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EVALUATION OF THE NEED, FEASIBILITY, AND SITING
OF THE MRS IN TENNESSEE

Draft Final Report

Contractors: University of Tennessee
Waste Management Research and Education Institute
Transportation Center
Energy, Environment, and Resources Center
Vanderbilt University
Oak Ridge Associated Universities
Institute for Energy Analysis
Nuclear Assurance Corporation

December 16, 1985

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Summary Report

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summary report prepared by

E. William Colglazier, Jr.
Director
Waste Management Research and Education Institute
and
Energy, Environment, and Resources Center
The University of Tennessee
327 South Stadium Hall
Knoxville, TN 37996-0710
(615) 974-4251

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EXECUTIVE SUMMARY

This summary report outlines the results of an independent assessment of the need, feasibility, and siting of the proposed Monitored Retrievable Storage (MRS) facility that was conducted for the state of Tennessee by a team of contractors that included the University of Tennessee, Vanderbilt University, Oak Ridge Associated Universities, and the Nuclear Assurance Corporation. The detailed reports of this assessment are included as appendices to the summary report.

The Department of Energy (DOE) has concluded that the MRS is not absolutely necessary, but preferred, in order to manage and move spent fuel from reactors to a repository. The team has attempted to assess "need" by comparing the advantages and disadvantages of various systems, with and without the MRS. "Feasibility" has been assessed by comparing the technical and economic advantages and disadvantages. The team was not asked to recommend a preferred system. That choice will depend on the importance that is attached by a decisionmaker to the various criteria that are used to compare alternatives.

The five key criteria selected by the team for comparing alternate systems were: (i) economic cost, (ii) radiological risk, (iii) non-radiological transportation impacts, (iv) the likelihood of successful implementation and operation of the system, and (v) the likelihood of meeting the schedule in the Nuclear Waste Policy Act.

The team compared twelve different systems and modeled the transportation impacts and risks with three repository sites and two MRS sites. In several of the cases, the team used an "improved transport scheme," which differed from DOE assumptions in the size of transport casks and in the split of shipments by truck and rail. The team also prepared its own forecasts of spent fuel generation and reactor storage capacity in order to estimate the annual amount of spent fuel storage that is needed beyond what can be accommodated in reactor pools. The team examined the economic cost estimates of the alternate systems and the technical feasibility of rod consolidation as proposed at the MRS. The approach used by DOE in siting the MRS in Tennessee was also reviewed.

The team's key findings from its analysis of the need, feasibility, and siting of the MRS are:

- (1) By using an improved transport scheme, the national transportation impacts of both the MRS and NO-MRS alternatives are comparable and much lower than DOE's original estimates. The transportation impacts on Tennessee are higher with the MRS, but not significantly so. DOE should be encouraged to examine in detail various options for improving its transport scheme.
- (2) The estimated radiological risks from transporting spent fuel are very low for both the MRS and NO-MRS alternatives.
- (3) The NO-MRS alternative is roughly \$2 billion cheaper than the MRS case.

(4) The engineering and economic feasibility of fuel rod consolidation on the scale planned at the MRS has not yet been demonstrated by DOE. DOE should be encouraged to continue its support of development, demonstration, and testing on both dry and in-pool rod consolidation, to refine its systems studies on the cost-benefit analysis of rod consolidation, and to consider a fee credit for utilities that deliver consolidated fuel.

(5) The programmatic advantages of either the MRS case or the NO-MRS case inevitably involve subjective judgments. With sufficient emphasis on coordination and control, an improved NO-MRS alternative could be designed to have many of the advantages and functions as DOE's MRS.

(6) The subjective judgment of the Director of the Office of Civilian Radioactive Waste Management formed the acknowledged basis for final MRS site selection. A large number of sites, including the DOE choices, would likely be technically acceptable for siting an MRS.

Comparing the alternate systems based on the original criteria, the conclusion on "need" can be summarized as follows. The second and third criteria -- reducing transportation impacts and risk -- do not significantly discriminate between the NO-MRS and MRS alternatives, provided that an improved transport scheme is used. The fifth criterion -- increasing the likelihood of meeting the schedule in the NWPA -- also does not significantly discriminate between the alternatives, presuming that the MRS case is implemented as proposed by DOE with a linkage in the schedules between the acceptance of spent fuel at the MRS and construction authorization of the repository. On the basis of cost, the first criterion, the MRS alternative is higher by about 6% of total estimated system cost.

The fourth criterion -- improving the likelihood of successful implementation and operation of the system -- is the key criterion for DOE in justifying its preference for the MRS, even with its higher cost. This is a matter of judgment. Reasonable people can conclude that the MRS system is desirable because of the programmatic benefits perceived by DOE. Other reasonable people can conclude that a properly designed NO-MRS alternative is preferable. It is highly likely that either alternative, particularly with additional testing and development, is technically feasible.

Introduction

The Department of Energy (DOE) has attempted to provide in its documents submitted to Congress a rigorous and credible "need and feasibility" analysis of the Monitored Retrievable Storage (MRS) facility as required by the Nuclear Waste Policy Act.(1,2) As long as questions of safety can be satisfactorily answered, one of the key issues for determining whether any state should host the MRS is an adequate justification of its need and feasibility. This summary report outlines the results of an independent assessment of the need, feasibility, and siting of the MRS that was conducted for the state of Tennessee by a team of contractors that included the University of Tennessee, Vanderbilt University, Oak Ridge Associated Universities, and the Nuclear Assurance Corporation. The detailed reports of this assessment are included as appendices to the summary report.

General Philosophy

As DOE and the Congressional Office of Technology Assessment (OTA) readily acknowledge, the MRS is not absolutely necessary in order to manage and move spent fuel from reactors to a repository.(3) "Need" can only be answered in terms of a comparison of the advantages and disadvantages of various alternate systems, with and without the MRS. The assessment of "feasibility," which can be used to compare alternatives, is an examination of the technical, economic, and political feasibility of each system.

A set of criteria and an estimate of their relative importance is needed to compare alternate systems. Before making a comparison, the alternatives should be defined and reasonably optimized using the criteria

and their weights. Also required is a fairly robust sensitivity analysis to take into account the effect of uncertainties and a possible shifting of the weights. Subjective judgments are involved, but the comparison should be systematic and clearly explain arguments for and against each system.

The purpose of the contractors' study was not to recommend a preferred system for managing spent fuel, but rather to examine carefully and assess the advantages and disadvantages to Tennessee and the nation of various alternatives. The contractor team compared the alternate systems according to each of several criteria. The choice of a preferred system will depend on the relative importance that is attached by a decisionmaker to the criteria. Although political feasibility is an important aspect, the team confined itself to examining only technical and economic feasibility.

Criteria

Before selecting tentative criteria, the team reviewed the major DOE justifications for the MRS. The DOE summary of the advantages of the MRS includes: (i) allows completion of important pre-emplacment waste management activities independent of repository complexities and schedules, (ii) simplifies the design, construction and operation of above-ground facilities at the repository, (iii) reduces overall transportation impacts, (iv) increases system flexibility and reliability by providing a buffer between waste acceptance and waste emplacement, (v) minimizes at-reactor impacts of potential delays in the repository, and (vi) provides for operational storage needs of Federal portion of the waste management system. (A less bureaucratic phrasing of these possible

advantages might be: (i) allows DOE to begin taking significant quantities of spent fuel from utilities by 1998, possibly even if the repository is delayed, (ii) demonstrates tangible progress now and increases system flexibility by implementing a portion of the waste management system that can be made independent of uncertainties surrounding the repository, (iii) makes building above-ground facilities at the repository somewhat easier, and (iv) reduces national transportation impacts.) Questions of cost and risk are also obviously important, as indicated by DOE's efforts to provide detailed information on these factors in its final documents.

The contractor team selected a tentative set of criteria that encompass the arguments used by DOE. The five key criteria for comparing alternate systems (not necessarily in order of importance) appear to be: (i) economic cost, (ii) radiological risk to people and the environment, (iii) non-radiological transportation impacts, (iv) the likelihood of successful implementation and operation of the system, and (v) the likelihood of meeting the schedule in the Nuclear Waste Policy Act.

From the information provided by DOE, it appears that the system economic cost is likely to be somewhat higher with the MRS. Therefore, DOE has placed some weight, but not the highest weight, on this criterion. Of course, all system cost estimates have considerable uncertainties. Minimizing the initial costs of the system will not necessarily minimize total costs in the long run. The system with the lowest cost if all goes well may have a large variance due to uncertainties in factors like the operational date of a repository or technical feasibility. As OTA emphasizes, the relative costs of systems with and without an MRS must be examined under a wide range of contingencies. Therefore, it seems reasonable to make the expected value

of system economic cost an important consideration, but not the overriding consideration. An alternate system that appears to be more expensive, however, will have to produce compensating advantages based on other criteria in order to be attractive.

DOE estimates that risks to people and the environment are likely to be small for any of the major alternate systems that are reasonably well-designed and operated. Thus, it seems that the criteria of reducing risks may not be significant in distinguishing between alternatives. The issue of risk, however, is of paramount importance to the public, and the analysis of risk must be carefully done for each system. If the expected risks of alternate systems are shown to be little different, then other criteria will be the determinants of the preferred system.

Minimizing transportation impacts nationally, measured in terms of cask-miles and trip-miles, is used as a major justification by DOE of the integral MRS option. Transportation impacts refer in part to nuisance, visibility, and perceptions, but reducing cask-miles and trip-miles also lowers transportation risk. DOE places considerable weight on this criterion, and many other analysts concur with DOE and believe that reducing transportation impacts is an exceedingly important consideration. OTA believes that it is potentially significant, but may not be as important as optimizing the last two criteria. What DOE did not do in its preliminary analysis was to examine what can be accomplished in minimizing transportation impacts without the MRS. (This omission was somewhat rectified by a revised analysis included as an appendix to the document submitted to Congress.) A credible comparison of alternatives requires examining a "no MRS" system that has been optimized to reduce transportation impacts.

The remaining two criteria -- likelihood of successful system implementation and operation and meeting the schedule in the NWSA -- are given great weight by both DOE and OTA. It is reasonable to make the last two criteria very important, but arguments in these highly subjective areas must be spelled out very carefully and be subjected to critical review when comparing alternate systems. Reaching consensus judgments on how well a system meets these two criteria may not be easy.

The five criteria selected by the team seem reasonable ones for comparing alternate systems, and all seem to be important. Several systems should be defined (based on optimization using different weights for the criteria) in order to give a feeling for the sensitivity of changes in weighting. Before discussing alternate systems that were considered by the contractor team, a discussion of the boundary conditions on the nuclear waste management system is needed.

Boundary Conditions

The key boundary condition is the annual amount of spent fuel storage that is needed beyond what can be accommodated in reactor pools. This supplemental storage requirement is affected by spent fuel generation and reactor storage forecasts. Therefore, a forecast must be made for the amount of spent fuel generated annually for the next twenty or thirty years. A forecast must also be made for utility at-reactor pool storage capacity, with and without rod consolidation, for the same period. These forecasts, when combined, result in an ultimate forecast of the annual amount of supplemental spent fuel storage needed -- storage outside of existing reactor pools -- which could be accommodated by additional storage (e.g., dry cask storage) at the reactor or removal of the spent

fuel to an MRS or repository.

Critical factors affecting the forecasts must be carefully examined in order to estimate the likelihood of different projections. Although the most likely forecast should be used in the first-order comparison of alternatives, the sensitivity analysis requires understanding the effect of different forecasts that have reasonable probabilities of occurrence.

Some of the technical factors that must be examined are: nuclear capacity projections, useful plant life, utility fuel cycle plans, plant capacity factors, fuel burnup, current spent fuel storage capacity, projected/planned increases in capacity, ability to increase capacity, maximum spent fuel storage capacity with and without rod consolidation, effects of burnup credit, incentives to perform consolidation, and transshipment between like reactors.

For the contractor team, the Nuclear Assurance Corporation (NAC) reviewed analyses and forecasts made by DOE and by TVA staff as well as prepared its own evaluation of future spent fuel generation and storage capacity. The team forecast of nuclear generating capacity to the year 2000 was based on reactors in operation and an evaluation of expected starting dates for reactors under construction. Beyond the year 2000, the team reference case was based on a scenario reflecting reactor orders at a rate necessary to replace existing nuclear plants at the end of their life. Replacement was projected to be with an 1,100 megawatt electric (MWe) unit, and only reactors of 400 MWe or more were replaced. (The capacity forecast increases because of replacement of small reactors by 1,100 MWe units.) Seventy-nine replacement reactors were added from 2004 through 2020.

The team also assumed a reactor operating life of 36 years, an average

capacity factor of 64%, and a conservative estimate of fuel burn-up increases (burnup reaching an average of 43,000 MWD/MT for PWRs and an average of 36,000 MWD/MT for BWRs by 1995). Sensitivity analyses were conducted by examining three other discharge scenarios: constant burnup at current levels, 60% capacity factor, and no new reactor orders.

Comparison of the DOE, TVA, and team reference forecasts of nuclear capacity and cumulative spent fuel discharges are given in Table 1. The team and TVA forecasts of cumulative spent fuel discharges in the year 2000 are approximately 41,000 metric tons, which is 8,000 metric tons less than the projection used by DOE in its MRS documents. A more recent analysis by DOE/EIA now also projects 41,000 metric tons in the year 2000.(4)

For the projection of additional spent-fuel storage needs, the team developed two reference estimates: an unconsolidated fuel estimate and an expected consolidated fuel estimate. Like DOE, the team assumed that new reactors added beyond 2000 will have adequate storage capacity to handle their needs through the time period covered by the study. The team's unconsolidated estimate is based on the maximum capacity from the Pacific Northwest Laboratory (PNL) data base, adjusted for additional data available to NAC. The expected consolidated estimate assumes an average 1.55 consolidation ratio compared with the unconsolidated case, allowing for the appropriate unconsolidated full core reserve plus an allowance of two unconsolidated reloads per reactor. An additional factor is applied for the assumption that, on average, only 90 percent of reactors will consolidate. The consolidation ratio also accounts for the storage of failed fuel and non-fuel bearing components. Furthermore, certain reactors are assumed not to consolidate because of specific constraints.

TABLE 1

SPENT FUEL DISCHARGE FORECAST
(CUMULATIVE THOUSAND MTU)

<u>END OF YEAR</u>	<u>DOE MIDCASE</u>	<u>TVA FORECAST</u>	<u>TEAM FORECAST</u>
1985	~12	14	13
1990	~22	--	21
1995	~35	--	31
2000	~49	40	41
2005	~65	--	50
2020	130	65	86

The two team reference cases also assume that currently planned/contracted fuel shipments will take place and that on-site transfer to and from like units on the same site will be fully utilized. For the sensitivity analysis, the team has evaluated two other scenarios: one assuming no on-site transfers or shipments beyond what has already occurred, and the other including off-site transshipment between like reactors within the same utility.

The team reference estimates for needed out-of-pool storage capacity are shown along with those of DOE and TVA staff in Figure 1. As can be seen, the team estimates for a particular year are lower than those for DOE. The only consequence of this difference for the team's analysis is in the estimate of the economic benefit of the MRS system to utilities for being able to avoid the cost of additional at-reactor storage capacity.

Alternate Systems

The basic systems that need to be examined include: DOE's integral MRS option (packaging, handling, and storage), the MRS as a back-up storage option only, the MRS as a packaging and handling facility only (no long-term backup storage allowed), and the "no MRS" option. The first and third cases are distinguished because the costs and benefits will differ if the repository is delayed.

In order to judge the sensitivity to changes in the weights of the first three criteria (cost, risk, and transportation impacts), some variations are needed for each basic system. For example, minimizing costs probably requires reducing ton-miles as much as possible and avoiding duplication of expensive packaging and handling facilities. Minimizing occupational risks may entail minimizing the number of times

FIGURE 1

CUMULATIVE ADDITIONAL SPENT-FUEL STORAGE NEEDS

the fuel is handled, and minimizing radiation exposure to the general population may require reducing the number of casks shipped and time in transit (i.e., reducing cask-days as much as possible). Minimizing transportation impacts requires reducing trip-miles as much as possible using techniques, when feasible, such as rod consolidation in reactor pools, maximizing the effective capacity of individual casks (using a family of casks), upgrading at-reactor transportation interfaces to maximize use of rail, and using dedicated train shipments to the MRS and/or the repository.

Twelve different systems were examined and modeled in a preliminary way by the contractor team. They include: (i) six cases of the "Integral MRS option" (four using the DOE spent fuel forecast, two using the team spent fuel forecast; two using a 70/30 ratio for plants shipping by rail versus truck to the MRS, two using an improved transport scheme; three using separate storage and transport casks, three using combined storage/transport casks); (ii) two cases of "MRS as a back-up storage option only" (both using the team spent fuel forecast and an improved transport scheme; one with some rod consolidation at reactors and one with no consolidation at reactors); (iii) one case of "MRS as a packaging and handling facility only" (using the team spent fuel forecast and an improved transport scheme for intact fuel); and (iv) three cases of the "no MRS option" (one using the DOE spent fuel forecast, two using the team forecast; two with some rod consolidation at reactors and one with none; all using an improved transport scheme).

These cases provide a sufficiently diverse universe of possible systems in which to make valid comparisons and to examine the consequences of varying the weights of the criteria. For simplicity, only

the five cases listed in Table 2 are discussed in this paper. The key differences between these five cases, which are indicated in the table, include assumptions about the spent fuel forecast, at-reactor consolidation, the MRS, and the transport scheme.

Improved Transport Scheme

Because reducing transportation impacts appears to be a very significant criterion, the team attempted to define an improved transport scheme that would decrease the number of shipments for both the MRS and NO-MRS systems. The team's improved transport scheme differs from DOE's assumptions in the size of the transport casks and in the split of shipments by truck and rail. The team tried to be fairly conservative in its modifications to the DOE base case; the suggested transportation changes were felt to be relatively easy to achieve and economical. The number of shipments could be reduced even beyond the team's results with additional measures that might prove feasible.

The Nuclear Assurance Corporation examined the spent-fuel cask handling and transportation capabilities for each U. S. plant, which are the primary factors in determining the mode of transportation of spent fuel from reactors. The cask handling and transportation capabilities that were reviewed included reactor crane capacity, cask set-down area dimensions, and access utilizing the data base from PNL-5384. NAC supplemented these data with reactor and site specific data gathered from recent plant visits where appropriate. Based on current capabilities and current cask models, approximately 70% of the reactors are capable of shipping by rail.

In developing an improved transport scheme, the fundamental criterion

TABLE 2

CASES

CASE	SPENT FUEL FORECAST	AT-REACTOR CONSOLIDATION	MRS	TRANSPORT SCHEME
A	DOE	NO	YES	DOE-1
D	TEAM	YES	NO	TEAM
E	TEAM	NO	NO	TEAM
F	TEAM	NO	YES	TEAM
F~	TEAM	NO	YES	TEAM

Note: Spent fuel from western reactors is sent to the MRS in case F and to the repository in case F~.

TRANSPORT SCHEMES

CASK CAPACITY (intact PWR/BWR fuel assemblies):

<u>TRUCK CASK</u>	<u>DOE-1</u>	<u>DOE-2</u>	<u>TEAM</u>
25 TON	1/2	2/5	2/5
40 TON	-	-	5/12
<u>RAIL CASK</u>			
70 TON	7/18	14/36	15/34
100 TON	-	-	24/56
125 TON	-	-	31/72
150 TON	-	36/90	-

Note: DOE-1 refers to the MRS siting document, DOE/RW-0023 (April 1985).
DOE-2 refers to the draft MRS submission to Congress (Nov. 1985).

PLANT ACCESS PROJECTION (% of plants):

<u>MODE</u>	<u>DOE</u>	<u>TEAM</u>
TRUCK	30%	13%
RAIL	70%	87%

Note: Team projection includes some intermodal shipments.

was to utilize the largest (highest capacity) cask capable of being handled by the reactor and transported effectively. A family of truck and rail casks was chosen instead of a single cask for each transportation mode. It was assumed that the 25 ton and 40 ton cask models would be transported on the highway as legal and overweight shipments, respectively. The sizes for rail casks were chosen to be 70, 100, and 125 tons. The analysis assumed all fuel to be standard PWR and BWR fuel as defined by the DOE utility waste contract. No special cask or transportation mode exceptions were made for non-standard (e.g., extra long) fuel.

The team's cask capacities in terms of intact PWR and BWR fuel assemblies are given in Table 2 and compared to the DOE assumptions. In DOE's MRS siting document of April 1985, the transportation impacts in terms of cask-miles and trip-miles, with and without the MRS, were presented assuming the use of existing casks, which have capacities indicated under the heading of "DOE-1" in the table. In the DOE draft MRS document of November 1985, the assumed cask capacities were approximately doubled, which is indicated under the heading of "DOE-2" in the table.

DOE assumed that those reactors without rail access, which is approximately 30% of the plants, would ship by truck. In order to maximize the shipments by train, because of the larger capacity of rail casks, NAC examined various means for decreasing the percentage of shipments moving by truck. For certain reactors that currently lack rail access, short intermodal shipments by heavy-haul vehicle or barge were assumed for transporting spent fuel to the nearest railhead. The longest intermodal shipment that was assumed was 26 miles.

Of the 118 reactors evaluated by NAC, 75 reactors were determined to

be capable of using a 125 ton cask, 25 reactors would be limited to a 100 ton cask, and four reactors would be limited to a 70 ton cask. The 125, 100, and 70 ton casks were assumed to be shipped by rail and represent 87% of the reactors. Approximately 13% of the plants would still use truck shipments, with ten reactors using a 40 ton cask and four using a 25 ton cask.

There are several concepts which have the potential to modify the results and reduce the number of spent-fuel cask shipments even further, but these would require further investigation and analysis. These concepts include the utilization of a transfer cask, on-site transshipment, transporting the 25 and 40 ton cask on rail, the feasibility of a 150 ton cask, and the need for a 70 ton cask model. (These options are briefly discussed in the NAC report.) DOE plans to issue two procurement activities of special interest directly related to these topics. DOE plans to contract for a reactor site interface evaluation with respect to spent fuel shipping, and plans to perform a design competition for a new generation of transportation and dual purpose (storage/transport) casks.

Transportation Modeling

The annual transportation requirements in cask-miles, trip-miles, and ton-miles for Tennessee and the U.S. were calculated for each of the twelve cases. Actual rail and truck mileages from each reactor to the MRS or repository were utilized in the calculations. The cask capacities were defined by either the DOE or team assumptions. The differences in spent fuel forecasts had essentially no effect on annual transportation requirements because annual shipments of spent fuel to the repository were

assumed to be 3,000 metric tons regardless of the scenario.

Results for DOE and several team cases in terms of annual U.S. cask-miles and trip-miles, assuming that the repository is in Washington and the MRS in Oak Ridge, are given in Figure 2. The analogous results for the repository in Texas are given in Figure 3. Figures 4 and 5 give the cask-miles and trip-miles in Tennessee for shipping to the Washington repository and Texas repository, respectively.

As before, DOE-1 refers to the use of existing casks (capacities are given in Table 2) and a 70/30 ratio for plants shipping by rail versus truck. DOE-2 refers to the use of larger casks (capacities are also given in Table 2) and the same split for rail and truck shipments. DOE assumes that casks will be individually shipped by rail as well as by truck from reactors. In some of the DOE cases, data was not available for inclusion in the figures. The team independently calculated one DOE case, "DOE-1 with an MRS," and these results are shown in the figures for comparison.

The team cases D, E, F, and F~ all assume the use of the team improved transport scheme, which includes the family of casks given in Table 2 and a 87/13 ratio for plants shipping by rail versus truck. In addition, the team assumes that rail shipments from reactors as well as from the MRS will be in dedicated trains with five casks per train.

The team's cases D and E are NO-MRS cases; spent fuel is shipped directly from the reactors to the repository. Case D assumes some rod consolidation at reactors (the team's estimated consolidation scenario); case E assumes no rod consolidation at reactors. Cases F and F~ are MRS cases, where spent fuel is consolidated at the MRS. In F, spent fuel from all reactors goes to the MRS. In F~, only eastern reactors ship to the MRS; western spent fuel goes directly to the repository. (Two MRS cases -

WASH. REP. / OAK RIDGE MRS

annual U. S. cask-miles and trip-miles

TEXAS REP./OAK RIDGE MRS

annual U. S. cask—miles and trip—miles

FIGURE 4

WASH. REP./OAK RIDGE MRS

annual TN cask-miles and trip-miles

FIGURE 5

TEXAS REP./OAK RIDGE MRS

annual TN cask-miles and trip-miles

G' and H' - are not shown. Case G' assumes some consolidation at reactors as well as consolidation at the MRS. Case H' assumes no consolidation at reactors or at the MRS. In terms of cask-miles, the national transportation impacts of G' are slightly less than F, and the impacts of H' are roughly 20% greater.)

Upon examining the figures, one can conclude that by using an improved transport scheme, the national transportation impacts measured in terms of cask-miles of both the MRS and NO-MRS alternatives are comparable and much lower than DOE's original estimates. The transportation impacts on Tennessee are higher with the MRS, but not significantly so. The spent fuel shipments from reactors to the repository in case E, or to the MRS in case F, are roughly 18 trucks and 4 trains monthly. An improved transport scheme makes sense whether or not there is an MRS.

Transportation Risks

The team estimated the radiological and non-radiological transportation risks for the various cases with and without the MRS. The unit risk factors from RADTRAN-III were examined and reviewed in some detail. These risk factors include the contribution from accidents as well as from incident-free transportation, and they separate the risk into occupational and non-occupational components.

The team judged that the unit risk factors were reasonable and conservative estimates, and were subsequently utilized in the team's transportation modeling. The annual transportation risks for both Tennessee and the U.S. in the case of shipping to the Nevada repository are shown in Table 3.

The estimated transportation risks are small for all of the cases, but

TABLE 3

ANNUAL TRANSPORTATION RISK
(Nevada Repository)

CASE	TN. RAD. FATALITIES	TN. NON-RAD. FATALITIES	TN. NON-RAD. INJURIES
A(MRS)	.029	.183	2.121
D(NO-MRS)	.001	.015	.163
E(NO-MRS)	.002	.018	.200
F(MRS)	.002	.057	.613
	U.S. RAD. FATALITIES	U.S. NON-RAD. FATALITIES	U.S. NON-RAD. INJURIES
A(MRS)	.159	1.630	17.804
D(NO-MRS)	.030	.729	7.747
E(NO-MRS)	.037	.874	9.301
F(MRS)	.015	.841	8.737

smallest for those using the improved transport scheme. The non-radiological risks are higher than the radiological risks. The estimated annual risks from transporting spent fuel are much less than that of transporting other commodities such as gasoline, chemicals, and coal.

System Cost

DOE estimates that the net system cost of its MRS alternative is \$1.5 to \$2.1 billion greater than its NO-MRS alternative. DOE also estimates a potential savings to utilities for avoided storage at reactors of \$.2 to \$.5 billion if both the repository and MRS are on time.

The team reviewed the DOE net system cost estimates and concluded that they are reasonable at this early stage of design and technology development, but there are considerable uncertainties. (The annual transportation and handling costs of any of the cases using the improved transport scheme are comparable and on the order of \$5 to \$7 million.) The DOE estimate of potential savings to utilities for avoided storage at reactors is high. Using the least cost options for additional on-site storage (using the team's estimate of cumulative additional spent fuel storage needs and estimates of the cost of rod consolidation in reactor pools and the cost of storage of consolidated fuel in metal casks), the team estimates a savings of at most \$.1 billion if the repository is on time and roughly \$.6 billion if the repository is delayed by ten years and the MRS can accept spent fuel during the interim.

The DOE net system cost estimates do not include the cost of any compensation to the state, which could be on the order of several hundred million dollars.

Rod Consolidation Feasibility

Fuel rod consolidation has the general advantage of increasing the capacity of a given container or storage space. Hence, there are possibilities for reducing the cost of spent fuel storage, transportation and ultimate disposal, and reducing the number of ton-miles and trip-miles of transportation.

DOE has only recently initiated the technology development program that would be required for an MRS-based or repository-based rod consolidation program. The team concluded that the DOE analyses and studies do not at this time support the position that rod consolidation should take place at an MRS. Rod consolidation at the MRS is simply an option. Of the operations proposed for the MRS, the consolidation operation has the greatest potential to generate accidents, unforeseen personnel exposure, by-product radioactive low-level wastes, and cost overruns. The DOE development program that has been initiated must demonstrate that these risks can be mitigated.

Many utilities already have some incentives to consolidate their own spent fuel. DOE might consider a fee credit for utilities that deliver consolidated fuel. The team felt that DOE should be encouraged to continue its support of development, demonstration, and testing on both dry and in-pool rod consolidation, and to continue to refine its systems studies on the cost-benefit analysis of rod consolidation versus shipment, storage, and/or disposal of intact fuel.

System Performance and Schedule

DOE's preference for the integrated MRS is based on its judgment that the MRS system offers significant programmatic advantages. These

perceived benefits include: decoupling the schedules for waste acceptance from utilities and waste emplacement at the repository, implementing in an early timeframe a major portion of DOE's waste management system which can be made independent of uncertainties surrounding the repository, increasing DOE's control and quality assurance of spent fuel consolidation and packaging, and providing the capability to accept significant quantities of spent fuel from utilities by 1998.

The programmatic advantages of either the MRS case or the NO-MRS case inevitably involve subjective judgments. Reasonable people can reach different conclusions about which alternative is preferable. With sufficient emphasis on coordination and control, the NO-MRS case could be designed to have many of the advantages and functions as DOE's MRS. For example, consolidation and dry storage could occur at reactors (as well as at the repository) with adequate quality control and standardization. (Private companies are willing to provide consolidation services to utilities.) Buffer storage could occur at the repository to decouple waste acceptance from waste emplacement. Shipments from reactors could be accomplished with dedicated trains. The NO-MRS system, however, would not enable the front leg of the waste transportation system to be finalized before the repository is selected.

If the MRS is successfully sited, the institutional arrangements between DOE and Tennessee may be a useful precedent for similar arrangements with the repository host state. This could help reduce potential repository delays. But overall, the MRS will be little help in resolving the major technical issues in repository siting. In order to alleviate the possible concern that the MRS might become a permanent storage facility, DOE has proposed that the MRS not accept significant

quantities of spent fuel before the repository receives a construction authorization from the Nuclear Regulatory Commission (NRC). With this strong linkage between the MRS and repository schedules, some of the flexibility benefits of the MRS may largely disappear. Utilities will still be unable to rely on DOE for a firm acceptance schedule until the repository issues are resolved to the satisfaction of the NRC. If the repository is delayed for a long period of time, the U.S. will likely have to confront the issue of centralized monitored retrievable storage of spent fuel.

MRS Site Screening Process

The Nuclear Waste Policy Act did not require DOE to use any particular screening process in selecting a site for the MRS. The site screening philosophy used by DOE was not to reject undesirable sites, but to focus quickly on those sites which were perceived to be especially desirable.

The MRS site will need to meet certain technical criteria in order to obtain a license from the Nuclear Regulatory Commission. Because the MRS facility is based on engineered containment, however, site specific requirements are not strong discriminating factors among potential sites. A large number of sites would likely be technically acceptable for siting an MRS.

DOE used a siting analysis based in part on minimizing total trip-miles. The team concluded that this criterion does not demonstrate significant advantages in terms of transportation risk or cost. The MRS could be almost anywhere with little effect on transportation risk or cost.

As DOE acknowledges, the subjective judgment of the Director of the

Office of Civilian Radioactive Waste Management formed the basis for final site selection. The factors of potential political acceptability, community technical familiarity with nuclear activities, and potential expediency in acquisition, permitting, and construction appeared to have played an important, and probably reasonable, role in site selection.

Findings

The team's key findings from its analysis of the need, feasibility, and siting of the MRS are:

(1) By using an improved transport scheme, the national transportation impacts of both the MRS and NO-MRS alternatives are comparable and much lower than DOE's original estimates. The transportation impacts on Tennessee are higher with the MRS, but not significantly so. DOE should be encouraged to examine in detail various options for improving its transport scheme.

(2) The estimated radiological risks from transporting spent fuel are very low for both the MRS and NO-MRS alternatives.

(3) The NO-MRS alternative is roughly \$2 billion cheaper than the MRS case.

(4) The engineering and economic feasibility of fuel rod consolidation on the scale planned at the MRS has not yet been demonstrated by DOE. DOE should be encouraged to continue its support of development, demonstration, and testing on both dry and in-pool rod consolidation, to refine its systems studies on the cost-benefit analysis of rod consolidation, and to consider a fee credit for utilities that deliver consolidated fuel.

(5) The programmatic advantages of either the MRS case or the NO-MRS case inevitably involve subjective judgments. With sufficient emphasis on coordination and control, an improved NO-MRS alternative could be designed to have many of the advantages and functions as DOE's MRS.

(6) The subjective judgment of the Director of the Office of Civilian Radioactive Waste Management formed the acknowledged basis for final MRS site selection. A large number of sites, including the DOE choices, would likely be technically acceptable for siting an MRS.

Comparing the alternative systems based on the original criteria, the

final conclusion on "need" can be summarized as follows. The second and third criteria -- reducing transportation impacts and risk -- do not significantly discriminate between the NO-MRS and MRS alternatives, provided that an improved transport scheme is used. The fifth criterion -- increasing the likelihood of meeting the schedule in the NWPA -- also does not significantly discriminate between the alternatives, presuming that the MRS case is implemented as proposed by DOE (with the linkage in the schedules between the acceptance of spent fuel at the MRS and construction authorization of the repository). On the basis of cost, the first criterion, the MRS alternative is higher by about 6% or so of total system cost. The fourth criterion -- improving the likelihood of successful implementation and operation of the system -- is the key criterion for DOE in justifying its preference for the MRS. This is a matter of judgment. Reasonable people can agree with DOE and conclude that the MRS is desirable because of the programmatic benefits perceived by DOE. Other reasonable people can conclude that a properly designed NO-MRS alternative is preferable. It is highly likely that either alternative, particularly with additional testing and development, is technically feasible.

(This summary report, for which the author assumes responsibility, is based on the work of the contractor team. The members of the team include: M. Bronzini, W. Colglazier, and D. Middendorf from the University of Tennessee; R. Stammer from Vanderbilt University; G. Marland, B. Sigmon, I. Spiewak, and C. Whittle from Oak Ridge Associated Universities; and R. Casper and W. Lee from the Nuclear Assurance Corporation. The team would like to thank the Safe Growth Team staff and its Technical Advisory Committee, the DOE staff, and DOE contractor staff for many helpful and illuminating discussions on the MRS.)

Notes

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DRAFT

SPENT-FUEL DISCHARGES AND ADDITIONAL SPENT-FUEL STORAGE NEEDS

October 1985

NUCLEAR ASSURANCE CORPORATION
5720 Peachtree Parkway
Norcross, Georgia 30092
Telephone: (404) 447-1144
Telex: 6827020, 6827114

1225 North 23rd Street, Suite 101
Grand Junction, Colorado 81501
Telephone: (303) 245-4320

Weinbergstrasse 9
8001 Zurich, Switzerland
Telephone: (01) 470844
Telex: 57275

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PREFACE

As a part of the study evaluating the impact of the location of a Monitored Retrievable Storage (MRS) facility in the state of Tennessee, forecasts of spent-fuel generation and the need for additional storage in the U.S. have been analyzed. These forecasts were developed for the state of Tennessee as a part of a team effort including the University of Tennessee, Vanderbilt University, Oak Ridge Associated Universities and Nuclear Assurance Corporation (NAC). This group is hereinafter referred to as the Team. Various assumptions regarding the discharge of spent fuel were evaluated, and a Team set of assumptions was established as the basis for a Team reference estimate of the quantities of spent fuel to be discharged through 2020. Additionally, scenarios of at-reactor capacity for spent-fuel storage were evaluated. These capacity scenarios were compared with the spent-fuel discharge estimate to develop Team reference estimates of additional storage needs through 2020. This report presents and discusses the analyses and compares them with previous estimates.

SECTION I

SPENT-FUEL DISCHARGES

A. Key Factors

The estimation of spent-fuel discharges depends on several variables. Of these variables, five factors were determined to be key:

1. Nuclear capacity forecasts
2. Useful service life of the plant
3. Cycle length
4. Capacity factor of the plant
5. Fuel burnup achieved

These factors were examined to determine a set of Team assumptions to be used in developing the spent-fuel discharge estimates. As a part of this evaluation, assumptions used by the Tennessee Valley Authority (TVA) and the U.S. Department of Energy (DOE) in similar analyses were examined, reviewed and compared.

Nuclear capacity forecasts represent the number and size of nuclear electrical generating units in the U.S. and the timing of their startup. This information is expressed in Megawatts or Gigawatts electrical (MWe or GWe). The possibility of additional orders must also be considered. The useful service life determines when a nuclear unit will be retired and, therefore, will no longer generate spent fuel. Cycle length refers to the interval between refuelings. Capacity factor represents the power generation performance of the unit relative to 100 percent. Fuel burnup achieved is a measure of fuel utilization.

B. DOE and TVA Assumptions

DOE and TVA have independently analyzed and developed projections of spent-fuel discharges through 2020. DOE's Energy Information Administration (EIA) is directly involved in determining the DOE projections. In addition, DOE has

obtained support from the Pacific Northwest Laboratory (PNL), which is operated for DOE by Battelle. DOE and TVA's assumptions regarding the five identified key factors were reviewed and compared. Table 1 highlights and compares their assumptions.

1. Nuclear Capacity Forecasts. TVA uses only reactors currently in operation or in the planning/construction pipeline for its expected forecast. However, on a completion probability basis, approximately 12 GWe is never completed. This results in about 105 GWe of light water reactor capacity on line by 1995. No additions or replacements are assumed by TVA after 1995 (i.e., no new orders). Startup of future units is adjusted according to available data on potential delays as appropriate. A list of reactors used by TVA, including start-up date, capacity and completion probability, is available in documentation transmitted by R. E. Hoskins of TVA to Florida Power and Light and Westinghouse, dated March 20, 1985. Beyond 1995, reactor retirements take place according to assumed reactor lifetime, causing the GWe forecast to decrease. TVA draws upon specific reactor data available from the PNL data base.

DOE examines several capacity scenarios--no new orders, low, mid and high--but relies on the mid-case as the reference basis for additional analyses regarding spent-fuel discharges. The no new orders case (similar to TVA's forecast) acts as a lower bound. The mid-case is based on the current set of known reactor projects in operation or in the pipeline, with utility start-up estimates adjusted for known potential changes as appropriate. All known reactor projects come on line by the year 2000. Lists of the reactors operating and under construction are available in "Commercial Nuclear Power 1984: Prospects for the United States and the World," DOE/EIA-0438(84), published in November 1984, and in "Reactor-Specific Spent-Fuel Discharge Projections: 1984 to 2020," PNL-5396, issued by PNL in April 1985. DOE's long-term capacity forecasts assume a continued reliance on nuclear electrical generation beyond 2000. Based on DOE's energy model, additional reactors are brought into service beginning in 2001. The average annual

TABLE 1
SPENT-FUEL DISCHARGE ASSUMPTIONS

TVA	DOE
<p><u>Nuclear Capacity Forecasts</u></p> <ul style="list-style-type: none"> - Uses only reactors currently in operation or in pipeline - 12 GWe of currently ordered capacity is never completed - Expected total 105,000 MWe, all on line by 1995 - No additions or replacements after 1995, only retirements - Startups adjusted to best data available 	<ul style="list-style-type: none"> - Several cases: No New Orders, Low, Mid and High - Mid is used as analysis basis with No New Orders often a lower bound - Intermediate term: through 2000 <p><u>Mid-Case</u></p> <ul style="list-style-type: none"> - Current set of known projects (operating or in pipeline) controls GWe - Utility startup estimates are adjusted for other effects - Long Term: 2000 to 2020 <p><u>Mid-Case</u></p> <ul style="list-style-type: none"> - Based on detailed energy model - Results in average increase of 2.8 percent per year from 2000 to 2020. Includes reactor retirements - Continued reliance on nuclear energy; nuclear industry problems resolved, e.g., licensing

TABLE 1
SPENT-FUEL DISCHARGE ASSUMPTIONS
(Continued)

TVA	DOE
<u>Useful Service Life of Plant</u>	
<ul style="list-style-type: none"> - Essentially a 30-year service life; this is used as an average for all plants 	<ul style="list-style-type: none"> - Existing units - operating life of 34 years on average based on 40 years from issuance of construction permit.
<ul style="list-style-type: none"> - Plant not replaced after useful life 	<ul style="list-style-type: none"> - New units - 40 years from issuance of operating license; new units are those in construction pipeline or undergoing low power testing, plus St. Lucie 2, Susquehanna 1, LaSalle 1 and additional reactors on line beyond 2000
	<ul style="list-style-type: none"> - There are no reactor retirements through 1995
<u>Cycle Length</u>	
<ul style="list-style-type: none"> - Plans as reported by utility 	<ul style="list-style-type: none"> - Plans as reported by utility
	<ul style="list-style-type: none"> - 18-month cycles used for additional reactors on line after 2000

TABLE 1
SPENT-FUEL DISCHARGE ASSUMPTIONS
(Continued)

TVA	DOE
<p><u>Nuclear Plant Performance (Capacity Factor)</u></p> <ul style="list-style-type: none"> - One expected average capacity factor of 60 percent is used - However, this one average value accounts for changes over the life of the plant 	<ul style="list-style-type: none"> - Capacity factor does not decrease in later reactor life - Based on historical experience and programs in place to improve performance, the composite average capacity factor is increased to 65 percent in 2000 - Remains constant thereafter - Equilibrium increases from current 60 percent level - Composite increases from average of 55-56 percent level

TABLE 1
SPENT-FUEL DISCHARGE ASSUMPTIONS
(Continued)

TVA	DOE
<p><u>Fuel Burnup and Effects</u></p> <ul style="list-style-type: none"> - Burnup increases to an average of 40,000 MWD/MT by mid-1990s - 42,000 MWD/MT--PWR - 36,000 MWD/MT--BWR 	<ul style="list-style-type: none"> - For reference mid-case, burnup is not increased above current levels - DOE does examine an increased burnup scenario: <ul style="list-style-type: none"> - 2.5 percent/year increase in average equilibrium cycle burnup from 1985 through 1996. Remains constant thereafter - In 1996, average burnup is 30 percent above pre-1985 levels - Additional reactors included beyond 2000 have burnups of about: <ul style="list-style-type: none"> - 35,000 MWD/MT--PWR - 30,000 MWD/MT--BWR

increase in nuclear GWe capacity from 2000 to 2020 in DOE's mid-case is about 2.8 percent; this includes the influence of reactor retirements. The following summary table shows the nuclear capacity in DOE's mid and no new orders forecasts for the given years:

Year	DOE GWe Forecast (Net)	
	Mid-Case	No New Orders Case
1985	85	81
1990	111	107
1995	119	109
2000	122	108
2005	148	108
2010	166	106
2015	189	68
2020	212	49

The GWe in TVA's estimate is in general less than DOE's since: 1) TVA reaches a maximum of only about 105 GWe in 1995, and 2) as will be discussed subsequently, TVA's rate of reactor retirement is faster.

2. Useful Service Life. TVA assumes an average useful service life of 30 years for each reactor. The reactor is subsequently retired and not replaced. DOE uses two categories of service life. An average operating life of 34 years is used for existing units. This is based on a 40-year license from issuance of the construction permit. For new units, a 40-year life is assumed, based on a 40-year license from issuance of the operating license.
3. Cycle Length. In TVA's analysis and in DOE's reactor-specific analysis (performed by PNL), the cycle length for currently operating reactors and those under construction is essentially that reported by the utility as the planned cycle length. For the DOE additional reactors brought on line beyond 2000, an 18-month cycle is assumed by PNL, from discharge to discharge. The actual cycle length used by TVA can be varied as a function of capacity factor

(see below). The cycle length estimate mainly affects the timing of discharges and the amount discharged at a specific refueling, all else being equal; it has a minimal effect on total discharges for a given reactor over its life.

4. Capacity Factor. The total cycle capacity factor essentially measures the amount of energy generated during the cycle (from startup to startup or shutdown to shutdown) as a percentage of what could be obtained if operation was at 100 percent power during the entire cycle. TVA assumed an expected average capacity factor of 60 percent for each reactor. However, this one average value is intended to account for changes over the life of the plant (e.g., improvements as the plant matures or reductions as the plant ages). DOE does not decrease the capacity factor later in reactor life, but does increase it from current levels. Essentially, DOE assumes an increase in composite average capacity factor from its current level to 65 percent by 2000. Current level is assumed to be about 60 percent for equilibrium cycles, with the composite (also including the first two cycles) currently at 55-56 percent. In the long term (beyond 2000), the composite capacity factor is held constant at 65 percent. Since capacity factor directly affects the amount of energy produced, the amount of fuel burned and subsequently discharged over a given time period is also affected.
5. Fuel Burnup. Fuel burnup, typically in units of megawatt days per metric ton uranium (MWD/MT), measures fuel utilization. The amount of fuel loaded/discharged is indirectly proportional to the burnup, all else being equal (such as cycle length and capacity factor). TVA, in its expected case, assumes that the fuel burnup will increase to an average for PWRs and BWRs combined of about 40,000 MWD/MT by the mid-1990s. PWR burnups would then reach about 42,000 MWD/MT and BWR burnups about 36,000 MWD/MT. DOE's reference mid-case assumes that burnup does not increase above current levels, remaining constant throughout. DOE does consider a burnup scenario that increases average equilibrium burnup by 2.5 percent per year from 1985 through 1996 and remains constant thereafter; the

resultant discharges from this scenario were not used in subsequent analyses regarding the waste program. However, additional reactors brought on line by DOE after 2000 have the following approximate burnups:

	<u>MWD/MT</u>
PWR	35,000
BWR	30,000

C. Team Assumptions

A set of Team assumptions pertaining to the five key factors for the calculation of reference spent-fuel discharges through 2020 has been developed. These assumptions were arrived at from an evaluation of in-house data and review of available external documents, including TVA and DOE information. Each of the assumptions is discussed as follows:

1. Nuclear Capacity Forecasts. The bases for the Team reference capacity or expected forecast through the year 2000 is NAC's Reasonable Case Megawatt Status Report, which establishes the number of reactors, their size (MWe-net), and their start-up or commercial operation date. The report includes operating reactors plus reactors that are under construction or planned. It is developed from a reactor-by-reactor evaluation, through 2000, of expected operation dates for reactors not yet operating.

The following summary table compares the reference DOE, TVA and Team capacity forecasts through the years 1995 and 2000.

Capacity Forecasts, GWe (Net)

	<u>DOE</u>	<u>TVA</u>	<u>Team</u>
1995	119	105	105
2000	122	<105	105

Although arrived at through different assumptions, the TVA and Team estimates are basically the same in terms of total GWe. The DOE forecast is 14 and 17 GWe higher than the Team estimate in the years 1995 and 2000, respectively. The primary reason for these differences is the inclusion of reactors by DOE that the Team assumed would not be completed. There are 14 additional reactors of various MWe ratings included by DOE.

To extend the Team nuclear capacity forecast beyond 2000, a bounding analysis has been utilized. The lower bound is based on a no new orders/replacements scenario. Essentially, reactors brought on line through 2000 continue to be retired through 2020 with no replacements. In the absence of a detailed energy model, to establish an upper bound beyond 2000, the Team examined the DOE low, mid and high cases with respect to projected real growth in Gross National Product (GNP). Established economic forecasts from experts predict real growth in GNP at approximately 3 percent per year. A direct correlation has previously been established between real GNP growth and growth in electrical generation. Therefore, if nuclear electrical generation maintains its share of electrical generation, then nuclear capacity could be expected to increase at approximately 3 percent per year.

In fact, the DOE mid-case exhibits an almost 3 percent per year average growth rate in nuclear capacity beyond 2000. Therefore, the Team upper bound starts with the Team reference case through 2000, and it adds reactors beginning in 2001 at the same size and rate as assumed in the DOE mid-case. The Team reference case beyond 2000 was then established within the lower and upper bound. A scenario reflecting orders of nuclear reactors, at a rate necessary to replace reactors at the end of their life (after retirement), conveniently lies within these bounds. This replacement reactor scenario defines the Team reference capacity forecast. Replacement is made with an 1,100 MWe unit, but only reactors of 400 MWe or more are replaced. As such, no replacements are made prior to 2000, although two reactors (Yankee 1 and Big Rock Point) with ratings

less than 400 MWe are assumed to be retired before 2000. Beyond 2000 in the Team reference case, the number of reactors remains constant, but the MWe forecast generally increases because of replacement of small reactors by 1,100 MWe units. Seventy-nine replacement reactors are added from 2004 through 2020.

The three Team capacity forecasts are summarized in Table 2. However, it is the Team expected forecast that is considered the reference case and used in subsequent analyses. Appendix A provides a list of reactors included through 2000, along with their start-up dates and MWe. Sensitivity of discharge estimates to the no new orders case will be discussed later.

2. Useful Service Life. The Team assumed an average reactor design operating life of 40 years, which is typical of current standards and similar to the assumption used by DOE. However, to introduce a degree of conservatism into the assumption, an average probability of 90 percent was applied to the 40-year design life, resulting in an average 36-year operating life. This was used for all units in the Team nuclear capacity estimate. At the time of retirement, the full core is discharged.
3. Cycle Length. As TVA and DOE, for operating reactors and reactors in the construction pipeline, the Team utilizes the cycle length specific to each reactor according to current utility plans. These cycle lengths are actually expressed in terms of effective fuel power days; they are modified by the assumed capacity factor given below and they range typically from 12 to 24 months. For new reactors added after the year 2000, the average cycle length is assumed to be approximately 18 months, as assumed by DOE.
4. Capacity Factor. An average capacity factor of 64 percent through 2020 is assumed by the Team for all reactors in the nuclear capacity forecast. This constant average value is based on increasing the capacity factor from its current level of about 60 percent to 65 percent in 1995 and assuming it remains constant thereafter. The

TABLE 2
TEAM NUCLEAR CAPACITY FORECASTS
GWe (Net)

<u>End of Year</u>	<u>Lower Bound (No New Orders)</u>	<u>Reference</u>	<u>Upper Bound</u>
1985	76.8	76.8	76.8
1986	81.2	81.2	81.2
1987	87.0	87.0	87.0
1988	95.8	95.8	95.8
1989	100.2	100.2	100.2
1990	103.7	103.7	103.7
1991	104.9	104.9	104.9
1992	104.9	104.9	104.9
1993	104.9	104.9	104.9
1994	104.9	104.9	104.9
1995	104.9	104.9	104.9
1996	104.9	104.9	104.9
1997	104.7	104.7	104.7
1998	104.7	104.7	104.7
1999	104.6	104.6	104.6
2000	104.6	104.6	104.6
2001	104.6	104.6	111.2
2002	104.6	104.6	116.7
2003	104.6	104.6	121.1
2004	103.7	105.9	124.6
2005	102.4	106.8	129.9
2010	77.0	119.9	160.6
2015	57.3	124.4	182.7
2020	38.5	125.4	187.0

resultant weighted average capacity factor is about 64 percent. This is of the same order of magnitude as the TVA and DOE assumptions.

5. Fuel Burnup. It is assumed that by the end of 1995, burnups will linearly increase from their current levels of about 28,000 MWD/MT (BWRs) and 32,000 MWD/MT (PWRs) to the following values:

PWR - 43,000 MWD/MT

BWR - 36,000 MWD/MT

These burnup values are based on the assumption that in approximately 10 years, the industry should be able to achieve about 95 percent (on average) of the higher burnups for which fuel will be designed and licensed, i.e., 45,000 MWD/MT for PWRs and 38,000 MWD/MT for BWRs. Historically, design burnups have been achieved over a comparable time period. The TVA assumption is very close to the Team estimate. It should be noted that DOE did not incorporate increased fuel burnup in its mid-case forecast, although it was considered in other scenarios.

D. Discussion of Reference Discharge Results

DOE, TVA and the Team have calculated spent-fuel discharges both on a reactor-by-reactor and a global basis. Cumulative discharges through the year 2020 in thousands of Metric Tons of Uranium (MTU) are presented on an annual basis in Table 3 and in Figure 1 for the DOE reference/mid-case, the TVA expected case, and the Team reference case.

TABLE 3
CUMULATIVE SPENT-FUEL DISCHARGES
1000s of MTU

	<u>Team Reference</u>	<u>DOE Reference/Mid¹</u>	<u>TVA Expected²</u>
1983	10.1	9.9	11.5
1984	11.6	11.1	12.6
1985	12.8	12.4	13.8
1986	14.3	13.8	15.1
1987	16.0	15.5	16.6
1988	17.8	17.5	18.4
1989	19.8	19.6	20.3
1990	21.5	21.9	22.1
1991	23.4	24.2	24.0
1992	25.5	26.7	25.8
1993	27.5	29.3	27.6
1994	29.4	31.9	29.4
1995	31.3	34.6	31.2
1996	33.3	37.3	32.8
1997	35.0	40.1	34.8
1998	36.9	43.0	36.6
1999	38.6	46.0	38.5
2000	40.8	49.0	40.5
2001	42.4	52.0	42.4
2002	44.3	55.0	44.7
2003	46.3	58.1	46.5
2004	48.0	61.4	48.8
2005	50.3	64.8	50.8
2006	52.3	68.6	52.1
2007	54.7	72.7	53.8
2008	56.9	77.4	54.9
2009	59.2	81.9	56.0
2010	62.1	86.4	57.1
2011	64.9	90.4	58.3
2012	67.1	94.5	59.3
2013	69.8	98.7	60.3
2014	71.8	102.9	61.6
2015	74.3	107.2	63.3
2016	76.5	111.5	64.4
2017	78.7	116.0	65.2
2018	81.3	120.7	65.6
2019	83.5	125.4	65.7
2020	86.2	130.3	65.8

1. From "Commercial Nuclear Power 1984," DOE/EIA-0438(84), November 1984

2. From transmittal from R. E. Hoskins, March 20, 1985

FIGURE 1

CUMULATIVE SPENT FUEL DISCHARGES

The following summary table illustrates the differences in the three cumulative discharge forecasts in the specified years:

Cumulative Spent-Fuel Discharges
1000s of MTU

	<u>Team Reference</u>	<u>DOE Reference/ Mid</u>	<u>DOE Percent Difference from Team</u>	<u>TVA Expected</u>	<u>TVA Percent Difference from Team</u>
1985	12.8	12.4	- 3.1	13.8	+ 7.8
1990	21.5	21.9	+ 1.9	22.1	+ 2.8
1995	31.3	34.6	+10.5	31.2	- 0.3
2000	40.8	49.0	+20.1	40.5	- 0.7
2005	50.3	64.8	+28.8	50.8	+ 1.0
2010	62.1	86.4	+39.1	57.1	- 8.1
2020	86.2	130.3	+51.1	65.8	-23.7

Although the DOE mid-case is about 3 percent below the Team estimate in 1985, it increases at a faster rate than the Team estimate. By 1995, DOE is about 10 percent higher on a cumulative basis, with that percentage increasing to about 20 through 2000. The differences through 2000 can be attributed mainly to the inclusion of reactors by DOE that the Team assumes will not be completed, and to DOE's assumption that burnup remains constant at current levels. By 2020, DOE's estimate is over 50 percent higher than the Team estimate. This is attributable to the two factors mentioned previously, and the addition by DOE of new reactors over and above the replacement reactors assumed by the Team.

Although the TVA case is almost 8 percent above the Team estimate in 1985, the difference decreases, and from the early 1990s through at least 2005 the two estimates are effectively identical. Beyond 2005, the TVA discharge estimate falls below the Team estimate and by 2020 it is almost 24 percent less. This difference is due primarily to TVA's assumption that no replacement reactors come on line after the year 2000. In addition, TVA retires reactors after a somewhat shorter life than that assumed by the Team.

The reference DOE and Team discharge estimates are also provided through 2020 for PWRs and BWRs in Table 4. In this case, the DOE estimate is obtained from "Reactor-Specific Spent-Fuel Discharge Projections: 1984 to 2020," PNL-5396, April 1985. The assembly discharge estimates are also shown in Figures 2a and 2b.

TABLE 4
CUMULATIVE SPENT-FUEL DISCHARGES
Number of Assemblies

	Team Reference		DOE Reference/Mid ¹	
	PWR	BWR	PWR	BWR
1983	14,258	23,317	14,114	23,157
1984	16,265	26,352	15,744	25,574
1985	18,069	28,979	18,054	28,105
1986	20,117	32,104	20,085	31,707
1987	22,637	35,364	22,611	35,206
1988	24,988	39,561	25,663	39,310
1989	28,064	43,326	28,755	43,438
1990	30,608	46,490	31,951	47,703
1991	33,400	50,255	35,163	52,467
1992	36,674	53,956	38,720	56,765
1993	39,313	58,214	42,314	61,629
1994	42,440	61,273	46,146	66,693
1995	45,228	64,862	49,822	71,643
1996	48,182	68,693	53,653	77,098
1997	50,647	71,925	57,701	82,383
1998	53,434	75,832	61,436	87,795
1999	56,304	78,165	65,479	93,035
2000	59,298	83,055	69,434	99,039
2001	61,985	85,188	73,247	103,858
2002	64,714	89,283	77,410	110,416
2003	67,565	92,827	81,729	116,381
2004	70,190	95,964	86,139	122,458
2005	73,482	100,779	90,916	129,979
2006	76,319	105,164	95,588	136,444
2007	79,725	109,644	100,416	145,934
2008	83,128	113,640	106,022	154,611
2009	86,433	118,312	112,791	164,896
2010	90,379	124,367	118,905	173,174
2011	94,301	129,890	124,328	183,377
2012	97,855	133,319	130,362	191,105
2013	101,729	138,601	135,773	198,803
2014	105,111	141,106	141,846	208,009
2015	108,607	146,170	147,543	215,754
2016	112,253	149,189	153,022	224,395
2017	115,833	152,383	159,076	233,415
2018	119,263	157,740	165,184	242,191
2019	122,448	162,230	171,321	251,031
2020	126,046	168,043	177,513	261,018

1. From "Reactor-Specific Spent-Fuel Discharge Projections: 1984 to 2020," PNL-5396, April 1985

FIGURE 2A

CUMULATIVE SPENT FUEL DISCHARGES

FIGURE 2B

CUMULATIVE SPENT FUEL DISCHARGES

SECTION II

ADDITIONAL SPENT-FUEL STORAGE NEEDS

A. Basic Assumptions

The factors underlying the determination of additional spent-fuel storage needs are essentially:

1. The spent-fuel discharge estimates
2. The at-reactor storage capacities by reactor allowing for full-core discharge reserve
3. Additional storage capacity based on rod consolidation
4. Extent of on-site transfers
5. Extent of transshipment

The first factor has been discussed in the previous section. Factors 2 through 5 will be discussed below with respect to the estimates made by DOE, TVA and the Team. Both DOE and the Team assume that new reactors added beyond 2000 will have adequate storage capacity to handle their needs through the time period covered by the study.

1. DOE Estimate. The assumptions and analysis for the DOE estimates of additional storage needs are documented in "Reactor-Specific Spent-Fuel Discharge Projections: 1984 to 2020," PNL-5396, April 1985. Reactor storage capacities are based on reracking to the maximum extent possible and are extracted from "Spent-Fuel Storage Requirements," DOE/RL-84, August 1984. A full-core discharge reserve (FCR) is maintained for each reactor unless a common or interconnected pool is shared. In this case, only one FCR is assumed for the sharing reactors. This FCR assumption is essentially the same for the estimates of DOE, TVA and the Team, and only deviations to this assumption will be discussed, as appropriate. Rod consolidation is not considered by DOE. On-site transfers and transshipments are only included in the DOE base estimate of additional storage needs as they are currently planned by utilities. DOE does examine a case

involving large-scale transshipment of spent fuel between reactors of the same type (PWR or BWR) within the same utility; however, this is considered a sensitivity case and is discussed later in the sensitivity section of this report.

2. TVA Estimate. The storage capacities assumed by TVA by reactor, and details regarding their development, are documented in the transmittal by R. E. Hoskins dated March 20, 1985. TVA considers a range of capacity estimates, including the current, maximum, limiting and expected/probable unconsolidated fuel estimates plus a consolidated fuel estimate. The current and maximum estimates are essentially those from the PNL data base; the maximum implies maximum reracking for unconsolidated fuel. The expected unconsolidated fuel estimate assumes that the capacity achieved will lie between the current or stated maximum capacity and the limiting capacity, depending on reactor type and situation (e.g., structural limitations). The consolidated fuel estimate assumes a 1.7 to 1.8 consolidation ratio compared with the expected unconsolidated case, allowing for an unconsolidated FCR. These two cases, the expected unconsolidated and the consolidated, are used in this report as TVA's base reference capacities. These reference capacities are the basis for TVA's associated, reference additional spent-fuel storage needs. The TVA maximum reracking (unconsolidated) case is included for comparison purposes. TVA does not consider future on-site transfers or transshipment, but, like DOE, does include the limited number of shipments already planned by specific utilities.
3. Team Estimate. The Team developed two reference estimates: an unconsolidated fuel estimate and an expected consolidated fuel estimate. The Team's unconsolidated estimate is based on the maximum capacity from the PNL data base, adjusted for additional data available to NAC. The expected consolidated estimate assumes an average 1.55 consolidation ratio compared with the unconsolidated case, allowing for the appropriate unconsolidated FCR plus an allowance of two unconsolidated reloads per reactor. The reload allowance takes account of the spent-fuel cooling necessary prior to consolidation.

An additional factor is applied for the assumption that, on average, only 90 percent of reactors will consolidate. The consolidation ratio also accounts for the storage of failed fuel and non-fuel bearing components. Furthermore, certain reactors are assumed not to consolidate because of specific constraints. The two reference capacity estimates are shown by reactor in Appendix A. The Team reference cases for the definition of additional fuel storage needs assume that currently planned/contracted fuel shipments will take place and that on-site transfer to and from like units on the same site will be fully utilized. This on-site transfer is in addition to the standard assumption on sharing common or interconnected pools. The planned shipments account for fuel being returned to reactor sites from the West Valley reprocessing site (to Ginna, Point Beach and Oyster Creek) and from the GE Morris site (to Point Beach). Also accounted for are shipments from reactor sites to the Morris site (from Cooper and Monticello) and to the Idaho National Engineering Laboratory (INEL) from Surry as a part of a dry storage cask demonstration program. In addition, modular dry storage plans at Robinson (NUHOMS) and dry cask storage at Surry are accounted for. The Team has evaluated two other scenarios: one assuming no on-site transfers or shipments beyond what has already occurred, and the other including transshipment between like reactors (PWR or BWR) within the same utility, along with the other reference case assumptions. These latter two scenarios are discussed further in the sensitivity section of this report.

B. Comparison of Reference Additional Storage Needs

The following reference estimates of additional spent-fuel storage needs are compared:

- DOE reference
- TVA maximum reracking (unconsolidated)
- TVA expected unconsolidated
- TVA consolidated
- Team unconsolidated
- Team expected consolidated

Using the discharge data from Section I and the storage capacities defined above, estimates of cumulative additional spent-fuel storage needs were defined through the year 2010 for the various alternatives, as possible. These are given in Table 5 and Figure 3. The following summary table compares the results in five-year increments. The year 1997 is also shown since it is the last year available for the DOE estimate and represents the amount of fuel to be stored prior to 1998, when DOE should begin accepting spent fuel.

Cumulative Additional Spent-Fuel Storage Needs (MTU)
(Reference Cases)

	DOE Reference	TVA			Team	
		Maximum Reracking Unconsolidated	Expected Unconsolidated	Consolidated	Unconsolidated	Expected Consolidated
1985	0	23	0	0	0	0
1990	544	578 (+6.3)*	147 (-73.0)	0 (-100)	163 (-70.0)	48 (-91.2)
1995	2,841	2,141 (-24.6)	758 (-73.3)	0 (-100)	1,343 (-52.7)	459 (-83.8)
1997	4,536	2,993 (-34.0)	1,085 (-76.1)	0 (-100)	2,165 (-52.3)	685 (-84.9)
2000	--	4,614	1,908	1	3,939	1,604
2005	--	7,714	3,343	113	8,287	3,778
2010	--	9,980	4,860	241	12,754	6,366
Year of First Need	1986	1983 (Only 4 MTU) Otherwise 1985	1986 (Only 1 MTU) Otherwise 1988	2000	1988	1989

The TVA and Team estimates through 1997 range from 34 to 100 percent below the DOE reference case. The differences are attributable to lower discharge estimates and the various scenarios with larger storage capacities. The first need for additional storage also varies substantially depending on the scenario selected.

The above comparisons refer to reference case additional storage needs in terms of MTU for both PWRs and BWRs combined. The following discussion will compare results in terms of cumulative number of assemblies for PWRs and BWRs separately. Since TVA has not provided conclusions in these terms, only the DOE and Team estimates will be discussed further.

* Percent difference from DOE reference

TABLE 5
CUMULATIVE ADDITIONAL SPENT-FUEL STORAGE NEEDS
REFERENCE CASES
(MTU - PWR and BWR Combined)

	DOE ¹ Reference	TVA ²			Team	
		Maximum Reracking	Expected	Consolidated	Unconsolidated	Expected
		Unconsolidated	Unconsolidated			Consolidated
1983	0	4	0	0	0	0
1984	0	4	0	0	0	0
1985	0	23	0	0	0	0
1986	20	59	1	0	0	0
1987	57	89	1	0	0	0
1988	168	240	48	0	8	0
1989	327	367	78	0	48	13
1990	544	578	147	0	163	48
1991	949	909	246	0	265	91
1992	1,292	1,090	314	0	415	141
1993	1,734	1,465	464	0	695	282
1994	2,326	1,717	558	0	942	301
1995	2,841	2,141	758	0	1,343	459
1996	3,650	2,493	901	0	1,664	500
1997	4,536	2,993	1,085	0	2,165	685
1998	--	3,400	1,320	0	2,666	921
1999	--	3,987	1,524	0	3,116	1,170
2000	--	4,614	1,908	1	3,939	1,604
2001	--	5,253	2,169	8	4,577	1,870
2002	--	5,891	2,437	62	5,380	2,341
2003	--	6,607	2,736	87	6,325	2,784
2004	--	7,182	3,000	87	7,134	3,202
2005	--	7,714	3,343	113	8,287	3,778
2006	--	8,134	3,554	113	9,167	4,367
2007	--	8,615	3,910	130	10,280	4,898
2008	--	9,079	4,137	130	11,251	5,449
2009	--	9,509	4,552	206	12,065	5,890
2010	--	9,980	4,860	241	12,754	6,366

1. From "Reactor-Specific Spent-Fuel Discharge Projections: 1984 to 2020," PNL-5396, April 1985 (data only given through 1997)

2. From transmittal from R. E. Hoskins, March 20, 1985

FIGURE 3

CUMULATIVE ADDITIONAL SPENT-FUEL STORAGE NEEDS

Table 6 shows the reference cumulative additional storage needs by number of PWR and BWR assemblies for the DOE reference case, the Team unconsolidated case, and the Team expected consolidated case. Figures 4a and 4b compare the PWR and BWR results, respectively, in graphical form. The following summary table compares the cumulative assembly storage needs in five-year increments; again the year 1997 is shown.

Cumulative Additional Spent-Fuel Storage Needs (Number of Assemblies)
(Reference Cases)

	DOE Reference		Team			
	PWR	BWR	Unconsolidated		Expected	Consolidated
			PWR	BWR	PWR	BWR
1985	0	0	0	0	0	0
1990	1,077	483	144 (-86.6)*	556 (+15.1)	112 (-89.6)	0 (-100)
1995	4,115	6,069	1,473 (-64.2)	3,897 (-35.8)	607 (-85.2)	1,086 (- 82.1)
1997	6,643	9,503	2,562 (-61.4)	5,840 (-38.5)	852 (-87.2)	1,750 (- 81.6)
2000	--	--	5,341	9,030	2,132	3,777
2005	--	--	12,065	17,047	5,132	8,636
2010	--	--	18,298	26,874	9,133	13,411
Year of First Need	1936	1987	1989	1988	1989	1992

The lower storage needs demonstrated by the Team unconsolidated estimates are due to lower fuel discharge estimates, changes in storage capacity, additional shipments, and on-site transfer. Consolidation clearly leads to a significant further reduction in additional storage needs.

* Percent difference from DOE reference

TABLE 6
CUMULATIVE ADDITIONAL SPENT-FUEL STORAGE NEEDS
REFERENCE CASES
(Assemblies)

	DOE Reference ¹		Team Unconsolidated		Team Expected Consolidated	
	PWR	BWR	PWR	BWR	PWR	BWR
1983	0	0	0	0	0	0
1984	0	0	0	0	0	0
1985	0	0	0	0	0	0
1986	50	0	0	0	0	0
1987	120	49	0	0	0	0
1988	379	49	0	43	0	0
1989	674	221	63	116	31	0
1990	1,077	483	144	556	112	0
1991	1,560	1,584	304	737	213	0
1992	2,113	2,176	471	1,164	267	146
1993	2,614	3,460	732	2,085	418	561
1994	3,278	5,185	1,091	2,599	463	561
1995	4,115	6,069	1,473	3,897	607	1,086
1996	5,271	7,838	2,004	4,407	703	1,086
1997	6,643	9,503	2,562	5,840	852	1,750
1998	--	--	3,282	6,892	1,117	2,423
1999	--	--	4,084	7,476	1,510	2,859
2000	--	--	5,341	9,030	2,132	3,777
2001	--	--	6,510	9,777	2,566	4,213
2002	--	--	7,630	11,543	3,077	5,596
2003	--	--	9,063	13,351	3,638	6,705
2004	--	--	10,233	15,037	4,169	7,746
2005	--	--	12,065	17,047	5,132	8,636
2006	--	--	13,234	19,122	5,950	9,941
2007	--	--	14,880	21,348	6,893	10,637
2008	--	--	16,112	23,774	7,645	11,886
2009	--	--	17,285	25,475	8,406	12,515
2010	--	--	18,298	26,874	9,133	13,411

1. From "Reactor-Specific Spent-Fuel Discharge Projections: 1984 to 2020," PNL-5396, April 1985

FIGURE 4A

CUMULATIVE ADDITIONAL SPENT-FUEL STORAGE NEEDS

FIGURE 4B

CUMULATIVE ADDITIONAL SPENT-FUEL STORAGE NEEDS

SECTION 3
SENSITIVITY ANALYSES ON SPENT-FUEL
DISCHARGES AND THE NEED FOR ADDITIONAL STORAGE

A. Team Spent-Fuel Discharge Estimates

In addition to the reference spent-fuel discharge case, the Team examined three other discharge scenarios, namely:

- Constant burnup at current levels
- 60 percent capacity factor
- No new reactor orders

In each case, other reference case assumptions were retained except for the one for which sensitivity was being analyzed. The following summary table provides an overview of the reference case assumptions compared to the assumptions for the sensitivity case:

	<u>Sensitivity Case</u>	<u>Reference Case</u>
1.	Constant burnup at current levels PWR - ~32,000 MWD/MT BWR - ~28,000 MWD/MT	Increasing burnup by 1996 to: PWR - 43,000 MWD/MT BWR - 36,000 MWD/MT
2.	Average 60 percent capacity factor	Average 64 percent capacity factor
3.	No replacement reactors	79 1,100 MWe replacement reactors added from 2004 to 2020

Table 7 summarizes the spent-fuel discharges from each of the sensitivity cases and compares them with the Team reference case. Results are provided in numbers of assemblies for PWRs and BWRs separately in five-year increments from 1985 to 2020. Percent differences from the reference case are also provided. Constant burnup at current levels results in an increase in the number of discharged assemblies of about 11 percent through 2000 and 14 to 15 percent through 2020. The result of operating at a 60 percent capacity factor (instead of 64 percent) is a decrease in cumulative discharges of about 5

TABLE 7
TEAM CUMULATIVE SPENT-FUEL DISCHARGE SENSITIVITY ANALYSES
Assemblies
(Percent Difference from Reference Case)

	Reference		Constant Burnup at Current Levels				60% Capacity Factor				No Replacement Reactors			
	PWR	BWR	PWR	%	BWR	%	PWR	%	BWR	%	PWR	%	BWR	%
1985	18,069	28,979	18,069	0.0	28,979	0	17,818	-1.4	28,469	-1.8	18,069	0.0	28,979	0.0
1990	30,608	46,490	31,298	+2.3	47,660	+2.5	29,286	-4.3	44,566	-4.1	30,608	0.0	46,490	0.0
1995	45,228	64,862	48,400	+7.0	69,626	+7.3	42,950	-5.0	61,958	-4.5	45,228	0.0	64,862	0.0
2000	59,298	83,055	65,769	+10.9	92,541	+11.4	56,073	-5.4	78,035	-6.0	59,298	0.0	83,055	0.0
2005	73,482	100,779	83,166	+13.2	114,522	+13.6	69,584	-5.3	95,262	-5.5	73,482	-1.6	100,779	0.0
2010	90,379	124,367	102,966	+13.9	141,479	+13.8	85,829	-5.0	118,062	-5.1	88,820	-1.7	122,143	-1.8
2015	108,607	146,170	123,995	+14.2	166,341	+13.8	102,727	-5.4	138,429	-5.3	100,301	-7.6	135,234	-7.5
2020	126,046	168,043	144,627	+14.7	181,517	+14.0	119,301	-5.4	159,562	-5.0	108,915	-13.6	145,303	-13.5

percent. In the no new reactor case, by 2020 there is a decrease in the cumulative quantity of fuel discharged of about 14 percent because of the decrease in number of reactors involved.

B. Additional Storage Needs

1. DOE. In addition to its reference case without transshipment, DOE analyzed a case for additional storage needs assuming transshipment between like reactors (BWR or PWR) within the same utility. The differences between the DOE cases with and without transshipment are shown in the following summary table.

Cumulative Additional Spent-Fuel Storage Needs (DOE)
Assemblies

	<u>Reference Without Transshipment</u>		<u>With Transshipment</u>	
	<u>PWR</u>	<u>BWR</u>	<u>PWR</u>	<u>BWR</u>
1985	0	0	0	0
1986	50	0	0 (-100)	0
1987	120	49	0 (-100)	49 (0)
1988	379	49	0 (-100)	49 (0)
1989	674	221	0 (-100)	221 (0)
1990	1,077	483	21 (- 98.1)	221 (-54.2)
1995	4,115	6,069	1,671 (- 59.4)	2,327 (-61.7)
1997	6,643	9,503	3,763 (- 43.4)	5,504 (-42.1)

The numbers in parentheses indicate the percent difference from the DOE reference case. For PWRs, transshipment delays the need for additional spent-fuel storage from 1986 to 1990. For BWRs, the small initial need is not delayed. However, for both PWRs and BWRs, the cumulative need for additional storage through 1997 is decreased by over 40 percent.

2. Team. The Team reference cases, unconsolidated and expected consolidated, include currently planned shipments and on-site transfers but do not include transshipments. Two sensitivity cases are examined for each reference case:

- No additional shipments beyond what has already occurred and no on-site transfers.
- Transshipment in addition to planned shipments and on-site transfers.

The no additional shipments case provides an upper bound on additional storage needs. The transshipment case represents the Team's lower bound. It includes transshipment between like reactors (PWR or BWR) within the same utility. An exception is the transshipment of spent fuel from Brunswick (BWR) to Harris (PWR). Table 8 shows the additional spent-fuel storage needs for the two Team sensitivity cases through 2010 and the reference cases. From Table 8 it can be seen that:

- For the no additional shipment/no on-site transfer cases, there is a significant advance in the date of the need for additional storage for PWRs. As expected, there is a substantial increase in the cumulative need for additional storage for both PWRs and BWRs through 2010.
- For the transshipment cases, substantial reductions in the additional needs for storage occur and the dates of the need are delayed.

Table 9 highlights the differences between the reference cases and the sensitivity cases in five-year increments. Percent differences from the reference case and the year of first need for additional spent-fuel storage are also shown. Data are shown separately for the unconsolidated and expected consolidated fuel cases.

For the unconsolidated case and no on-site transfer scenario, the first date for additional storage is advanced from 1989 to 1985 for PWRs and remains unchanged (1988) for BWRs. There are substantial increases in additional storage needs, compared to the reference case, which are most significant in the time period 1990 to 1995.

TABLE 8
TEAM CUMULATIVE ADDITIONAL SPENT-FUEL STORAGE NEEDS SENSITIVITY ANALYSES
Assemblies

	Team Reference*				No Additional Shipments No On-site Transfer				Transshipment, Planned Shipments, On-site Transfer			
	Unconsolidated		Expected Consolidated		Unconsolidated		Expected Consolidated		Unconsolidated		Expected Consolidated	
	PWR	BWR	PWR	BWR	PWR	BWR	PWR	BWR	PWR	BWR	PWR	BWR
1983	0	0	0	0	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	55	0	4	0	0	0	0	0
1986	0	0	0	0	210	0	109	0	0	0	0	0
1987	0	0	0	0	326	0	109	0	0	0	0	0
1988	0	43	0	0	567	43	224	0	0	0	0	0
1989	63	116	31	0	855	296	280	0	32	0	0	0
1990	144	556	112	0	1,123	1,000	421	0	32	0	0	0
1991	304	737	213	0	1,347	1,415	525	0	91	0	0	0
1992	471	1,164	267	146	1,702	2,324	752	154	148	0	0	0
1993	732	2,085	418	561	1,906	3,316	956	569	148	126	0	0
1994	1,091	2,599	463	561	2,340	3,928	1,124	709	313	276	0	0
1995	1,473	3,897	607	1,086	2,722	5,310	1,320	1,604	552	510	42	0
1996	2,004	4,407	703	1,086	3,326	6,000	1,597	1,800	804	803	42	0
1997	2,562	5,840	852	1,750	3,941	7,517	1,855	3,074	1,135	1,134	96	0
1998	3,282	6,892	1,117	2,423	4,719	8,794	2,185	3,747	1,753	1,728	251	0
1999	4,084	7,476	1,510	2,859	5,590	9,614	2,635	4,183	2,429	2,467	353	0
2000	5,341	9,030	2,132	3,777	6,919	11,863	3,330	5,092	3,635	4,214	936	80
2001	6,510	9,777	2,566	4,213	8,058	13,165	3,834	5,588	4,482	5,106	1,233	80
2002	7,630	11,543	3,077	5,596	9,347	15,375	4,348	6,937	5,381	7,210	1,582	625

* Includes planned shipments and on-site transfers; no transshipment

TABLE 8
TEAM CUMULATIVE ADDITIONAL SPENT-FUEL STORAGE NEEDS SENSITIVITY ANALYSES
Assemblies
(Continued)

	Team Reference*				No Additional Shipments No On-site Transfer				Transshipment, Planned Shipments, On-site Transfer			
	Unconsolidated		Expected Consolidated		Unconsolidated		Expected Consolidated		Unconsolidated		Expected Consolidated	
	PWR	BWR	PWR	BWR	PWR	BWR	PWR	BWR	PWR	BWR	PWR	BWR
2003	9,063	13,351	3,638	6,705	10,803	17,780	4,982	8,152	6,466	9,000	1,898	976
2004	10,233	15,037	4,169	7,746	11,959	19,646	5,513	9,288	7,623	11,032	2,366	2,492
2005	12,065	17,047	5,132	8,636	13,867	21,733	6,549	10,274	9,306	13,066	3,200	3,541
2006	13,234	19,122	5,950	9,941	15,045	23,892	7,412	11,838	10,433	15,084	3,813	4,918
2007	14,880	21,348	6,893	10,637	16,799	26,118	8,543	12,630	11,923	17,622	4,582	6,125
2008	16,112	23,774	7,645	11,886	18,121	28,544	9,379	14,167	13,120	19,776	5,355	7,102
2009	17,285	25,475	8,406	12,515	19,457	30,245	10,314	15,243	14,313	21,343	6,193	7,812
2010	18,298	26,874	9,133	13,411	20,549	31,644	11,184	16,139	15,401	22,604	6,967	8,570

* Includes planned shipments and on-site transfers; no transshipment

TABLE 9
TEAM CUMULATIVE ASSEMBLY ADDITIONAL SPENT-FUEL STORAGE NEEDS SENSITIVITY
(Percent Difference from Reference Cases)
Unconsolidated Case

	Team Reference*		No Additional Shipments No On-site Transfer				Transshipment, Planned Shipments, On-site Transfer			
	PWR	BWR	PWR	%	BWR	%	PWR	%	BWR	%
1985	0	0	55	--	0	0.0	0	0.0	0	0.0
1990	144	556	1,123	+680.0	1,000	+79.9	32	-77.8	0	-100.0
1995	1,473	3,897	2,722	+ 84.8	5,310	+36.3	552	-62.5	510	- 86.9
2000	5,341	9,030	6,919	+ 29.5	11,863	+31.4	3,635	-31.9	4,214	- 53.3
2005	12,065	17,047	13,867	+ 14.9	21,733	+27.5	9,306	-22.9	13,066	- 23.4
2010	18,298	26,874	20,549	+ 12.3	31,644	+17.7	15,401	-15.8	22,604	- 15.9
Year of First Need	1989	1988	1985		1988		1989		1993	

Expected Consolidated Case

	PWR	BWR	PWR	%	BWR	%	PWR	%	BWR	%
1985	0	0	4	--	0	0.0	0	0.0	0	0.0
1990	112	0	421	+276.0	0	0.0	0	-100.0	0	0.0
1995	607	1,086	1,320	+117.0	1,604	+47.7	42	- 93.1	0	-100.0
2000	2,132	3,777	3,330	+ 56.2	5,092	+34.8	936	- 56.1	80	- 97.9
2005	5,132	8,636	6,549	+ 27.6	10,274	+19.0	3,200	- 37.6	3,541	- 59.0
2010	9,133	13,411	11,184	+ 22.5	16,139	+20.3	6,967	- 23.7	8,570	- 36.1
Year of First Need	1989	1992	1985		1992		1995		2000	

* Includes planned shipments and on-site transfer; no transshipment

For the unconsolidated case with transshipment, the first date for additional storage is delayed from 1988 to 1993 for BWRs and remains unchanged (1989) for PWRs. Both PWRs and BWRs exhibit significant reductions in additional storage needs, which are again most significant in the period 1990 to 1995.

Similar tendencies are shown for the expected consolidated cases.

APPENDIX

APPENDIX A
STORAGE CAPACITIES AT TEAM REFERENCE REACTORS THROUGH 2000

Reactor	Commercial Operation Date	Net MWe	Assembly Storage Capacity	
			Unconsolidated	Expected Consolidated
Farley-1	77.92	804	1,407	1,840
Farley-2	81.50	829	1,407	1,840
Palo Verde-1	85.97	1,270	1,329	1,703
Palo Verde-2	86.92	1,270	1,329	1,703
Palo Verde-3	87.92	1,270	1,329	1,703
Arkansas Nuclear-1	74.92	836	968	1,224
Arkansas Nuclear-2	80.17	858	988	1,242
Calvert Cliffs-1	75.33	825	830	1,057
Calvert Cliffs-2	77.25	825	1,000	1,292
Pilgrim-1	72.92	670	2,320	2,855
Robinson-2	71.17	665	544	544
Brunswick-2	75.83	790	1,839	2,197
Brunswick-1	77.17	790	1,803	2,147
Harris-1	89.50	915	2,528	2,528
Perry-1	87.08	1,205	4,020	4,020
Dresden-1 (R)	60.58	197	720	820
Dresden-2	70.58	772	3,537	4,506
Dresden-3	71.67	773	3,537	4,506
Quad Cities-1	73.08	769	3,657	3,657
Quad Cities-2	73.17	769	3,897	3,897
Zion-1	73.92	1,040	0 }	0 }
Zion-2	74.67	1,040	2,079 }	2,743 }
La Salle-1	82.75	1,078	1,080	1,462
La Salle-2	84.33	1,078	1,080	1,462
Byron-1	85.50	1,120	0 }	0 }
Byron-2	88.83	1,120	1,050 }	1,519 }
Braidwood-1	89.42	1,120	0 }	0 }
Braidwood-2	90.42	1,120	1,050 }	1,519 }

(R) = Retired

} = Share common pool

APPENDIX A
STORAGE CAPACITIES AT TEAM REFERENCE REACTORS THROUGH 2000
(Continued)

Reactor	Commercial Operation Date	Net MWe	Assembly Storage Capacity	
			Unconsolidated	Expected Consolidated
Connecticut Yankee	68.00	555	1,168	1,523
Indian Point-1 (R)	62.75	262	756	1,004
Indian Point-2	74.50	849	980	1,232
Big Rock Point	63.17	64	545	710
Palisades	71.92	635	892	1,108
La Crosse	69.83	48	440	565
Ferme-2	85.92	1,123	2,305	2,681
Oconee-1	73.50	860	0	0
Oconee-2	74.67	860	1,312	1,651
Oconee-3	74.92	860	825	1,024
Mc Guire-1	81.92	1,180	1,463	1,916
Mc Guire-2	84.17	1,180	1,463	1,913
Catawba-1	85.42	1,145	3,000	4,058
Catawba-2	87.00	1,145	3,000	4,058
Beaver Valley-1	76.75	810	833	1,041
Beaver Valley-2	88.00	852	1,088	1,396
Crystal River-3	77.17	782	1,157	1,490
Turkey Point-3	72.92	646	1,404	1,846
Turkey Point-4	73.67	646	1,404	1,842
St. Lucie-1	76.92	817	728	1,008
St. Lucie-2	83.58	842	1,076	1,546
Hatch-1	75.92	757	3,181	4,211
Hatch-2	79.67	771	2,845	3,743
Vogtle-1	90.00	1,100	936	1,343
River Bend-1	86.92	934	3,172	4,052
Clinton-1	87.67	950	2,672	3,296

(R) = Retired

} = Share common pool

APPENDIX A
STORAGE CAPACITIES AT TEAM REFERENCE REACTORS THROUGH 2000
(Continued)

Reactor	Commercial Operation Date	Net MWe	Assembly Storage Capacity	
			Unconsolidated	Expected Consolidated
D. C. Cook-1	75.58	1,044	0}	0}
D. C. Cook-2	78.50	1,082	2,270}	2,959}
Duane Arnold	74.42	515	2,050	2,616
Oyster Creek	69.92	620	2,600	3,241
Wolf Creek	85.75	1,150	1,340	1,733
Waterford-3	85.92	1,104	1,366	1,760
Maine Yankee	72.92	810	1,476	1,907
TMI-1	74.67	776	2,283	3,043
Grand Gulf-1	85.00	1,250	5,148	5,148
Cooper	74.50	764	2,566	3,361
Nine Mile Point-1	69.92	610	2,776	3,473
Nine Mile Point-2	89.17	1,080	4,049	5,128
Millstone-1	70.92	654	2,184	2,655
Millstone-2	75.92	864	667	913
Millstone-3	88.17	1,159	1,836	2,426
Monticello	71.50	536	2,237	2,845
Prairie Island-1	73.92	503	0}	0}
Prairie Island-2	74.92	500	1,574}	2,068}
Fort Calhoun-1	73.67	478	728	926
Humboldt Bay (R)	63.58	63	486	605
Diablo Canyon-1	85.33	1,084	1,400	1,612
Diablo Canyon-2	86.17	1,106	1,400	1,612
Susquehanna-1	83.42	1,052	2,840	3,613
Susquehanna-2	85.08	1,052	2,840	3,613
Peach Bottom-2	74.50	1,051	2,816	3,418
Peach Bottom-3	74.92	1,035	2,816	3,405

(R) = Retired

} = Share common pool

APPENDIX A
STORAGE CAPACITIES AT TEAM REFERENCE REACTORS THROUGH 2000
(Continued)

Reactor	Commercial Operation Date	Net MWe	Assembly Storage Capacity	
			Unconsolidated	Expected Consolidated
Limerick-1	88.42	1,065	2,862	3,485
Trojan	76.33	1,080	1,408	1,845
Fitzpatrick	75.50	810	2,434	3,020
Indian Point-3	76.58	965	840	1,028
Seabrook-1	87.92	1,194	1,220	1,575
Salem-1	77.42	1,079	1,170	1,489
Salem-2	81.75	1,104	1,170	1,520
Hope Creek-1	88.00	1,067	3,666	3,666
Ginna	70.17	470	1,016	1,346
Rancho Seco-1	75.25	873	1,080	1,388
Virgil C Summer	84.00	900	1,276	1,658
San Onofre-1	68.00	436	216	216
San Onofre-2	83.58	1,140	800	800
San Onofre-3	84.25	1,140	800	800
South Texas Proj-1	88.00	1,250	2,100	2,800
South Texas Proj-2	90.08	1,250	2,100	2,800
Browns Ferry-1	74.58	1,065	3,471	4,509
Browns Ferry-2	75.17	1,065	3,471	4,509
Browns Ferry-3	77.17	1,065	3,471	4,359
Sequoyah-1	81.50	1,128	0 }	0 }
Sequoyah-2	82.42	1,140	1,386 }	1,721 }
Watts Bar-1	85.67	1,165	0 }	0 }
Watts Bar-2	88.17	1,165	1,312 }	1,618 }
Bellefonte-1	89.00	1,235	1,058	1,317
Bellefonte-2	91.33	1,235	1,058	1,317

(R) = Retired

} = Share common pool

APPENDIX A
STORAGE CAPACITIES AT TEAM REFERENCE REACTORS THROUGH 2000
(Continued)

Reactor	Commercial Operation Date	Net MWe	* Assembly Storage Capacity	
			Unconsolidated	Expected Consolidated
Comanche Peak-1	86.67	1,150	1,364	1,813
Comanche Peak-2	88.17	1,150	1,364	1,813
Davis Besse-1	78.50	890	735	1,040
Callaway-1	84.92	1,150	1,340	1,732
Vermont Yankee	72.83	504	2,500	3,263
Surry-1	72.92	775	0 }	0 }
Surry-2	73.33	775	1,149 }	1,149 }
North Anna-1	78.42	865	0 }	0 }
North Anna-2	80.92	865	1,737 }	2,249 }
WNP-2	84.92	1,103	2,658	3,269
Point Beach-1	70.92	495	0 }	0 }
Point Beach-2	72.75	495	1,502 }	1,999 }
Kewaunee	74.42	509	990	1,305
Yankee	61.50	175	721	947

(R) = Retired

} = Share common pool

OPTIMIZED TRANSPORTATION SCHEME

DRAFT

October 1985

NUCLEAR ASSURANCE CORPORATION
5720 Peachtree Parkway
Norcross, Georgia 30092
Telephone: (404) 447-1144
Telex: 6827020, 6827114

P. O. Box 40158
Grand Junction, Colorado 81504
Telephone: (303) 245-4320

Weinbergstrasse 9
8001 Zurich, Switzerland
Telephone: (01) 470844
Telex: 57275

2-21-4 Nishi Azabu
Minato-ku,
Tokyo 106, Japan
Telephone: (03) 4077734
Telex: 2422022

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OPTIMIZED TRANSPORTATION SCHEME

The spent-fuel cask handling and transportation capabilities for each plant in the U.S. are the primary factors in determining the mode of transportation of spent fuel from the reactors. Based on current capabilities and conditions with current cask models, approximately 70 and 30 percent of the reactors are capable of shipping by rail and truck, respectively. However, since conditions are expected to change with respect to shipping spent fuel, an optimized transportation scheme would detail the optimum and expected transportation modes and cask models.

The optimized transportation scheme was developed by reviewing individual reactor capabilities with respect to cask handling and transportation capabilities. The reactor and site parameters evaluated to determine the optimum cask and transportation mode included crane capacity, cask set down area dimensions and access capability. The primary source of the reactor and site data was PNL-5384, Spent Nuclear Fuel Shipping Cask Handling Capabilities of Light Water Reactors, April 1985. NAC supplemented these data with reactor and site specific data gathered from recent plant visits where appropriate. The fundamental criterion was to utilize the largest (highest capacity) cask capable of being handled by the reactor and transported effectively. In addition, it was assumed that the 25 ton and 40 ton cask models would be transported on the highway as legal and overweight shipments, respectively. The larger cask models (70, 100 and 125 tons) are assumed to be shipped by rail. Within the evaluation, there are instances in which intermodal shipments (heavy-haul and barge-rail) have been assumed. This analysis has assumed all fuel to be standard PWR and BWR fuel as defined by the DOE utility waste contract. No special cask or transportation mode exceptions have been made for non-standard (e.g., extra long) fuel.

Table 1 lists individual reactor and site values used in the evaluation in addition to the optimum transportation scheme. The notes to the table are an integral part of the evaluation and should be considered when reviewing the results. Of the 119 reactors listed on the table, 75 reactors were determined to be limited to using a 125 ton cask, 25 reactors would be limited to

transporting a 100 ton cask and only 4 reactors would be limited to a 70 ton cask. The 125, 100 and 70 ton cask models were assumed to be shipped predominantly by rail and represent 87 percent of the reactors. Truck shipments were assumed to be performed by utilizing 40 and 25 ton cask models. There are a total of 10 and 4 reactors that are limited to shipping 40 and 25 ton casks, respectively. Thus, 13 percent of the plants are assumed to perform truck shipments.

The results presented in the optimized transportation scheme have been developed based upon the current data available and current spent-fuel transportation practices. There are several concepts which have the potential to modify the results and reduce the number of spent-fuel cask shipments, but these require further investigation and analysis and are not included in this evaluation. These specific topic areas include the utilization of a transfer cask, on-site transshipment, transporting the 25 and 40 ton cask on rail, the feasibility of a 150 ton cask and the need for a 70 ton cask model.

For plants limited to 25, 40 and 70 ton cask models because of plant crane capacity, the utilization of a transfer cask and a larger (100 or 125 ton) rail cask could be beneficial in reducing the shipment miles and the number of shipments. The basic concept would be that a large cask would be transported to the site and set up at a staging area by using a mobile crane. The transfer cask would be loaded with spent fuel in the spent-fuel pool and moved to the staging area, where the fuel would be transferred into the larger cask. The required further analysis would entail a plant-by-plant evaluation to determine the feasibility of transporting a larger cask to and from the site, the conceptual design and operation, and the cost/benefit analysis. A similar topic would be on-site transshipment. This concept is described by the situation where there are at least two reactors with separate spent-fuel pools on one site and one reactor has a more limiting conditioning (i.e., a smaller crane capacity) than the other reactor. It is feasible to transfer or transship from the reactor with the more limiting condition to the other unit and ship to the MRS or repository from the second unit in a larger cask. The additional analysis required would cover the impacts on the utility, including cost, radiation exposure and storage space, and the benefit to the overall system.

Another area requiring additional investigative analysis is the transportation of truck casks (25 and 40 ton models) by rail. Based upon initial review, this alternative would reduce the shipment miles when placing multiple casks on a train. However, this may increase the cost in terms of railcars and trailers required and may increase the number of casks required because of possible lower cask utilization. Additional analysis can cover the assumption of intermodal (heavy-haul and barge-rail) shipments in terms of feasibility, cost and operational procedures. In addition, further analysis can review the cost/benefit to shipping as a common carrier compared to dedicated train.

While reviewing each plant's crane capacity, it was noted that 17 out of 118 reactors have a crane capacity of 150 tons. Based upon our transportation knowledge, 150 ton load casks can be easily handled by the railroad. However, the dimensional limit of 120 inch maximum width for free interchange may be the limiting parameter. This dimensional limit encompasses the entire cask package, primarily including the cask and impact limiters. There may be some specific cask design and materials that would allow the utilization of a 150 ton cask. The cost of cask manufacturing, material availability and specific plant feasibility, among other factors, needs to be investigated further. In addition, a 150 ton or larger cask may have an overwhelming benefit in shipping from the MRS to the repository.

It should be noted that DOE has plans to issue two procurement activities of special interest directly related to some of these topics. In the near future DOE has plans to contract for reactor site interface evaluation with respect to spent fuel shipping. There is a great benefit in having qualified, experienced, spent-fuel shipping personnel to evaluate each site as to its actual cask handling situation and site access. In addition, in the Draft Transportation Business Plan, DOE has outlined plans to perform a design completion for a new generation of transportation and dual purpose (storage/transport) casks. DOE is strongly encouraged to continue these and other efforts so as to clearly define the optimum transportation scheme. In 1984, DOE awarded several contracts in the Program Research and Development Analysis (PRDA) area. The complete results of these contracts should be available in November/December 1985. Several of these contracts and their results could impact the results of this optimum transportation scheme, especially in large cask, mobile consolidation equipment, and dual and universal cask utilization.

TABLE 1
REACTOR OPTIMIZED TRANSPORTATION SCHEME

Plant Name	Crane Capacity (Tons)	Cask Setdown			Rail Access		Optimized Transportation Scheme						
		Area Depth	Dimensions (feet)		Plant Site	Railhead Distance	Cask Model						
			Width	Length			25	40	70	100	125	Hwy	Transportation Mode Intermodal (DIST)
Arkansas Nuclear One - 1 (PWR)	100	43.0	9.50	10.2	Y	0.00 mi.			X				X
Arkansas Nuclear One - 2 (PWR)	100	43.0	9.50	10.2	Y	0.00 mi.			X				X
Arnold (BWR)	100	39.1	9.00	10.0	Y	0.00 mi.			X				X
Beaver Valley - 1 (PWR)	125	41.5	12.00	12.0	Y	0.00 mi.				X			X
Beaver Valley - 2 (PWR)	125	41.5	12.00	12.0	Y	0.00 mi.				X			X
Bellefonte - 1 (PWR)	150	43.0	12.00	12.0	Y	0.00 mi.				X			X
Bellefonte 2 (PWR)	150	43.0	12.00	12.0	Y	0.00 mi.				X			X
Big Rock Point (BWR)	24	31.0	5.00	7.0	N	0.00 mi.	X					X	
Braidwood - 1 (PWR)	125	41.0	11.00	11.0	Y	0.00 mi.				X			X
Braidwood - 2 (PWR)	125	41.0	11.00	11.0	Y	0.00 mi.				X			X
Browns Ferry - 1 (BWR)	106	39.0	8.00	8.0	N	7.00 mi.			X				7.00 mi.
Browns Ferry - 2 (BWR)	106	39.0	8.00	8.0	N	7.00 mi.			X				7.00 mi.
Browns Ferry - 3 (BWR)	106	39.0	8.00	8.0	N	7.00 mi.			X				7.00 mi.
Brunswick - 1 (BWR)	125	38.8	10.30	10.3	Y	0.00 mi.				X			X
Brunswick - 2 (BWR)	125	38.8	10.30	10.3	Y	0.00 mi.				X			X
Byron - 1 (PWR)	125	40.0	9.00	9.0	Y	0.00 mi.				X			X
Byron - 2 (PWR)	125	40.0	9.00	9.0	Y	0.00 mi.				X			X
Callaway - 1 (PWR)	150	44.3	16.00	18.0	N	0.00 mi.				X			N/A
Calvert Cliffs - 1 (PWR)	150	41.0	9.00	11.0	N	50.00 mi.	X					X	
Calvert Cliffs - 2 (PWR)	150	41.0	9.00	11.0	N	50.00 mi.	X					X	
Catawba - 1 (PWR)	125	48.4	9.10	11.5	Y	0.00 mi.				X			X
Catawba - 2 (PWR)	125	48.4	9.10	11.5	Y	0.00 mi.				X			X
Clinton - 1 (BWR)	125	43.0	8.70	8.7	Y	0.00 mi.				X			X
Comanche Peak - 1 (PWR)	130	47.0	13.00	13.0	Y	0.00 mi.				X			X
Comanche Peak - 2 (PWR)	130	47.0	13.00	13.0	Y	0.00 mi.				X			X
Cooper (BWR)	100	38.7	N/A	N/A	Y	0.00 mi.			X				X
Crystal River - 3 (PWR)	120	43.7	10.00	10.0	N	1.00 mi.			X				1.00 mi.
D. C. Cook - 1 (PWR)	150	44.3	11.00	11.0	Y	0.00 mi.				X			X
D. C. Cook - 2 (PWR)	150	44.3	11.00	11.0	Y	0.00 mi.				X			X
Davis Besse (PWR)	125	42.0	10.00	10.0	Y	0.00 mi.				X			X
Diablo Canyon - 1 (PWR)	125	45.5	10.00	10.0	N	20.00 mi.			X				20.00 mi.
Diablo Canyon - 2 (PWR)	125	45.5	10.00	10.0	N	20.00 mi.			X				20.00 mi.

TABLE 1
REACTOR OPTIMIZED TRANSPORTATION SCHEME
(Continued)

Plant Name	Crane Capacity (Tons)	Cask Setdown			Rail Access		Optimized Transportation Scheme						
		Area Depth	Dimensions (feet)		Plant Site	Railhead Distance	Cask Model						
			Width	Length			25	40	70	100	125	Hwy	Transportation Mode
													Rail Intermodal (DIST)
Dresden - 1 (BWR)	75	40.0	10.00	15.8	Y	0.00 mi.			X				on site
Dresden - 2 (BWR)	125	37.8	8.00	12.0	Y	0.00 mi.					X		X
Dresden - 3 (BWR)	125	37.8	8.00	12.0	Y	0.00 mi.					X		X
Farley - 1 (PWR)	125	40.6	11.00	13.3	Y	0.00 mi.					X		X
Farley - 2 (PWR)	125	40.6	11.00	13.3	Y	0.00 mi.					X		X
Fermi - 2 (BWR)	125	37.7	9.00	9.0	Y	0.00 mi.					X		X
Fitzpatrick (BWR)	125	39.0	12.00	14.0	Y	0.00 mi.					X		X
Fort Calhoun (PWR)	75	44.0	7.30	7.7	N	6.00 mi.			X				6.00 mi.
Ginna (PWR)	40	40.0	12.40	12.4	N	5.00 mi.	X					X	
Grand Gulf - 1 (BWR)	150	49.0	16.00	16.0	Y	0.00 mi.					X		X
Haddam Neck (PWR)	100	35.0	6.50	6.5	N	15.00 mi.		X				X	
Harris - 1 (PWR)	150	35.0	12.00	12.0	Y	0.00 mi.					X		X
Hatch - 1 (BWR)	125	39.0	12.00	14.0	Y	0.00 mi.					X		X
Hatch - 2 (BWR)	125	39.0	12.00	14.0	Y	0.00 mi.					X		X
Hope Creek (BWR)	150	45.0	11.00	11.0	N	15.00 mi.					X		15.00 mi.
Humboldt Bay (BWR)	75	36.0	12.50	10.0	N	--	X					X	
Indian Point - 1 (PWR)	75	40.0	10.00	19.0	N	1.50 mi.		X					X
Indian Point - 2 (PWR)	40	40.4	8.00	8.0	N	1.50 mi.	X					X	
Indian Point - 3 (PWR)	40	40.0	7.90	8.4	N	1.50 mi.	X					X	
Kewaunee (PWR)	125	40.8	9.50	9.5	N	5.00 mi.					X		5.00 mi.
La Crosse (BWR)	50	36.8	5.50	5.5	N	0.00 mi.	X					X	
La Salle - 1 (BWR)	125	44.0	10.00	10.0	Y	0.00 mi.					X		X
La Salle - 2 (BWR)	125	44.0	10.00	10.0	Y	0.00 mi.					X		X
Limerick - 1 (BWR)	110	42.0	9.00	14.0	Y	0.00 mi.				X			X
Maine Yankee (PWR)	125	36.5	10.00	10.0	Y	0.00 mi.					X		X
McGuire - 1 (PWR)	125	48.4	9.10	11.1	Y	0.00 mi.					X		X
McGuire - 2 (PWR)	125	48.4	9.10	11.1	Y	0.00 mi.					X		X
Millstone - 1 (BWR)	110	38.8	7.30	7.3	Y	0.00 mi.				X			X
Millstone - 2 (PWR)	100	38.5	9.00	9.0	Y	0.00 mi.				X			X
Millstone - 3 (PWR)	100	--	--	--	Y	0.00 mi.				X			X
Monticello (BWR)	85	39.0	6.00	9.0	Y	0.00 mi.			X				X

TABLE 1
REACTOR OPTIMIZED TRANSPORTATION SCHEME
(Continued)

TABLE 1
REACTOR OPTIMIZED TRANSPORTATION SCHEME
(Continued)

Plant Name	Crane Capacity (Tons)	Cask Setdown			Rail Access		Optimized Transportation Scheme						
		Area Dimensions (feet)	Length		Plant Site	Railhead Distance	Cask Model						
		Depth	Width	Length			25	40	70	100	125	Hwy	Transportation Mode
													Intermodal (DIST)
Sequoyah - 1 (PWR)	125	25.0	12.00	12.0	Y	0.00 mi.				X	X		X
Sequoyah - 2 (PWR)	125	25.0	12.00	12.0	Y	0.00 mi.				X	X		X
South Texas - 1 (PWR)	150	41.0	10.00	10.0	Y	0.00 mi.				X	X		X
South Texas - 2 (PWR)	150	21.0	10.00	10.0	Y	0.00 mi.				X	X		X
St. Lucie - 1 (PWR)	105	41.2	10.00	12.0	N	5.00 mi.	X					X	
St. Lucie - 2 (PWR)	150	41.2	11.60	12.5	N	5.00 mi.		X				X	
Summer (PWR)	125	39.0	13.00	13.0	Y	0.00 mi.					X		
Surry - 1 (PWR)	125	40.5	12.00	12.0	N	26.00 mi.				X	X		X
Surry - 2 (PWR)	25	40.5	12.00	12.0	N	26.00 mi.				X	X		X
Susquehanna - 1 (BWR)	125	38.8	9.00	14.0	Y	0.00 mi.				X	X		X
Susquehanna - 2 (BWR)	125	38.8	9.00	14.0	Y	0.00 mi.				X	X		X
Three Mile Island - 1 (PWR)	110	44.5	7.33	7.9	Y	0.00 mi.			X		X		X
Trojan (PWR)	125	43.5	9.00	12.0	N	2.00 mi.				X	X		2.00 mi.
Turkey Point - 3 (PWR)	105	40.0	9.80	10.1	N	10.00 mi.	X					X	
Turkey Point - 4 (PWR)	105	40.0	9.80	10.1	N	10.00 mi.	X					X	
Vermont Yankee (BWR)	110	38.8	7.00	7.0	Y	0.00 mi.			X				
Yogtle - 1 (PWR)	125	46.4	13.40	13.4	Y	0.00 mi.					X		
WNP - 2 (BWR)	125	39.0	8.00	8.0	N	0.25 mi.				X	X		
Waterford - 3 (PWR)	125	45.5	12.00	13.0	Y	0.00 mi.				X	X		
Watts Bar - 1 (PWR)	125	50.0	8.10	8.1	Y	0.00 mi.				X	X		
Watts Bar - 2 (PWR)	125	50.0	8.10	8.1	Y	0.00 mi.				X	X		
Wolf Creek (PWR)	150	46.5	14.00	14.0	Y	0.00 mi.				X	X		
Yankee (PWR)	35	37.0	5.00	5.0	N	25.00 mi.	X					X	
Zion - 1 (PWR)	125	40.5	8.30	8.3	Y	0.00 mi.				X	X		X
Zion - 2 (PWR)	125	40.5	8.30	8.3	Y	0.00 mi.				X	X		X

TABLE 1
REACTOR OPTIMIZED TRANSPORTATION SCHEME
NOTES

1. Intermodal (heavy-haul to railhead or barge/rail) shipments have been assumed at:

Browns Ferry 1, 2, 3
Callaway
Crystal River
Diablo Canyon
Hope Creek
Indian Point 1
Kewanuee

Ocone 1, 2 3
Peach Bottom 2, 3
Pilgrim
Salem
San Onofre 2, 3
Surry 1, 2
WNP-2

2. Calvert Cliffs 1 and 2 cask drop reanalysis has been assumed to allow at least the use of a 40 ton cask.
3. Diablo Canyon limited by original design analysis.
4. Plant access restricts the use of the optimum cask at Ginna.
5. Dimensional limits restrict the use of optimum cask at Haddam Neck.
6. A 40 ton cask shipped on the highway has been assumed for Humboldt Bay.
7. Plant limitations at La Crosse restrict the use to only a 25 ton cask.
8. Presently, the rail spur at Palisades has been asphalted over: however, the assumption is that when necessary the rail spur could be made operational.
9. A 125 ton crane upgrade is being planned at Point Beach 1 and 2.

TABLE 1
REACTOR OPTIMIZED TRANSPORTATION SCHEME
NOTES
(Continued)

10. An air pallet has to be utilized with a spent-fuel shipping cask and currently limits the use to a 25 ton cask at San Onofre-1. Reanalysis and use of a 40 ton cask has been assumed.
11. Cask drop analysis at St. Lucie 1 limits the use to a 25 ton cask and reanalysis is unlikely to increase limit.
12. Roads surrounding the St. Lucie site are limited to 80,000 lb GVW.
13. Site limitations at Turkey Point 3 and 4 restrict the use to a 25 ton cask.

EVALUATION OF THE NEED, FEASIBILITY, AND SITING OF THE MRS IN TENNESSEE

**Appendix: Financial Cost
of the Integrated Monitored Retrievable Storage Option**

Contractor Report
Prepared by

Institute for Energy Analysis
Oak Ridge Associated Universities
Post Office Box 117
Oak Ridge, Tennessee 37831-0117

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DRAFT

FINANCIAL COST OF THE INTEGRATED MONITORED RETRIEVABLE STORAGE OPTION

Introduction

The DOE case for integral monitored retrievable storage (MRS) is not based on cost savings; the benefits claimed for the MRS option are not easily expressed in financial terms and DOE has not tried to do so. Rather, DOE has compared the financial costs of the MRS with the projected costs of the entire DOE waste management program and then subjectively determined that the incremental financial cost to the Nuclear Waste Fund is an acceptable price for the various benefits. One benefit is a reduced need for at-reactor storage--costs borne directly by the utilities instead of indirectly through the Nuclear Waste Fund. When credit is taken for this saving, MRS financial costs are lower and it is this total financial cost to utilities which is to be weighed against the subjective benefits.

DOE estimates the total cost of the I-MRS option to be \$1.0 to 1.9 billion.* This range is solely a function of the range of assumed boundary conditions (i.e., repository media and at-reactor storage costs) and does not reflect the uncertainty of the estimates themselves. That is, DOE has presented estimates for several situations but has not presented information about the accuracy of its estimation techniques. Two questions are relevant: How uncertain are the estimates and how appropriate is the range of assumed boundary conditions? This paper reports a review of DOE's cost estimates and an examination of these questions.

Although the accuracy of cost estimates for systems as large and complex as those evaluated here cannot be certain, we find no reason to question the accuracy of these estimates as a basis for decisionmaking. They are roughly consistent with estimates by other DOE contractors. Furthermore, the additional systems costs incurred under the MRS option are

*DOE typically presents its cost data as undiscounted totals. For our purposes this assumption, that the time an expenditure occurs does not matter, is not unreasonable; the options being evaluated do not materially change the timing of expenditures. At a discount rate of 3%, the present worth costs are approximately 60 percent of the undiscounted totals.

largely the costs of supporting an additional site and these costs are better known than are the costs of other major components of the waste management program. For instance, fuel consolidation costs are not well known. But in comparing systems with and without MRS, the cost and uncertainty of fuel consolidation is irrelevant; only the location changes. Thus, uncertainties in estimating net MRS costs are relatively smaller than are uncertainties in estimating total system costs.

The range of situations or boundary conditions evaluated by DOE varies only two parameters: repository medium and at-reactor storage cost. Other relevant parameters include need for at-reactor storage, transportation system efficiency, and whether and where fuel consolidation takes place. Evaluation of DOE's assumptions suggests that need for storage has been overestimated, overstating the savings of at-reactor utility costs. MRS' impact on transportation cost is relatively insensitive to variation of the other parameters.

One major omission in DOE's estimates is compensation of the state and community for the socioeconomic costs of the MRS facility; a plausible estimate of this cost is \$0.8 billion over the life of the facility. The resulting net MRS cost rises to \$2.2 - 2.8 billion.

Altogether, this analysis suggests that MRS will cost about a billion dollars more than DOE has estimated. Using a net cost of \$2.5 billion and average burnup of 35,000 megawatt-days (thermal)/metric ton, MRS would cost 0.15 mills/kilowatt-hr. for the fuel going into the first repository.

MRS Cost Estimates

Table 1 summarizes DOE's MRS cost estimates. Net cost to the Nuclear Waste Fund is \$1.5-2.1 billion, depending on repository medium. Transportation cost differences are negligible. Of the net cost, \$0.5 billion is storage costs; the remaining \$1.0-1.6 billion is the cost of duplicated and additional capabilities resulting from the additional site (DOE,¹ Table 2.9).

Dividing the storage cost by 14,000 MTU (1,000 MTU of lag storage is included in the non-storage facilities) yields a unit cost of ~\$35/kgU. Storage at the MRS site replaces at-reactor options costing

Table 1. DOE Cost Estimates for MRS, Billion 1985 Dollars

	<u>Basalt</u>	<u>Salt</u>	<u>Tuff</u>
MRS facilities and operations	2.7	2.7	2.7
Savings at repository	-1.1	-1.0	-0.6
Incremental transportation cost	<u>-0.1</u>	<u>+0.1</u>	<u>0.0</u>
Net DOE cost	1.5	1.8	2.1
Utility storage savings	-0.5 to -0.2	-0.5 to -0.2	-0.5 to -0.2
Net utility cost	1.0 to 1.3	1.3 to 1.6	1.6 to 1.9

Source: DOE,¹ p. 1.2.25 and Tables H.8, H.9, H.10, and H.11; Scenario 4A (Eastern fuel only).

\$50-125/kgU (DOE,¹ p. J.26). Thus the highest MRS cost, from utilities' perspective, is a situation where the MRS site's storage capabilities do not replace needed at-reactor storage. DOE claims a credit of \$0.2 - 0.5 billion for at-reactor storage costs that MRS would obviate (4,000 MTU times the range of storage costs cited above).

Reliability of Estimates

DOE's cost estimates could be wrong either because of the many unknowns involved in a project of this magnitude (a random error), or because of a conscious or subconscious systematic bias. Adding MRS to the waste management system involves moving some facilities from the repository to another site and duplicating other facilities at the new site. The duplicated facilities are largely support related--security, site preparation, laboratory and monitoring, cask receiving and handling--and we have substantial experience with these kinds of items. The large unknowns are the production scale hot cells and equipment for disassembly and packaging, which will be built at one location or the other, and the underground portion of the repository. Any uncertainties here zero out when the two alternative systems are compared. Therefore, random uncertainties as to

differences between the alternatives are likely to be small compared with the uncertainties about total system cost.

Systematic error is more difficult to evaluate. We can compare DOE's estimates with those made by other parties but it is difficult to be sure one is matching truly comparable estimates. This test is limited, too, by the necessity to use estimates by DOE contractors as the "independent" values against which DOE estimates are compared. The estimates probably are not completely independent.

Table 2 compares estimates of transportation costs of MRS. The Westinghouse costs are for both repositories and assume that all fuel is shipped first to the MRS site; the costs for transportation to the first repository alone cannot be separated out. The three sources are in agreement as to the relative unimportance of transportation cost differences.

Table 2. Comparison of Transportation Costs With and Without MRS, \$ Billion^a

	<u>W/MRS</u>	<u>W/O MRS</u>	<u>Differences</u>
DOE	1.0	0.9	0.1
NUS	0.9	0.9	0.0
Westinghouse	1.7	1.4	0.3

^aTo salt repository except Westinghouse, which is combined cost to both repositories, salt and tuff respectively.

Sources: DOE - Ref. 1; NUS - Ref. 2; Westinghouse - Ref. 3

Johnson Associates provide the only detailed examination of the cost of fixed MRS facilities and their operation.⁴ The numbers in Table 3 must be viewed with caution as Johnson assumed a double-sized MRS serving both repositories. I estimate that \$0.7 billion of Johnson's MRS cost is associated with the second repository and that the net cost for the one repository case would be \$0.7 billion (compared with DOE's \$1.2 billion). This comparison is hardly definitive but indicates (1) that the two sources

Table 3. Comparison of MRS Costs and Repository Savings, \$ Billion

	<u>DOE</u>	<u>Johnson^a</u>	<u>Johnson^b</u>
MRS Facilities and Operations Less Storage	2.2	2.6	1.9
Savings at First Repository (salt)	-1.0	-1.2	-1.2
Savings at Second Repository (salt)	<u>na</u>	<u>-0.3</u>	<u>na</u>
Net Fixed Facilities Cost	1.2	1.1	0.7
Total Reference System Less Development and Evaluation	16.4	13.8	13.8

^aMRS facility serves both repositories, has throughput capacity of 6000 MTU/year.

^bAuthor's estimate of Johnson results for MRS serving only the first repository.

Sources: DOE - Ref. 1, except reference system cost from Ref. 6;
Johnson - Ref. 4.

agree within a factor of two and (2) that DOE's estimate is not biased downward.

Effect of Boundary Condition Assumptions

The cost of the entire spent fuel management program will depend on such factors as whether and where fuel is consolidated, the efficiency of the transportation system, and the need for out-of-pool storage. What effect do these factors have on the difference between system costs with and without MRS?

We do not have access to detailed computations with which to answer this question. Nevertheless, we can satisfactorily answer the question with simpler analyses.

Consider the transportation system. The effect of adding MRS to the system configuration is to increase average travel distance by roughly 40 percent while decreasing the number of casks and trips on the MRS-to-repository leg of the journey. In DOE's analysis, these effects are

approximately offsetting. If DOE were to forego consolidation, much of the saving on the final leg would be negated. Transportation costs might increase proportionally to the distance increase, 40 percent or \$0.4 billion. This appears to be the upper limit. For instance, at-reactor consolidation also negates the benefit of consolidation at MRS but reduces costs throughout the system by approximately the inverse of the consolidation ratios; the 40 percent increase because of distance is multiplied by a smaller base (no-MRS) transport cost. Transport system efficiencies, too, negate the transportation cost benefits of MRS but reduce the base cost. Thus, transportation cost differences are small under any set of assumptions.

For fixed facilities and operations we can perform a similar analysis. Should DOE drop fuel consolidation from the system for whatever reason, the cost differential would be the same with or without MRS. Net MRS costs result from duplication; removal of consolidation is unlikely to significantly change that net cost.

Need for and cost of at-reactor dry storage is the most important variable in assessing the cost of MRS to utilities. DOE places MRS-induced utility savings at \$0.2 - 0.5 billion. But the spent fuel forecast on which these savings are based appears dated and high.⁵ DOE says MRS will obviate 4,000 MTU of at-reactor storage. The forecast in Reference 5 shows 1,400 MTU to be a more reasonable estimate for the case with on-time repository startup (as DOE assumes). Using at-reactor storage costs in the middle of DOE's range implies likely savings of only \$0.1 billion.

Should the repository be significantly delayed without an MRS delay, storage-related savings would increase. Note that DOE's announced intention to link repository and MRS schedules limits storage savings because a repository delay is likely to delay MRS deployment. Postulating an extended repository delay that somehow does not delay MRS, storage savings might approach DOE's estimates for the on-time repository case, but this scenario is an unlikely one.

DOE's cost estimates apparently neglect state and community compensation, including, but not limited to, tax equivalency grants similar to those authorized for the first repository. The Oak Ridge community has requested compensation that might amount to \$10 million/year for 40 years.

Comparable compensation for the state would yield a total cost of \$0.8 billion. This level of compensation would be a significant component of MRS cost, amounting to roughly one-third of the total net cost.

Summary

DOE understates MRS costs in two ways. Most importantly, it neglects state and local compensation. Compensation could easily cost \$0.8 billion over the MRS project lifetime. DOE also overstates utilities' storage cost savings stemming from the earlier fuel acceptance possible with MRS. Instead of \$0.2 to 0.5 billion in savings, \$0.1 is a more likely estimate. These changes raise utilities net MRS cost by about \$1.0 billion, for a total cost to utilities of \$2.2 to 2.8 billion, depending on repository (Table 4).

Table 4. Likely MRS Cost, Billion 1985 Dollars

	<u>Basalt</u>	<u>Salt</u>	<u>Tuff</u>
Net DOE cost (from Table 1)	1.5	1.8	2.1
Compensation cost	<u>0.8</u>	<u>0.8</u>	<u>0.8</u>
Revised net DOE cost	2.3	2.6	2.9
Revised utility storage savings	<u>-0.1</u>	<u>-0.1</u>	<u>-0.1</u>
Revised net utility cost	2.2	2.5	2.8

Source: Author's estimates, see text.

The median, \$2.5 billion, might be considered the most likely cost. This increment is about 10 percent of DOE's estimated total program cost.⁶ For the fuel scheduled for the first repository, MRS adds 0.15 mills/kWh to its disposal cost. The MRS option is not cheap.

Against this substantial cost, Congress must weigh intangible benefits. DOE claims that the MRS option reduces interaction between the public and spent fuel transportation, that it allows transportation

planners a 5-year head start, that it gives utilities earlier and firmer information on which to base their spent fuel management plans, and that it decouples system components and allows greater operational flexibility, providing a cushion for various unforeseen technical or institutional problems. In DOE's view, these direct benefits increase the likelihood that the repository can be built on schedule. Whether Congress will agree with DOE that the benefits of having an MRS outweigh the costs remains to be seen.

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EVALUATION OF THE NEED, FEASIBILITY, AND SITING OF THE MRS IN TENNESSEE

Appendix: Rod Consolidation and the MRS

Contractor Report
Prepared by

Institute for Energy Analysis
Oak Ridge Associated Universities
Post Office Box 117
Oak Ridge, Tennessee 37831-0117

December 1985

DRAFT

TASK 4. ROD CONSOLIDATION

1. Waste handling system options and the role of rod consolidation.

It is difficult to grasp the role of any element of the spent fuel disposal system because of the diversity and complexity of fuel handling options. The options are displayed in general terms in Figure 1. The most important of these options are the following:

- Where to store the spent fuel--at-reactor in a pool, at-reactor dry, at an MRS, or in the repository.
- How long to store the fuel before final disposal.
- How to transport the fuel--truck, rail or some combination.
- Whether to consolidate* the fuel and where.

Rod consolidation has the general advantage of being able to increase the capacity of a given container or storage space. This parameter affects very broadly the costs and impacts of the spent fuel management system, as outlined in Section 1.3.

1.1 General description of rod consolidation options.

At-reactor consolidation

Spent fuel is stored as fuel elements in at-reactor storage pools. As the storage space is filled, utilities generally seek NRC permission to "rerack," providing a more compact arrangement of spent fuel elements. Most utilities have either already begun reracking or are expected to do so.

As spent fuel inventories continue to increase, utilities will reach a point where they will have to either (a) enlarge the pools, (b) ship spent fuel off-site, (c) build on-site dry storage facilities, or (d) consolidate the fuel and either return it to the pool or place it into dry storage. The Atomic Industrial Forum has created a Working Group on Rod Consolidation that is focusing on rod consolidation issues including

*Consolidation is the disassembly of nuclear fuel assemblies followed by repositioning of the fuel rods into a closely packed bundle.

Figure 1. Spent Fuel Options

interface questions such as acceptance criteria for dry storage or transfer to DOE. The Working Group has generated a list of reactor sites that will have to consider rod consolidation prior to 1998, shown in Table 1. The list includes 27 reactors.

Rod consolidation operations in reactor storage pools have been demonstrated, and other demonstrations are planned (Section 1.2). Several nuclear service companies currently offer to consolidate fuel in a storage pool under contract. The contract price for such service is expected to be in the range of \$10-15/kgU. Contrasted with expectations of \$70 to \$100/kg for on-site dry storage (unconsolidated), there is clearly a cost incentive to consolidation when running out of pool storage space.

The consolidation has economic merit for either continued in-pool storage or for on-site dry storage, cutting the cost of the latter option nearly in half as compared to unconsolidated storage.

Consolidation at an MRS.

Westinghouse/Parsons performed an assessment of process alternatives for an MRS fuel consolidation facility rated at 1800 MTU/yr.¹ This study considered both wet and dry alternatives. The dry horizontal facility operated remotely in a hot cell was considered most promising. This type of facility bears some resemblance to fuel disassembly equipment that might be associated with a fuel reprocessing plant.

Consolidation at a repository

The approach would be similar to that for an MRS.

1.2 Experience to date with rod consolidation.

Pacific Northwest Laboratory has summarized the status of rod consolidation technology.² The operation was demonstrated with four PWR fuel assemblies at the Oconee Nuclear Station (1982) and one PWR at Maine Yankee (1983). Additional demonstrations have been programmed under the sponsorship of DOE, EPRI, TVA and several investor-owned utilities.

Wet storage of the consolidated fuel is underway. Dry storage of consolidated spent fuel is to be part of a dry storage demonstration sponsored by Virginia Electric Power Company and DOE at Idaho Falls.¹

The experience gained with the development work thus far is favorable, and prospects for having this technology licensed by NRC are

Table 1. Reactors Potentially Requiring Additional On-Site Storage Capabilities Prior to 1998

<u>Unit</u>	<u>Company</u>	<u>Anticipated Loss of FCR Capability</u>
San Onofre 1	Southern Cal. Ed.	1982
Surry 1 & 2	VEPCO	1985
Millstone 2	NNEC	1986
Palisades	Consumers Power	1987
Grand Gulf 1	Mississippi P & L	1988
La Salle 1 & 2	Commonwealth Edison Company	1988
Millstone 1	NNEC	1988
Robinson 2	Carolina Power and Light	1988
Peach Bottom 2 & 3	Philadelphia Electric	1989
Oconee 1, 2, & 3	Duke Power	1990
Pilgram	Boston Edison Company	1990
Vermont Yankee	Vermont Yankee	1990
Brunswick 1 & 2	Baltimore G & E	1992
Calvert Cliffs 1 & 2	Baltimore G & E	1992
J. Fitzpatrick	New York Power Authority	1992
LaCrosse	Dairyland	1992
D. Besse 1	Toledo Edison	1993
Indian Point 3	New York Power Authority	1993
Monticello	Northern State	1993
Oyster Creek	GPU	1993

Source: Atomic Industrial Forum

considered good. The major concern that must be dealt with in future work is the control of radioactive crud that may become suspended in the storage pool, impairing visibility and creating low-level wastes. Another concern, that can be alleviated by consolidating only spent fuel that has been allowed to decay for about 10 years, is the extremely unlikely accidental loss of water from the pool leading to overheating; the aged fuel has a lower heat generation rate and would heat to a lesser extent.

1.3 Advantages/disadvantages of rod consolidation.

The generic advantages of rod consolidation are as follows:

- Substantially reduces the volume required to store or transport a given weight of fuel, to about half the volume required for fuel elements.
- The reduced volume reduces the costs of wet storage, dry storage and transportation.
- There are a reduced number of shipments, reducing radiation exposure and other transportation impacts.

The generic disadvantages are as follows:

- Provision must be made to deal with a higher amount of heat generation per unit volume.
- Provision must be made to deal with secondary low-level wastes released during consolidation--non-fuel bearing hardware and crud.
- There is radiation exposure during the consolidation operation.
- The costs in some cases may be greater than the benefits.

The advantages of consolidating spent fuel at the reactor site are as follows:

- Where pool storage volume is limited and DOE is not ready to accept the spent fuel, consolidation is likely to be the lowest cost strategy.
- The technology appears to be within reach, and competitive suppliers providing compacting services appear to be available.
- A number of utilities appear to be willing to try it.
- At-reactor consolidation minimizes subsequent transportation and storage costs and impacts.

The disadvantages appear to be as follows:

- Many utilities may be unwilling to diversify their activities into this area.
- Where ample pool storage volume is available, it may not be perceived as the lowest cost option.
- Technical problems may develop at some reactors with radioactive crud, personnel exposure, accidents, etc., making this an unattractive option.
- DOE interface requirements may not be stable, implying some financial risk.

The advantages of consolidating spent fuel at an MRS are as follows:

- It minimizes subsequent storage and transportation costs and impacts.
- Rod consolidation at a centralized facility should lead to economics of scale and uniform adherence to repository interface requirements.

The disadvantages appear to be as follows:

- Lack of demonstrated low-cost, worker-friendly technology (low radiation dose).
- If many utilities undertake to consolidate fuel rods at reactor pools, an uncertain throughput requirement. (Low capacity utilization would increase unit costs.)
- Aggregated benefits may not exceed increased costs.

The advantages of consolidating spent fuel at the repository are as follows:

- It minimizes emplacement costs in that fewer repository casks must be fabricated and emplaced.

The disadvantages appear to be as follows:

- Lack of demonstrated low-cost, worker-friendly technology.
- Aggregated benefits may not exceed increased costs.

2. Review of waste handling plans and studies.

2.1 The DOE Mission Plan³ and MRS Needs and Feasibility Study⁴

The DOE Mission Plan is based on the consolidation of spent fuel rods at the MRS. Fuel is then stored in reinforced concrete casks weighing 220 tons (loaded) and containing 20 tons of fuel rods. The incremental cost of storing these rods at the MRS is said to be less than \$20/kg. The report describes the DOE-utility cooperative program to develop at-reactor consolidation and states there will be some development of equipment suited to fuel consolidation at an MRS.

The needs and feasibility analysis included in Volume 2 of the submission to Congress gives estimates suggesting a storage cost closer to \$35/kg. A Prototypical Consolidation Demonstration Project is to develop and demonstrate dry consolidation and provide design data for the MRS production scale facilities, based on Westinghouse technology.

The Westinghouse fuel consolidation technology is described in references 5 and 6. It is a horizontal, dry, "pull-fuel" type of system operated in a hot cell with a processing capability of 1800 MTU/year. The cost claimed by Westinghouse, \$2.2/kgU,⁷ is substantially below the cost of at-reactor consolidation and below the cost of MRS consolidation inferred from reference 4, Table 1.

2.2 The PRDA Reports.

DOE sponsored a series of studies in response to a Program Research and Development Announcement (PRDA). These reports present innovative technology applicable to spent fuel handling and disposal.

Table 1. Cost of Fuel Consolidation

A. Total System Cost, Billion \$

Computed from MRS cost ^a	1.6
Computed from repository savings ^b - basalt	1.4
- salt	1.3
- tuff	.9

B. Unit cost,^c \$/kgU

	<u>Capital</u>	<u>Operating</u>	<u>Total</u>
Computed from MRS cost ^a	13.68	16.71	30.39
Computed from repository savings ^b - basalt	11.31	14.66	25.97
- salt	12.01	12.26	24.27
- tuff	9.08	8.60	17.68

^aScenario 3A, "Waste handling" only; excludes "Site" and "Support and Utilities" as these cannot be allocated between consolidation and storage. If attributed to consolidation, these components add \$0.7 billion or \$12.93/kgU to the total. Also excludes waste package costs of \$0.50/kg for basalt and salt or \$1.25/kgU for tuff.

^bDifference between Scenarios 1 and 3A.

^cAssumes capital costs spread evenly over 62,000 MTU over 30 years at 3% discount rate.

Source: Ref. 4, Tables H.7 and H.9.

Westinghouse-Tennessee Valley Authority-Florida Power & Light Company.⁸

This study builds on the previous Westinghouse references⁵⁻⁷ and represents a system study with various alternatives. The principal focus is on flexible large cast steel casks useful for storage and transportation, or useful for storage, transportation and emplacement in a repository. These universal casks have attractive features for minimizing spent fuel handling, and for some scenarios, cost. The largest metal casks considered can handle up to 24 PWR/52 BWR assemblies or fuel rods from 48 PWR/104 BWR assemblies.

E.R. Johnson Associates⁹

This study develops data and costs for a number of system options with or without an MRS.

Transnuclear¹⁰

This study focuses on the conceptual design of extra large storage and transport casks with capacities up to 57 PWR/148 BWR intact assemblies or 117 PWR/293 BWR consolidated assemblies. The large capacity is achieved partly by using thermally conducting baskets within the cask and external cooling fins. The report also describes a transportable dry fuel consolidation rig suitable for temporary operation at a reactor site. This rig has a claimed capacity of 1.5 MTU/day.

GA Technologies¹¹

This study focuses on a universal canister suitable for containing 3 PWR/6 BWR fuel assemblies or consolidated fuel rods from up to 8 PWR/16 BWR assemblies. Up to 6 canisters can be fitted into a shipping or storage cask. This report has more neutronic-thermal analysis as a function of fuel exposure time from discharge than other reports in this series.

NUS Corporation¹²

The study focuses on the efficacy of half-square cans to increase the carrying capacity of truck casks. The study concludes that a legal weight truck cask for 6 PWR/16 BWR consolidated fuel elements is feasible and NUS states that the availability of this technology enhances the attractiveness of at-reactor consolidation since a feasible truck transport scheme is available.

2.3 The NAC Study Reports.^{13, 14}

The Nuclear Assurance Corporation has performed some computations and analysis for the University of Tennessee's MRS assessment project. The first of these reports reviews DOE's projections of spent fuel discharges and finds them to be high. This report also develops projections of the

spent-fuel storage capacity short-fall and shows that rod consolidation can substantially reduce the projected needs for (at-reactor or at-MRS) storage capacity.

The second report estimates the costs and impacts of optimized spent fuel transportation schemes, considering also whether fuel is consolidated and/or whether there is an MRS. The data indicate that relatively large economies are possible from optimized transport (preference for rail and large casks) and smaller economies from rod consolidation. The report considers up to 125 ton rail casks capable of handling 31 PWR/72 BWR fuel elements or consolidated fuel from 56 PWR/122 BWR fuel assemblies.

2.4 Other relevant studies and reports.

E.R. Johnson Associates conducted a study comparing fuel bundle disassembly and close packing of fuel pins against 4 other alternative spent fuel management schemes. Conceptual plant designs were prepared and evaluated. The disassembly-consolidation approach was favored over the others, principally because it had the most favorable economics.¹⁵

K.L. Huppert,¹⁶ Gesellschaft zur Wiederaufarbeitung von Kernbrennstoffen mbH, reported that more than 80 tonnes of spent LWR fuel had been disassembled underwater at Karlsruhe prior to reprocessing. "In spite of the fact that burnups were high (up to 39,000 MWd/t) and that pulling the pins out of the spacers is a rude treatment, practically no breakage of pins has occurred."

3. Discussion and overall conclusions.

3.1 Desirability/undesirability of rod consolidation.

The work performed to date has uncovered certain benefits from rod consolidation and certain costs. The benefits, which are more clearly defined than the costs, include:

- increasing the capacity of at-reactor storage pools.
- reducing the number of packages for spent fuel storage, transportation and burial.
- reducing the radiation dosage in transportation, and the transport risks and visual impacts.

The costs, not well defined at present, include:

- economic costs of consolidation in a manner consistent with occupational safety.
- increased radiation dosage in the consolidation operation and in disposal of byproduct low-level wastes to be traded off against reduced radiation exposure in transportation and during final disposal at the repository.
- risks of incidents/accidents during consolidation.

The desirability of rod consolidation at certain reactor pools that have limited capacity may be much stronger than the desirability of rod consolidation at an MRS. If many utilities voluntarily elect to consolidate, the incentives to consolidate the residual fuel at the MRS are weakened because unit costs would increase.

3.2 Role of the MRS.

The technical functions of an integral MRS in the national waste program can potentially include the following:

- acceptance of spent fuel from utilities that have exceeded their on-site storage capacity.
- preparation and packaging the spent fuel for emplacement in a repository.
- rod consolidation.
- storage of spent fuel.
- shipment of spent fuel packages to the repository at an optimal rate and in an optimal mode.

The first two technical functions are clear-cut and require no discussion here.

Regarding rod consolidation, DOE has not presented any clear-cut analysis that demonstrates that the rod consolidation (carried out at the MRS) benefits outweigh the costs. Rod consolidation at the MRS is simply an option and not a need.

The storage function may not be as simple as it appears. Repository interface requirements may change with time so that packages would have to be reworked. With the current trend toward large packages of spent fuel (consolidated or unconsolidated) there may be increased incentives for

ex-repository storage of these packages until the heat generation rates have somewhat decayed. Some European countries plan to store spent fuel on the order of 40 years to limit repository heating. DOE has apparently not studied this aspect of the storage/consolidation question, but consolidated fuel packages tend to have about twice the heat generation of unconsolidated packages. Consequently, at-MRS storage needs may be somewhat greater than currently projected.

The final technical function listed is clear-cut and requires no discussion here.

The unresolved issues and questions to be addressed by DOE are covered in the next section. Further development, demonstration and analysis must be conducted over a period of years to clarify these issues and lead to decisions that are optimal both for the nation and for Tennessee.

3.3 Conclusions and questions to be addressed by DOE.

The DOE research, analysis and studies to date do not support the position that rod consolidation should be conducted at an MRS.

Of all the operations to be associated with the MRS, the consolidation operation has the greatest potential to generate accidents, unforeseen personnel exposure, byproduct radioactive low-level wastes, and embarrassing cost overruns. This part of the MRS project should not be adopted until such time that DOE's development, demonstration and analysis has clearly established the desirability of this part of the operation.

DOE might consider the alternative of crediting utilities an appropriate fee for delivering consolidated fuel rods. Apparently many utilities already have some incentives to consolidate spent fuel. If this can be done in a manner acceptable to the health and safety of workers at the plants and the public, it would reduce the need for major DOE consolidation facilities.

DOE should be encouraged to continue its development on both dry and in-pool rod consolidation so that the costs and undesirable side effects (if any) can be better defined.

DOE should be encouraged to continue to refine its systems studies to improve the cost-benefit analysis of rod consolidation. A related parameter that should bear additional study is the optimal storage mode

and time, prior to emplacement of spent fuel into the repository. Present trends toward higher burnup, fuel consolidation and large fuel packages may call for storage of spent fuel for more than 10 years from time of discharge from the reactor on average.

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EVALUATION OF THE NEED, FEASIBILITY, AND SITING OF AN MRS IN TENNESSEE

**Appendix: Siting Review, Monitored Retrievable Storage (MRS)
Why Tennessee?**

Contractor Report
Prepared by

Institute for Energy Analysis
Oak Ridge Associated Universities
Post Office Box 117
Oak Ridge, Tennessee 37831-0117

December 1985

DRAFT

SUMMARY

The Director of the U.S. Department of Energy's Office of Civilian Radioactive Waste Management has nominated, as required by the Nuclear Waste Policy Act of 1982, a preferred site and two alternative sites for an MRS facility. All three sites are in Tennessee. The three sites were named after an evaluation of ways to minimize shipment miles for transport of the spent nuclear fuel and an extensive task force review of potential sites and site characteristics. The Director exercised his judgment in selecting among the final five candidate sites. A fundamental premise of the site screening process was that the MRS facility relies on engineered containment of spent fuel, does not have site specific requirements or risks, and therefore that the screening process can be appropriately used not to discard unsuitable sites, but to focus on the most desirable sites.

The desirability of minimizing total shipment miles and the associated risks and costs was taken to be the "primary criterion for discriminating among possible MRS sites." With many decisions on systems integration yet to be made, it is not convincing that the 390,000 square mile "preferred siting region" defined will truly result in minimizing total shipment miles or, in fact, that total shipment miles should even be an overriding consideration.

However, the site screening then focused on sites within the "preferred siting region" and for which information was readily available (sites which were previously considered for NRC licensing or were DOE-owned). Sites under 1100 acres, sites with other nuclear facilities, and privately-owned sites, were successively eliminated as the technical data review did not reveal any of the candidates with severe physical limitations. All of the physical and technical data gathered fail to provide definitive discrimination among the sites considered.

Political acceptability and perceived expediency in permitting and construction seem to have been the primary criteria on which site selection was ultimately based. The preferred site is in an area with a long history, close familiarity, and relative comfortableness with nuclear facilities. In this case, political criteria seem to provide entirely valid reasons for selection, if indeed, the facility is environmentally benign and has no site-specific requirements or risks.

MRS - WHY TENNESSEE?

The Nuclear Waste Policy Act of 1982¹ required that by June 1, 1985 the Secretary of Energy submit to Congress a proposal for the construction of one or more monitored retrievable storage (MRS) facilities for high-level radioactive waste and spent nuclear fuel. The Act further required that this proposal include site-specific designs for at least three alternative sites. The only limitation spelled out for these sites was that "no monitored retrievable storage facility...may be constructed in any state in which there is located any site approved for site characterization" (as a permanent repository).

In April 1985, the Secretary announced the locations of three such sites, a preferred site and two alternatives--all in Tennessee. The preferred site is on the Clinch River within the city limits of Oak Ridge in Roane County. The alternative sites are respectively in the Roane County portion of Oak Ridge and in Trousdale and Smith Counties near Hartsville. This paper reviews the literature which describes the formal studies of the site selection process and comments on other factors which seem to have influenced the final decisions. The objective here is to clearly establish what the selection criteria really were and how it came to pass that three specific Tennessee sites were named.

The site screening and identification process is elaborated in three reports. The first (PNL-5424),² prepared by Batelle's Pacific Northwest Laboratory in April 1985, describes an analysis which attempts to minimize transportation requirements. It identifies a roughly circular region of 700 miles diameter centered approximately on Oak Ridge, Tennessee which it characterizes as the "preferred siting region." The second report (hereafter DOE/NBB-0071)³ describes the efforts of a site screening task force to identify and evaluate potential MRS sites within the preferred siting region.

The site screening and evaluation process is summarized by the DOE Office of Civilian Radioactive Waste Management in DOE/RW-0023.⁴ This last document describes how the three final sites were selected from among the 11 candidates which were evaluated by the site screening task force.

"The Director, Office of Civilian Radioactive Waste Management (OCRWM), Department of Energy (DOE), has identified the Clinch River Breeder Reactor Site, the DOE Oak Ridge Reservation and the Tennessee Valley Authority (TVA) Hartsville Nuclear Plant site as preferred and alternate sites, respectively, for development of site-specific designs as part of the proposal for construction of an integrated Monitored Retrievable Storage (MRS) facility.... The Director expects to propose to Congress that an MRS be constructed at the preferred site. This judgment could change based on information to be developed between now and January 1986.... The Director's judgment is based on the results of a vigorous site screening and evaluation process...." (DOE/RW-0023, p. 1)

The final DOE Report on Screening and Identification of Sites for a Proposed Monitored Retrievable Storage Facility begins with these words and makes it clear that final site selection was based on the Director's judgment. The site screening process evaluated sites and the "differences allow the Department and Congress to exercise discretionary preferences in choosing from a wide range of technically acceptable alternatives. It is a matter of judgment as to which sites are most appropriate for detailed consideration as candidate MRS sites. The Director exercised his judgment..."

(DOE/RW-0023, p. 1)

This paper is to review and critique the process which preceded the Director's judgment among 11 preferred sites, and to try to discern the basis for his final recommendations.

The final siting decision is reserved to Congress.

AN OVERVIEW

DOE's site selection summary (DOE/RW-0023) describes site selection as a four step process (Figure 1). Site screening criteria were established and used to select 11 especially suitable sites from the universe of acceptable sites. A melange of data of varying relevance was reviewed and all sites were found suitable for safe, effective operation. After comparison on the basis of potential for regulatory or construction delay because of competition with other public objectives, final selection was narrowed to five federally-owned sites. The director exercised his judgment to designate from these a primary and two alternative sites for candidacy.

Objectives:

- Identify safe sites with minimal adverse environmental impact
- Enhance mission of integral MRS
- Timely, cost effective selection

FIGURE 1. PROCESS FOR SITE SCREENING AND IDENTIFICATION OF CANDIDATE MRS SITES (FROM DOE/RW-0023).

Our reading, in fact, identifies seven screens through which the designated sites are reported to have passed (Figure 2). It is important to keep in mind the stated philosophy of the site screening, "factors were identified which were likely to point out particularly desirable lands rather than to develop exclusionary criteria to screen out undesirable lands... No land was determined to be unacceptable; rather, the process quickly focused upon sites which were expected to be especially desirable..." (DOE/RW-0023, p. 22.)

The dominant screening factor was the ability to judge the suitability of the site for development of a nuclear facility. The ability to judge site suitability depended upon availability of site data. Two sets of sites have particularly appropriate and available data: (1) sites docketed with the Nuclear Regulatory Commission for development of production and utilization facilities (e.g., nuclear reactors), and (2) lands owned by DOE and used for nuclear activities.

MINIMIZING TRANSPORTATION REQUIREMENTS

"The primary considerations in identifying a preferred and two alternative sites for an MRS facility are to locate sites:

1. where an MRS facility can be constructed in a safe, cost-effective and timely fashion, with minimal adverse impacts on the local community or environment, and
2. that will enhance the role of an MRS facility as an integral part of the Federal nuclear waste management system.

Because the MRS facility is based on engineered containment of the radioactive materials, performance of an MRS facility would be relatively independent of the specific conditions of the site. In this respect, an MRS facility is quite different from a repository, which is strongly dependent on site conditions for successful performance. Because of this relative independence from specific site conditions, an MRS facility could be successfully built and operated at any of a large number of sites throughout the U.S." (PNL-5424, p. 1.4)

With site specific characteristics not of critical importance, MRS siting studies were confronted with the need to set objectives and to establish some appropriate set of screening criteria for site selection. PNL-5424 argues that if the location of the MRS facility could provide a substantial reduction in total shipment miles for spent fuel and high level waste, then this "could be used as a primary criterion for discriminating among possible MRS sites" (PNL-5424, p. 3.1).

FIGURE 2. SITE SCREENING PROCESS FOR MRS SITE SELECTION

The study to identify a preferred siting region thus took as its stated objective: "to determine

1. the location and shape of a preferred geographic region within which locating an MRS facility would minimize total shipment miles for spent fuel transported through the MRS facility to a repository.
2. The sensitivity of the location and shape of this region and the reduction in total shipment miles to possible variations in waste management system logistics."

In deciding on this "primary criterion," shipment miles was chosen to characterize "transportation activities interface with the public" (PNL-5424, p. 3.3). Total shipment miles are notably different from ton miles, which will be increased by the presence of any MRS facility in the system, or from shipment costs. An MRS facility is able to produce a reduction in total shipment miles for 3 reasons: (1) some spent fuel is brought to the MRS facility by truck but is sent on by rail using larger capacity casks; (2) fuel consolidation at the MRS facility increases the amount of spent fuel that can be placed in a single cask; and (3) with a central staging point it is possible to optimize multiple cask rail shipments.

The rationale for minimizing total shipment distance is that shipment costs and risks are ultimately proportional to shipment miles. The potential for ordinary traffic accidents, the costs of security and monitoring, and public anxieties are all reduced by minimizing shipment miles. The PNL study showed, however, that "reducing total shipment miles by including an MRS facility in the waste management system does not result in significant changes in transportations costs" and "the risks associated with the transportation operation are small, so the risk reduction is probably not significant from a public safety standpoint." (PNL-5424, p. A.1)

With no significant impact on transportation costs or public safety, total shipment miles was nonetheless retained as the "primary criterion for discriminating among possible MRS sites." Little further technical justification was offered in PNL-5424. It is, rather, a matter of public perception and visibility:

"Reduction of total shipment miles is a logical dominant objective in identifying suitable MRS sites. Transportation of spent fuel and other wastes is a major function of the waste management system which most directly interfaces with the

public. In commenting on past and current DOE plans and activities, interested groups and individuals have repeatedly identified transportation as a concern regarding the waste management system." (PNL-5424, p. 1.4)

The PNL study thus proceeded in the selection of a region which would limit total shipment miles to and from the MRS facility to within 20 percent of the lowest achievable. In three basic steps the study (1) permuted all currently considered "systems logistics options," (2) for each permutation of system options, outlined the region which is within 20 percent of the minimum for total shipment miles and, (3) identified the common region which is within the 20 percent contour for all options considered. The system logistics factors which were considered and the range of variability for each are listed in Table 1. A final variable was whether spent fuel from Western reactors would be brought to an Eastern MRS facility.

TABLE 1. RANGES OF WASTE SYSTEM LOGISTICS
FACTORS USED FOR SITING ANALYSIS*

Factor	Range Used
Assumed Repository	Nine sites from Hanford, Washington to Richton, Mississippi ^(a)
MRS Lifetime Spent Fuel Throughput	70,000 MTU to 100,000 MTU ^(b)
Spent Fuel Rod Consolidation at MRS	None (1:1) to 2:1 ^(c)
Spent Fuel Shipping Cask Capacities	
- PWR Truck Cask	1 to 2 intact assemblies
- BWR Truck Cask	2 to 5 intact assemblies
- PWR Rail Cask	7 to 12 intact assemblies
- BWR Rail Cask	18 to 32 intact assemblies
Rail Casks Per Shipment ^(d)	
- from reactors to MRS	1 to 3
- from MRS to repository ^(e)	1 to 10

(a) Extremes of location for nine sites under consideration for first repository.

(b) Upper limit is all spent fuel projected from existing or planned reactors.

(c) Indicates ratio of spent fuel volume in to volume out.

(d) Truck shipments are limited to one cask per shipment.

(e) All shipments from MRS to repository assumed to be by rail.

* From PNL-5424, p. 5.2.

A key assumption in the transportation analysis was the location of the spent nuclear fuel. The analysis assumed that the oldest fuel is always brought to the MRS site first so the required data was the locations of the first generated 70,000 - 100,000 MTU of spent fuel. The Energy Information Administration's "No New Orders Case" was used to model where this spent fuel will be located.

The process is demonstrated in Figure 3 where the preferred siting region, as defined by three of the possible permutations, is shown. Table 2 gives the parameter values for the three cases and Figure 3 shows the

TABLE 2. WASTE SYSTEM LOGISTICS FACTORS FOR THREE EXAMPLE CASES			
Factor	Case A	Case B	Case C
Assumed Repository	Hanford, Wash.	Hanford, Wash.	Richton, Miss.
MRS Lifetime Spent Fuel Throughput	70,000 MTU	70,000 MTU	70,000 MTU
Spent Fuel Rod Consolidation at MRS	1.5:1	1:1	1:1
Spent Fuel Shipping Cask Capacities			
- PWR Truck Cask	1 assembly	1 assembly	1 assembly
- BWR Truck Cask	2 assemblies	2 assemblies	2 assemblies
- PWR Rail Cask	7 assemblies	7 assemblies	7 assemblies
- BWR Rail Cask	18 assemblies	18 assemblies	18 assemblies
Rail Casks Per Shipment			
- from reactors to MRS	1	1	1
- from MRS to repository	3	1	1

+20 percent contours with respect to minimum total shipment miles for each case, with the area shaded which is within the 20 percent contour for all three cases. The ultimately achieved preferred siting region is shown in Figure 4 and it is clear that the three cases shown provide much of its definition.

Careful examination of Figure 3 will also reveal how much the preferred siting region is constrained by consideration of the Richton, Mississippi repository site, a site which has now been eliminated from consideration for the first repository. In fact, the shipment mile analysis was conducted

FIGURE 3. PREFERRED SITING REGION FOR A MONITORED RETRIEVABLE STORAGE FACILITY FOR THREE DIFFERENT COMBINATIONS OF SYSTEMS LOGISTICS OPTIONS.
 The +20 percent contours with respect to the minimum achievable total shipment miles are shown for the three cases elaborated in Table 2. the shaded region is that which falls inside of the +20 percent contour for all 3 options.

FIGURE 4. PREFERRED SITING REGION FOR A MONITORED RETRIEVABLE STORAGE FACILITY IF TOTAL SHIPMENT MILES ARE WITHIN 20 PERCENT OF THE MINIMUM ACHIEVABLE FOR ANY CURRENTLY CONSIDERED SET OF SYSTEMS LOGISTICS OPTIONS.

using nine possible repository sites, only three of which are now being seriously evaluated (as of January 1985). Although the analysis has not been repeated here, it is clear that if only the three extant repository sites were considered in the factor permutations, the preferred siting region would be larger and its center would be shifted to the north and west.

To raise, once again, the distinction between total shipment distance and total shipment cost, the text of PNL-5424 shows minimum transport cost contours for two sample options, both with the repository site taken to be at Hanford, Washington. In both cases Hanford itself is within 20 percent of the minimum achievable transport cost and in one of the examples it is within 10 percent of the minimum achievable. In one example the 20 percent contour encompasses the entire contiguous United States.

It is also clear that the PNL transportation study has not considered all of the possibilities. In a research proposal prepared by the Special Projects Staff of TVA, other systems integration options were briefly explored. The TVA group used a different model of spent fuel generation, a different model for transportation mode, and arrived at quite different conclusions. They did agree that transportation is an important consideration. Using the TVA group's model, the centroid for ton-miles for spent fuel is in Southwestern Ohio (it is in West Virginia in the PNL model). However, "the lowest possible transportation impact in terms of trip-miles (e.g., shipment miles) is for consolidated fuel in a dual-purpose cask shipped by dedicated train directly to the repository..." That is, a system without an MRS. Total shipment miles were claimed to be reduced to 5 percent of those in the DOE MRS Base Case. If an MRS facility is to be built,

"The type of transportation system assumed and the extent to which it is integrated into the overall system have a major effect on the preferred location of an MRS. The optimum location of an MRS to minimize trip-miles for the type of transportation system DOE has assumed, as described above, is in the eastern part of the country in an area centered around Ohio. The optimum MRS location for a fully integrated system using dual-purpose casks shipped by dedicated train is at the repository site. However, the NWPA forbids siting the MRS in a repository state. Assuming the repository site is unknown and the three sites currently under consideration have equal probability of being selected, the optimum MRS site for a fully integrated transportation system would be in the vicinity of Southeastern Colorado near the Oklahoma panhandle." (TVA Special Projects Staff, 1985, pp. 42-43.)⁵

The two locations are both based on equal probability for the three repository sites at Hanford, Washington; Yucca Flats, Nevada; and Deaf Smith, Texas and the latter location on the further assumption of all shipments by dedicated trains.

The preferred siting region in Figure 4 was used by DOE as the first level screening factor for identification and evaluation of potential MRS sites in subsequent studies.

SITE SCREENING

The Monitored Retrievable Storage Facility Site Screening and Evaluation Report (DOE/NBB-0071) was prepared by a task force and bears all of the symptoms thereof. It is three volumes long and contains tables of everything that could be tabulated regardless of its relevance to the issues at hand. As a consequence of the structure of the study, the report lacks precision and conviction. The task force consisted of approximately 60 people in six organizations. Work was concentrated into three months. Potential MRS facility sites, all in the Eastern United States were evaluated and compared without a site visit and the basis for cost comparisons was Los Angeles Basin data. The report takes 15 chapters to select and evaluate 11 sites. Transportation, Socioeconomic, Institutional, Regulatory, Environmental, Geotechnical, Infrastructure, and Cost considerations are discussed and a few items identified as discriminators for site selection. Discriminators are those factors which vary significantly among the sites and are important in assessing the potential for MRS facility development. The seven factors which discriminated among the sites chosen for evaluation were:

1. existing federal ownership and control;
2. granting by NRC of a limited work authorization or construction permit;
3. potential land use competition;
4. potential competition with environmental regulatory objectives;
5. potential geotechnical site conditions;
6. potential problems with local transportation access;
7. proximity to population centers.

The site screening process began with task force acceptance of the 390,000 square mile area described in Figure 4. The task force was also

provided by PNL with three screening criteria. The three criteria were:

"Status: Candidate MRS facility sites (1) must have been previously considered for licensing by the NRC for construction and operation of a nuclear power plant or fuel reprocessing facility under 10 CFR 50 or (2) must be owned and controlled by DOE.

Size: Candidate MRS facility sites must be of sufficient size to allow construction and operation of the facility.

Site-Use Conflict: No unacceptable or undesirable site-use conflict may exist at potential MRS facility sites" (DOE/NBB-0071, p. 4.1).

Site size requirements are dependent on how much spent fuel is stored and how it is stored. The base case MRS facilities could store 15,000 tons of spent fuel in storage casks on a 280 acre site but an alternate scheme would use field drywell storage and if a full 70,000 tons were accumulated at an arid MRS site, 1100 acres would be required. Thus, 1100 acres was adopted as the minimum acceptable site even though it applies to an arid site and the focus is the Southeastern United States.

A question about the 1100 acre requirement was raised at a July 10, 1985 MRS Workshop at Tennessee State University. According to the workshop summary prepared by S.W. Haegart of the Tennessee Department of Health and Environment, "The DOE staff pointed out that when the candidate sites were selected, DOE was still retaining its option to use the MRS as a backup to a permanent repository. The staff stated that the DOE will seek to limit the size of the facility to 15,000 MTU in the authorizing legislation, particularly if the state requests such a limitation." The fact remains, no site smaller than 1100 acres was considered. Despite these kinds of inconsistencies in the physical data, DOE seems committed to the sites selected. At this same workshop, "The DOE staff/contractors agreed that the site selection document was unclear on some of these questions. The document will not be redone, but some of the issues may be investigated further, and addressed in an Appendix to the final need and feasibility document."

Siting adjacent to a licensed nuclear power plant was judged undesirable because, while no combined risk was perceived, it might create undesirable licensing delays. Site use conflict was thus used to reject sites which adjoin or are shared with a licensed nuclear power plant.

Thirty-seven sites in 12 states were identified to pass the first of these three screens, 10 were eliminated because they were known to be less than 1100 acres, and another 16 failed to pass the site-use conflict screen, leaving 11 sites for further consideration. The 11 sites are listed in Table 3 and shown on Figure 5.

TABLE 3. CANDIDATE MRS SITES FROM THE INITIAL THREE-STEP SCREENING

State	Site Name	Site Type
Alabama	Barton	Nuclear Power Plant
Kentucky	Paducah	DOE Facility
Mississippi	Yellow Creek	Nuclear Power Plant
North Carolina	Perkins	Nuclear Power Plant
South Carolina	Barnwell	Reprocessing Plant
	Cherokee	Nuclear Power Plant
	Savannah River	DOE Facility
Tennessee	Clinch River	Nuclear Power Plant
	Hartsville	Nuclear Power Plant
	Oak Ridge	DOE Facility
	Phipps Bend	Nuclear Power Plant

Site selection was thus focused on 11 specific locations in six southeastern states. In bluntest terms, selection of these sites was based on public perception (shipment miles) and expediency (site status and site-use conflict), the only physical/technical criteria employed being an ultra-conservative allotment of site size. Evaluation of the 11 sites proceeded on a variety of bases, most of which were ultimately acknowledged to be "nondiscriminators" or inadequately known. Interestingly the tables in Chapter 5 report two of the sites (Yellow Creek and Clinch River) to be under 1100 acres.

Chapters 7 to 14 of DOE/NBB-0071 go through site specific discussions of transportation, socioeconomic, institutional, regulatory, environmental, geotechnical, infrastructure, and cost considerations respectively. In this text we will try to simply point out the factors considered, note those which were judged useful in discriminating among sites, and call attention to a few site-specific items raised in regard to the three alternate sites selected.

FIGURE 5. CANDIDATE MRS SITES AFTER ANALYZING TOTAL SHIPMENT MILES AND APPLYING A THREE-STEP INITIAL SCREEN ON POTENTIAL SITES.

The task force's stated intent was to "identify and present significant strengths and weaknesses of each site." It is noted that all of the data are based on material available in the open literature and that no site visits were made. This lead to some unusual data omissions, such as the concession that for the preferred site, "it is uncertain who has custody of the land at this time" (DOE/NBB-0071, p. 5.7).

Under Transportation Considerations, "Although it is expected that the necessary transportation capabilities could be made available at each site, there could be important differences between the sites in the cost of providing these services, in the effects of the transportation operations on the people living in the vicinity of the facility, and in the efficiency of the transportation operations" (DOE/NBB-0071, p. 7.1). The eight attributes selected to characterize the transportation considerations are listed in Table 4. Access to barge service was included although there is no current

TABLE 3. ATTRIBUTES SELECTED TO CHARACTERIZE THE TRANSPORTATION CONSIDERATIONS AND SERVE AS A BASIS FOR EXAMINING DIFFERENCES AMONG SITES.

1. Local population density.
 2. Number of communities on access route.
 3. Distance to main transportation link.
 4. Number of large cities on regional transit corridors.
 5. Amount of new access required.
 6. Special operating conditions (e.g., weather).
 7. Number of rail carriers.
 8. Access to barge service.
-

discussion of using barge transport. Although the sites were ranked on the basis of attractiveness, "review of the transportation characteristics for each of the sites indicated that a safe and reasonably efficient transportation system could be put in place at all of the sites" (DOE/NBB-0071, p. 7.7). On a relative scale, the Clinch River and Oak Ridge sites were rated "better than average," the Hartsville site "below average." On the topic of "number of large cities on regional transit corridors," it is

interesting to note the fraction of reactors whose shipments to the MRS facility would pass through, for example Knoxville and Nashville, if shipped by truck (see Table 5). The point is that so long as the MRS facility is in

TABLE 5. PERCENT OF REACTORS WHOSE SPENT-FUEL SHIPMENTS WOULD PASS THROUGH KNOXVILLE AND NASHVILLE IF ALL WERE SHIPPED BY TRUCK TO AN MRS SITE

MRS Site	% of shipments	
	Through Knoxville	Through Nashville
Barton, Alabama	23	31
Paducah, Kentucky	<20	25
Yellow Creek, Mississippi	26	49
Perkins, North Carolina	44	<20
Barnwell, South Carolina	30	<20
Cherokee, South Carolina	31	<20
Savannah River, South Carolina	30	<20
Clinch River, Tennessee	47	31
Hartsville, Tennessee	36	24
Oak Ridge, Tennessee	47	31
Phipps Bend, Tennessee	60	<20

the Southeast, a significant fraction of the spent fuel will travel along the regions' principal transport corridors following similar routes.

Socioeconomic considerations focus on "the ability of each site to absorb the potential socioeconomic impacts that would accompany the construction and operation of an MRS facility, and estimates the relative increases in demand upon local government resources that may be caused by MRS construction and operation" (DOC/NBB-0071. p. 8.1). A peak work force of 1300 was foreseen. The task force considered the size of the impact relative to the existing base, the current growth trends in the area, and the capacity of existing community resources. Impact projections were based on the PNL Metropolitan and State Economic Regions model. The impact area was defined as all counties lying completely or partially within a 50-mile

radius of the site* and no attempt was made to evaluate intra-area shifts or stresses. On this basis they projected that all of the areas have large and growing populations and will have to construct new schools regardless of an MRS facility. "Baseline population growth will also require the expansion or construction of hospitals in every area except Yellow Creek" (DOE/NBB-0071, p. 8.7). While the study found some difference in the ability of the respective candidate sites, "the primary result of this analysis is that the communities surrounding each of the eleven sites could easily absorb an MRS-related socioeconomic impact" (DOE/NBB-0071, p. 8.9). Factors evaluated were employment, population, income, schools and hospitals, water, electric and sewer supply, and housing.

"The focus of the effort for the institutional component was to identify characteristics or considerations that could be used to differentiate or discriminate between potential sites. However, ...it was difficult to conceive of any institutional considerations that could serve as absolute discriminators between potentially acceptable sites." Acknowledging further that "we do not know what institutional considerations will be important at any particular site because so much of their context is political and their operation is not triggered until a siting decision is made..." (DOE/NBB-0071, p. 9.1), the task force discussion goes on to tabulate the political affiliation of state legislators, the nature of nuclear-related state agencies and legislation, state and local tax structures, the existence of indian tribes, distance to the state capitol, the ethnic composition of the county population, etc. Institutional considerations were ultimately relegated to the important realm of "secondary discriminators," factors that, other things being equal, might be used to distinguish on the basis of, for example, technical sophistication with respect to nuclear matters.

The chapter on regulatory compliance "examines the characteristics of the candidate MRS facility sites with respect to the site suitability requirements of 10 CFR part 72, and other legally-imposed requirements. At this stage of siting, it is not possible to project regulatory compliance. Therefore, this section provides only indicators of relative ease of achieving

*For the Clinch River and Oak Ridge sites this means that Anderson, Knox, Loudon and Roane counties were considered to be the impact area. For Hartsville, the impact area was considered to be Macon, Smith, Trousdale, and Wilson counties. Declining school enrollment in Oak Ridge, for example, does not show in overall growth of the four county area.

regulatory compliance at each potential site. These indicators are 'conditions' which may need to be investigated in order to ultimately judge whether a facility located at a site can achieve regulatory compliance" (DOE/NBB-0071, p. 10.1).

The significant attributes, based on 10 CFR 72, and other applicable legislation, are listed in Table 6.

TABLE 6. FACTORS THAT MIGHT DISCRIMINATE AMONG SITES
ON THE BASIS OF EASE OF REGULATORY COMPLIANCE

1. Prior review under 10 CFR 50.
 2. Co-location with another nuclear facility.
 3. Proximity to other nuclear facilities.
 4. Location within a flood plain.
 5. Protection of population under emergency plan.
 6. Engineering provisions (to compensate for geological or seismological conditions).
 7. External events (e.g., meteorological).
 8. Special characteristics.
 9. Significant impacts on use of water.
 10. Significant impacts on use of land.
 11. Potential environmental impacts.
 12. Historical or aesthetic considerations.
 13. Location within area of known seismicity.
 14. Evaluation under Appendix A, 10 CFR 100.
 15. Unstable geologic characteristics.
 16. Evidence of soil instability.
 17. Proximity to environmentally sensitive areas.
 18. Potential impairment or degradation of air or water.
 19. Proximity to federal or state protected lands.
 10. Regulatory constraints other than 10 CFR 72.
-

An overlapping of factor classifications is seen in the site evaluation of environmental considerations. The ten attributes considered (Table 7) overlap considerably with those already raised. Aesthetics is highly concerned with site visibility, that is, how many people will see the facility. "The least number of people who would see the project area is considered a desirable attribute" (DOE/NBB-0071, p. 11-14). This is an interesting

TABLE 7. ENVIRONMENTAL ATTRIBUTES CONSIDERED
AS POSSIBLE SITE DISCRIMINATORS

1. Aesthetics
 2. Air Quality
 3. Cultural Resources
 4. Ecology
 5. Health and Safety
 6. Land Use
 7. Meteorology
 8. Noise and Vibration
 9. Transportation
 10. Water Quality
-

contrast to the Clinch River Task Force⁶ request for a visitor center (if either Oak Ridge site is chosen) so that the plant would not appear mysterious or dangerous.

Geotechnical considerations "were based on the judgment concerning which technical issues are most likely to affect:

- the performance of engineered systems;
- the requirements for successful and timely regulatory approval;
- the feasibility and economy of site development."

The cursory level of inquiry and the overriding belief that an MRS facility could be engineered for almost any site is reflected in the task force statement that "The list of geotechnical considerations does not include all possible geotechnical factors, but is considered to be appropriate for the current scale of study, the level of available data, and the purpose of identifying important distinctions among various potential sites" (DOE/NBB-0071, p. 12.1).

The most important characteristics were considered to be those related to geology/seismology, ground water, surface water, and foundation and construction considerations. Many of the factors considered did not meaningfully distinguish among sites at the level investigated. For example, all three of the Tennessee sites selected were cited for the same deficiencies: the possibility of solution cavities, inadequate depth to the saturated

zone, the necessity of extensive rock excavation, and surface materials of questionable bearing strength to support the Receiving and Handling buildings. All of these are amenable to engineered solutions but ultimately affect project cost. In the summary tables, all three sites were shown to be subject to moderate cost impact due to these four factors, but the factors were not perceived to have an important impact on licensing, the environment, or scheduling.

"Infrastructure consists of elements that are required to tie the MRS facility into the local environment" (p. 13.1). The attributes that were considered as potential discriminators in this area were utilities, transportation (again), labor, and supplies (fuel oil). With no attempt to contact local authorities for information, some of the possible criteria were laid aside for lack of information. While the conclusion was that "none of the infrastructure attributes are a constraint at any of the sites" (DOE/NBB-0071, p. 13.4), indications were that all 11 sites would require onsite sewage treatment systems.

Finally, the site screening study dealt with costs. Not absolute costs or all costs, but relative costs, and those costs which might be significantly different at the different sites. Costs of land, right-of-way and easements, were not included. Socioeconomic, geotechnical, environmental, and infrastructure considerations were included as were existing site conditions. Los Angeles Basin costs were used as a basis and then translated to the various local conditions with an adjustment factor which compensated for differences in labor rates, material costs, freight and productivity. For the geotechnical considerations flagged, costs were included to permit detailed studies and to develop design criteria but not to engineer solutions that might be required. Normalized costs of an MRS facility at each of the 11 sites are compared in Table 8.

The site screening study did not offer a suggestion among the 11 sites evaluated. It concluded with the recommendation "that DOE, prior to identification of a preferred and two alternative candidate sites for the MRS facility, confirm, to the extent possible, the condition and status of the site, as well as the applicable federal, state, and local agencies to confirm general conclusions and data base conditions" (DOE/NBB-0071, p. 15-16).

	Barton	Paducah	Yellow Creek	Perkins	Barnwell	Cherokee	Savannah River	Clinch River	Hartsville	Oak Ridge	Phipps Bend
CONSTRUCTION	101.24	115.16	105.84	98.90	98.90	98.90	98.90	102.34	100.07	102.34	102.34
SOCIOECONOMICS	.20	.22	.17	.20	.21	.20	.24	.21	.21	.21	.19
INVESTIGATIONS	-0-	.09	.04	.02	.10	.02	.10	.07	.07	.07	.05
SITE MITIGATIONS	.08	1.73	.28	-0-	.31	-0-	.58	1.86	3.85	.17	3.06
SITE MODIFICATIONS	.47	2.52	1.64	.77	.90	2.10	.87	1.37	1.68	1.12	1.49
ENVIRONMENTAL	.22	.36	.31	.30	.40	.28	.27	.34	.36	.44	.25
INFRASTRUCTURE											
TRANSPORTATION	-0-	(.38)	.45	.01	(.34)	.13	(.02)	(.30)	.01	(.18)	(.29)
POWER	(.29)	(.28)	.02	(.20)	(.27)	(.13)	-0-	(.32)	.03	(.31)	DNA
Cost Factor Total	101.92	119.42	108.75	100.00	100.21	101.50	100.94	105.57	106.28	103.86	107.09*

*Some data not available
() - indicates a credit

TABLE 8. COST FACTORS SUMMARY FOR SEALED STORAGE CASK CONCEPT.
VALUES ARE BASED ON A GENERIC, BASELINE FACILITY.

The evaluations were summarized in 11 Tables (see Appendix). There is no obvious quantitative relationship between these tables and the three sites ultimately chosen, suggesting that indeed the majority of the site screening data did not figure importantly in the site selection process. In fact, in the executive summary, four of the eight types of considerations were dismissed as unimportant (see Table 9), leaving only regulatory, environmental, geotechnical and cost issues for discrimination among sites. In closing comments, the task force also underlined the advantage of DOE-owned sites:

"DOE-owned sites may offer several schedule, infrastructure and cost advantages over privately-owned sites. These advantages are related to site access, site acquisition, security provisions, and emergency preparedness and response. Those advantages have not risen to the level of the evaluations of the task force. It is recommended that the potential advantages be accounted for prior to final siting decisions" (DOE/NBB-0071, p. 1.10).

SITE SELECTION

As a final step, the question was posed, Which of the data available truly discriminate among the sites with respect to ease and likelihood of success of deploying an MRS facility? This was seen not in terms of technical suitability or safety, but in terms of potential delay or disapproval as a result of conflict with public priorities or existing regulations. Congressional authorization, NRC licensing, and EPA permitting are the three steps where such obstacles would be encountered. Table 10 lists the areas of potential competition with existing public priorities. On this basis, the Yellow Creek and Paducah sites were eliminated from further consideration. Yellow Creek because of proximity to the recreation area at Pickwick Lake, and Paducah because it is in non-attainment of national air quality standards and because it is in an area designated by EPA for preventing further deterioration of air quality. In both cases problems were not anticipated but licensing delays were seen as more likely than for the other sites.

Of the remaining nine sites, five are under federal ownership and final selection was made from among the Clinch River, Hartsville, Oak Ridge, Phipps Bend, and Savannah River sites. "The advantages of current federal ownership" (DOE/RW-0023, p. 2) were cited as, "Federal ownership reduces

TABLE 9. NONDISCRIMINATING CONSIDERATIONS
(FROM DOE/NBB-0071 EXECUTIVE SUMMARY)

Transportation Considerations

"Transportation considerations identified differences between sites. However, the differences are, in the judgment of the task force, relatively minor."

Socioeconomic Considerations

"While the socioeconomic impacts varied from site to site, no potential impacts were identified which would exclude any site from consideration as a candidate MRS facility site. The socioeconomic impacts at each site are, in general, projected to be small."

Institutional Considerations

"...few significant differences were identified between sites which are relevant to MRS siting decisions."

Infrastructure Considerations

"Infrastructure considerations revealed differences between sites. However, these differences were not found to be significant in terms of discriminating sites."

TABLE 10. SITE DISCRIMINATING FACTORS IN TERMS OF POTENTIAL
CONFLICT WITH EXISTING PUBLIC PRIORITIES

1. Land-use competition or proximity to special areas.
 2. Competition with environmental regulatory objectives.
 3. Geotechnical site conditions.
 4. Local transportation access.
 5. Proximity to population centers.
-

potential for conflict regarding use of the site and assures access for additional investigations" (DOE/RW-0023, p. 2). It also does not needlessly remove land from the private domain.

As described earlier, this final selection was based on the judgment of the Director of the DOE Office of Civilian Radioactive Waste Management and his advisors. Although at this point there was a 40 percent chance that random selection would place all three sites in Tennessee, there was apparently a conscious decision to do so.

The only statements directly confronting the selection of three sites in a single state are:

"The Department will assure that the State of Tennessee has adequate opportunity to understand the technical and nontechnical effects of MRS development. In that the three sites are all in a single state, this can be accomplished without diverting attention to interstate procedural or programmatic parity. The decision to identify sites within a single state came only after determination that none of the other federal sites carried with them characteristics (technical, environmental or land use) which made them superior to the three sites identified." (DOE/RW-0023, p. 2)

In elaborating "several particularly desirable features" in support of the Clinch River selection, DOE cited three which are logical outgrowths of the site screening process plus a fourth which is a new point, "4) technical community in the vicinity of site which can provide experienced nuclear support functions." (DOE/RW-0023, p. 2)

CONCLUSION

Our conclusion is that the technical basis for selection of Oak Ridge to host an MRS facility is very weak indeed. There is no convincing argument that the site offers advantages in the way of transportation risk or cost. Selection of a preferred siting region was based on some outdated information and a "system" for spent fuel processing and disposal which is still poorly defined and subject to many important variables. Screening on the basis of 1100 available acres was unnecessarily conservative and the site evaluation process found all 11 nominated sites to be acceptable on the basis of environmental, geotechnical, socioeconomic, etc., factors. The subjective judgment of the Director formed the acknowledged basis for final

selection. If we accept the arguments of the site screening and evaluation task force, there are a near infinite number of U.S. sites that could be engineered to host the MRS facility without significant change in public risk or cost.

This is not to argue that the final choices were not good choices, but simply to make the point that the detailed site selection documentation fails to make convincing argument that there is any technical reason for the choices. The three Tennessee sites are neither unique nor technically essential to the success of the spent fuel handling system. We note, however, that a sense of expediency, of acceptability, played an important, and undoubtedly valid, role in site selection. The political, infrastructure, considerations are real and seem to have played a more important role than one would necessarily perceive in the bulk of the site screening evaluations. Because of its "existing proximity to nuclear infrastructure" Tennessee, and Oak Ridge in particular, provide a relatively hospitable climate for what will inevitably be a controversial project. If the site screening and evaluation process fails to make a compelling technical argument in favor of Oak Ridge, it does show that, at a cursory level, other possible choices are not demonstrably preferable. If Oak Ridge is at least as good as other possibilities, and casts an image such that local and state acceptance appear likely, then, Why not Oak Ridge? This is, in fact, in keeping with the stated philosophy of the site screening.

"Factors were identified which were likely to point out particularly desirable lands rather than to develop exclusionary criteria to screen out undesirable lands. In employing this approach, large amounts of land were eliminated from consideration even though acceptable sites could be found among such lands. No land was determined to be unacceptable; rather, the process quickly focused upon sites which were expected to be especially desirable and for which detailed information was available" (DOE/RW-0023, p. 22.)

Our feeling is that there are many reasons for selecting Oak Ridge, none of which have very much to do with the geographic, physical, or economic attributes of the site. This feeling is supported by an October 21 meeting at which Oak Ridge City Council expressed that it "would willingly accept" the MRS facility, given a list of specific conditions.

Regulatory compliance and conflict with other public priorities are clearly stated screening criteria, and DOE's perception of how these will come into play has had a major role in the site selection. Political expediency is not necessarily a poor basis for selection if the facility is truly benign and has no site-specific impacts or requirements.

Oak Ridge, and Tennessee, thus have the option of accepting the MRS facility while acknowledging that there is little persuasive technical argumentation in favor of selecting this preferred site. Or, they can easily oppose the site by arguing, "Why Tennessee?"

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APPENDIX

SUMMARY OF EVALUATION FOR
11 CANDIDATE SITES FOR AN MRS FACILITY

DEFINITIONS OF DESCRIPTORS FOR TABLES A.1 - A.11

Difficulty of regulatory compliance

L = Low

M = Moderate

H = High difficulty in attaining compliance with applicable regulations

Capital Cost

L = estimated increase up to 1 percent

M = estimated increase of 1-5 percent

H = estimated increase greater than 5 percent

Schedule Impacts

L = up to 6 months delay

M = 6-18 months delay

H = greater than 18 months delay

NA = Not Available

TABLE A.1. SUMMARY OF EVALUATIONS FOR BARTON, ALABAMA SITE
 OWNERSHIP: ALABAMA POWER COMPANY

	<u>Difficulty in Regulatory Compliance</u>	<u>Capital Cost Impacts</u>	<u>Schedule Impacts</u>
Transportation	L	L	L
Socioeconomics	N/A	L	L
Institutional	L	L	L
Environmental	L	L	L
Geotechnical	L	L	L
Infrastructure	L	L	L
Site Development	L	M	L

TABLE A.2. SUMMARY OF EVALUATIONS FOR PADUCAH, KENTUCKY SITE
 OWNERSHIP: DEPARTMENT OF ENERGY

	<u>Difficulty in Regulatory Compliance</u>	<u>Capital Cost Impacts</u>	<u>Schedule Impacts</u>
Transportation	L	L	L
Socioeconomics	N/A	L	L
Institutional	L	L	L
Environmental	H	L	H
Geotechnical	H	H	H
Infrastructure	L	L	M
Site Development	L	L	L

TABLE A.3. SUMMARY OF EVALUATIONS FOR YELLOW CREEK, MISSISSIPPI SITE
OWNERSHIP: TENNESSEE VALLEY AUTHORITY

	<u>Difficulty in Regulatory Compliance</u>	<u>Capital Cost Impacts</u>	<u>Schedule Impacts</u>
Transportation	L	L	L
Socioeconomics	N/A	L	L
Institutional	L	L	H
Environmental	M	L	M
Geotechnical	L	M	L
Infrastructure	L	L	L
Site Development	L	M	M

TABLE A.4. SUMMARY OF EVALUATIONS FOR PERKINS, NORTH CAROLINA SITE
OWNERSHIP: DUKE POWER COMPANY

	<u>Difficulty in Regulatory Compliance</u>	<u>Capital Cost Impacts</u>	<u>Schedule Impacts</u>
Transportation	L	L	L
Socioeconomics	N/A	L	L
Institutional	L	L	L
Environmental	M	L	L
Geotechnical	L	L	L
Infrastructure	L	L	L
Site Development	L	M	M

TABLE A.5. SUMMARY OF EVALUATIONS FOR BARNWELL, SOUTH CAROLINA SITE
OWNERSHIP: ALLIED CHEMICAL

	<u>Difficulty in Regulatory Compliance</u>	<u>Capital Cost Impacts</u>	<u>Schedule Impacts</u>
Transportation	L	L	L
Socioeconomics	N/A	L	L
Institutional	L	L	L
Environmental	L	L	L
Geotechnical	M	M	M
Infrastructure	L	L	L
Site Development	L	L	L

TABLE A.6. SUMMARY OF EVALUATIONS FOR CHEROKEE, SOUTH CAROLINA SITE
OWNERSHIP: DUKE POWER COMPANY

	<u>Difficulty in Regulatory Compliance</u>	<u>Capital Cost Impacts</u>	<u>Schedule Impacts</u>
Transportation	L	L	L
Socioeconomics	N/A	L	L
Institutional	L	L	L
Environmental	M	L	M
Geotechnical	L	L	L
Infrastructure	L	L	L
Site Development	L	M	M

TABLE A.7. SUMMARY OF EVALUATIONS FOR SAVANNAH RIVER, SOUTH CAROLINA SITE
OWNERSHIP: DEPARTMENT OF ENERGY

	<u>Difficulty in Regulatory Compliance</u>	<u>Capital Cost Impacts</u>	<u>Schedule Impacts</u>
Transportation	L	L	L
Socioeconomics	N/A	L	L
Institutional	L	L	L
Environmental	L	L	L
Geotechnical	M	M	M
Infrastructure	L	L	L
Site Development	L	L	L

TABLE A.8. SUMMARY OF EVALUATIONS FOR CLINCH RIVER, TENNESSEE SITE
OWNERSHIP: U.S. GOVERNMENT (TVA CUSTODY)

	<u>Difficulty in Regulatory Compliance</u>	<u>Capital Cost Impacts</u>	<u>Schedule Impacts</u>
Transportation	L	L	L
Socioeconomics	N/A	L	L
Institutional	L	L	L
Environmental	M ^(a)	L	M ^(a)
Geotechnical	L	M	M
Infrastructure	L	L	L
Site Development	M	M	M

(a) State has applied for attainment status for ozone. If EPA does not grant this request the difficulty for regulatory compliance will increase.

TABLE A.9. SUMMARY OF EVALUATIONS FOR HARTSVILLE, TENNESSEE SITE
 OWNERSHIP: TENNESSEE VALLEY AUTHORITY

	<u>Difficulty in Regulatory Compliance</u>	<u>Capital Cost Impacts</u>	<u>Schedule Impacts</u>
Transportation	L	L	L
Socioeconomics	N/A	L	L
Institutional	L	L	L
Environmental	M	L	M
Geotechnical	L	H	M
Infrastructure	L	L	L
Site Development	L	H	M

TABLE A.10. SUMMARY OF EVALUATIONS FOR OAK RIDGE, TENNESSEE SITE
 OWNERSHIP: DEPARTMENT OF ENERGY

	<u>Difficulty in Regulatory Compliance</u>	<u>Capital Cost Impacts</u>	<u>Schedule Impacts</u>
Transportation	L	L	L
Socioeconomics	N/A	L	L
Institutional	L	L	L
Environmental	M ^(a)	L	M ^(a)
Geotechnical	L	M	M
Infrastructure	L	L	L
Site Development	L	M	M

(a) State has applied for attainment status for ozone. If EPA does not grant this request the difficulty for regulatory compliance will increase.

TABLE A.11. SUMMARY OF EVALUATIONS FOR PHIPPS BEND, TENNESSEE SITE
OWNERSHIP: TENNESSEE VALLEY AUTHORITY

	<u>Difficulty in Regulatory Compliance</u>	<u>Capital Cost Impacts</u>	<u>Schedule Impacts</u>
Transportation	L	L	L
Socioeconomics	N/A	L	L
Institutional	L	L	L
Environmental	M	L	M
Geotechnical	L	M	M
Infrastructure	L	L	L
Site Development	M	H	H

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