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RESEARCH AND DEVELOPMENT TASKS OF THE BASALT WASTE ISOLATION
PROGRAM - AND THEIR RELATIONSHIP TO THE LICENSING PROCESS

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RESEARCH AND DEVELOPMENT TASKS OF THE
BASALT WASTE ISOLATION PROGRAM - AND
THEIR RELATIONSHIP TO THE LICENSING
PROCESS

W. P. Kunkel

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I. BACKGROUND

The Waste Isolation Program of Rockwell Hanford Operations is aimed at establishing the feasibility and providing the technology to design and construct a geologic repository for the storage of radioactive waste in basalt formations within the Columbia Plateau. As part of this effort, a commitment has been made to obtain a federal license to construct and operate such a facility.

It is the purpose of this document to present a preliminary licensing program and outline the research and development strategy by which a license will be obtained for the repository. Although the paper addresses the base data covering the major areas of investigation and technology which will provide input to the licensing process, it should be noted that a more comprehensive discussion of these facets and their relationship to the licensing process may be found in the Waste Isolation Program Plan⁽¹⁾ for the repository. In addition to the program plan, it is anticipated that a detailed licensing plan for the program will be developed during FY 1979.

Basically, each facet of the program, as described in the plan, will be used as part of the documentation required for the Preliminary and Final Safety Analysis Report (PSAR and FSAR), as well as the Environmental Report (ER). In addition, these data will be included in all design considerations.

II. GENERAL SCOPE OF THE LICENSING PLAN

The storage of radioactive waste in a geologic repository encompasses many safety considerations which have not been encountered in the safety evaluation and licensing of nuclear power facilities. As such, the Basalt Repository licensing plan must contain many aspects which are unique to this type of a facility. Some precedence may be established in the licensing activities for the Waste Isolation Pilot Plant (WIPP) in Carlsbad, New Mexico, but even in this case, there are sufficient differences in the media and environment to modify the detailed information to be considered. A simplified bar chart of the licensing schedule, as it is presently planned, is shown in Figure 1. The interface between the data acquisition activities, the design effort, and the preparation of the PSAR and the ER is apparent.

Table I presents a more detailed listing of the major steps currently anticipated for the licensing process. In order to meet these programmatic goals, several impact points have been identified. The key accomplishments which must be met to achieve these goals are summarized in Table II. It is apparent that a definitive evaluation of the licensing plan will be required to fill in many of these details, especially with regard to the timely inclusion of engineering data, specific site characterization, and other important aspects of the licensing process. It is presently anticipated that such a detailed licensing plan will be developed during FY 1979. The date is predicated upon the early availability of Regulatory Guidance such as 10CFR60 and associated documentation.

FIG. 1
SIMPLIFIED LICENSING SCHEDULE FOR REPOSITORY

o FISCAL YEAR 1978

- o CONTENTS OF ENVIRONMENTAL REPORT DEFINED AND OUTLINE SUBMITTED TO DOE
- o CONTENTS OF PRELIMINARY SAFETY ANALYSIS REPORT DEFINED AND OUTLINE SUBMITTED TO DOE
- o METHODOLOGIES INVESTIGATED FOR ASSESSMENT OF LONG-TERM RISK
- o ER AND PSAR STARTED- HANFORD SITE DATA ASSEMBLED

o FISCAL YEAR 1979

- o RISK ASSESSMENT DEVELOPED AS DESIGN PROGRESSES
- o NON-HANFORD SITE DATA DEVELOPED (IF APPLICABLE)

o FISCAL YEAR 1980

- o ER AND PSAR IN PREPARATION

o FISCAL YEAR 1981

- o ER AND PSAR COMPLETED AND SUBMITTED TO DOE
- o NRC ACCEPTS PSAR AND ER AND DOCKETS
- o NRC ISSUES DRAFT ENVIRONMENTAL IMPACT STATEMENT (DEIS)
- o NRC ISSUES SAFETY EVALUATION REPORT (SER)

TABLE I

SIGNIFICANT GOALS OF THE LICENSING SCHEDULE

o FISCAL YEAR 1982

- o RECEIVE PUBLIC COMMENT
- o NRC ISSUES FINAL ENVIRONMENTAL IMPACT STATEMENT (FEIS)
- o PUBLIC HEARINGS

o FISCAL YEAR 1983

- o NRC ISSUES LIMITED WORK AUTHORIZATION (LWA) FOR SITE PREPARATION
- o NRC ISSUES CONSTRUCTION PERMIT (CP)

o FISCAL YEAR 1984 AND BEYOND

- o CONTINUE LICENSING DOCUMENTATION TO OBTAIN OPERATING LICENSE

TABLE I (Continued)

SIGNIFICANT GOALS OF THE LICENSING SCHEDULE

A. SITING

- o SITES SELECTED FOR PRELIMINARY CHARACTERIZATION BY SEPTEMBER 1978
- o SITE SELECTION NARROWED TO THREE OR LESS BY SEPTEMBER 1979
- o DRAFT ER'S COMPLETED FOR FINAL SITE CANDIDATES BY SEPTEMBER 1980

B. DESIGN

- o DESIGN CRITERIA AVAILABLE BY JULY 1978
- o SUFFICIENT DESIGN INFORMATION TO SUPPORT PREPARATION OF A LICENSING APPLICATION AVAILABLE BY JUNE 1979

TABLE II
REQUIREMENTS AND ASSUMPTIONS FOR LICENSING SCHEDULE

III. APPLICATION OF SPECIFIC RESEARCH ACTIVITIES TO THE PSAR AND ER

Several areas of specific research activities have been identified in recent correspondence⁽²⁾ as those which will receive a thorough review by the Department of Energy and the Nuclear Regulatory Commission during a repository licensing process. These are described briefly below, together with other additional areas of concern which have been identified.

All of these areas will eventually be considered in a depth sufficient to assure that the safety considerations of the repository have been adequately explored. The following sections describe for these research areas their content, schedule, and relationship to the licensing process. The list will be expanded as the requirements for the PSAR and the ER are developed in more detail.

A. THERMAL MODELING

The results of thermal modeling studies are required to provide input into the PSAR and ER for risk assessment and other facets of the repository safety evaluation. In addition, these data will be utilized extensively during the design effort.

Thermal modeling studies will be conducted in three phases: The first of these, Lab Testing of Core Samples (presently being conducted by the Colorado School of Mines), will subject core samples of typical deep basalt and other rock to basic thermal and engineering characterization tests. These studies will lead into follow-on studies in FY 79 which will include more advanced testing of cores from candidate flows. The advanced tests will include the effect of irradiation, pressure, temperature, moisture, and other variables on the thermal and engineering

characteristics. A sensitivity analysis of these parameters and their effect upon analytic and design values will be conducted by a computer modeling study to be run by the University of Minnesota. Results for the entire laboratory phase are anticipated by December 1980.

The second phase of the thermal modeling studies is planned with the emplacement and testing of *in situ* heater experiments in the Near Surface Test Facility. These tests are planned to begin in September 1979, with completion in January 1980, and will result in the preliminary qualification of basalt as a storage media. The design and computer verification of the test design is being performed by Lawrence Berkeley Laboratory, with additional review and evaluation by the University of Minnesota.

The third phase of the thermal modeling studies will be directed towards the establishment of a computer model for predicting repository performance. Variables to be studied will be the effects of heat, borehole depth, and spacing. This study, which is directed by the University of Minnesota, was started in November 1977. Design has now been completed, and parametric design studies are underway to model the design, check room sizes, evaluate the effects of thermal perturbations on seismic events and to conduct other regional studies.

B. ION MIGRATION

Ion migration studies are necessary in the licensing process to provide data, models, and methodology by which radioactivity transfer can be considered in both the PSAR and the ER. Several studies are being conducted which can be considered as part of the ion migration

characterization. These include the development of a solid diffusion model as well as detailed ground water flow studies.

1. Solid Diffusion

The ion migration or solid diffusion model development is being conducted by Boeing Computer Services of Richland, Washington. Basically the model assumes an essentially dry repository in a dense basalt stratum, and determines (for solid diffusion transport) the amount of time necessary for radionuclides to migrate through the basalt stratum to an overlying permeable interbed. The model has been completed and a document which describes the model development will be available in July 1978. It is intended that this model will be used in the PSAR and possibly in the ER, as one case for evaluating radioactivity transport from the repository. To provide the basis for a sensitivity analysis, all parameters can be varied to determine the magnitude of the effects, although the initial selection of parameters have been chosen to be conservative. Fundamental data which are used in the modeling are diffusion coefficients for various nuclides through dense media. These are obtained from the literature. Specific diffusion coefficients for basalt and the specific nuclides which are of significance would be useful, but do not appear to be necessary at this stage of development.

2. Ground Water Flow

A characterization of ground water flow is essential in the evaluation of radioactivity transfer considerations for both the PSAR and the ER. In addition, ground water flow studies are a portion of the hydrologic input for both the preliminary site selection and the final site

characterization. Detailed ground water flow definition and onsite field studies are being done by Lawrence Berkeley Laboratory and Rockwell. It is anticipated that licensing inputs from the Pasco Basin flow model will be available by June 1979, and similar data from the regional flow model will be available by September 1979. Further characterization of ground water flow for the specific site of the repository will be integrated into a model for evaluation of site hydrologic response. The studies of hydrologic testing are directed towards quantifying and qualifying the basalt effective porosity, permeability, storage, dispersion coefficients, and natural flow velocities. This testing will be done with withdrawal tests, injection tests, temperature gradients, and a downhole laboratory to measure low moisture conditions.

Other studies of ion migration are being done as part of the multiple barrier studies. Since the migration of radionuclides through the basalt is influenced by waste-rock interactions, these studies are discussed in the next section.

C. WASTE-ROCK INTERACTION

One of the more important phases of the licensing effort is concerned with the changes to the normal dispersion coefficients and transport velocity of radionuclides as a result of waste rock interaction.

Migration of these nuclides, as well as perturbations in the near field stress effects may be influenced by the thermal response of the basalt to the emplaced capsule, and also by an attendant chemical interaction between the waste, the basalt media, ground water, or other repository materials. Waste-Rock interaction studies therefore are being conducted

to provide data in these areas, and to permit the development of models to simulate these effects.

Simulated spent unprocessed fuel experiments are presently underway at Pennsylvania State University to determine the magnitude of the fuel/canister ground water/basalt interactions. In this manner, potential chemical reactions can be determined and a method developed whereby the distance and rate of radionuclide transport through the basalt and other surrounding materials can be determined. The effects of independent variables, such as temperature, pressure, Eh, and pH on the sorption and diffusion characteristics of the various materials will be determined. The results of these studies, which will be completed in FY 1980, will be utilized extensively in the PSAR and the ER. They will be followed by hot-cell experiments in FY 1982 to further provide design information and to provide the additional detail required for subsequent safety evaluations.

D. SEISMIC EVENTS

One of the licensing requirements which concerns the geologic aspects of a nuclear waste repository, is the fact that the repository site must be shown to be geologically stable so that the rate and amount of predictable long-term regional uplift and subsidence of bedrock does not pose a threat to the physical integrity of the repository. Base data programs have been established to study seismic events of the Columbia Plateau to assure this stability exists, and to provide the necessary input to the PSAR and ER.

1. Seismic Monitoring Network Program

The network monitoring program, which is presently under the direction of the Geophysics Department of the University of Washington, has been acquiring data since 1969. These data will be used in the PSAR and ER to formulate maximum potential earthquake magnitudes and ground acceleration levels, as well as to describe the stress field and pattern of stress release. The fundamental data from these studies will also be used to develop a predictive capability, and formulate a tectonic model.

2. Remote Sensing Program

The objective of this program is to identify, through the examination of aerial photographs, linear features which may be geologically significant. Pacific Northwest Laboratory is conducting this program and will produce a map of detectable linears greater than 10 km in length for the Columbia Plateau. It is anticipated that these data will be available for use in the licensing documentation by the end of FY 1979.

3. Regional Mapping and Stratigraphic and Structural Modeling Program

The objective of this program is to develop, through geologic mapping, a concept of the stratigraphy of the basalts (Columbia River), the overlying sediments, and the deformational pattern of these rocks. These data will be used to evaluate potentially capable faults, and to provide data for alternate site studies in the ER. The portion of these studies dealing with the Columbia River basalts is being conducted by the U.S. Geological Survey. The Washington Department of Natural Resources is studying the sediments. The study of the basalt and sediments within the Pasco Basin is being done by Rockwell Hanford Operations (RHO). As

a result of these studies, fundamental data for the production of a geologic map of the Columbia Plateau underlain by the Columbia River Basalt will be available by the end of FY 1979.

E. TECTONIC STABILITY AND VOLCANISM

A tectonic modeling program is presently being developed. The goal of the activity, for which no definite contractual arrangements have yet been made, is to develop a regional tectonic model for the Columbia Plateau. The data from this effort, which will be used to predict future deformation, volcanism and faulting for the PSAR, are essential to estimate the integrity of the multiple barrier concept. It is anticipated that an initial model will be formulated by the end of FY 1979. Models are currently available, but cannot be satisfactorily evaluated until additional data are collected.

F. ACCIDENT SCENARIOS AND ANALYSIS

Although many of the accident evaluation studies to be performed as part of the PSAR will require detailed design and site specific information, some of the fundamental data upon which these analyses will be based can be developed early in the project. There are therefore, several efforts currently underway (or shortly to begin) which will supply information to develop repository accident scenarios and to obtain the data required for their analysis. Some of the more significant of these are the fission product or fissile material release scenario development, and the disruptive events analysis. It is anticipated that, as the design progresses, these studies will require iteration and modification. Other studies will be added during design evolution.

1. Radioactivity Release Scenarios

In order to postulate release scenarios that could occur at the repository site, the safety analysis model developed for the Waste Isolation Safety Analysis Program (WISAP) will be used, in conjunction with specific site data from Hanford and/or the nearby region. These scenarios, in addition to their obvious use in the PSAR and the ER accident analyses, will also be used in the design considerations to promulgate designs that will mitigate the possible effect of these releases. The effort is to be completed by Battelle Northwest Laboratories at the end of FY 1978 or shortly thereafter, depending upon available funding. The sensitivity analysis for the effort will comprise a statistical analysis and a variation of the input parameters to evaluate sensitivity. Fundamental data for this portion is being acquired by the Waste Isolation Program through its various program tasks, and is being supplemented by regional data where available.

2. Disruptive Events Analysis

One of the more important aspects of the accident scenario development and accident analysis is the analysis of those events that could possibly disrupt a geologic repository at Hanford, with a resulting release of radioactive material from the emplacement. This analysis will also determine the interrelationships between events that could release such material to the biosphere. Thus, these data are directly applicable to the accident evaluations of the PSAR and the ER, and the appropriate sensitivity analysis of the material obtained can be determined by variation of the input parameters. Work is just beginning in these analyses, with the first step being the selection of an external consultant group to provide the analysis. Woodward-Clyde Consultants, have been selected by the open bid

process in June of 1978, and the scheduled completion of Phase I will be early in FY 1979. This study, which will essentially be a scoping study, will be followed by Phase II, wherein transport modeling will be developed, and Phase III, in which the consequences (i.e. radioactive transport and effect on man) will be studied.

G. REPOSITORY SEALING

One of the primary environmental safety concerns of the licensing documentation for the geologic repository concept, is the method of eventual sealing for the boreholes associated with the repository. These boreholes represent a conduit through the dense basalt media by which radioactive material (if released from emplacement) could be transported to the biosphere. Consequently, the research directed towards demonstrating adequate repository sealing (or as it is described in this program) borehole plugging, forms an important part of the repository studies for support of the licensing activities. These results will be used in evaluating accident scenarios, and in release mitigation studies for the PSAR and the ER. The fundamental data which are required to ascertain the media characteristics are being developed by the Waste Isolation Program tasks. The borehole plugging activity is divided into three inter-related phases which are intended to progress concurrently throughout the project until final specifications for borehole plugging are developed, and the sealing system is demonstrated.

1. Material Evaluation

Material evaluation is a program to define the chemical and physical environment of the boreholes to be plugged, and to locate and test various

types of materials to fill the holes. The preparation of work packages is now underway and it is anticipated that a contract will be let later this year, with an initial report to be available late in Fiscal Year 1979.

2. Machine Design

Some sections of the borehole may be dry, while others are wet. It is therefore anticipated that two types of plugging machines will be developed. Since conventional post-emplacement inspection is not possible, these machines must be instrumented to record the condition of the plug during emplacement, and assure a quality plug. This study will also be contracted to a qualified consultant. Initial results from this phase will be completed by September 1980.

3. Demonstration and Specification

As the material development program and the machine design are progressing, specifications and procedures will be prepared. These will be preliminary specifications near the beginning of the work to guide the work in progress on material selection and demonstration machine design. When the machines and materials are ready for demonstration, final specifications and a bid package will be prepared for demonstration of the borehole-plugging system.

H. GROUND WATER FLOW

Characterization efforts currently underway which will enable hydrologic models to be developed are basically divided into two study areas: The Columbia Plateau Hydrology Program, which is designed to provide a regional hydrologic model; and the Pasco Basin Hydrology Program, which will develop a submodel specific to the Pasco Basin.

This information is necessary to understand the complex hydrologic relationships between sub-basins and the hydrology within a single basin.

The information will be used in the Preliminary Safety Analysis Report (PSAR) and Environmental Report (ER) to describe the existing environment and to aid in the development of site specific accident scenarios.

1. Columbia Plateau Hydrology

The Columbia Plateau Hydrology Program is divided into three tasks:

- a. Data Consolidation and Flow System Evaluation
- b. Data Acquisition and Landsat Imagery
- c. Model Formulation and Preliminary Verification

The Data Consolidation and Flow System Evaluation task will develop and evaluate a hydrologic data base for the Columbia Plateau. The Department of Ecology of the State of Washington (with a subcontract to Washington State University) will perform and document this work by the end of Calendar Year 1978. This effort will provide the fundamental data required for intensive hydrologic modeling efforts.

The Data Acquisition and Landsat Imagery task will acquire hydrologic data from deep wells penetrating the basalt sequence along the periphery of the Pasco Basin as necessary to support the Columbia Plateau hydrology program. The data will be required to describe the existing environment as well as to provide information necessary for accident analysis in the PSAR and ER. Battelle-Northwest will conduct this task to: (1) monitor the drilling, sampling, and aquifer testing of four exploratory wells; and, (2) acquire geologic, hydrologic, soils and vegetation data using Landsat satellite imagery. The Data Acquisition and Landsat imagery task will provide further fundamental hydrologic data necessary for the development of an accurate regional hydrology model. These data will be available by the end of FY 1978. Appropriate sensitivity analysis will be performed when the data are inputted into the computer models.

The Model Formulation and Preliminary Verification task will provide a regional ground water simulation model that will aid in the selection of sites for a repository. Rockwell will complete the simulation model by the end of FY 1978. The model will be made available to the U. S. Geological Survey (U.S.G.S.).

The U.S.G.S will perform a data analysis and evaluation study preparatory to the regional modeling. The regional model will make extensive use of sensitivity analysis methods to determine the degree of variation of the results as a function of the input parameters. Fundamental data will come from the two previous tasks as well as from existing U.S.G.S. information.

2. Pasco Basin Hydrology

The purpose of the studies concerning the Pasco Basin Hydrology is to characterize the fracture network, especially in the deeper basaltic horizons

where a repository may be constructed, and to establish the overall permeability of the rock mass. A third benefit resulting from these studies is the provision of input to the first critical problem of site selection for the exploratory shafts.

The Pasco Basin Hydrology program is divided into four tasks:

- a. Data compilation and evaluation;
- b. Hydrostratigraphic mapping;
- c. Field hydrology studies; and,
- d. Basin modeling.

The data compilation and evaluation phase of the Pasco Basin studies will compile and evaluate the existing hydrologic data on the ground water flow system occurring in the Pasco Basin basalts. In addition to a detailed literature survey, a compilation will be made of all data available describing well structures drilled below the Mabton interbed of the Saddle Mountain Basalt Formation. Additional studies will be conducted to characterize and collate physical characteristics of basalt rock core and interbed sample data, geophysical logs, and piezometric information on the basalts. Chemical data including chemical and radiochemical analysis, stable isotopic ratios, and age determinations will be documented and compiled. The last task of this data compilation and evaluation phase involves completing an evaluation of the characteristics, identification, and correlation of the ground water flow systems from available data.

All of the data compilation and evaluation effort will be conducted by W. K. Summers and Associates, and a completion date of September 1978 is anticipated for this phase.

The Field Hydrology Studies are subcontracted to Lawrence Berkeley Laboratory. The objective of this phase of the Pasco Basin studies is to measure the vertical and horizontal fluid flow characteristics of the basalts at intervals corresponding to the repository depth, and to geo-chemically characterize the ground waters and determine residence times.

The chemical characterization and age dating will be used to evaluate the ground water's past history and the possible hydrologic inter-relationships of the deep basaltic flow systems and shallower aquifers.

The PSAR and the ER completion are highly dependent upon reliable hydrology field data. Further results of these studies will be used to assure proper site selection and repository construction.

Hydrostratigraphic mapping studies are underway to define the ground water flow conditions existing at depth of the proposed waste repository. The data used for this task will principally be taken from the Data Compilation and Evaluation task during FY 1978 and from the Field Hydrology Task in subsequent years. Much of the risk analysis of the SAR and ER is dependent upon the data acquired in this study to permit an evaluation of the potential transport of radionuclides from a repository site. These studies will also evaluate interaction of this flow with the regional flow systems of the Columbia Plateau and with possible shallower aquifers within the Pasco Basin. This task is being conducted by W. K. Summers and Associates.

Basin Modeling of the Pasco Basin is required to develop a mathematical model for simulating ground water flow through the deep basaltic rocks of

the basin, and to provide a method whereby the Pasco Basin modeling effort can be integrated with the regional flow modeling research. These efforts are being conducted by Lawrence Berkeley Laboratory and Rockwell, and will provide additional input to the risk analysis studies of the PSAR and ER.

IV. OTHER STUDIES IN WHICH WORK IS ANTICIPATED

It is recognized that there may be other events which will require consideration during the licensing process. Some of these will be of a catastrophic geologic nature. Others may be considered under the category of man-caused events. In any case, a complete evaluation of these will be necessary to assure the viability and licensability of radioactive waste emplacement in basalt as a storage concept. A partial list of those events would include meteorite impacts, hurricanes, tsunamis, effects of erosion, sedimentation, glaciation, pluvial periods, and sea level variations. Associated with each of these, there will be required a careful evaluation of radiological release mechanisms. It is in this context that fission gas release will be evaluated. To date, no detailed studies of fission gas release have been conducted.

V. REFERENCES

1. RHO-CD132 (REV). Basalt Waste Isolation Program Plan (May 1978).
2. Letter to Dick Goransen, DOE Richland Operations Office, from Colin A. Heath, DOE-Headquarters. "Preparation of Document Outlining Strategy to Obtain a License for a Repository." Feb. 23, 1978.