SITE CHARACTERIZATION FOR HIGH LEVEL NUCLEAR WASTE REPOSITORIES - LESSONS TO BE LEARNED FROM WIPP

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ABSTRACT

The Waste Isolation Pilot Plant Project (WIPP) is a non-NRC licensed repository for defense transuranic wastes and for experimental emplacement of small quantities of high level wastes, being constructed in southeastern New Mexico. The experience of site characterization for WIPP (from 1974 to present) has much relevance for the impending site characterization activities at three sites for the first high level waste repository. The lessons to be learned from the WIPP program include a need to plan for at least six years of site characterization effort, follow a step-by-step process, place less emphasis on shaft sinking and more on boreholes and plan for organizational continuity for a long period. The expected benefits of following these lessons include an enhanced credibility for the program and saving of resources.

INTRODUCTION

The site characterization phase for three sites, one of which will be nominated by the Department of Energy (DOE) as the site for the first high-level waste (HLW) repository, is scheduled to begin in 1986. According to the Mission Plan[1], this phase will last for 47 months barring unforeseen delays. The site characterization will consist of surface-based studies as well as in situ experiments in shafts to be drilled at each of the sites. Since the 47 month schedule includes the time needed to prepare the reports, the actual time available for geological studies will most likely be three years or less. The surface-based and underground studies will thus have to be carried out simultaneously.

The Waste Isolation Pilot Plant (WIPP), under construction in southeastern New Mexico for the disposal of defense transuranic waste, is a pioneer facility for deep geological repositories for nuclear wastes. There are three main differences between WIPP and the planned high level waste repositories. WIPP will not be licensed by the Nuclear Regulatory Commission (NRC) and the bulk of the waste (transuranic-remote and contact handled) will not be heat-producing (although about 150 cubic feet of heat-producing defense high-level waste will be emplaced for experimental purposes, to be retrieved after 25 years). Finally, there will be no State veto authority. While they are not "hot", the radionuclides have long half-lives (e.g. 24,000 years for Pu-239 and 162,000 years for U-233) and therefore have to be isolated for very long periods of time. The need for long-term isolation of the high-level wastes also stems from the potential radiological hazards associated with the transuranic elements contained in such wastes. The site selection and characterization of the WIPP repository has therefore been a rigorous process, similar to that about to be undertaken for the first high-level waste repository, and the lessons to be learned from the WIPP experience are directly applicable and useful.

The WIPP repository is being excavated in the lower part of a 2000 ft thick salt bed, the Salado Formation, at a depth of 2150 ft below the surface. The present site was selected in 1975 and the site characterization will continue at least through 1988 with some activities continuing to 1993. The long process has resulted from the need to understand certain geologic processes and to define the hydrologic system since the scenarios for long-term breach of the repository and transportation of radionuclides to the biosphere depend on these factors. The Environmental Evaluation Group (EEG) was established in 1978 and has closely evaluated, commented upon and recommended changes or additional work in the site characterization studies conducted by DOE contractors. A history of the federal/state (DOE/EEG) interaction in the development of the site characterization program for WIPP is given below. It is followed by suggestions for development of the site characterization program for the HLW repositories.

HISTORY OF WIPP SITE CHARACTERIZATION

The Delaware Basin in southeastern New Mexico was selected for WIPP by the U. S. Geological Survey (USGS) and the Oak Ridge National Laboratory (contractors to AEC) as a result of a nationwide search following the abandonment of Lyons, Kansas site in 1972. In addition to the geological considerations of depth, thickness and purity of the salt, and distance from potable aquifers, an important criterion was to have at least a two mile distance from any boreholes penetrating through the Salado Formation. A 2 mile by 1½ mile rectangular site about 7 miles northeast of the present site was selected by Oak Ridge National Laboratory (ORNL). Cores from two core holes (AEC-7 and AEC-8, Fig. 1) penetrating through the Salado Formation drilled at the northeast and the southwest corners of this site indicated acceptable geology. In 1975, the responsibility for WIPP site selection and characterization was passed on to Sandia National Laboratory (SNL). A third core hole (ERDA-6) was drilled by SNL in the northwest corner in 1975 and it found intense structural disturbance and brine under artesian pressure in the Castile Formation, which underlies the Salado. Figure 1 shows the locations of all known boreholes where Castile brine pockets have been encountered to date. A review of the oil and gas industry generated seismic and drilling data confirmed the existence of structural deformation bordering the Capitan Reef, and a decision was made to move the site

at least 6 miles away from the Reef. Apparently since no suitable site could be found in the area which would satisfy the geological and natural resources criteria and be at least 2 miles away from any existing boreholes, the required distance from the boreholes was reduced to 1 mile. SNL and USGS selected the present site. In 1976 a stratigraphic core hole, ERDA-9 (Fig. 1) was drilled through the Salado Formation at the center of the new site. The new "WIPP site" (Fig. 1) is a 4 mile by 4 mile square. The octagon contained within the "WIPP site" is the 2000 acre area where the repository is located.

During the next two years (1976-78), 43 more holes were drilled to support the site characterization for WIPP. Of these, 8 were exploratory stratigraphic holes, 21 were potash holes to characterize the extent and quality of the potash ores present in the upper part of the Salado Formation and 14 were hydrologic holes to characterize the hydrology of the Rustler Formation. Four of the potash holes were converted to also provide hydrologic data. Two of the stratigraphic holes were specifically drilled outside the site area to obtain dissolution and paleoclimate data. Based on these boreholes, several miles of seismic reflection profiles, resistivity measurements, hydrologic studies, laboratory studies and regional geologic and geomorphologic studies, the Sandia Laboratories prepared a two volume Geological Characterization Report[2] (GCR) which was published in December 1978 and stated, "Sufficient information has now been developed to allow the site to be adequately characterized for site selection purposes." (GCR, p. 2.7). The site characterization is still not completed in 1986.

The "WIPP/EEG Site Characterization Milestones" (Fig. 2) provides a summary of major activities related to the WIPP site characterization from 1979 to date as well as the planned future activities through 1993.

The Environmental Evaluation Group started functioning in late 1978 and reviewed the GCR as its first major task. The draft Environmental Impact Statement (DEIS) for WIPP was published by DOE in April 1979 and it contained the findings of GCR in a condensed form. The EEG published a detailed document[3] containing its comments on the DEIS, which included a critique of the GCR. Several questions concerning the site were left unanswered by DOE. The final EIS (FEIS) for WIPP was issued by DOE in 1980.

In order to find ways to resolve the outstanding issues related to the suitability of the WIPP site, EEG organized a conference of geo-scientists from various disciplines and organizations in January 1980. The conference identified a number of geological issues which needed resolution. A three-day geological field trip was organized in June 1980 during which field evidence relating to the issues of dissolution, breccia chimneys, brine reservoirs, deformation and natural resources were seen and discussed. The EEG report[4] of this field trip clearly identified several geological issues concerning the WIPP site and made specific recommendations to DOE to conduct additional studies to resolve these issues. During 1979 to 1982, EEG scientists independently conducted analyses of various scenarios for possible breach of the repository and release of radioactivity to the biosphere and published 9 reports on this subject.

The State of New Mexico and the DOE began negotiations for a Consultation and Cooperation (C & C) Agreement in 1979. In the fall of 1980 these negotiations broke down. The following spring, the State Attorney General filed suit in federal district court seeking to enjoin the project from proceeding[5]. Among other issues in the litigation, the State demanded additional studies to prove the WIPP site suitability. On July 1, 1981, the State and DOE entered into a "Stipulated Agreement", which included eleven "topical reports"

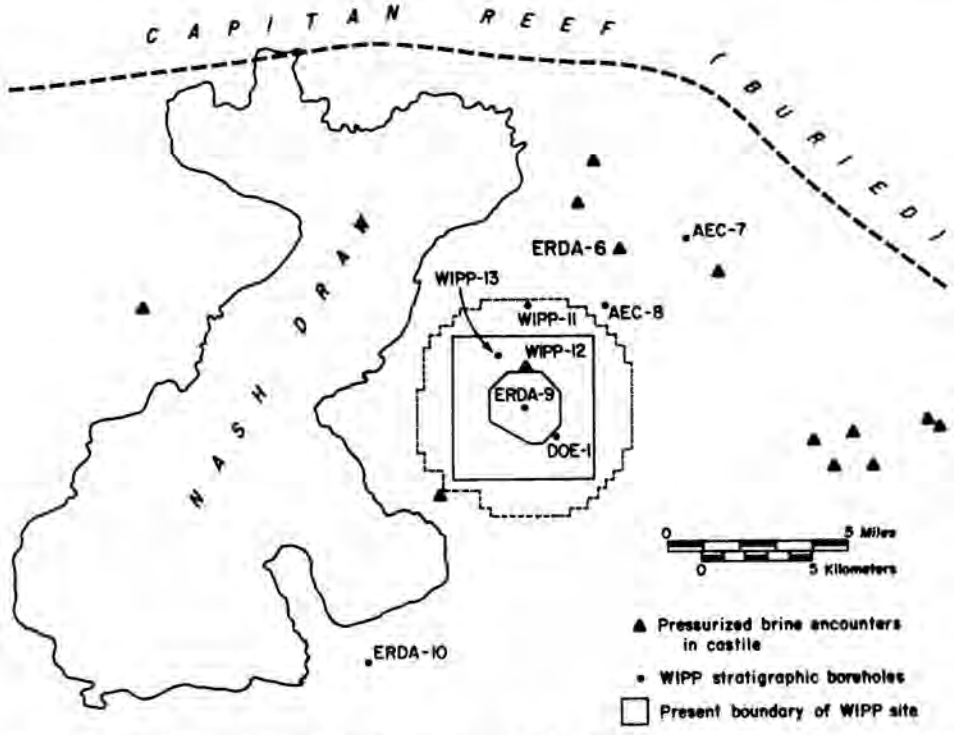

Fig. 1. Location of WIPP stratigraphic boreholes and the ones which encountered brine in the Castile Formation.

and five "additional investigations" which had to be carried out and the results made available to EEG for review. The Agreement also provided that DOE would not make the decision to construct the repository until the State had time to review and comment on the new site characterization reports.

Work to resolve the site characterization issues began in earnest in the fall of 1981. The borehole WIPP-12, which had been drilled to a depth of 2790 ft to the top of the Castile Formation in 1978, was deepened to explore possible underlying structure that had been indicated by seismic surveys. The borehole encountered pressurized brine at a depth of 3020 ft. The initial flow rate of brine, under artesian pressure, was 350 gallons per minute. Detailed hydrologic and geochemical investigations performed over a year period estimated that the volume of the brine reservoir intercepted by WIPP-12 is about 20 million barrels and that the ERDA-6 and WIPP-12 brine reservoirs were not interconnected.

Two human intrusion scenario analyses [6,7] were performed by EEG to calculate the effect of brine if it existed under the repository. These analyses concluded that significant quantities of radionuclides could be brought to the accessible environment at an exploratory borehole connecting a brine reservoir, the repository, and the surface. The encounter of brine in a structure just outside the 2000 acre area (inner octagon in Fig. 1) designated for the WIPP repository also indicated that the deformed zone bordering the Reef extended just north of this area. The WIPP repository itself would occupy only about 100 acres and the plans in 1981 were to construct it in the northern part of the 2000 acre octagon north of ERDA-9. EEG recommended in early 1982 that the repository be shifted to the southern part of the octagon. Another deep hole (DOE-1) was drilled in the summer of 1982 just outside the 2000 acre area to the southeast (Fig. 1) to confirm the existence of less structural deformation to the south. After reviewing the information from this borehole as well as from the geophysical surveys, DOE accepted in late 1982 the EEG suggestion to shift the repository one and a quarter mile to the south.

The Stipulated Agreement reports were completed by DOE contractors (mainly Sandia National Laboratory and D'Appolonia Consulting Engineers) during late 1982 and early 1983 and EEG reviewed each of these in draft[8]. Three shafts were drilled by DOE in 1982. Detailed geological mapping was done and rock-mechanics instrumentation was installed in the shafts and in four test rooms to provide in situ data for studying the geomechanical behavior of repository horizon rocks. This work was done as part of a Site and Preliminary Design Validation (SPDV) program. The DOE issued its summary of the site characterization work[9] in March 1983 and concluded that the site had been adequately characterized and the repository construction should begin. The EEG evaluated all the data and analyses from the Stipulated Agreement and the SPDV program reports and presented its evaluation for discussion at a major meeting of geo-scientists and health physicists in Carlsbad, N.M. on May 12-13, 1983. Fifteen days later EEG published its findings in EEG-23[10], which concluded that the site had been sufficiently characterized to warrant confidence in its suitability for TRU waste disposal, although additional work needed to be done to address some uncertainties about the hydrology and certain gegeological concerns. The DOE accepted the specific recommendations made in EEG-23 but there was no discernible progress for one year. The EEG recommendations were subsequently included in a Modification to the C and C Agreement in November 1984. The studies now in progress by DOE mainly concern a characterization of the hydrology of the Rustler water-bearing zones. Much of this work is expected to be completed by 1988.

The much-awaited Environmental Protection Agency (EPA) standards for high-level and transuranic wastes (40CFR191) were issued in 1985 and apply to WIPP. A Performance Evaluation program has been initiated by DOE to determine compliance of WIPP project with these standards. Some geohydrological and geotechnical work

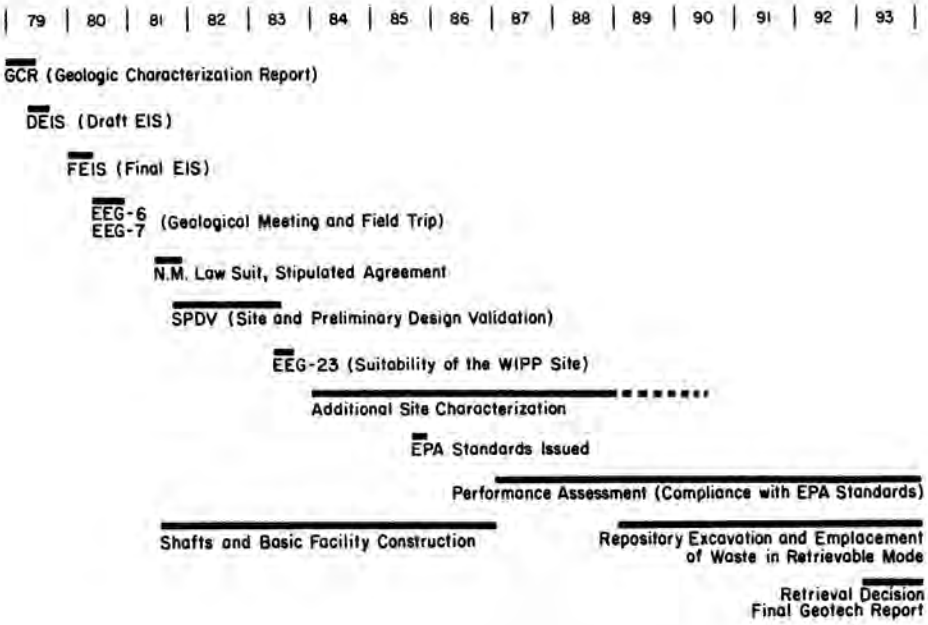

Fig. 2. WIPP/EEG Site Characterization Milestones.

to demonstrate compliance with the EPA standards will most likely continue through 1993, the year when the decision will be made whether or not to change the status of the WIPP from a research, development and demonstration project to a permanent nuclear waste repository.

Some unforeseen conditions have recently been encountered underground in the WIPP test rooms and drifts. The creep-rate of salt, 2½ years after the excavation, is over three times that predicted from pre-excavation calculations based on laboratory testing. Large fractures have been observed 4 to 5 ft below the floor of the test rooms in anhydrite and clay beds as well as in salt. Instrument data indicate that such fractures have appeared above the ceiling of the 13 ft high test rooms as well. The largest crack is up to 4 inch wide, parallel to the floor, about 4 to 5 ft below the floor. The same anhydrite "Marker Bed" in which fractures have been noticed also produces small, but significantly larger than normal, amounts of brine and gas. These conditions have caused some concerns and their impact on the operation, retrievability and long-term integrity of the repository is being evaluated.

The EEG has continued its practice of conducting detailed analyses of issues where such analysis is warranted. Since the site evaluation report (EEG-23)[10], nine more reports have been published. The most recent, EEG-32[11], examines the adequacy of data about the Rustler Formation and provides additional justification of the need to complete the hydrologic characterization work as soon as possible.

LESSONS FROM WIPP EXPERIENCE FOR HLW PROGRAM

Fortunately for the high level waste repository development program and for all the parties associated with it (DOE, NRC, EPA, the States and Tribes and the public), the WIPP experience can help avoid many pitfalls in the course of selection and development of the nation's first HLW nuclear repository. The lessons learned from WIPP are summarized below.

Time Required for Site Characterization

The site characterization for WIPP has been in progress for 12 years and is still not completed. A proper planning and investment of resources could possibly cut this time in half at future sites, but the planned three years or so of actual work does not seem sufficient to resolve anticipated issues at each of the sites. To save time, the scope of the work should be sufficiently broad and detailed from the beginning to include resolution of potential problems and issues which could come to light, as detailed information begins to accumulate. The planners of the HLW program should immediately plan to address the issues as they are raised because the concerns do not just go away with time. A likely scenario at the time of the final site selection is that some unresolved issues will remain for all the three that are characterized. Even though one might be selected as having the maximum potential, one or two other sites may remain as alternatives for several years until remaining uncertainties are resolved. A trade-off between time and additional cost may have to be made.

Need for a Step-by-Step Process

The site characterization at each site should follow a step-by-step process. Compilation and review of the existing information should precede any further work. Site-specific issues to be resolved should be identified at this stage. This was not done at WIPP, and time-consuming and expensive studies to resolve the concerns of hydrology, salt dissolution, pressurized brine pockets and natural resources had to be carried out after the EIS was issued.

Field mapping, geophysical surveys and borehole drilling should constitute the next stage. The program should be well integrated to provide the optimum results. Any preliminary hydrologic modeling and consequence analyses of breach scenarios will need to be re-evaluated after sufficient data is obtained, otherwise these efforts will have to be repeated as is happening at WIPP.

Shafts Do Not Answer Most of the Questions

The HLW repository program requires a shaft at each of the sites to be characterized. Because of the mine ventilation and safety considerations, more than one shaft will have to be sunk. The site characterization money to be spent on this activity can be much better utilized in drilling several boreholes and conducting hydrologic tests as well as having cores with which studies and tests can be conducted. A shaft will not address the issues of regional hydrology, tectonism, continuity of strata, regional structure and future changes, upon which the suitability of a site will depend. Like a manned space flight in space exploration, shaft sinking provides some "glamour" and something for the public to "see" for its money and is therefore popular with the program managers. The event also provides a good "milestone" for the Consultation and Cooperation Agreements. A shaft should be sunk only after regional and local investigations of coreholes, and seismic measurements have not ruled out the site and further surficial investigations have yielded diminishing returns. Because of the established program, however, since shafts will be sunk at all the three sites, their sinking should at least be delayed till the tail end of each site's characterization program. This will help in determining their location, and if a serious flaw is found in a site during detailed site characterization, the site can be abandoned without having committed resources to the shafts.

Organizational Continuity

For a long-term program involving large amounts of public funds, it is essential that a lead organization has management control over the program for the entire period. For HLW repositories, this organization is the Department of Energy with crucial regulatory authority from NRC and EPA. The DOE management of the site characterization program should include strong technical expertise in the geosciences. Only a technically competent management will be able to discriminate between relevant and productive studies and "snake-oil remedies." Furthermore, in order for States to exercise their legal authorities and responsibilities in a responsive and productive manner, a strong technical capability must be established early and maintained. It is also necessary to enforce a policy of prohibiting the site characterization contractors from competing for the repository construction and/or operation contracts. If this policy is *promulgated* at the outset, it will remove a major potential impediment to the perceived objectivity in the site suitability determination.

CONCLUSION

If the lessons from the WIPP program are recognized and implemented in the site-characterization programs for the high-level waste repositories, the benefits will be enhanced credibility for the program and a possible savings of resources.

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