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Federal Policy for the Disposal of Highly Radioactive Wastes From Commercial Nuclear Power Plants

An Historical Analysis

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Preface and Summary

How to dispose of highly radioactive wastes from commercial nuclear power plants is a question that has remained unresolved in the face of rapidly changing technological, economic, and political requirements. In the three decades following World War II, two federal agencies -- the Atomic Energy Commission and the Energy Research and Development Administration -- tried unsuccessfully to develop a satisfactory plan for managing high level wastes. The history of their efforts, beginning with debates in the Atomic Energy Commission in 1949, reveals one fact of paramount importance: despite changes in terminology and situations, the policy issues related to nuclear waste disposal which the Department of Energy faces today are strikingly similar to those tackled by the Atomic Energy Commission in 1955 and inherited by ERDA in 1975. Significantly, the fundamental questions have endured for almost two decades:

(1) What should be the federal role in managing the reprocessing of spent fuel from commercial power reactors?

(2) How should nuclear wastes be processed and in what form for ultimate disposal?

(3) What processing requirements are necessary to protect the public health and safety?

(4) What method should be adopted for the permanent disposal of radioactive wastes?

(5) To what extent is retrievable surface storage acceptable or desirable?

(6) What mode of storage represents the optimum solution in terms of feasibility, cost, environmental reliability, and public

acceptance?

(7) What mode or modes of permanent storage should be adopted for wastes generated in federal production of special nuclear materials or in federal nuclear research?

(8) What nontechnical factors bear on specific policy issues? How can these be evaluated and accommodated?

The fact that questions such as these have persisted over more than two decades suggests three possibilities. One is that the questions have no definite answers and must be continually reexamined as circumstances change. A second possibility is that federal officials have come up with the wrong answers. Finally, it is even possible that they have been asking the wrong questions.

No doubt there is some truth in all of these explanations. It is certainly true that a dynamic nuclear technology has constantly raised issues which have required new responses. There has also been a common, and understandable, tendency among federal officials to adopt temporary, short-term solutions even when such expediency was obviously not the best course of action. Government managers, however, are generally required to solve immediate problems before they take on long-range ones involving uncertain options and consequences.

As for the second possibility, there is ample evidence of wrong decisions, particularly in terms of piecemeal decisions which seemed to make sense in one isolated area but which had undesirable effects elsewhere. The AEC, for example, continually made the mistake of considering civilian and defense wastes in separate, unrelated compartments when in fact the failure to establish an understandable policy for disposing of

defense wastes undermined public confidence in the AEC's ability to find an adequate and reliable solution for civilian wastes. There are also examples of decisions that were just plain wrong, either because federal officials did not have all the facts they needed for a good decision (the Lyons repository), or because they did not understand the implications of their decision (Hanford tank leaks), or because they did not have the organization or management control necessary to implement the decision (AEC's 1970 waste disposal plan).

The third possibility, that federal officials were not asking the right questions, appears to be the most common and fundamental explanation of failure. Although the degree of misperception varied from time to time, federal officials throughout the period of this study failed to understand that they were dealing with problems that were not solely or even primarily technical in nature. In this sense, there has been some truth to the claims of critics of "hard" technologies that government officials have been prone to take refuge in the technological "fix." The criticism is probably unfair and misleading when taken out of historical context, but it is true that in the area of nuclear waste disposal there has been a tendency to believe that all problems could be answered with technology or that technical solutions would make it unnecessary to face the less tractable issues outside the scope of technology. There never has been any shortage of feasible technical solutions to the problems of waste management. In fact, the extraordinary accomplishments of federal laboratories and contractors in this area have tended to dazzle the policymakers and to lead them to believe that brilliant technology was sufficient. Yet as new public sensitivities to the implications of

science and technology developed in the 1950s, federal officials persisted in limiting their analysis to technical solutions.

Lip service was given to the importance of such nontechnical factors as public understanding and acceptance, economic incentives or disincentives, and federal-state relationships, but almost nothing was invested in the analysis or evaluation of these factors. There is no evidence at all that attention was given to such matters as social, cultural, or psychological phenomena that might serve as constraints in implementing technical solutions.

The following historical analysis of the nation's various nuclear waste management programs has investigated four questions concerning the formulation of United States' policy:

(1) What did the government perceive to be the principal policy issues in nuclear waste disposal?

(2) What factors did they consider in formulating policy?

(3) What were the results of these policies?

(4) Why did these policies fail or succeed?

Although not a comprehensive narrative history of the subject, the study shows that the management of nuclear wastes has been a persistent problem that has not yielded to patchwork solutions. Furthermore, it describes solutions attempted in various situations in the past, and suggests what kinds of consequences may be expected if certain courses of action are adopted. An historical perspective, of course, does not prescribe future action. On the other hand, a knowledge of the history of nuclear waste management is essential if policymakers are to be fully aware of the limitations and possibilities of the present situation.

Early Perceptions

From the outset of development, responsible officials understood, at least in a theoretical sense, the safety and environmental implications of nuclear technology. In the earliest days of the Manhattan project during World War II scientists were fully aware of the dangers of radioactivity. In July 1942, before the first experimental reactor was built, the Manhattan District established a health physics program to monitor radioactive hazards in its laboratories.[1] Although the safety systems and techniques used during World War II were primitive and unsophisticated by modern standards, there was a clear recognition among project scientists that nuclear operations were extremely hazardous and required extraordinary safety systems to protect workers in the project and the public at large. Radiation hazards posed important questions in themselves and thus attracted the interest of first-rate scientists. The ability to detect extremely small amounts of radiation also helped to create safety systems and standards that were unprecedented in industrial practice at that time.

The Atomic Energy Commission inherited this same sensitivity to the hazards of radiation. In addition to supporting a broad program of biomedical research, the Commission gave special attention to the hazards of radioactivity in a variety of activities from uranium ore extraction to deployment of nuclear weapons. In 1949 the Commissioners and staff struggled for months to agree on the text of a public report on handling waste materials from the atomic energy program.[2]

Although the 1949 report recognized the operation of production reactors as a primary source of radioactive wastes, it did not stress the high level liquid wastes produced at Hanford. Rather the report addressed the whole range of possible dangers in production operations, laboratory research, and medical uses. Furthermore, the report discussed radioactive wastes in terms of "handling" rather than "disposal" because at that time the volume of high-level waste stored at Hanford was relatively small. The question of disposal would not arise until chemical processes could be developed to extract the tons of unfissioned uranium which had been left behind in underground storage tanks when plutonium was removed for use in weapons. The new processes for extracting the uranium were not placed in operation until 1952, and by that time the Commission had millions of gallons of high-level wastes stored at Hanford.

With the passage of the Atomic Energy Act of 1954, the Commission had to give some thought to the radioactive wastes that would be generated by private industry, particularly the high-level materials that would be produced in nuclear power reactors. Early in 1955 the Commission asked the National Academy of Sciences - National Research Council (NAS-NRC) to study the feasibility of disposing of wastes in geologic formations. New regulations on radiation exposure adopted by the Commission in 1956 in effect would require all high-level wastes to be permanently isolated from the environment. The NAS-NRC endorsed this restriction and reported in 1957 that it favored disposal by placing the high-level liquid wastes in chambers in bedded salt formations or injecting the liquids into permeable geologic formations below the water table.[3] By this time the Commission had already moved ahead on research on various methods of geologic

storage and was focusing on processes that would fix the radioactivity in solid, stable media or discharge it under controlled conditions into selected geologic formations. Research was also being done at Hanford on isolating the long-lived and highly radioactive fission products cesium 137 and strontium 90 from the large volume of wastes for special containment.[4]

Although the generation of wastes in commercial power reactors was still some years in the future in 1957, the volume of so-called "defense" wastes now exceeded 62 million gallons and was growing rapidly. These wastes were generated mostly in producing plutonium for nuclear weapons at Hanford and Savannah River but also in operating nuclear submarines and AEC test reactors. Even this figure was dwarfed by the then projected accumulation of as much as 3 billion gallons from civilian power reactors by the year 2000. The Commission's reactor development staff concluded: "High-level, liquid waste disposal is the major waste problem in the AEC today as measured in dollars, curies of radioactivity and potential health hazard. All of the other kinds and categories of wastes, though significant, are several orders of magnitude less important."[5] In addition to the technical problems, the staff also recognized that the Commission would have to resolve political questions, such as the role of the federal government and industry in waste disposal, as well as public concerns about the safety of the ultimate disposal system.

The Limits of Early Achievements

Valuable as these early perceptions of the waste disposal problem were, they did not lead automatically to a comprehensive solution. On the purely technical side, the AEC made real progress. Over the eight

years from 1957 to 1965, the Commission substantially increased its support of research and development on a variety of processing techniques for both military and civilian reactor wastes. At the Idaho Chemical Processing Plant, engineers had successfully developed a fluidized-bed calcination facility that could convert high-level liquid wastes from AEC's experimental reactors into a relatively inert granular calcine that could be stored in stainless steel bins buried in shallow excavations at the Idaho reservation. By the time all available bins were filled in October 1964, the plant had converted more than 500,000 gallons of waste into calcine. Other Commission laboratories and contractors were studying fixation processes using clay, glass, ceramics, and synthetic feldspars. At Savannah River AEC had supported extensive exploratory drilling to determine whether it was feasible to store high-level wastes in tunnels mined out of crystalline bedrock beneath the plant site.[6]

Oak Ridge National Laboratory during these years investigated the technical problems of storing solidified high-level wastes in bedded salt deposits, including experiments in an abandoned salt mine near Lyons, Kansas. At Hanford good progress was being made in extracting the most intensely radioactive isotopes such as cesium 137 and strontium 90 from the liquid wastes and then reducing the volume of the residual material by evaporation in place to deposit a damp salt cake in the tanks. This process greatly reduced not only the volume of material in the tanks but also the possibility that radioactive materials would seep from leaking tanks into the environment.

By 1964 all these developments had markedly reduced the volume of wastes that would be generated per unit of nuclear power produced. While

Commission estimates of installed nuclear power in 1980 had risen by almost a factor of three since 1959, the predicted accumulated volume of wastes had dropped by a factor of 10 or more, depending on the process used. The 1959 estimate of 330 million gallons from the nuclear power industry by the year 2000 had now been revised downward to 22 million gallons.[7]

Independent assessments of the Commission's efforts by the National Academy of Sciences in 1965 recognized the substantial technical progress made in waste management practices and research, but the Academy detected serious flaws in the system. Because AEC was still primarily an operating organization concerned with producing nuclear materials for weapons, the agency, in the Academy's opinion, tended to solve waste storage and disposal problems on an ad hoc basis.[8]

This opinion was another way of saying that the Commission's division of production looked upon nuclear wastes more in terms of interim storage than ultimate disposal. Storage methods were evaluated in terms of efficiency and economy rather than long-term considerations of environmental integrity and public acceptability. In 1961, for example, the production division had rejected out-of-hand a suggestion by the NAS-NRC committee that all waste disposal facilities be located at sites suitable for ultimate geologic disposal. The high cost and practical difficulties of transferring millions of gallons of wastes at Hanford and Savannah River to reprocessing sites made that suggestion unacceptable to the production division staff, and the overriding priority of the production program made that opinion unchallengeable.[9]

There was no central coordination of waste management within the AEC

because responsibility was divided. Two operating divisions, production and reactor development, managed wastes created in their programs. The division of biology and medicine and the AEC's regulatory staff were responsible respectively for health and safety aspects and for official regulations.[10] Even within the production division there was no inclination to adopt uniform processes or procedures to be used at all sites. The rationale was that the waste disposal requirements at each site were in many ways unique and that processes and procedures should be designed to meet those requirements. From a strictly technical perspective, the argument made some sense, but the lack of coordination made the AEC's efforts difficult to explain, understand, and justify. The argument probably also reflected the attempt by the operating staff to resist any limitations on its authority. Although organizations and situations would change constantly over the next decade, AEC continued to be vulnerable to the charge that it had no single office in charge of its waste disposal program and no comprehensive policy for the ultimate storage of nuclear wastes.

By the end of 1967 there was growing concern outside the AEC that, despite the substantial technical achievements of the preceding decade, the agency was not moving fast enough in formulating a policy for disposing of high-level wastes. As one member of the NAS advisory committee on nuclear science pointed out, earlier hopes had faded that the use of power from fission reactors would be at most a transition on the way to fusion energy. As civilian nuclear power plants came closer to being economically competitive and public concern grew over pollution from fossil-fueled plants, utility companies were turning to nuclear power.

This development raised new dimensions in planning for waste disposal. Apparently in response to the NAS concern, the Commission agreed to establish a NAS-National Academy of Engineering committee on radioactive waste management to replace the earlier committees that had become inactive.[11]

A few months later, in April 1968, the General Accounting Office expressed concern about the other half of the AEC's high-level waste program: the storage of defense wastes at the Hanford, Savannah River, and Idaho sites. The GAO investigators noted the increasing incidence of leaks from the storage tanks at Savannah River and Hanford and the absence of decisive action by the Commission to meet the problem. The GAO urged better management by senior AEC officials and suggested the need for assigning responsibility to a single headquarters office.[12]

Formulating an AEC Policy

Under these pressures and circumstances the Commission set out in the spring of 1968 to formulate segments of a coherent policy on nuclear waste disposal. The patchwork of ad hoc decisions made over the previous decade and the fragmentation of responsibility within AEC posed formidable obstacles to comprehensive planning. Given the difficulty of the task, it is not surprising that more than two years elapsed before the outlines of such a policy began to emerge. The Commission had no choice but to try to build a coherent policy by first tackling the same fragmented programs that had defied integrated analysis in the past.

The first issue to be considered -- and the most complicated -- was how irradiated fuel elements from commercial nuclear power plants were to be reprocessed and how the resulting wastes were to be prepared for perma-

nent disposal. Assuming that most nuclear power plants to be built before the 1980s would be located in the eastern part of the United States, the AEC staff envisioned the construction of two or three reprocessing plants near the eastern seaboard. More for ideological than technical reasons, the reprocessing plants were to be owned and operated by private industry, although there was initially some contention within the AEC staff that the plants should be located on federal property. The Commission and the staff reached early agreement: (1) that the inventory of high-level liquid wastes held at the reprocessing plants should be limited in volume to the amount produced in the prior five years; (2) that wastes above that amount would have to be converted to an AEC-approved solid form; and (3) that these solid wastes would have to be transferred to a federal repository no later than ten years following separation of the fission products from the irradiated fuel. Upon receipt the federal repository would assume physical responsibility for the material and industry would pay a one-time charge that would cover ultimate disposal and perpetual surveillance.[13]

Although the essentials of this policy were established in 1968, the process of reviewing the details with AEC staff and contractors, industry representatives, and the NAS-NAE advisory committee took more than a year. Two successive publications of the draft notice in the Federal Register and consideration of public comments added another year to the process. Finally, disagreements among the Commissioners and clearance by the Office of Management and Budget and the Council on Environmental Quality delayed final issuance until November 1970.[14]

The second major issue to be considered was how to plan for ultimate

disposal of commercial high-level wastes. The Commission's regulations on commercial siting of reprocessing plants rested clearly on a decision that civilian wastes would be placed in a federal repository to be established and maintained by the government. In making this commitment, the Commission was relying on the paper studies and experiments which had begun in 1955 with the NAS-NRC committee's recommendation that bedded salt deposits be considered for this purpose. In 1965 Oak Ridge National Laboratory had expanded its studies in a salt mine at Lyons, Kansas to include a two-year experiment to determine the thermal and radiation effects produced in salt by irradiated fuel elements. Following successful completion of that experiment, Oak Ridge investigated the technical and economic feasibility of establishing a prototype disposal facility in salt. In the spring of 1970, as the Commission was moving toward decision on the commercial siting policy, it approved a staff proposal for a demonstration project in the salt mine at Lyons. Although not a part of the public announcement, the Commission intended to use the Lyons site for permanent, irretrievable disposal of solid wastes, first expected to be delivered by a commercial reprocessing plant in 1972, on the condition that further study of the Lyons site revealed no serious deficiencies.[15]

The third issue to be resolved in the comprehensive policy formulation was how to dispose of the defense wastes, particularly the 80 million gallons that had now accumulated at Savannah River and Hanford. Until the late 1960s the disposal of defense wastes had been considered a separate problem unrelated to commercial reprocessing. There were good technical reasons for this distinction: (1) the defense wastes in their chemical composition were very different from civilian wastes and, therefore,

required different methods of processing and disposal; (2) the enormous volume of stored defense wastes imposed restraints that did not apply to civilian wastes, which did not yet exist in significant quantities; and (3) there was still no intention to transfer defense wastes to off-site repositories such as the Lyons facility. The sheer magnitude of the defense wastes, however, made it impossible to ignore them in devising a comprehesnive AEC policy.

A policy for the defense wastes at Hanford was all but an accomplished fact. Since 1960 Hanford engineers had been solidifying the high-level wastes by evaporation in the storage tanks and devising processes to remove strontium 90 and cesium 137 for separate disposal, probably in a geologic repository. The residual salt cake, which was not highly radioactive, tended to seal leaks that would ultimately develop in the tanks, while the dry climate and underlying geologic structure of the Hanford site supported the contention that none of the solidified waste would ever reach the biosphere even if it leaked from the tanks.[16]

The Commission had also assumed that the Savannah River wastes would also be disposed of on-site. Here, however, environmental considerations made the task much more difficult than at Hanford. The Savannah River plant, unlike Hanford, was located in an area of high rainfall and high water table. In fact, the site overlay the prolific Tuscaloosa aquifer, one of the major water sources of the southeastern states. To reduce the possibility of leaking radioactive wastes into the ground water, AEC had constructed double-bottomed tanks at Savannah River. The only possibility for permanent disposal of wastes at Savannah River was to place the material in caverns mined in the crystalline bedrock below the aquifer.[17]

AEC had first proposed this idea to the NAS-NRC committee in 1960 and began test borings on the site to determine the characteristics of the bedrock. Although the committee was impressed by the thoroughness of the geologic investigations, the majority of the committee concluded in 1966 that it was essentially dangerous to place wastes below the aquifer and doubted whether the investigation should continue. The AEC chose, however, to follow the minority recommendation that a shaft and experimental chamber in the bedrock should be excavated as the only certain way of determining the integrity of the system. In October 1970, AEC announced that the work would proceed on selection of the bedrock site and design of the shaft and exploratory tunnels.[18]

Thus by the end of 1970 the AEC had committed itself on the three essential elements of a policy for ultimate disposal of radioactive wastes: (1) fuel elements from civilian power reactors would be processed by commerical plants and the high-level wastes would be solidified in a form acceptable to AEC for shipment to a federal repository; (2) AEC would build a federal repository using a bedded salt formation for permanent, irretrievable storage of these wastes, the Lyons site serving as a demonstration facility; and (3) high-level wastes from the defense program at Hanford, Savannah River, and Idaho would be disposed of on-site.

In the past the Commission had protected its operational flexibility by avoiding general policy statements on waste disposal and by making ad hoc decisions. Even in 1970 the Commission had been careful to avoid any suggestion that it had formulated a comprehensive plan. But the three policies announced to the public in 1970 were so closely related that the failure of one would likely affect the others. Failure of the com-

mercial processing plants to produce solidified waste in acceptable form could upset plans for the Lyons repository. Problems at Lyons could leave the commercial plants with no ultimate disposal site. Failure of the production sites to find acceptable methods for permanent on-site disposal could place new requirements on the federal repository and disrupt plans for disposing of commercial wastes. By 1970 the Commission could no longer avoid these commitments, but it would pay a price in terms of loss of flexibility.

Flexibility was especially important in waste disposal technology because it would take years to put any of the decisions into effect. Successful demonstration of the Lyons facility would take several years. The first solidified waste from the commercial plants would not be ready for disposal until 1979 or 1980. The bedrock experiment at Savannah River would not be completed for several years. The safety of in-tank solidification at Hanford might not be fully demonstrated for decades. In the meantime new technical problems or public concerns could threaten any one of the projects and thus the whole waste disposal program. As it happened, all three parts of the plan soon encountered formidable obstacles.

Commercial Reprocessing Plants

The AEC's plan for ultimate disposal of high-level radioactive wastes depended first of all on the successful operation of commercial reprocessing plants. At the end of 1970 most of the required capability was still on paper. Only one commercial reprocessing plant was then in operation, a small unit owned by Nuclear Fuel Services, Inc., built on state land at West Valley, New York. The plant, which started operating in April 1966 used a process that generated liquid wastes. The waste material had been

neutralized so that it could be stored in steel tanks similar to those which the AEC had used at Hanford and Savannah River. From the start a risky commercial venture at best, the West Valley plant faced a bleak future after the AEC adopted the new regulations in November 1970 requiring all commercial wastes to be solidified in a form acceptable for ultimate disposal in a federal repository. Operations continued until 1972, when the plant was shut down, ostensibly for modifications which would enlarge capacity and improve processing efficiency. In fact the plant never operated again.

Other commercial plants were being designed in 1971, but they were a long way from completion. General Electric was building a commercial plant at Morris, Illinois, which was scheduled for completion in July 1971. The plant, however, was designed to use processing techniques which had never been tested on a production scale. Even farther in the future was the commercial plant which Allied Gulf Nuclear Services was building at Barnwell, South Carolina, near the AEC's Savannah River plant. Thus in the early 1970s the first link in the AEC's waste disposal plan was a weak one at best.

The Lyons Debacle

The second link in the AEC waste disposal chain was the Lyons project, which was already under attack. During the spring of 1970 a lone Kansas Congressman who did not represent the Lyons district had addressed seven lengthy letters to AEC raising questions about the project. Although the AEC replies were prompt, conscientious, and complete in a technical sense, Congressman Joe Skubitz considered them condescending and evasive. Lacking the knowledge to challenge AEC on technical grounds, Skubitz

eventually resorted to political arguments. He maintained that the will of the people of Kansas, and not just technical feasibility as determined by a federal agency, should determine whether the Lyons facility should be built.[19]

Although the AEC was initially successful in winning the tentative approval of the governor and other state and local officials, Skubitz's persistent queries began to attract attention in the Kansas press during the fall of 1970. By March 1971, when AEC was supporting the inclusion of the Lyons project in the FY 1972 authorization bill, Congressman Skubitz had built some impressive opposition to the project. Concurrent resolutions supported by nine members of the Kansas Senate and 48 members of the Kansas House opposed the Lyons project. In the United States Congress, Skubitz appeared before the Joint Committee on Atomic Energy during the authorization hearings and convinced the committee to adopt a proviso that would give the State a veto over the project. It was now clear that AEC had seriously underestimated Skubitz's potential influence and had mishandled its response to his inquiries and charges. In the Skubitz incident the AEC learned a classic lesson in American politics: A federal agency disregards at its peril the potential power of state and local officials whose opinions reflect the consensus of their constituency on matters of health and safety.

Dramatic and instructive as the Skubitz incident may have been for the AEC, however, it did not bring about the final demise of the Lyons project. In the fall of 1970 the Commission chose to release for public comment a draft environmental impact statement on the Lyons facility. The draft elicited a number of responses from both state and federal agencies.

Although AEC felt confident that it had answered most of the comments in the final statement issued in June 1971, the comments did seem to strengthen the belief among public officials in Kansas that the AEC had been less than forthright in its initial presentation of the Lyons project. Moreover, the fact that local scientists could come up with a number of oversights and discrepancies in the draft report damaged confidence in the reliability of earlier studies sponsored by AEC.[20]

AEC's credibility dropped to a new low during the summer of 1971 when further investigation revealed that there were 29 oil and gas bore holes in the Lyons site, of which only 26 could be plugged. It was also learned that a salt company was planning to expand its solution mining activities in the Lyons area. This operation might well result in surface subsidence and the formation of a lake, which could threaten the integrity of the repository. The salt company also reported that it had lost a large volume of water during mining operations in the Lyons area in 1965. The loss suggested faults or leaks in the salt formation. In September 1971 AEC began quietly to seek alternate sites in Kansas or elsewhere and stopped all work related to the Lyons site. Although AEC tried to keep the Lyons option alive, these unfavorable discoveries, plus the growing public opposition to the Lyons site, effectively killed AEC's hopes that Lyons would become the nation's first permanent storage facility for high-level wastes.[21]

The Search for Alternatives

Loss of the Lyons option removed the keystone of the AEC's plan for processing commercial wastes. The Commission's spontaneous reaction was to begin at once to seek an alternative. Early in 1972 the staff presented

the full range of possibilities: (1) storage in similar bedded salt deposits in other states; (2) storage in salt deposits other than bedded salt; (3) storage in geologic formations other than salt; (4) storage in man-made structures; (5) deep-sea disposal; (6) extraterrestrial disposal; and (7) conversion of radionuclides to stable nuclides.[22]

The AEC staff at the time sensed the dilemmas in the situation. On the one hand, the most promising and most nearly demonstrated method of permanent disposal was no longer available, while on the other hand more attractive long-range solutions, such as extraterrestrial disposal or nuclide conversion, depended upon the development of very expensive, sophisticated systems, which could be justified only in part for waste management. Another dilemma, which became apparent during the Lyons experience, was that irretrievable disposal not only accomplished the purpose of placing the material beyond the need for surveillance and maintenance, but it also destroyed any hope of recovering the material if the disposal method proved a health or safety hazard to future generations. The complementary dilemma was also relevant: that man-made surface storage systems had the advantage of keeping the material available for new processing technologies, but they did impose the awesome responsibility for surveillance and maintenance for hundreds if not thousands of years.

The most striking aspect of the Commission's reaction to the waste disposal problem in 1972 was the almost exclusive concentration on technological solutions. A new location or new technologies seemed to be the answer. There was apparently very little thought given to the economic, political, or historical factors in the demise of the Lyons project. The only staff suggestion was that, while new technologies were being in-

vestigated, the Commissioners should "develop a rapport with the political and other leaders in Kansas to pave the way for top level acceptance of the Repository in Kansas."[23] There is no evidence that any thought was given to just what might be necessary in terms of nontechnical studies and dialogue to establish that rapport.

Instead of examining the broad nontechnical implications of their policy, the Commission moved quickly to settle on an alternative technology. In February the staff was instructed immediately to begin the design of surface storage facilities at Hanford for high-level commercial wastes and low-level wastes from both commercial and AEC activities. The principal operating contractor at Hanford would design a facility with a capacity to store all commercial wastes generated during the remainder of the century, using as much as possible the conceptual designs for the Lyons facility.[24]

The decision to select the surface storage option was specifically a response to the dilemma of irretrievability. That is, the surface storage facility, although admittedly less desirable for ultimate storage than geologic disposal, had the advantage of keeping the waste in a retrievable form until a permanent storage facility was available. The retrievable storage facility at the Hanford site would presumably avoid many of the problems stemming from public reaction to Lyons. It would also give the Commission more time (which it would need) to explore some of the long-term alternatives suggested in January. The surface storage decision appeared to be a practical answer to a difficult political and technical problem.[25]

The surface storage decision, however, did not fully resolve the

dilemma of retrievability; it merely postponed resolution until an ultimate storage facility could be placed in operation. In fact the Commission had pushed that decision farther into the future than ever by directing that for the interim, bedded salt repositories would be pilot facilities only, in that all wastes would be retrievable. This decision had the advantage of keeping all options open until better data were available. It had the disadvantage of leaving the Commission with a tentative and unresolved waste disposal program and open to continuing charges that the waste disposal problem could not be solved.[26]

Defense Wastes: New Uncertainties

For more than a decade, as noted earlier, AEC had administered its civilian and defense waste disposal programs with separate staffs. The civilian wastes were administered in 1972 by the division of waste management and transportation; the defense wastes by the division of production and materials management, which operated the AEC's major production facilities. In terms of perspective, objectives, and even technology, the two programs were distinctly separate. Lyons and the surface storage facility planned for Hanford were intended for civilian wastes only. The defense wastes in tanks at Hanford and Savannah River were so enormous in volume that the cost of solidifying this material and moving it to another site for permanent disposal seemed impractical. Furthermore, as a strategy it probably seemed wise to separate the civilian waste program, which was still in the planning stage, from the monumental if less volatile problems in the defense area.

The reasoning behind this distinction made sense in terms of technology, but it eventually proved ineffective and damaging as the public

grew more sensitive to environmental issues in the 1970s. The Commission's decision not to contest the judicial decision in the Calvert Cliffs case in the summer of 1971 dramatically announced a new and more responsive AEC attitude toward environmental questions, one that would have implications for nuclear waste disposal as well as for the siting of nuclear power plants. As public concerns about nuclear power became more articulate, the Commission's nice distinctions between the civilian and defense waste programs were lost for the general public with disastrous results.

For years the AEC's production staff had taken a methodical, unhurried approach to the ultimate disposal of the defense wastes. Although the AEC had long taken the position that movement of the defense wastes to another site was impractical and that storage of wastes in liquid form in tanks offered no acceptable long-term solution, the AEC production staff had never fully abandoned the idea of permanent storage in tanks if the wastes could be solidified in place. Because soil and climate conditions at Savannah River did not make this solution plausible, AEC had been exploring the possibility of bedrock storage at that site. In fiscal year 1972 AEC was spending more than $1 million on exploratory drilling and concept design of a bedrock facility and had requested $3 million for fiscal year 1973.

By this time, however, reports on the bedrock project had begun to draw attention in the Savannah River area and beyond. Both Governor Jimmy Carter of Georgia and Senator Ernest F. Hollings of South Carolina had expressed reservations about the project, and AEC had received a number of probing questions from the Natural Resources Defense Council, one of the most effective environmental groups. Perhaps in response to this criticism and

a very cautious evaluation by the Environmental Protection Agency, the House Appropriations Committee had cut the 1973 appropriation for the Savannah River project to $1 million. Rather than wage a fight for the project in the face of growing opposition, the Commission decided during the summer of 1972 to delete all funds for the bedrock experiment from its 1974 budget and withdrew the draft environmental statement which had been issued for public comment in January. Although the Commission reserved the option of resuming the project at a later date, it was dead in the eyes of the public.[27]

At Hanford the AEC had not concluded that geologic storage of the enormous volume of high-level wastes would be necessary. There was still hope that after certain long-lived fission products had been removed from the bulk of the material, the residue could be safely stored by evaporating it in the tanks to produce sludge and a damp salt. One potential difficulty of this approach was that the older tanks built during World War II were subject to leaks. Since 1958, fourteen of the tanks had been known to leak, some of them as much as 70,000 gallons of high-level wastes, before the leaks were discovered. By monitoring the tanks closely, replacing those that leaked, and solidifying wastes by evaporation, the AEC contractor at Hanford was confident that the leak problem could be handled in a technical sense. AEC maintained on the basis of detailed studies that none of the leaked material had ever escaped to the biosphere.[28]

At the very time AEC was giving these assurances, however, in the spring of 1973, a fifteenth tank at Hanford was leaking 115,000 gallons of high-level wastes, including about 40,000 curies of cesium 137 and 14,000 curies of strontium 90. Although workers monitoring the tanks recorded the evidence of a leak as early as April 20, 1973, this information did not come

to the attention of responsible supervisors until June 6. Full investigation revealed that the operating contractor did not have effective operating procedures or a reliable quality assurance program. The AEC investigation also showed a prevalent belief at Hanford that releases of radioactivity to the environment were not overly dangerous.[29]

Even before the investigation had revealed these facts, the AEC came under heavy public attack. Within two weeks of the discovery of the accident, AEC received a nine-page letter of protest from the Union of Concerned Scientists. The letter, signed by Ralph Nader and others, charged the AEC with negligence in using "primitive" storage techniques. The AEC critics demanded emergency action to recover the lost radioactive materials, immediate steps to correct the situation at Hanford, and the answers to a number of specific questions. The group protested the AEC's "imprudence in allowing continued accumulation of radioactive wastes without prior resolution of the waste storage problem."[30]

This last charge underscored a potential weakness that had been present in the AEC's waste disposal program for years. Despite the confidence of the Hanford engineers in being able to control the escape of radioactivity from leaking tanks, the fact that the tanks were leaking conveyed to the public a sense that AEC had never solved the problem of waste disposal. Such an indication of failure was especially damaging at Hanford because it was the AEC site where waste disposal technology had been under development the longest. If thirty years after the first wastes had been placed in tanks at Hanford, the AEC was still not able to devise a reliable system for permanent disposal, why should anyone believe that the AEC could develop a safe method of disposing of commercial wastes? Thousands rather

than hundreds of people would be asking that question after a newspaper reporter published a sensational (and inaccurate) account of the most recent Hanford leak in the Los Angeles Times on July 5, 1973. Despite AEC efforts to correct glaring misstatements in the article, it provoked widespread fears that would affect public attitudes on nuclear power in California for years to come.[31]

Now that plans for ultimate disposal of high-level defense wastes at both Savannah River and Hanford had either been abandoned or discredited, it was clear that the AEC's effort to separate the military from the civilian program had failed. The apparent collapse of ultimate disposal plans in the defense area certainly damaged public confidence in any ultimate disposal system for commercial wastes. No longer could the AEC credibly postpone decisions on the military program until the civilian program was established.

The AEC Reevaluation

From today's perspective the lessons to be drawn from the AEC's failures in the waste management area during the early 1970s seem clear: (1) the entire waste disposal problem, both defense and civilian, had to be considered as a whole; (2) management of the AEC's waste disposal programs likewise needed to be consolidated under one headquarters division; (3) the dilemma of irretrievability needed to be resolved once and for all in terms of permanent geologic disposal, interim surface storage, or both; and (4) much more attention had to be given to economic, political, and social restraints on proposed technical solutions.

During the final eighteen months of AEC's existence, from the summer of 1973 until January 1975, the Commission only partly understood these

lessons and for practical reasons seemed unable to implement important aspects of all of them. The most glaring failure was the inability to face up to the necessary consolidation of program and organization. The bankruptcy of the defense program, at least in terms of ultimate disposal, reinforced the earlier tendency to isolate the defense program from the civilian rather than stimulating a comprehensive approach. The Commission's response on the defense side was to improve interim storage methods at Hanford and Savannah River by building more and better tanks and using better procedures to reduce leaks. Ultimate disposal of defense wastes was pushed off into the indefinite future.[32]

Despite recommendations from its own staff and from outsiders, the Commission did not consolidate its headquarters staff. The division of production and materials management continued to direct the defense program while the division of waste management and transportation supervised the civilian program through the transition to ERDA.[33]

Thus in the final eighteen months the Commission, increasingly distracted by the uncertainties of federal energy reorganization, tried to concentrate its attention on the commercial program. The Commission was not successful in accommodating the dilemma of irretrievability. After considering several options, including the abandonment of all work on bedded salt disposal at the one extreme or interim surface storage on the other, the Commission came down firmly for continued development of both technologies. Safe permanent disposal would require emplacement in geologic structures. But time, perhaps decades, might be necessary to demonstrate the reliability of the technology. The Commission recognized in the meantime that highly reliable surface storage facilities would be needed.[34]

Having agreed on these broad policies the Commissioners were not able to resolve some of the technical alternatives presented. These included selecting the design of the surface storage facility from the several options presented and determining how calcine wastes could be further processed to form ceramics or glass in order to inhibit leaking of radioactive materials over long periods. Instead of attempting to resolve these questions, the Commission decided to include them as alternatives in a comprehensive environmental impact statement covering the entire civilian waste program.[35]

The draft environmental statement issued in November 1974 did represent in several respects a more enlightened AEC view of the waste disposal problem than had existed earlier. The statement did go beyond the highly fragmented approach of the 1960s, when AEC tried to justify each facility as an independent entity. Now it would be possible to examine the entire civilian waste program as a whole, from fuel reprocessing to permanent storage. The statement also revealed some relaxation in the AEC's rigid interpretation of its environmental responsibilities under the National Environmental Policy Act. In the past AEC had usually insisted that environmental impact statements be prepared only for specific facilities. Now, in the last days of its existence the Commission had published a draft statement covering an entire program which called for facilities at undesignated sites.

There was, however, an obvious deficiency in the draft statement. By the time it was written, the Energy Reorganization Act of 1974 had been signed. Under the act the regulatory functions of the AEC were to be assigned to the Nuclear Regulatory Commission. Thus for political and

bureaucratic reasons the draft statement, written by the AEC's operational staff, was carefully limited to operational matters and did not consider the many regulatory issues raised. Environmental groups did not fail to see this omission.

As for taking a broad view of the nontechnical aspects of waste disposal, the Commission did little more than pay lip service to the idea. The Commission did agree to incorporate all of the technical alternatives for the civilian program into a single environmental impact statement on which the Commission offered to hold public hearings.[36] This decision did recognize the need for public participation in designing technologies that would have an impact on the physical or culture environment. But the Commission did nothing to broaden staff capabilities beyond those of the scientists, engineers, and administrators who had been directing various aspects of the waste disposal program since 1947. No effort was made to study the economic, political, and social factors that could well determine whether a specific waste disposal system could be installed at a given site. In this sense the Commission learned little from fifteen years of frustration and disappointment in attempting to establish an acceptable waste disposal system.

Reappraisal by ERDA

When the Energy Research and Development Administration took over the nation's nuclear program in January 1975, there was a general consensus in government and industry that the civilian nuclear power program was in serious trouble and that the biggest obstacles involved uncertainties, both technical and administrative, about "the back end of the fuel cycle." Consequently ERDA considered resolution of these uncertainties one of the

highest priorities facing the new agency if the nation was to achieve its goal of energy independence. Two weeks after ERDA was activated, a special task force was appointed to review all aspects of the nuclear fuel cycle.

Within a month the task force had completed a report that was both comprehensive and perceptive. Rather than dig into the mass of technical details that had been recurrently studied for years, the task force undertook an overview of the complete nuclear fuel cycle. After following the flow of uranium from the mine through processing, enrichment, fuel fabrication, and irradiation in power reactors, the task force found a complete break in the cycle at the point of spent fuel reprocessing. The task force found that there was "no capability in the U. S. for the processing of spent commercial reactor fuels." The NFS plant at West Valley, New York had operated intermittently from 1966 to 1972 and then was shut down for modifications to increase its capacity and efficiency. A second plant, constructed by General Electric at Morris, Illinois, had never been operated because of major errors in design. The third plant, nearing completion at Barnwell, South Carolina, could not be completed until the government decided whether plutonium recycle would be permitted.

Even if the Barnwell plant could be placed in operation by 1976 and West Valley in 1979 as planned, the capacity of the two plants would be exceeded by about 1982 by the amount of spent fuel removed from civilian power reactors. The task force estimated that it would then be necessary to place an additional plant the size of Barnwell in operation in 1982 and successive plants of similar size every eighteen months thereafter.[37]

If the operation of commercial fuel processing plants was delayed by

licensing or technical problems, spent fuel elements would have to be stored or disposed of in unprocessed form. A quick decision would be needed on whether spent fuel elements were to be processed if ERDA was to complete all the procedural actions and engineering work necessary to have storage facilities ready to receive material in 1983. In fact, the task force concluded, this decision came very close to making waste management the pacing item in the nuclear fuel cycle.

In many respects, however, the ERDA task force accepted the AEC strategies for waste disposal. The ERDA group acknowledged the extensive research that had shown that both retrievable surface storage and permanent geologic deposit were technically feasible, but the group noted that neither technology had been demonstrated. The task force agreed with AEC that the most urgent decision was to select a site for the retrievable surface storage facility. Before that could be done, ERDA would have to decide whether to issue the September 1974 environmental impact statement in final form or to withdraw it and prepare a new one which would include the whole fuel cycle.

At the same time the task force identified the major weaknesses in the AEC program. Regardless of the existence or rate of growth of a civilian nuclear power program, the task force found it essential to settle on a plan for ultimate disposal of defense wastes. For both the civilian and defense programs it was important to demonstrate permanent disposal in terms of actual hardware as soon as possible.[38]

Beyond technical considerations, the task force saw public acceptance of nuclear power as a major concern. ERDA should be objective and candid in dealing with the public. The biological and environmental effects of

radiation should be clearly explained. An effective and well safeguarded system should be developed for the back end of the fuel cycle. Finally, ERDA should support industry in educating the public on the advantages and disadvantages of nuclear power.[39]

The task force report illustrated the freedom of action which ERDA enjoyed as a new federal agency. For AEC it would have been impossible to reexamine once again the basic assumptions of the waste disposal program. Such an effort would have drawn public charges of delay and indecision. Furthermore, as a result of fears of public criticism, the AEC staff had adopted some of the psychology of the besieged bureaucrat. Under constant public attack, the AEC staff had a tendency to become hypersensitive to potential criticism and therefore less than fully imaginative and creative in formulating plans. Although the members of the ERDA staff in the waste management area were for the most part the same persons who had directed the AEC program, they could now disavow the errors and commitments of the past. As managers in a new federal agency they could afford to take a fresh and unbiased look at waste disposal technology.

The ERDA Program

ERDA moved quickly in 1975 to adopt several of the recommendations in the task force report. Early in April ERDA withdrew the AEC's draft environmental impact statement published in November 1974. ERDA announced that the draft would be replaced with an expanded statement that would "encompass all environmentally significant aspects of the overall federal strategy for disposition of spent fuel from commercial nuclear reactors, including the steps from fuel reprocessing through permanent disposal of the radioactive wastes." ERDA also withdrew its request for authorization

and partial funding of the retrievable surface storage project. This action dissipated, at least for the time being, criticisms by environmental groups that the government was trying to push ahead with the surface storage facility before a comprehensive environmental impact statement had been issued.[40]

In July ERDA centralized its headquarters waste management activities. The old division of waste management and transportation was abolished and all operational responsibilities for waste management in both the civilian and defense areas were transferred to an expanded division of nuclear fuel cycle and production.[41] Environmental oversight of the program was vested in a new division of environmental control technology. This centralization of management had been recommended by AEC advisory groups for a decade and by the ERDA fuel cycle task force. Long overdue, the reorganization enabled the ERDA headquarters staff to develop a coherent policy on waste management.

Even before the new ERDA divisions were officially established, the staff had taken steps to reorient and enlarge the waste disposal program. The first step was to break out of the stereotypes which had grown up in the AEC, to take a broad and objective look at the whole technology of waste disposal, and to present the alternatives for public discussion. This approach coincided nicely with a request from the Joint Committee on Atomic Energy for a comprehensive report on the technical alternatives available in the waste disposal program. This five-volume document, completed in the spring of 1976, presented detailed technical descriptions of the options available for treating the various waste streams from power reactors, reprocessing plants, and fuel fabrication facilities that com-

prised the back end of the fuel cycle. The report did not evaluate the relative economies, environmental impact, or safety aspects of the alternative technologies. Rather it described their state of development in terms of their readiness for scale-up and commercial application.[42]

While the technical alternatives document was being prepared, the ERDA staff formulated a new conception of the waste management program. The changes were sometimes subtle but none the less significant. ERDA's aim was to place "multiple barriers" between high-level wastes and the environment. This goal could be achieved by converting liquid waste into a stable solid form and then sealing it in a high-integrity container which could then be transported and placed in a terminal repository in a deep, stable geologic formation. If no reprocessing was done, the spent fuel elements themselves would constitute high-level waste and could be transported and placed in the repositories.[43]

There were several significant innovations in this statement of the ERDA plan. One was that no matter what form the waste took, it would be solidified and sealed in a high-integrity container. This arrangement placed another barrier between the waste and the environment whether the material was stored at the processing plant, in transit, or in a permanent storage facility. It also recognized that unprocessed spent fuel elements in themselves had a barrier between the highly radioactive materials and the environment. Secondly, the material was to be placed in a terminal storage facility. The word terminal solved the old dilemma of irretrievability. Because all the wastes were to be sealed in containers, they could be placed in geologic storage in either a retrievable or irretrievable mode. By backfilling and sealing, the retrievable mode could be changed

to essentially irretrievable. Thus geologic sites could be called terminal storage facilities rather than retrievable or irretrievable.

The concept of terminal storage avoided the problem of demonstrating permanent disposal capability while retaining retrievability. The first few geologic repositories would be engineered and operated as pilot plants so that, if unexpected problems were encountered, the waste cannisters could easily be moved to another repository.

ERDA's enlarged conception of the waste disposal process offered new opportunities for flexibility. The first was the idea of multiple sites for terminal storage facilities. This meant that a number of acceptable sites would be investigated simultaneously in a variety of geographic locations and geologic formations. AEC had suggested this approach after the Lyons experience, but ERDA could more easily adopt it as part of its broad approach to the problems of waste disposal.

The multiple-site idea offered several advantages. By locating and developing more than one site at a time, ERDA could avoid the AEC mistake of putting all of its hopes on a single site. Furthermore, a nation-wide survey for acceptable sites in a variety of geologic formations tended to avoid the charge which Kansas officials had made that one state was being singled out as the "national garbage dump." Multiple-site development might also introduce some competition between states or localities for a federal project instead of giving a single state or jurisdiction leverage over the entire waste disposal program.

Another kind of flexibility in the multiple-site idea appeared in the form of additional time for evaluation and demonstration. The sharp decline during the early 1970s in forecasts of nuclear power growth meant

a lower requirement for fuel reprocessing capacity. With no commercial processing plant likely to be in operation before 1983, the first terminal storage facility would not need to be ready to receive solidified wastes until 1985. By developing more than one terminal facility at a time, ERDA could spread out the development and demonstration of the technology over a decade or more while still having all the capacity needed for storage in retrievable form. The ERDA staff told the Joint Committee on Atomic Energy in February 1976 that geologic surveys across the country would probably continue until 1980 and alternate site investigations until 1983. On-site experiments with radioactive wastes would proceed from 1977 through 1986 and terminal demonstrations would be conducted from 1985 through the end of the century.[44]

The substantial expansion of the waste disposal program was clearly reflected in the ERDA budget for fiscal year 1977. Operating funds for research and development for disposal of commercial wastes increased more than five times to almost $60 million, the greatest increase coming in funds for terminal storage, which jumped from $5 million to about $34 million. Funding for research and development on long-term management of defense wastes increased by 63 percent to more than $30 million. There was a smaller increase in funding for work on interim storage of defense wastes, an indication that ERDA was indeed concentrating on ultimate disposal of defense wastes.[45]

Two ERDA decisions in 1976 demonstrated the agency's commitment to resolving the uncertainties in long-term management of defense wastes. The first came in an ERDA announcement in June 1976 that the agency was preparing studies which would describe the technological status and antici-

pated costs of all reasonably available waste forms and storage modes for handling defense wastes at Hanford, Savannah River, and Idaho. The three studies, which were completed before ERDA was superseded by DOE in 1977, described a wide variety of feasible alternatives which had emerged from extensive research over the years at all three sites. The reports illustrated once again that there was no shortage of technological solutions to waste disposal; the problem came rather in determining the economic and other "soft" criteria that would be used in selecting a disposal system.[46]

The second ERDA decision on long-term disposal of defense wastes was to build a waste isolation pilot plant in a bedded salt deposit near Carlsbad, New Mexico. Although the facility would use the technology developed at Lyons, it would be designed for pilot studies only, all the wastes being retrievable when the study was completed. Initially ERDA decided that the Carlsbad facility would be used only for low-level transuranic wastes (such as packaged rags and equipment) from ERDA operations and for some intermediate wastes. This restricted use avoided the requirement for licensing of the facility by the Nuclear Regulatory Commission, but in June 1977 the ERDA staff concluded that the credibility of the project would be improved both by removing the restriction and providing a clear basis for NRC licensing. By this time, however, major policy decisions by the new Administration had raised new issues and no action was taken on the staff recommendation.[47]

ERDA also vigorously pursued the idea of nation-wide surveys to find multiple sites for geologic storage. Working carefully with state and local authorities, ERDA began exploratory drilling in several states in 1976. Strong objections, however, from the governor of Michigan in July 1976 even to exploratory drilling in that state caused ERDA to concede to

the states a role in developing "appropriate and workable procedures for determining the acceptability of potential sites for the deep geological isolation of radioactive wastes." The concession served only to provide the Michigan governor with a basis for terminating plans for exploratory drilling in that state and raised the possibility that other governors might take similar action. To forestall this result, ERDA sent letters to the governors and Congressional delegations of the forty-five states in which geologic investigations were to be made.[48]

Impact of the National Energy Plan

On April 7, 1977 President Carter announced that the United States would defer indefinitely all processing of spent fuel from civilian power reactors and asked other nations to join this country in deferring use of this technology so that alternative fuel cycles and processes could be evaluated in an effort to reduce the risk of proliferation of nuclear weapons. This announcement made necessary an extensive reorganization of ERDA's waste disposal program. First of all, the decision eliminated any immediate requirement for commercial reprocessing plants. Second, it suggested that additional facilities might have to be provided in the relatively near future for storing spent fuel assemblies from commercial power reactors. Third, it raised the possibility that terminal storage facilities would be used, at least initially, for spent fuel assemblies rather than for solidified wastes.

Before ERDA could fully assess the implications of the President's decision, the agency was superseded by the new Department of Energy. In a summary memorandum on September 20, 1977, the Acting ERDA Administrator

posed some of the policy issues that awaited resolution in the waste management program:

1. Should the pilot studies at the Carlsbad facilities be expanded to include high-level defense wastes and thereby expose the facility to licensing by the Nuclear Regulatory Commission?
2. What combination of interim storage facilities, either privately or government owned, and geologic facilities should be used for storing spent fuel assemblies?
3. Should the scope of the geologic survey initiated by ERDA be reduced to the eight states in which the most promisng geologic formations had been found?
4. What course should be pursued in developing methods for long-term disposition of defense wastes at Hanford and Savannah River?
5. What should be the federal responsibility for commercially-operated, state-owned burial grounds for low-level wastes?
6. What should be the federal role for the disposition of commercial transuranium wastes?[49]

Although the terminology had changed with circumstances over the years, these questions were strikingly similar to those which the federal government had faced in managing nuclear wastes since 1955. The enduring nature of these issues suggested that solutions would not be found in short-term responses to technical problems or adjustments to political pressures. Rather, ultimate solutions seemed likely to lie in a wise and penetrating analysis of the amalgam of economic, political, cultural, and technical factors that determines the restraints on effective use of nuclear technology in today's world.

a very cautious evaluation by the Environmental Protection Agency, the House Appropriations Committee had cut the 1973 appropriation for the Savannah River project to $1 million. Rather than wage a fight for the project in the face of growing opposition, the Commission decided during the summer of 1972 to delete all funds for the bedrock experiment from its 1974 budget and withdrew the draft environmental statement which had been issued for public comment in January. Although the Commission reserved the option of resuming the project at a later date, it was dead in the eyes of the public.[27]

At Hanford the AEC had not concluded that geologic storage of the enormous volume of high-level wastes would be necessary. There was still hope that after certain long-lived fission products had been removed from the bulk of the material, the residue could be safely stored by evaporating it in the tanks to produce sludge and a damp salt. One potential difficulty of this approach was that the older tanks built during World War II were subject to leaks. Since 1958, fourteen of the tanks had been known to leak, some of them as much as 70,000 gallons of high-level wastes,before the leaks were discovered. By monitoring the tanks closely, replacing those that leaked, and solidifying wastes by evaporation, the AEC contractor at Hanford was confident that the leak problem could be handled in a technical sense. AEC maintained on the basis of detailed studies that none of the leaked material had ever escaped to the biosphere.[28]

At the very time AEC was giving these assurances, however, in the spring of 1973, a fifteenth tank at Hanford was leaking 115,000 gallons of high-level wastes, including about 40,000 curies of cesium 137 and 14,000 curies of strontium 90. Although workers monitoring the tanks recorded the evidence of a leak as early as April 20, 1973, this information did not come

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ERDA moved quickly in 1975 to adopt several of the recommendations in the task force report. Early in April ERDA withdrew the AEC's draft environmental impact statement published in November 1974. ERDA announced that the draft would be replaced with an expanded statement that would "encompass all environmentally significant aspects of the overall federal strategy for disposition of spent fuel from commercial nuclear reactors, including the steps from fuel reprocessing through permanent disposal of the radioactive wastes." ERDA also withdrew its request for authorization

and partial funding of the retrievable surface storage project. This action dissipated, at least for the time being, criticisms by environmental groups that the government was trying to push ahead with the surface storage facility before a comprehensive environmental impact statement had been issued.[40]

In July ERDA centralized its headquarters waste management activities. The old division of waste management and transportation was abolished and all operational responsibilities for waste management in both the civilian and defense areas were transferred to an expanded division of nuclear fuel cycle and production.[41] Environmental oversight of the program was vested in a new division of environmental control technology. This centralization of management had been recommended by AEC advisory groups for a decade and by the ERDA fuel cycle task force. Long overdue, the reorganization enabled the ERDA headquarters staff to develop a coherent policy on waste management.

Even before the new ERDA divisions were officially established, the staff had taken steps to reorient and enlarge the waste disposal program. The first step was to break out of the stereotypes which had grown up in the AEC, to take a broad and objective look at the whole technology of waste disposal, and to present the alternatives for public discussion. This approach coincided nicely with a request from the Joint Committee on Atomic Energy for a comprehensive report on the technical alternatives available in the waste disposal program. This five-volume document, completed in the spring of 1976, presented detailed technical descriptions of the options available for treating the various waste streams from power reactors, reprocessing plants, and fuel fabrication facilities that com-

prised the back end of the fuel cycle. The report did not evaluate the relative economies, environmental impact, or safety aspects of the alternative technologies. Rather it described their state of development in terms of their readiness for scale-up and commercial application.[42]

While the technical alternatives document was being prepared, the ERDA staff formulated a new conception of the waste management program. The changes were sometimes subtle but none the less significant. ERDA's aim was to place "multiple barriers" between high-level wastes and the environment. This goal could be achieved by converting liquid waste into a stable solid form and then sealing it in a high-integrity container which could then be transported and placed in a terminal repository in a deep, stable geologic formation. If no reprocessing was done, the spent fuel elements themselves would constitute high-level waste and could be transported and placed in the repositories.[43]

There were several significant innovations in this statement of the ERDA plan. One was that no matter what form the waste took, it would be solidified and sealed in a high-integrity container. This arrangement placed another barrier between the waste and the environment whether the material was stored at the processing plant, in transit, or in a permanent storage facility. It also recognized that unprocessed spent fuel elements in themselves had a barrier between the highly radioactive materials and the environment. Secondly, the material was to be placed in a terminal storage facility. The word terminal solved the old dilemma of irretrievability. Because all the wastes were to be sealed in containers, they could be placed in geologic storage in either a retrievable or irretrievable mode. By backfilling and sealing, the retrievable mode could be changed

to essentially irretrievable. Thus geologic sites could be called terminal storage facilities rather than retrievable or irretrievable.

The concept of terminal storage avoided the problem of demonstrating permanent disposal capability while retaining retrievability. The first few geologic repositories would be engineered and operated as pilot plants so that, if unexpected problems were encountered, the waste cannisters could easily be moved to another repository.

ERDA's enlarged conception of the waste disposal process offered new opportunities for flexibility. The first was the idea of multiple sites for terminal storage facilities. This meant that a number of acceptable sites would be investigated simultaneously in a variety of geographic locations and geologic formations. AEC had suggested this approach after the Lyons experience, but ERDA could more easily adopt it as part of its broad approach to the problems of waste disposal.

The multiple-site idea offered several advantages. By locating and developing more than one site at a time, ERDA could avoid the AEC mistake of putting all of its hopes on a single site. Furthermore, a nation-wide survey for acceptable sites in a variety of geologic formations tended to avoid the charge which Kansas officials had made that one state was being singled out as the "national garbage dump." Multiple-site development might also introduce some competition between states or localities for a federal project instead of giving a single state or jurisdiction leverage over the entire waste disposal program.

Another kind of flexibility in the multiple-site idea appeared in the form of additional time for evaluation and demonstration. The sharp decline during the early 1970s in forecasts of nuclear power growth meant

a lower requirement for fuel reprocessing capacity. With no commercial processing plant likely to be in operation before 1983, the first terminal storage facility would not need to be ready to receive solidified wastes until 1985. By developing more than one terminal facility at a time, ERDA could spread out the development and demonstration of the technology over a decade or more while still having all the capacity needed for storage in retrievable form. The ERDA staff told the Joint Committee on Atomic Energy in February 1976 that geologic surveys across the country would probably continue until 1980 and alternate site investigations until 1983. On-site experiments with radioactive wastes would proceed from 1977 through 1986 and terminal demonstrations would be conducted from 1985 through the end of the century.[44]

The substantial expansion of the waste disposal program was clearly reflected in the ERDA budget for fiscal year 1977. Operating funds for research and development for disposal of commercial wastes increased more than five times to almost $60 million, the greatest increase coming in funds for terminal storage, which jumped from $5 million to about $34 million. Funding for research and development on long-term management of defense wastes increased by 63 percent to more than $30 million. There was a smaller increase in funding for work on interim storage of defense wastes, an indication that ERDA was indeed concentrating on ultimate disposal of defense wastes.[45]

Two ERDA decisions in 1976 demonstrated the agency's commitment to resolving the uncertainties in long-term management of defense wastes. The first came in an ERDA announcement in June 1976 that the agency was preparing studies which would describe the technological status and antici-

pated costs of all reasonably available waste forms and storage modes for handling defense wastes at Hanford, Savannah River, and Idaho. The three studies, which were completed before ERDA was superseded by DOE in 1977, described a wide variety of feasible alternatives which had emerged from extensive research over the years at all three sites. The reports illustrated once again that there was no shortage of technological solutions to waste disposal; the problem came rather in determining the economic and other "soft" criteria that would be used in selecting a disposal system.[46]

The second ERDA decision on long-term disposal of defense wastes was to build a waste isolation pilot plant in a bedded salt deposit near Carlsbad, New Mexico. Although the facility would use the technology developed at Lyons, it would be designed for pilot studies only, all the wastes being retrievable when the study was completed. Initially ERDA decided that the Carlsbad facility would be used only for low-level transuranic wastes (such as packaged rags and equipment) from ERDA operations and for some intermediate wastes. This restricted use avoided the requirement for licensing of the facility by the Nuclear Regulatory Commission, but in June 1977 the ERDA staff concluded that the credibility of the project would be improved both by removing the restriction and providing a clear basis for NRC licensing. By this time, however, major policy decisions by the new Administration had raised new issues and no action was taken on the staff recommendation.[47]

ERDA also vigorously pursued the idea of nation-wide surveys to find multiple sites for geologic storage. Working carefully with state and local authorities, ERDA began exploratory drilling in several states in 1976. Strong objections, however, from the governor of Michigan in July 1976 even to exploratory drilling in that state caused ERDA to concede to

the states a role in developing "appropriate and workable procedures for determining the acceptability of potential sites for the deep geological isolation of radioactive wastes." The concession served only to provide the Michigan governor with a basis for terminating plans for exploratory drilling in that state and raised the possibility that other governors might take similar action. To forestall this result, ERDA sent letters to the governors and Congressional delegations of the forty-five states in which geologic investigations were to be made.[48]

Impact of the National Energy Plan

On April 7, 1977 President Carter announced that the United States would defer indefinitely all processing of spent fuel from civilian power reactors and asked other nations to join this country in deferring use of this technology so that alternative fuel cycles and processes could be evaluated in an effort to reduce the risk of proliferation of nuclear weapons. This announcement made necessary an extensive reorganization of ERDA's waste disposal program. First of all, the decision eliminated any immediate requirement for commercial reprocessing plants. Second, it suggested that additional facilities might have to be provided in the relatively near future for storing spent fuel assemblies from commercial power reactors. Third, it raised the possibility that terminal storage facilities would be used, at least initially, for spent fuel assemblies rather than for solidified wastes.

Before ERDA could fully assess the implications of the President's decision, the agency was superseded by the new Department of Energy. In a summary memorandum on September 20, 1977, the Acting ERDA Administrator

posed some of the policy issues that awaited resolution in the waste management program:

1. Should the pilot studies at the Carlsbad facilities be expanded to include high-level defense wastes and thereby expose the facility to licensing by the Nuclear Regulatory Commission?
2. What combination of interim storage facilities, either privately or government owned, and geologic facilities should be used for storing spent fuel assemblies?
3. Should the scope of the geologic survey initiated by ERDA be reduced to the eight states in which the most promisng geologic formations had been found?
4. What course should be pursued in developing methods for long-term disposition of defense wastes at Hanford and Savannah River?
5. What should be the federal responsibility for commercially-operated, state-owned burial grounds for low-level wastes?
6. What should be the federal role for the disposition of commercial transuranium wastes?[49]

Although the terminology had changed with circumstances over the years, these questions were strikingly similar to those which the federal government had faced in managing nuclear wastes since 1955. The enduring nature of these issues suggested that solutions would not be found in short-term responses to technical problems or adjustments to political pressures. Rather, ultimate solutions seemed likely to lie in a wise and penetrating analysis of the amalgam of economic, political, cultural, and technical factors that determines the restraints on effective use of nuclear technology in today's world.

NOTES

1. R. G. Hewlett and O. E. Anderson, Jr., The New World, 1939-1946, Vol. 1 of A History of U. S. Atomic Energy Commission (University Park: Pennsylvania State University Press, 1962), pp. 206-207.

2. Minutes, Commission Meeting 228, Jan. 4, 1949; AEC, Report on the Handling of Radioactive Waste Materials, AEC 180/2, Oct. 14, 1949; AEC 180/1, Oct. 17, 1949; Minutes, Commission Meeting 320, Oct. 20, 1949; AEC Press Release 232, Dec. 9, 1949.

3. Letter to Committee on Waste Disposal, AEC 180/13, Sept. 20, 1960.

4. Handling and Disposal of Radioactive Wastes, AEC 180/6, June 14, 1957.

5. Ibid.

6. Management of Radioactive Wastes from the Nuclear Power Industry, Feb. 17, 1965; Radioactive Materials Management Program, AEC 180/8, Oct. 6, 1958.

7. Management of Radioactive Wastes from the Nuclear Power Industry, Feb. 17, 1965; Utilization of Radioactive Materials in Kansas Mine, AEC 180/15, June 30, 1961.

8. Frederick Seitz, NAS president, to Glenn T. Seaborg, AEC chairman, Aug. 30, 1965.

9. Letter to Committee on Waste Disposal, AEC 180/17, Sept. 20, 1960.

10. Coordination did not go beyond the formation of internal working groups. First Meeting of the AEC Waste Disposal Working Group, AEC 719/20, April 3, 1958.

11. D. Allan Bromley to Edwin Goldwasser, Nov. 7, 1967 in NAS-NAE Advisory Committee on Radioactive Waste Management, AEC 180/27, Dec. 6, 1967; Organizational Meeting of NAS Committee, AEC 180/44, Aug. 13, 1968.

12. Summary from GAO Draft Report, AEC 180/31, April 8, 1968; High-Level Radioactive Waste Management: Draft GAO Report, AEC 180/34, April 19, 1968.

13. The issue was first presented to the Commission in AEC 180/47, Siting of Commercial Reprocessing Plants and Related Waste Management Facilities, Oct. 9, 1968. Subsequent papers with the same title were: AEC 180/50, Dec. 12, 1968; AEC 180/52, May 1, 1969; AEC 180/88, June 17, 1970; SECY-160, July 31, 1970.

14. Minutes, Commission Meeting 2356, Dec. 16, 1968; Minutes, Commission

Meeting 2373, May 12, 1969; CRMM Comments on Siting of Chemical Processing Plants, AEC 180/58, Aug. 6, 1969; Commissioner T. J. Thompson to the Commissioners, June 22, 1970; Minutes, Commission Meeting 2429, Aug. 8, 1970. The regulation was published in the Federal Register on Nov. 14, 1970 as Appendix F of 10 CFR, Part 50.

15. Long-Term High-Activity Waste Management, Sept. 8, 1967; Solid Radioactive Wastes: Salt Mine Storage, AEC 180/81, April 23, 1970; Minutes, Information Meeting 1009, March 16, 1970; Minutes, Commission Meeting 2414, April 27, 1970; AEC 180/87, June 12, 1970; AEC Press Release N-102, June 17, 1970; Minutes, Commission Meeting 2433, July 6, 1970.

16. Hanford technology in 1968 is described in Hanford's Highly Radioactive Waste Management Program, AEC 180/30, April 5, 1968. See also Notes, Information Meeting 791, April 10, 1968.

17. Radioactive Waste Storage Facility in Bedrock at SR, AEC 180/76, Feb. 19, 1970; AEC 180/80, Supplement to AEC 180/76, April 6, 1970.

18. NAS Review of SR Bedrock Caverns Concept, SECY-148, July 28, 1970. AEC Press Release N-172, Oct. 2, 1970.

19. Correspondence with Rep. Skubitz, SECY-156, July 30, 1970 contains the first 7 Skubitz letters. For a summary of Skubitz's political arguments, see Skubitz to G. T. Seaborg, March 1, 1971.

20. The draft is in Federal Waste Repository: Environmental Statement, SECY-630, Nov. 13, 1970. The final report, including all comments and AEC's responses are in Environmental Statement: Radioactive Waste Repository, Lyons, Kansas (AEC, June 1971).

21. A. G. Fremling, Note on Kansas, Sept. 23, 1971; Robert Docking, Governor of Kansas, to James R. Schlesinger, AEC chairman, Oct. 27, 1971, Schlesinger to Docking, Nov. 19, 1971.

22. High-Level Waste Management, SECY-2271, Jan. 25, 1972.

23. Ibid.

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25. Many of these issues were discussed in Management of Commercial High Level Radioactive Wastes, SECY-2371, March 17, 1972. Although prepared for distribution at an AEC press conference as a comprehensive statement of AEC policy, only a three-page press release ultimately was approved. See AEC Press Release P-143, May 18, 1972.

26. House Subcommittee on Public Works, Committee on Appropriations, Hearings on AEC Appropriation Bill, April 20, 1972, Part 4, p. 92.

27. Ibid., pp. 156-58; J. G. Speth of NRDC to J. R. Schlesinger, Nov. 4, 1971; Schlesinger to Speth, Nov. 24, 1971; AEC, Notice of Cancellation of Environmental Statement, June 19, 1972; Notes, Policy Session 61, Sept. 1, 1972.

28. J. H. Rubin, AEC Assistant General Manager for Environment and Safety, to NRDC, May 8, 1973.

29. F. P. Baranowski to the Commissioners, June 15, 1973; General Manager's Report #226, SECY-3168, June 22, 1973; Ralph Nader and others to the AEC, June 25, 1973; Minutes, Policy Session 74-4, July 24, 1973.

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31. The article written by Lee Dye appeared in the Los Angeles Times on July 5, 1973. C. E. Larson, acting AEC chairman, to Congressman John E. Moss, Aug. 21, 1973.

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33. Minutes, Limited Attendance Session 75-13, Aug. 29, 1974.

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38. Ibid., pp. 45-48.

39. Ibid., pp. 49-51.

40. Seamans to Sen. John O. Pastore, April 9, 1975; ERDA Press Release 75-51, April 11, 1975; John V. Flynn, Notes on Meeting with NDRC Representatives, April 2, 1975; L. Douglas De Nike, technical consultant, California Committee for Nuclear Safeguards, to Seamans, April 23, 1975.

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44. JCAE, Hearings on ERDA Authorizing Legislation, Fiscal Year 1977, Part 2, Feb. 4, 1976, p. 1443; F. P. Baranowski, Statement Before the JCAE, Nov. 19, 1975.

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47. R. W. Roberts to Terry R. Lash, NDRC, Aug. 19, 1976; Robert D. Thorne, Acting Administrator for Nuclear Energy to Robert W. Fri, Acting Administrator, June 26, 1977.

48. Roberts to Seamans, Sept. 14, 1976; Seamans to Governor William G. Milliken, Sept. 17, 1976; Milliken to Robert W. Fri, May 12, 1977; Roberts to Seamans, Nov. 23, 1976, with draft letters to governors and Congressmen; ERDA Press Release 76-355, Dec. 2, 1976.

49. Fri to James R. Schlesinger, Sept. 20, 1977.