EXECUTIVE SUMMARY
HIGH-LEVEL WASTE
OVERSIGHT COMMITTEE REPORT

I. PURPOSE OF THE COMMITTEE AND SUMMARY OF ITS PRINCIPAL RECOMMENDATIONS

Within the Nuclear Regulatory Commission (NRC), responsibility for carrying out licensing activities for a high-level radioactive waste (HLW) geologic repository is assigned to the Office of Nuclear Material Safety and Safeguards (NMSS). To carry out this complex activity in a focused manner, the Division of Waste Management (WM) was created in 1979. In addition, to ensure internal coherency and coordination of the agency-wide HLW program and a single point for external contacts with respect to certain HLW activities, the Director, WM, has served (since 1980) as Program Area Manager for HLW management. In this dual capacity, the Director, WM, ensures that a program for regulating geologic disposal of HLW exists within NRC to provide for (1) an independent determination that DOE's siting, design, construction, and operation of a HLW repository are performed in a manner that adequately protects the public health and safety and the environment and (2) a HLW regulatory program responsive to the Commission's Policy and Planning Guidance that, "in the absence of unresolved safety concerns, the NRC regulatory program will not delay implementation of the Executive Branch's program." Although the NRC's HLW program has been underway and has been receiving continuing scrutiny for the last several years, it has not been reviewed systematically and comprehensively, particularly from the perspective of the Nuclear Waste Policy Act of 1982 (NWPA or Waste Policy Act) since the NWPA was passed.

To this end, a High-Level Waste Oversight Committee (Committee) composed of representatives from NMSS, the Office of Nuclear Regulatory Research (RES) and the Office of the Executive Legal Director (ELD) was established to conduct such a review and provide advice to the Director, WM, concerning the adequacy of NRC's regulatory strategy for implementing Part 60 with respect to the

Waste Policy Act. Specifically, the purpose of the review was to ensure that NRC has a program that is prepared to receive, review, and make a technically sound licensing decision on the DOE application for a HLW repository in accordance with all the statutory and regulatory requirements. The Committee was to advise the Director, WM, on whether the present and planned NRC technical programs of NMSS and RES are complete and adequate to survive the legal and technical challenges of the licensing (hearing) process. The review would also be useful to the Director, RES, in reviewing and planning the NRC HLW research program.

The first task of the Committee was to achieve an overall understanding of the HLW licensing strategy as presently conceived, the HLW research program in relation to that strategy, and any legal considerations that bear on licensing or research such as those pertaining to conflicts of interest or the conduct of hearings.

Questions such as the following guided the Committee's deliberations:

1. What are the technical issues, both generic and site specific, involved in the regulatory decisions NRC must make at each stage of the licensing process? Where are these identified? Is the identification of technical issues technically correct and complete?

2. Have the issues that should be addressed by DOE as the applicant been clearly identified and has DOE been formally advised to address these issues?

3. What advice does DOE need to receive to satisfy the legal requirements of the licensing process?

4. Is action underway to ensure that all the technical issues are being addressed by DOE or NRC as appropriate?

5. Does NRC have programs underway to ensure that we can independently* analyze and evaluate those issues that DOE is addressing, i.e., can NRC independently ensure the quality and completeness of the DOE work?

6. For which issues:

   a. Does NRC foresee the need to perform an independent analysis or have independent data to compare with DOE's analysis or data?

   b. Are the present technical programs directed at providing such capability?

   c. Are there additional areas where such capabilities are needed?

   d. Are technical programs focusing on areas where the licensing staff plans to perform its licensing function solely by reviewing the completeness and adequacy of DOE's submission?

7. Is the NRC work being performed and documented in a manner that meets the legal requirements of the licensing process?

8. Which of these issues might be amenable to treatment through rulemaking? What technical support would be needed to carry out such efforts?

9. What technical capabilities or expertise does NRC need for the hearing? Of these, which imply maintenance of research support to ensure their availability at the time of hearing?

10. Can criteria be articulated that are useful in planning research programs relevant to licensing needs and consistent with established schedules?

---

*This, of course, does not mean 100% replication, but an audit in areas of high uncertainty.

11. What considerations are pertinent to the use by DOE and NRC of the same contractors in their HLW programs for either generic research or technical assistance directly related to licensing?

With respect to the specific interests of the Director, RES, the following questions are relevant:

12. Is there work currently underway in RES that should be redirected or canceled as a result of this assessment of the needs of the licensing/hearing process?

13. Is there work currenty underway in RES that should be performed by DOE as the applicant (generally using the approach of the so-called "Ross Criteria" that were developed for CRBR)?

14. Is there work that RES should be undertaking that has not yet been identified and planned?

15. What on-going method should be established to ensure that RES is aware of the current "operational thinking" about a repository program and to provide continuing assurance that the RES work is pertinent to the program needs?

In developing its recommendations, the Committee considered past research and licensing approaches in other licensing and hearing arenas where novel considerations and potential conflicts of interest were involved (e.g., CRBR); Commission guidance for the conduct of research (e.g., PPG); the present criteria and process for planning research in HLW and other areas; and the DOE HLW program, to the extent available information permitted. Attention was given to identifying effective mechanisms for better expression and transmission of research results into licensing activities and of licensing needs into research planning. This executive summary report represents a summary of the results of

the Committee's review and deliberations. Volume 2 will contain more details and set forth the basis for Volume 1. We divided our principal recommendations into two categories:

A. Technical;
B. Management and Administration.

A. Technical

We conclude that technical programs exist within NRC to permit independent audits of DOE submittals. However, they must be strengthened in the following ways:

1. Model and Code Development and Validation for Compliance Assessment

An independent method of calculating the performance of a site is needed in order to provide the desired credibility to NRC licensing decisions. Some work is underway, but the analysis and modeling are outrunning field and laboratory experimental work. More attention needs to be given to uncertainty analyses in the modeling and to identifying data needs for both model and code validation. We see no impediment to the use of DOE data provided data collection is conducted according to sound principles of quality assurance and quality control; the task is so difficult and resource intensive that the taxpayer should not pay twice unless absolutely necessary. However, NRC should specify, and soon, its further needs in this area, giving careful attention to the question of independence, i.e., of ensuring NRC's regulatory integrity to carry out licensing. A research review group should be established for assessing the HLW model and code development and validation activities of NRC. The group should include both NRC personnel and contractors.

2. Near-Field Effects

We noted that most of the compliance assessment modeling effort tended to focus on the far-field effects. Yet we believe that more attention should be given to validated modeling of storage, retention, and controlled release of

radionuclides within and from the underground facility. This will take some added resources, but we believe it to be important.

3. Waste Form Bias

We believe that there may be a disproportionate emphasis on the disposal of the glass waste form (reprocessed) and not enough on disposal of spent fuel. This certainly could affect leaching studies and corrosion studies.

4. Emphasis on Licensing Tools

The emphasis in the technical program to date has been on identification and exploration of sources of uncertainty that would have to be considered and resolved either in establishing the regulatory framework of 10 CFR Part 60 or in making the required licensing findings. Greater emphasis than has been the case until now needs to be placed, where appropriate and possible, on developing tools the NRC staff can use in carrying out assessments of the DOE prelicensing program and license application and on providing guidance to DOE concerning acceptable methods of meeting NRC requirements. This capability will be very important to NRC's assessment of DOE's demonstration of compliance with the EPA standard.

5. Prioritization

The present program planning and development process identifies work appropriate for NRC to do but does not assign relative priorities that reflect budget realities. Further effort should be devoted to ensuring not only, as now, that the NRC technical program is consistent with NRC's regulatory mission and strategy, but also that it focuses on those problems that will best contribute to the soundness of regulatory decision-making, particularly at the time of the construction authorization and during the prelicensing period. The feasibility of such methods for setting priorities as sensitivity analyses where reliable models are available and the Analytical Hierarchical Process (AHP) now being investigated by RES should be considered to determine the most important sources of uncertainty and expected repository performance.

6. Expression of Research Results

Research results have contributed to the technical basis for the 10 CFR Part 60 rulemakings and have been used in the preparation of NRC's draft Site Characterization Analysis for the Hanford Site Characterization Report. Expertise developed as a result of NRC research has been useful in the NRC/DOE prelicensing discussions. Formal documentation of research results could be improved, however, to increase their utility to the licensing staff, direct applicability to licensing activities, and assist dissemination of research results among NRC HLW contractors. In planning and scoping projects, RES must pay greater attention to the timing and content of the deliverables in terms of their direct application in the licensing process.

B. Management & Administration

The Committee charter also covered preparedness for licensing, which is treated below.

1. Scheduling

The milestones laid out in the Waste Policy Act appear to be unsuitable for planning purposes in view of the missed milestones to date. Every attempt should be made to establish realistic planning horizons and, where National policy reflects optimism in scheduling, NRC planning should include contingency in the event of further slippage. Careful attention should be given to staging research programs to improve the knowledge base for making regulatory decisions, both the accommodate present schedules and to take advantage of schedule slippage. The Committee believes that the basis for scheduling should be drawn from the Mission Plan and that NRC should continue its efforts to ensure that the Mission Plan reflects realistic schedules.

2. Prelicensing Resolution of Issues by Use of Regulatory Guidance, and Rulemaking

Every attempt should be made to identify licensing issues early in the prelicensing process to provide sufficient lead time to adequately develop and

analyze the necessary data. The staff should continue to develop and issue for public comment branch technical positions on acceptable approaches to various technical issues. However, because the approach established in regulatory guidance is open to challenge in a licensing proceeding whereas the approach set forth in a rule is not, the staff should use rulemaking to resolve generic licensing issues whenever feasible. The staff should seek to identify on a systematic and continuing basis issues ripe for resolution through rulemaking and should undertake such rulemaking where appropriate.

3. Advisory Groups, Peer Review, and Panels of Experts

The Committee encourages the use of peer review and panels of experts to deal with discrete technical issues. However, the Committee does not believe that a new advisory committee for ongoing oversight of the HLW program ("alternative ACRS") is warranted. With respect to ACRS, the Committee thinks it would be useful for the Commission to make a special effort to appoint members with particular expertise and interest in and understanding of the geologic disposal of HLW. In addition, the Committee believes that a more systematic approach to ACRS review of HLW issues, including procedures for the conduct of such reviews, is necessary.

4. Program Area Manager

The role of Program Area Manager emphasizes the licensing perspective rather than reflecting an overall regulatory or agency perspective. The Committee believes that role should be broadened to reflect an agency-wide perspective so the Program Area Manager can serve outside the NRC not only as licensing spokesman but also as staff spokesman. This reflects a practical consideration that, even when the Director, WM, is speaking from a licensing perspective, those outside NRC regard him as an agency spokesman, not merely a licensing spokesman. Where the issues go beyond licensing concerns, greater attention needs to be paid to ensuring representation of all cognizant functions in developing staff positions. Likewise, greater care should be taken to identify and draw upon the full range of staff expertise pertinent to issues development and resolution, even when that expertise is outside the licensing office.

5. The Licensing Process

A system needs to be established for document control and retrieval to support NRC's role in licensing a high-level waste repository. The system would be used to assist the staff in preparing testimony and to enable the NRC to respond to discovery and FOIA requests in a timely manner. Procedures to establish such a system must address the following issues:

. Identification of documents that would be publicly available and those that should have restricted access.

. The need to ensure that all relevant documents are in the system.

6. Conflict of Interest in Contract Awards

There is a limited pool of expertise in many technical areas associated with HLW and a heavy demand by several users, including NRC. This situation presents two problems:

. Potential conflict of interests from a contracting perspective.

. The perception of a conflict of interest in a licensing proceeding when different parties utilize the same organization to support their point of view.

In addition to continuing the review of conflict of interest issues in individual cases under existing procedures, the committee recommends that the staff not place sole or primary reliance on contracter information in evaluating licensing issues.

II. THE NATIONAL HLW DISPOSAL PROGRAM

Three Federal agencies have major roles in the national program for disposal of high-level radioactive wastes. The Department of Energy (DOE) has programmatic responsibility at the Federal level for developing technology for disposal of high-level radioactive waste (HLW) as well as responsibility for developing particular installations for long-term storage of such waste. The Nuclear Regulatory Commission (NRC) has licensing and regulatory authority over the facilities for the disposal of HLW. The Environmental Protection Agency (EPA) acting under its authority to develop and promulgate generally applicable standards for radiation in the environment has been developing standards for HLW disposal.

DOE prepared a Generic Environmental Impact Statement (GEIS) to consider alternative disposal strategies. Deep geologic disposal in mined repositories was adopted as the preferred option. In a parallel effort, NRC undertook the development, through rulemaking, of a regulatory framework for HLW disposal in geologic repositories (10 CFR Part 60 and conforming amendments). The rulemaking was bifurcated, the licensing procedures being completed in February 1981 (46 FR 13971) and the technical criteria for use in making licensing decisions being completed in June 1983 (48 FR 28194).

In parallel with NRC efforts to develop the regulatory framework for HLW disposal in geologic repositories, the EPA has been developing 40 CFR Part 191, "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Waste." In December 1982, EPA published these proposed standards for public comment. NRC commented extensively on these proposed standards, particularly with respect to the interrelated questions of jurisdiction and implementability. These comments emphasized NRC concerns over difficulties in demonstrating compliance with the proposed standards in an adjudicatory proceeding. In 10 CFR Part 60, the Commission indicated its intention to adopt the final EPA standards as its

overall system performance standard for HLW disposal. In order to determine whether a repository will meet the standards, a "bottom line" assessment of expected repository performance must be carried out by DOE. In making its findings of reasonable assurance, NRC must evaluate the adequacy of the DOE performance assessment. Thus the form of the final standards will have significant programmatic impact on the development of NRC's compliance assessment and modeling capability.

The Nuclear Waste Policy Act of 1982 (42 U.S.C. 1010 et seq.), signed into law by the President on January 7, 1983, is the most comprehensive legislation passed by Congress on the subject of radioactive waste disposal. This statute establishes schedules and procedures for the Department of Energy to follow in siting, construction, and operation of geologic repositories for HLW disposal. It authorizes DOE to carry out a program to have a geologic repository for disposal of commercial HLW in operation by 1998. It focuses heavily on the process by which potential repository sites are screened and selected for repository development. In so doing, it spells out how DOE is to conduct itself vis a vis the States and affected Indian Tribes (sections 113, 114, 115, 116, 117). Further, it requires DOE to develop the siting guidelines DOE is to use during certain phases of site screening and selection (section 112). The Commission must concur in these guidelines before DOE can issue them in final form. The content of these guidelines and how DOE expects to apply them have a bearing on the Commission's own responsibilities with respect to geologic dispoal of HLW.

The Waste Policy Act establishes within the Department of Energy an Office of Civilian Radioactive Waste Management (OCRWM) to carry out the functions of the Secretary of Energy under the Act. The OCRWM is responsible for planning and coordinating of the National HLW Disposal Program. A principal function of the OCRWM is to develop a Mission Plan for the execution of the repository development program and the research, development, and demonstration program required by the Act.

The Waste Policy Act requires DOE to publish a draft of the Mission Plan for review by State and Federal Agencies by April 7, 1984. A preliminary draft has already been reviewed by NRC staff. The DOE Mission Plan is a key document in the planning of the NRC technical programs because it identifies the schedules for submittal of DOE documents and for DOE activities that the NRC must be prepared to review. The Commission has statutory deadlines under the Waste Policy Act for acting on a DOE license application and is basing its programs on the premise that, in the absence of unresolved safety questions, the NRC will not delay the administration's HLW program. The Committee believes, therefore, that it is most important (1) that the Mission Plan adequately portray what is necessary to achieve disposal of HLW in a geologic repository, (2) that schedules be realistic and provide for adequate contingency, and (3) that the RD&D DOE must carry on to develop a repository be integrated into the Mission Plan.

The Department of Energy is conducting investigations in four geologic media for the first HLW repository: salt deposits (bedded and dome), volcanic tuff, and basalt. Investigations have also begun in crystalline rock formations for potentially acceptable sites for the second repository. DOE is required by the Waste Policy Act to select, by January 1985,* three sites for the purpose of characterizing the site properties to determine site suitability. Following at-depth investigations of the candidate sites, the Waste Policy Act requires that a license application for construction of the first repository be submitted to NRC in March 1987. Assuming a favorable decision by NRC, construction of the underground facility would take place in the early 1990s, and an updated license application would be submitted to NRC with repository operation before the end of the century. Recent DOE plans state that the application for the first repository will not be submitted to NRC until 1991.

*NRC staff comments on the draft Mission Plan questioned whether this date could be met.

Both the Waste Policy Act and the NRC procedures require an extensive period of prelicensing consultation between NRC and DOE staffs before DOE submits a license application for a repository. During this period, DOE is required to characterize three sites at depth before selecting its preferred site for a repository. DOE is required to submit its plans for characterizing each site to NRC for review and comment prior to sinking an exploratory shaft for in-depth testing at a site. DOE is further required to submit semiannual progress reports to NRC on its site characterization work.

During this period of site characterization, NRC's technical programs must support the licensing staff in identifying potential licensing issues regarding the sites and the designs being tested by DOE and in identifying acceptable methods of resolving those issues that can later be relied on in the licensing proceeding.

The Waste Policy Act requires further rulemaking to conform the Commission's regulations to the Act itself and also to the EPA standards when the latter are promulgated in final form (probably some time in 1984).

At the time of the Committee's review, NRC financial resources for high-level-waste programs appeared to be fairly well established for fiscal years through FY85. NRC resources allocated to major sections of the high-level-waste program are:

(thousands $)	FY83	FY84	FY85
Compliance Assessment and Modeling			
Regulatory Research (RES)	2,530	2,085	2,300
Technical Assistance (NMSS)	2,775	2,370	2,885
Subtotal	5,305	4,455	5,185
Materials and Engineering			
Regulatory Research (RES)	2,000	1,320	1,630
Technical Assistance (NMSS)	1,320	1,573	1,525
Subtotal	3,320	2,893	3,155
Geochemistry and Hydrology			
Regulatory Research (RES)	2,350	2,500	1,750
Technical Assistance (NMSS)	1,000	2,500	3,050
Subtotal	3,350	5,000	4,800
TOTAL	11,975	12,348	13,140

For fiscal years beyond FY 85, budget numbers are much less certain. Total spending for waste management regulatory research (RES) is given in the Long Range Research Plan (LRRP) as:

	FY86	FY87	FY88	FY89
(millions $)	10.8	13.0	14.0	14.0

The LRRP does not break down the waste management spending into high-level waste and low-level waste for FY 86 and beyond. Approximately 66 percent of the total waste management research budget for FY 85 is planned for high-level waste research. If this same percentage holds for FY 86 through FY 89, the amounts devoted to high-level waste would be:

	FY86	FY87	FY88	FY89
(millions $)	7.1	8.6	9.2	9.2

NMSS requests for HLW technical assistance in FY86 and FY87 are $8.3 million and $8.6 million, respectively.

Comparable numbers for the DOE high-level waste management program came from DOE's draft mission plan. Total spending for repository development at DOE is:

(millions $)

	FY84	FY85	FY86	FY87
First Repository	247	247	427	339
Second Repository	16	30	51	76
Testing & Evaluation	-0-	-0-	-0-	5
Program Management	40	40	41	41
TOTAL	303	317	519	521

More detail for FY 84-85 is presented in Table 2.1.

The DOE research program in HLW has, up to now, been dominated by media-specific work: research on salt, basalt, tuffaceous rock, and crystalline rock. There has been a generic program as well. The DOE program is in a state of transition. R&D work that had been funded by the Office of the Assistant Secretary for Nuclear Energy has been shifted to the new OCRWM. All DOE R&D work for civilian HLW is expected to be funded out of the Waste Fund established by the Nuclear Waste Policy Act. The DOE Office of Basic Energy Sciences conducts some research that is applicable to HLW although there were no specific programs of HLW research in FY 83. The amounts devoted to areas of applicable research were $4 million for work in materials, $4.5 million for work in chemical sciences, and $4.9 million for work in geosciences and engineering.

TABLE 2.1

ESTIMATES OF SPENDING FOR HIGH-LEVEL WASTE R&D BY DOE

	FY 84 (Millions $)	FY 85
First Repository		
Systems (performance assessment)	15.0	17.9
Waste package	20.7	21.8
Site (geochemistry, hydrology, tectonics)	97.6	58.2
Repository (design, engineering)	41.2	37.4
Regulatory/institutional	15.1	15.5
Exploratory shaft	25.2	56.2
Test facility	5.2	3.5
Total	220.0	210.5
Second Repository		
Systems (performance assessment)	1.0	2.6
Waste package	0.1	0.2
Site (geochemistry, hydrology, tectonics)	5.6	11.5
Repository (design, engineering)	0.5	2.0
Regulatory/institutional	1.7	2.9
Exploratory shaft	0.0	0.0
Test facility	1.7	2.5
Total	10.6	21.7
Total for Both Repositories	230.6	232.2

III. NRC ORGANIZATIONAL FRAMEWORK FOR HLW DIPOSAL

A. Office Roles

Sections 202(3) and 202(4) of the Energy Reorganization Act of 1974, as amended, provide the NRC with licensing and regulatory authority regarding DOE facilities used primarily for the receipt and storage of HLW resulting from activities licensed under the Atomic Energy Act and certain other long-term HLW storage facilities of the DOE. (The Commission interprets "storage" as used in the Energy Reorganization Act to include disposal.)

Office of Nuclear Materials Safety and Safeguards (NMSS). The licensing activities associated with exercise of this authority are carried out by the Division of (Waste Management) within NMSS. Thus, overall responsibility for developing the licensing strategy with respect to geologic disposal of HLW rests with NMSS/WM. In addition, the Director, WM, serves as Program Area Manager for HLW management and in that capacity ensures the coordination of the entire NRC HLW program both within NRC and with external agencies having HLW responsibilities or interest in HLW disposal.

Office of Nuclear Regulatory Research (RES). Section 205 of the Energy Reorganization Act established the Office of Nuclear Regulatory Research to carry out the NRC's research activities. One purpose of this office, as stated in the conference report, was to provide NRC with an independent capability for developing and analyzing the technical information that would be needed for making licensing and regulatory decisions concerning protection of the public health and safety and the environment. Consistent with this purpose, RES is directing its HLW research activities to contribute to the NRC's ability to make sound and independent licensing and regulatory decisions concerning safe disposal of HLW in geologic repositories. In addition, RES conducts for the Commission the rulemakings associated with establishing the regulatory framework for HLW disposal.

Office of the Executive Legal Director. In regulating HLW disposal, not only policy and technical questions must be resolved, but also legal questions. The Office of the Executive Legal Director (ELD) provides continuing advice concerning the legal requirements and considerations of the licensing and rulemaking processes; the litigative risks of alternative courses of action; avoiding conflicts of interest, real or apparent, and maintaining openness in interactions with DOE, the National Laboratories, the States, Indian Tribes, and other interested parties, particularly during the lengthy prelicensing phases; and improving preparedness for hearings.

Office of State Programs. The Office of State Programs (SP), with its extensive experience with States and the interested public, is responsible for developing and implementing plans, policies, and programs for the coordination and integration of Federal and State responsibilities in the regulation of nuclear materials and facilities.

Resident Inspection Program. At the present early prelicensing stage of the national HLW program, the role of the Office of Inspection and Enforcement and the NRC Regional Offices is limited. The role at this time involves consultation with and advice to the licensing staff on generic matters, particularly in the area of quality assurance. However, as construction of the repository begins, resident inspectors would have a major role in ensuring that the conditions of the construction authorization are satisfied. NRC's licensing procedures provide for a resident inspection program at a geologic repository operations area similar to that for nuclear power plants.

Advisory Committee on Reactor Safeguards. Neither the statutory authorization of the Advisory Committee on Reactor Safeguards nor 10 CFR §1.20 of the Commission's regulations specifically provide for ACRS jurisdiction over HLW licensing. However, the ACRS has reviewed such generic regulatory actions in the HLW area as rules and regulatory guides and such site-specific issues as the BWIP Site Characterization Report. The Committee believes that a more systematic approach to ACRS's reviews of HLW issues, including procedures for

the conduct of such reviews, is necessary. The role of the ACRS vis a vis the HLW program could be strengthened by the appointment of members with special expertise and interest in the geologic disposal of HLW and understanding of the associated issues.

B. Program Area Manager Concept

To ensure the internal coherency and coordination of the agency-wide HLW program and to provide a single point of control with respect to certain external HLW activities, the Director, WM, has served since 1980 as Program Area Manager for HLW management. The Director, WM, does serve as the single point of contact with respect to the HLW program area vis a vis DOE; however, the focus in these contacts has concerned licensing issues, and the protocols that have been developed are primarily directed at licensing questions. There has been no parallel arrangement for regulatory research questions. Such liaison would be valuable, particularly for purposes of program planning. If NRC wishes only one point of contact with DOE concerning HLW regulatory matters including those related to licensing and research, the role of the Program Area Manager for HLW Management should be expanded to encompass the full range of regulatory concerns related to HLW disposal. Alternatively, an NRC point of contact for regulatory research could be identified. Either way, the Committee believes that it is important for DOE and NRC to discuss research matters periodically at the management level for purposes of program planning and direction. The principal points of contact for licensing, research, and other activities should be made clear to external entities with an interest in the HLW program, especially DOE. Similarly, the NRC staff should develop a sensitivity concerning this use of proper contacts for external interfaces.

The Director, WM, as Program Area Manager, also has responsibility for internal coordination of regulatory issues related to HLW disposal with NRC staff. Where these issues go beyond licensing concerns, representation of all cognizant functions and offices in the development of staff positions should be ensured. Similarly the full range of pertinent staff expertise in the licensing office and in other offices should be applied to the development and resolution of issues. When the Director, WM, as Program Area Manager

represents agency interests, both coordination with and the concurrence of cognizant offices is necessary in the development of underlying positions.

C. Program Area Planning

The HLW technical support program in place today consists of those projects that have emerged from the Waste Management Review Group (WMRG) process and the pre-WMRG discussions with technical staff. Thus, the program is developed and put in place on a project-by-project basis and appears to be ad hoc in nature. While each project follows from a regulatory objective such as a technical requirement of 10 CFR Part 60 or is related to a licensing issue identified in the BWIP Site Characterization Analysis (SCA) or the NRC/DOE prelicensing discussions, the set of projects as a whole is not the outcome of systematic program planning. The projects generally have not been developed in response to (managerial) requests from NMSS, although NMSS has provided general endorsement of the program in the RES Long Range Research Plan (LRRP). The most recent LRRP is contained in NUREG-1080. The HLW technical support program is discussed in Section V. The Committee believes the program itself is technically sound and relevant to regulatory needs but requires improved program area planning and integration.

The Committee believes that program area planning could be improved in several ways and that such improvement would foster, among other things, achievement of the integration objectives discussed in Section V and would provide increased confidence in the utility of research results to regulatory needs, in particular, prelicensing and licensing needs. Preparation of topical program plans in compliance assessment and modeling, materials and engineering, and geochemistry and hydrology, as well as an overall program plan could contribute to meshing the research schedules with the DOE Mission Plan schedules. Synchronizing the research schedules with the DOE Mission Plan schedules, with contingency for schedule changes, would provide confidence in the timely delivery of research results. Coordinated research planning meetings between DOE and NRC could assist in better targeting of limited NRC research dollars. Planning should also take account of the staging of research to provide for continuing delivery of improved tools that, over time, will enhance the

licensing staff's assessment capability. Deliverables should be scoped, to the extent possible, to be directly usable by the licensing staff in their day-to-day activities.

In particular, the responsibility of the Program Area Manager should be exercised to produce a research and technical assistance (TA) plan for each programmatic area (none was in evidence). As a minimum, this plan should include:

1. The DOE assumptions (by site, if necessary).

2. The models that DOE will be required to produce.

3. The physical research to be audited; for example, the plan for materials and engineering should include enough materials auditing to thoroughly explore accelerated corrosion testing protocol.

4. The simple and detailed models to be developed and used by NRC and the physical verification needed (with heavy reliance on properly qualified data from DOE).

5. The integration of models within each area and in relation to the other programmatic areas.

6. The agreed-upon demarcation between RES and NMSS work areas.

7. Formulation and control of review groups.

8. Projected guides, rules, and standards and associated resource estimates.

IV. NRC REGULATORY FRAMEWORK AND PROGRAMMATIC IMPLICATIONS

The regulatory framework for the disposal of HLW in geologic repositories is set forth in 10 CFR Part 60 of the Commission's regulations, and the surrounding policy is articulated in the Statements of Consideration. These regulations include licensing procedures promulgated on February 25, 1981 (46 FR 13971), and technical criteria promulgated on June 21, 1983 (48 FR 28194). Except for certain pending modifications concerning disposal in the unsaturated zone or necessitated by the Nuclear Waste Policy Act of 1982, the basic NRC framework is essentially in place, and the NRC staff has moved into the implementation phase.

The licensing procedures call for a multistep licensing process commencing with the present prelicensing phase in which DOE develops information about a candidate site through a program of site characterization. (Selection of sites for characterization and sites for a repository are governed by procedures set forth in the Nuclear Waste Policy Act.) Based on this information, DOE prepares and submits to NRC a license application to receive or possess source, special nuclear, or byproduct material at a particular site. Following a mandatory hearing, the Commission may authorize construction of the repository on a determination that there is reasonable assurance that the types and amounts of radioactive materials described in the application can be received, possessed, and disposed of in a geologic repository without unreasonable risk to the health and safety of the public. When construction is substantially complete, a license to receive and emplace waste may be issued if, among other findings, the Commission determines that the licensed activities will not constitute an unreasonable risk to the health and safety of the public. If the Commission grants the license, the repository moves into an operational stage, which will terminate at some

future date in either a decision to close the repository permanently or retrieve the waste already emplaced.

In reaching its decisions on construction authorization and waste emplacement, the Commission must consider whether the technical criteria in 10 CFR Part 60 are met. These technical criteria require a multibarrier repository system of engineered and natural barriers to contribute to waste isolation and to provide confidence in repository performance, establish the EPA's generally applicable environmental standard as the overall performance objective for the repository, establish performance objectives for selected subsystems of the repository (a containment period for the waste package, a maximum controlled release rate from the engineered barrier system, and a maximum groundwater travel time to the accessible environment), establish qualitative criteria concerning identification and assessment of favorable and potentially adverse conditions of the site, and establish design criteria related to the engineered barrier systems. The technical criteria also establish requirements for land ownership and control, performance confirmation, quality assurance, and training and certification of personnel.

Part 60 of the Commission's regulations and section 113 of the NWPA require that DOE perform extensive characterization before submitting a license application to the Commission. Site characterization is necessary to ensure that sufficient data are available to support the safety determinations required by 10 CFR Part 60 before a commitment can reasonably be made to one site. At least three sites must be characterized in detail.

The investigations will include field tests, including boreholes, of geology, hydrology, and other safety-related properties; laboratory tests; and exploratory shafts to the proposed depth of the repository where DOE will conduct large-scale in situ tests. At the beginning of the site characterization stage, DOE will submit Site Characterization Plans for NRC review. States and Indian Tribes and the public will also review and comment on the Site Characterization Plans. The NRC staff comments will be in the

form of a Site Characterization Analysis, which will also be made widely available to the public. The Site Characterization Plans must identify all the potential licensing issues that must be addressed at each site and present specific plans for resolving these issues. The NRC staff analysis of these Site Characterization Plans will provide specific guidance to DOE. To ensure that the process is capable of identifying and dealing with new issues as investigations progress, the NRC staff will analyze and comment on DOE's semiannual reports that are required by the NWPA.

Prior to the enactment of the Nuclear Waste Policy Act, the DOE submitted, in accordance with NRC regulations, a Site Characterization Report for the Hanford site for NRC review. This report had basically the same scope and purpose as the Site Characterization Plan now required by the NWPA. The NRC analysis of this report identified a number of important questions about the direction of the planned characterization activities. After receiving NRC comments, DOE modified a major part of its site investigation program at the Hanford site. This is illustrative of the kind of constructive dialogue that will be carried out in the prelicensing consultations.

The Commission has identified in 10 CFR Part 60 the information that will be required at each stage of the licensing process and has indicated in general how the applicant (DOE) is to develop that information. The NRC will assess this information in order to make the required licensing findings. The information will include a review of the geologic history of the site, an identification of the anticipated and unanticipated processes and events that must be analyzed and accounted for in the repository design, an assessment of the projected performance of the site with respect to the favorable and potentially adverse conditions that may exist, and an assessment, which may include independent staff analyses using NRC models, of the ability of the repository to meet the numerical performance objectives of 10 CFR Part 60. The staff, in implementing 10 CFR Part 60, is continuing to elaborate on the information required to carry out its required licensing assessments and is developing the capability to perform these assessments.

This will increase the NRC's capability to resolve central issues at the time of hearing.

Guidance to DOE as to NRC's expectations about an adequate site characterization program to support a license application, including the acquisition and review of site-specific data and the site-specific conceptual design, is a major focus of the licensing activities during the prelicensing phase. The primary emphasis of the NRC HLW research program is the development of independent understandings and the tools and methods necessary for independent assessment and evaluation of a DOE application for a geologic repository with respect to the repository's capability for waste isolation over the long term and over a wide range of conditions. In particular, in light of the technical criteria of 10 CFR Part 60 and the emerging licensing component of the regulatory strategy, the Commission's research program is focused on three topical areas: compliance assessment and modeling, materials and engineering, and geochemistry and hydrology. This program is designed to be relevant to the regulatory needs of the Commission's licensing staff and to provide the information needed by the licensing staff on a timely basis and in usable form so they will be able to incorporate the research findings in their discussions with DOE.

The licensing findings must be made in the face of substantial uncertainties concerning the expected performance of a repository system over very long periods of time. There will, of necessity, be extensive reliance on quantitative models to calculate expected repository performance and to estimate the uncertainties. However, not all of the uncertainties will be quantifiable; nor will quantitative models alone provide an adequate basis for making the required licensing findings. Therefore, the Commission will have to place strong reliance on qualitative understandings and descriptive models of what is important to repository performance and where the uncertainties lie. The NRC HLW research program is addressing both of these areas.

The amount of close interaction between NRC and DOE that is required has raised questions about the ability of the NRC staff to maintain an independent viewpoint. In addition to the staff's inherent sensitivity to the importance of this independence, the openness of the DOE/NRC dialogues and the careful attention to the documentation of technical interactions will help to ensure NRC's independence.

In addition, maintenance of the Commission's independent regulatory research capability contributes to the ongoing prelicensing process between NRC and DOE by providing to the licensing staff a constant infusion of independently acquired information against which to assess the information being developed by DOE as applicant. Thus the Commission's HLW regulatory research program ensures that DOE is not the sole source of information available to the licensing staff. The Commission's regulatory research contributes to the development of the base of independent evaluations of the relative importance and uncertainties and of the quality and interpretation of the DOE site-specific data.

The emphasis in the NRC HLW research program to date has been on identifying and exploring the sources of uncertainty that would have to be considered and resolved either in establishing the regulatory framework for 10 CFR Part 60 or in making the required licensing findings. At the current stage, greater emphasis needs to be placed, where appropriate and possible, on developing tools the NRC staff can use in carrying out assessments of the DOE prelicensing program and license application and in providing guidance to DOE concerning acceptable methods of meeting NRC requirements. The most pressing need is to develop an integrated set of performance assessment tools, both quantitative and qualitative, for NRC to make its licensing determinations.

In addition, efforts should continue on the identification of licensing issues early in the prelicensing phase in order to provide sufficient lead time to adequately develop and analyze the necessary data. The staff should continue to develop and issue for public comment regulatory guidance (branch

technical positions, standard review plans, and regulatory guides) on acceptable approaches to various licensing issues. However, the Committee believes that more emphasis should be placed on the use of rulemaking as a mechanism to resolve generic technical issues prior to hearing. Such issues could not be raised anew in the formal licensing proceedings. Although the use of regulatory guidance is an appropriate method for addressing particular issues, the approach selected is open to challenge in a licensing proceeding whereas the technical approach set forth in a rule is not; rulemaking can therefore provide more certainty in the early resolution of technical issues. The rulemaking process may be an especially suitable vehicle for establishing the necessary information and developing a consensus on matters involving policy judgments as well as factual issues. As a general principle, the Committee believes that a number of generic questions can be dealt with effectively in this manner without prejudicing the quality of the decisionmaking or the opportunity of all interested parties to participate fully.

For these reasons, the Committee recommends that the staff pursue additional rulemaking on selected important potential licensing issues based on the information from ongoing investigations. This will help ensure regulatory stability in the prelicensing and licensing processes and permit certain issues to be closed out as site characterization proceeds. The result should be a more orderly hearing and, quite possibly, an ultimate decision with a more solid technical foundation. One useful application of this approach would be the revision of Section 60.21, which sets forth the information that is required in DOE's license application. This section could be revised to better reflect the type of information necessary to satisfy the technical criteria of Part 60.

V. NRC TECHNICAL SUPPORT PROGRAM

A. Description

In determining whether to license DOE's geologic disposal of HLW, the NRC must assess the adequacy of both the expected performance of the repository claimed by DOE and DOE's demonstration that the repository will perform as expected. The continuing objective of the NRC's HLW technical support program is to identify and understand the processes that determine repository performance sufficiently well to enable assessment of the uncertainties associated with both performance of a geologic repository and the demonstration of that performance. It consists of two components, research and technical assistance, that are administered by RES and NMSS, respectively.

Initially, the research program was directed at developing support for the Commission's regulations for licensing and regulating geologic disposal of HLW in 10 CFR Part 60. The results of the research program were used to provide the basis for the "multibarrier" concept and the containment and controlled release performance objectives of Part 60. These results were also used to show how the requirements of Part 60 would contribute to the assessment of whether there could be reasonable assurance of safe disposal at a geologic repository. In addition, the NRC's HLW research program made contributions to the development of the Commission's comments on EPA's proposed HLW standard.

Since the promulgation of Part 60, the research program has been focused more sharply on the mechanisms of containment and isolation of HLW, although it will continue to contribute to the technical support for future HLW rulemakings. The multitude of physical, chemical, hydrologic, and geologic processes that determine repository performance is being examined in detail to ensure that the DOE will adequately address the technical issues that bear upon confidence in the safety of geologic disposal of HLW. These issues have been and are continuing to be defined and refined in the on-going NRC/DOE prelicensing discussions covered in Section IV of this report. Accordingly, the research

program is structured to facilitate both dealing with those issues and the ready correlation between those issues and individual research projects. To make the management of the research program tractable, the research program is divided into research topic areas that cover that range of scientific and technical disciplines relevant to descriptions, designs, and assessments of the safety of geologic disposal of HLW. Further, these topic areas correspond to the major elements of a repository (the engineered barrier system and the geologic setting) and the major subject of license review (prediction of performance). The topic areas are compliance assessment and modeling, materials and engineering, and geochemistry and hydrology.

The HLW technical assistance component also covers the topic areas of compliance assessment and modeling, materials and engineering, and geochemistry and hydrology. Its primary focus is directed at short-term licensing needs using existing technology. It provides a capability to assist the licensing staff in performing case-specific license reviews and preparing license review plans and branch technical positions. In addition, existing technology and the state of the art for applicability or adaptability to licensing are reviewed, assessed, and summarized, and methods or products developed by NRC research are applied by and adapted to the licensing process.

Current NRC technical programs are directed primarily at understanding the phenomena that lead to release from the waste package and migration of radioactive materials to the accessible environment. Because of this focus, programs are not at present clearly directed at the types of evaluations that will need to be done to show compliance with 10 CFR Part 60, and some redirection of existing projects appears in order, as discussed below.

Under 10 CFR Part 60, processes and events affecting waste isolation are considered either "anticipated" or "unanticipated." Anticipated processes and events include those natural processes and events that are reasonably likely to occur during the period an intended performance objective must be achieved. To the extent reasonable in light of the geologic record, it is assumed that the natural processes operating in the geologic setting during the Quaternary Period (approximately the past two million years) continue to operate but with

the perturbations caused by the presence of the emplaced radioactive waste superimposed on the isolation system. This class of processes and events has special significance in Part 60 because the numerical performance objectives for containment by the waste package and controlled release from the engineered barrier system must be met for anticipated processes and events. The design basis for the engineered barrier system must consider the range of physical and chemical conditions that could occur in the underground facility for those events and processes (scenarios) that are determined to be "anticipated," and the NRC staff must have the capability to assess performance for this range of conditions. Thus the NRC programs must provide the capability to assess design of the engineered barriers to meet numerical criteria, taking into account uncertainties in the conceptual models used to predict performance, in the parameters that affect performance, and in the scenarios that could affect these models and parameters.

Unanticipated processes and events are those processes and events affecting the geologic setting that are less likely to occur but are not so incredible that they can be ignored. They include both natural processes and human activities that could affect repository performance; however, human activities that would disrupt repository performance are considered credible only if certain criteria specified in the rule are met. The performance of the repository for these processes and events must be shown to meet the applicable EPA standard, and these processes and events may need to be considered in the design basis for the engineered barriers system if necessary to meet that EPA standard. However, it is not necessary to meet the numerical performance objectives for containment and controlled release for these scenarios. Thus NRC's ability to assess performance of the engineered barriers system for these scenarios primarily involves being able to bound the release or the source term for a given design in order to determine whether the EPA standard, as it applies to unanticipated processes and events, is met. This approach differs from the "single-failure criterion" used in reactor licensing in that arbitrary "nonmechanistic failures" would not be analyzed but the system performance would be evaluated in response to initiating geologic or human-induced events that are derived after an examination of the geologic record for the site, particularly in light of the favorable and potentially adverse conditions of

10 CFR §60.122. The present technical support programs do not reflect the approach to performance assessments that will be needed to find that 10 CFR Part 60 is met. The Committee believes that future program planning should reflect the need to accommodate this approach.

B. Assessment of Research Criteria

The broad objectives of both technical assistance and research are to assist the NRC staff in identifying what DOE must do in site characterization to produce a complete license application (i.e., to address all licensing issues) and in developing the capability to evaluate the adequacy of DOE's license application. Within these objectives, NRC activities would involve the review of DOE data and methodologies, the development of methodologies for data gathering and performance assessment, and independent data collection in certain areas. In addition to generally supporting the NRC licensing review, technical assistance and research may be used to support rulemaking on a particular technical issue or as the basis for regulatory guidance setting forth acceptable approaches to various licensing issues.

The nature and scope of technical assistance contracts are based on the licensing information needs derived from the technical criteria of 10 CFR Part 60. The performance objectives of the technical criteria have been broken down into broad performance issues corresponding to the various elements of the repository system. These performance issues have been further refined into specific issues that are significant for a licensing decision (see BWIP, Draft Site Characterization Analyses, Appendix C, NUREG-0960). Technical assistance contracts are utilized to provide support to the NRC staff in identifying issues that DOE should address in site investigation and characterization and in reviewing specific materials and documents developed by DOE in the process of site investigation, site characterization, and environmental assessment. The priorities for selecting specific technical assistance projects are based on the issues that are the most important for assessing repository performance, the issues that are most difficult to resolve, and the amount of time available before a particular issue needs to be addressed.

The criteria used by the Office of Nuclear Regulatory Research to identify projects for HLW research* are:

1. is it needed to develop expertise in unfamiliar technology, e.g., to confirm or negate generic findings or to understand phenomena, mechanisms, uncertainties?

2. is it needed to assist in performing audits of tests or analyses submitted by DOE, e.g., acceptable test procedures, generic methods to assess models that predict performance?

3. is it needed to develop regulatory tools (regulations, guides, standards, general design criteria, staff technical positions), e.g., to understand phenomena, mechanisms, uncertainties?

The application of these criteria occurs within the framework of the technical criteria, but no formal mechanism has been developed to establish priorities among potential research projects. RES is, however, currently engaged in a feasibility study to determine whether some variant of the Analytic Hierarchical Process (AHP) can be applied to establish priorities within the HLW research program.

A fourth criterion for HLW research might be:

4. is it needed to develop a capability to assess the total repository system, e.g., to understand the synergistic relationships among such subcomponents as waste form, waste packages, other engineering, rock, heat, water chemistry?

The establishment and application of the criteria developed by NMSS and RES provide a sound foundation for a relevant external support program. However, the following improvements could be made, both in the office criteria and in

*These are general criteria paraphrased here for HLW.

the NRC approach to coordinating technical assistance and research projects in the HLW area:

1. As the site characterization analyses are developed, they should be used to focus the program on the relevant licensing issues; for example, Appendix C of the BWIP Site Characterization Analysis (NUREG-0960) is a useful planning tool;

2. The following questions should be used in the evaluation of proposed projects:

   a. What regulatory issues or licensing findings does this contract support?

   b. How is DOE expected to approach this issue and how will the project help NRC assess the DOE data or analysis?

   c. Is the focus of the project assessing uncertainties in the data or technology that need to be considered in the NRC review as opposed to gathering data or developing technology?

   d. Is the work needed to assist NRC in developing its assessment techniques and acceptance criteria or to develop guidance for DOE?

   e. Does the work duplicate other work in progress or completed under NRC contract?

   f. Is it clear how the results of the work will be used by the NRC staff in the licensing or regulatory process?

   g. When will results that can be used in the licensing or regulatory process be available?

   h. Are there any potential conflict of interest issues that should be noted?

3. Mechanisms must be developed to establish priorities among the various proposed projects to ensure that NRC AHP resources are allocated in the most effective manner. In addition to the AHP method referenced above, other methods should be investigated, including the use of sensitivity analyses, where reliable models are available, to determine the most important sources of uncertainty in performance. Also, scoping studies could be undertaken prior to initialing major new projects to ensure that they would address well-defined, relevant, substantive, and solvable problems.

4. Now that the regulatory framework is largely in place, the NRC HLW program will benefit from an increased emphasis on research that achieves the objectives of research criteria 2 and 3 as these are more focused on licensing needs.

5. The process for coordinating the technical assistance program with the research program should be strengthened to ensure consistency and effective integration of individual projects into overall program objectives. The existing formal and informal dialogue between NMSS and RES, including the operation of the Waste Management Review Group (WMRG), already contribute to a coordinated effort. However, the existing process could be improved in order to provide a more focused, systematic, and integrated approach, e.g., by identification by the Director, NMSS, of specific areas requiring technical work by RES and by increased and more creative use of research review groups.

C. Technical Areas

As discussed in Section IV, the overriding finding that the Commission must make with respect to HLW disposal at a particular geologic repository is that the issuance of a license will not constitute an unreasonable risk to the public health and safety based on whether there is reasonable assurance that the performance objectives and criteria of 10 CFR Part 60 will be met. In making this finding, the Commission must place heavy reliance on modeling of both a qualitative and quantitative nature. To do so, the Commission must have

a capability to make determinations as to confidence in the expected performance of the natural systems (geochemistry and hydrology), of the engineered systems and materials, and of the overall repository system.

This section presents an assessment of NRC's technical support program with respect to developing that capability and provides recommendations for improving that capability. The discussion consists of discrete presentations of the three programmatic areas of compliance assessment and modeling, materials and engineering, and geochemistry and hydrology. These three areas developed largely independently of one another on a project-by-project basis and have not been integrated to any great extent. While the Committee believes this lack of integration was acceptable during the regulatory development phase, it believes that integration must occur if the research is to contribute to the development of the licensing capability.

1. Compliance Assessment and Modeling

Because of the long isolation period (at least 10,000 years) expected to be mandated by 40 CFR Part 191 for HLW disposal, there is no way that a prototypical geologic repository can be constructed and tested fully over its isolation period to provide a complete set of empirical information on how it will work. Consequently, DOE is expected to rely heavily on predictive modeling in its demonstrations of compliance with 10 CFR Part 60. (For example, see SD-BWI-PAP-001, "Basalt Waste Isolation Project Performance Assessment Plan.") DOE will select sites for repositories, characterize the sites, design and construct waste packages for the repositories, design and construct the repositories, put the waste packages into the repositories, and close the repositories. DOE will be responsible for collecting all data needed to support models for predicting the performance of the repositories and these data will be shared with NRC. DOE will use models of its own in making demonstrations of compliance.

On a general level, questions that NRC expects DOE to answer in its demonstrations of compliance with 10 CFR Part 60 have been posed in Part 60. More specific questions based on these general questions have been posed to DOE

by NRC during many prelicensing review meetings among DOE staff, NRC staff, and their supporting contractors. In the case of the Basalt Waste Isolation Project, many of these detailed questions have been listed in Appendix C to NUREG-0960, "Draft Site Characterization Analysis of the Site Characterization Report for the Basalt Waste Isolation Project." Of the questions listed in Appendix C to NUREG-0960, many are applicable to all sites and provide a general indication of NRC's HLW licensing policy. NRC will respond to DOE's assertion in the license application of compliance with 10 CFR Part 60 by performing an audit that, at the very least, will require an understanding of the relevant phenomena involved and their associated models or at the very most, will involve a complete independent demonstration of compliance that will involve the use of predictive models by NRC.

Qualitative and Quantitative Models

In the process of modeling a set of physical phenomena, two kinds of models are considered: qualitative and quantitative. A qualitative model is a verbal description of the physical processes that are taking place. This kind of model is often called a conceptual model. What a modeler considers to be an adequate qualitative model is always a matter of judgment. The accuracy of a qualitative model is a measure of how closely it describes the physical processes under consideration. One always has to formulate a qualitative model before emulating it with a quantitative model. The quantitative model will not be any more accurate in mapping the physical processes being modeled than the qualitative model from which it was derived.

There is no assurance that the solutions to HLW disposal problems provided by the models are unique. There could be many combinations of parameters that could reproduce the measured potentials. Engineered systems are generally more amenable to modeling by direct methods than are natural systems. HLW repositories will consist of a combination of the two types of systems.

Validation of Models

In the absence of confirmatory experimentation, the formulation of a model is purely a hypothetical exercise. On the other hand, experiments themselves are designed with some sort of model in mind. Experimentation and qualitative and mathematical modeling do form alternative lines of inquiry that can show whether a particular phenomenon is understood well enough that its model is in some sense "valid." For phenomena that are not particularly well understood, it is necessary to use an iterative process in which experiments (possibly involving physical models) and models (possibly involving qualitative, mathematical, and complementary physical models) are designed and tested over and over with successive refinements until both the experimentalists and the modelers believe that the phenomena are sufficiently well understood to permit the models that have evolved to be used with confidence to predict the behavior of the phenomena. This process is called validation, and it is often open ended in the sense that there will not be absolute confidence that the particular phenomena (such as turbulence of fluids and hydrodynamic dispersion of contaminants) that have been subjected to extensive testing and modeling are well enough understood.

Status of Modeling for Deep Geologic Disposal of HLW

In the current state of modeling physical processes associated with deep geologic disposal of HLW, the verbal (qualitative) description of what is expected to happen is better understood than is the quantitative description. There remain uncertainties associated with both descriptions. The present research program has been developed to increase understandings in the face of the uncertainties discussed below, i.e. largely in accord with research criterion 1. While DOE, as the potential applicant, has the principal responsibility to develop the technology needed for safe disposal of high-level wastes, NRC in its role as regulator must possess the capability to independently assess DOE's demonstration of compliance with NRC's regulations.

Waste Package. Both the long-term (300-1000 years) qualitative and quantitative models for the breach of the overpack and canister of the waste package remain poorly understood. Reliable ways to project behavior from better understood short-term models do not exist. Radiation and thermal effects on the degradation of overpacks and canisters are poorly understood for both the short and long terms.

Mechanisms of leaching and dissolution of radionuclides from the waste form are somewhat better understood. However, some controversy remains over whether leaching or dissolution is the dominant release mechanism. The problem of modeling the influence of elevated temperature on the release of radionuclides from the waste form still needs to be solved.

Flow of Groundwater. The flow of groundwater is well understood in saturated porous media but not so well understood in saturated fractured media. There are several qualitative models of isothermal flows in saturated fractured media that, in the absence of empirical verifications, seem to be sound. Each of these models forms the descriptive basis for the corresponding quantitative model. Very little field testing of the quantitative models has been done, and procedures for using field tests to select appropriate models and obtain parameter data for them are still in the developmental stage. Very little is known quantitatively about how thermal effects on fracture apertures and rock properties will influence groundwater flows in saturated fractured media. Also, very little is known about how geochemical effects such as the clogging of flow passages by large colloidal particles can alter the flow paths. For flow in unsaturated media, even the qualitative models are still controversial. In both saturated and unsaturated flows, the specification of appropriate boundary conditions remains controversial because of the difficulty of selecting the "boundary" of a natural groundwater system.

Transport of Radionuclides. In the deep geologic disposal of HLW, radionuclides are expected to be carried from the emplaced waste to the accessible environment mainly by transport by the groundwater. Transport of heat and dissolved salts can also have a major impact on transport of radionuclides. While experts are in general agreement on the qualitative

description of transport processes, uncertainty and controversy remain over how quantification should be done. The major sources of uncertainty in transport modeling are hydrodynamic dispersion and geochemical retardation. There are also other presumably secondary sources of uncertainty whose effects are more difficult to identify in field situations. For example, matrix diffusion is often ignored but may be comparable in importance to dispersion and geochemical retardation.

Dispersion. Although some controversy remains over whether commonly used Fickian dispersion models are correct, such models are generally accepted as being correct for long times. Most uncertainty related to dispersion arises from the inability to measure accurate dispersion coefficients for use in transport models. Experience with comparing predictions by transport models to observed field data has shown that dispersion coefficients increase with the gross length scale of the region being simulated. For applications to HLW disposal, dispersion coefficients are measurable only on a much smaller scale than the one required for HLW transport analysis. Recently a method has been developed for projecting dispersion coefficients measured on a small scale to a much larger scale, but the method has not been validated in the field.

Geochemical Effects. At the present time there are two methods of estimating geochemical effects on transport that lie at opposite extremes of complexity. The problem that one faces in estimating geochemical effects on transport is that the evolution of both the aqueous (radionuclides carried by the groundwater) and solid (radionuclides absorbed onto the host rock from the groundwater) concentrations of each radionuclide must be understood. The evolution equations for the solid and aqueous concentrations are coupled by an exchange term that is very difficult to evaluate. One approach is to simplify the geochemical modeling process by adding the two sets of evolution equations so that the exchange term is canceled. In lieu of evaluating the exchange term, laboratory tests are performed on samples of host rock to determine a priori what the relationship between solid and aqueous concentrations will be, and the assumption is made that this relationship is applicable to the field situation. Critics of this approach point out that it omits any consideration of the exchange process and that the relationships obtained in the laboratory

may not be applicable to field situations. There are also nonphysical ramifications of such an approach and examples of field situations where the approach obviously fails. The obvious alternative approach is not to add the two sets of evolution equations and to recognize that the exchange process will have to be considered explicitly. At the present time, this latter approach is intractable because of a lack of thermodynamic data needed to support it and because the exchange term is neither sufficiently understood to permit calculations to be done with confidence nor simple enough to allow calculations to be performed at a reasonable cost. To date, all of the considerations of geochemical modeling discussed in this paragraph have been given some thought for flows in saturated porous media by various investigators. While many of the ideas developed may carry over to saturated fractured media, very little research has been done on the effects of geochemical retardation on transport in unsaturated media.

Analogue and Scale Models

In addition to the qualitative and quantitative models discussed above, there are two types of physical models that are used to obtain technical data. One is based on observed similarities or analogies between the behavior of apparently unrelated systems, e.g., electrical and mechanical systems. Experiments are performed on one system to obtain information on the other, less tractable, system. The other physical model is based on the principle that experiments on a given phenomenon can be conducted at different scales, e.g., length or time scales. Wind-tunnel testing on a small-scale model of a large aircraft is a well-known example of the use of this principle.

Repositories for HLW are so complex that no totally representative analogue or scale model of one can be established. However, physical models of parts of repositories that provide insight into some of the phenomena that need to be understood have been established for the NRC HLW research program.

The Australian Atomic Energy Commission is studying the geochemical analogies between HLW repositories and ore bodies left over from "natural reactors." Lawrence Berkeley Laboratory has just begun a project to study the extent to

which geothermal systems (about which much research has been done) and HLW repositories are analogous. The Pacific Northwest Laboratory's LLW project on radionuclide migration from a meltdown at Chalk River, Ontario, also may provide some insight into the geochemistry of HLW repositories.

Battelle Columbus Laboratory is performing tests on what could be considered partial scale models of waste packages to study the possibility of accelerated leaching of HLW under conditions of limited corrosion. Argonne National Laboratory has set up a geochemical scale- model test to provide insight into hydrogeochemical interactions. The University of Delaware will soon begin heat transfer tests using the principle of similarity to set up scale-model tests of heat transfer from individual waste packages and from the aggregate of emplaced waste. Lawrence Berkeley Laboratory has done laboratory experiments on geochemistry that LBL calls "laboratory analogues" to HLW disposal, although they could also be considered as partial scale-model tests. The University of Arizona has conducted scale-model tests on the flow of groundwater and the transport of contaminants in saturated geologic media on two scales: laboratory (with simple parallel plate flow passages and sandbox experiments) and field (at Oracle, which is intended to be a scale model of the larger geologic regions expected around some HLW repositories).

Conclusions

The Committee believes that, in its compliance assessment role, the NRC will be faced with a situation in which historical input-output data in support of site-specific models will be scarce. The NRC will therefore find it necessary to rely on models that provide as detailed a description of the governing natural processes at the scale of the model as the current state of the relevant sciences allows and resources permit. The parameters of these models will have to be either measured in situ at the appropriate scale or computed from other parameters measured on a different scale by means of a coherent theory relating the two scales. In other words, the key to compliance assessment will be the identification of the most important physical and physico-chemical processes governing subsurface transport, their dependence on scale, their translation into appropriate mathematical equations on the various

scales, and the development of field methods to determine the parameters of these equations. While computer code development and benchmarking are important, they are only the last stage of this lengthy and difficult model identification phase. These computer codes are only as good as the equations on which they are based and the parameters entering into them. Unfortunately, confidence in these equations and parameters is often lacking because of insufficient background theoretical and field research. Both DOE and NRC have to address this problem: DOE in order to develop its modeling capability for performance assessment and NRC to the extent necessary to be able to assess the DOE capability at the time of licensing.

Therefore, the Committee believes that the NRC HLW research program should continue to include field and laboratory research projects that will aid the NRC in its model development and assessment activities as well as in its assessment of DOE's field parameter measurement techniques. For example, questions relating to the appropriateness of modeling fluid flow and chemical transport in fractured rocks by means of existing porous media models, the utility of various "fracture flow" models proposed in the literature, the scale at which these various models may or may not apply, the feasibility of measuring appropriate parameters in the field, and the possibility of computing parameters required for modeling on one scale from other parameters that are more easily measured on another scale are being addressed by NRC research. The Committee believes that, along with improved integration of research, the NRC may benefit from continued investment of resources into studies of this kind, as it is this type of theoretical and field research that has the greatest potential for providing the NRC with the scientific support necessary to justify or reject the application of a given model to a particular site considered for HLW storage. However, the Committee sees no impediment to the use of data collected by DOE provided data collection is conducted according to sound principles of quality assurance and quality control and sensitivity to the issue of regulatory independence is maintained.

2. Materials and Engineering

In the beginning of the national waste management program, the emphasis of the materials and engineering development program was placed on safety aspects of operation, including transportation, temporary storage, emplacement, and on-site handling. The long-term isolation of radionuclides from the biosphere was to be achieved primarily through the hydrogeologic and geochemical characteristics of the site. During the comprehensive review of the national program conducted by the Interagency Review Group for Nuclear Waste Management (IRG), it was recognized that variability of geotechnical parameters together with the limited understanding of long-term geologic processes would result in considerable uncertainties in predictions of geologic isolation performance of HLW repository systems. To compensate for the uncertainties, a "multiple barrier system" approach in which the natural barriers would be augmented by man-made engineered barriers was recommended. This multiple barrier system approach is required by NRC's HLW regulations (10 CFR Part 60). Subsequently, the role of materials and engineering has been expanded to include both near-term containment and long-term isolation of radionuclides. In fact, containment and controlled release (isolation) are now the principal focus of NRC materials and engineering research on waste management.

The role of materials research is primarily associated with the waste package. The basic performance objectives described in 10 CFR Part 60 require (1) containment of radionuclides for 300 to 1000 years within waste packages and (2) limiting the release rate of radionuclides from the engineered system to less than one part in 10^5 per year thereafter. The waste package materials also need to have characteristics adequate to allow safe handling during transport and emplacement.

The DOE's materials development program is built around the two sources of HLW: liquid HLW from spent fuel reprocessing (principally defense wastes) and unprocessed spent fuel. Present DOE plans call for the liquid HLW to be solidified and encapsulated within a canister/overpack. Based on considerations of material performance, developmental costs and difficulties, and process difficulty and costs, DOE has selected borosilicate glass as the

reference form of waste material for defense HLW. The DOE is still working on optimization of the glass composition.

Type 304L stainless steel has been selected by DOE for the container to hold the glass waste form for defense wastes from the Savannah River Plant. Cast iron and mild steel are also under consideration as container materials.

Various options for pretreatment of spent fuel assemblies ranging from encapsulation of intact assemblies to processing involving chopping, release of volatiles, and chemical reconstitution are being considered for a spent fuel waste form. The candidate materials for the canister/overpack, however, are similar to those for liquid HLW.

In addition to waste form and waste package materials, DOE is considering various materials for backfilling drifts and galleries and for sealing shafts, tunnels, and galleries.

The main features of engineering in geologic disposal of HLW include the geotechnical and mining technology associated with excavating and constructing repository cavities (shafts, tunnels, galleries, vertical or horizontal emplacement holes) and support structures. Detailed site-specific design and construction techniques for underground facilities are not yet available and will probably need to await site characterization by DOE. Hence our research in the area at present is confined to general investigations of the excavation techniques and geotechnical testing methods.

The glass waste form is expected to play the major role of controlling radionuclide release from the engineered barrier system following the containment period. The current DOE specification for glass waste form in salt repositories sets the maximum element release rate at one part in 10^4 per year. The additional factor of 10 needed to meet 10 CFR Part 60 is expected to be achieved by the rest of the engineered barrier system. The major technical issues associated with borosilicate glass waste form are (1) the element release mechanism, (2) the total glass surface area for leaching, (3) the effect of

thermal and radiological aging of glass with respect to bulk properties, (4) alteration of the glass surface, (5) the effect of manufacturing QA parameters, and (6) the effect of minor phases.

Relevant information and data with respect to the long-term isolation performance of the spent fuel waste form are not yet developed. In general, the two major issues identified for glass, that is, leaching mechanism and total leaching surface area, should apply for the spent fuel waste form as well as (1) high thermal and radiation history including neutron flux, (2) local burnup effects, (3) changes in the microcrystal structure of UO^2 matrix due to diffusion, and (4) the interaction of cladding (Zircaloy) with filler materials.

The containment requirement is expected to be met by the canister/overpack. The most likely mode of containment failure appears to be corrosion, although mechanical failure may also be significant. Corrosion failure can be divided into two categories generally applicable to all metals and alloys being considered by DOE: uniform corrosion and other forms of corrosion (e.g., pitting corrosion, grain boundary corrosion, and stress corrosion cracking). Loss of containment due to uniform corrosion is probably easier to handle with respect to design, manufacture, and demonstration of compliance with regulations than the other corrosion mechanisms. Uniform corrosion rates (material loss per unit time) for many metals are generally known under a variety of environmental conditions. Other corrosion mechanisms, however, are more difficult to handle. These mechanisms attack locally and apparently randomly, and the rate of propagation is controlled by local chemistry. Thus it is difficult to design relevant experiments and perform competent analyses and interpretations of data.

Two failure modes that can be classed as mechanical and may be important to containment are hydrogen embrittlement and weldment/sealing failure. Hydrogen embrittlement, together with stress corrosion cracking, is a mechanism that may lead to catastrophic failure. Weldment failure may be caused by a change of the metallic properties of the canister/overpack in the welding zone.

Waste packages, their components, and related engineering are generally discussed individually assuming some "fixed" environment within the underground facility. It is very difficult both experimentally and theoretically to study a system in which there are interactions between components and between the components and the environment in which they are placed. Most studies conducted have isolated individual components and treated environmental parameters as variables. The observed effects are combined to quantitatively estimate or bound performance. This approach may be valid and even conservative if synergistic effects are not significant. However, there are a number of possible interactions that could be of concern. The following interactions are examples:

1. Waste form/container - diffusion of wastes into the canister/overpack material may cause deteroriation of canister properties.

2. Waste form/container/backfill - release of canister corrosion products to backfill materials may change the retardation characteristics of the backfill.

3. Waste package/groundwater - release of waste package constituents into groundwater may change the geochemistry.

4. Waste package/groundwater/host rock - hydrothermal effects (hydro fracturing), radiation effects on material properties (radiolysis of groundwater), temperature gradient degradation mechanisms, groundwater path alterations.

Licensing Review

Ultimately, NRC will review and will base its licensing decisions on the adequacy of DOE's demonstration of compliance with 10 CFR Part 60. That demonstration invariably will contain arguments and analyses of the performance of individual repository components and their contribution to overall system performance or to confidence in that performance. Knowledge of DOE's programs

as well as NRC's own phenomonological research has allowed NRC to identify many of the elements of that demonstration.

Simple screening tests (short-term laboratory coupon tests) will probably be used to identify and eliminate modes of containment failure. For relevant failure modes, simple tests (e.g., weight loss as a function of time) are likely to be performed to determine the rates of failure. Extrapolation (if possible) will then be used to argue that the containment requirement is met by the canister/overpack. DOE will need to incorporate adequate data with respect to QA/QC of waste package manufacture and welding practice as well as other information on product reliability.

NRC's licensing review will focus on the following:

1. Completeness of DOE's investigation to identify failure modes that might operate over long time periods,

2. Adequacy of DOE's program assessing failure rates based on physical/chemical mechanisms,

3. Adequacy of DOE's treatment of uncertainties in measurement, modeling, and data interpretation with the use of appropriate statistical methods,

4. Adequacy of DOE's consideration of waste package environment with respect to waste package design and expected performance, and

5. Adequacy of the engineered features of the underground facility to provide the above environment.

In addition, NRC is likely to face the following questions:

1. What is an acceptable reliability of the canister/overpack with respect to early failure?

2. What constitutes canister/overpack failure (e.g., is one pinhole penetration with an area, say, of 0.1 mm^2 regarded as canister/overpack failure)?

3. What percentage of failed canister/overpacks constitutes containment failure?

4. How do the components contribute to overall system performance or to confidence in overall system performance?

Again, simple screening tests are likely to be used to identify modes and determine rates of the release of radionuclides from the waste form and other components of the engineered system. DOE will support its arguments through in situ testing programs during operation of the repository. However, it is expected that element release will occur long after the repository is closed. NRC's licensing review will focus on:

1. The completeness issue (have all operating mechanisms been addressed?),

2. Release rates based on physical principles, and

3. Understanding and assessment of uncertainties.

Licensing Strategy

Based on the expected focus of the licensing review, the licensing strategy should require of DOE:

1. Development of the waste package environment,

2. Development of models, including theories for extrapolation to very long times, that can be used to show compliance with 10 CFR Part 60,

3. Actual use of models at candidate sites and for actual materials and waste form,

4. Such further tests as might be needed to verify and assess the aptness of the models, and

5. Consideration of interfaces between repository subsystems in developing the performance assessment models, including the overall system model.

Given that NRC's strategy obtains the above from DOE, the collateral question is what should NRC do. It appears wise that NRC should have programs in the following areas, for the reasons given:

1. NRC should continue its research in the materials area on an audit basis to obtain a reasonable idea of the dominant corrosion mechanisms for canister materials, to become more familiar with this technology, and to provide the basis for issuing guidance on accelerated testing.

2. NRC should modify the licensing strategy to include a major role for modeling of the release and transport of fission products within the repository and the release to the undisturbed surroundings. It may well be that the licensing strategy may be founded on simplified bounding models, and properly so. But we believe that a more detailed assessment capability will be needed. NRC would use this capability to assess DOE models as well. Some effort in this area is underway (i.e., LBL); future work needs to be defined. This work also needs to be integrated with the hydrogeologic transport models. In this way, some notion of the adequacy of the defense in depth of Part 60 can be assessed.

3. The materials work at BCL has to date emphasized the glass waste form. Several contracts in the technical assistance program of NMSS-WM include studies of the DOE waste package program. We believe that there should be greater specificity of the waste form and some notion of how the approximately $2 million of TA should be divided (or prioritized) among the candidate materials, waste form, and environment.

4. The overall expenditure rate for the two offices in this area (slightly less than $4 million did not seem disproportionate in contrast to much heavier DOE rates. We did not find NRC to be "carrying DOE's water." However, it seems that a lot of money (at least a million $) is being given to contractors to review DOE's work. In light of recent augmentation of the staffing in WM, it may be desirable to reconsider this farming out of licensing reviews, which has produced hardships in other areas and could well do so there. More effort in developing guidance might be a better use of money. In this context, the Aerospace work seemed like a good use of technical assistance in that it produces manuals for NRC use and not "final" licensing positions.

3. Geochemistry and Hydrology

This area of the NRC HLW technical program encompasses hydrogeology, geochemistry, and geology/geophysics. Programs in these areas account for approximately $6 million of the total HLW Program Area budget for FY84. The efforts are distributed among 37 individual projects, approximately equally divided between the Offices of Research and Nuclear Material Safety and Safeguards.

The overall framework for the geosciences technical work is based on the performance objectives and siting criteria of 10 CFR Part 60, which were being developed while the present technical program was being established. As its overall performance objective, 10 CFR Part 60 uses the containment requirements of the proposed EPA standard applicable to geologic disposal of HLW, which requires an assessment of cumulative radionuclide releases to the accessible environment over the 10,000 years following disposal of the wastes. Assessment of compliance with this performance objective requires consideration of releases with respect to both anticipated and unanticipated processes and events. Categorization of these processes and events must be based on an examination of the geologic record for a particular site, with emphasis on identifying those processes and events that have occurred during the Quaternary Period (approximately the past two million years) that are likely to occur in the future. As noted earlier in this section, categorization of process and

events as "anticipated" and "unanticipated" is necessary both to perform the assessments of whether the EPA standard is met and to determine the design basis for the engineered barrier system and is a key concept underlying the regulatory approach of 10 CFR Part 60.

In addition to this overall performance objective, 10 CFR Part 60 requires that the groundwater travel time from the disturbed zone to the accessible environment at a site before waste emplacement be at least 1000 years unless the Commission approves some shorter time. The rule also contains siting criteria (§ 60.122) that require assessing the ability of the geologic repository to meet the performance objectives relating to isolation of the waste in light of a number of specified favorable and potentially adverse conditions that may exist at a site. The NRC technical program in the geoscience area must provide the technical capability needed to assess DOE's evaluations of compliance with these requirements. Based on briefings presented to the Committee, the geosciences projects now in place are generally relevant to this regulatory framework, although in many cases the justification for the work is very broad (i.e., improved understanding of the relevant phenomena or investigation of areas of uncertainty in NRC's ability to assess DOE's programs) and only generally related to particular licensing assessments or findings that must be made to meet Part 60.

In order to assess whether the requirements of 10 CFR Part 60 have been met, the NRC staff must have an adequate understanding of the individual geological processes affecting repository performance. As part of its review of DOE's Site Characterization Report for the BWIP site, the NRC staff performed a systematic review of the geologic processes affecting repository performance and developed a detailed list of technical issues that must be addressed to evaluate repository performance. These detailed issues were documented in Appendix C to NUREG-0960 and are discussed in more depth in Volume II of this report.

Current technical programs are examining the relevant physical phenomena involved in the flow of groundwater in the kinds of hydrogeologic systems DOE is investigating for potential repository sites. These programs involve

examining the phenomena governing flow of groundwater in fractured rocks in both saturated and unsaturated hydrologic systems, examining the factors affecting geochemical retardation of radionuclide transport through hydrogeologic systems, assessing the geophysical methods used to measure the physical properties of the rocks, understanding the geochemical environment in the host rock as it is affected by the construction of the underground facility and emplacement of the waste, understanding the interactions of these geologic systems with the engineered barriers, and assessing the reliability and associated uncertainties in the geophysical methods used to measure site properties that affect performance.

During the past year, the staff has attempted to relate the present technical projects to the more specific issues developed by the NRC staff in Appendix C to NUREG-0960. In the briefings the Committee received, many examples were given of how current projects related to one or more of the specific issues in Appendix C. The Committee generally agreed that the site characterization analyses will be useful in providing a framework that can be applied to focus the program on the relevant technical issues for licensing. However, Appendix C focuses primarily on performance issues by using the performance objectives of 10 CFR Part 60 to derive a hierarchy of more detailed performance issues to evaluate DOE's site characterization plans. While this approach addresses the principal factors affecting repository performance, it may not be complete with respect to the criteria of 10 CFR Part 60 since it does not explicitly consider matters such as DOE's plans for identifying anticipated and unanticipated processes and events and for investigating and evaluating favorable and potentially adverse conditions. While such matters are implicit within the issue breakdown of Appendix C, they will eventually need to be explicitly addressed during DOE's site characterization program and are an integral part of the prelicensing guidance to be provided to DOE by the NRC staff. NRC's technical programs must support guidance to DOE in these areas.

Further, the present statements of work need to be reviewed to ensure that contract products will specifically address the relevant issues from the site characterization analyses.

Another shortcoming of the present technical program is that at present there is no means to prioritize the technical issues and to make decisions regarding allocation of resources among them. The question of how to better prioritize the issues so that resources are applied to the most important licensing questions is a difficult one to deal with at this stage of the national HLW program. This is because DOE has not yet (1) recommended the three sites to be characterized, (2) developed site-specific conceptual designs, and (3) set targets for the level of performance to be achieved by the major natural and engineered barriers. In the absence of these key decisions by DOE, NRC must have a program with adequate breadth and flexibility to be able to address a number of alternative media, materials of construction, and design approaches. The program will be able to become more focused after the SCPs are submitted in mid-FY85.

In the interim, one method that can be used to set priorities where reliable models are available is more use of simplified performance assessments and sensitivity analyses to determine what are the important sources of uncertainty in performance on which NRC's resources should be focused. Any such application of performance assessment should recognize that the models themselves are uncertain and should take into account alternative models that could yield different results. Also, the staff should investigate methods for establishing priorities of technical programs when adequate performance assessment models are not yet available. The feasibility of methods that have been used in other program areas such as AHP should be investigated to determine their applicability to prioritizing HLW issues.

A final observation is that there are at present so many individual projects in the geosciences that integration and management of the program is an almost overwhelming task. The potential for duplication and lack of consistency of individual contractor products with regulatory policies is also increased by the multiplicity of projects. In future program planning, measures should be considered to ease the administrative burden on the staff, and careful attention needs to be given to effective program integration.