spent fuel pin and waste cannister leakage rates, applied to a total cannister inventory estimate based on Rockwell preconceptual design working documents adjusted for thermal loading considerations. The logic of this approach is shown schematically in Figure D-1. The method of computing the radioactive inventory of the repository was adapted conservatively from GESMO (NUREG-002,1976) and from ERDA-76-43. The estimate of radionuclide emissions from a reprocessing plant was taken from the environmental statement prepared for the Barnwell reprocessing plant in South Carolina (NRC Docket No.50-332,1974). The analysis focused mainly on two gaseous radionuclides, ^{85}Kr and ^{3}H; iodine (^{129}I and ^{131}I) was also considered.

D.1.2 Results

Estimates of maximum annual release radioactive effluents from a repository, a reprocessing plant and a 1000 MWe power reactor are presented in Table I. The significant releases concern ^{85}Kr and ^{3}H. The expected releases of these radionuclides are two-to-three orders of magnitude greater for a repository than for a reactor. Dispersion calculation incorporating these values were performed for various dispersion scenarios, solving for the amount of release that would be necessary to yield the maximum permissible concentrations (MPC's) allowed by federal regulations. The results of these calculations are shown in Table II. Under all dispersion scenarios examined, the expected release from the repository would be insufficient to yield concentrations in excess of the MPC's at a distance of one kilometer from the point of release. If a five kilometer from the point of release. If a five kilometer population setback around a repository were applied (a distance typically used in reactor siting) the amount of radionuclides released would have to increase by several order of magnitude before radionuclide concentrations at the site boundary could exceed the standards. Therefore, a five kilometer (three mile) setback is a conservative guideline for use in screening. Table III contains assumptions and calculations used to estimate releases from a repository. Table IV presents estimates of the inventory of two radionuclides (^{85}Kr and ^{3}H) during 25 years of repository operation. Table V presents decay factors used in computing radioactivity in the repository over time. Table VI

TABLE II

ANNUAL RELEASE OF SIGNIFICANT RADIONUCLIDES IN GASEOUS EFFLUENTS

CURIES/YEAR

NUCLIDE	1000 MWe REACTOR[a]	REPOSITORY[b]	SURFACE FACILITIES[c]	REPROCESSING PLANT[d]
^{3}H	43 - 1100	1.3×10^{4}	Negligible	7×10^{5}
^{14}C	8 - 9.5	-	-	1360[e]
^{85}Kr	290 - 470	$5 \times 10^{4} - 1.4 \times 10^{5}$	Negligible	1.4×10^{7}
^{87}Kr	3 - 200	-	-	-
^{88}Kr	23 - 240	-	-	-
^{33}Xe	3200 - 12000	-	-	-
^{35m}Xe	1 - 740	-	-	-
^{35}Xe	86 - 1100	-	-	-
^{38}Xe	1 - 1400	-	-	-
^{29}I	-	-	-	0.05
^{31}I	0.03 - 0.3	-	-	0.5
^{33}I	0.02 - 1.1	-	-	-

a) U.S. Nuclear Regulatory Commission, "Final Generic Environmental Statement on the Use of Recycle Plutonium In Mixed Oxide Fuel in Light Water Cooled Reactors" (GESMO), NUREG - 002, 1976. Tables IV C-17 & IV C-19.
b) Woodward-Clyde Estimates, conservatively based on GESMO; ERDA-76-43 and
c) GESMO, TABLE IV H-14
d) U.S. Atomic Energy Commission, "Environmental Statement Related to Construction And Operation of Barnwell Nuclear Fuel Plant", Docket No. 50-332, 1974.
e) GESMO, TABLE IV E-8

TABLE II

10 CFR 20 MPC's

	uCi/ml		
Kr^{85}	3×10^{-7}	$t^{1}/_{2}$ = 10.76y	B-0.67 µev £0.514 (0.41%)
H^{3}	2×10^{-7}	$t^{1}/_{2}$ = 12.26y	B-0.0185 µev £ none

If we take various χ/Q's from Table IV J(A)-2 of GESMO, we can calculate releases that will equal 10 CFR20 MPC's.

100m	from	ground	level	release	(6.4E-5)	1.48×10^{5} ci/yr
300m	"	"	"	"	(1.4E-5)	6.75×10^{5} ci/yr
500m	"	"	"	"	(5.4E-6)	1.75×10^{6} ci/yr
*1000m	"	"	"	"	(1.5E-6)	6.30×10^{6} ci/yr
*1000m	"	100m Stack		"	(1.6E-8)	5.63×10^{8} ci/yr

* This may be interpreted to say that a 1km setback will bring all expected releases from a repository within the MPC levels expressed in 10 CFR 20. A three mile (5km) setback typically applied to power reactors is therefore a guideline to use in screening.

TABLE III

RADIOACTIVE RELEASE CALCULATIONS

2010 Inventory X f1 f2 f3 f4 f5 = Release

f1 - fuel pins leaking = .1

f2 - fraction of reaionuclide escaping cladding in year = .5

f3 - canisters leaking = .1

f4 - fraction of radionuclide escaping canister in year = .5

f5 - fraction of sealed boreholes leaking = .1

2010 Release (^{85}K) = $5.5 \times 10^{8} \times .1 \times 5 \times 10^{-1} \times .1$
$= 1.4 \times 10^{5}$ Ci/yr

2010 Release (^{3}H) = $5.0 \times 10^{7} \times .1 \times 0.5 \times .1 \times 0.5\ .1$
$= 1.3 \times 10^{4}$ Ci/yr

TABLE IV

^3H & ^{85}Kr INVENTORIES IN A REPOSITORY

Based on number of assemblies per Table A-4 RHO-BWI-CD-2 and activity per assembly per Table 2.3 ERDA-76-43 and 5-yr delay to emplacement.

Time Interval	^3H Ci	^3H Ci (as of 2010)	^{85}Kr Ci	^{85}Kr Ci (as of 2010)
1985*	3.76E	9.0E5	4.3E7	8.1E6
1986	8.3E5	2.1E5	9.5E6	2.0E6
1987	9.4E5	2.5E5	1.1E7	2.5E6
1988	1.1E6	3.3E5	1.3E7	2.5E6
1989	1.3E6	4.1E5	1.5E7	3.9E6
1990	1.5E6	4.7E5	1.7E7	4.7E6
1991	1.6E6	5.6E5	1.9E7	5.5E6
1992	1.8E6	6.5E5	2.1E7	6.5E6
1993	2.0E6	7.5E5	2.3E7	7.6E6
1994	2.2E6	8.6E5	2.5E7	9.0E6
1995	2.3E6	1.0E6	2.7E7	1.0E7
1996	2.5E6	1.1E6	2.9E7	1.2E7
1997	2.7E6	1.3E6	3.1E7	1.3E7
1998	2.9E6	1.5E6	3.3E7	1.5E7
1999	3.1E6	1.7E6	3.6E7	1.7E7
2000	3.3E6	1.9E6	3.8E7	2.0E7
2001	3.6E6	2.2E6	4.2E7	2.3E7
2002	2.9E6	2.5E6	4.5E7	2.7E7
2003	4.2E6	2.8E6	4.8E7	3.1E7
2004	4.4E6	3.1E6	5.1E7	3.5E7
2005	4.7E6	3.5E6	5.4E7	3.9E7
2006	4.7E6	3.8E6	5.4E7	4.2E7
2007	4.7E6	3.9E6	5.4E7	4.5E7
2008	4.7E6	4.2E6	5.4E7	4.8E7
2009	4.7E6	4.5E6	5.4E7	5.1E7
2010**	5.9E6	5.9E6	6.8E7	6.8E7
		TOTAL-5.0E7 (2010 - no leaks)		TOTAL-5.5E8 (2010 - no leaks)

* 1980 in Table 2.3

** 2005 in Table 2.3

Note: 3.7E6 = 3.7×10^6

TABLE V

DECAY FACTORS USED IN CALCULATING RADIONUCLIDE INVENTORIES

Years From Emplacement	Decay Factor ^{3}H	Decay Factor ^{85}Kr
25	.24	.20
24	.26	.21
23	.27	.23
22	.29	.24
21	.31	.26
20	.32	.28
19	.34	.29
18	.36	.31
17	.38	.33
16	.40	.36
15	.43	.38
14	.45	.41
13	.48	.43
12	.51	.46
11	.54	.49
10	.57	.53
9	.60	.56
8	.64	.60
7	.67	.64
6	.71	.68
5	.75	.72
4	.80	.77
3	.84	.83
2	.89	.88
1	.95	.94

TABLE VI

Preliminary Dose Calculation, based on conservative assumptions, for ^{85}Kr

For Immersion GESMO IVJ (A-9)

$$D_{WB} = R \times \chi/Q < D_c$$

D_{WB} = Dose to whole body from immersion

R = Release rate, Ci/sec

χ/Q = Atmospheric dispersion factor sec/in^3

Dc = Dose conversion factor R/Ci - sec/in^3

$$1.4 \times 10^5 \frac{Ci}{yr} \times \frac{1}{3.15 \times 10^7} \frac{yr}{sec} \times 1.5 \times 10^{-6} \frac{sec}{m^3} \times 4.3 \times 10^{-2} \frac{R.m^3}{Ci\text{-}sec} =$$

2.9×10^{-10} R/sec = 2.9×10^{-7} mR/sec

$\times\ 3.15 \times 40^7$ sec/yr = 9.1 sec/yr

10 CFR 20 MPC

3×10^{-7} µCi/ml = 3×10^{-7} Ci/m^3

$\bar{D}_s = 4.3 \times 10^{-2} \times 3 \times 10^{-7} = 1.3 \times 10^{-9}$ R/sec $\times\ 3.15 \times 10^7$ = 31.5 mR/yr

$D_{WB} = 5.1 \times 10^{-4} \times \underline{1.4 \times 10^5} \times 1.5 \times 10^{-6} = 0.1$ mR/yr

$$D_{WB} = 7.88 \times 10^9 \times \frac{1.4 \times 10^5}{3.15 \times 10^7} \times 0.514 \times 0.0041 \times 1.5 \times 10^{-6} = .1$$

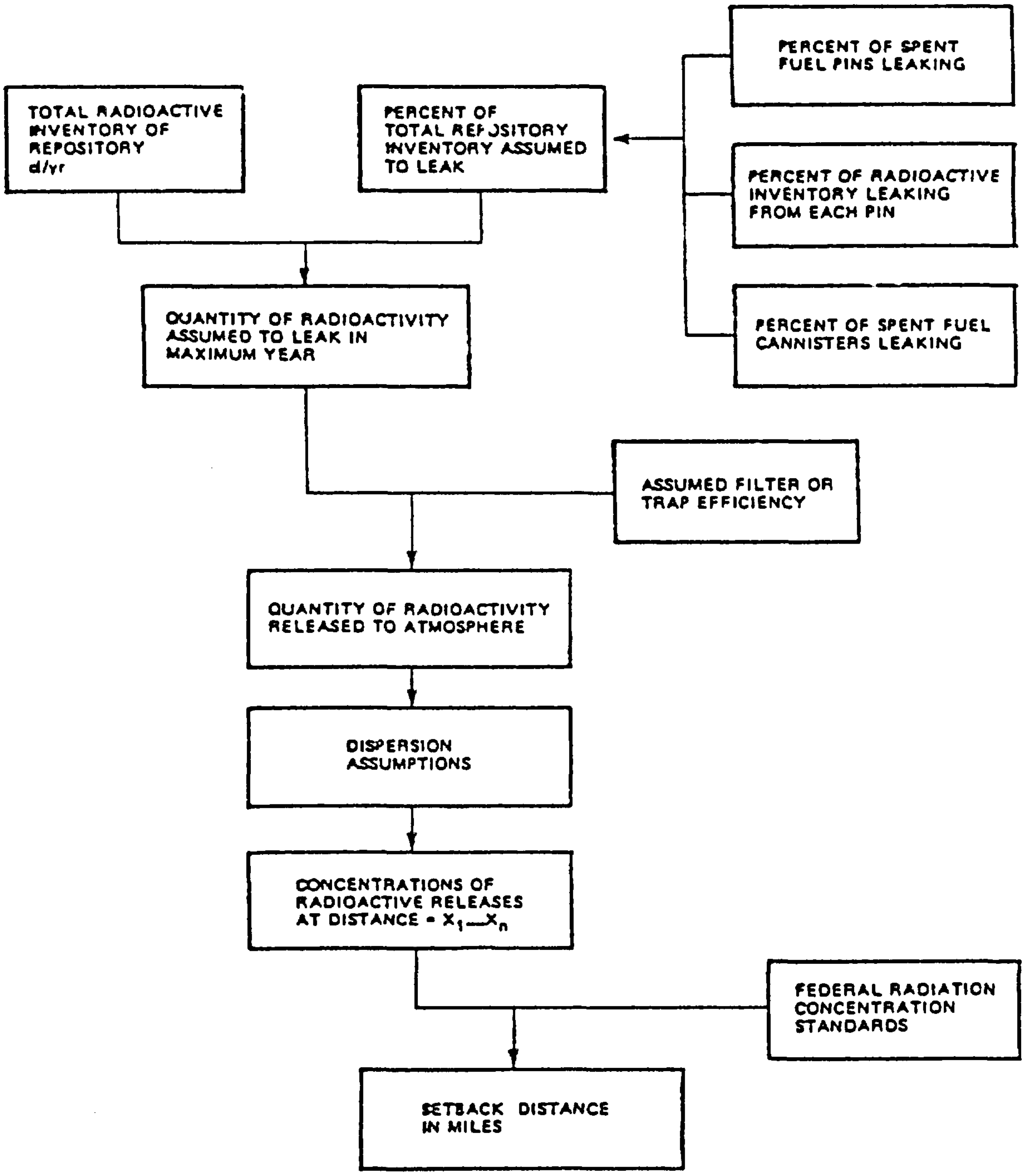

FIGURE D-1

APPROACH TO EVALUATION OF OPERATIONAL RADIATION RELEASE FROM A REPOSITORY presents the results of a check using dose calculations. This check was performed to verify that maximum releases from a repository would not exceed federal standards for whole body does to the public in an annual period. The results show that operational releases from a repository would yield a whole body dose amounting to a small fraction of the federal standard.

D.1.3 Conclusions

Based on an evaluation of operational radiation releases from a repository, a population setback distance of five kilometers (three miles) was selected for use as a screening guideline in the repository site identification study. This value is conservative in terms of expected releases, and in terms of applicable federal standards.

D.2 LITERATURE SURVEY AND PRELIMINARY EVALUATION OF GROUND MOTION IN THE SUBSURFACE

D.2.1 Purpose

A literature search was performed in order to determine the available data from which to make a preliminary evaluation of the effects of vibratory ground motion on underground facilities. This evaluation complemented development of ground motion guidelines in Table II which were used in the Task 5 screening process. The evaluation was based on the consideration of pertinent published literature in geology, rock mechanics, mining, engineering and seismology.

D.2.2 Sources of Data

A preliminary survey of available in-house references was done as well as utilization of the Georef computer access technical information service for relevant sources. A total of approximately 50 pertinent references was located, many of which were contained in a special report to DOE by Pratt and others (1978) on earthquake damage to underground facilities. The references contained herein, include pertinent secondary as well as primary references and are annotated in the project bibliography. The primary references will be discussed in the results and conclusions section.

D.2.3 Results and Conclusions

The most recent work on earthquake damage to underground facilities has consisted primarily of data compilations from world-wide studies on mine and tunnel damage due to earthquakes. Based on this preliminary literature survey, it was found that very little is presently being done by way of instrumentation of underground facilities for the express purpose of using recorded earthquake motion for developing seismic design specifications and criteria. The application of accoustic emission and microseismic recording techniques to underground workings such as rock and coal mines and underground gas storage facilities are discussed in review article by Hardy (1977). A few studies have examined the problem of the recording and analysis of ground motions in mines from small earthquakes actually occurring in association with mining activities. (Armstrong and others, 1969; Kaufman and others, 1978; McGarr, 1971; Smith and others, 1974; McGarr and others, 1977). These studies have shown that ground motions associated with tremors in mines can be recorded and located, earthquake magnitude can be determined, local stress patterns can be obtained, spectral analysis of wave forms can be performed and regions of anomalous stress in the mine vicinity can be identified. In particular, McGarr and others, (1978) have obtained peak accelerations of as much as 129 from mine tremors for events of local magnitudes -1 to 2.6 and in the hypocentral distance range of 50m to 1.6 km. The recorded accelerograms typically have frequencies of several hundred Hz.

One of the most complete surveys of available data draws heavily upon ground motions recorded during nuclear explosions (Pratt and others, 1978). The principal conclusions are given below:

- o Little data exists of damage in the subsurface due to earthquakes. This in itself attests to the lessened effect of earthquakes in the subsurface since mines exist in areas where strong earthquakes have done extensive damage to surface structures.

- o More damage is reported in shallow near-surface tunnels than in deep mines. Data are sparse for mines deeper than 500 meters.

- o In mines and tunnels, large displacements occur primarily along pre-existing faults and fractures or at the surface entrance to these facilities.

- o Data indicate vertical structures such as wells and shafts are also not as susceptible to damage as are suface facilities. Even in the Alaska earthquake of 1964 ($M_s = 8.5$), few wells were damaged in Anchorage except those sheared by landslides.

- o Data were insufficient to assess the exact influence of rock type on damage; however, the effects are less in well consolidated materials than in alluvium. Stevens (1977) has compiled data principally from the U.S. and covering earthquakes occurring during pre-instrumental time. He suggests also that the severity of ground motion in a mine located in competent rock is les than one located in less competent, weathered, or unconsolidated rock. Little data are available to strictly test this hypothesis. Geologic structures, such as faults, appear to be a dominant factor in damage to underground facilities.

- o Frequencies most likely to cause damage to subsurface facilities are significantly higher (50 to 100 Hz) than the frequencies (2 to 10 Hz) that cause damage to surface facilities.

- o Acceleration, velocity, and displacement data from nuclear explosions may give near-source upperbound limits for large earthquake ground motion when a facility is very near the epicenter.

- o More analysis is required before seismic criteria can be formulated for siting of nuclear waste repositories.

One of the shortcomings of comparing earthquake vibratory ground motion with