Status of AEC Project to Establish a Salt Mine Radioactive Waste Repository*

W. C. McClain
Oak Ridge National Laboratories
Oak Ridge, Tennessee

ABSTRACT

The various research and development efforts leading toward the eventual establishment, in a salt mine, of a repository for the solidified high-level radioactive wastes produced from the reprocessing of fuel from commercial nuclear power reactors has been reported at each of the previous symposia on salt. Since the last report, the emphasis of this program has been directed toward locating an appropriate site for a pilot plant waste facility and the geologic and other investigations required to confirm its suitability. Potential sites in Kansas were initially examined and the search was later expanded to include several other salt deposits, especially the thick Permian salt sequence in southeastern New Mexico.

INTRODUCTION

If nuclear power is to fulfill its promise of providing a major share of our energy requirements over the next several decades, it is imperative that technically, politically and sociologically acceptable methods of managing the by-product radioactive waste be developed. These wastes are generated at several points in the fuel cycle but the most important contributions are the so-called high-level fission product wastes, the "ashes" of the nuclear disintegration process in reactors, which are separated in the chemical reprocessing of spent fuel. These wastes are heat generating, are extremely hazardous biologically for periods of time of the order of several centuries and contain a small fraction of the extremely long-lived actinides. Furthermore, in a fully developed U.S. nuclear power industry, they will be produced in staggering quantities.

There are basically two approaches to the management of these wastes: the first is active storage where the wastes are contained in closely monitored, specially designed structures which are replaced as needed. This method has been successfully used for the storage of liquid wastes in tanks generated in the weapons programs over the last 30 years. The alternate approach is to permanently dispose of the materials in such a way that their isolation from the environment over their hazardous lifetimes does not depend upon continued monitoring, surveillance and active manipulation by man.

A broad range of possible techniques for achieving this type of isolation are currently being re-evaluated by Pacific Northwest Laboratories. Some examples of these include:

1. Space disposal, either solar impact or solar orbit;
2. Ocean disposal, either in deep trench subduction zones where the wastes eventually would be incorporated into the mantle, or in areas of high sedimentation rate where they would be rapidly buried to great depth;
3. Polar ice cap disposal, where packages of solidified waste would be allowed to melt their way into and perhaps to the bottom of the ice; and
4. Neutron transmutation to stable species in special reactors.

All of these techniques have some promise for future application but at the present time, they all have some serious disadvantages—either technical, economical or political.

However, the preferred disposal concept remains that initially recommended by the National Academy of Sciences nearly 20 years ago and actively pursued since that time by Oak Ridge National Laboratory (ORNL)—geologic disposal in natural salt formations. As pointed out at that time, salt formations offer several significant advantages over other geologic materials for this purpose:

1. Salt deposits are widespread and abundant, underlying portions of 23 of the 48 contiguous United States. Its

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use for this purpose would not sterilize a valuable natural resource.

2. Natural rock salt has strength and shielding properties approximately equivalent to concrete.

3. Underground mining in salt is a highly developed, low cost technology.

4. Compared with other rock types, salt has very good thermal properties for conducting heat away from the wastes.

5. In general, salt deposits are located in tectonically stable areas of low seismicity, thereby minimizing the chances of major disruption.

6. Perhaps most importantly, salt formations are essentially impermeable to circulating ground water and demonstrably have remained so throughout their geologic history. Furthermore, the unique plastic properties of salt would tend to heal fractures should any develop, thereby preserving that impermeability.

One of the most important milestones in the research and development program on the utilization of salt formations for this purpose was the field scale demonstration experiment carried out several years ago at the disused Lyons, Kansas, mine of the Carey Salt Company using highly radioactive spent reactor fuel assemblies and electrical heat to simulate containers of solidified wastes.

PROJECT SALT VAULT DEMONSTRATION EXPERIMENT

The principal objectives of this experiment, called Project Salt Vault, were to demonstrate the feasibility and safety of both the technique and the equipment used to handle the radioactive containers underground and to obtain data on the properties of in situ salt which would permit rational design of an actual disposal facility.

The main experimental area consisted of five rooms newly mined at a level approximately 15 ft. (4.6 m) above the existing mine floor which is about 1000 ft. (300 m) deep (Fig. 1). This increase in elevation was necessary to assure that the holes in the floor into which the radioactive material was deposited would be in the purest available salt strata. The main part of the experiment was carried out in the two end rooms of the experimental area. The

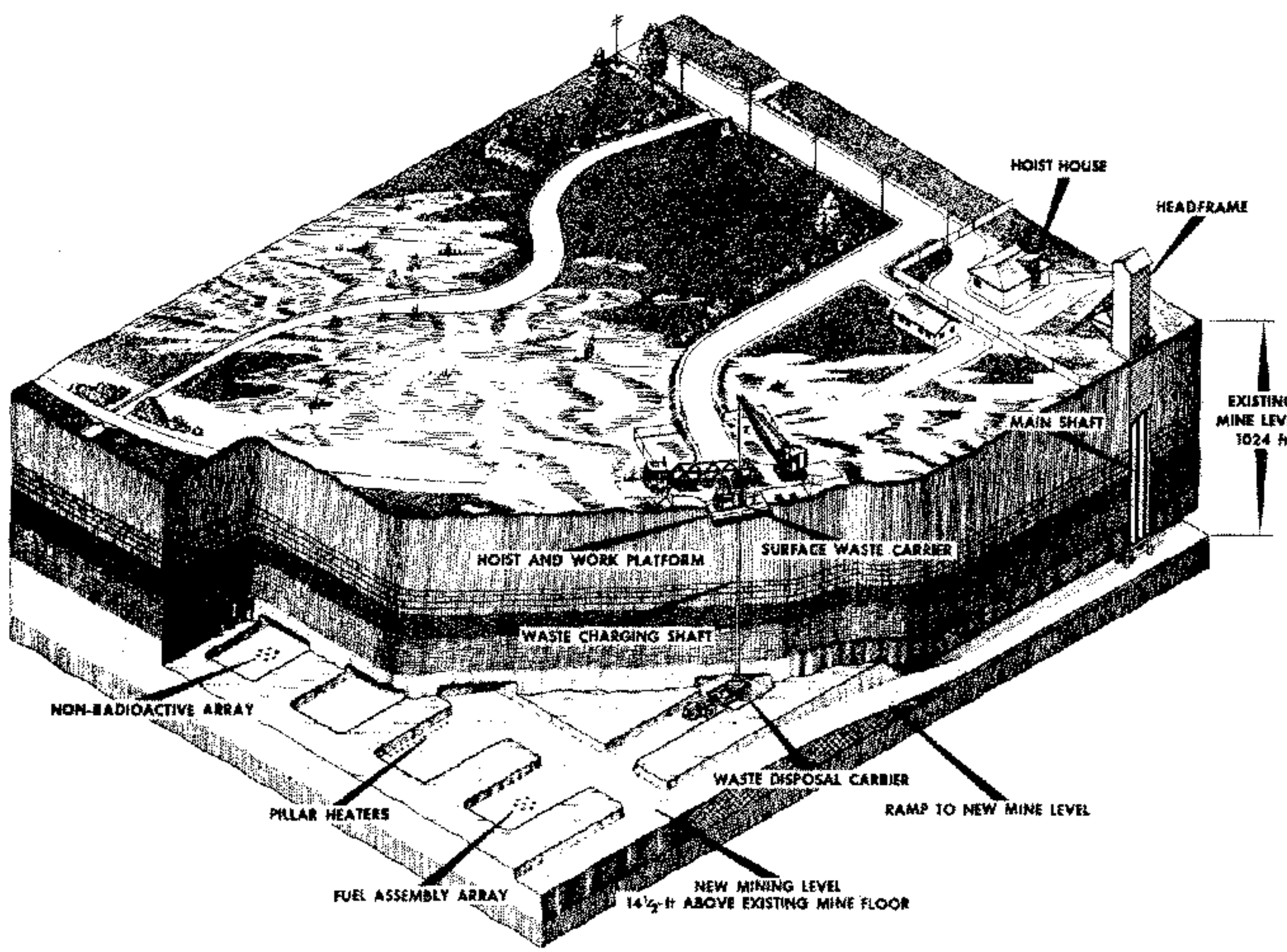

Figure 1. Demonstration of Radioactive Solids Disposal in Salt.

first room contained the main radioactive array of seven specially lined 12-ft. (3.7 m) deep holes in the floor, laid out in a circular pattern on 5-ft. (1.5 m) centers. Each of these holes contained auxiliary electrical heaters and two fuel assemblies from the Engineering Test Reactor at Idaho Falls sealed in a 7-ft. (2.1 m)-long canister. The end room contained an electrical array which was identical with the main array in every way except for the absence of radioactivity and served as a control. The two center rooms of the experimental area contained a part of the experiment which was designed especially and exclusively to obtain additional information on the deformational properties of the in situ salt at elevated temperatures. A row of electrical heaters was installed in the floor along both sides of the intervening pillar which was narrower than the other support pillars. These heaters simulated the heat flowing into the base of the pillar from a room filled with waste.

The various operations involved in the handling of the radioactive materials began in a hot cell at Idaho where two spent reactor fuel assemblies were placed in each canister (Fig. 2). Seven of these canisters were then loaded into a shielded shipping cask which was transported to the Kansas mine by truck, along with its self-contained cooling system. At the mine, the cask was removed from the truck and placed in a vertical position over the 20-in. (50 cm) shaft leading to the experimental area. The canisters were then lowered, one at a time, into the underground transporter at the mine level. This transporter carried the canister to the experimental room and deposited it into an awaiting hole.

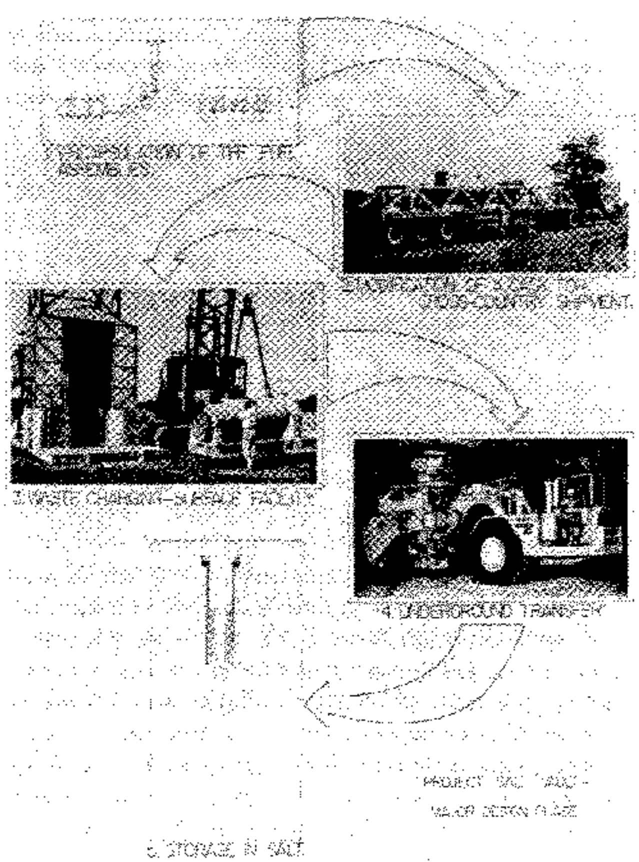

Figure 2. Project Salt Vault—Principal Fuel Assembly Handling Operations.

In order to increase the radiation dose delivered to the salt and to gain additional experience with the handling equipment and techniques, the canisters were exchanged for fresh ones every 6 months. Over the 19-month course of the experiment, three different sets of seven canisters were handled into the mine and subsequently out of the mine for return to the National Reactor Test Station. Each of these canisters contained approximately 200,000 curies of activity when first received at the mine. All handling operations were performed by remote control without the aid of hot cells. Hot cells would be required in a disposal facility. The experiment was completed without any accidental exposure of mine personnel or releases of activity to the off-gas system. The experiment successfully achieved the objective of demonstrating the feasibility of salt mine disposal and the operation of the handling equipment.

In addition, a large quantity of data was obtained on: temperature distributions around the heaters (Fig. 3); heat transfer properties of in situ rock salt; and the deformation of the salt, especially the support pillars, under the combined effects of overburden load, elevated temperatures and thermal stresses (Fig. 4).

NATIONAL WASTE REPOSITORY AT LYONS

Following the successful completion of the Project Salt Vault (PSV) experiment in 1968, a series of feasibility studies were undertaken from which a number of conclusions were drawn:

1. There was a real, but not urgent, need for the establishment of a national waste repository for both solidified high-level wastes and packaged materials contaminated with small quantities of transuranium elements, principally plutonium, produced by the rapidly expanding nuclear energy industry.
2. A modestly sized facility, involving about 1000 acres (400 hectares) of mined space, would be capable of servicing the entire United States commercial nuclear power industry through the end of this century and that the costs of these operations would be well within acceptable levels.
3. An area adjacent to and encompassing the existing Lyons mine where the PSV experiment was conducted appeared to be a technically acceptable site and offered several outstanding advantages for this first facility.

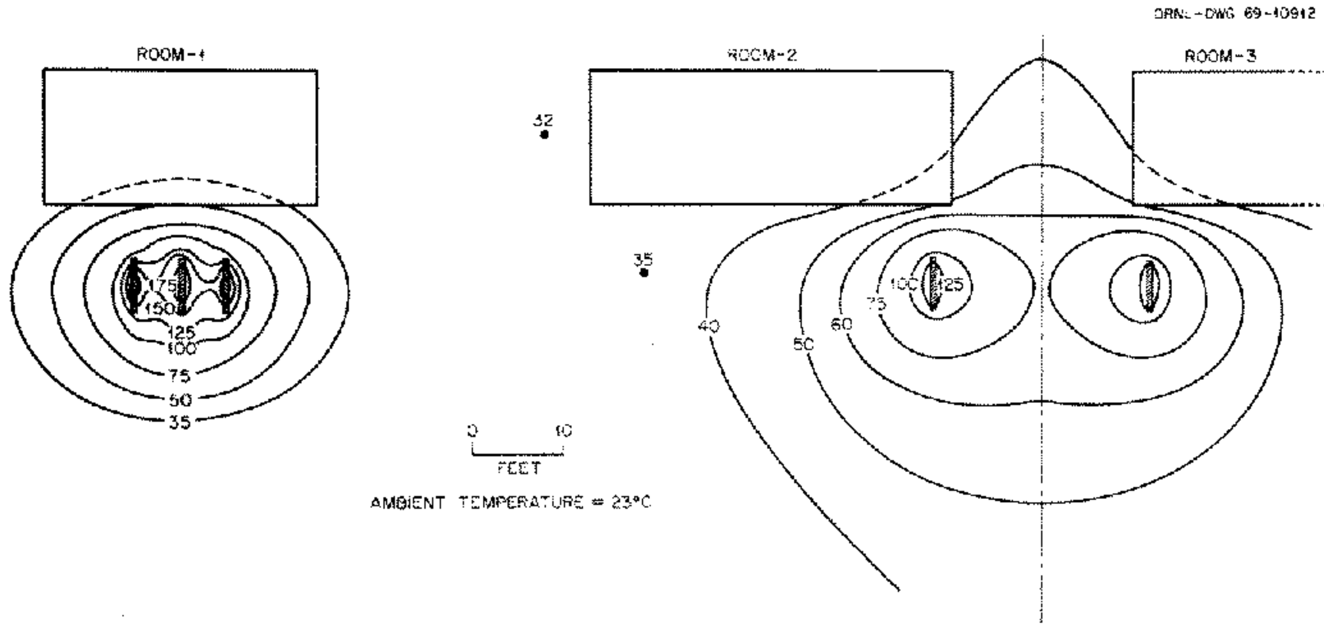

Figure 3. Summary of Maximum Salt Temperatures Achieved in Project Salt Vault—Isotherms Along Vertical Cross Section Through Experimental Area.

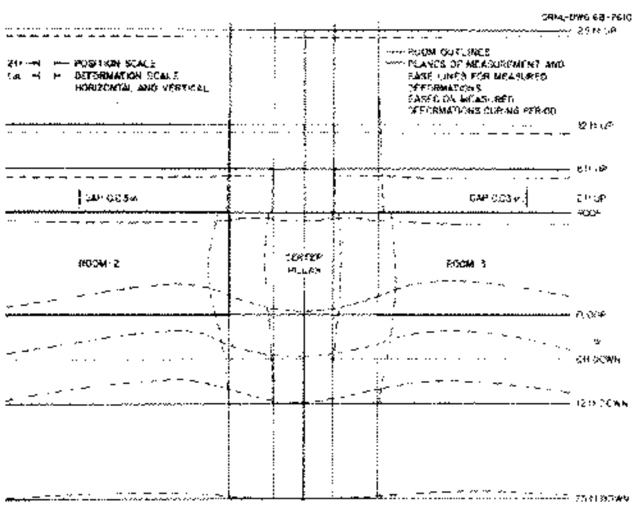

Figure 4. Summary of Deformations Measured In and Around the Center Pillar of the Project Salt Vault Experimental Area.

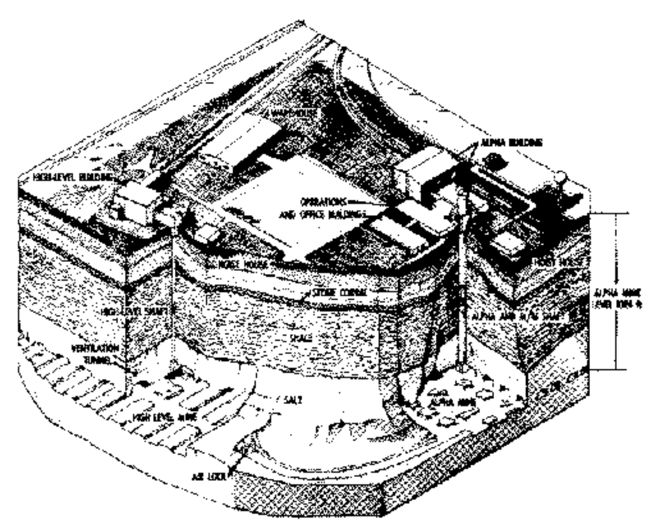

Figure 5. Pictorial View of the National Waste Repository Proposed at Lyons, Kansas.

Based on these conclusions, the U.S. Atomic Energy Commission (AEC) in June of 1970 announced its intention of installing a national waste repository at the tentatively selected Lyons site provided that extensive geological studies confirmed the suitability of that location.

This proposed facility (Fig. 5) was to have included both disposal of drums of waste containing low levels of alpha emitters by stacking the drums in the existing mined-out space and an independently operated high-level waste area. For these operations, canisters of solidified waste up to 12 in. in diameter and 10 ft. in length would have been handled in a mannèr quite similar to that used in Project Salt Vault. Heavily shielded shipping casks containing a number of canisters would be received by rail and placed in a hot cell. There the shipping cask would be opened and the waste canisters removed, one-at-a-time, inspected and lowered into the mine through a shaft used for this purpose alone. At the underground shaft station, the waste container would be handled through a hot cell into a shielded transporter similar to that used in the Project Salt Vault experiment, for moving to the waste disposal area. This area would be newly excavated in a room and rib-pillar configuration with connecting corridors. The waste canisters would be placed in holes drilled to the floor of the rooms at a spacing and pattern designed to optimize heat dissipation. Shielding would be provided by backfilling the holes over the waste canisters with several feet of crushed salt. This would permit unlimited access to the room except while transfers were in progress. When a room had been filled with waste canisters in this way, the room itself would be backfilled with salt obtained from the excavation of future rooms. The plastic deformation of the pillars and resulting closure of the rooms, will eventually reconsolidate and recrystallize the backfill salt. The wastes will then be contained within a solid massive salt formation.

As can be seen, this type of facility represents permanent disposal of the type mentioned earlier. Although a certain amount of monitoring and surveillance would be carried out, the continued integrity of the containment and isolation of the waste would not depend upon those activities. Furthermore, although the wastes could be retrieved at some point in the future by remining the recrystallized backfill salt and overcoring the waste canisters, this would obviously be an extremely difficult and expensive undertaking.

After devoting about 18 months to the effort to establish this facility at Lyons, it became obvious that such a permanent, essentially irrevocable commitment of wastes in salt was not a politically acceptable alternative regardless of its technical viability and philosophical merit. Furthermore, the extensive investigations directed toward confirming the suitability of the Lyons site revealed a couple of factors which rendered it suspect. These factors were related to existing man-made penetrations of the salt formation, specifically the oil and gas test holes in the area, and the nearby operations of the American Salt Corporation.

It is estimated that perhaps 50,000 oil and gas test holes have been drilled in the area of central Kansas underlain by salt deposits. In four known instances, the situation has developed where fresh water has gotten into a well from surface aquifers, circulated past the salt section dissolving it, and been discharged into lower, highly permeable zones. The removal of the salt causes the collapse of the overlying rocks and subsidence of the surface.

There is some reason to suspect that this dissolutional process may be self-limiting and restricted to a few hundred feet from the well. Furthermore, it is obvious that the process cannot occur in properly plugged wells. Nevertheless, the mere existence of some 29 oil and gas tests on and within one mile of the site boundaries at Lyons certainly raises some doubts concerning its long-term integrity.

The second principal concern was related to the nearby salt production operations and especially the solution mining. The problem, of course, is that the resulting cavities represent a situation where water is known to be in the salt formation. The second part of this issue concerned a hydraulic fracturing test carried out in 1965. During this test, the volume of water injected exceeded the volume of brine returned by about 225,000 gal. (850 m^3). The pressure data and other information were not adequate to define where the lost water went, although it is surmised that it entered permeable zones in the overlying rocks. Consequently, this remained an anomolous situation and therefore one raising serious questions about the integrity of the salt deposit in this area over the periods of time required for containment of the waste.

CURRENT PROGRAM

Based upon the reactions to the Lyons waste repository proposal, the AEC has now considerably revised and reoriented its approach to the waste management problem. In the first place, the main thrust of the program is now toward the development of a specially designed long-term storage system at or near the surface. "Storage" is the key word in this concept because the intent is to provide a structure capable of fully containing the high-level waste in a packaged, solidified form for an indefinite but limited period—several decades to perhaps a century—but with continued monitoring, surveillance and control. Several alternative design concepts are presently being investigated with one of the leading contenders being simply a series of water filled basin modules, each designed to hold 500 waste canisters in racks. Each basin would have its own closed circuit water circulation system for cooling.

The design, construction and operation of such a facility is certainly well within present technical capability and its existence would provide a temporary interim solution to the immediate problem. The AEC will probably request construction funds for this facility in fiscal year 1975.

Although an engineered and retrievable surface storage facility now comprises the main thrust of the AEC policy, it is recognized as only an interim solution. Therefore, work is still proceeding with the development of a repository facility in underground salt formations as the most promising prospect for permanent disposal of radioactive wastes. However, this work has also been redirected so that the intention now is to establish a demonstration pilot plant. This pilot plant would operate exactly like a full scale repository except that only a limited quantity of waste would be received. Furthermore, that waste would be maintained in such a way that it could be quickly and easily removed (for transferral to the surface storage facility) should that ever become necessary or desirable. This capability will be achieved by depositing the waste canisters into specially prepared sleeved holes and by not backfilling the rooms.

It is intended that this pilot plant will operate for perhaps 10 years while extended monitoring and in situ experiments provide a background of data confirming the acceptability of permanent disposal in salt. At that time, an operational repository would be established, possibly—but not necessarily—at the same location as the pilot plant. That being the case, it is apparent that the site chosen for the pilot plant should be acceptable as a permanent disposal site. Most of our recent activities have been concerned with site selection investigations.

The first step in this direction was a broadly based series of studies of salt deposits and other potentially suitable geologic formations, which was performed by the U.S. Geological Survey. These geological alternative studies included: (1) an overview of the tectonic and hydrological relationships throughout the entire Permian basin of Kansas, Oklahoma, west Texas and eastern Colorado and New Mexico; (2) examination of the Salado and Castile salt formations of the Delaware basin portion of the Permian basin in southeastern New Mexico; (3) evaluation of the salt structures in the Paradox basin of southwestern Colorado and southeastern Utah; (4) review of the limited information available on the Supai salt formation and the Luke salt structure, both in Arizona; (5) a reassessment and updating of the information available on the salt domes of the Gulf Coast province; (6) compilation of geologic and hydrologic data on the Williston basin of Montana, North Dakota, and South Dakota and; (7) the Salina basin in Michigan, Ohio, Pennsylvania and New York; (8) a general survey of the potential of argillaceous formations, especially claystones and selected shales and (9) examination of a few existing mines in dense limestone formations which are known to be totally isolated from circulating ground water.

From these studies, it was concluded that the southeastern New Mexico area was by far the most promising. The principal factors which led to this conclusion were the large amount of geologic data available because of the potash mining industry in the region; the presence of extensive and thick beds of high quality salt located at appropriate depths; the ideal surface conditions of low rainfall, very limited ground water availability and low population density; and the fact that most of the area is currently in U.S. Government ownership.

A more detailed evaluation of a smaller (144-sq.-mile) area was then undertaken in order to identify the most attractive actual site area. The investigations included: (1) surface geologic mapping; (2) development of stratigraphic and structural maps and sections based upon existing information; (3) compilation of available hydrologic data; (4) examination of the lithology and mineralogy of the area, especially in those zones having potential for waste disposal operations; (5) evaluation of the mineral resources of the area (i.e., potash, oil and gas) and assessment of the regional and local seismicity and tectonic stability.

Based upon the results of these studies, a tentative Bedded Salt Pilot Plant site at sections 10 and 11, Township 22 East, Range 31 South, Eddy County, New Mexico, was selected for further investigation. The combined thickness of the Salado and Castile salt formations at this area is 3,200 ft. (975 m) and an apparently suitable disposal strata is available at a depth of about 2,100 ft. (640 m). The site area is located approximately 30 miles (48 km) due east of the community of Carlsbad (Carlsbad Caverns National Park is over 45 miles (72 km) southwest of the site). The site area has not been extensively explored for hydrocarbons and the density of existing holes is quite low; the nearest existing hole is approximately two miles distant. Similarly, the nearest potash mining operation is about five miles (8 km) distant. It is also significant that this site is located at a ground water divide. Consequently, available ground water is expected to be nil.

Plans are now being made to begin exploratory drilling adjacent to the site during the summer of 1973. The first hole will be core drilled from the surface to a depth of about 3,000 ft. (915 m) and will be extensively tested hydrologically. These tests and the subsequent analysis of the core will serve to verify that the geologic and hydrologic characteristics at the site are suitable. In the meantime, various studies related to the long-term integrity of the site are continuing, such as: evaluation of the regional dissolutional history; examination of the few apparently diapiric structures in the area and evaluation of the potential for large mass flow phenomena at the site; and the continuation of the seismicity and tectonic stability investigation with special emphasis on the regional source mechanisms.

It is anticipated that all of these studies, including the drilling of three additional exploratory holes at the site and associated testing, will be completed in about 18 months. An overall evaluation and confirmation of the suitability of the site will then be carried out, taking into consideration the results of all of the geologic investigations that have been performed at that time. If all goes well, construction of this pilot plant facility should begin in the fall of 1976 and actual operations should commence about 1981.