KEEPING RADWASTE OUT OF SIGHT

The choices for a permanent, high-level radioactive waste repository are narrowing to a few locations deep inside the earth

BY IVARS PETERSON

Second of a three-part series on high-level nuclear waste management.

"Consider the little mouse, how sagacious an animal it is which never entrusts its life to one hole only." — PLAUTUS

As the inventory of high-level nuclear waste mounts, increasing efforts are going into finding a permanent repository for the waste. Stored temporarily as liquids in stainless steel tanks or as spent fuel at the bottom of pools of water near nuclear reactors, the growing volume of waste threatens to overwhelm current storage capacity.

By the year 2000, commercial waste will increase from its present level of 104,000 cubic feet (8,000 tons spent fuel plus some reprocessed waste) to more than nine times that amount. Solidified defense waste will occupy an even greater volume.

Finding a suitable hole in which to dispose of high-level radioactive waste permanently has been a worrisome task for many years. Now the process is accelerating. In the last few months, Congress has been grappling with the complex issues involved, while the Nuclear Regulatory Commission and the Environmental Protection Agency have been developing regulations for such repositories.

The Department of Energy has endorsed geologic isolation in mined vaults deep inside the earth as the primary option for high-level waste disposal. Attention is focusing increasingly on three sites and three types of rock. Although the sites under consideration appear promising, they also have potential problems that raise questions about their ability to contain the waste indefinitely without leakage. And some scientists are concerned the evaluation process is becoming too rushed.

DOE's timetable calls for the sinking of exploratory shafts at the three selected sites during 1983. Two years later, the drilling should be completed, and one of the sites will be chosen for the development of an unlicensed Test and Evaluation Facility. Its purpose will be to gain experience in the handling and placement of waste. Meanwhile, from 1985 to 1987, exploration and evaluation at depth, including horizontal drilling, will provide data to enable selection of the first repository site and to file a license application with the NRC.

"We could expect to have a repository available by about the year 2000," says Carl Cooley of DOE's nuclear waste management office.

One of the three finalists is likely to be a site on the DOE's Hanford Reservation in the state of Washington. Astride a bend in the Columbia River, this sprawling piece of federal land is the location of a spent-fuel reprocessing plant that extracts plutonium for building nuclear weapons. Large quantities of high-level liquid radioactive waste rest in "temporary" storage tanks on the site.

Geologic studies indicate the Hanford site lies over a series of thin lava flow layers composed of basalt, a dense, strong, dark-colored volcanic rock, interspersed with clay minerals. Within Hanford's Cold Creek syncline, these flows appear nearly flat and lie across areas larger than tens of square kilometers. The most promising candidate is a layer about 1,000 meters below the surface. The interior of the layer has a relatively constant thickness of about 50 meters, a texture rich with glass and some minerals that can take up moisture.

Basalt has a low permeability and moisture content and remains strong even at elevated temperatures. However, basalt structures are typically jointed and generally consist of irregular and inconsistent columns. These joints are potential channels for water flow and influence the strength of the rock.

Paul A. Witherspoon, head of the earth sciences division at the Lawrence Berkeley Laboratory, has doubts about basalt. "A crucial issue is the vertical permeability within the basalt flow," he says. The lava flow lies between two permeable, water-bearing layers, so possible leakage paths need to be identified. "It's become a major issue that people are now beginning to recognize," he adds. Witherspoon is also uncertain a shaft to the basalt layer can be completed within the time allowed.

John Robertson of the United States Geological Survey agrees that not enough is known about the groundwater system at Hanford to make good, well-founded judgments.

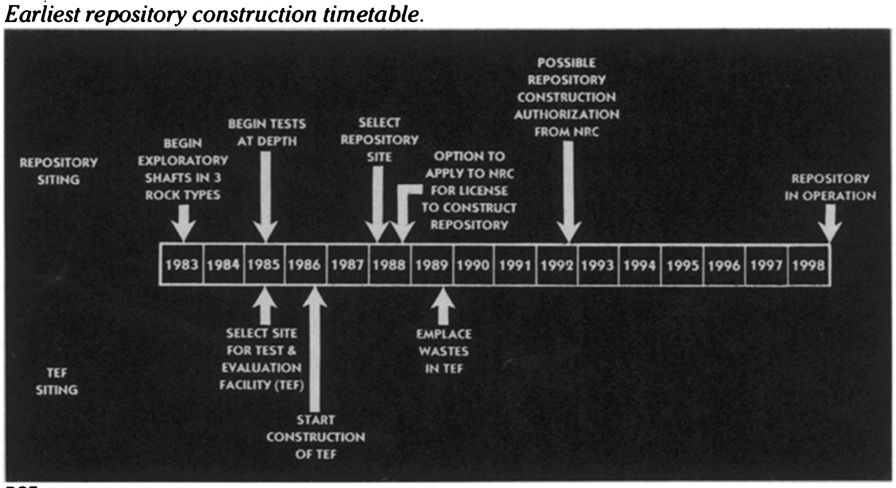
A variety of technical studies are in progress, including investigations of the flow path, travel time and discharge of ground water, stress in the basalt at repository depth and the potential for tectonic activity in the surrounding area. Other assessments indicate technologies are available for excavation of a repository but may require improvements. One researcher reports, "Field-scale tests will be essential to ascertain the impact of excavation methods on rock damage and disturbance in a repository in basalt."

The Basalt Waste Isolation Project, as the Hanford program is called, will be the first to prepare a site characterization report in preparation for further detailed study and shaft construction. The repository design for basalt is also nearing completion.

Another likely candidate, but a relatively new entry in the race, is the Nevada Test Site, federal land in southern Nevada used for weapons testing. Although the mixture of mountains and desert also contains shale, granite and alluvium deposits, investigations have concentrated on a volcanic rock called tuff, found at Yucca Mountain. Tuff is a light-colored rock composed of small volcanic rock fragments and ash compacted into a material that has a rough, gritty feel.

Welded tuff is a high-density rock that contains many water-filled fractures. A second form, zeolitic or non-welded tuff, has a low density, high water content and retains some important radionuclide ions. Some researchers believe a waste repository mined in a welded tuff formation surrounded by non-welded tuff might make an attractive waste disposal facility. The welded tuff would dissipate the heat, while the surrounding non-welded tuff would

Earliest repository construction timetable.



DOE

form a barrier capable of absorbing migrating radionuclides.

"That region of the country is geologically complicated and has to be studied very carefully before one can assure the Department of Energy that there really is a promising site," says Richard W. Lynch, manager of Sandia National Laboratories' waste management and environmental program department. "One of the very attractive things about the Nevada Test Site is that it's a very arid region, and it suggests a very favorable minimal groundwater situation," he says.

Lynch also says, "Additional research is required, however, to better define hydrologic conditions, tectonic stability and the tuff's response to long periods of heating from waste products."

A. R. Lappin of Sandia reported recently, "In the last three years, the study of tuffs as a repository medium has become increasingly focused. Test results to date indicate considerable complexity." Yet, studies at the Nevada Test Site have had to be speeded up to meet the new DOE schedule, despite the risks.

Robertson says, "We don't know much about the tuffs yet. We anticipate there'll be surprises. We don't know that the answers can be gathered in sufficient time, but they might be."

The third candidate, a salt site, is the veteran. Salt has long been considered a prime candidate as a radioactive waste disposal medium. Salt is plastic and flows under pressure. This assures cracks and discontinuities will seal automatically over time, but this may make waste difficult to retrieve, if necessary. The existence of salt beds and domes indicates long-term stability, although both forms are not dry and often contain brine inclusions. However, salt is soluble in fresh water, which may enter as the result of drilling into the salt, and becomes more soluble if heated. This property allows brine inclusions to move through salt in the direction of a heat source, such as a radioactive waste package.

Salt beds were laid down during the evaporation of prehistoric seas. Domed salt was formed when salt beds of lower density than adjacent rock bubbled upward through the overlying layers. Current activities focus on selecting two Gulf Coast salt domes (the Richton dome in Mississippi is a prime candidate) and a site in each of two bedded salt basins in Utah and Texas for confirmatory boreholes. Then one of these sites will be chosen for the exploratory shaft in mid-1983.

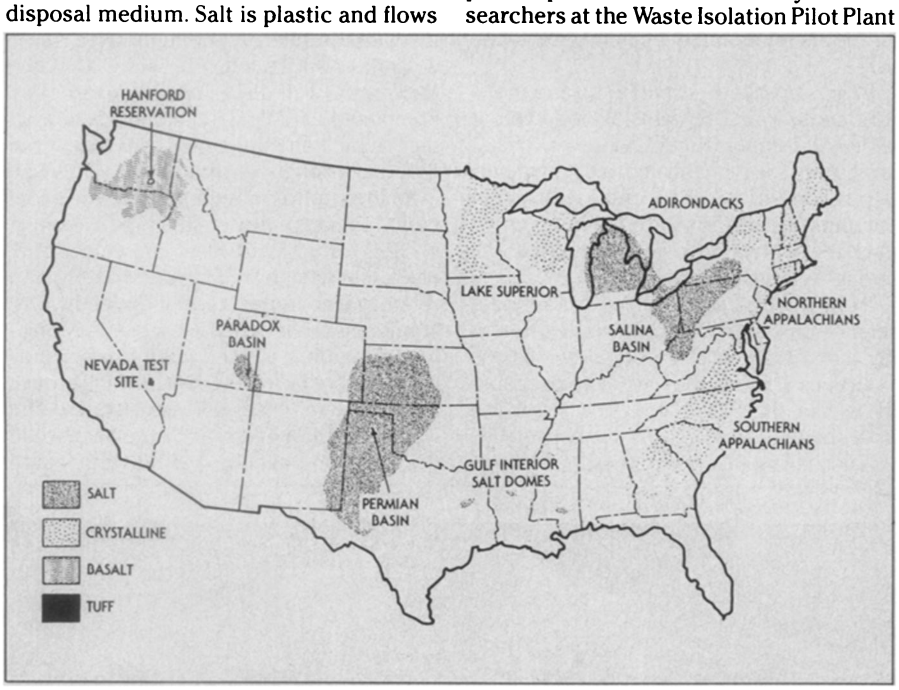
USGS geologists say the bedded salt sites are likely to be more predictable than the salt domes. The salt domes are smaller in size and are more complicated geologically, so more data are needed to characterize them.

However, earth science studies often yield surprises, and even bedded salt deposits provided one recently for researchers at the Waste Isolation Pilot Plant (WIPP) project in New Mexico. The WIPP is being constructed in bedded salt for transuranic, defense wastes rather than commercial, high-level wastes, but the program is providing useful information for the later high-level repository projects.

The "encounter" occurred when an exploratory hole drilled by DOE was deepened to provide information about the layering at the northernmost extension of the WIPP site. The researchers wanted to see where the clay seams and salt beds were located and whether they were continuous. At a depth of 3,015 feet, well below the repository depth and in a layer of anhydrite (calcium sulphate) lying beneath the salt layer, the drillers struck a brine pocket. In order to core through the zone where the fracture occurred, they allowed about 1.1 million gallons of brine out of the hole.

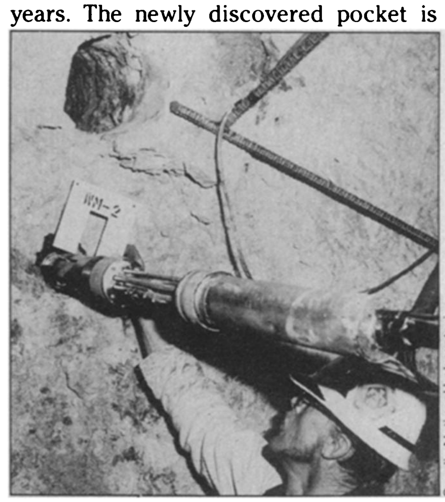
Wendell Weart of Sandia National Laboratories notes, "The concern, of course, over brine pockets is whether or not they could in some way represent a safety hazard to waste disposal." Some people are worried that these may be relatively new, actively developing features. In this case, the fluid-filled pockets could enlarge and extend themselves.

One other, smaller brine pocket found in this formation has been analyzed. The analyses showed the brine had been stagnant and not subject to replacement by other fluids for a minimum of 800,000 years. The newly discovered pocket is



DOE

Regions studied or now being considered for storage of high-level nuclear waste.



Sandia National Laboratories

Data instrumentation package is placed in a hole drilled in tuff at the Nevada Test Site.

DOE

Pump testing and water quality determinations at drill sites help define the characteristics of confined and unconfined aquifers and water surface levels within areas being considered for repository sites.

possibly an old one, too, Weart thinks.

"Even if brine pockets existed underneath the site, if we can show they are no threat to the repository by virtue of having been there for over a million years, and they've never shown any tendency to penetrate up to the horizon where the repository is, let alone to the surface, then there is probably no real threat," says Weart.

However, that has yet to be determined. Surface remote-sensing geophysical techniques can detect only the anhydrite anticline features where brine pockets are most likely to occur, not the brine pockets themselves. Not every anhydrite anticline contains brine pockets, so their presence is unpredictable.

"Clearly there is a lot of concern over the encounter," says Weart. "The state technical review group and our people here who are looking at the technical end feel that it's not as serious a thing as has been portrayed. What one must make sure of is these fluids and bodies of accumulating brine are stagnant, not developing."

Although salt, both in domes and beds, has been studied longer than the other candidate rocks, and continues to be studied in a wide range of research projects, many uncertainties remain.

A draft USGS report dated April 1980 said, "The major impediment to the resolution of technical questions leading to the establishment of a mined geologic repository for commercial radioactive waste is the lack of specific sites on which to conduct detailed *in situ* geologic research." Now the field is narrowing to a few specific sites. However, key questions concern the amount of information needed to characterize a site adequately, whether engineering can overcome the inherent faults of a given site and what an appropriate timetable for the required research and construction effort may be.

One of the most difficult problems is understanding a site sufficiently to make predictions about future performance, says Colin Heath, formerly with DOE and now in the consulting division of NUS Corp. "It's for that reason that one puts weight on trying to find sites that are as geologically simple as possible. Unfortunately, no site is geologically simple, but there are degrees. Some are simpler than others."

Some critics, however, claim that the choices have narrowed to sites that were best known and most accessible or convenient, rather than most simple or suitable geologically. Witherspoon agrees with DOE that isolation deep in the earth's crust is the best waste disposal method, but he says, "I just don't believe they are looking at all the rock types that ought to be considered for the very first repository."

In selecting a site, some agreement must exist on what sufficient characterization is, but this is tied in with funding and scheduling. USGS geologists have indicated they are not comfortable with DOE's new, accelerated schedule. Robertson says, "We agree that it's still possible to arrive at a good site on the schedule, but it's being extremely optimistic to think it'll go so smoothly. The way earth science works, we know there'll be some surprises."

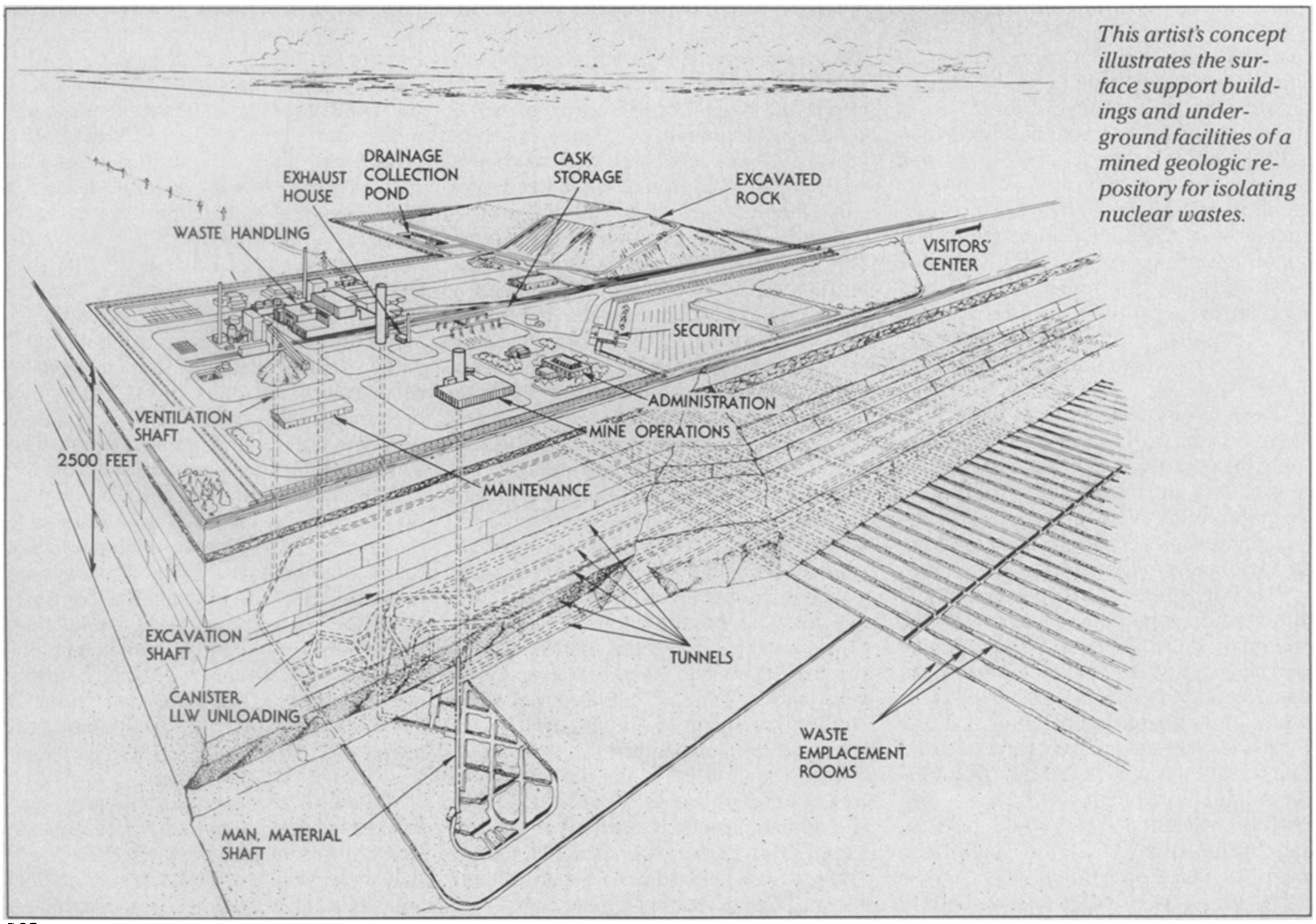
Heath notes, "People, especially scientists, always want to know everything they can about everything. This is very legitimate, but you have to make a conscious decision how much more money you pour into going after a particular issue if it isn't really that important."

Irwin Remson, applied earth sciences department chairman at Stanford University and a member of several federal committees dealing with nuclear wastes, says, "My personal opinion is that this is going in a very cautious way. It is beginning to look as if nuclear waste disposal solutions are going to emerge fairly quickly. Given reasonable time scenarios, there is absolutely no reason why we shall not be able to engineer safe repositories in many places."

Remson also tackles the engineering problem. "My perception is that these repositories are going to be the most over-engineered installations ever built in the history of humanity. There are going to be so many redundant safety factors that it is absolutely inconceivable that we shall ever have any problems with them."

Remson says engineering and other considerations can overcome geologic deficiencies in a particular site. If a facility as

Continued on page 15



This artist's concept illustrates the surface support buildings and underground facilities of a mined geologic repository for isolating nuclear wastes.

DOE

RADWASTE

(Continued from page 11)

a unit meets design specifications, as defined by the NRC, then the facility opens. "You can do a hell of a lot with engineering. If it turns out none of the sites are going to meet the specifications, then we'll have to go find a whole new timetable," he says.

Witherspoon is more doubtful. "This business of engineering around problems as they occur may prove to be very naive," he says. Time and money are needed to do full-scale underground tests at depths and conditions expected to be encountered in an actual repository.

A. L. Lindsay and D. L. Watson of Kaiser Engineering reported recently that geologic repositories are to be constructed in environments that have many more unknowns associated with them than those of, for example, nuclear power reactors constructed on the earth's surface. They listed several conditions that may be found underground that are undetectable from the surface: for salt, trapped brine, trapped gas (methane, carbon dioxide or nitrogen), cavities or faults; for hard rock, excessive water, explosive or toxic gas, excessive rock pressure, unacceptable faulting or folding.

Work has not stopped completely on alternative high-level waste disposal strategies, although most of the funding is concentrated on the near-term goal of preparing the three potential sites. Lynch says, "I think the Department of Energy is committed to looking at some alternatives, including long-term exploration of potential granite sites and subseabed disposal. The question is at what rate."

Witherspoon, who has been conducting research on crystalline rocks like granite, including field studies in a mine at Stripa, Sweden, says, "We have been completely cut off from all funds. Our work on Stripa has been completely stopped, and we can't even publish some reports that were just about to go to print."

Continuing studies are being supported to maintain granite as an option for a later repository. Over the last year, the DOE reached agreement with 15 states to initiate regional literature studies to evaluate potential granite sites. In early 1982, these studies should be complete, and then the program can be narrowed to areas of the most significant interest. In addition, the DOE has established a cooperative program with the Canadian government, which is testing at a granite site in the Canadian shield.

The USGS this summer began a study of an eight-state area in western United States to identify places that appear favorable for a repository site. The focus in earlier site surveys had been on specific rock types to find out where they were present and then to see if other factors were suitable. The new approach in this study is to look at rock type and hydrology at the same time, because any waste is going to be carried in the ground water if it gets loose from the repository.

Critics of the current DOE program are concerned about the rush to characterize sites and begin developing a permanent repository. They point to plans in other countries that provide more time for testing and evaluation. One significant idea that is accepted in Sweden, England and other countries is surface storage of high-level waste for up to 50 years so its temperature will decay to much lower levels. Most U. S. repository design studies have used as a design basis the assumption waste has been cooled about 10 years since removal from the reactor.

Several years ago, a USGS report suggested that one little-understood geologic problem was the interaction between the host rock and the waste due to the heat of the wastes. Robertson says, "That remains a question that we are concerned about. The geologic answer to that is don't put hot waste down." The DOE appears to be bending in the direction of allowing waste to cool longer before final deposal. This relaxes the requirements for a suitable geologic host and makes the choice of a suitable disposal medium easier.

In the end, the NRC, through its licensing procedure and design specifications, will decide how safe is safe enough. The DOE, whatever timetable it follows, will need to meet those requirements. □

Next: International nuclear waste management efforts.