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Civilian Radioactive Waste Management System
Management and Operating Contractor

AT-REACTOR DRY STORAGE ISSUES

Revision 1

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EXECUTIVE SUMMARY

PURPOSE

Although a substantial amount of spent nuclear fuel (SNF) can be stored in existing spent fuel pools at reactor sites, the storage capability is limited. Once the pool storage capacity for a given site has been reached, additional storage capacity is required. Utilities have thus far selected the use of dry storage technologies to meet additional at-reactor storage capacity needs.

The purpose of this report is to analyze the logistic and economic impacts of SNF storage at reactors. At-reactor dry storage capacity requirements, dry storage capital and operating costs, shutdown pool storage operation costs, and dry storage areal land requirements are specifically evaluated for both the reference scenario and the Multi-Purpose Canister (MPC) system. Other issues addressed are the impact on at-reactor dry storage requirements of not having a Monitored Retrievable Storage (MRS) facility in the system and the impact of not beginning SNF pick up from utilities until the year 2000. Particular emphasis is given to at-reactor dry storage requirements during the first five years of program operation from 1998 to 2002.

METHODOLOGY

Evaluations are performed for the reference scenario and the MPC system as defined in the *Concept of Operations for the Multi-Purpose Canister System* report, as well as for the MPC system with no Monitored Retrievable Storage (MRS) facility. Other systems or alternatives are not addressed, although the data does provide a broad basis which could serve as a point of departure for performing contingency analyses or evaluating other systems.

The quantitative evaluations of these three systems are driven by at-reactor storage logistics data which include, for example, the number of assemblies requiring dry storage, the number of dry storage casks, and the number of years of dry storage or shutdown reactor pool operation. The logistic data for all three systems were produced by running a series of system model computer programs which have the capability of simulating and quantitatively analyzing the logistics of both the reference scenario and the MPC system. The output from these systems models was used as input to a set of cost model spreadsheets that were used to perform the cost analyses for the three scenarios.

ASSUMPTIONS

MPCs are used for dry storage in the MPC system, and non-transportable MESCs are assumed for the reference scenario. The MPC system assumes transfer directly from dry storage to transportation without going back through the spent fuel pool. It is assumed that shutdown reactor spent fuel pools are unloaded into dry storage in the MPC system while pool storage continues in the reference scenario.

In the reference scenario, as spent fuel pools are filled, the additional SNF requiring storage beyond the capacity of the spent fuel pools will be loaded into non-transportable Multiple Element Sealed Canisters (MESCs) and stored in Dry Vertical Concrete Casks (DVCCs). All

SNF stored in spent fuel pools at the time of reactor shutdown will continue to be stored in the spent fuel pools until it is picked up into the CRWMS, and the spent fuel pools will continue to accrue operations and maintenance costs. For purposes of analysis, sites not capable of handling large casks (truck cask capability) will store SNF in small non-transportable MESC in DVCCs.

In the MPC system, as spent fuel pools are filled, the additional SNF requiring storage beyond the capacity of the spent fuel pools will be loaded into MPCs and stored in DVCCs at those sites having rail cask modal capability. For purposes of this analysis, sites which have only truck cask modal capability will use small non-transportable MESCs stored in DVCCs, as in the reference scenario. Sites having rail cask capability will complete transfer of all SNF stored in spent fuel pools at the time of reactor shutdown into dry storage in MPCs five years after reactor shutdown.

Detailed descriptions of the system parameters and assumptions used for the reference scenario and the MPC system are defined in the *Concept of Operations for the Multi-Purpose Canister System* report.

CONCLUSIONS AND RECOMMENDATIONS

Detailed information is developed on an annual basis for the number of sites, number of assemblies, total MTU, and number of dry storage canisters (MPCs and MESCs) required for at-reactor storage. At-reactor dry storage requirements based only on exceeding pool capacity are very similar for the reference scenario and the MPC system. However, the MPC system does require additional dry storage canisters due to a lower unit capacity. The MPC system requires more at-reactor dry storage than the reference scenario as a result of unloading shutdown reactor spent fuel pools into dry storage after reactor shutdowns. Additional at-reactor dry storage is required for the MPC system with no MRS because SNF pick-up does not begin until 2010.

At-reactor dry storage requirements in the early years of the program were evaluated for the MPC system with an MRS beginning in the year 2000. In 1998, additional at-reactor dry storage requirements are estimated to be 339 MTU, including 26 125-ton MPCs, 15 75-ton MPCs, and 17 small non-transportable MESCs. In 1999, estimates are that an additional 545 MTU, including 56 125-ton MPCs, 10 75-ton MPCs, and 9 small non-transportable MESCs will be required. In 2000, estimates are that an additional 441 MTU, including 30 125-ton MPCs, 13 75-ton MPCs, and 36 small non-transportable MESCs will be required. These estimates include cask-rounding to complete loading of each MPC and MESC.

At-reactor storage costs are evaluated, including both at-reactor dry storage and pool storage at shutdown reactors. Cost estimates are developed for the annual operating cost of an Independent Spent Fuel Storage Installation (ISFSI). Costs are estimated to be $240,000 per year at a site with operating facilities (i.e., operating reactors) and $840,000 per year at a site with no operating facilities (i.e., shutdown reactors).

At-reactor storage costs are evaluated and compared for the reference scenario, the MPC system, and the MPC system with no MRS. For the nominal system with an MRS, the total at-reactor storage costs that are non-waste fund costs for the reference scenario and MPC system are $5.5 billion and $3.4 billion, respectively. Results for the MPC system show a savings in non-waste fund at-reactor storage costs of $2.10 billion relative to the reference scenario. Overall savings for the MPC system result from a reduction of $2.95 billion in shutdown reactor spent fuel pool operating costs which is only partially offset by an increase of $0.76 billion in at-reactor dry storage costs. This demonstrates the potential cost savings available in unloading shutdown reactor spent fuel pools into dry storage following reactor shutdown. This savings is contingent on having a dry storage technology that does not have to be returned to the spent fuel pool prior to transportation. A comparison of at-reactor on-site dry storage costs driven only by exceeding spent fuel pool storage capacity shows the utility costs for the MPC system (non-waste fund costs) to be less expensive, saving $260 million relative to the reference scenario.

Note that although the savings in non-waste fund costs is important in itself, it must be combined with the CRWMS waste fund costs to determine the total cost impact on the overall system. The total system cost comparison (non-waste fund plus waste fund) is presented in the *Life Cycle Cost Comparison for the Multi-Purpose Canister System* report.

When there is no MRS in the system, the total at-reactor storage costs that are non-waste fund costs for the reference scenario and MPC system increase to $6.7 billion and $4.3 billion, respectively. With no MRS, the at-reactor storage cost savings in non-waste fund costs for the MPC system increase to $2.41 billion relative to the reference scenario. It appears that any delay in SNF pick up, such as delays or lack of an MRS, will increase the at-reactor storage cost advantage of the MPC system. It should be noted however, that even though the cost savings for the MPC system increase with no MRS in the system, the overall cost for at-reactor storage does increase. Therefore, relative to at-reactor storage costs, it is beneficial to have an MRS in the system.

Land requirements for at-reactor dry storage are estimated on a site-by-site basis. No attempt is made to determine the land availability for an ISFSI for each reactor site. Other potential limitations for at-reactor dry storage ISFSIs are not considered.

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1. INTRODUCTION

1.1 BACKGROUND

Although a substantial amount of discharged spent nuclear fuel (SNF) can be stored in existing spent fuel pools at reactor sites, the ultimate storage capability is limited. Once the spent fuel pool storage capacity for a given site has been reached, all future SNF discharges will require additional storage capacity outside the pool. For operational reasons, the actual spent fuel pool storage capacity prior to reactor shutdown typically allows excess storage capacity for one full core discharge. When pool capacity has been reached and additional SNF fuel storage capacity is required, utilities have selected the use of dry storage technologies to meet storage capacity needs. Aspects of at-reactor dry storage including dry storage capacity requirements, costs, and land requirements are evaluated for both operating reactors and shutdown reactors. The evaluations are performed for the reference scenario and the Multi-Purpose Canister (MPC) system as they are defined in the *Concept of Operations for the Multi-Purpose Canister System* report (Reference 1).

Until the Civilian Radioactive Waste Management System (CRWMS) begins to pick up SNF from the reactors sites, utilities will continue to store the SNF generated at their reactor sites. A large number of reactors are projected to ultimately require some capacity of at-reactor dry storage. Operating reactors will require dry storage when additional SNF is discharged beyond the spent fuel pool capacity. Shutdown reactors may use dry storage as a method of removing all SNF from the spent fuel pool and decommissioning the pool prior to all of the SNF being picked up from the site by the CRWMS. This strategy for shutdown reactors requires a dry storage technology which has the capability to transfer SNF directly to transportation casks without having to go back through the spent fuel pool at the time of SNF pick up.

The MPC technology is a dry storage technology which offers the advantage of going directly from dry storage to transportation without returning to the spent fuel pool. The MPC dry storage technology is the near-term focal point of the MPC system. The MPC system is based on the use of a clean, sealed metal canister for all CRWMS operations, including storage, transportation, and disposal. The MPC system is being evaluated as an alternative to the reference scenario which uses uncanistered fuel as the basis for all CRWMS operations.

1.2 OBJECTIVE

The objective is to analyze the logistic impacts and economic impacts of SNF storage at reactors. At-reactor dry storage capacity requirements, dry storage capital and operating costs, shutdown pool storage operation costs, and dry storage areal land requirements are specifically evaluated for both the reference scenario and the MPC system. Input data are provided on at-reactor storage requirements and costs that will be used directly and indirectly, through the life cycle cost analysis, in the overall evaluation of the MPC system. Other issues addressed are the impact on at-reactor dry storage requirements of not having a Monitored Retrievable Storage (MRS) facility in the system and the impact of not beginning SNF pick up from utilities until the year 2000. Particular emphasis is given to at-reactor dry storage requirements during the first five years of program operation from 1998 to 2002.

1.3 SCOPE

At-reactor dry storage issues are addressed for the reference scenario and the MPC system as defined in the *Concept of Operations for the Multi-Purpose Canister System* report (Reference 1). Also included is an analysis of the MPC system with no MRS in the system. Other systems or alternatives are not addressed, although the data does provide a broad basis which could serve as a point of departure for performing contingency analyses or evaluating other systems.

1.4 QUALITY ASSURANCE

A QAP-2-3 analysis has determined that this activity is not quality affecting. The analysis is documented in the document *QAP-2-3 Analysis for Systems Engineering MPC Activities* (Reference 2).

2. APPROACH

The at-reactor dry storage issues evaluation is performed for three system scenarios: the reference scenario, the MPC system, and the MPC system with no MRS. This section describes the analytical methodology and the assumptions used in the evaluation.

2.1 METHODOLOGY

The quantitative evaluation is driven by at-reactor storage logistics data which includes, for example, the number of assemblies requiring dry storage, the number of dry storage casks, and the number of years of dry storage or shutdown reactor pool operation. The logistic data for all three scenarios were produced by running a series of system model computer programs which have the capability of simulating and quantitatively analyzing the logistics of both the reference scenario and the MPC system. The output from these systems models was used as input to a set of cost model spreadsheets that were used to perform the cost analyses for the three scenarios.

2.1.1 Logistic Models and Data

The system models used to produce the at-reactor storage logistics data are the Waste Stream Model (WSM) and the Interface Model. WSM simulates the movement of spent fuel, either as individual spent fuel assemblies or as sealed canisters, through all system elements of the CRWMS. WSM tracks the history of each unit from the time of production (i.e., discharge to the spent fuel pool) through to eventual disposal in a geologic repository. The WSM system parameter input data can be tailored to simulate alternatives such as allocation rights, fuel selection rules, dry storage operations, and shutdown reactor operations. The other primary input data to WSM is the historical and projected spent fuel discharge data, including the type, discharge date, enrichment, and burnup for each individual spent fuel assembly, based on the 1992 DOE Energy Information Administration (EIA) "No New Orders/No Life Extensions" data as presented in Reference 3. The output from WSM provides data on the shipments of casks, assemblies, and MTU within the system, and the required quantity of at-reactor dry storage. The output from WSM also provides input data to the Interface Model.

Input for the Interface Model includes output from WSM plus system concept of operations parameter inputs in accordance with the scenario being analyzed. The output from the Interface Model includes data related to cask and canister loading and handling. Data in the tables were generated primarily by the Interface Model.

2.1.2 Cost Model and Data

The cost analysis was developed using several interlinked spreadsheets which provided a simple and flexible methodology. The cost analysis methodology combined the number of units of a particular item, as produced by the logistics models, with a unit cost for each, into a total cost for those units summed over all units into a total at-reactor storage cost for each scenario. The logistics data inputs for the cost analysis were those produced by WSM and the Interface Model. The dry storage cost input data were developed based on analysis and communication with some dry storage technology vendors and utilities experienced in planning, constructing, and operating an Independent Spent Fuel Storage Installation (ISFSI) on their reactor sites. A more detailed presentation of this cost input data is provided in Appendix A. The cost input for the annual operating costs of shutdown reactor pools is based on the August 1991 Pacific Northwest Laboratory (PNL) report *Cost Estimates of Operating Onsite Spent Fuel Pools After Final Reactor Shutdown* (Reference 4). The cost input data for the annual operating costs of a stand-alone Independent Spent Fuel Storage Installation were developed based on communications with some utilities on the requirements for personnel and non-personnel inputs for a stand-alone ISFSI, and were combined using a method of calculation based on that in Reference 4. The input data for construction costs and loading costs are based communications with some utilities and an evaluation of the data in an Electric Power Research Institute (EPRI) report on the Surry Station ISFSI (Reference 5).

2.2 ASSUMPTIONS

The general and specific assumptions are presented for the reference scenario, the MPC system, and the MPC system with no MRS. The assumptions for the reference scenario and the MPC system are consistent with those in the *Concept of Operations for the Multi-Purpose Canister System* report (Reference 1). The MPC system with no MRS is an extension of the MPC system as defined in Reference 1.

2.2.1 General Assumptions

Reference Scenario

As spent fuel pools are filled, the additional SNF requiring storage beyond the capacity of the spent fuel pool will be loaded into non-transportable Multiple Element Sealed Canisters (MESCs) and stored in Dry Vertical Concrete Casks (DVCCs). All SNF stored in spent fuel pools at the time of reactor shutdown will continue to be stored in the spent fuel pool until it is picked up into the CRWMS, and the spent fuel pools will continue to have operations and maintenance costs accrue to them. Dry storage SNF in non-transportable MESCs will be returned to the spent fuel pool prior to being picked up into the CRWMS. Therefore, spent fuel pools at shutdown reactors will continue to operate and be maintained until all the SNF, both in pool storage and dry storage, is removed from the reactor site. SNF in dry storage at the ISFSI will be stored in non-transportable MESCs with a size and capacity tailored to the site's cask handling capability. Sites capable of handling large casks (rail cask capability) will store SNF in large non-transportable MESC in DVCCs as storage overpacks. For purposes of analysis, sites not capable of handling large casks (truck cask capability) will store SNF in small non-transportable MESC in DVCCs.

MPC System

As spent fuel pools are filled, the additional SNF requiring storage beyond the capacity of the spent fuel pool will be loaded into MPCs and stored in DVCCs at those sites having rail cask modal capability. For purposes of analysis, sites which have only truck cask modal capability will use small non-transportable MESCs stored in DVCCs, as in the reference scenario. Sites having rail cask capability will complete transfer of all SNF stored in spent fuel pools at the time of reactor shutdown into dry storage in MPCs five years after reactor shutdown. After all SNF in the pool is loaded into MPCs in dry storage, the spent fuel pools will be decommissioned. The reason for this assumption is that the effective capital cost and annual operating cost of a stand-alone dry storage ISFSI is considerably lower than the alternative annual cost of continuing to maintain and operate a spent fuel pool. When the SNF in dry storage in MPCs is to be picked up into the CRWMS, the SNF will be transferred directly from dry storage into transportation casks, without having to be returned to the spent fuel pool. Sites having truck cask capability will continue to store their SNF in the spent fuel pool until it is picked up into the CRWMS, as in the reference scenario.

MPC System with No MRS

This case is similar to the MPC system except there is no MRS facility in the system. The SNF pick up schedule from the reactor sites is therefore delayed until 2010, when the Mined Geologic Disposal System (MGDS) begins operations, and all SNF is shipped directly from the reactor sites to the MGDS.

Reactor sites limited to truck cask capability are treated identically in all three of the above scenarios. All sites having only truck cask capability use small non-transportable MESCs for at-reactor dry storage and continue to maintain and operate their spent fuel pools even after reactor shutdown.

2.2.2 Specific Assumptions

Starting Date

Only dry storage requirements and shutdown reactor issues occurring after 1997 are specifically analyzed. Dry storage and shutdown reactor storage conditions projected to exist in 1997 are used as a point of departure for this work. The MRS, if there is one in the system, is assumed to begin operations in the year 2000. The MGDS is assumed to begin operations in 2010. The impact of potential MGDS delays beyond 2010 were not evaluated. MGDS delays are considered in the *Programmatic Risk and Contingency Analysis for the Multi-Purpose Canister System* report (Reference 6).

Throughput Rate

The steady state throughput rate for all scenarios is 3000 MTU/year. The specific year-by-year throughput rate for the reference system and the MPC system is that defined in the *Concept of Operations for the Multi-Purpose Canister System* report (Reference 1). The MPC system with no MRS uses the MGDS annual emplacement rate from Reference 1 as both the pick up rate from the utilities and the MGDS emplacement rate. The storage capacity of the MRS is assumed to be 10,000 MTU prior to the opening of the first MGDS, and 15,000 MTU after that date.

Modal Capability

The modal capability used is defined in the *Concept of Operations for the Multi-Purpose Canister System* report (Reference 1). All rail-cask capable facilities in the reference scenario are assumed to use large non-transportable MESCs for at-reactor dry storage. Rail cask capable facilities in the MPC system are assumed to use MPCs in a size consistent with their modal capability for at-reactor dry storage. Truck cask facilities are assumed to use small non-transportable MESCs for dry storage in both the reference scenario and MPC system.

SNF Allocation, Pick Up, and Selection

All waste acceptance related system parameters are assumed to be based on oldest-fuel-first (OFF) logic. Maintaining Full Core Reserve (FCR) for operational flexibility was assumed in determining the capacity of all spent fuel pools until the time of reactor shutdown.

Total Amount of SNF Projected to be Discharged

The assumption for total amount of SNF projected to be discharged is based on the 1992 DOE Energy Information Administration (EIA) "No New Orders/No Life Extensions" data as presented in Reference 3. This data includes a total projected discharge of 86,155 MTU of SNF.

Cask Capacity

The following cask capacities were used for the reference scenario and MPC system:

Reference scenario	
Large non-transportable MESC	24 PWR / 52 BWR
Small non-transportable MESC (for truck sites)	7 PWR / 17 BWR
MPC system	
125-ton MPC	21 PWR / 40 BWR
75-ton MPC	12 PWR / 24 BWR
Small non-transportable MESC (for truck sites)	7 PWR / 17 BWR

The MPC cask capacities are based on the assumption of 10-year old SNF for full loading. The impact of derating the MPC capacity to accommodate SNF between five and ten years old was not considered because of a lack of available design information on MPC derating.

Processing Times

Table 2-1 shows the at-reactor cask processing times for the following activities:

- for loading non-transportable MESCs and MPCs and transferring to the ISFSI. (Loading Time - MESCs and MPCs)
- for unloading non-transportable MESCs in the spent fuel pool and transferring SNF into a transportation cask for shipment to the MRS or MGDS. (Unloading Time - MESCs)
- for transferring MPCs from a storage overpack (DVCC) at the ISFSI into an MPC transportation cask for shipment to the MRS of MGDS. (Unloading Time - MPCs)

The unloading times for the non-transportable MESCs are the same as the loading times because the operation of transit to or from the pool and transfer of SNF to or from the SNF storage racks is essentially the same for the unloading and loading operation. The unloading and loading times for the MPCs are different because the loading time does not require MPC operations in the spent fuel pool or the handling of individual SNF assemblies in the pool, operations which are required for MPC loading.

Table 2-1. Processing Time for MESCs and MPCs At-Reactors

Cask Type	Loading Time (hours)	Unloading Time (hours)
7 PWR MESC	63.25	63.25
17 BWR MESC	68.25	68.25
24 PWR MESC	71.75	71.75
52 BWR MESC	85.75	85.75
12 PWR MPC	73.75	21.5
24 BWR MPC	79.25	21.5
21 PWR MPC	78.25	21.5
40 BWR MPC	87.75	21.5

Note: MESCs, as defined in this report, are non-transportable.
These processing times that were developed for this work are consistent with MRS facility design assumptions.

MESC and MPC Operations Staff

It is assumed that 13 Full Time Equivalents (FTEs) are required to load an MPC in the spent fuel pool and to transfer the MPC to dry storage in an on-site ISFSI. Ten FTEs are assumed to be required to load or unload a MESC in the spent fuel pool and to transfer the MESC to or from dry storage in an on-site ISFSI.

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3. AT-REACTOR DRY STORAGE REQUIREMENTS

After the capacity of the reactor spent fuel pools have been reached and additional SNF continues to be discharged, significant quantities of SNF will be transferred to at-reactor dry storage in ISFSIs. One example of expanded dry storage facilities being pursued is the metal storage cask ISFSI in operation at the Surry Power Station. Some sites at which the reactors are shutdown are searching for an ISFSI dry storage technology which can decouple their SNF storage from their spent fuel pools after reactor shutdown (e.g., Rancho Seco). This section evaluates the SNF storage requirements for at-reactor dry storage and shutdown pool storage throughout the lifetime of the CRWMS program. Spent fuel pool storage requirements at shutdown reactors are included in this analysis to provide data for the possible scenario in which all SNF in a shutdown reactor pool is transferred into dry storage to facilitate spent fuel pool decommissioning. Storage requirements prior to 1998 are developed as an initial boundary condition. At-reactor storage beginning in 1998 and going until all SNF is picked up from the reactor sites is evaluated for the reference scenario, the MPC system, and the MPC system with no MRS. Comparisons are made between the at-reactor storage requirements for each of the three scenarios. Section 4 provides a more focused analysis of the dry storage requirements during the first five years of the program, from 1998 until 2002, with a facility-by-facility focus on the years 1998 and 1999.

3.1 AT-REACTOR DRY STORAGE REQUIREMENTS PRIOR TO 1998

Prior to 1998, several reactor sites will have requirements for SNF storage beyond the capacity of their spent fuel pools. An option for meeting these storage requirements is at-reactor dry storage. This an option is already in place and operational at several sites. Technologies for out-of-pool at-reactor dry storage have been available and in use since 1986. In 1986, the Nuclear Regulatory Commission (NRC) licensed an ISFSI using metal cask dry storage at the Surry Station Power and horizontal concrete module dry storage at the H.B. Robinson site. Several years later, the Oconee site received NRC approval for an ISFSI using a larger version of the horizontal concrete module dry storage technology pioneered at H.B. Robinson. Since then, several additional sites have received NRC approval for a dry storage ISFSI, while several other sites are considering the use of at-reactor dry storage to meet their expected storage capacity requirements. The at-reactor dry storage requirements and shutdown reactor sites storage requirements prior to 1998 were evaluated and are presented below.

Before 1998, eight reactor facilities with spent fuel pools are projected to be shutdown. Each of the spent fuel pools is anticipated to have a number of SNF assemblies stored in the pool after the reactor is shutdown. This projection includes the number of SNF assemblies from the final full core discharge following reactor shutdown. Table 3-1 shows the spent fuel pools and the number of SNF assemblies stored in each pool at reactors projected to be shutdown prior to 1998. The data shows the status for these pools at the beginning of 1998. Although it was recently shutdown, the Trojan reactor was not shutdown at the time that information was developed for the 1992 EIA database (see Reference 3) and therefore Trojan it is not considered shutdown in the logistics model used for this report (see Section 2.1.1 for more information on the logistics model and inputs).

Table 3-1. Spent Fuel Pools and SNF Storage at Reactors Shutdown Before 1998

Pool Name	Fuel Type	Number of Assemblies
Dresden 1	BWR	683
Indian Point 1	PWR	160
Lacrosse	BWR	333
Three Mile Island 2	PWR	a
Shoreham	BWR	560
Humboldt Bay	BWR	390
Trojan	PWR	b
Fort St. Vrain	HTGR	c
Rancho Seco	PWR	493
San Onofre 1	PWR	256
Yankee-Rowe	PWR	533

Notes:
a) SNF stored at Idaho National Engineering Laboratory. Shown for completeness, not included in reminder of evaluation.
b) Not included as a shutdown reactor in 1992 EIA database (Reference 3). Therefore, not included as a shutdown reactor in remainder of analysis
c) HTGR fuel; this report is focused on LWR fuel only. Shown for completeness, not included in reminder of evaluation.

Before 1998, 22 spent fuel storage pools will have reached their maximum capacity and will require additional storage capacity, which is assumed to be at-reactor dry storage. Table 3-2 presents the list of pools and the total number of SNF assemblies requiring at-reactor dry storage before 1998.

These at-reactor storage requirements prior to 1998 are only considered as boundary conditions throughout the remainder of the report.

Table 3-2. Dry Storage Requirements Before 1998

Pool Name	Fuel Type	Number of Assemblies
Ark Nuclear 1	PWR	48
Ark Nuclear 2	PWR	48
Calvert Cliffs 1, 2	PWR	264
Pilgrim	BWR	85
Brunswick 1	BWR	468
Robinson 2	PWR	128
Big Rock 1	BWR	34
Palisades	PWR	168
Oconee 1, 2	PWR	648
Oconee 3	PWR	168
Oyster Creek	BWR	156
Maine Yankee	PWR	24
Nine Mile Point	BWR	312
Millstone 1	BWR	52
Prairie Island 1, 2	PWR	288
Fort Calhoun	PWR	70
Limerick 1, 2	BWR	156
Davis-Besse	PWR	48
Surry 1, 2	PWR	592
Point Beach 1, 2	PWR	96

3.2 AT-REACTOR DRY STORAGE REQUIREMENTS AFTER 1998

The primary focus of this report is on at-reactor storage requirements beginning in the year 1998. It is assumed that the SNF already in dry storage prior to 1998 will continue to be stored at an ISFSI. At-reactor dry storage and shutdown reactor pool storage requirements are evaluated for the reference scenario, the MPC system, and the MPC system with no MRS. At-reactor storage requirements are evaluated from 1998 until the time all SNF has been removed from the reactor sites. Figure 3-1 shows aggregate at-reactor dry storage data for a system in which the CRWMS begins picking up SNF from the reactor sites in the year 2000. Figure 3-1 shows the aggregate total number of pools requiring dry storage, total number of pools associated with shutdown reactors, total MTU of SNF in dry storage, and the total MTU of SNF in spent fuel pools at shutdown reactors, given on an annual basis.

3.2.1 Reference Scenario

This scenario considers large and small non-transportable MESCs for SNF at-reactor dry storage for utilities requiring SNF storage capacity in excess of the capacity of their spent fuel pools. At reactors that shutdown, all SNF in the spent fuel pool at the time of reactor shutdown is assumed to remain in pool storage until it is picked up to be shipped to the MRS or MGDS. For this scenario, it is assumed that the CRWMS begins picking up SNF from the reactors for shipment to the MRS beginning in 2000. Information for the year 1997 is shown in the table as a boundary condition for at-reactor storage prior to 1998.

Table 3-3 presents the following cumulative data by year for the reference scenario:

- Number of spent fuel pools and sites having shutdown reactors.
- Number of spent fuel pools and sites requiring at-reactor dry storage.
- Number of SNF assemblies in spent fuel pools and dry storage at shutdown reactors.
- Number of SNF assemblies in dry storage, including operating and shutdown reactor sites.
- Total MTU in spent fuel pools and dry storage at shutdown reactors.
- Total MTU in dry storage, including operating and shutdown reactor sites.
- Number of dry storage canisters (both large and small non-transportable MESCs), including operating and shutdown reactor sites, by BWR and PWR.

The following results for at-reactor dry storage and shutdown reactor pool storage for the reference scenario can be summarized based on the results shown in Table 3-3:

- the maximum number of shutdown reactor spent fuel pools in any given year is 73 pools (at 59 sites), which occurs in the year 2033.

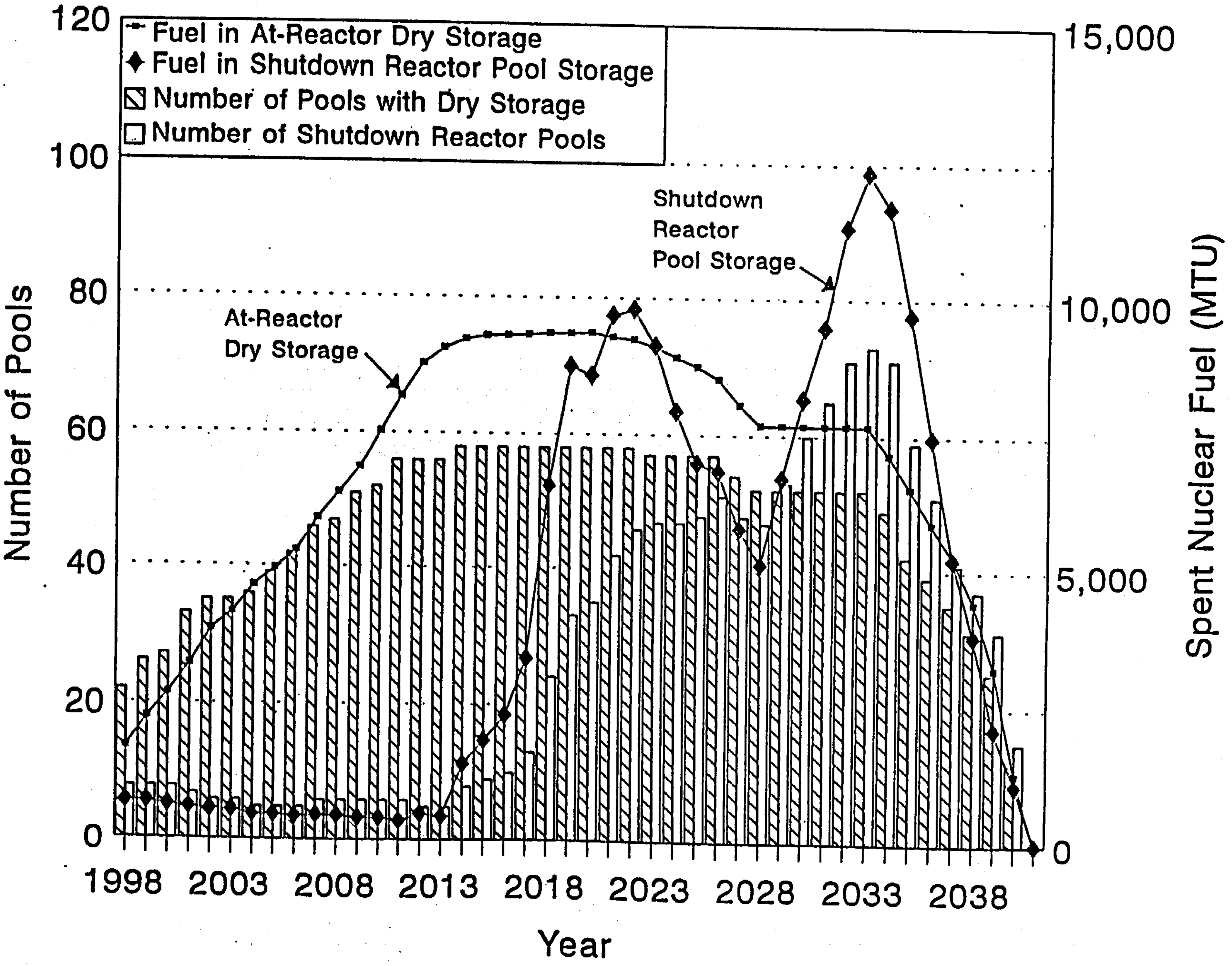


Figure 3-1. At Reactor Dry Storage and Shutdown Reactor Pool Storage Data - Starts in Year 2000

Table 3-3. Cumulative Dry Storage and Shutdown Reactor Storage Requirements for Reference Scenario.

	Number of				Assemblies-cumulative			MTU-cumulative			Dry Storage Canisters-cumulative			
	Shutdown[2]		Dry Storage		Fuel in Shutdown Pools[1]		Total Dry	Fuel in Shutdown Pools[1]		Total Dry	BWR	PWR	BWR	PWR
	Pools	Sites	Pools	Sites	Truck	Rail	Storage	Truck	Rail	Storage	LG-MESC	LG-MESC	SM-MESC	SM-MESC
1997	8	8	20	18	0	0	3853	0	0	1362.94	22	102	7	34
1998	8	8	22	20	0	0	5140	0	0	1720.49	35	120	13	45
1999	8	8	26	24	0	0	6837	0	0	2239.34	51	153	14	53
2000	8	8	27	24	0	0	8297	0	0	2685.00	58	179	36	67
2001	7	7	33	30	0	0	10214	0	0	3218.90	81	207	36	74
2002	6	6	35	32	0	0	12423	0	0	3835.45	103	242	48	77
2003	6	6	35	32	0	0	13755	0	0	4135.49	124	252	48	77
2004	5	5	36	32	0	0	15655	0	0	4638.55	149	277	48	77
2005	5	5	39	35	0	0	16731	0	0	4956.40	160	298	48	77
2006	5	5	42	35	0	0	18263	0	0	5320.92	183	312	48	77
2007	6	6	46	39	347	0	20511	45.49	0	5929.64	211	345	48	77
2008	6	6	47	40	320	0	22139	42.00	0	6413.90	228	376	48	77
2009	6	6	51	43	320	0	24067	42.00	0	6908.49	254	400	48	77
2010	6	6	52	44	302	0	26363	39.66	0	7525.42	282	435	48	77
2011	6	6	56	47	266	0	28811	34.91	0	8189.68	312	472	48	77
2012	6	6	56	47	962	0	31099	302.15	0	8768.69	344	498	48	77
2013	5	5	56	47	888	0	32075	276.70	0	9062.13	354	517	48	77
2014	8	8	58	49	1427	5058	32655	466.96	868.90	9223.32	361	526	48	77
2015	9	9	58	49	1299	7130	32775	426.84	1351.61	9277.93	361	531	48	77
2016	10	9	58	49	2838	8860	32775	670.56	1626.42	9277.93	361	531	48	77
2017	13	12	58	49	4080	13124	32715	962.69	2365.30	9293.57	358	535	48	77
2018	24	23	58	49	8988	17630	32783	2077.40	4470.52	9339.36	357	540	48	77
2019	33	30	58	49	12110	25266	32783	2582.59	6152.69	9339.36	357	540	48	77
2020	35	31	58	49	11203	24794	32831	2391.83	6175.91	9361.25	357	542	48	77
2021	42	37	58	49	11511	27380	32482	2736.92	6917.94	9278.22	352	539	47	77
2022	46	41	58	49	11018	26573	32362	2684.53	7114.81	9223.33	352	534	47	77
2023	47	41	57	48	9534	26320	31842	2327.56	6817.58	9078.18	347	526	43	77
2024	47	41	57	48	8982	22300	31280	2184.30	5754.95	8891.24	342	512	43	77
2025	48	42	57	48	7789	19627	30917	1867.10	5125.75	8728.03	342	496	43	77
2026	51	43	57	48	6302	18807	30194	1510.03	5346.01	8454.85	339	473	43	69
2027	48	41	54	46	5593	15041	28385	1322.37	4469.16	7981.75	315	454	43	54
2028	47	39	52	45	3878	12964	27159	963.30	4208.40	7569.76	306	423	43	52
2029	53	45	52	45	3878	20924	27159	963.30	5852.97	7569.76	306	423	43	52
2030	60	51	52	45	3878	25708	27159	963.30	7320.84	7569.76	306	423	43	52
2031	65	53	52	45	3878	30971	27159	963.30	8626.23	7569.76	306	423	43	52
2032	71	57	52	45	3878	36715	27159	963.30	10458.98	7569.76	306	423	43	52
2033	73	59	52	45	3878	38990	27159	963.30	11493.92	7569.76	306	423	43	52
2034	71	56	49	42	2951	36548	25614	768.63	11033.74	7021.09	301	390	28	18
2035	60	48	42	37	1530	30570	23816	449.15	9392.24	6391.47	291	342	28	0
2036	52	42	39	34	394	23748	21448	179.12	7376.44	5788.76	268	313	0	0
2037	41	35	35	31	0	16927	19432	0	5320.97	5146.66	250	268	0	0
2038	38	32	32	28	0	11792	16456	0	3863.89	4329.18	214	222	0	0
2039	31	26	25	22	0	6367	12116	0	2226.01	3077.77	167	143	0	0
2040	15	14	12	12	0	2714	4976	0	1135.61	1285.96	68	60	0	0
2041	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Notes: 1. Excludes fuel in pools shutdown prior to 1998

2. Shutdown reactor data is based 5 years after discharge date

- the maximum number of reactor sites requiring at-reactor dry storage is 49 sites (comprising 58 spent fuel pools), which occurs in the year 2014.
- the maximum number of SNF assemblies in at-reactor dry storage is 32,831 assemblies, which occurs in the year 2020. This number of SNF assemblies yields a maximum total MTU in at-reactor dry storage of 9,361 MTU in 2020.
- the maximum number of dry storage canisters, and therefore dry storage casks, in at-reactor dry storage is 1024 canisters, which occurs in the year 2020. These dry storage canisters are made up of both large and small non-transportable MESCs.

3.2.2 MPC System

This scenario considers 125-ton rail cask MPCs and 75-ton rail cask MPCs for SNF at-reactor dry storage at those reactor sites with rail cask modal capability, and small non-transportable MESCs for sites limited to truck cask modal capability requiring SNF storage capacity in excess of the capacity of their spent fuel pools. At reactors that shutdown, all SNF in the spent fuel pool at the time of reactor shutdown at sites with rail cask modal capability is assumed to be loaded into MPCs and transferred to at-reactor dry storage five years after the date of reactor shutdown. In this way, the spent fuel pools at shutdown reactors can be unloaded and decommissioned prior to the time all SNF is picked up from the site by the CRWMS. At the time SNF is to be picked up from these sites, the MPCs will be transferred directly from dry storage into transportation casks for shipment to the MRS or MGDS, without having to first be returned to the spent fuel pool. At shutdown reactors having only truck cask modal capability, all SNF in the spent fuel pool at the time of reactor shutdown is assumed to remain in pool storage until it is picked up to be shipped to the MRS or MGDS. For this scenario, it is assumed that the CRWMS begins picking up SNF from the reactors for shipment to the MRS beginning in 2000. Information for the year 1997 shows up on Table 3-4 as a boundary condition for at-reactor storage prior to 1998, and therefore large and small MESCs loaded prior to 1998 are carried in the analysis. They are unloaded and their SNF is picked up into the CRWMS.

Table 3-4 presents the following cumulative data by year for the MPC system:

- Number of spent fuel pools and sites having shutdown reactors.
- Number of spent fuel pools and sites requiring at-reactor dry storage.
- Number of SNF assemblies in spent fuel pools and dry storage at shutdown reactors.
- Number of SNF assemblies in dry storage, including operating and shutdown reactor sites.
- Total MTU in spent fuel pools and dry storage at shutdown reactors.
- Total MTU in dry storage, including operating and shutdown reactor sites.

Table 3-4 . Cumulative Dry Storage and Shutdown Reactor Storage Requirements for MPC System

	Number of				Assemblies-cumulative			MTU-cumulative			Dry Storage Canisters (MPCs and MESCs)-cumulative[1]							
	Shutdown[2]		Dry Storage		Fuel in Shutdown Pools[1]		Total Dry	Fuel in Shutdown Pools[1]		Total Dry	BWR	PWR	BWR	PWR	BWR	PWR	BWR	PWR
	Pools	Sites	Pools	Sites	Truck	Rail	Storage	Truck	Rail	Storage	LG-MESC	LG-MESC	SM-MESC	SM-MESC	LG-MPC	LG-MPC	MD-MPC	MD-MPC
1997	8	8	20	18	0	0	3853	0	0	1362.98	22	102	7	34	0	0	0	0
1998	8	8	22	20	0	0	5054	0	0	1702.22	22	102	13	45	8	18	12	3
1999	8	8	26	24	0	0	6866	0	0	2247.97	22	102	14	53	25	57	22	3
2000	8	8	27	24	0	0	8356	0	0	2688.72	22	102	36	67	32	83	28	7
2001	7	7	33	30	0	0	10157	0	0	3203.31	22	102	36	74	56	115	33	7
2002	6	6	35	32	0	0	12366	0	0	3821.01	22	102	48	77	81	155	39	7
2003	6	6	35	32	0	0	13799	0	0	4146.35	22	102	48	77	107	168	44	7
2004	5	5	36	32	0	0	15688	0	0	4649.34	22	102	48	77	139	197	44	7
2005	5	5	39	35	0	0	16747	0	0	4958.97	22	102	48	77	151	220	48	7
2006	5	5	42	35	0	0	18182	0	0	5302.55	22	102	48	77	179	235	48	7
2007	6	6	46	39	347	0	20441	45.49	0	5917.67	22	102	48	77	215	274	48	7
2008	6	6	47	40	320	0	22054	42.00	0	6385.58	22	102	48	77	238	307	48	7
2009	6	6	51	43	320	0	23998	42.00	0	6863.26	22	102	48	77	274	331	48	7
2010	6	6	52	44	302	0	26429	39.66	0	7534.04	22	102	48	77	311	374	48	11
2011	6	6	56	47	266	0	28785	34.91	0	8178.97	22	102	48	77	348	410	48	21
2012	5	5	56	47	962	0	31123	302.16	0	8765.66	22	102	48	77	391	436	48	27
2013	5	5	56	47	888	0	32121	276.71	0	9058.50	22	102	48	77	405	454	48	32
2014	8	8	58	49	1427	5029	37760	466.98	863.95	10087.53	22	102	48	77	480	464	151	32
2015	9	9	58	49	1299	7125	39994	426.86	1354.07	10640.72	22	101	48	77	477	470	224	74
2016	10	9	58	49	2838	8868	41758	670.57	1631.05	10927.39	22	101	48	77	469	471	312	70
2017	13	12	58	49	4080	13120	45959	962.71	2367.75	11683.83	19	101	48	77	465	476	499	65
2018	24	23	58	49	8988	17602	50485	2077.30	4465.33	13812.80	19	101	48	77	460	737	473	61
2019	33	30	58	49	12110	25250	58133	2582.57	6155.90	15503.37	19	101	48	77	592	769	523	111
2020	35	31	58	49	11203	24794	57716	2391.78	6182.43	15547.68	19	100	48	77	584	763	497	168
2021	42	37	58	49	11511	27426	59979	2736.85	6946.26	16225.13	19	97	47	77	602	824	522	151
2022	46	41	58	49	11018	26495	58952	2684.47	7113.42	16348.12	19	93	47	77	583	882	467	147
2023	47	41	57	48	9534	26220	58227	2327.57	6799.43	15905.00	19	84	43	77	618	836	439	131
2024	47	41	57	48	8982	22246	53704	2184.30	5754.85	14673.75	19	72	43	77	580	778	384	115
2025	48	42	57	48	7789	19532	50599	1867.10	5107.90	13859.36	19	60	43	77	555	745	342	103
2026	51	43	57	48	6293	18628	49115	1508.39	5319.89	13843.11	19	41	43	69	527	808	294	104
2027	48	41	54	46	5593	14982	43738	1322.34	4455.30	12519.99	9	23	43	54	483	772	224	92
2028	47	39	52	45	3878	12797	40340	963.30	4136.97	11825.25	6	11	43	52	454	787	146	74
2029	53	45	52	45	3878	20603	48146	963.30	5750.22	13438.50	6	11	43	52	629	830	146	74
2030	60	51	52	45	3878	25371	52914	963.30	7212.82	14901.10	6	11	43	52	689	947	146	74
2031	65	53	52	45	3878	30649	58192	963.30	8518.16	16206.44	6	11	43	52	786	1016	146	74
2032	71	57	52	45	3878	36398	63941	963.30	10350.59	18038.87	6	11	43	52	852	1167	146	74
2033	73	59	52	45	3878	38679	66222	963.30	11388.07	19076.35	6	11	43	52	852	1277	146	74
2034	71	56	49	42	2951	36109	62210	768.59	10915.54	18082.10	3	5	28	18	840	1171	74	171
2035	59	47	42	37	1530	30101	54413	449.25	9259.13	15805.16	3	2	28	0	750	1029	45	140
2036	51	42	39	34	368	23509	45283	169.17	7297.71	13190.78	0	0	0	0	644	868	24	107
2037	41	35	35	31	0	16635	36530	0	5228.22	10502.61	0	0	0	0	544	672	0	92
2038	37	31	31	27	0	11576	28434	0	3798.15	8219.54	0	0	0	0	416	534	0	76
2039	31	26	25	22	0	5976	18647	0	2131.30	5351.88	0	0	0	0	278	338	0	54
2040	15	14	12	12	0	2679	7798	0	1125.49	2446.90	0	0	0	0	99	166	0	39
2041	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Notes: 1. Excludes fuel in pools shutdown prior to 1998

[illegible] Shutdown reactor data is based 5 years after discharge date

- Number of dry storage canisters (including 125-ton MPCs, and 75-ton MPCs, and small MESCs), including operating and shutdown reactor sites, by BWR and PWR. The number of large MESCs loaded prior to 1998 is also listed.

The following results for at-reactor dry storage and shutdown reactor pool storage for the MPC system can be summarized based on the results shown in Table 3-4:

- the maximum number of shutdown reactor spent fuel pools in any given year is 73 pools (at 59 sites), which occurs in the year 2033. This is the same as the reference scenario.

- the maximum number of reactor sites requiring at-reactor dry storage is 49 sites (comprising 58 spent fuel pools), which occurs in the year 2014. This is the same as the reference scenario.

- the maximum number of SNF assemblies in at-reactor dry storage is 66,222 assemblies, which occurs in the year 2033. This includes SNF loaded into dry storage in order to unload spent fuel pools at shutdown reactor sites. This number of SNF assemblies yields a maximum total MTU in at-reactor dry storage of 19,076 MTU in 2033.

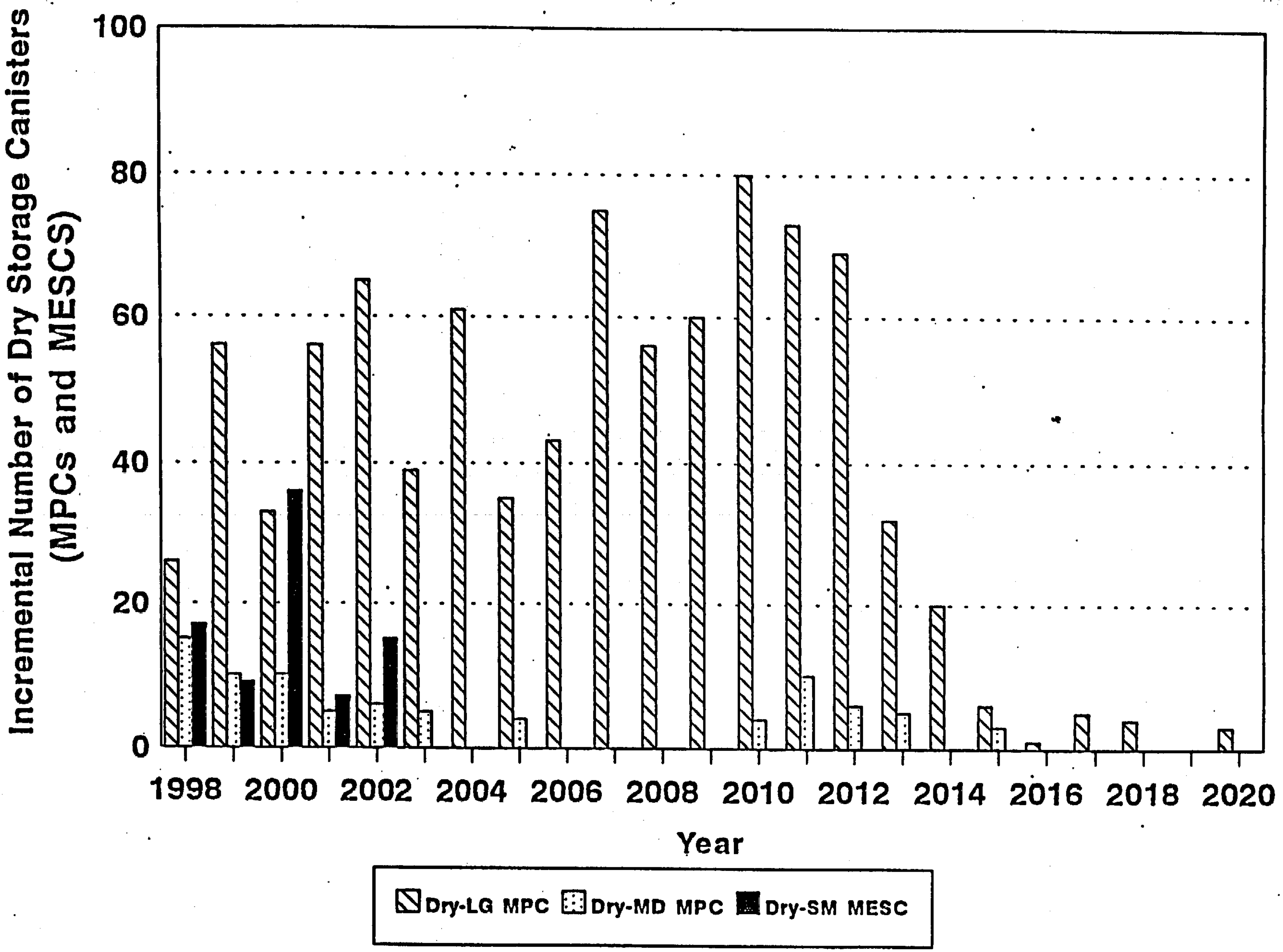
- the maximum number of dry storage canisters, and therefore dry storage casks, in at-reactor dry storage is 2461 canisters, including 2349 MPCs and the remainder MESCs, which occurs in the year 2033. The MPC needs include 2129 125-ton MPCs and 220 75-ton MPCs.

Appendix B, Table B-1 presents the number of dry storage canisters, and therefore dry storage casks, required for at-reactor dry storage subdivided into dry storage required as a result of exceeding spent fuel pool storage capacity and dry storage required as a result of unloading the spent fuel pools at shutdown reactors. The information in Appendix B is given in the same format of number of dry storage canisters by type, size, and fuel type, provided cumulatively by year.

Figure 3-2 presents the number of incremental dry storage canisters, including MPCs and small MESCs, required on an annual basis specifically for at-reactor dry storage as a result of exceeding spent fuel pool storage capacity. This figure does not include potential dry storage requirements for unloading spent fuel pools at shutdown reactors. After 2020 there is no need for additional at-reactor dry storage based on exceeding pool storage capacity limits,.

3.2.3 MPC System with No MRS

This scenario considers the same MPC system described in the preceding section, but with no MRS. Thus it addresses the impact on at-reactor dry storage of not having an MRS in the CRWMS. The MPC system with No MRS uses the same 125-ton rail cask MPCs and 75-ton rail cask MPCs for SNF at-reactor dry storage at those reactor sites with rail cask modal capability, and small non-transportable MESCs for at-reactor dry storage at those sites limited to truck cask modal capability. The primary difference for this scenario is that, with no MRS in the system, SNF pick up from the reactor sites does not begin until 2010, when the MGDS begins operations. In the no MRS system, all SNF (including that loaded in MPCs) picked up



Notes: - Prior to 1998 124 Large MESC's were used at rail sites (not shown)
- After 2020 There are No Additional At-Reactor Dry Storage Requirements

Figure 3-2. Incremental Number of Dry Storage Canisters (MPCs and MESCs) Required for At-Reactor Dry Storage - MPC System from reactor sites will be shipped directly to the MGDS, and the pick up rate will be coupled directly to the MGDS annual emplacement rate. The no MRS system scenario leads to an increase in the requirements for at-reactor dry storage and an increase in the length of time SNF is stored in dry storage and in spent fuel pools at shutdown reactors.

Table 3-5 presents the following cumulative data by year for the MPC system with no MRS:

- Number of spent fuel pools and sites having shutdown reactors.
- Number of spent fuel pools and sites requiring at-reactor dry storage.
- Number of SNF assemblies in spent fuel pools and dry storage at shutdown reactors.
- Number of SNF assemblies in dry storage, including operating and shutdown reactor sites.
- Total MTU in spent fuel pools and dry storage at shutdown reactors.
- Total MTU in dry storage, including operating and shutdown reactor sites.
- Number of dry storage canisters (including 125-ton MPCs, and 75-ton MPCs, and small MESCs), including operating and shutdown reactor sites, by BWR and PWR. The number of large MESCs loaded prior to 1998 is also listed.

The following results for at-reactor dry storage and shutdown reactor pool storage for the MPC system can be summarized based on the results shown in Table 3-5:

- the maximum number of shutdown reactor spent fuel pools in any given year is 73 pools (at 59 sites), which occurs in the year 2033. This is the same as the MPC system with an MRS and the reference scenario.
- the maximum number of reactor sites requiring at-reactor dry storage is 64 sites (comprising 78 spent fuel pools), which occurs in the year 2014. The MPC system with an MRS required at-reactor dry storage has a maximum of only 49 sites (58 pools). Therefore, the lack of an MRS in the system will require at-reactor dry storage at 15 additional sites over the MPC system with an MRS.
- the maximum number of SNF assemblies in at-reactor dry storage is 94,432 assemblies, which occurs in the year 2021. This includes SNF loaded into dry storage in order to unload spent fuel pools at shutdown reactor sites. This is more than a 40 percent increase over the maximum 66,222 assemblies requiring at-reactor dry storage in the MPC system with an MRS
- the maximum number of dry storage canisters, and therefore dry storage casks, in at-reactor dry storage is 3920 canisters, including 3251 MPCs and the remainder MESCs, which occurs in the year 2022. The MPC needs include 2335 125-ton MPCs and 916 75-ton MPCs.

Table 3-5. Cumulative Dry Storage and Shutdown Reactor Storage Requirements for MPC System with No MRS

	Number of				Assemblies-cumulative			MTU-cumulative			Dry Storage Canisters (MPCs and MESCs)-cumulative[1]							
	Shutdown[2]		Dry Storage		Fuel in Shutdown Pools[1]		Total Dry	Fuel in Shutdown Pools[1]		Total Dry	BWR	PWR	BWR	PWR	BWR	PWR	BWR	PWR
	Pools	Sites	Pools	Sites	Truck	Rail	Storage	Truck	Rail	Storage	LG-MESC	LG-MESC	SM-MESC	SM-MESC	LG-MPC	LG-MPC	SM-MPC	SM-MPC
1997	8	8	20	18	0	0	3853	0	0	1363.00	22	102	7	34	0	0	0	0
1998	8	8	22	20	0	0	5054	0	0	1702.24	22	102	13	45	8	18	12	3
1999	8	8	26	24	0	0	6866	0	0	2247.99	22	102	14	53	25	57	22	3
2000	8	8	27	24	0	0	8356	0	0	2688.76	22	102	36	67	32	83	28	7
2001	8	8	37	33	0	0	10649	0	0	3324.38	22	102	43	84	56	118	41	11
2002	8	8	40	36	0	0	13781	0	0	4171.56	22	102	63	103	90	165	54	11
2003	8	8	41	36	0	0	16373	0	0	4833.37	22	102	88	115	115	196	70	15
2004	8	8	42	36	0	0	19740	0	0	5746.72	22	102	94	134	157	244	87	18
2005	8	8	46	40	0	0	22415	0	0	6514.11	22	102	119	144	171	296	109	18
2006	8	8	51	41	0	0	25609	0	0	7362.75	22	102	140	174	203	335	129	22
2007	9	9	55	45	438	0	29706	57.11	0	8408.08	22	102	161	184	249	389	158	22
2008	9	9	57	47	438	0	33648	57.11	0	9533.55	22	102	196	212	277	456	182	26
2009	9	9	63	52	438	0	37594	57.11	0	10522.45	22	102	220	226	318	504	215	26
2010	9	9	66	55	438	0	42220	57.11	0	11854.65	22	102	234	243	366	589	236	31
2011	9	9	70	58	420	0	46797	54.82	0	13073.34	22	102	280	262	410	651	256	41
2012	8	8	71	59	1326	0	52002	408.63	0	14466.85	22	102	280	281	469	723	303	47
2013	7	7	74	60	1256	0	55819	384.91	0	15590.58	22	102	291	281	523	797	297	52
2014	11	11	78	64	1769	5531	65228	566.75	952.00	17638.70	22	102	291	291	654	865	408	57
2015	13	13	78	64	1560	7567	69961	497.23	1421.79	18884.85	22	101	291	291	687	914	485	104
2016	15	14	78	64	3365	8510	72720	771.84	1559.38	19585.66	22	99	291	291	694	958	552	105
2017	16	15	78	64	4421	12210	78541	1017.54	2200.00	20754.18	22	94	291	291	728	988	716	106
2018	26	25	78	64	8639	16333	83456	2003.35	4189.77	22973.39	22	94	291	291	735	1243	688	107
2019	35	32	78	64	11688	23677	91192	2496.36	5844.93	24743.88	22	93	291	291	859	1272	747	180
2020	35	31	78	64	10413	23511	91098	2238.27	6072.46	25005.17	22	89	291	291	853	1288	704	258
2021	42	37	78	64	10878	26915	94432	2663.50	6984.41	25899.34	21	83	291	291	900	1356	726	239
2022	46	41	78	64	10558	27033	94195	2688.04	7572.16	26323.86	21	66	291	291	879	1456	681	235
2023	48	42	78	64	9285	26480	93275	2387.15	7269.84	25904.88	19	54	291	291	917	1428	630	219
2024	48	42	78	64	8179	22895	89091	2118.27	6333.48	24782.89	19	41	291	284	875	1382	588	205
2025	49	43	78	64	7411	19993	85714	1898.49	5684.59	23935.34	19	28	290	280	845	1350	541	205
2026	53	45	78	64	6053	20250	85324	1577.09	6219.90	24234.03	17	17	289	270	827	1431	509	191
2027	53	45	77	63	5167	17356	81455	1380.09	5494.99	23184.06	13	9	285	254	797	1382	470	179
2028	56	46	77	63	4185	16656	79234	1120.61	5500.91	22678.26	9	2	285	234	778	1388	427	175
2029	62	52	77	63	3130	22713	83567	856.49	6439.62	23078.41	3	0	285	213	955	1339	388	160
2030	68	57	76	62	2383	23123	81885	710.77	6776.84	22712.82	0	0	279	178	953	1347	343	145
2031	73	59	76	62	1521	22815	79612	491.53	6555.18	21889.82	0	0	262	162	968	1285	303	130
2032	73	59	70	59	993	23513	75270	354.90	7009.68	21077.78	0	0	243	132	927	1301	207	116
2033	73	59	68	57	547	22716	71817	239.73	7071.94	20482.12	0	0	206	132	885	1304	161	107
2034	71	56	63	52	468	21097	65410	206.66	6724.78	18904.67	0	0	144	91	845	1194	82	171
2035	59	47	52	44	420	18063	56052	186.15	5817.39	16249.75	0	0	76	42	755	1041	53	140
2036	51	42	45	39	284	13772	45932	130.68	4364.74	13423.87	0	0	0	12	647	882	24	107
2037	41	35	37	33	0	8641	36954	0	2816.42	10685.55	0	0	0	0	544	688	0	92
2038	37	31	32	28	0	5724	28848	0	2115.74	8341.18	0	0	0	0	420	544	0	76
2039	31	26	26	23	0	2995	18859	0	1231.41	5427.59	0	0	0	0	278	345	0	54
2040	15	14	12	12	0	1448	7875	0	654.16	2486.44	0	0	0	0	97	171	0	39
2041	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

N[illegible] 1. Excludes fuel in pools shutdown prior to 1998

2. Shutdown reactor data is based 5 years after discharge date

Appendix B, Table B-2 presents, for the MPC system with no MRS, the number of dry storage canisters, and therefore dry storage casks, required for at-reactor dry storage subdivided into dry storage required as a result of exceeding spent fuel pool storage capacity and dry storage required as a result of unloading the spent fuel pools at shutdown reactors. The information in Appendix B is given in the same format of number of dry storage canisters by type, size, and fuel type, provided cumulatively by year.

3.3 COMPARISON BETWEEN SYSTEMS

The results for at-reactor dry storage and shutdown reactor storage are compared for the reference scenario, the MPC system, and the MPC system with no MRS. The comparison provides contrast in the number of sites requiring at-reactor dry storage, the number of sites with shutdown reactors, the amount of SNF in at-reactor dry storage, and the amount of SNF in storage in pools at shutdown reactors. A comparison is made between the reference scenario and the MPC system, to provide a basis for evaluating at-reactor storage issues for the MPC system, and between the MPC system with an MRS and the MPC system with no MRS, to provide a basis for evaluating the impact of not having an MRS in the system.

3.3.1 Comparison Between Reference Scenario and MPC System

A comparison between the results for the reference scenario and the MPC system indicates there are no significant differences in the two with respect to the number of reactor sites requiring at-reactor dry storage, number of shutdown reactor spent fuel pools, and the number of SNF assemblies in the at-reactor dry storage as a result of exceeding spent fuel pool capacity. One primary difference is the number of SNF assemblies in at-reactor dry storage as a result of unloading spent fuel pools at shutdown reactors, which is done in the MPC system and is not done in the reference scenario. This results in an increase in the number of SNF assemblies in dry storage from 32,831 in the reference scenario to 66,222 in the MPC system. This is an increase of about 100 percent over the reference scenario. The second primary difference between the two scenarios is the number of dry storage canisters required. This is driven by the difference in the capacities for the MPCs and the MESCs, as well as the difference in the treatment of SNF storage for spent fuel pools at shutdown reactors. From a logistics standpoint, the reference scenario and the MPC system are very similar. The only differences are driven by canister capacity and shutdown reactor assumptions. The related issue of how the two scenarios compare on the basis of cost is discussed in Section 5.

3.3.2 Comparison Between MPC System and MPC System with No MRS

A comparison of these two scenarios reveals that there are significant differences for at-reactor dry storage with respect to whether or not there is an MRS in the system. These differences can be categorized into two parts: impacts on at-reactor dry storage and shutdown reactor storage prior to 2010, when the MGDS begins operations; and impacts on the maximum value for at-reactor dry storage and shutdown reactor storage requirements.

Figure 3-3 presents a comparison between the total amount of SNF in at-reactor dry storage for the MPC system with an MRS and the MPC system with no MRS. The figure also provides a comparison of the number of reactor spent fuel pools which have reached their storage capacity

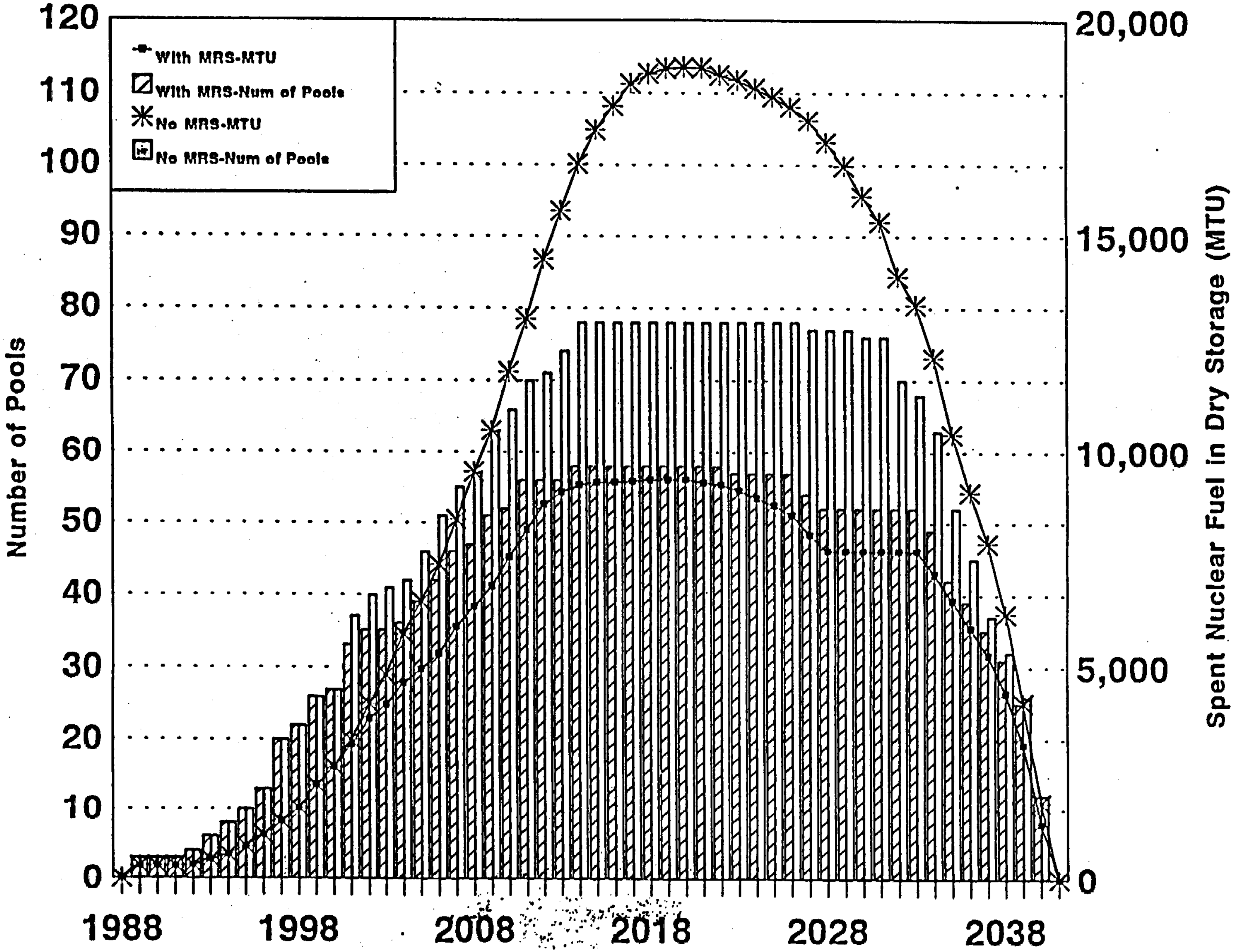


Figure 3-3. Comparison of At-Reactor Dry Storage for MPC System and MPC System with No MRS

and require some amount of dry storage for the MPC system with and without an MRS. Information on at-reactor storage requirements is provided starting from a historical perspective, based on existing dry storage, through to 2040, when all the SNF has been picked up from the reactor sites. The most significant difference occurs during the years 2014 to 2028, when the total MTU of SNF in at-reactor dry storage for an MPC system with no MRS is twice as high as the dry storage required for the MPC system with an MRS. In the years 1998 and 1999, the MRS issue does not have a major impact on the amount of at-reactor dry storage required.

Figure 3-4 presents a comparison focused on shutdown reactor storage issues between the total amount of SNF stored in spent fuel pools at shutdown reactors for the MPC system with an MRS and the MPC system with no MRS. The figure also provides a comparison of the number of spent fuel pools at shutdown reactors for the MPC system with and without an MRS. Having an MRS in the system reduces the total amount of SNF stored in spent fuel pools at shutdown reactors, although the total number of shutdown reactor spent fuel pools at shutdown reactors is almost unaffected by the MRS assumption.

The following results for the comparison between the MPC system with an MRS and the MPC system with no MRS can be summarized based on the results shown in Tables 3-4 and 3-5:

- By the year 2010, the MPC system with no MRS has 63 spent fuel pools (at 52 sites) which have reached their storage capacity and require some amount of dry storage, while the MPC system with an MRS has only 51 spent fuel pools (at 43 sites) which have reached their storage capacity and require some amount of dry storage.

- By the year 2010, the MPC system with no MRS has 1,633 dry storage canisters (MPCs and MESCs) in at-reactor dry storage, while the MPC system with an MRS has 909 dry storage canisters (MPCs and MESCs).

- By the year 2010, the MPC system with no MRS has nine spent fuel pools at shutdown reactors with SNF still in their pools, while the MPC system with an MRS has only six spent fuel pools at shutdown reactors with SNF still in their pools.

- For the MPC system with no MRS the maximum number of spent fuel pools which have reached their storage capacity and require some amount of dry storage is 78 spent fuel pools (at 64 sites), while for the MPC system with an MRS, the maximum number of spent fuel pools which have reached their storage capacity and require some amount of dry storage is 58 spent fuel pools (at 49 sites).

- For the MPC system with no MRS the maximum number of SNF assemblies in at-reactor dry storage (including SNF from unloading spent fuel pools at shutdown reactors) is 94,432, while for the MPC system with an MRS, the maximum number of SNF assemblies in at-reactor dry storage is 66,222. In terms of MTU of SNF, for the MPC system with no MRS the maximum amount of MTU in at-reactor dry storage is 26,323 MTU, while for the MPC system with an MRS, the maximum amount of MTU in at-reactor dry storage is 19,076 MTU.

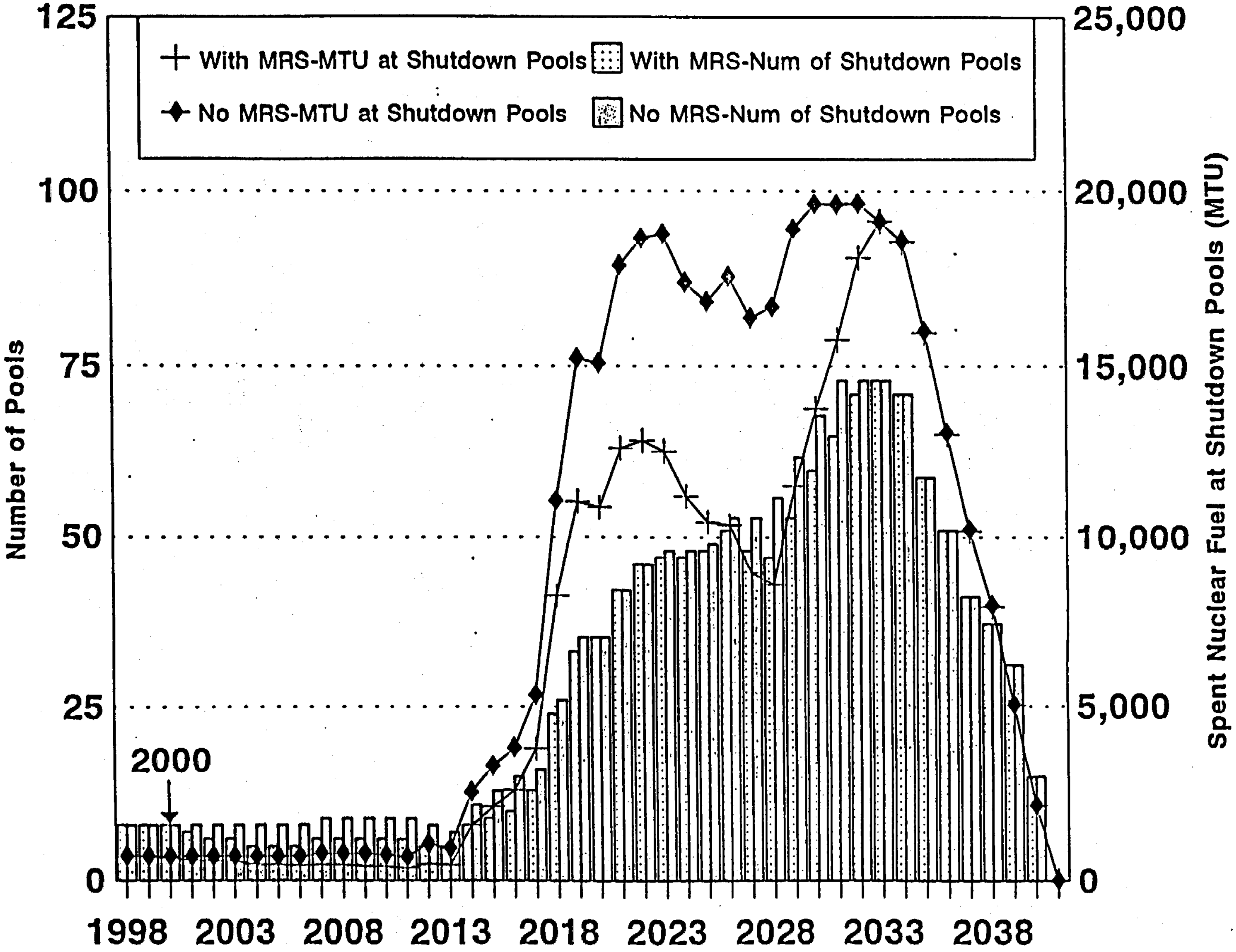


Figure 3-4. Comparision of Spent Fuel Pool Storage at Shutdown Reactors for MPC System and MPC System with No MRS

- For the MPC system with no MRS the maximum number of dry storage canisters (MPCs and MESCs) in at-reactor dry storage is 3,251, while for the MPC system with an MRS, the maximum number of dry storage canisters (MPCs and MESCs) is 2,349.

3.4 SITES WITH STORAGE MODE HANDLING LIMITATIONS

There are 19 reactor facilities assumed to be limited to truck cask capability, and therefore unable to accommodate the 125-ton rail cask MPC and the 75-ton rail cask MPC. Small non-transportable MESCs were assumed for at-reactor dry storage at those truck cask capability sites which have at-reactor dry storage requirements. It was further assumed that after reactor shutdown at these sites, all SNF stored in the spent fuel pool at the time of reactor shutdown will continue to be stored in the pool until the SNF is picked up by CRWMS.

There are only five truck capability sites which require at-reactor dry storage. These five sites are:

Big Rock Point - requires at-reactor dry storage prior to 1998.

Fort Calhoun - requires at-reactor dry storage prior to 1998.

Ginna - requires at-reactor dry storage beginning in 1999. This site requires at-reactor dry storage as a result of SNF pick up not beginning until the year 2000. If SNF pick up begins in 1998, Ginna does not require at-reactor dry storage.

Palisades - requires at-reactor dry storage prior to 1998.

Pilgrim - requires at-reactor dry storage prior to 1998.

Figure 3-5 presents the list of sites limited to truck cask capability requiring some amount of at-reactor dry storage, and shows the incremental number of dry storage canisters (small MESCs) required each year. At-reactor dry storage requirements for these truck capability sites only occurs up to year 2002; beyond 2002 no additional at-reactor dry storage is needed. This figure also shows the list of truck capability sites requiring at-reactor dry storage before 1998.

Issues concerning at-reactor dry storage at sites currently limited to truck cask capability are not investigated in detail. Other technologies could be used to increase storage capacity or the facilities could be upgraded to accommodate rail casks. An important assumption is that the truck sites are treated the same in each of the scenarios. The assumptions for the number of truck cask capability sites and the logistics and cost analysis are identical for the reference scenario, the MPC system, and the MPC system with no MRS.

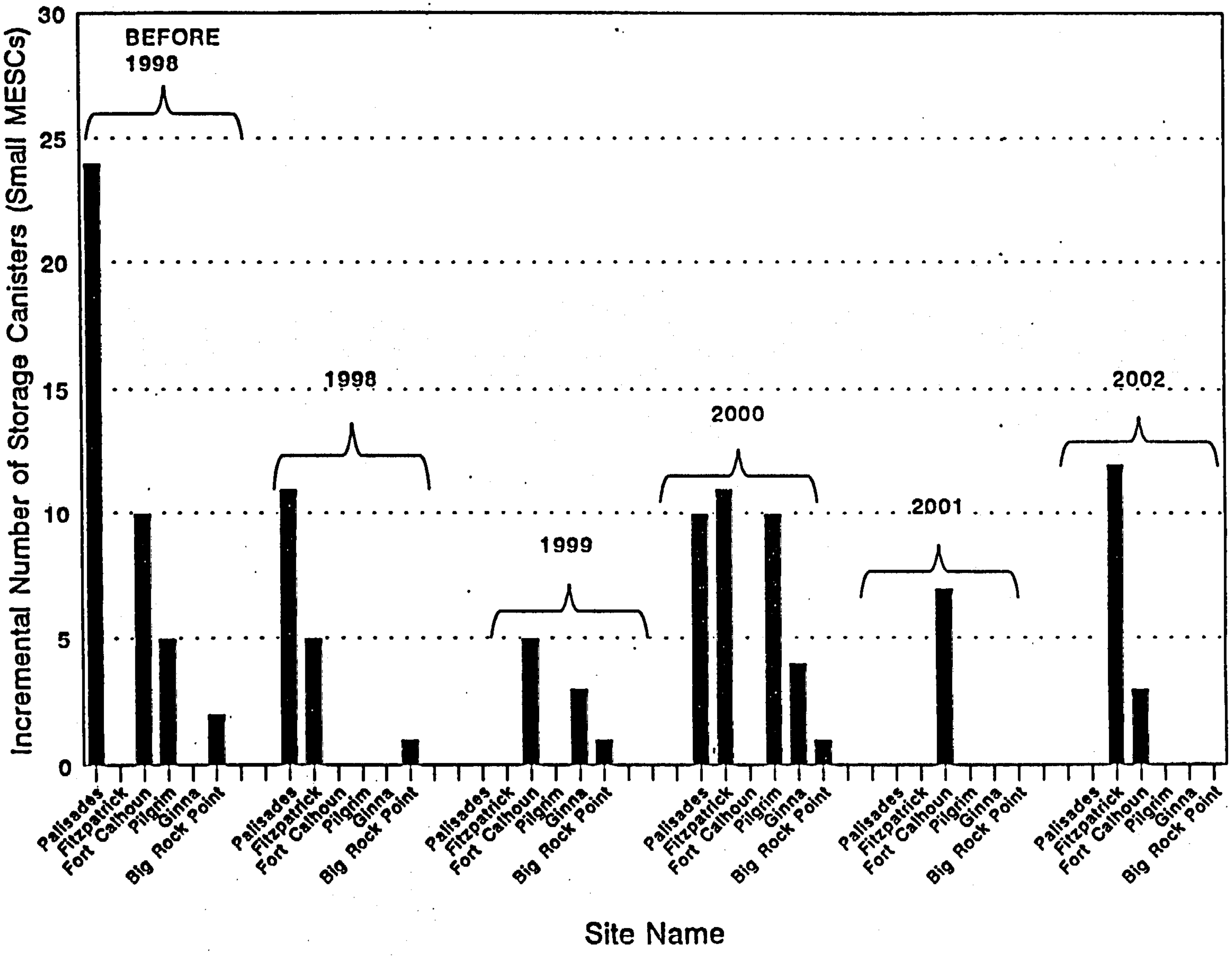


Figure 3-5. Incremental Number of Dry Storage Canisters at Sites with Truck Cask Capability

4. AT-REACTOR DRY STORAGE REQUIREMENTS IN EARLY YEARS

At-reactor dry storage requirements and shutdown reactor storage requirements are presented on a facility-by-facility basis during the three initial years of 1998, 1999, and 2000. Information presented in Section 3.1 provides boundary conditions on at-reactor dry storage and shutdown reactor storage prior to 1998 (status up through 1997). The number of shutdown reactors in 1997 is eight, and no additional reactors are projected to shutdown during 1998, 1999, and 2000. Data on the number of dry storage canisters required prior to 1998, and in 1998, 1999, and 2000 are presented in Table 4-1. The dry storage canisters prior to 1998 are assumed to be non-MPC storage modes. The dry storage canisters beginning in 1998 are 125-ton MPCs, 75-ton MPCs and small non-transportable MESCs (for sites limited to truck cask capability) as shown in Table 4-1. This information is based on beginning SNF pick up from the reactor sites in the year 2000.

Table 4-1. Early Years Dry Storage Canister Requirements for the MPC System

POOL NAME	MODE	YEAR			
		Before 1998	1998	1999	2000
ARK NUCLEAR 1	125-ton MPC	2	0	1	0
ARK NUCLEAR 2	125-ton MPC	2	0	3	0
CALVERT CLF 1	125-ton MPC	11	4	5	4
PILGRIM 1	Truck	5	0	0	10
BRUNSWICK 1	75-ton MPC	9	12	5	6
ROBINSON 2	75-ton MPC	6	3	0	4
BIG ROCK 1	Truck	2	1	1	1
PALISADES	Truck	24	11	0	10
OCONEE 1	125-ton MPC	29	0	6	5
OCONEE 3	125-ton MPC	7	3	0	2
OYSTER CRK 1	125-ton MPC	3	0	5	0
DUANE ARNOLD	125-ton MPC	0	1	3	0
MAINE YANKEE	125-ton MPC	1	0	3	4
NINE MILE PT1	125-ton MPC	6	0	3	0
MILLSTONE 1	75-ton MPC	1	0	5	0
MILLSTONE 3	75-ton MPC	0	0	0	3
PRAIRIE ISL 1	125-ton MPC	12	2	5	2
FORT CALHOUN	Truck	10	0	5	0
LIMERICK 1	125-ton MPC	3	7	6	7
FITZPATRICK	Truck	0	5	0	11
SALEM 1	125-ton MPC	0	0	1	0
GINNA	Truck	0	0	3	4
DAVIS-BESSE 1	125-ton MPC	2	0	2	0
NORTH ANNA 1	125-ton MPC	0	0	6	0
SURRY 1	125-ton MPC	26	6	2	3
POINT BEACH 1	125-ton MPC	4	3	3	2
KEWAUNEE	125-ton MPC	0	0	2	1

Note: Shading is first time dry storage is required; no shading means prior to 1998. Canisters non-MPC before 1998.

The highlighted blocks indicate the first time a site requires at-reactor dry storage. In 1998 two additional sites require dry storage: Duane Arnold (125-ton MPC rail site) and Fitzpatrick (truck site). Duane Arnold requires only one 125-ton MPC for dry storage in 1998. Fitzpatrick requires five small non-transportable MESCs for dry storage in 1998. In 1999 four additional sites require dry storage: Salem 1 (125-ton MPC rail site), Ginna (truck site), North Anna 1 (125-ton MPC rail site), and Kewaunee (125-ton MPC rail site).

By the beginning of 1998, 18 sites (14 rail sites and 4 truck sites) will have required at-reactor dry storage. For the MPC effort, it is assumed that all sites that can accommodate the 125-ton MPC and the 75-ton MPC (as defined in the MPC modal capability analysis in Reference 1) and those requiring at-reactor dry storage will use MPCs for dry storage. Those sites which cannot accommodate either the 125-ton or 75-ton MPC (the "truck sites") are assumed to use small (7P/17B) non-transportable MESCs for at-reactor dry storage. The number of sites and the incremental number of dry storage canisters (MPCs and non-transportable MESCs) required for at-reactor dry storage in the years 1998, 1999, and 2000 are presented below. This data is driven by dry storage requirements based only on exceeding the storage capacity of the spent fuel pools, as no reactors are projected to shutdown during this time period.

In 1998, eight sites with MPC (rail cask) capability and three sites with truck cask capability require the following number of dry storage canisters (MPCs and MESCs) for at-reactor dry storage:

- 26 125-ton MPCs
- 15 75-ton MPCs
- 17 small non-transportable MESCs

In 1999, 17 sites with MPC (rail cask) capability and 3 sites with truck cask capability require the following number of dry storage canisters (MPCs and MESCs) for at-reactor dry storage:

- 56 125-ton MPCs
- 10 75-ton MPCs
- 9 small non-transportable MESCs

In 2000, 11 sites with MPC (rail cask) capability and 5 sites with truck cask capability require the following number of dry storage canisters (MPCs and MESCs) for at-reactor dry storage:

- 30 125-ton MPCs
- 13 75-ton MPCs
- 36 small non-transportable MESCs

Table 4-2 summarizes the data on at-reactor dry storage requirements for the years 1998, 1999, and 2000. This data is based on the assumption that SNF pick up from the reactor sites begins in 2000. This table shows the total MTU, number of SNF assemblies, number of MPCs required, and number of small non-transportable MESCs required (for sites with truck capability) for at-reactor dry storage. These estimates include cask-rounding to complete loading of each MPC and MESC.

Table 4-2. Summary of At-Reactor Dry Storage Requirements For 1998, 1999, and 2000

YEAR	MTU	ASSEMBLIES	NUMBER OF MPCs	NUMBER OF SMALL MESCs
1998	339	1201	41	17
1999	545	1812	66	9
2000	441	1490	43	36

NOTE: Total MTU and assemblies are based on rounding up the storage casks.

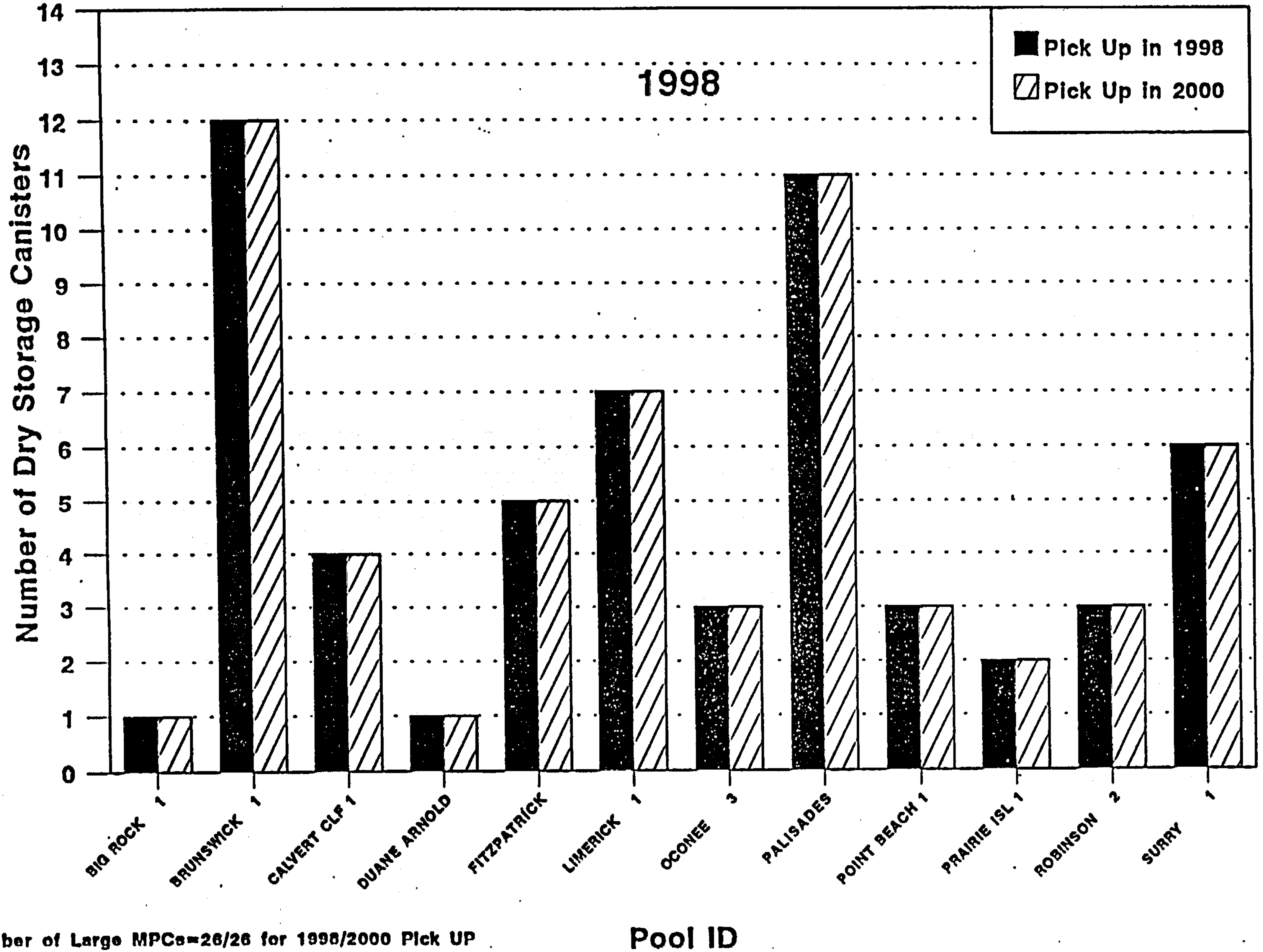
4.1 IMPACT OF BEGINNING SNF PICK UP IN 2000 VERSUS 1998

The impact on the number of sites requiring at-reactor dry storage and the incremental number of dry storage canisters for beginning pick up of SNF from the reactor sites in 2000 versus in 1998 is analyzed.

Figure 4-1 and 4-2 show comparisons between beginning SNF pick up in 2000 and in 1998 for the number of dry storage canisters required for the years 1998 and 1999, respectively. These figures also show which sites will require additional at-reactor dry storage in 1998 and 1999. An inspection of Figure 4-1 shows that there is no difference in the number of sites or dry storage canisters required between beginning SNF pick up in 2000 and in 1998. However, Figure 4-2 shows that the number of sites and dry storage canisters required is the same for SNF pick up beginning in 2000 and in 1998, with the following exceptions:

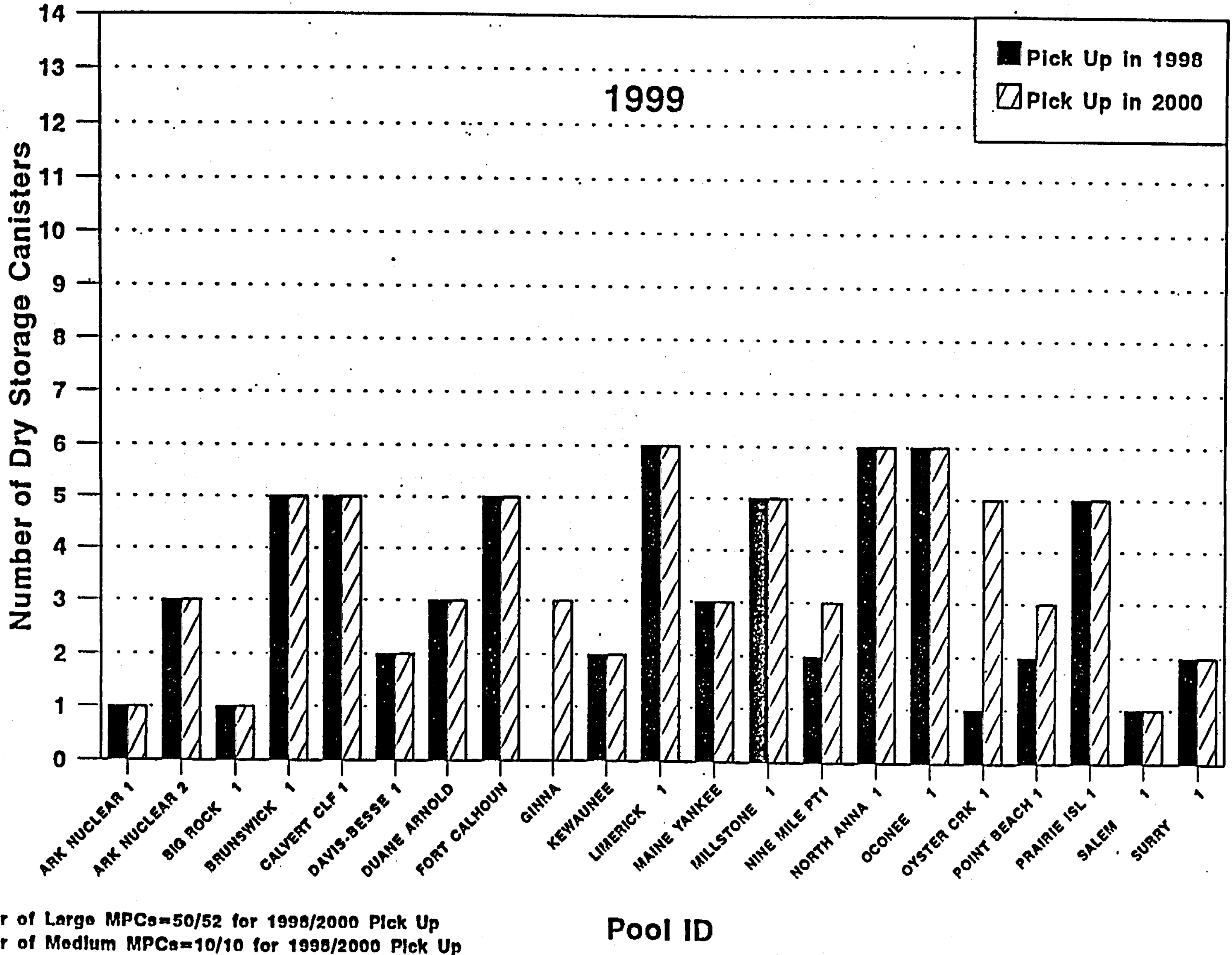
> Ginna (truck site): By delaying the beginning of SNF pick up from 1998 to 2000, Ginna will need an at-reactor dry storage ISFSI on its site in the year 1999 for three small non-transportable MESCs. If SNF pick up begins in 1998 instead of 2000, there is no need for an ISFSI at Ginna.
>
> Nine Mile Point 1 (125-ton MPC rail site): Both cases, beginning SNF pick up in 2000 or in 1998, require an ISFSI at this site. However, delaying SNF pick up from 1998 to 2000 results in a requirement of one additional 125-ton MPC.
>
> Oyster Creek (125-ton MPC rail site): Both cases, beginning SNF pick up in 2000 or in 1998, require an ISFSI at this site. However, delaying SNF pick up from 1998 to 2000 results in a requirement of four additional 125-ton MPCs.
>
> Point Beach 1 (125-ton MPC rail site): Both cases, beginning SNF pick up in 2000 or in 1998, require an ISFSI at this site. However, delaying SNF pick up from 1998 to 2000 results in a requirement of one additional 125-ton MPC.

By beginning SNF pick up in 2000 instead of 1998 three additional sites: Braidwood, Ginna, and Summer 1, will require an at-reactor dry storage ISFSI. These three sites do not require ISFSIs if SNF pick up begins in 1998. Braidwood and Summer 1 do not show up in the above analysis because they will not require at-reactor dry storage until sometime after 2000.



Note: Number of Large MPCs=26/26 for 1998/2000 Pick UP
Number of Medium MPCs=15/15 for 1998/2000 Pick Up
Number of Small MESCs=17/17 for 1998/2000 Pick Up

Figure 4-1. Comparison of Dry Storage Canisters (MPCs and MESCs) Needed in 1998 for Pick Up in 1998 verses Pick Up in 2000



Note: Number of Large MPCs=50/52 for 1998/2000 Pick Up
Number of Medium MPCs=10/10 for 1998/2000 Pick Up
Number of Small MESCs=6/9 for 1998/2000 Pick Up

Figure 4-2. Comparison of Dry Storage Canisters (MPCs and MESCs) Needed in 1999 for Pick Up in 1998 verses Pick Up in 2000

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5. AT-REACTOR DRY STORAGE COSTS

5.1 AT-REACTOR DRY STORAGE COST DATA

Most of the at-reactor dry storage cost data was developed through communication with personnel from utilities who either already have or are in the process of pursuing an ISFSI for their reactor sites. Table 5-1 summarizes the at-reactor storage cost data used for this evaluation. Additional details on this cost data and are provided in Appendix A.

Table 5-1. At-Reactor Storage Cost Data for the Reference Scenario and the MPC System

COST CATEGORIES	REFERENCE SCENARIO	MPC SYSTEM
Large MESC/ 125-ton MPC	$250,000	$354,000 (PWR)/ $432,000 (BWR)
Small MESC/ 75-ton MPC	$200,000	$287,000 (PWR)/ $276,000 (BWR)
DVCC for Large MESC/ 125-ton MPC	$175,000	$175,000
DVCC for Small MESC/ 75-ton MPC	$140,000	$140,000
Construction Cost of ISFSI per Site	$7,600,000	$7,600,000
Cost of Pad per DVCC	$58,000	$58,000
Loading /Unloading Cost per Hour per FTE	$24/hr/FTE	$24/hr/FTE
Consumable Cost per Cask	$30,000	$15,000
Canister Transfer System	$600,000/site	$600,000/site
Decommissioning cost	20% of capital cost	20% of capital cost

Detailed cost calculations for loading a dry storage cask and construction of an ISFSI are presented in Appendix A.

This cost comparison methodology is based on identifying and evaluating the cost differences between the reference scenario and the MPC system. Costs considered minor and equivalent for the two systems are not specifically addressed in the evaluation. An example of this type of cost category is some consumable costs. A key assumption of this analysis is that the cost for the MPCs themselves in the MPC system is not included in the at-reactor storage costs, while the cost of non-transportable MESCs in the reference scenario are included here. The reason for this is that the MPC is only purchased once, and because it is used as part of the waste package, its cost is allocated there (and therefore is part of the CRWMS cost). The non-transportable MESCs are used only for at-reactor dry storage, and are therefore allocated to that part of the system. The decommissioning cost for both the reference scenario and the MPC system is assumed to be 20 percent of the total capital cost. The total capital cost for the reference scenario includes the MESCs, storage overpacks, and transfer system. The total capital cost for the MPC system includes the storage overpacks and the transfer system, but does not include the MPCs, for the reasons discussed above.

For comparison purposes, the following cost categories were calculated and evaluated:

- construction cost including storage pads.
- cost of canisters (non-transportable MESCs), only for the reference scenario.
- cost of storage overpacks.
- cost of loading transfer casks at the pool and moving them to the ISFSI.
- cost of unloading non-transportable MESCs in the pool after storage for the reference scenario.
- cost of transferring MPCs from storage overpacks to transportation casks for shipment to the MRS or MGDS.
- cost of loading SNF from the pool into transportation casks for the reference scenario.
- consumable costs for loading casks such as helium used to fill the cask cavities and O-ring gaskets for lid sealing.
- decommissioning costs.
- total operating cost of shutdown reactor spent fuel pools which continue to store SNF.

For comparison purposes a very similar ISFSI design is assumed for the reference scenario, based on the use of MESCs in concrete casks, and the MPC system, based on the use of MPCs in concrete casks. These ISFSI designs are similar and provide a consistent basis for comparison.

It should be noted that the preceding cost data estimated for at-reactor dry storage may be somewhat optimistic with respect to the construction cost per site. The construction cost for an

ISFSI per site used in this evaluation is $7.6 Million, although some estimates for construction costs range as high as $20 Million per site.

5.2 SHUTDOWN REACTOR STORAGE COST DATA

Reference Scenario

The at-reactor dry storage technology used for the reference scenario is non-transportable MESCs, which must be returned to the spent fuel pool and unloaded prior to pick up of their SNF. Therefore, shutdown reactors in the reference scenario do not unload their spent fuel pools into dry storage five years after the shutdown of the reactor, and any SNF stored in the spent fuel pool at the time of reactor shutdown is assumed to remain there until it is picked up into the CRWMS. The estimated annual operating cost of shutdown reactor pools is based on the August 1991 PNL report *Cost Estimates of Operating Onsite Spent Fuel Pools After Final Reactor Shutdown* (Reference 4). The costs have been escalated to 1993 dollars and the are presented in Table 5.2.

Table 5-2. Annual Operating Costs at Shutdown Reactors for the Reference Scenario (in 1993 dollars)

Situation at Reactor site	Pool Status	Number of Reactors Onsite		
		1	2	3
1 reactor shutdown	1 pool on site	$4,240,000		
	2 pools on site		$670,000	$670,000
	3 pools on site			$670,000
2 reactors shutdown	1 pool on site		$4,240,000	
	2 pools on site		$4,670,000	$670,000
	3 pools on site- 1 pool shut			$670,000
	3 pools on site- 2 pools shut			$1,430,000
3 reactors shutdown	1 pool on site			
	2 pools on site			$4,760,000
	3 pools on site			$5,530,000

MPC System

The at-reactor dry storage technology used for the MPC system is MPCs, which can be transferred directly from dry storage to transportation casks without being returned to the spent fuel pool. The cost of operating a stand-alone ISFSI is lower than the cost of operating the spent fuel pool at a shutdown reactor. Therefore, shutdown reactors in the MPC system are assumed to unload all of the SNF remaining in the pool into dry storage five years after the reactor is shutdown. This allows utilities to discontinue spent fuel pool operations at shutdown reactors. The annual operating cost of a stand-alone ISFSI after the spent fuel pool is unloaded at shutdown reactors was developed based on estimates of the required number of operating personnel and associated operations at the ISFSI which were based on communications with some utilities considering this type of operation. Appendix A provides the detailed calculation of annual operating costs for a stand-alone ISFSI. Based on these calculations, two different cost categories for ISFSI annual operating costs were developed:

1) Annual operating costs for an ISFSI at a site with an operating reactor facility, or facilities at the site.
   Estimated annual operating cost of operating site ISFSI: $240,000/year
2) Annual operating costs for an ISFSI at a site with no other operating facility at the site, such as a site with only shutdown reactors.
   Estimated annual operating cost of shutdown site ISFSI: $840,000/year

5.3 AT-REACTOR STORAGE COST COMPARISON

At-reactor storage costs are compared for the reference scenario, the MPC system, and the MPC system with no MRS. All cost evaluations are based on at-reactor storage costs that are non-waste fund costs. Note that although the impact on non-waste fund costs is important in itself, it must be combined with the CRWMS waste fund costs to determine the total cost impact on the overall system. The total system cost comparison (non-waste fund plus waste fund) is presented in the *Life Cycle Cost Comparison for the Multi-Purpose Canister System* report (Reference 8). The total at-reactor storage cost for each system is broken down into at-reactor dry storage costs (ISFSI) and shutdown reactor storage costs. The at-reactor dry storage costs (ISFSI) are made up of several individual cost components which take into account both capital and operating costs. The shutdown reactor spent fuel pool operating costs are based on the work in Reference 4. Total at-reactor storage costs from 1998 until all SNF is picked up from the sites are evaluated for the reference scenario, the MPC system, and the MPC system with no MRS. The costs for the reference scenario and the MPC system are tabulated and compared. All costs are in 1993 dollars. It should be noted that no contingency was added to the cost data. Also, the final section assesses the sensitivity of assuming that all rail sites would use the large MESC.

5.3.1 Reference Scenario

Costs for at-reactor storage in the reference scenario are presented. The reference scenario costs include shutdown reactor spent fuel pool operating costs at all shutdown reactors, including both rail and truck modal capabilities, until all SNF is picked up from the pools. Table 5-3 presents the cost results for at-reactor storage, including both dry storage and shutdown reactor pool storage, for the reference scenario.

Table 5-3. At-Reactor Storage Costs for the Reference Scenario (in millions (M) of 1993 dollars)

At-Reactor Dry Storage (ISFSI) Costs	
Construction	$241 M
Transfer System	18 M
Canisters (MESCs)	211 M
DVCCs	148 M
Loading cost (pool to storage)	16 M
Unloading cost (storage to pool)	16 M
Consumables	26 M
Decommissioning	124 M
Loading cost (pool to transportation, truck and rail)	69 M
TOTAL At-Reactor Dry Storage (ISFSI) Costs	$870 M
Shutdown Reactor Pool Operating Costs	
TOTAL Shutdown Reactor Pool Operating Costs	$4,653 M
TOTAL At-Reactor Storage Costs	**$5,523 M**

5.3.2 MPC System

Costs for at-reactor storage in the MPC system are presented. The MPC system only includes shutdown reactor spent fuel pool operating costs at shutdown reactors with truck modal capability. The shutdown reactors with rail modal capability are assumed to unload all SNF remaining in the spent fuel pool into MPCs for at-reactor dry storage. Table 5-4 presents the cost results for at-reactor storage, including both dry storage and shutdown reactor pool storage, for the MPC system.

Table 5-5 summarizes and compares the at-reactor storage costs for the reference scenario and the MPC system. The total at-reactor storage costs for the reference scenario and MPC system are $5.5 billion and $3.4 billion, respectively. The results for the MPC system show a savings in at-reactor storage costs of $2.10 billion relative to the reference scenario. This overall savings in at-reactor storage costs for the MPC system results from a savings of $2.95 billion in shutdown reactor spent fuel pool operating costs which is only partially offset by an increase of $0.76 billion in at-reactor dry storage costs. This demonstrates the potential cost savings available in unloading shutdown reactor spent fuel pools into dry storage following reactor shutdown. This savings, however, is contingent on having a dry storage technology that does not have to be returned to the spent fuel pool prior to transportation.

Table 5-4. At-Reactor Storage Costs for the MPC System
(in millions (M) of 1993 dollars)

At-Reactor Dry Storage (ISFSI) Costs	
Construction	$500 M
Transfer System	28 M
Welding equipment for pre-1998 dry storage sites	4 M
Canisters (MESCs for truck sites)	17 M
DVCCs	680 M
Loading cost (pool to storage)	103 M
Unloading cost (storage to transportation or pool)	18 M
Consumables	17 M
Decommissioning	246 M
Loading cost (pool to transportation, truck only)	17 M
TOTAL At-Reactor Dry Storage (ISFSI) Costs	$1,631 M
Shutdown Reactor Pool Operating Costs	
TOTAL Shutdown Reactor Pool Operating Costs	$1,799 M
TOTAL At-Reactor Storage Costs	**$3,430 M**

Table 5-5. Comparison of At-Reactor Storage Costs for Reference Scenario and MPC System
(in millions (M) of 1993 dollars)

	At-Reactor Dry Storage (ISFSI) Costs	Shutdown Reactor Pool Operating Costs	Total At-Reactor Storage Costs
Reference Scenario	$870 M	$4,653 M	$5,523 M
MPC System	$1,631 M	$1,799 M	$3,430 M
Differential	($761 M)	$2,954 M	$2,093 M

A comparison of the at-reactor dry storage costs driven only by exceeding spent fuel pool storage capacity once again shows the MPC system to be less expensive for at-reactor dry storage. Based solely on dry storage needs due to exceeding spent fuel pool storage capacity, the MPC system still saves $260 million in at-reactor dry storage costs relative to the reference scenario. This primarily results from the fact that the dry storage unit cost for the MPC system is lower than that for the reference scenario because the MPC itself (the canister) is not included in at-reactor dry storage costs as the MPC is part of the system.

5.3.3 MPC System with No MRS

Costs for at-reactor storage in an MPC system with no MRS are presented. The primary difference for the MPC system with no MRS is that pick up of SNF would not begin until 2010 when the MGDS begins operations, as opposed to pick up beginning in 2000 in the MPC system with an MRS. Costs presented in this section are based on the same cost data as the previous two sections, but use the logistics data developed for the MPC system with no MRS. Results are also given for a reference scenario with no MRS as a basis for comparison. The results for the reference system with no MRS were developed on a consistent basis with the other cost evaluations. For the purposes of comparison, Table 5-6 presents cost results for at-reactor storage, including both dry storage and shutdown reactor pool storage, for the MPC system with no MRS and the reference scenario with no MRS, for the purposes of comparison.

Table 5-6. Comparison of At-Reactor Storage Costs for Reference Scenario with No MRS and MPC System with No MRS (in millions (M) of 1993 dollars)

	At-Reactor Dry Storage (ISFSI) Costs	Shutdown Reactor Pool Operating Costs	Total At-Reactor Storage Costs
Reference Scenario with No MRS	$1,775 M	$4,913 M	$6,688 M
MPC System with No MRS	$2,288 M	$1,992 M	$4,280 M
Differential	($513 M)	$2,921 M	$2,408 M

These results show that the at-reactor storage cost savings of the MPC system relative to the reference scenario will increase with no MRS in the system. When there is no MRS in the system, the total at-reactor storage costs for the reference scenario and MPC system increase to $6.7 billion and $4.3 billion, respectively. The results show a savings in at-reactor storage costs of $2.41 billion for the MPC system with no MRS relative to the reference scenario with no MRS. This overall savings in at-reactor storage costs for the MPC system results from a savings of $2.92 billion in shutdown reactor spent fuel pool operating costs which is only partially offset by an increase of $0.51 billion in at-reactor dry storage costs. A general conclusion of this is that any for delay in the beginning of SNF pick up, such as delays in or lack of an MRS, the at-reactor storage cost advantages for the MPC system will increase. It should be noted that, even though the at-reactor storage cost savings for the MPC system increase with no MRS in the system, the overall cost for at-reactor storage does increase. For at-reactor storage costs, it is beneficial for both the reference scenario and the MPC system to have an MRS in the system.

A comparison of at-reactor dry storage costs driven only by exceeding spent fuel pool storage capacity also shows the MPC system with no MRS to be less expensive for at-reactor dry storage. Based solely on dry storage needs due to exceeding spent fuel pool storage capacity, the MPC system with no MRS saves $470 million in at-reactor dry storage costs relative to the reference scenario with no MRS.

5.3.4 Use of 75-ton MESC for Sites with 75-ton Cask Capability

One of the assumptions used for at-reactor storage cost evaluation is that all sites with rail modal capability will use large 125-ton MESCs in the reference scenario, while a small subset of these sites use 75-ton MPCs in the MPC system. The sensitivity of this assumption is assessed by evaluating the effect of having the appropriate subset of sites in the reference scenario using a 75-ton MESC instead of a 125-ton MESC.

There are seven sites which have 75-ton cask modal capability and also require at-reactor dry storage. Only one size of large non-transportable MESC (24 PWR/52 BWR) is assumed for all sites with rail modal capability. A reasonable assumption for the capacity of a 75-ton MESC is 12 PWR or 24 BWR, similar to the 75-ton MPC. An analysis of the cost impact of replacing the large 125-ton non-transportable MESC with a smaller 75-ton (12 PWR/24 BWR) non-transportable MESC for the appropriate seven sites showed an increase in reference scenario at-reactor storage costs of only $28 million, or about 0.5 percent of the total. The total cost for at-reactor storage is relatively insensitive to the assumption of using a large MESC at all sites in the reference scenario with rail modal capability, and therefore this assumption is valid.

6. AT-REACTOR DRY STORAGE LAND REQUIREMENTS

The land area that would be required at reactor sites for at-reactor dry storage is estimated assuming the use of MPCs and the system parameter assumptions defined in Section 2. It appears that most reactor sites requiring at-reactor dry storage will generally have sufficient land area available to accommodate an ISFSI with capacity for projected at-reactor dry storage requirements based on storage capacity needed in excess of the spent fuel pool capacity and the potential unloading of shutdown reactor spent fuel pool into dry storage. It is assumed that utilities will have sufficient land to operate an ISFSI on their reactor sites. No attempt is made to interpret the land availability for an ISFSI for each reactor site. Some utilities have reported potential difficulties with land availability that may occur at their reactor sites, but these utilities have not yet officially addressed the issue of an ISFSI at their site. The potential institutional and technical issues related to the development of an ISFSI are not analyzed. This report is not intended to imply that land availability for at-reactor dry storage may be a problem for any reactor sites or, conversely, that all reactors will have sufficient space available.

One of the assumptions made for the MPC system is that five years after reactor shutdown all SNF would be unloaded from the spent fuel pool into MPCs and transferred to at-reactor dry storage. Under this assumption, the spent fuel pool could be closed and decommissioned, resulting in large cost savings to the utility owning the shutdown reactor. Then at the time the SNF is picked up from the reactor site, the MPC would be transferred directly from dry storage to a transportation cask without having to be returned to the spent fuel pool. The unloading of the spent fuel pool into dry storage at shutdown reactors may not occur, and therefore, the land requirements were calculated both with and without this assumption.

The land requirements calculations are based on the ISFSI land usage data from the ISFSI designs for the Surry Power Station ISFSI (Reference 5) and the Prairie Island ISFSI (Reference 7). Land requirements are estimated in number of acres. Both a low and a high land requirement number are used, and both are based on an assumption of the number of dry storage casks (or units) per acre based on the information in Reference 5 and Reference 7. The low land requirement number assumes 12 casks per acre and the high land requirement number assumes 6 casks per acre for an at-reactor dry storage facility.

Table 6-1 presents the at-reactor dry storage land requirements for storage based only on storage capacity needed in excess of the spent fuel pool capacity. Table 6-2 presents the at-reactor dry storage requirements based on storage capacity in excess of pool capacity plus the potential unloading of shutdown reactor spent fuel pool into dry storage. The assumption of unloading shutdown reactor spent fuel pools into dry storage makes the land requirements in Table 6-2 higher than those in Table 6-1.

Based on the low and high land requirements in Table 6-2, an average land requirement (in acres) was calculated for each site requiring at-reactor dry storage. This data is presented in Figure 6-1. As with Table 6-2, the information in Figure 6-1 is based on dry storage capacity in excess of pool capacity plus the potential unloading of shutdown reactor spent fuel pool into dry storage.

Table 6-1. Land Requirements for At-Reactor Dry Storage (Based only on Exceeding Pool Storage Capacity)

POOL ID	POOL NAME	CASK TYPE	TOTAL MPC	LOW AREA (Acres)	HIGH AREA (Acres)
102	FARLEY	RAIL-MPC	0	0.0	0.0
303	PALO VERDE	RAIL-MPC	41	3.4	6.8
402	ARK NUCLEAR	RAIL-MPC	27	2.3	4.5
501	CALVERT CLF	RAIL-MPC	21	1.8	3.5
701	BRUNSWICK	RAIL-MPC	43	3.6	7.2
703	HARRIS 1	RAIL-MPC	0	0.0	0.0
705	ROBINSON	RAIL-MPC	7	0.6	1.2
901	PERRY	RAIL-MPC	15	1.3	2.5
1001	BRAIDWOOD	RAIL-MPC	2	0.2	0.3
1003	BYRON 1	RAIL-MPC	8	0.7	1.3
1007	DRESDEN	RAIL-MPC	0	0.0	0.0
1008	LASALLE	RAIL-MPC	0	0.0	0.0
1010	QUAD CITIES	RAIL-MPC	0	0.0	0.0
1012	ZION	RAIL-MPC	0	0.0	0.0
1402	ENRICO FERMI2	RAIL-MPC	25	2.1	4.2
1502	CATAWBA 2	RAIL-MPC	0	0.0	0.0
1505	MCGUIRE	RAIL-MPC	28	2.3	4.7
1508	OCONEE	RAIL-MPC	29	2.4	4.8
1602	BEAVER VALLEY 2	RAIL-MPC	6	0.5	1.0
1802	ST LUCIE 2	RAIL-MPC	23	1.9	3.8
1803	TURKEY PT	RAIL-MPC	0	0.0	0.0
1901	3 MILE ISL 1	RAIL-MPC	0	0.0	0.0
1903	OYSTER CRK	RAIL-MPC	5	0.4	0.8
2001	HATCH	RAIL-MPC	33	2.8	5.5
2003	VOGTLE	RAIL-MPC	28	2.3	4.7
2101	RVR BEND	RAIL-MPC	18	1.5	3.0
2202	SOUTH TEXAS	RAIL-MPC	0	0.0	0.0
2301	CLINTON	RAIL-MPC	12	1.0	2.0
2401	DUANE ARNOLD	RAIL-MPC	9	0.8	1.5
2501	WOLF CREEK	RAIL-MPC	11	0.9	1.8
2601	SHOREHAM	RAIL-MPC	0	0.0	0.0
2701	WATERFORD	RAIL-MPC	24	2.0	4.0
2801	MAINE YANKEE	RAIL-MPC	7	0.6	1.2
2901	GRAND GULF 1	RAIL-MPC	48	4.0	8.0
3001	COOPER STN	RAIL-MPC	0	0.0	0.0
3102	NINE MILE PT	RAIL-MPC	22	1.8	3.7
3203	MILLSTONE	RAIL-MPC	29	2.4	4.8
3302	PRAIRIE ISL	RAIL-MPC	15	1.3	2.5
3502	DIABLO CANYON 2	RAIL-MPC	21	1.8	3.5
3601	SUSQUEHANNA 1	RAIL-MPC	78	6.5	13.0
3701	LIMERICK	RAIL-MPC	92	7.7	15.3
3801	TROJAN	RAIL-MPC	0	0.0	0.0
4201	HOPE CREEK	RAIL-MPC	26	2.2	4.3
4203	SALEM	RAIL-MPC	18	1.5	3.0
4501	RANCHO SECO 1	RAIL-MPC	0	0.0	0.0
4601	SUMMER 1	RAIL-MPC	1	0.1	0.2
4703	SAN ONOFRE	RAIL-MPC	38	3.2	6.3
4805	BROWNS FERRY	RAIL-MPC	0	0.0	0.0
4808	SEQUOYAH 1	RAIL-MPC	7	0.6	1.2
4810	WATTS BAR 1	RAIL-MPC	33	2.8	5.5
4901	COMANCHE PK 1	RAIL-MPC	0	0.0	0.0
5001	DAVIS-BESSE 1	RAIL-MPC	13	1.1	2.2
5101	CALLAWAY	RAIL-MPC	17	1.4	2.8
5201	NORTH ANNA	RAIL-MPC	32	2.7	5.3
5203	SURRY	RAIL-MPC	16	1.3	2.7
5302	WASH NUCLEAR2	RAIL-MPC	32	2.7	5.3
5401	POINT BEACH	RAIL-MPC	10	0.8	1.7
5501	KEWAUNEE	RAIL-MPC	8	0.7	1.3
5801	COOK 1	RAIL-MPC	0	0.0	0.0
5901	SEABROOK 1	RAIL-MPC	3	0.3	0.5

Table 6-2. Land Requirements for At-Reactor Dry Storage (Based only on Exceeding Pool Storage Capacity and Unloading Shutdown Reactor Pool)

POOL ID	POOL NAME	CASK TYPE	TOTAL MPC	LOW AREA (Acres)	HIGH AREA (Acres)
102	FARLEY	RAIL-MPC	55	4.6	9.2
303	PALO VERDE	RAIL-MPC	115	9.6	19.2
402	ARK NUCLEAR	RAIL-MPC	61	5.1	10.2
501	CALVERT CLF	RAIL-MPC	59	4.9	9.8
701	BRUNSWICK	RAIL-MPC	107	8.9	17.8
703	HARRIS 1	RAIL-MPC	28	2.3	4.7
705	ROBINSON	RAIL-MPC	46	3.8	7.7
901	PERRY	RAIL-MPC	66	5.5	11.0
1001	BRAIDWOOD.	RAIL-MPC	83	6.9	13.8
1003	BYRON 1	RAIL-MPC	81	6.8	13.5
1007	DRESDEN	RAIL-MPC	197	16.4	32.8
1008	LASALLE	RAIL-MPC	99	8.3	16.5
1010	QUAD CITIES	RAIL-MPC	207	17.3	34.5
1012	ZION	RAIL-MPC	81	6.8	13.5
1402	ENRICO FERMI2	RAIL-MPC	48	4.0	8.0
1502	CATAWBA 2	RAIL-MPC	64	5.3	10.7
1505	MCGUIRE	RAIL-MPC	66	5.5	11.0
1508	OCONEE	RAIL-MPC	59	4.9	9.8
1602	BEAVER VALLEY 2	RAIL-MPC	66	5.5	11.0
1802	ST LUCIE 2	RAIL-MPC	31	2.6	5.2
1803	TURKEY PT	RAIL-MPC	47	3.9	7.8
1901	3 MILE ISL 1	RAIL-MPC	54	4.5	9.0
1903	OYSTER CRK	RAIL-MPC	42	3.5	7.0
2001	HATCH	RAIL-MPC	87	7.3	14.5
2003	VOGTLE	RAIL-MPC	129	10.8	21.5
2101	RVR BEND	RAIL-MPC	55	4.6	9.2
2202	SOUTH TEXAS	RAIL-MPC	57	4.8	9.5
2301	CLINTON	RAIL-MPC	49	4.1	8.2
2401	DUANE ARNOLD	RAIL-MPC	34	2.8	5.7
2501	WOLF CREEK	RAIL-MPC	35	2.9	5.8
2601	SHOREHAM	RAIL-MPC	0	0.0	0.0
2701	WATERFORD	RAIL-MPC	35	2.9	5.8
2801	MAINE YANKEE	RAIL-MPC	43	3.6	7.2
2901	GRAND GULF 1	RAIL-MPC	69	5.8	11.5
3001	COOPER STN	RAIL-MPC	83	6.9	13.8
3102	NINE MILE PT	RAIL-MPC	79	6.6	13.2
3203	MILLSTONE	RAIL-MPC	188	15.7	31.3
3302	PRAIRIE ISL	RAIL-MPC	42	3.5	7.0
3502	DIABLO CANYON 2	RAIL-MPC	68	5.7	11.3
3601	SUSQUEHANNA 1	RAIL-MPC	111	9.3	18.5
3701	LIMERICK	RAIL-MPC	149	12.4	24.8
3801	TROJAN	RAIL-MPC	29	2.4	4.8
4201	HOPE CREEK	RAIL-MPC	72	6.0	12.0
4203	SALEM	RAIL-MPC	61	5.1	10.2
4501	RANCHO SECO 1	RAIL-MPC	0	0.0	0.0
4601	SUMMER 1	RAIL-MPC	25	2.1	4.2
4703	SAN ONOFRE	RAIL-MPC	76	6.3	12.7
4805	BROWNS FERRY	RAIL-MPC	160	13.3	26.7
4808	SEQUOYAH 1	RAIL-MPC	57	4.8	9.5
4810	WATTS BAR 1	RAIL-MPC	33	2.8	5.5
4901	COMANCHE PK 1	RAIL-MPC	58	4.8	9.7
5001	DAVIS-BESSE 1	RAIL-MPC	21	1.8	3.5
5101	CALLAWAY	RAIL-MPC	37	3.1	6.2
5201	NORTH ANNA	RAIL-MPC	53	4.4	8.8
5203	SURRY	RAIL-MPC	31	2.6	5.2
5302	WASH NUCLEAR2	RAIL-MPC	54	4.5	9.0
5401	POINT BEACH	RAIL-MPC	44	3.7	7.3
5501	KEWAUNEE	RAIL-MPC	33	2.8	5.5
5801	COOK 1	RAIL-MPC	67	5.6	11.2
5901	SEABROOK 1	RAIL-MPC	36	3.0	6.0

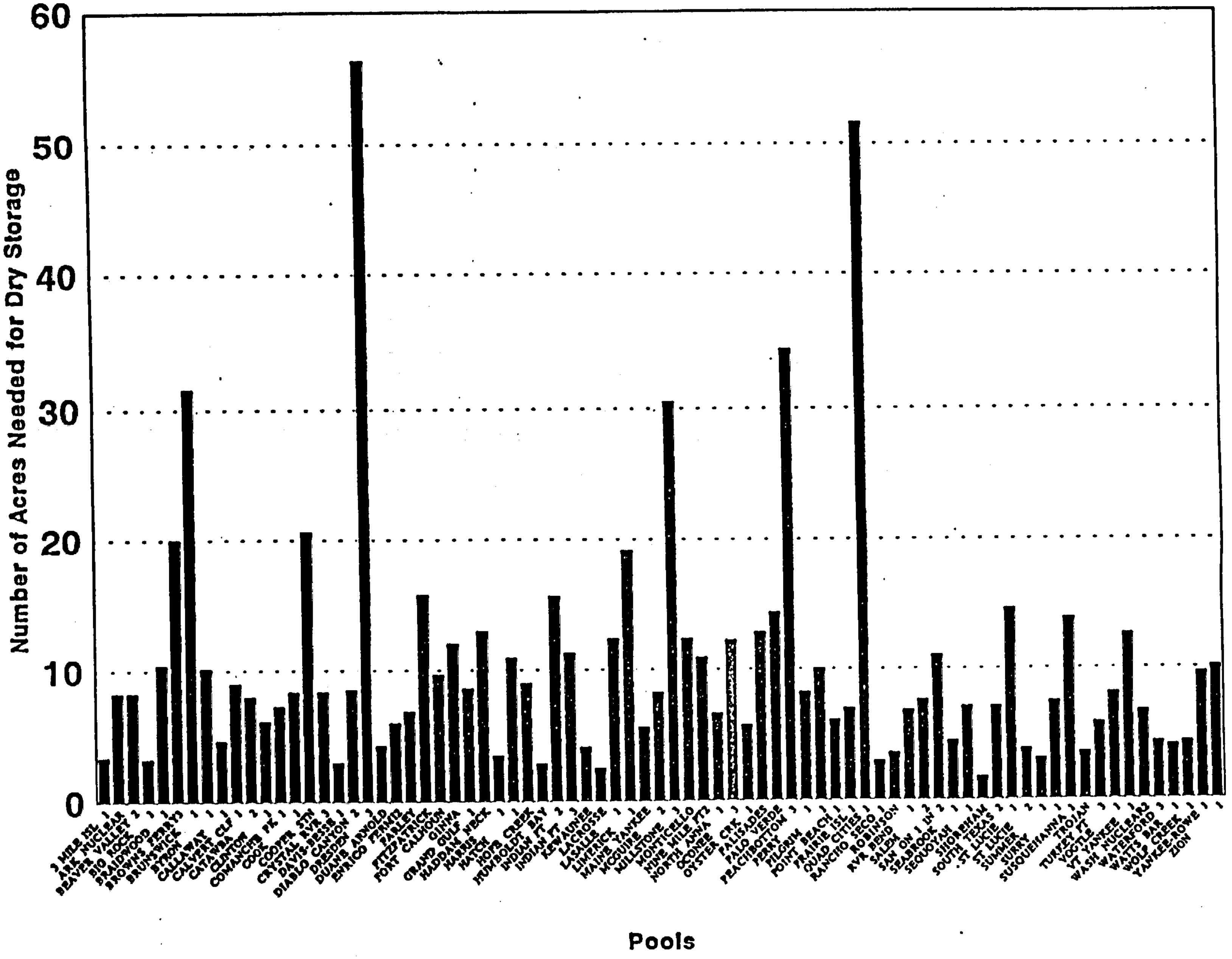

Figure 6-1. Estimated Land Requirements for At-Reactor Dry Storage

7. SUMMARY AND CONCLUSIONS

The at-reactor storage issue is an important element in planning for the CRWMS program. Utilities will continue to store the SNF they generate at their reactor sites until the CRWMS begins picking up the SNF to ship it to an MRS or MGDS. Although a substantial amount of SNF can be stored in the existing spent fuel pools at reactor sites, the capacity of these pools is ultimately limited. After spent fuel pool capacity has been reached, some form of additional storage is required. Dry storage of SNF is a proven, cost-effective method for meeting additional storage needs. The MPC system is a technology which can be used to meet at-reactor dry storage needs. The MPC system also offers the significant advantage of facilitating SNF transfer directly from dry storage to transportation without going back through the spent fuel pool.

At-reactor storage issues evaluated include annual requirements, costs, and land needs. Aspects of at-reactor storage considered are at-reactor dry storage and shutdown reactor spent fuel pool storage. At-reactor storage is evaluated for the reference scenario, the MPC system, and the MPC system with no MRS. The primary system parameters used for the reference scenario and the MPC system are those defined in the *Concept of Operations for the Multi-Purpose Canister System* report (Reference 1). Other parameters and assumptions are defined in Section 2. The MPC system is assumed to use MPCs for at-reactor dry storage, while the reference scenario is assumed to use non-transportable MESCs. An important assumption for the MPC system is that all SNF in shutdown reactor spent fuel pools will be transferred into MPCs for dry storage five years after shutdown; the reference scenario assumes all SNF remains in shutdown reactor spent fuel pools until it is picked up into the CRWMS. Logistics calculations for this work were performed by system models which simulate the movement of SNF through the CRWMS; cost calculations were performed using spreadsheets to combine cost inputs with the logistics results.

At-reactor dry storage requirements are evaluated both before and after 1998. The dry storage requirements and shutdown reactor storage requirements prior to 1998 are calculated as boundary conditions for the rest of the evaluation. At-reactor dry storage requirements after 1998 are calculated for the reference scenario, the MPC system, and the MPC system with no MRS. Detailed information is developed on an annual basis for the number of sites, number of assemblies, total MTU, and number of dry storage canisters (MPCs and non-transportable MESCs) required for at-reactor dry storage, and similar information is presented related to spent fuel pool storage at shutdown reactors. The amount of SNF requiring at-reactor dry storage is very similar for the reference scenario and the MPC system based on dry storage requirements driven by exceeding spent fuel pool capacity. The MPC system does require additional dry storage canisters (MPCs and MESCs) because the MPCs have a lower unit capacity. The MPC system does require more at-reactor dry storage than the reference scenario as a result of unloading shutdown reactor spent fuel pools into dry storage after reactor shutdown. At the same time, the reference scenario has more SNF storage in shutdown reactor spent fuel pools. This results in significant economic benefits to the MPC system. Additional at-reactor dry storage is required for the MPC system with no MRS because SNF pick up does not begin until 2010.

The at-reactor dry storage requirements in the early years of program operation are addressed on a facility-by-facility basis for the MPC system with an MRS beginning in 2000. In 1998, at-reactor dry storage requirements are estimated to be 339 MTU including 26 125-ton MPCs, 15

75-ton MPCs, and 17 small non-transportable MESCs. In 1999, the estimates are 545 MTU including 56 125-ton MPCs, 10 75-ton MPCs, and 9 small non-transportable MESCs. In 2000, the estimates are 441 MTU including 30 125-ton MPCs, 13 75-ton MPCs, and 36 small non-transportable MESCs. These estimates include cask-rounding to complete loading of each MPC and MESC. An analysis of the impact of beginning SNF pick up in 2000 versus 1998 shows this assumption to have little effect on the overall magnitude of at-reactor dry storage requirements.

Costs are evaluated for at-reactor storage, including both at-reactor dry storage and pool storage at shutdown reactors. Cost estimates are developed for the annual operating cost of an ISFSI, both at a site with operating facilities (i.e., operating reactors) and with no operating facilities (i.e., shutdown reactors). Annual operating costs for an ISFSI at a site with operating facilities is estimated to be $240,000 per year, while annual operating costs at a site with no operating facilities is estimated to increase to $840,000 per year. Other cost inputs are based on previous reports and input from the MPC conceptual design effort.

At-reactor storage costs are evaluated and compared for the reference scenario, the MPC system, and the MPC system with no MRS. For the nominal system with an MRS, the total at-reactor storage costs that are non-waste fund costs for the reference scenario and MPC system are $5.5 billion and $3.4 billion, respectively. Results for the MPC system show a savings in non-waste fund at-reactor storage costs of $2.10 billion relative to the reference scenario. Overall savings for the MPC system result from a reduction of $2.95 billion in shutdown reactor spent fuel pool operating costs which is only partially offset by an increase of $0.76 billion in at-reactor dry storage costs. This demonstrates the potential cost savings available in unloading shutdown reactor spent fuel pools into dry storage following reactor shutdown. This savings is contingent on having a dry storage technology that does not have to be returned to the spent fuel pool prior to transportation. A comparison of at-reactor on-site dry storage costs driven only by exceeding spent fuel pool storage capacity shows the utility costs for the MPC system (non-waste fund costs) to be less expensive, saving $260 million relative to the reference scenario. This primarily results from the fact that the dry storage unit cost for the MPC system is lower than that for the reference scenario because the MPC itself is not included in at-reactor dry storage costs since it is part of the overall system.

Note that although the savings in non-waste fund costs is important in itself, it must be combined with the CRWMS waste fund costs to determine the total cost impact on the overall system. The total system cost comparison (non-waste fund plus waste fund) is presented in the *Life Cycle Cost Comparison for the Multi-Purpose Canister System* report (Reference 8).

When there is no MRS in the system, the total at-reactor storage costs that are non-waste fund costs for the reference scenario and MPC system increase to $6.7 billion and $4.3 billion, respectively. With no MRS, the at-reactor storage cost savings in non-waste fund costs for the MPC system increase to $2.41 billion relative to the reference scenario. It appears that any delay in SNF pick up, such as delays or lack of an MRS, will increase the at-reactor storage cost advantage of the MPC system. It should be noted however, that even though the cost savings for the MPC system increase with no MRS in the system, the overall cost for at-reactor storage does increase. Therefore, relative to at-reactor storage costs, it is beneficial to have an MRS in the system.

The land requirements for at-reactor dry storage ISFSIs are not anticipated to be a problem except, potentially, for a very small number of sites. Land requirements (in acres) are estimated on a site-by-site basis for at-reactor dry storage. Estimates are developed for potential dry storage requirements based on storage capacity needed in excess of spent fuel pool capacity and on potential unloading of shutdown reactor spent fuel pools into dry storage. No attempt is made to interpret the land availability for an ISFSI for each reactor site. Other potential limitations for at-reactor dry storage ISFSIs are not considered.

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APPENDIX A

COST CALCULATION METHODOLOGY

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COST CALCULATION METHODOLOGY

This appendix presents the calculation used to develop certain cost data for at-reactor dry storage. The cost data developed in this Appendix include ISFSI capital and annual operating costs, and dry storage loading operations costs. Other at-reactor dry storage cost data, such as decommissioning costs, canister costs (MPCs and MESCs), and DVCC costs, can be found in Section 5 of the report. The cost data developed here is based on information gathered through communications with personnel from reactor sites evaluating at-reactor dry storage, including: Brunswick, Calvert Cliffs, Fort St. Vrain, Harris, Palisades, Prairie Island, Rancho Seco, Robinson, St. Lucie, Surry, and Turkey Point, in addition to EPRI and some vendors.

A.1 ISFSI CAPITAL COSTS

The capital costs of designing, licensing, and constructing an ISFSI were developed based primarily on the Calvert Cliffs, Surry, and Rancho Seco ISFSI projects. The cost data developed for designing, licensing, and constructing an ISFSI are presented in Table A-1.

Table A-1. ISFSI Capital Costs Related to Construction

Cost Category	Costs
Licensing and Design	$1,057,215
Equipment (includes the following: welding equipment $255,847 tractor equipment $58,959 radiation monitor $252,494)	$567,300
ISFSI Facility Construction plus First Set of Pads	$2,005,397
Non-ISFSI Facility Construction	$1,384,055
Startup & Test	$741,615
Supervision & Engineering	$1,835,023
TOTAL Construction Cost per ISFSI Site	$7,600,000

[illegible] – [illegible]

The total ISFSI construction cost of $7,600,000 includes the building of the first set of 28 pads, with the capability to hold 28 DVCCs or similar dry storage mode units. The capital cost for each additional storage pad (including site preparation, storage pad, and other indirect costs) is assumed to be $58,000 per pad, based on cost data for the Surry ISFSI in Reference 5. The capital costs for canisters, either MESCs or MPCs, and DVCCs are presented in Section 5 of the report. Note that the non-ISFSI facility construction costs shown in Table A-1 include road upgrading, equipment for storage buildings, and other related plant modifications.

A.2 ISFSI OPERATING COSTS

The annual operating costs for a stand alone ISFSI were developed based on communication with utilities and analysis of the treatment of operating costs for shutdown reactor spent fuel pools in Reference 4. Cost estimates are developed for both an ISFSI at a site having at least one operating reactor, and for an ISFSI at a site with no other operating facilities (i.e., all reactors at the site are shutdown). Tables A-2 and A-3 show the estimated annual operating costs for an ISFSI at a site with operating reactors and at a site with no other operating facilities, respectively. The two tables show the estimated staffing requirements for an ISFSI at a site with other operating facilities (i.e., operating reactor) and an ISFSI at a site with no operating facilities (i.e., shutdown reactor). A minimum estimate, maximum estimate, and midrange estimate of the annual operating cost of an ISFSI are given. The midrange estimate was used as the basis for the cost analyses in this report.

Table A-2. ISFSI Annual Operating Cost - Operating Reactor On Site (1989 dollars)

	MINIMUM ESTIMATE			MIDRANGE ESTIMATE			MAXIMUM ESTIMATE		
	Person	$/Person	TOTAL	Person	$/Person	TOTAL	Person	$/Person	TOTAL
Security[3]	0	$32,500	$0	0	$32,500	$0	0	$32,500	$0
Technician	1	$38,000	$38,000	1	$38,000	$38,000	1	$38,000	$38,000
Engineer[3]	1	$51,500	$51,500	1	$51,500	$51,500	1	$51,500	$51,00
Manager[1]	0	$74,100	$0	0	$74,100	$0	0	$74,100	$0
Admin.Sup.[3]	0	$25,500	$0	0	$25,500	$0	0	$25,500	$0
Personnel Tot.			$89,200			$89,200			$89,200
	Rate		TOTAL	Rate		TOTAL	Rate		TOTAL
Staff Overhead	0.4		$35,680	0.475		$42,513	0.55		$49060
Consumables	0.1		$12,488	0.2		$26,403	0.4		$55,304
Utilities	--		$20,000	--		$20,000	--		$20,000
NRC Fees[2]	--		$35,000	--		$65,000	--		$157420
NLP Insur.[3,4]	--		$0	--		$0	--		$0
Emerg. Prep.[4]	--		$0	--		$0	--		$0
Operating Total[5]			$190,000			$240,000			$370,000

Notes:
1. ISFSI manager.
2. NRC license fee and inspection fee are included in this category.
3. Nuclear Liability and Property Insurance.
4. All the zero categories are included in the balance of plant costs for other operating facilities on the site (i.e., operating reactor).
5. Totals include rounding.

Table A-3. ISFSI Annual Operating Cost - No Operating Facilities (Shutdown Reactors)

	MINIMUM ESTIMATE			MIDRANGE ESTIMATE			MAXIMUM ESTIMATE		
	Person	$/Person	TOTAL	Person	$/Person	TOTAL	Person	$/Person	TOTAL
Security	4	$32,500	$128,000	5	$32,500	$160,000	5	$32,500	$160,000
Technician	1	$38,000	$38,000	1	$38,000	$38,000	1	$38,000	$38,000
Engineer	0	$51,500	$0	1	$51,500	$51,500	1	$51,500	$51,500
Manager[1]	1	$74,100	$74,100	1	$74,100	$74,100	1	$74,100	$74,100
Admin.Sup.	0	$25,500	$25,500	1	$25,500	$25,500	1	$25,500	$25,500
Personnel Tot.			$240,100			$349,100			$349,100
	Rate		TOTAL	Rate		TOTAL	Rate		TOTAL
Staff Overhead	0.4		$96,040	0.475		$166,923	0.55		$192,005
Consumable	0.1		$33,614	0.2		$102,985	0.4		$216,442
Utilities	--		$20,000	--		$20,000	--		$20,000
NRC Fees[2]	--		$35,000	--		$65,000	--		$157,420
NLP Insur.[3]	--		$60,000	--		$120,000	--		$600,000
Emerg. Prep.	--		$10,000	--		$20,000	--		$40,000
Operating Total[4]			$490,000			$840,000			$1,570,000

Notes:
1. ISFSI manager.
2. NRC license fee and inspection fee are included in this category.
3. Nuclear Liability and Property Insurance.
4. Totals include rounding.

A.3 LOADING COSTS PER HOUR PER FTE

The cost data for at-reactor dry storage loading costs per hour per Full Time Equivalent (FTE) were developed based on information from some utilities and vendors involved with at-reactor dry storage technology. The data shown here are primarily based on information related to the Calvert Cliffs and Oconee ISFSIs. Tables A-4 and A-5 present the cost data calculation for the dry storage loading costs per FTE based on the data from Oconee and Calvert Cliffs, respectively. Based on these two data points, an average dry storage loading cost of $24 per hour per FTE is assumed.

Table A-4. Loading Cost Per Hour Per FTE Based on Oconee Information

Position	Worker Salary ($/hour)	Number of Workers Needed	Cost of Worker Category per Hour
Senior Operator	$33.93	1	$33.93
Operator	$25.08	4	$100.30
Mechanical Technician	$19.18	3	$57.53
HP Technician	$19.18	2	$38.35
Total Cost per Hour		10	$230.01
Average Cost Per Worker Hour (FTE) based on Oconee			$23.00

Table A-5. Loading Cost Per Hour Per FTE Based on Calvert Cliffs Information

Position	Worker Salary ($/hour)	Number of Workers Needed	Cost of Worker Category per Hour
Senior Operator	$33.93	2	$67.85
Operator	$25.08	5	$125.38
Mechanical Technician	$19.18	4	$76.70
HP Technician	$19.18	2	$38.35
Total Cost per Hour		13	$308.28
Average Cost Per Worker Hour (FTE) based on Calvert Cliffs			$23.71

APPENDIX B

AT-REACTOR DRY STORAGE REQUIREMENTS BASED ON STORAGE CAPACITY LIMITATIONS AND ON UNLOADING SPENT FUEL POOLS AT SHUTDOWN REACTORS

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Table B-1. Cumulative Breakdown of At-Reactor Dry Storage Canister (MPCs and MESCs) Requirements for MPC System

	Pool Capacity Driven Dry Storage Needs-Cumulative								Shutdown Reactor Driven Dry Srorage Needs^{1,2}-Cum.			
	BWR	PWR	BWR	PWR	BWR	PWR	BWR	PWR	BWR	PWR	BWR	PWR
	LG-MESC	LG-MESC	SM-MESC	SM-MESC	LG-MPC	LG-MPC	MD-MPC	MD-MPC	LG-MPC	LG-MPC	MD-MPC	MD-MPC
1997	22	102	7	34	0	0	0	0	0	0	0	0
1998	22	102	13	45	8	18	12	3	0	0	0	0
1999	22	102	14	53	25	57	22	3	0	0	0	0
2000	22	102	36	67	32	83	28	7	0	0	0	0
2001	22	102	36	74	56	115	33	7	0	0	0	0
2002	22	102	48	77	81	155	39	7	0	0	0	0
2003	22	102	48	77	107	168	44	7	0	0	0	0
2004	22	102	48	77	139	197	44	7	0	0	0	0
2005	22	102	48	77	151	220	48	7	0	0	0	0
2006	22	102	48	77	179	235	48	7	0	0	0	0
2007	22	102	48	77	215	274	48	7	0	0	0	0
2008	22	102	48	77	238	307	48	7	0	0	0	0
2009	22	102	48	77	274	331	48	7	0	0	0	0
2010	22	102	48	77	311	374	48	11	0	0	0	0
2011	22	102	48	77	348	410	48	21	0	0	0	0
2012	22	102	48	77	391	436	48	27	0	0	0	0
2013	22	102	48	77	405	454	48	32	0	0	0	0
2014	22	102	48	77	415	464	48	32	65	0	103	0
2015	22	101	48	77	415	470	48	35	62	0	176	39
2016	22	101	48	77	415	471	48	35	54	0	264	35
2017	19	101	48	77	415	476	48	35	50	0	451	30
2018	19	101	48	77	414	480	48	35	46	257	425	26
2019	19	101	48	77	414	480	48	35	178	289	475	76
2020	19	100	48	77	414	483	48	35	170	280	449	133
2021	19	97	47	77	407	483	48	35	195	341	474	116
2022	19	93	47	77	407	483	48	35	176	399	419	112
2023	19	84	43	77	402	483	48	35	216	353	391	96
2024	19	72	43	77	396	482	48	35	184	296	336	80
2025	19	60	43	77	395	478	48	35	160	267	294	68
2026	19	41	43	69	393	477	48	35	134	331	246	69
2027	9	23	43	54	377	475	48	35	106	297	176	57
2028	6	11	43	52	369	464	43	28	85	323	103	46
2029	6	11	43	52	369	464	43	28	260	366	103	46
2030	6	11	43	52	369	464	43	28	320	483	103	46
2031	6	11	43	52	369	464	43	28	417	552	103	46
2032	6	11	43	52	369	464	43	28	483	703	103	46
2033	6	11	43	52	369	464	43	28	483	813	103	46
2034	3	5	28	18	368	435	43	28	472	736	31	143
2035	3	2	28	0	355	384	43	28	395	645	2	112
2036	0	0	0	0	339	350	22	28	305	518	2	79
2037	0	0	0	0	332	299	0	28	212	373	0	64
2038	0	0	0	0	286	242	0	28	130	292	0	48
2039	0	0	0	0	227	155	0	28	51	183	0	26
2040	0	0	0	0	91	55	0	27	8	111	0	12
2041	0	0	0	0	0	0	0	0	0	0	0	0

Notes: 1. Excludes fuel in pools shutdown prior to 1998

2. Shutdown reactor data is based 5 years after discharge

Table B-2. Cumulative Breakdown of At-Reactor Dry Storage Canister (MPCs and MESCs) Requirements for MPC System with No MRS

	Pool Capacity Driven Dry Storage Needs-Cumulative								Shutdown Reactor Driven Dry Srorage Needs[1,2]-Cum.			
	BWR	PWR	BWR	PWR	BWR	PWR	BWR	PWR	BWR	PWR	BWR	PWR
	LG-MESC	LG-MESC	SM-MESC	SM-MESC	LG-MPC	LG-MPC	MD-MPC	MD-MPC	LG-MPC	LG-MPC	MD-MPC	MD-MPC
1997	22	102	7	34	0	0	0	0	0	0	0	0
1998	22	102	13	45	8	18	12	3	0	0	0	0
1999	22	102	14	53	25	57	22	3	0	0	0	0
2000	22	102	36	67	32	83	28	7	0	0	0	0
2001	22	102	43	84	56	118	41	11	0	0	0	0
2002	22	102	63	103	90	165	54	11	0	0	0	0
2003	22	102	88	115	115	196	70	15	0	0	0	0
2004	22	102	94	134	157	244	87	18	0	0	0	0
2005	22	102	119	144	171	296	109	18	0	0	0	0
2006	22	102	140	174	203	335	129	22	0	0	0	0
2007	22	102	161	184	249	389	158	22	0	0	0	0
2008	22	102	196	212	277	456	182	26	0	0	0	0
2009	22	102	220	226	318	504	215	26	0	0	0	0
2010	22	102	234	243	366	589	236	31	0	0	0	0
2011	22	102	280	262	410	651	256	41	0	0	0	0
2012	22	102	280	281	469	723	303	47	0	0	0	0
2013	22	102	291	281	523	797	297	52	0	0	0	0
2014	22	102	291	291	581	865	297	57	73	0	111	0
2015	22	101	291	291	620	914	297	68	67	0	188	36
2016	22	99	291	291	642	958	297	73	52	0	255	32
2017	22	94	291	291	680	988	297	79	48	0	419	27
2018	22	94	291	291	692	1000	297	84	43	243	391	23
2019	22	93	291	291	697	1008	297	88	162	264	450	92
2020	22	89	291	291	697	1016	297	88	156	272	407	170
2021	21	83	291	291	697	1022	297	88	203	334	429	151
2022	21	66	291	291	697	1022	297	88	182	434	384	147
2023	19	54	291	291	695	1027	297	88	222	401	333	131
2024	19	41	291	284	688	1029	297	88	187	353	291	117
2025	19	28	290	280	688	1023	297	88	157	327	244	117
2026	17	17	289	270	687	1015	297	88	140	416	212	103
2027	13	9	285	254	685	1000	297	88	112	382	173	91
2028	9	2	285	234	676	971	297	85	102	417	130	90
2029	3	0	285	213	668	938	290	82	287	401	98	78
2030	0	0	279	178	660	889	282	78	293	458	61	67
2031	0	0	262	162	653	849	265	75	315	436	38	55
2032	0	0	243	132	610	802	197	61	317	499	10	55
2033	0	0	206	132	599	771	158	61	286	533	3	46
2034	0	0	144	91	587	720	79	61	258	474	3	110
2035	0	0	76	42	535	619	53	61	220	422	0	79
2036	0	0	0	12	471	568	24	61	176	314	0	46
2037	0	0	0	0	437	481	0	61	107	207	0	31
2038	0	0	0	0	375	352	0	61	45	192	0	15
2039	0	0	0	0	267	216	0	54	11	129	0	0
2040	0	0	0	0	97	99	0	39	0	72	0	0
2041	0	0	0	0	0	0	0	0	0	0	0	0

Notes: 1. Excludes fuel in pools shutdown prior to 1998

2. Shutdown reactor data is based 5 years after discharge date

EIS COMMITMENT RESOLUTION LETTER #4

ATTACHMENT C

(8 pages)

IN THE UNITED STATES COURT OF FEDERAL CLAIMS

YANKEE ATOMIC ELECTRIC COMPANY,

Plaintiff,

v.

UNITED STATES OF AMERICA,

Defendant.

No. 98-126C
(Senior Judge Merow)

JAMES P. MALONE EXPERT WITNESS REPORT

This report addresses matters relevant to the contract entered into by Yankee Atomic Electric Company ("Yankee Atomic") with the government for the acceptance of spent nuclear fuel and high-level radioactive waste (together "spent fuel"). This contract is one of approximately 50 such contracts with essentially the same terms between the government and commercial nuclear utilities. The form of each such contract is sometimes referred to as a Standard Contract. I am aware that the Court has held that the government breached Yankee Atomic's contract by not beginning to accept spent fuel from Yankee Atomic by January 31, 1998.

Frank Graves has submitted an expert report in this matter addressing the pace and schedule on which the government would accept spent fuel from Yankee Atomic and other contracting utilities after January 31, 1998 pursuant to the parties' contracts. In his report, Mr. Graves relies on various data to develop factors used in his economic analysis to demonstrate how the fuel removal program would have operated. This data includes: costs for the dry storage of spent fuel; information on dry storage cask capacity, handling, and transportation; the operations and maintenance costs associated with the wet storage of spent fuel; and historical and projected fuel discharge data for U.S. nuclear utilities. I was asked to supply the above-noted data for Mr. Graves' report. This report presents my opinions in supplying that data, together with the other information called for in Fed. R. Civ. P. 26(a)(2)(B).

I. Opinions to be Expressed and the Bases Therefor

I offer the following points as the opinions to which I expect to testify at the trial of this matter. I present my reasoning for reaching my conclusions along with the conclusions themselves. In general, my opinions are based on my over 30 years of experience in nuclear engineering and economics in the nuclear power industry, and my review of relevant documents. The cost numbers I supplied to Mr. Graves were provided through Nuclear Assurance Corporation International ("NAC"), where I currently serve as Vice President, Consulting. I have worked for NAC since 1990 in various positions, all of which were related to spent fuel management. NAC has performed extensive spent fuel transportation and management work for the U.S. Department of Energy ("DOE") for more than 20 years.

My principal opinion is that the data concerning the costs of dry and wet storage for spent fuel, dry storage cask capacity, handling, and transportation, and fuel discharges, that I supplied to Mr. Graves is accurate and reliable for purposes of the economic models that Mr. Graves has constructed.

A. Spent fuel dry storage cost data

I supplied Mr. Graves with data on the costs of various aspects of a dry storage system for spent fuel. The cost data supplied is as follows:

> Dry Storage Fixed Costs include licensing, engineering, construction of the ISFSI, engineering and technical support of the cask/canister system, and equipment and materials of the cask/canister system. Together these fixed costs total $6.4 million and represent the fixed costs associated with implementing a dry storage system.
>
> Variable (per canister) initial costs associated with dry storage include varying the size of the storage pad, fabrication oversight, quality assurance oversight, project management, and variable equipment and materials. Together, these variable costs total $167,000 per canister. In addition, the physical cask/canister system is $720,000. Together, these costs represent the variable costs on a per canister basis associated with implementing a dry storage system. *
>
> Costs associated with a crane upgrade, if needed, are $3.5 million for an upgrade of less than 30 ton handling capacity, and $4.5 million for a greater that 30 ton upgrade. In addition, an average of $1 million per site for structural modifications to buildings to accommodate a larger crane is necessary, if a crane upgrade is needed. Together, these fixed costs represent the fixed costs associated with upgrading a crane when implementing a dry storage system.
>
> Dry Storage Decommissioning Cost is $240,000 per canister. This cost represents the decommissioning expense associated with an ISFSI.
>
> Dry Storage Operating & Maintenance Cost (per year) is $3,500,000. This cost is largely associated with monitoring, surveillance and support, and represents the expenses on an annual basis associated with the operation and maintenance of an ISFSI.

NAC has developed a substantial body of knowledge concerning dry storage systems including, in particular, the following areas:

- the design, licensing, and construction of independent spent fuel storage installations (ISFSI) at reactor sites for the storage of spent fuel using dry storage cask/canister systems;

- the design, engineering, and fabrication of dry storage cask/canister systems;
- the movement of spent fuel from a spent fuel pool to an ISFSI; and
- the annual Operations and Maintenance costs for an ISFSI.

Through my employment at NAC I have gained a substantial body of experience in these areas as well. During my tenure at NAC I served as the person in charge of domestic and international sales of dry storage systems for spent fuel. I have acquired a substantial body of knowledge in the pricing of spent fuel dry storage systems and the various components of such systems. I have prepared and reviewed bids submitted by NAC for the provision of dry storage systems for spent fuel. I have also reviewed commercial bids and contracts drafted by other companies and submitted to NAC for the provision of such services.

The numbers I supplied to Mr. Graves for the category of Dry Storage Fixed Costs have several bases. In part, these numbers are derived from bids for the provision of dry storage services that were either developed and submitted by NAC, or submitted to NAC by other contractors and reviewed by NAC. An additional source of information is the Owl Creek Energy Project, a private interim storage facility being developed in Wyoming for which NAC is the project manager. It is NAC's responsibility to develop pricing information for this project, and some of the information developed is reflected in the cost numbers supplied to Mr. Graves.

The Dry Storage Cost numbers are also formed by the experience of Virginia Power, which is currently operating two ISFSIs -- one of which is the longest operating domestic ISFSI and one of which is the newest domestic ISFSI in operation. Cost information from these ISFSIs was used as an additional basis for the numbers supplied to Mr. Graves.

The numbers for Crane Upgrade Costs, Dry Storage Canister Cost, Dry Variable Construction Costs, and Dry Storage Decommissioning Costs are all developed from NAC's extensive experience in dry storage systems for spent fuel. In large part these numbers are derived from bids submitted by and/or to NAC for the various aspects of a dry storage system.

The Dry Storage Operating and Maintenance Cost number is based upon cost information supplied by several utilities for their ISFSIs.

I personally supervised the compilation of, and personally reviewed all of, the dry storage cost information discussed above. Based upon my experience in and knowledge of the subject of dry storage of spent fuel, particularly the pricing of spent fuel dry storage systems, it is my opinion that these cost numbers are reliable estimates of the indicated expenses associated with a dry storage system.

B. Dry storage cask capacity, handling, and transportation data

I supplied Mr. Graves with data on the capacity of casks used for the transportation and dry storage of spent fuel, as well as data on aspects of the handling and transportation of such casks. The data concerns the following aspects of dry storage:

- capacities for transportation and storage casks for boiling water reactors and pressurized water reactors; and
- spent fuel pool crane design capacities and loaded transfer cask weights for spent fuel pools currently in service.

The data on cask capacities is derived from transportation and storage cask designs created by NAC. These cask designs have been approved for use by the NRC. The data on the capacity of canister based systems is based on the NAC-UMS design, which is currently in the NRC review process. The UMS should receive storage and transport approval from the NRC next year.

The data on cask removal is derived from NAC's experience in conducting shipping campaigns for spent fuel. NAC has made over 3200 shipments of spent fuel and has developed a sizable body of knowledge concerning the time necessary to complete the various operations associated with a spent fuel shipping campaign.

The information on crane design capacities and transfer cask weights is derived from Facility Interface Capability Assessment (FICA) studies performed by NAC for the Department of Energy ("DOE"). The purpose of these studies was to evaluate the cask handling capabilities of the nuclear utilities that entered into Standard Contracts with the government. All of the studies were submitted to DOE at their completion.

I personally supervised the compilation of, and personally reviewed all of, the information discussed above. Based upon my experience in and knowledge of the subject of dry storage of spent fuel, particularly in the areas of cask/canister systems and the movement of spent fuel from a spent fuel pool to an ISFSI, it is my opinion that the information provided to Mr. Graves is accurate and reliable.

C. Operations and maintenance costs associated with the wet storage of spent fuel

I supplied Mr. Graves with data indicating that a conservative estimate of the average annual cost of operating and maintaining a spent fuel pool at a shutdown nuclear plant is approximately $8 million. NAC is in the business of collecting data on the management of spent fuel by nuclear utilities. In the course of this business, NAC has collected information on the costs of wet storage for spent fuel. The $8 million cost number supplied to Mr. Graves is derived from cost information collected by NAC from shutdown nuclear plants that are currently operating spent fuel pools. *

I personally supervised the compilation of, and personally reviewed all of, the information from which the wet storage operations and maintenance costs discussed above were derived. Based upon my experience in and knowledge of spent fuel management and storage, it is my opinion that the information provided to Mr. Graves is accurate and reliable.

D. Historical and projected fuel discharge data

I supplied Mr. Graves with data on historical and projected discharges of nuclear fuel from the reactors of U.S. nuclear utilities. This data is a product of NAC's research and analysis of nuclear fuel cycles and markets, areas in which NAC has provided extensive consulting services for over 30 years. I currently manage the nuclear fuel consulting group at NAC, the group that provides these particular consultation services. I personally supervised the compilation of, and personally reviewed all of, the fuel discharge information supplied to Mr. Graves. Based upon my experience in and knowledge of the research and analysis of fuel cycles and markets, it is my opinion that the information provided is accurate and reliable.

II. Data or Information Considered in Forming Opinions

Data and other information I considered in forming my opinions is listed in Exhibit 1 to this report.

III. Qualifications

My qualifications to offer the opinions included in this report, including a list of all publications I have authored within the preceding ten years, are set out herein and in Exhibit 2 to this report.

IV. Compensation

NAC is being paid $250 per hour for my time working on this matter.

V. Other Expert Testimony

I have not testified as an expert at trial or by deposition in any other cases within the preceding four years.

Respectfully submitted,

James P. Malone

Dated: June 30, 1999

James P. Malone

EIS COMMITMENT RESOLUTION LETTER #4

ATTACHMENT D

(8 pages)

96 FUEL CYCLE
New Orleans
MARCH 24-27

UTILITY ON-SITE SPENT FUEL STORAGE ISSUES

Kenneth R. Miller
Senior Project Manager
Rancho Seco Nuclear Generating Station
Sacramento Municipal Utility District

NEI
NUCLEAR ENERGY INSTITUTE

UTILITY ON-SITE SPENT FUEL STORAGE ISSUES

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Herald. California 95638

Introduction

Utilities with both operating and decommissioning plants are currently investigating the economic and technical feasibility of spent nuclear fuel storage and disposition. As a result, assessments are being made to determine the impact of on-site dry spent fuel storage. Not only are the capital and operating costs of the equipment or modifications being evaluated, but staffing levels, project management, the regulatory/licensing process, technical issues, the vendor/fabrication process, offsite considerations, interference with other plant activities, and the ability to eventually transfer the fuel to DOE all factor into the assessments.

In the case of the Rancho Seco Nuclear Generating Station, a decommissioning plant, the Sacramento Municipal Utility District (SMUD) developed three objectives related to spent fuel disposition to support the safe and economical closure of the plant. These objectives are:

1. Minimize occupational and public radiation exposure.
2. Minimize spent fuel storage costs, including the need to maintain the spent fuel pool, and
3. Prepare the fuel for Department of Energy (DOE) acceptance.

These universal goals are being met for Rancho Seco through the development and use of a canister-based spent fuel transportable storage system (system).

Spent Fuel Disposition Options

Shortly after the shutdown of the Rancho Seco Nuclear Generating Station in June of 1989, SMUD staff determined that the storage and disposition of the plant's spent nuclear fuel to be one of the most important factors affecting the schedule and method for ultimately decommissioning the facility. SMUD commissioned an independent spent fuel study to evaluate the alternatives available to Rancho Seco.

The following is a brief description of the spent fuel disposition alternatives considered:

1. Direct shipment to a Federal repository: This alternative is the preferred solution for the disposition of the spent fuel. However, no federal repositories or storage facilities are available.

2. Dry cask storage on-site: Storage of spent fuel in a dry shielded canister/overpack above ground which can be shipped off-site without repackaging. This alternative appears to be the most desirable method of on-site storage at the present time.

3. Reprocessing: No commercial reprocessing facilities are currently operating in the United States. Reprocessing facilities are operating in the United Kingdom, France, Germany, and Japan. However, the prospect of shipping domestic spent fuel to a foreign country for reprocessing is obscure, extremely expensive, and may be in conflict with United States Government policies.

4. Storage at another utility's spent fuel pool: SMUD asked several neighboring utilities if they would be willing to store Rancho Seco's spent fuel in their spent fuel pools or in a dry storage facility. The utilities that responded uniformly rejected the proposal.

5. Continued wet storage in the Rancho Seco spent fuel pool: In lieu of any other alternative, SMUD could keep the spent fuel in the existing spent fuel pool, modified for maximum cost efficiency. This would preclude decommissioning the facility until the DOE removes the spent fuel from the site at some future date.

Decommissioning Schedule

At this point, the SMUD staff decided to evaluate the specific costs of keeping the spent fuel in wet storage in the spent fuel pool compared to dry cask storage. A schedule was developed for the long term storage and disposition of the spent fuel. Staff assumed that the spent fuel would be kept in the pool until 1997, during which time the fuel could cool, the dry cask storage system could be procured, and the Independent Spent Fuel Storage Facility (ISFSI) constructed. The fuel would be dry stored by 1998 and remain in storage until DOE acceptance. Rancho Seco decommissioning is scheduled to begin in 2008 and be completed by 2011. At the end of plant decommissioning, the 10 CFR 50 license will be terminated and the ISFSI will stand-alone, licensed under 10 CFR 72.

Dry Storage Cost Evaluation

Based on the alternatives evaluated, only wet storage in the current spent fuel pool or dry storage were considered practical. A cost study was commissioned to determine the overall plant decommissioning cost and effect on activities and maintenance by dry casking the spent fuel.

The economic aspects of keeping spent fuel in the spent fuel pool as opposed to dry storage indicate that the capital costs associated with dry storage can be recovered in less than two years and that a substantial amount can be recovered over the period the plant is in SAFSTOR. Additionally, unrealized economic benefits from dry storage allow plant decommissioning to proceed on an optimized, cost effective schedule, not driven by the DOE's acceptance of spent fuel.

The economics associated with SMUD's decision to dry store Rancho Seco's spent nuclear fuel include:

Description	Cost
* Annual Cost of Plant/Fuel Pool Operation	$15.1 million
* Annual Cost of Plant/Dry Cask Storage	$ 3.8 million
* Cost of Transportation/Storage System	$14.7 million
* Cost of ISFSI/Site Modifications	$ 3.3 million
* Total Cost of ISFSI	$18.0 million
* Realized Savings Over 10 Year SAFSTOR Period	$95.0 million

Spent Fuel System Strategy/Function

The next step in the process was for SMUD staff to evaluate spent fuel transportable storage systems. Regulators determined SMUD must demonstrate the ability to move Rancho Seco's spent fuel off-site before (the spent fuel pool) decommissioning could proceed. After reviewing various proposals, staff concluded that a "dual purpose" canister based system would be the most effective fuel storage and disposition method for Rancho Seco. The selected system consists of multi-purpose casks, canisters, storage modules, and auxiliary equipment.

During the storage mode, the canisters would be stored in concrete storage modules. To ship the canisters off-site, the multi-purpose casks could be used for canister transport to a Federal repository. DOE would eventually take title to one cask as the result of a SMUD/DOE Demonstration Program.

Additionally, this approach provides the capability to recover from an off-normal ISFSI condition, since the multi-purpose casks can be used as a storage overpack for an "off-normal" canister. The multi-purpose casks can also be used for on-site transfer from the spent fuel pool to the ISFSI. The concrete storage modules are also transportable, and may be reused by DOE or another utility, thus mitigating the cost to SMUD for their decommissioning.

Economic Impact

With the decision to dry cask Rancho Seco's spent fuel resulting in a $11.3 million annual cost savings, SMUD can recover its ISFSI capital investment of about $18 million (system and ISFSI) in less than two years. Over the 10 year period of SAFSTOR, after the spent fuel is in dry storage, SMUD will realize a savings (after recovery of capital investment) of about $95 million.

Additionally, significant savings continue for the period from when the nuclear plant facility is decommissioned until the DOE finally accepts the Rancho Seco spent fuel. Based on the anticipated savings and the potential capability of the proposed system, SMUD staff believes it has made the best possible decision by purchasing a canister-based transportable storage system.

Project Management/Task Force

SMUD staff recognized a project management team was essential to the future success of the program. A project manager was selected early, right after the dry storage option was selected and in turn, a multi-disciplined task force was developed to support and carry out the many tasks and activities in the years to come. The project manager and task force team visited other sites with spent fuel storage facilities and reviewed lessons learned and experiences from other utilities and the system's owners group. The team developed a spent fuel master plan and schedule for site and facility modifications, construction of the Independent Spent Fuel Storage Installation (ISFSI), transportable storage system and support equipment procurement, training programs, licensing activities, and technical procedures. SMUD also hired a spent fuel consultant to integrate with the program manager and task force members and to provide technical oversight for the project. Both the project manager and the task force recognized it was important to set and maintain high standards for the project for others to follow and to ensure the support of the public and local community.

Technical Issues

Decommissioning the spent fuel pool requires an integrated approach to at-reactor spent fuel management. The fuel must not only be placed in long-term dry storage in a "stand-alone" Independent Spent Fuel Storage Facility until DOE acceptance, but must also be transportable without repackaging. In addition, both intact and damaged (failed) fuel assemblies must be packaged so that the pool can be completely emptied.

The transportation overpack is designed for on-site transfer, off-site rail transportation, and as a recovery/storage cask for a credible "off-normal" event (a capability required by the NRC since the spent fuel pool will be unavailable and the ISFSI is stand-alone).

Technical procedures were developed for such activities as heavy loads/cask movements, failed fuel detection, spent fuel verification, cask/canister loading and unloading, canister welding, cask/canister decontamination, pre-operational testing, and ISFSI/system operations. An analysis was also performed to evaluate effects on the spent fuel and the spent fuel pool building in the event of a cask drop. The turbine gantry crane, to be used for the heavy loads lift of the cask was evaluated and subsequently upgraded and refurbished. Canister weld mockups were fabricated to help train and certify welding personnel. Finally, a safety evaluation and review process was developed in accordance with the guidelines of 10 CFR 72.48 (similar to 10 CFR 50.59) for site changes.

System dry runs are scheduled for later this year.

Procurement/Quality Assurance

One major attribute regarding the transportable storage system procurement is a well negotiated contract with the system equipment supplier. SMUD staff and the project manager spent over 100 hours negotiating the details of such a contract. Because the contract involved the development of an unlicensed spent fuel storage and transport system, it was important that all terms and conditions be well documented in order to protect both parties. Additionally, it was important to define the technical specifications and performance requirements of the system to ensure final product expectations are met.

Task force engineering personnel spent countless hours reviewing the product design and subsequent design changes. A product "readiness review" was conducted including SMUD personnel, the equipment supplier, and sub-contractors to ensure all design activities were complete and approved before the start of fabrication of each major component of the system.

SMUD Quality Assurance personnel continue to play an essential role in the system documentation and fabrication process, both at the site and at sub-contractor's fabrication facilities. "Intrusive Oversight" of the equipment supplier and sub-contractors has become an assurance mode of operation for SMUD. SMUD Quality Assurance personnel currently provide a near constant presence at sub-contractor facilities.

Licensing/Regulatory Compliance

The licensing approach for the system design has been conservative as well. Meetings were conducted (at Rockville, MD) with NRC Part 50, Part 71 and Part 72 personnel, SMUD project personnel and DOE observers at the beginning and throughout the licensing process. NRC and DOE officials have visited the Rancho Seco site throughout the project. SMUD officials also presented the status and objectives of the Rancho Seco Spent Fuel Project to NRC officials at Regional Headquarters in Texas. Regional staffers have also visited the site several times and are planning an inspection of SMUD's spent fuel program.

- 10 CFR 71: The system supplier has applied to the NRC for a Certificate of Compliance for the transportation system. The general approach for compliance with 10 CFR 71 is engineering analysis. Conservative hand calculations and widely accepted computer analysis programs were used to perform structural, thermal, shielding, and criticality safety analyses to verify compliance with the requirements of 10 CFR 71 for the various normal conditions of transport and hypothetical accident conditions. For auxiliary cask components such as impact limiters, limited bench tests, small scale model tests, and scale model drop tests (performed at Rancho Seco) were used to verify the analysis tools being used to demonstrate compliance with the 10 CFR 71 requirements.

  The system Safety Analysis Report (SAR) was submitted for Part 71 review in the fall of 1993 and the NRC is currently reviewing SMUD's response to the second round of questions. Licensing success is expected by mid-1996.

- 10 CFR 72: SMUD has elected to license the storage portion of the system under 10 CFR 72 since a site specific license is required for an ISFSI to support decommissioning. With the goal of decommissioning and abandoning the spent fuel pool, all of the fuel and control components will have to be stored and subsequently shipped without repackaging. Any credible off-normal event must have a recovery mode as well. The dual purpose conservatism provided by the cask/canister package mitigates the loss of the spent fuel pool recovery capability.

  The Safety Analysis Report and 10 CFR 72 license application was submitted for the NRC's review in the fall of 1993. The NRC is currently reviewing SMUD's responses to second round questions. Licensing success is also expected by mid-1996.

The project manager and task force personnel have developed a matrix document that identifies all applicable regulatory requirements (e.g. 10 CFR 72) and has assigned responsible individuals or organizations to assure their compliance.

Department of Energy Interface

SMUD and the Department of Energy have collectively engaged in a Cooperative Agreement to demonstrate the dry cask system and (potentially support) a spent fuel dry transfer system demonstration. SMUD and DOE officials have also met to discuss spent fuel waste form acceptance, spent fuel verification and safeguards issues and the disposition of GTCC waste.

Institutional Issues

Additionally, assessments of the requirements of the California Environmental and Quality Act (CEQA) and the National Environmental Policy Act (NEPA) were performed to address regulations and other constraints associated with federal, state, and local laws. Public meetings/hearings were conducted and comments were received from the general public. Additional briefings were provided for local law enforcement, fire protection, and emergency responders regarding SMUD's plans for spent fuel storage and disposition. SMUD's public information personnel have been active in developing a positive interface with the local news medias. Plant staff has also provided presentations to local business organizations, such as the Rotary Club.

Schedule

SMUD staff expects to begin the Rancho Seco spent fuel dry storage campaign in the fall of 1996, with completion about a year later, in the fall of 1997.

Summary Conclusion

The canister-based spent fuel system meets SMUD's decommissioning goals. Radiation exposures are minimized because fuel handling is minimized. Economically, the projected $95.0 million savings over a 10 year period is conservative since it is highly unlikely that all of the SMUD spent fuel will be accepted by the DOE before then. Although the specific solution to SMUD's spent fuel program may not be universally applicable, the related spent fuel storage and disposition attributes and objectives are. By understanding the canister-based system approach and associated programmatic issues, those utilities considering decommissioning or those operating plants needing to dry store spent fuel can make more informed decisions that may save additional work and expense.

EIS COMMITMENT RESOLUTION LETTER #4

ATTACHMENT E

(7 pages)

NES/BOSTON EDISON

Decommissioning Workshop

". . . innovative approaches towards reducing post–shutdown decommissioning costs".

Boston, Massachusetts

February 18 & 19, 1993

MAJOR COST ELEMENTS OF A WET STORAGE PROGRAM WITH EXISTING PLANT SYSTEMS

Item	Annual Cost	Total Cost for 24 Years
Utility Staff*	$14,198,000	$340,752,000
Insurance	1,015,000	24,360,000
Taxes*	2,400,000	57,600,000
Security*	5,785,000	138,840,000
Maintenance/HP Supplies	150,000	3,600,000
Energy	578,000	13,872,000
TOTAL	$24.126.000	$579.024.000

---

*Candidate for cost reduction or elimination.

UTILITY STAFF DURING WET STORAGE PROGRAM WITH EXISTING PLANT SYSTEMS

Title	Staff Number	Total Annual Cost
Management	15	$2,050,000
Engineering	15	918,000
Maintenance	20	1,716,000
Administration	16	1,621,000
QA/QC	10	995,000
Health Physics/Safety	34	2,807,000
Technician	8	680,000
Security	4	344,000
Operations	35	3,067,000
TOTAL	157	$14,198,000

OTHER MAJOR COSTS DURING WET STORAGE WITH EXISTING PLANT SYSTEMS

	Annual Cost
Insurance:	
Nuclear Property - $100,000,000 coverage	$655,000
Nuclear Liability - $100,000,000 coverage	360,000
TOTAL	$1,015,000
Taxes:	
Estimated value of plant upon shutdown = $240,000,000	
$240,000,000 x 1% =	$2,400,000
Security:	
(27 guards + 1 supervisor) per shift x 4 shifts	$5,785,000

MAJOR COST ELEMENTS OF A WET STORAGE PROGRAM WITH MODIFIED PLANT SYSTEMS

Item	Annual Cost	Total Cost for 24 Years
Utility Staff*	$3,954,000	$94,896,000
Insurance	1,015,000	24,360,000
Taxes*	1,000,000	24,000,000
Security*	2,066,000	49,584,000
Maintenance/HP Supplies	100,000	2,400,000
Energy	500,000	12,000,000
TOTAL	$8,635,000	$207,240,000

---

*Candidate for cost reduction or elimination.

UTILITY STAFF DURING WET STORAGE PROGRAM
WITH MODIFIED PLANT SYSTEMS

Title	No. of Shifts	No./Shift	Staff Number	Total Annual Cost
Site Manager	1	1	1	$157,000
Health & Safety/QA Manager	1	1	1	124,000
Engineering	1	2	2	203,000
Administration	1	2	2	122,000
Operations	4	5	20	1,752,000
Health Physicist	4	1	4	330,000
Maintenance/Technicians (I&C, Electrical, Mechanical)	1	15	15	1,266,000
TOTAL			45	$3,954,000

OTHER MAJOR COSTS DURING WET STORAGE WITH MODIFIED PLANT SYSTEMS

	Annual Cost
Insurance:	
Nuclear Property - $100,000,000 coverage	$655,000
Nuclear Liability - $100,000,000 coverage	$360,000
TOTAL	$1,015,000
Taxes:	
Estimated value of plant upon shutdown = $100,000,000	
$100,000,000 x 1% =	$1,000,000
Security:	
10 guards per shift: o 4, including supervisor, at main gate/control center o 3 on perimeter patrol o 3 in the plant, including 1 in the pool area	
10 x 4 shifts	$2,066,000

EIS COMMITMENT RESOLUTION LETTER #4

ATTACHMENT F

(9 pages)

Spent Fuel and Decommissioning

presented by
William A. Cloutier, Jr.
Vice President, TLG Services, Inc.
December 4, 1997

Introduction

- *TLG Services, Inc. provides 80% of the decommissioning cost studies being used by commercial utilities for financial planning*
- *Participant in engineering and planning activities at all of the sites where decommissioning is underway or anticipated*
- *Worked with commercial utilities during the past 10 years - identifying the constraints on reactor decommissioning posed by post-operation spent fuel storage and in evaluating alternatives*
- *Participates in economic evaluations where decommissioning and spent fuel management are factored into decisions for continued plant operation*

Decommissioning

- *Definition*
  - *"… permanently removing a nuclear facility from service and reducing radioactive material on the licensed site to levels that would permit termination of the NRC license." [DG-1067}*
  - *Decommissioning Alternatives*
  - *DECON - removal or decontamination of equipment, materials and facilities that contain radioactive contaminants to a level that permits termination of the license shortly after the cessation of operations*
  - *SAFSTOR - placement and maintenance of the facility in a stable, safe condition for a period not to exceed 60 years, at which time the facility is decontaminated to permit termination of the license*
  - *ENTOMB - physical isolation and containment of radioactive material in a structurally long-term substance (concrete) until decay permits release -- generally not practical for commercial reactors with long-lived radioisotopes, even after 100 years of storage*

Decommissioning Regulations and Spent Fuel Management

- *NRC has historically excluded the storage and management of spent fuel from the financial requirements for reactor decommissioning in its development of its certification levels*
-
- *NRC Staff Position - Decommissioning trust funds are not to be used for maintenance and storage of spent fuel including the construction of supplemental storage (additional funds can be included if specifically identified)*
-
- *Current regulations on decommissioning do not contain guidance on the management or funding for the storage of spent fuel during the decommissioning period once the licensee has certified permanent defueling, except to recognize its potential role in the site license termination process*

NRC's Interest in Spent Fuel During Decommissioning

- *Isolation of the plant's spent fuel storage area(s) including safety (cooling water, power) and security systems*
- *Potential accidents - heavy lifts around or over spent fuel storage areas, loss of cooling water from demolition activities, use of the pool for staging of waste and cask loading*
-
- *Siting, construction and licensing of supplemental storage, including design and fabrication of dry storage canisters*
- *Repackaging capabilities in the event of package failure or with the use of single-function containers*

Utility Interest - Historically

- *Mid 1980s - interest restricted to facilities facing loss of full core off-load due to insufficient pool capacity or those utilities with operating ISFSIs (Independent Spent Fuel Storage Installations)*
- *Premature closure of several large generating units beginning in 1989: continued spent fuel management obligations raised concerns on feasibility of "prompt" decommissioning*
-
- *Deregulation - ability of utilities to recover increases in the decommissioning cost considering the uncertainty of spent fuel disposal and the associated ability to decommission*
-

Fuel Management Costs - Continued Wet Storage

- *Cost/Benefit Considerations*

  Anticipated storage period

  Current operating capabilities (i.e., to achieve end-of-life without the need for supplemental storage)

  Current storage pool configuration/location

  Preferred decommissioning alternative

  Utility's future organization and business ventures

- *Capital and Engineering Expenditures*

  Fuel storage facility isolation and protection, alternate decay heat removal systems, alteration of operating specifications, license modifications or re-licensing of facility, facility upgrades to accommodate DOE's transfer/transport cask

Fuel Management Costs - Continued Wet Storage

- *Operating Expenditures*

  Security, systems operating personnel, technicians, certified fuel handlers, chemistry, energy, waste processing, corporate support costs

- *Decommissioning Considerations*

  Sequence of removal and disassembly, material movement, controlled dismantling, license termination

Typical Costs

	Wet Storage	*Dry Storage*
Initial Expenditures (including licensing)	*$3-4 MM*	*$5-10 MM*
Canister Costs (per unit) (single/multipurpose)	*n/a*	*0.5 to 1.5 MM*
Annual Operating Costs (post-decommissioning)	*$6-10 MM*	*$3-5 MM*

EIS COMMITMENT RESOLUTION LETTER #4

ATTACHMENT G

(3 pages)

ENERGY RESOURCES INTERNATIONAL, INC.

1015 18TH STREET, N.W., SUITE 500
WASHINGTON, D.C. 20036

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MICHAEL H. SCHWARTZ

JULIAN J. STEYN

COPY

December 18, 1991

Ms. Julie Jordan
Program Manager, UWASTE
Edison Electric Institute
701 Pennsylvania Avenue
Washington, D.C. 20004-2696

Dear Julie:

I apologize for the delay in providing comments on the Pacific Northwest Laboratory report, "Cost Estimates of Operating Onsite Spent Fuel Pools After Final Reactor Shutdown," PNL-7778, dated August 1991. However, we were waiting for promised information from individual electric utility companies that had also prepared estimates of such costs for their internal use. As it is, the enclosure is being sent as an interim report since we are still waiting for some additional information.

Based on input from the three electric utility companies that had looked at this issue internally, it appears that the PNL estimate may be low by a factor of 2 to 6. That is to say the annual cost of operating a spent fuel pool after final reactor shutdown could be $8 million to $25 million, instead of $4 million. The information that we are still waiting for will hopefully include a fairly detailed buildup of the costs. This will allow us to respond to the PNL report more constructively with respect to specific areas of difference.

I will get a final product to you as soon as possible. In the meantime, please be aware that the PNL numbers appear to be low.

Sincerely,

Mike

Michael H. Schwartz

Enclosure

COPY

SUMMARY OF COMPARISONS AMONG COST ESTIMATES FOR OPERATION OF ON-SITE SPENT FUEL POOLS AFTER FINAL REACTOR SHUTDOWN

Status of Review as of December 17, 1991

Introduction

The primary document under review is the report, "Cost Estimates of Operating Onsite Spent Fuel Pools After Final Reactor Shutdown," Pacific Northwest Laboratory, PNL-7778, dated August 1991, which was prepared under contract to the U.S. Department of Energy (DOE). Since DOE has in the past used the results of such studies as a basis for comparison of alternative approaches to operating the civilian radioactive waste management system, the Edison Electric Institute's Utility Nuclear Waste and Transportation Program (EEI/UWASTE) decided that the conclusions of the report should be reviewed on behalf of its member electric companies.

During the past two years, several electric companies with operating nuclear power plants have prepared internal estimates of the cost of operation of on-site spent fuel pools after final reactor shutdown. These estimates, have been prepared at varying degrees of detail. Three such estimates were made available for comparison with the above mentioned PNL report. The following review compares the major assumptions and results of evaluations by Companies A, B and C, to the extent that details were provided, with those of the PNL report. Additional information has been requested and this review will be updated when that information becomes available.

Results

Estimates appear to consolidate into several main areas of interest:

- Staffing costs,
- Electric power costs,
- Other non-staffing related costs.

For these areas, the PNL report provides estimates based on the Morris spent fuel storage facility, which gives a staffing cost of 64% of total, with electric power and other non-staffing related costs contributing 5% and 31%, respectively. Of these cost estimates, the allowance for security staff (9) and electric power (2 million KWHr/year) appear to be low. Total staffing for the facility is estimated at 46 positions, with a total facility operating cost estimate of $3,385,400 per year.

Estimates from Company A are based on current departmental staffing for an operating unit and give a staffing cost of 53%, with electric power and non-staffing costs contributing 31% and 18%, respectively. This cost estimate acknowledges that further optimization of electric power usage could likely be attained, but this still represents a 15 fold increase in electric power consumption. Also, the security contingent for this estimate consists of 24 positions. Total staffing is estimated at 93 positions, approximately twice the PNL estimate, which is somewhat in line with the increase in total cost estimate to $7,830,000 per year.

Estimates from Company B are based initially on fuel storage in the current fuel pool, after which all fuel could be transferred to a low maintenance on-site storage facility. This estimate gives a projected staffing level of 47 for the eventual configuration, of which 30 positions would be assigned to the security force. An O&M budget of $20,000,000 was estimated for the period of time when fuel is in the fuel pool. During this period, staffing levels are expected to stabilize near 250 positions.

Estimates from Company C are based on two possible long term configurations: ongoing wet storage of the ISFSI and for ongoing dry storage alone. Initial conversion cost for the facility, including costs associated with license changes, is $15,097.215, while total annual operating cost for wet storage is estimated at $25,662,550. The largest share of cost is associated with staffing costs (91% of the pre-contingency allowance estimate or $22,315,263 for wet storage). No breakdown of staffing levels for various departments was provided.

Conclusions

- There appears to be a significant variation in both the cost estimates for facility operation, as well as staffing levels, between the various cost estimates. All utility estimates provide for a much larger security contingent than the PNL estimate. Overall staff estimates range by more than a factor of 2.
- Only one estimate (Company C) provided an estimate of land use costs, at $1,000,000 per year.
- Estimates of electric power usage and associated costs vary by more than a factor of 15 between estimates.
- While the PNL report allows for higher staffing levels (46 versus 35 positions) than currently used at the Morris facility, treatment of uncertainty centers on variations in geographic and pool capacity factors, as opposed to staffing levels and electric power requirements, which appear to dominate the variations between the various cost estimates reviewed.
- Estimates prepared by electric companies indicate annual costs of between 2 and 6 times those presented in the PNL report.

EIS COMMITMENT RESOLUTION LETTER #4

ATTACHMENT H

(6 pages)

ENERGY RESOURCES INTERNATIONAL, INC.

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WASHINGTON, D.C. 20036

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MICHAEL H. SCHWARTZ

JULIAN J. STEYN

COPY

February 24, 1992

Ms. Julie Jordan
Program Manager, UWASTE
Edison Electric Institute
701 Pennsylvania Avenue
Washington, D.C. 20004-2696

Dear Julie:

Enclosed is a Supplement to the summary of comparisons among cost estimates for operation of on-site spent fuel pools after final reactor shutdown. This supplement is based on additional details that we recently received from individual electric utility companies on this subject.

Hopefully, this Supplement will enable DOE to improve its own cost estimate, as originally presented in the Pacific Northwest Laboratory report, "Cost Estimates of Operating On-site Spent Fuel Pools After Final Reactor Shutdown," PNL-7778, dated August 1991. It still appears that the PNL estimate may be low by a factor of 2 to 6. That is to say the annual cost of operating a spent fuel pool after final reactor shutdown could be $8 million to $25 million, instead of the $4 million reported by PNL. A substantial part of the difference between the PNL estimate on one hand and the utility estimates on the other appears to be due to the fact that PNL began with a dedicated spent fuel storage facility and attempted to adjust for the nuclear power plant environment, whereas the utilities began with an operating nuclear power plant and adjusted for the changes due to cessation of power production.

Please call us if you would like to discuss this subject further.

Sincerely,

Mike

Michael H. Schwartz

Enclosure

COPY

SUPPLEMENT TO SUMMARY OF COMPARISONS AMONG COST ESTIMATES FOR OPERATION OF ON-SITE SPENT FUEL POOLS AFTER FINAL REACTOR SHUTDOWN

After receipt of additional information, an effort was made to identify any areas showing significant variations between estimates that could lead to improvement in the PNL estimate.

In general, the estimates varied widely and within all areas for which data was provided. This spread in the data is shown on two attached figures.

- Figure 1 shows the estimates for facility staffing by department. It was noted during review that the estimates prepared by Utility B and Utility C show that a facility staffing level that is 31% to 43% (69% to 57% reduction) of that required during normal power plant operation would be required to maintain spent fuel pool operation after final reactor shutdown. The PNL estimate is equivalent to a staff of 6% (94% reduction) of that required for normal power plant operation. Utility A is the closest to the PNL estimate and it estimates approximately twice as many personnel will be required to support fuel pool operation as PNL.

- Figure 2 shows the estimates for total annual operating cost for each cost center identified within the estimates. The total annual cost ranges from $3.9 million for PNL, to $7.9 million for Utility A and $21.2 million for Utility C. While Utility B did not provide a specific cost breakdown, it estimated total annual cost at $20 million. This indicates an extremely broad range among estimates.

  It was also noted during review that the estimated staff cost per person is higher for the PNL estimate ($58,678, versus $45,000 for the utility estimates). This tends to bring the total PNL cost estimate closer to the utility estimates. Also, it was noted that the PNL estimate and the two highest utility estimates (Utility B and Utility C) all specified estimates for single unit/single fuel pool sites.

The data used to generate these figures is provided in Table 1.

The variations among individual cost center estimates are, in general, extremely large. For example,

- Utility A had the highest estimate for electric power costs (by $1.7 million, or 300% of the next closest estimate). However, PNL estimated electric power costs at less than 20% of the next closest estimate.

- Utility B had the largest estimated security contingent (by 33 positions, or 190% of the next closest estimate). However, PNL estimated security staff requirements at half of the next closest estimate.

- Utility C had the largest estimated maintenance work force (by 52 positions, or 224% of the next closest estimate) and administrative staff (by 41 positions, or 286% of the next closest estimate). However, PNL estimated maintenance staff at less than 40% of the next closest estimate.

- The PNL estimates for operations staff and chemistry/health physics/radwaste staff were only 30% and 25% of the next closest estimate, respectively.

Finally, only one estimate (Utility A) is within 50% of the average annual cost of the group of three utilities and PNL ($13,223,537). This indicates that there is much broader uncertainty in the key aspects of these estimates, particularly in the areas of staff requirements and electric power consumption, than shown in the PNL report. Nonetheless, the PNL estimate represents only 30% of the average and 50% of the lowest utility estimate.

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TABLE 1

	Staffing Levels				Range Factor (High/Low)
Data Source	PNL Report	Utility A	Utility B	Utility C	
Security	12	24	70	37	5.83
Maintenance	11	30	42	94	8.55
Admin	9	2	22	63	31.50
Operations	5	17	41	63	12.60
Health Physics	4	16	29	36	9.00
Engineering	3	2	10	26	13.00
Licensing/QA	2	2	16	18	9.00
Warehouse/Materiel			10	12	N/A
Training			14		N/A
Total Staff	46	93	254	349	7.59
Normal operating staff			821	819	
Percent reduction from operating staff			69%	57%	
Reduction from projected operating staff of 820	94%	89%			

	Cost Estimates			Range Factor (High/Low)
Data Source	PNL	Utility A	Utility C	
Maintenance	$867,953	$1,272,960	$3,938,678	4.54
Security	$568,428	$720,000	$1,330,315	2.34
Admin staff	$451,166	$50,000	$2,883,397	57.67
Operations	$361,375	$600,000	$3,098,133	8.57
HP/Radcon/Radwaste	$714,488	$1,304,000	$1,682,533	2.35
Engineering	$242,084	$100,000	$1,445,708	14.46
QA	$139,756	$101,000	$882,314	8.74
Materiel			$622,609	N/A
Electric power	$136,800	$2,408,562	$799,459	17.61
Licensing fees			$178,880	N/A
Other overheads	$420,000	$1,316,724	$4,256,828	10.14
Total	$3,902,050	$7,873,246	$21,118,854	5.41
Average staff cost per person	$58,678	$44,602	$45,512	1.32

PNL.XLS

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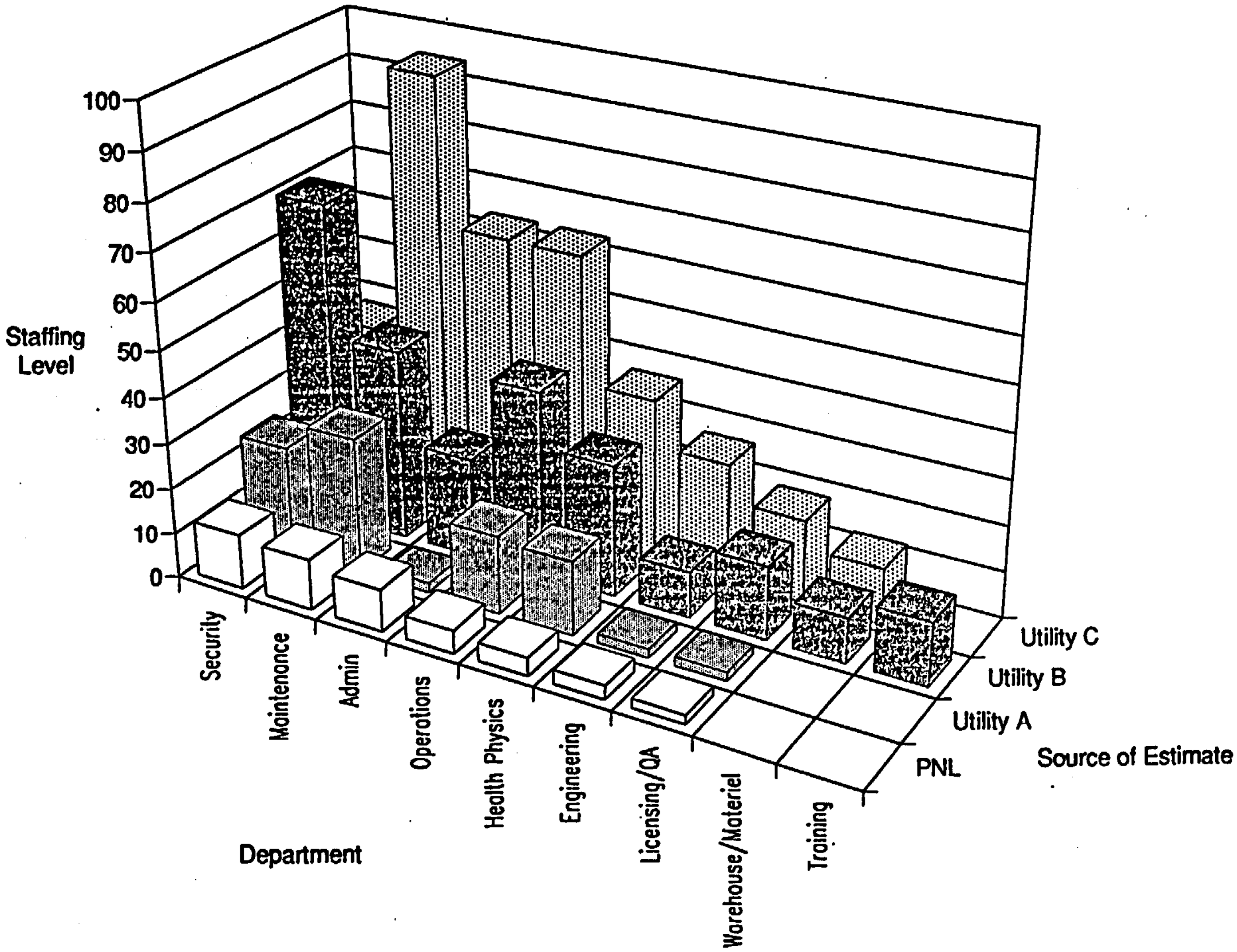
FIGURE 1

ESTIMATES OF STAFFING LEVELS BY DEPARTMENT



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PNL-STAF.XLC

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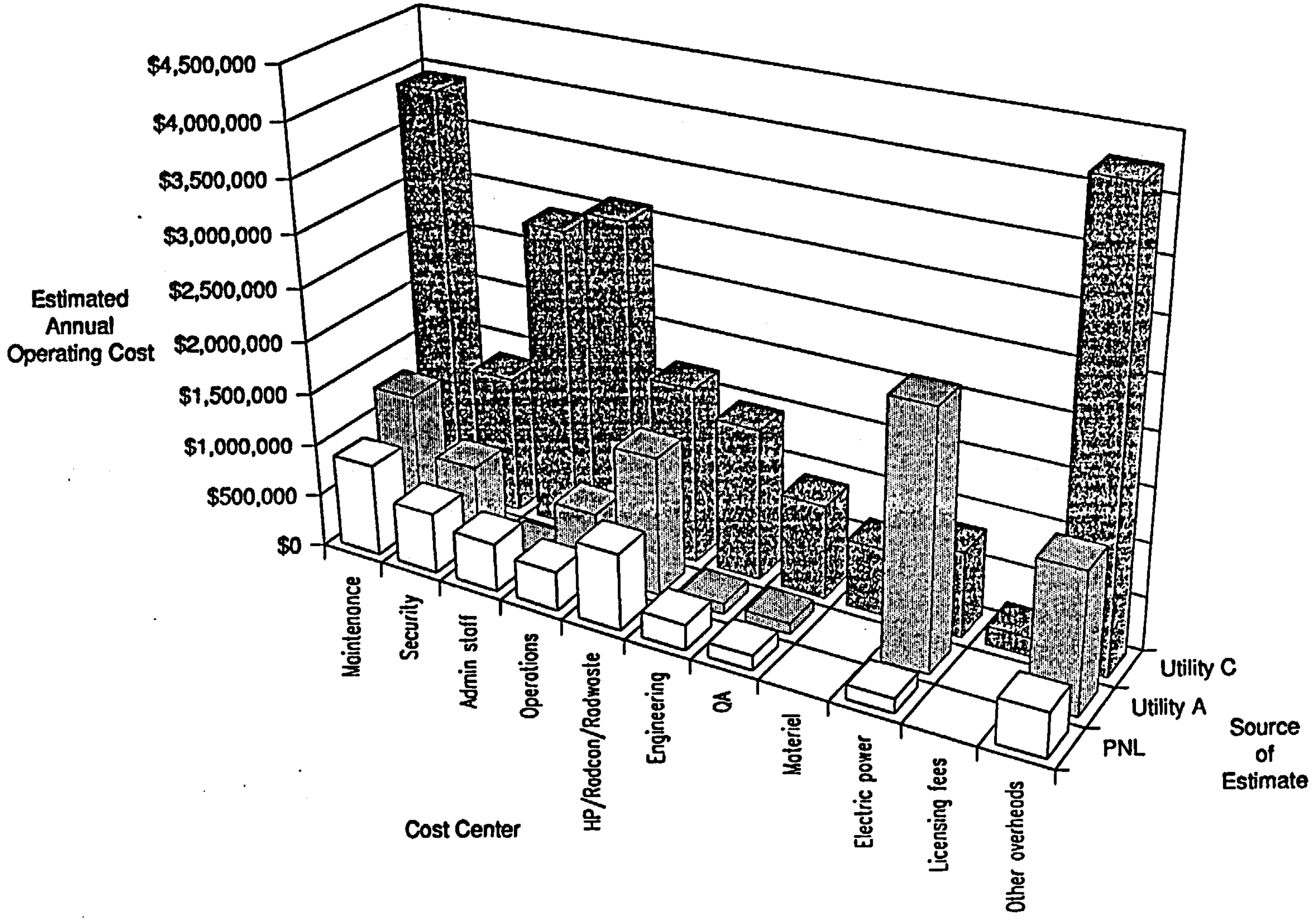
FIGURE 2

ESTIMATES OF COST BY COST CENTER



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